MODULE_9

Ecodesign and Ecoinnovations

Simona ISTRIȚEANU

Ecoinnovations of products offering environmental benefits

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DRIVEN

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ABBREVIATIONS

ADAS	Advanced Driver Assistance Systems
BEV	Battery Electric Vehicle, also called All-Electric Vehicle AEV
CE	Circular Economy
EESs	Energy Storage Systems
E-GMP	Electric-Global Modular Platform
FCEVs	Fuel Cell Electric Vehicles, also known as fuel cell vehicles (FCVs) or Zero Emission Vehicle
HEV	Hybrid Electric Vehicle
ICE	Internal Combustion Engines
ICEVs	Internal Combustion Engine Vehicles
PEF	Product Environmental Footprint
PHEV	Plug-in Hybrid Electric Vehicle
RFID	Radio-Frequency Identification
VCMS	Vehicle Charging Management System
VCU	Vehicle Control Unit
ZEV	Zero-Emission Vehicles

KEY TERMS

ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS): Conventionally, ADAS technology enables the car to detect objects, perform necessary clarification, and alert the driver of any hazardous road conditions. In other cases, the ADAS technology can slow down or stop the vehicle. It also brings applications such as blind spot monitoring, forward collision warnings, and lane change assistance.

AUTONOMOUS VEHICLES: Self-driving vehicles. The technologies used in these vehicles offer significant benefits that increase mobility and reduce crashes, fuel consumption, congestion.

BATTERY ELECTRIC VEHICLE: They are fully electric vehicles and use an external electrical charging outlet to charge the battery.

INTERNET OF THINGS (IoT): Technologies in the IoT perform various tasks such as linking to smartphones, registering real-time alerts, offer emergency roadside assistance among others. Vehicles also will have the ability to send and receive data.

TELEMATICS: These are methods of monitoring a vehicle through the combination of a GPS system with onboard diagnostics. Through this combination, one can map and record exactly where a car is and how fast it is traveling as well as how the car is behaving internally.

ELECTRIC VEHICLE (EV): It is a vehicle operating with a single or several electric motors using energy stored in rechargeable batteries. There are three types of EVs based on the degree of electricity they use. They are;

HYBRID-ELECTRIC VEHICLES (HEVS): They generate their power from both electricity and petrol. The car's braking system makes its electric energy to recharge the battery.

PLUG-IN HYBRID-ELECTRIC VEHICLES (PHEVS): They generate their power from both petrol and electricity. They use plugging-in to an external charging outlet and regenerative braking to recharge their battery.

ECOLOGICAL DESIGN OR ECODESIGN is an approach to designing products with special consideration for the environmental impacts of the product during its whole life cycle.

LIFE-CYCLE ASSESSMENT (LCA), also known as life-cycle analysis, is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing ("cradle"), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it ("grave"). These assessments can extend to economic and social impacts.

DIGITAL PRODUCT PASSPORT refers to an online portal or database where anyone can access information on the sustainability of products. This initiative is under active development in the EU region and by the ITU-T globally, and is targeted at both industries and consumers.

Many processes in the life of a digital device involve human effort. Sometimes these activities are recognised as work subject to protection by laws and conventions, but some of this work is done informally, and prone to abuse. For instance, in contrast to the growing pressure for monitoring work conditions in manufacturing, many other activities in the circular economy are not even recognised as work: artisanal mining, informal repair, or the informal handling of e-waste.

EXTENDED PRODUCER RESPONSIBILITY (EPR) is a concept that has revolutionized waste management practices around the world. Under EPR, producers of goods are held responsible for the proper disposal and management of the waste generated by their products. The application of EPR to the automotive industry has been a game-changer in terms of reducing the environmental impact of the sector.

1 INTRODUCTION

The course entitled ”Ecoinovation of products offering environmental benefits” proposed the following structure:

Products and customers at the heart of circular economy loops

- Sustainable production and consumption
- Sustainable industrial policies

- **Policy instruments:** Ecolabels, Green public procurement, Environmental Management and Audit Scheme (EMAS).
- **Extended Producer Responsibility (EPR)**
- **Ecodesign**: going beyond energy efficient products to include material efficiency considerations
- **Product Environmental Footprint (PEF)** Bottom-up instruments across Member States

The European Commission has proposed the Product Environmental Footprint and Organisation Environmental Footprint methods as a common way of measuring environmental performance.

- **Green system innovations** - Alternative systems of production and consumption that are more environmentally benign than existing systems: Example renewables-based energy system.
- **Organisational eco-innovation -** New organisational methods and management systems for dealing with environmental issues.
- **Eco-innovative products and services**

In order to define an eco-innovative product, its innovation should be determined in direct and indirect influence on the environment.

Environmental services: solid and hazardous waste management, water and waste water management, environmental consulting, testing and engineering, testing and analytical services - Services that are less pollution and resource intensive.

- **Innovation and quality in the automotive industry**

Modern production technologies in the automotive industry.

Perfectly harmonized systems, consisting of processing centers, transport systems and industrial robots, allow a series production with low costs, while meeting the individual wishes of customers in terms of equipment.

Every process of the complex automobile production business - the pressing plant, the construction of the bodies, the varnishing, the construction of the aggregates and the final assembly - must work reliably, with a high availability of all machines and installations.

- **Trends in the automotive sector. The car of the future**

At the horizon of 2030, the main trends in the automotive sector are related to digitization, connectivity, autonomy, electrification, use of vehicles in car-sharing (PwC, 2018).

The car of the future will be "green" and intelligent, and these aspects have major implications for manufacturers of car parts and accessories, which must develop their capabilities to integrate digital technologies and translate new concepts of the circular economy into production processes and portfolio of products (European Commission, 2017, Gear 2030).

- **Environmental technologies:**

Environmental technologies refers to process technologies (including energy conversion technologies) and measurement technologies used for environmental purposes (to measure pollution or to identify toxics).

- **Sustainable materials in automotive industry**

2 SUSTAINABLE POLICIES, REGLEMENTATIONS AND INSTRUMENTS

2.1 ENVIRONMENT ACTION PROGRAMME TO 2030

On 2 May 2022 the 8th Environment Action Programme entered into force, as the EU's legally agreed common agenda for environment policy until 2030 [[1]].

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. Building on the European Green Deal [[2]], the action programme aims to speed up the transition to a climate-neutral, resource-efficient economy, recognising that human wellbeing and prosperity depend on healthy ecosystems.

The 8th EAP calls for active engagement of all stakeholders at all levels of governance, to ensure that EU climate and environment laws are effectively implemented. It forms the EU's basis for achieving the United Nation's 2030 Agenda and its Sustainable Development Goals.

The **long-term priority objective** is that, by 2050 at the latest, Europeans live well, within planetary boundaries, in a well-being economy where nothing is wasted. Growth will be regenerative, climate neutrality will be a reality, and inequalities will have been significantly reduced.

There are six priority objectives to 2030

- achieving the 2030 greenhouse gas emission reduction target and climate neutrality by 2050;
- enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change;
- advancing towards a regenerative growth model, decoupling economic growth from resource use and environmental degradation, and accelerating the transition to a circular economy;
- pursuing a zero-pollution ambition, including for air, water and soil and protecting the health and well-being of Europeans;
- protecting, preserving and restoring biodiversity, and enhancing natural capital;
- reducing environmental and climate pressures related to production and consumption (particularly in the areas of energy, industry, buildings and infrastructure, mobility, tourism, international trade and the food system).

Enabling framework

In line with the European Green Deal's oath to 'do no harm,' the 8th EAP supports an integrated approach to policy development and implementation.

Article 3 of the action programme sets out the enabling conditions needed to achieve the priority objectives. Among others, it highlights the need for:

- a full **implementation** of existing legislation
- significantly **decreasing** the Union's **material and consumption footprints**
- achieving **environmental fairness**
- boosting s**ustainable finance**
- making use of **economic and tax incentives** to facilitate the sustainability transition
- **phasing out fossil fuel subsidies**
- developing a summary **'beyond GDP' dashboard**
- uptake by and **cooperation** at all levels of policy-making between different levels of actors
- harnessing the potential of **digitalisation**
- ensuring that policy action is firmly anchored in **latest science and knowledge**.

2.2 ECO-INNOVATION ACTION PLAN (ECO-AP) COM(2011) 899 FINAL

The Eco-innovation Action Plan (EcoAP) was complemented 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 "Industrial Policy for a Globalized Era" places the EcoAP as one tool to identify and implement measures for the deployment of key environmental technologies, to enhance coordination and cooperation between the EU and Member States and to generate awareness of the potential of new technologies.

The Agenda for new Skills and Jobs calls for the EcoAP to support competences for sustainable development, and promote appropriate skills development and tackle skills mismatches.

THE MAIN ELEMENTS OF THE ACTION PLAN ARE:

- demonstration projects and innovation partnerships to accompany technologies from basic research to market introduction
- improving market conditions through policies and legislation which advance swift development and market uptake
- opening up global markets, especially for innovative SMEs
- supporting the development of eco-innovation skills in the workforce and corresponding jobs
- improving steering schemes – enhanced interlinking of different areas of policy.

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 [[3]].

2.3 THE CIRCULAR ECONOMY ACTION PLAN

On 11 March 2020, the European Commission adopted a new Circular Economy Action Plan [[4]], one of the main building blocks of the European Green Deal [[5]], Europe's new sustainable growth agenda. The new action plan provides the measures throughout the product life cycle and aims to prepare European economy for a green future, strengthen competitiveness, while protecting the environment and give new rights to consumers. The new Circular Economy Action Plan paves the way for a competitive, climate-neutral economy in which consumers are held accountable.

The Circular Economy Action Plan, part of the EU Industrial Strategy [[6]], presents measures to:

- **MAKE SUSTAINABLE PRODUCTS THE NORM IN THE EU**. The Commission will propose legislation on Sustainable Product Policy, to ensure that products placed on the EU market are designed to last longer, are easier to reuse, repair and recycle, and incorporate as much as possible recycled material instead of primary raw material. Single-use will be restricted, premature obsolescence tackled and the destruction of unsold durable goods banned.
- **EMPOWER CONSUMERS.** Consumers will have access to reliable information on issues such as the reparability and durability of products to help them make environmentally sustainable choices. Consumers will benefit from a true ‘Right to Repair'.
- **FOCUS ON THE SECTORS THAT USE THE MOST RESOURCES AND WHERE THE POTENTIAL FOR CIRCULARITY IS HIGH.** The Commission will launch concrete actions on:
  - **electronics and ICT** – a ‘Circular Electronics Initiative' to have longer product lifetimes, and improve the collection and treatment of waste
  - **batteries and vehicles –** new regulatory framework for batteries for enhancing the sustainability and boosting the circular potential of batteries
  - **packaging –** new mandatory requirements on what is allowed on the EU market, including the reduction of (over)packaging
  - **plastics** – new mandatory requirements for recycled content and special attention on microplastics as well as biobased and biodegradable plastics
  - **textiles** – a new EU Strategy for Textiles to strengthen competitiveness and innovation in the sector and boost the EU market for textile reuse
  - **construction and buildings** – a comprehensive Strategy for a Sustainably Built Environment promoting circularity principles for buildings
  - **food** – new legislative initiative on reuse to substitute single-use packaging, tableware and cutlery by reusable products in food services.

- **ENSURE LESS WASTE.** The focus will be on avoiding waste altogether and transforming it into high-quality secondary resources that benefit from a well-functioning market for secondary raw materials. The Commission will explore setting an EU-wide, harmonised model for the separate collection of waste and labelling.The Action Plan also puts forward a series of actions to minimise EU exports of waste and tackle illegal shipments.

2.4 ECODESIGN REGULATION FOR SUSTAINABLE PRODUCTS

In May 2023, the European Council has adopted its position ('general approach') on the proposed regulation establishing a framework for setting ecodesign requirements for sustainable products. The new regulation **WILL REPLACE THE EXISTING 2009 DIRECTIVE** and enlarge the scope to set environmental sustainability requirements for almost all kind of goods placed on the EU market. It establishes a Digital Product Passport and sets out rules regarding transparency about and prohibition of the destruction of certain unsold consumer goods.

The Council position improves the framework for the Commission empowerment on the setting of ecodesign requirements and reinforces the ambition of this regulation through a direct ban on the destruction of unsold textiles (with an exemption for micro and small enterprises and a transition period for medium sized companies). It excludes motor vehicles from the scope of the regulation and gives companies a minimum time to adapt to new requirements coming from the Commission.

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.

There are **FOUR MAIN OBJECTIVES OF THE PROPOSED ECODESIGN FOR SUSTAINABLE PRODUCTS REGULATION (ESPR)**:

- ⇨ to reduce the negative environmental impacts of products' life cycle,
- ⇨ increase their sustainability,
- ⇨ enable better access to information along supply chains,
- ⇨ incentivize more sustainable goods and business models to improve value retention.

Goals that the EU Executive wants to achieve by extending the scope of ecodesign legislation to all physical products (as of today, Framework Directive 2009/125/EC is limited to energy-related products), making sustainability requirements such as minimum product life, recyclability, reparability, recycled material content, mandatory – depending on the different product groups, which will need specific regulations.

The proposal – aside from the introduction of incentive systems, guidelines to support circular business models, a Europe-wide information hub, as well as a ban on the destruction of unsold goods and transparency requirements – also envisions the creation of a digital product passport for the electronic registration, processing and sharing of product information between supply chain companies, market surveillance authorities and consumers. This – likely through the development of sustainability performance classes – should increase transparency, both for supply chain enterprises and the general public, and increase efficiency in terms of information transfer.

ECODESIGN FOR SUSTAINABLE PRODUCTS: DATA FROM THE EUROPEAN ENVIRONMENTAL BUREAU

The new ecodesign requirements could result in additional costs for consumers, which, however, according to research conducted by the nonprofit European Environmental Bureau, are likely to be offset by the combined benefits of less frequent product replacement, energy efficiency – in 2021, current measures stemming from Directive 2009/125/EC saved EU consumers 120 billion euros in energy expenditure – and reduced environmental impact. In addition, the measures will have positive spillover effects on the economic activity of product repair and maintenance services, including in terms of employment. EU estimates for extending the scope of eco-design standards indicate a greenhouse gas emission savings potential of at least 117 Mt CO2eq per year. From the four case studies compiled by analysts at the European Environmental Bureau, the greener production of cotton T-shirts alone could contribute nearly 3 percent of this potential, the spread of energy-efficient microwaves and kettles another 4 percent, and innovations in cement production at least 6 percent.
Technology and innovation are turning industries around the world at a breakneck pace. The rising popularity of so-called “circular economy” (CE) models has developed in responseto this context of environmental degradation. The term “circular economy” encompassesand builds on a number of similar schools of thought, including Cradle to Cradle, theperformance economy, biomimicry, industrial ecology, natural capitalism, the blue economy,and regenerative design. Thus, while the ideas behind the CE are not new, the conceptcarries value, as it brings together existing practices and concepts under a single frameworkthat encompasses a different conceptual approach to thinking about material use and output.

2.5 BOTTOM-UP INSTRUMENTS

2.5.1 EXTENDED PRODUCER RESPONSIBILITY FOR VEHICLE

Extended producer responsibility for vehicle transforms automotive waste management [[7]]

EXTENDED PRODUCER RESPONSIBILITY (EPR) is a concept that has revolutionized waste management practices around the world. Under EPR, producers of goods are held responsible for the proper disposal and management of the waste generated by their products. The application of EPR to the automotive industry has been a game-changer in terms of reducing the environmental impact of the sector.

The automotive industry is a significant contributor to global waste generation. According to the United Nations Environment Programme, the global automotive industry generates around 12 million tons of waste each year, with end-of-life vehicles being a significant contributor. End-of-life vehicles can contain hazardous materials, such as lead, mercury, and cadmium, which can be harmful to the environment and human health if not managed properly.

EPR FOR VEHICLES requires producers to take responsibility for the proper disposal of their end-of-life vehicles. This involves establishing collection centers where consumers can bring their used vehicles for disposal or recycling. Producers must also work with authorized dismantlers or recyclers to ensure that the waste generated by their products is managed in an environmentally sound manner.

To implement EPR for vehicles, producers must obtain certification from the relevant regulatory bodies. This involves filling out the necessary forms and undergoing inspection to ensure compliance with EPR regulations. Producers must also file compliance reports and submit annual records to show that they are complying with EPR regulations.

EPR for vehicles has been a game-changer in terms of reducing the environmental impact of the automotive industry. By holding producers responsible for the proper disposal of their end-of-life vehicles, EPR has incentivized the development of sustainable waste management practices in the industry. As the global demand for vehicles continues to rise, the application of EPR to the automotive industry will play an increasingly important role in reducing the environmental impact of the sector.

2.5.2 PRODUCT ENVIRONMENTAL FOOTPRINT (PEF)

The European Commission has proposed the Product Environmental Footprint and Organisation Environmental Footprint methods as a common way of measuring environmental performance. The Product Environmental Footprint, also the PEF methodology, is an important initiative from the European Commission. It's a new and improved method on how companies should measure the environmental performance of any product throughout its Life Cycle (taking into account all the upstream supply chain and downstream activities).

The PEF is based on the scientific method for measuring environmental footprints called Life Cycle Assessments (LCA).

The PEF outlines an improved common framework for all the steps and specific rules that are necessary to make an appropriate and comparable Life Cycle Assessment.

Its mission is to strengthen the (European) market for green alternatives and ensure that environmental impacts are transparently assessed and, in the end, of course, reduced [8].

The PEF being a single LCA method used by everyone, helps improve the validity and comparability of the environmental performance evaluation of EU member states and the private sector. Especially compared to the existing methods.

Having this new organisational standard in environmental impact measurements will tackle greenwashing and false sustainability claims. Motivating companies to stay on the 'right sustainability path'- and helping consumers recognise to what extent a product, company, or service is environmentally friendly.

The PEF methodology is still in progress and in the so-called 'transition phase' (pilot phase). This transition phase is planned to be completed by the end of 2024. This means that using the PEF isn't mandatory yet.

The European Commission is still further developing the details for the PEF Product Category Rules (also PEFCR's or PCR's) in order to finalise the PEF methodology developments. These category rules will define footprint measurement rules specific to industries.

The Product Environmental Footprint exists out of two components: (1) The PEF methodology; (2) The PEF database.

THE METHODOLOGY includes new cohesive rules for performing LCA's in line with the EU's Green Deal and Taxonomy. Currently, we have reached the 3.0 version of PEF methodology. The main difference with the previous versions is that some environmental impact categories have been divided into new subcategories.

THE PEF DATABASE is meant to support the PEF methodology and create a new standard environmental database for the European industries. With the PEF impact database, the EU hopes to create a more complete database to use in LCA's. The PEF methodology doesn't need to be used solely with the PEF database. It's also possible to mix the methodology with the biggest database for environmental data Ecoinvent.

2.5.3 THE ECO-INNOVATION SCOREBOARD AND THE ECO-INNOVATION INDEX

The aim of the Eco-Innovation Index and the Eco-Innovation Scoreboard is to reflect performance of the EU member states (MS) on innovations with environmental effects, i.e. eco-innovations. They measure this performance in five different fields, each of them based on a set of indicators, namely:

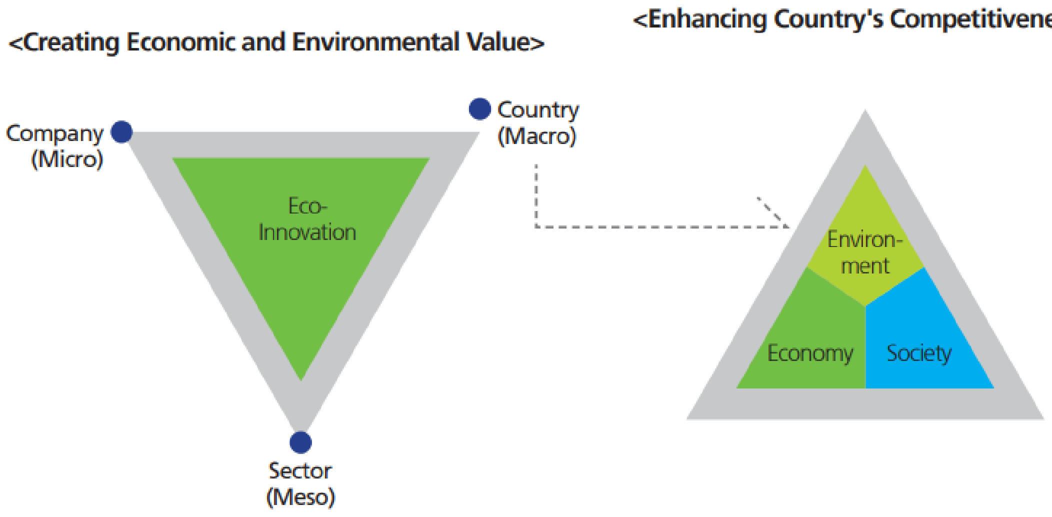
1. Inputs
1.1 Governments environmental and energy R&D appropriations and outlays (% of GDP)
1.2 Total R&D personnel and researchers (% of total employment)
1.3 Total value of green early-stage investments (USD/capita)
2. Activities
2.1 Enterprises that introduced an innovation with environmental benefits obtained within the enterprise (% of total firms)
2.2 Enterprises that introduced an innovation with environmental benefits obtained by the end user (% of total firms)
2.3 ISO 14001 registered organisations (per million population)
3. Outputs
3.1 Eco-innovation related patents (per million population)
3.2 Eco-innovation related academic publications (per million population)

3.3 Eco-innovation related media coverage (per numbers of electronic media)
4. Economic outcomes
4.1 Material or Resource productivity (GDP/Domestic Material Consumption)
4.2 Water productivity (GDP/total freshwater abstraction)
4.3 Energy productivity (GDP/gross inland energy consumption)
4.4 GHG emissions intensity (CO2e/GDP)
5. Environmental outcomes
5.1 Exports of products from eco-industries (% of total exports)
5.2 Employment in eco-industries and circular economy (% of total employment across all companies)
5.3 Revenue (turnover) in eco-industries and circular economy (% of total revenue across all companies).

2.5.4 ASEM ECO-INNOVATION INDEX

Established in 1996, the Asia-Europe Meeting (ASEM) initiated its intergovernmental partnership among member countries in Asia and Europe. Consisting of 51 member countries at the current status, the ASEM member countries were deeply empathetic with the importance of SMEs as a core driver of innovation and growth. For instance, SMEs accounts for 99 percent of all business in Europe while being core essence of various industries in Asia [[9]].

In order for the sustainable growth of SMEs, the ASEM attempts to define eco-innovation as an idea to achieve environmental improvements, to enhance competitiveness of enterprises and to provide new business opportunities by means of using low cost and non-technology-intensive methods. The ASEM SMEs Eco-innovation Center (ASEIC) was established in 2011 as a part of joint effort between Europe and Asia to enhance their cooperation for eco-innovative growth of small- to medium-sized enterprises (SMEs). The ASEIC, thus, an international cooperative organization, was established to widespread the principles of ecofriendly growth to SMEs as well as to support those SMEs for new business strategy by utilizing those principles.



2-1. Figure_ Why Eco-innovation is needed [ASEM Eco-Innovation Index, 2016]

Eco-innovation, by reducing impacts on the environment, increasing resilience against external pressures and using resources more efficiently, is vital in supporting this transition to a circular economy and achieving the objectives of the European Green Deal.

2.5.5 EMAS (ECO-MANAGEMENT AND EUROPEAN AUDIT)

EMAS (Eco-management and European Audit) is an environmental management tool developed by the European Commission for businesses and organizations that want to assess their impact on the environment and improve their performance in this area. EMAS covers all economic and service sectors and applies worldwide. Being a part of the system, it requires periodic renewal of registration certificates and periodic checks, therefore the certificate provides relevant information for the customers of a particular operator. Possession of the EMAS certificate denotes compliance with many rigorous rules (compared to the ISO 14001 standard, the EMAS requirements include an additional 4 elements), the certificate providing an indisputable prestige to the operator [[10]].

2.5.6 EU ECOLABEL

EU Ecolabel- The European Ecolabel certificate helps to identify products and services that have a low impact on the environment during their life cycle. Recognized in Europe, Ecolabel is a credible label applied to products and services that are truly ecological [[11]].

3 ECO-INNOVATION AND ECODESIGN TOWARDS CIRCULAR ECONOMY

3.1 THE CONCEPT, ROLE AND FUNCTIONS OF ECO-INNOVATION

Innovation is vital to survival in the automotive industry. Due to structural changes in the market, more intense competition, stricter regulations, increasing fragmentation and shorter product life cycles, manufacturers are required to continuously incorporate new technologies, designs and features into the development process of the product.

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 [12]. In 1997, Peter James defined eco-innovation as "new products and processes which provide customer and business value but significantly decrease environmental impacts" [13].

The term eco-innovation describes three kinds of changes related to sustainable development: technological, social and institutional innovation [14].

Eco-innovation is often linked with environmental technology, eco-efficiency, eco-design, environmental design, sustainable design, or sustainable innovation.

While the term "environmental innovation" is used in similar contexts 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 rather than the societal and political aspects.

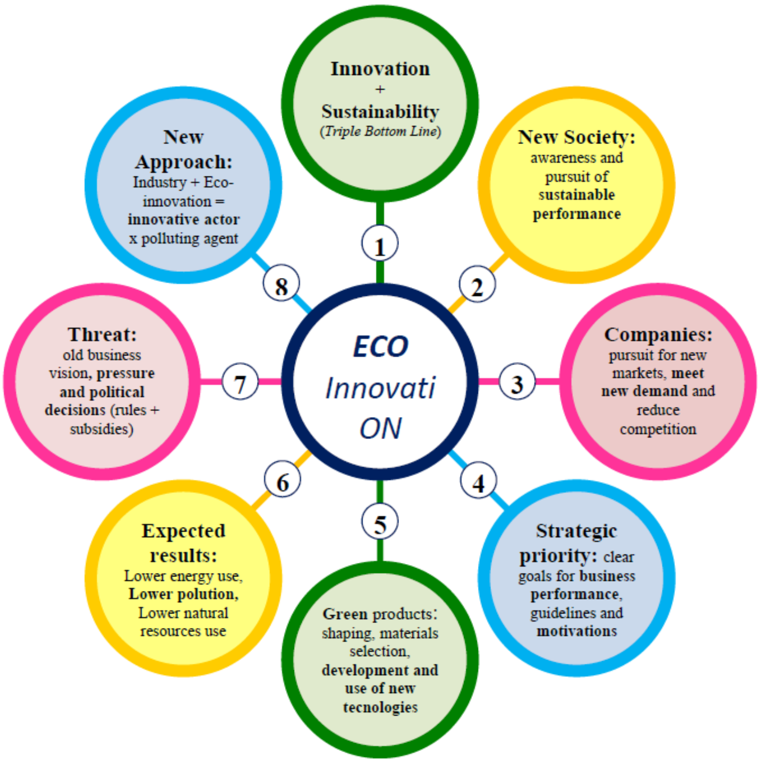
Eco-innovation is the process by which business adopts ecological innovation to create products which have a generative nature and are recyclable.

The most common usage of the term "eco-innovation" is to refer to innovative products and processes that reduce environmental impacts, whether the main motivation for their development or deployment is environmental or not. This is often used in conjunction with eco-efficiency and eco-design. Leaders in many industries have been developing innovative technologies in order to work towards sustainability.

Eco-innovation is defined by the European Commission as “any form of innovation aiming at significant and demonstrable progress towards the goal of sustainable development, through reducing impacts on the environment or achieving a more efficient and responsible use of resources including both intended and unintended environmental effects from innovation as well as not only environmental technology but processes, systems and services.”

The Eco-Innovation Observatory (EIO), a three-year initiative financed by the European Commission, defines eco-innovation as: “any innovation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle.” EIO’s definition went beyond the traditional notion of innovating to reduce negative environmental effects; it also encompasses the ways and methods of minimizing the use of natural resources in the design, production, use, re-use and recycling of products and materials [15].

According to the Organization for Economic Cooperation and Development (OECD), what makes eco-innovation distinct from any other type of innovation is that it “results in the mitigation of environmental impact, whether the effect is intended or not. Furthermore, its scope may transcend the traditional structural limitations of the innovating organization, thus involving broader social arrangements that could spur socio-cultural and institutional changes.”

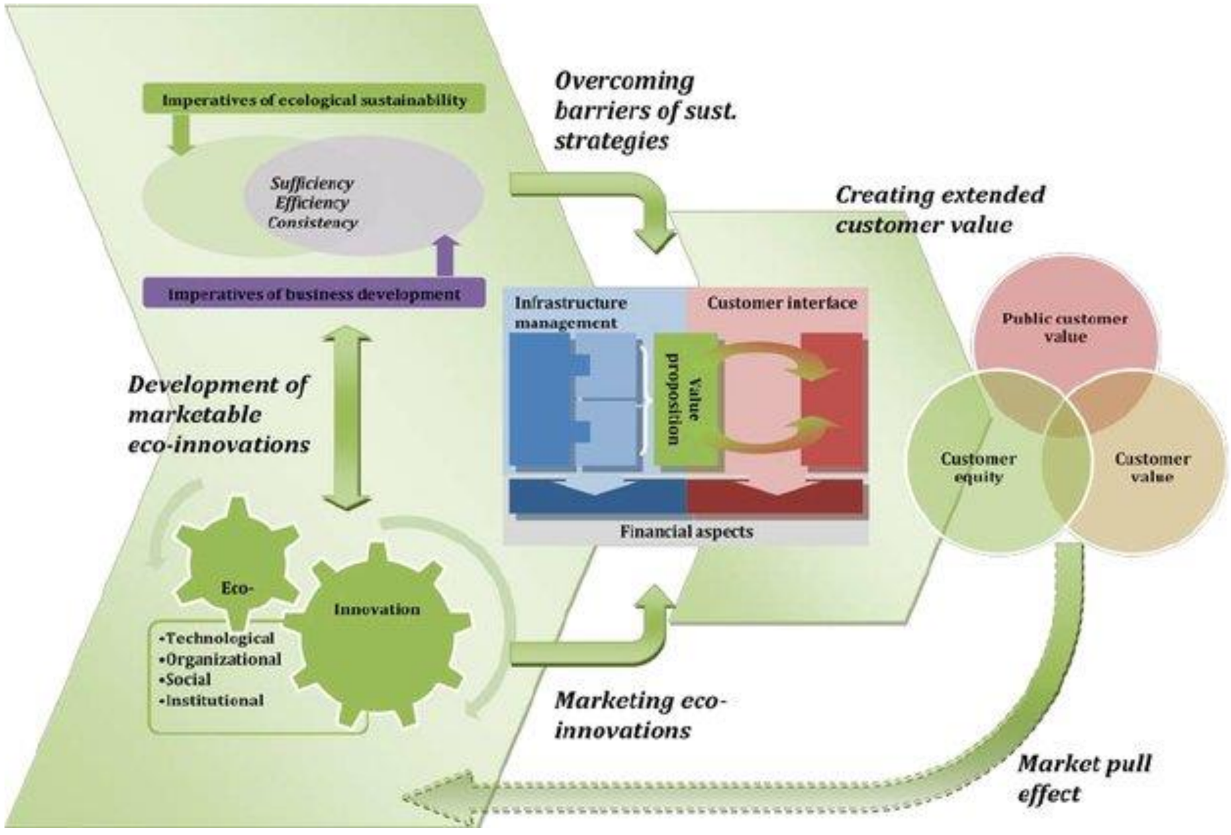


3-1. Figure_ Framework about Eco-innovation [16]

According to the OECD’s report on “The Future of Eco-Innovation: The Role of Business Models in Green Transformation, eco-innovation is a "key pre-requisite for sustainable development" at macro level as it brings positive synergetic effects towards economic, social and environmental conditions of a country. International organizations, research institutes, academia, etc. are continuously emphasizing the importance of eco-innovation, highlighting the role of public and private sector to create enabling conditions.For exemple, to encourage eco-innovation, manufacturers may obtain emission credits for vehicles equipped with innovative technologies for which it is not possible to demonstrate the full CO_2 savings during their type of approval. The manufacturer must demonstrate these savings based on independently verified data. The maximum emission credits for these eco-innovations per manufacturer are 7 g CO_2/km per year. As of 2025, also the efficiency improvements for air conditioning systems will become eligible as eco-innovation technologies. Eco-innovation influences organizational and consumer practices, based on the basic principle of reduction in environmental impact, seeking positive exchanges between environmental attributes and critical factors in development of products and processes [17].

ECO-INNOVATIONS differ from other innovations in their environmental goals. They are often defined as innovations (new or significantly improved products and processes, marketing techniques, organizational strategies) that contribute to significantly ddecreasingenvironmental impacts (for example,reducinge the use of natural resources, including materials, energy, water and land, and/or decrease the release of harmful substances across the whole life-cycle) when compared with existing alternatives [18], although this definition is somehow problematic.

Environmental innovations involve many changes at different levels, in particular in infrastructure able to receive the new technology. Environmental innovations are thus part of system innovations. The differentiated development of each sub-system can create bottlenecks that can hinder technological development and diffusion.



3-2. Figure_Conceptual framework of business model eco-innovation

[DOI: 10.13140/RG.2.1.2565.0324]

The innovativeness of a particular sector depends on factors such as the maturity of the dominant technology, scale, capital intensity, R&D intensity of the industry, and competitiveness. Relevant sector-specific features influencing eco-innovation include the existence of technological opportunities, the properties of innovative processes, the market structure, the maturity of the sector, the environmental impact and the exposure to societal pressures. Sectoral differences and their influence on eco-innovation have been addresse superficiallyer, however, only through the inclusion of a sectoral dummy variable.

ECO-INNOVATION is the development and application of a business model, shaped by a new business strategy that incorporates sustainability throughout all business operations based on lifecycle thinking and in cooperation with partners across the value chain. It entails a coordinated set of modifications or novel solutions to products (goods/services), processes, market approach and organizational structure which leads to a company's enhanced performance and competitiveness.

The ***ENVIRONMENTAL PRACTICES*** used in the automotive sector are [16]:

emissions reductions, life cycle analysis, cleaner production, reverse logistics and eco-innovation.

The sustainable innovations in the automobile manufacturing processes were the transition from internal combustion engines to the fuel cells (FCV), within the environmental practice of **emissions reductions.**

Within the **life cycle practice**, the sustainable innovations were the technological innovations of products and processes in manufacturing. Also, the development of hybrid cars fits into this practice as well, that is, a car that has an internal combustion engine, usually gasoline, and an electric motor that reduces the effort of the combustion engine and thus reduces consumption and emissions. The practice of **cleaner production** and **reverse logistics** appear in the reuse of materials in the process. The practice of **eco-innovation** brings improvements in the car manufacturing process that minimizes the negative impact on the environment.

3.2 KEY MECHANISMS IN ECO-INNOVATION

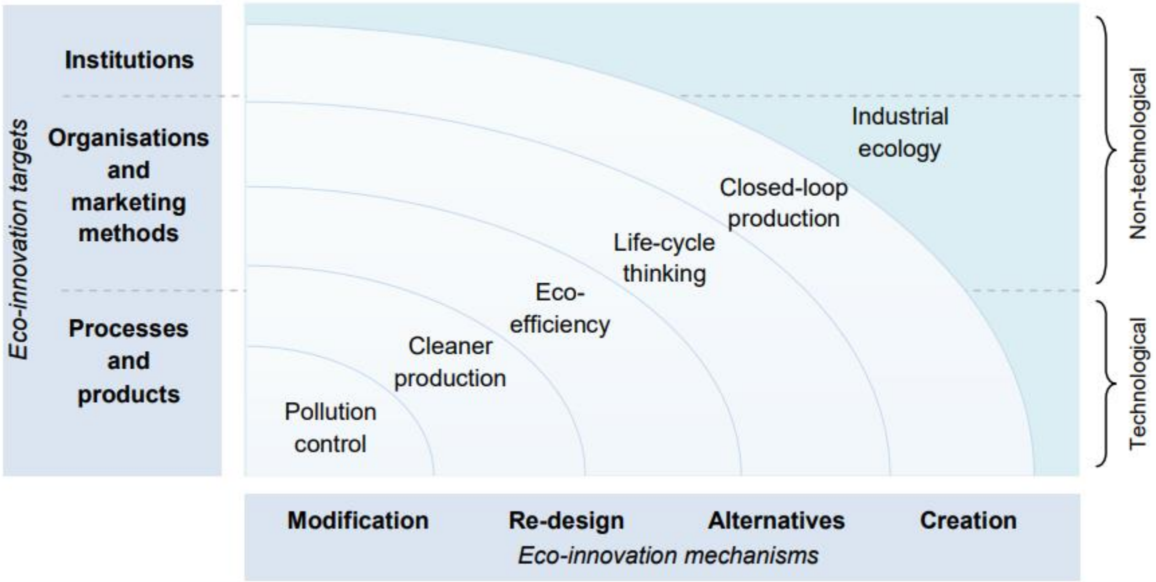
Key mechanisms in eco-innovation:

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.



3-3. Figure_Conceptual relationships between sustainable manufacturing and eco-innovation

[https://www.oecd.org/sti/inno/43423689.pdf]

3.3 TYPOLOGY OF ECO-INNOVATION

Keeping in with the view that any innovation that offers environmental benefits compared to relevant alternatives is to be viewed an eco-innovation the following classification for eco-innovation is [[19]]:

A. ENVIRONMENTAL TECHNOLOGIES

- Pollution control technologies including waste water treatment technologies.
- Cleaning technologies that treat pollution released into the environment;
- Cleaner process technologies: new manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives;
- Waste management equipment;
- Environmental monitoring and instrumentation;
- Green energy technologies;
- Water supply;
- Noise and vibration control.

B. ORGANISATIONAL INNOVATION FOR THE ENVIRONMENT:

the introduction of organisational methods and management systems for dealing with environmental issues in production and products.

A finer classification is:

- Pollution prevention schemes: aimed at prevention of pollution through input substitution, more efficient operation of processes and small changes to production plants (avoiding or stopping leakages and the like);

- ⇨ Environmental management and auditing systems: formal systems of environmental management involving measurement, reporting and responsibilities for dealing with issues of material use, energy, water and waste (EMAS and ISO 14001 are examples);
- ⇨ Chain management: cooperation between companies so as to close material loops and to avoid environmental damage across the value chain (from cradle to grave).

C. PRODUCT AND SERVICE INNOVATION OFFERING ENVIRONMENTAL BENEFITS: new or environmentally improved products and environmentally beneficial services

- ⇨ New or environmentally improved material products (goods) including ecohouses and buildings;
- ⇨ New materials such as lightweight composite materials;
- ⇨ Green financial products (such as eco-leases or climate mortgages);
- ⇨ Environmental services: solid and hazardous waste management, water and
- ⇨ waste water management, environmental consulting, testing and engineering,
- ⇨ other testing and analytical services;
- ⇨ Services that are less pollution and resource intensive (car sharing is an
- ⇨ example).

D. GREEN SYSTEM INNOVATIONS

- Alternative systems of production and consumption that are more environmentally benign than existing systems: biological agriculture and a renewables-based energy system are examples.

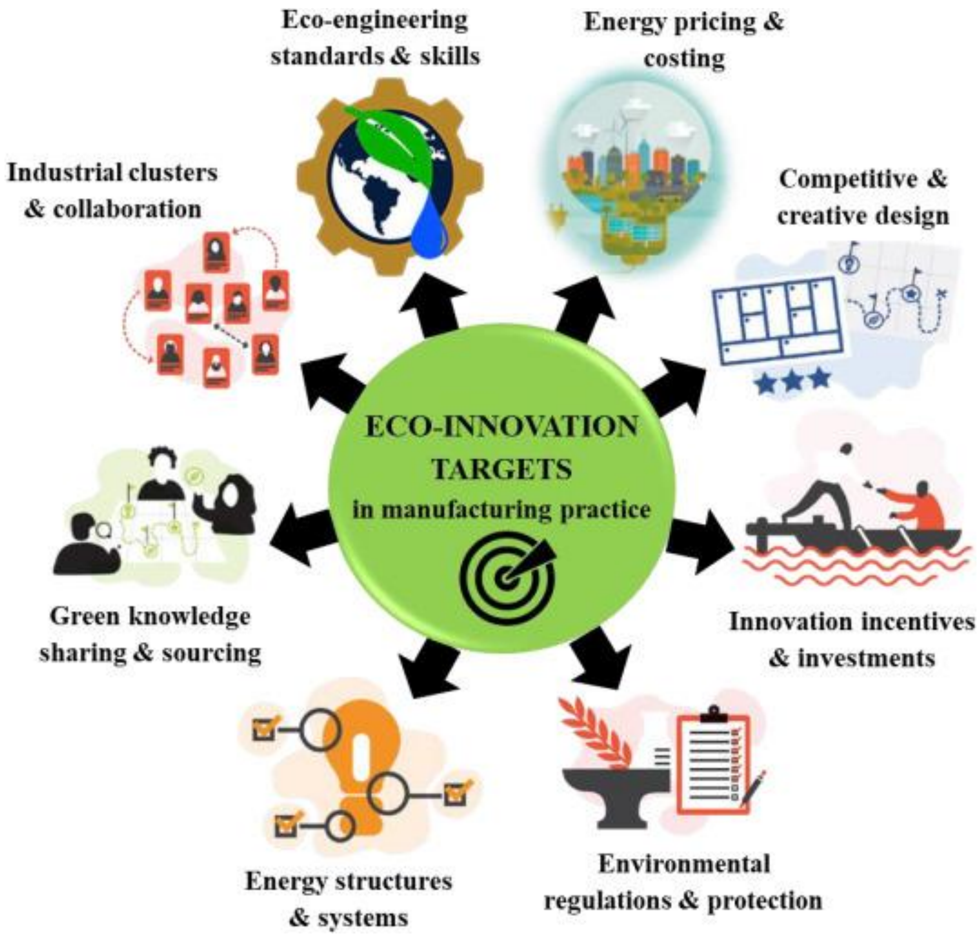
3.4 ECO-INNOVATION STRATEGIES

Eco-innovation, concerning novel endeavours that promote environmental, green, and sustainability-oriented solutions, is a concept of a significant importance to manufacturing firms, due to innovation prospects of environmental benefits [[20]].

Manufacturing firms are used here to mean businesses involved in the production of new products (or finished goods) from raw materials and/or assembled components, e.g., Volkswagen the automobile manufacturer, Caterpillar the construction equipment manufacturer, Sony the electronics manufacturer, and Pfizer the pharmaceuticals manufacturer.

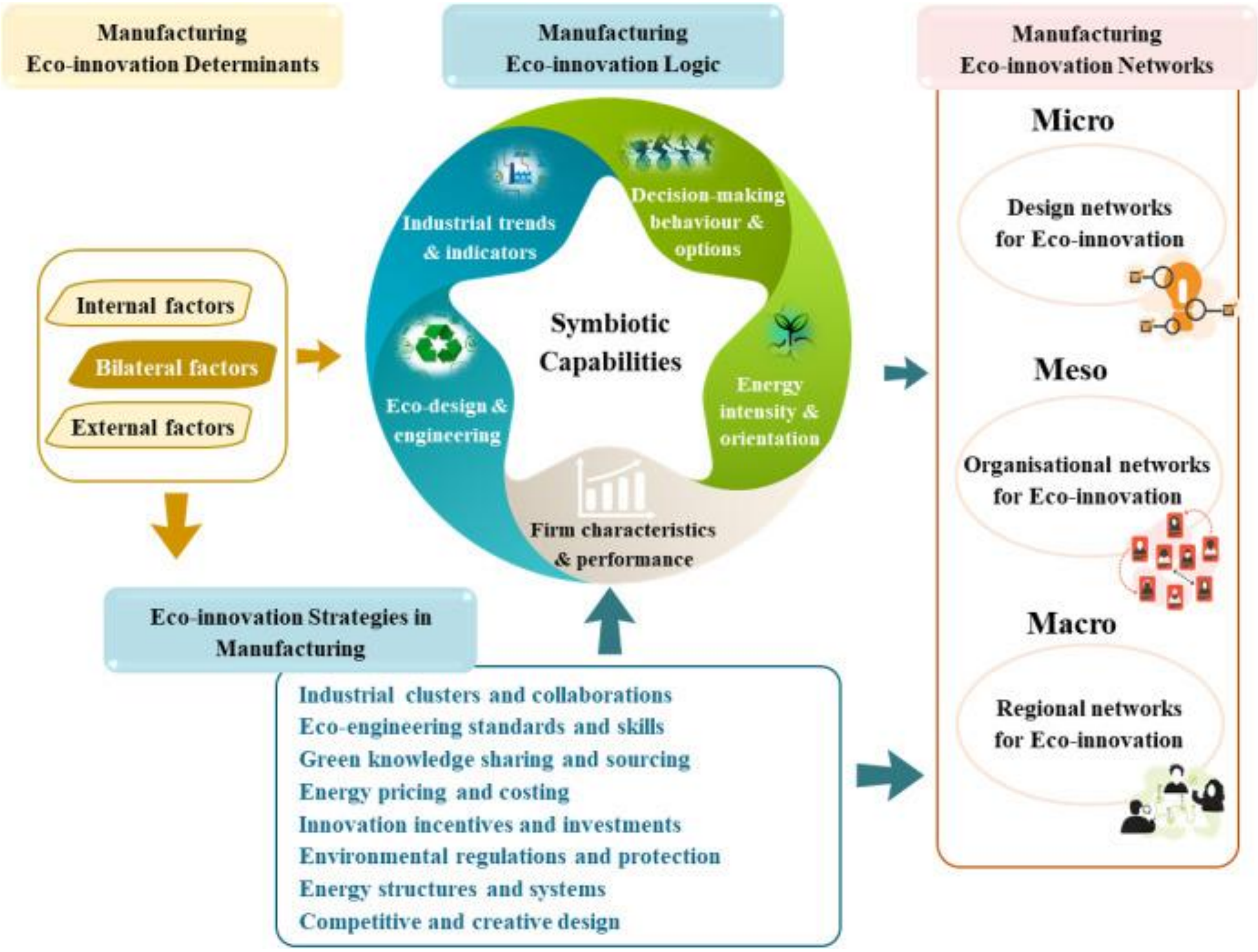
Past research and practice tended to primarily focus on pollution control and waste reduction activities or on environmental initiatives for public goods and within the service sector. However, research on eco-innovation strategies transcends environmentally motivated innovations and encompasses products, processes, business model, marketing, and organisational innovations with environmental benefits.

Eco-innovation strategy means a set of actions and commitments by manufacturing firms for realising innovation that targets and boosts sustainable development. Therefore, the challenge for manufacturing remains to analyse eco-innovation strategies for an inclusive view of environmental, green, and sustainability-oriented solutions – as opposed to atomistic, piecemeal proposals.



3-4. Figure_ Targets as strategies for eco-innovation in manufacturing practice

[https://www.sciencedirect.com/science/article/pii/S2666790821003037]



3-5. Figure_Multi-level strategic framework for manufacturing eco-innovation

[https://www.sciencedirect.com/science/article/pii/S2666790821003037]

ECO-INNOVATION - BASIC GROUPS IN THE PRODUCTION CYCLE

With regard to the place where eco-innovation is to be found in the production cycle, three basic groups can be distinguished:

a) innovations leading to the creation of **PRODUCTS WITH ENTIRELY NEW ECOLOGICAL PARAMETERS**, exerting much lesser pressure on the environment (ex. fuel-efficient cars);

b) innovations leading to the generation of **PRODUCTS WITH THE SAME ECOLOGICAL PARAMETERS** as other products available on the market, but using **LESS ENERGY AND RAW MATERIALS** owing to the use of new technologies in the production process,

c) the third groups combine the features of the first two groups, which means **THAT BOTH THE PRODUCT AND THE TECHNOLOGY OF ITS PRODUCTION ARE ECO-INNOVATIVE**.

3.5 ECO-INNOVATION DETERMINANTS

Eco-innovation implies institutional changes, the adoption of specific management systems as well as compliance with various regulations. These changes, together with different levels of research and innovation development, the availability of knowledge infrastructure or cooperation networks create differences in the success of eco-innovation in European countries. Eco-innovation could be influenced by numerous determinants, which in turn depend on geographical conditions as well as various environmental domains. Four categories of eco-innovation determinants are highlighted: regulation, market factors, technology and company-specific mechanisms. [21, 22].

Table 3.1 Eco-innovation determinants in companies [23]

External Drivers	**Relationship with EI**
Cooperation agreements Environmental regulations Public financial support Access to external information sources such as customers and suppliers	+
Internal Drivers	
R&D investment Long-term cost savings Better corporate image Employee training for innovation activities Implementation of quality and environmental systems Access to new markets	+
External Barriers	
Market uncertainty Long investment payback periods	-
Internal Barriers	
Lack of financial resources Lack of qualified human resources Lack of technological competence	-
Structural characteristics	
Company size (number of employees)	+
Company age	+
Market orientation	+
Business financial performance (sales)	+
Sector	+

The symbol (+) indicates a positive relationship with EI and the symbol (–) indicates a negative relationship with EI.

*Table 3.2_* Determinants of eco-innovation activities [24]

Supply Side	Technological and managerial skills Innovation capabilities of organizations Collaboration with key institutions Access to the proper data

	Experience and knowledge transfer Qualified human resources
Demand Side	Market demand Public understanding of the importance of clean production; concern for the environment and a desire for ecologically friendly products
External influence (political, institutional)	Existing and future regulatory approaches Institutional capabilities and structure

3.6 DRIVERS FOR THE ADOPTION OF ECO-INNOVATION TOWARDS A CIRCULAR ECONOMY

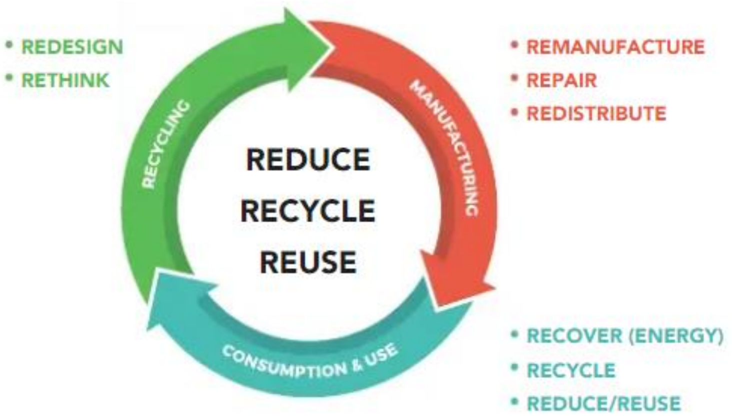
CE is characterized by three key principles:

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

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

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

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



3-6. Figure_The multi-R approach.

Source: Association of Cities and Regions for Recycling and Sustainable Resource Management

The European Environment Agency (2016) recognises EI as a key enabler in the transition towards CE. Eco-innovation 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 (sustainable cities, ecological mobility, smart energy systems, etc.)(Eco-Innovation Observatory, 2014)

EI has the potential to trigger change, create pressure, and stimulate adaptation to a new socio-technical system, thereby facilitating the emergence of a circular economy.

According to the Eco-Innovation Observatory (2016), the CE requires eco-innovation in two different fields, labelled “hardware” and “software”.

HARDWARE includes the technologies and technical infrastructures for transforming waste into resources, while **SOFTWARE** involves the skills, experience, and business models that will make this transformation a good business opportunity.

EI represents a fundamental pillar of the EU strategy for the development of an EC [[25]]. It is systemic eco-innovations that contribute to achieving high levels of circularity [[26]].

Table 3.3 Classification of drivers for the adoption of eco-innovation towards a circular economy [[27]]

Category	Variables	Implementation Drivers	Sustainability Drivers
Government/ institutional	Regularity and normative pressures/cooperation/technology and infrastructure	Determined by governments, noncompliance with regulations can be very costly to the firm (local, regional, and international level)	Environmental legislative demand
Management and organization	Adoption of certifications/environmental managerial concerns, and leadership/organizational culture towards eco-innovation	Environmental management approach, the role of top executives in adopting eco-innovation and in integrating innovation and sustainability in companies' strategy/organizational innovation	Company's management quest for a better environment /environmental initiatives and advances in product innovation
Stakeholders and customers	Publicity/demand	Develop more environmentally friendly products /processes	The wish to be on the forefront of future legislative demands /customer's demands
Consumer behavior and culture/employee satisfaction	Awareness/responsible consumption	Satisfy customer demand /extend product range	Product re-use and share /personal quest for a better environment

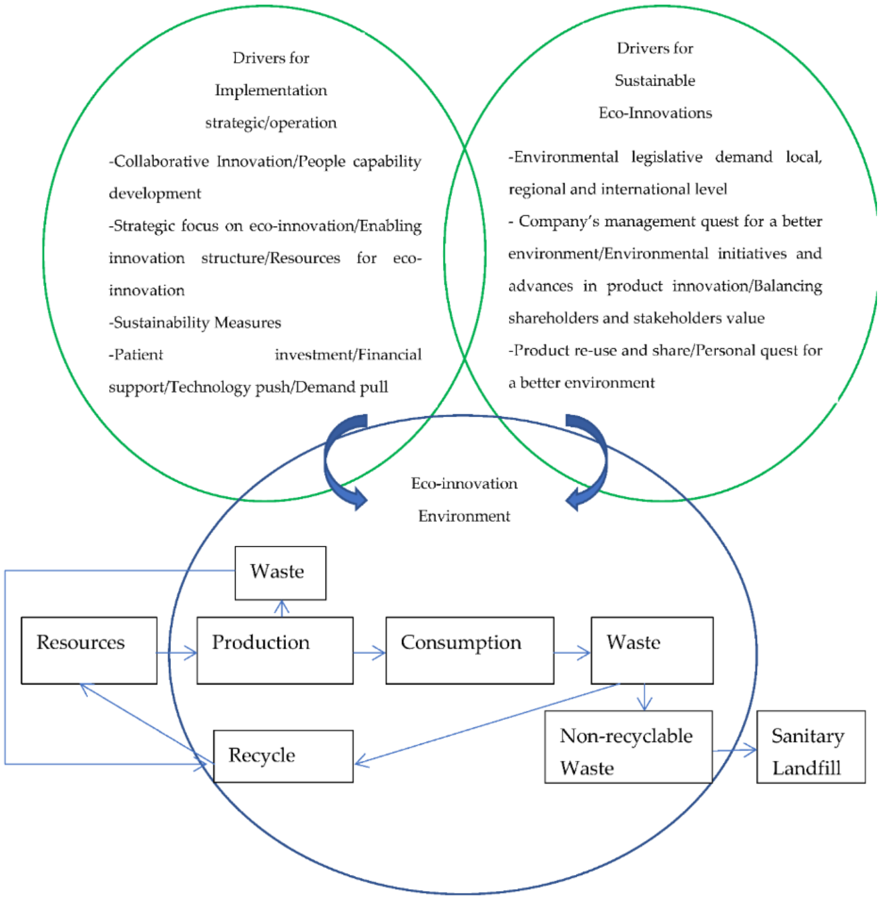
There is a relationship:

- ➔ between political approaches, infrastructural changes, and the organizational capabilities with regard to product eco-innovation and process eco-innovation was confirmed.
- ➔ between political approaches, eco-design, and organizational capabilities for eco-innovation and product eco-innovations.

Furthermore, the relationship between political approaches towards a circular economy, eco-design, and the consumer/producer behavioral changes through exploitative strategies regarding infrastructural, institutional and organizational changes, education, trainings, and social awareness proved to be true as well.

THE CIRCULAR ECONOMY concept and the prospective market for eco-innovative products, as well as the possibility to increase a firm's organizational efficiency through new organizational methods or the adoption of environmental processes, and sought to comprehend how eco-innovation has been studied in the literature.

The conceptual framework was drawn concerning the drivers of eco-innovation towards a circular economy with regard to organizational capability and exploitative strategies (3-7. Figure). In general, external factors impact internal factors, and they both affect the eco-innovation adoption process, leading to the positive performance of companies.



3-7. Figure_Conceptual relationships between sustainable manufacturing and eco-innovation [27]

The comprehension of the drivers of eco-innovation serves as a map towards the sustainable behavior of businesses, which often face tradeoffs when they undertake financing eco-innovation activities in the circular system.

Understanding their motivations can aid policymakers in guiding and predicting company behavior, as well as developing instruments to encourage more environmental management. In terms of the firms' resources and capacities, the findings show that collaborations with partners, alliances, and networks have a favorable impact on the product, process, and radical eco-innovations.

The company size is positively related with the decision to eco-innovate the product and process with respect to organizational capability.

The scale of the company is used as a proxy for the possible strategic and operational eco-innovation drivers. Small businesses confront greater challenges in implementing environmental solutions. the size of a company has a positive impact on environmental efforts in general.

The concept of a circular economy is a socio-technical frame to transform the linear economy into a more sustainable, restorative, and regenerative system. Such a transition between the linear economy and the circular economy is actually a move towards ecological sustainability, is about a structural change leading to the introduction of transformative innovation.

3.6.1 RELATION BETWEEN A CIRCULAR ECONOMY, ECO-INNOVATION AND ECO-DESIGN

The link between producer and consumer behaviour, policy approaches towards a circular economy and product/process eco-innovations is a driving force in the development of organizational capabilities and exploitation strategies.

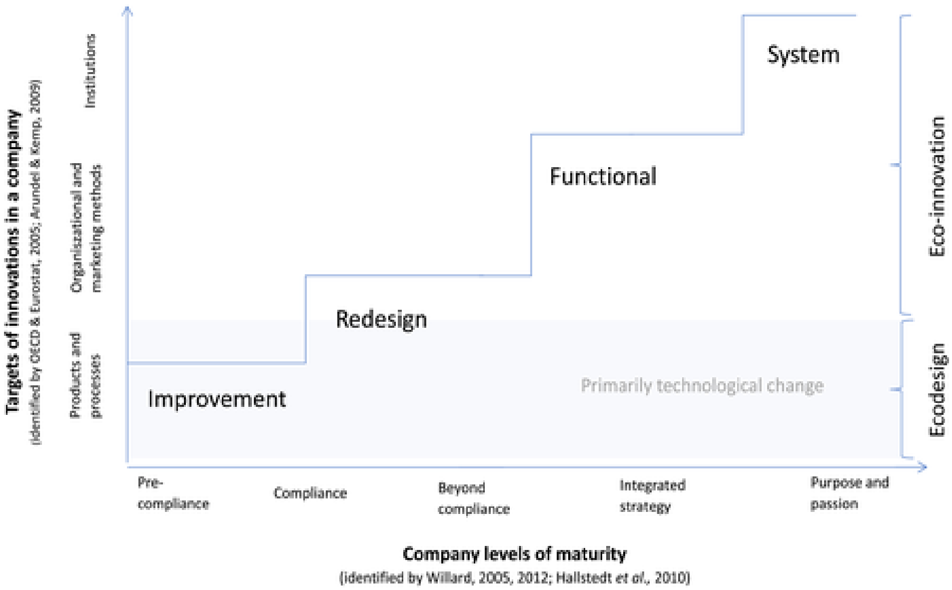
Industrial production processes cannot include an ecological production process without addressing sustainability, societal development and, most importantly, a circular economy. Companies can achieve financial and environmental benefits through sustainable production processes.

Eco-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 ecodesign and eco-innovation, as they focus on product life cycles, process efficiencies, marketing methods and business models, which together promote institutional changes. Ecodesign approaches support eco-innovation activities and help companies identify and reduce the negative environmental impact associated with their activities [[28]].

Multiple approaches at different levels are required to achieve a systemic sustainability transition. Ecodesign and eco-innovation complement each other, with the former focusing more on technological improvements and the latter on both nontechnological incremental and radical changes [[29]].

Companies can be classified according to five consecutive stages of maturity that reflect how sustainability is integrated into business activities.



3-8. Figure_The model combining company maturity levels, targets, and mechanisms of innovation [30]

The difference between ecodesign, sustainable design and circular design for products, is that they approach what 'sustainability' in product design means – slightly differently. As sustainability becomes part of business, understanding the different sustainable design approaches is crucial for R&D.

Table 3.4 Ecodesign, sustainable design and circular design [https://ecochain.com/blog/guide-to-sustainable-product-design/]

	SUSTAINABLE DESIGN	ECODESIGN	CIRCULAR DESIGN
Definition	Designing a product in a way that takes the reduction of social, environmental, and economic impacts at the heart. Minimize these impacts as much as possible.	Ecodesign focuses on reducing environmental impact in every step of your product's life cycle. The foundation for Ecodesign is environmental data on a product.	Circular design means designing a product or service that creates no waste and pollution and keeps products and materials in use.
In practise	Look at design choices that reduce social and environmental impacts along every step in the life cycle of your products. From production to the waste phase. Where can you improve?	Environmental data is calculated through Life Cycle Assessments (LCA). The result: 15+ impact categories for each step in a product's life cycle. Analyze which process, material, or component causes your biggest impact- and improve your design.	Analyze and improve your product's design with two specific goals: (1) Minimum (preferably zero) waste & pollution throughout your product's life cycle. (2) Make sure your product's value doesn't decrease at the end of its life.
Examples	• *Analyze Social impact: Are workers being paid fair wages? Will your product have health-endangering effects on consumers when it's used?* • *Analyze environmental impact: Which materials in production are impact-intensive? Which processes could be sustainably optimized?*	• *Product Stewardship: Take full responsibility for your product's entire lifecycle. And make sure the product doesn't get lost at the end of its life- but stays in the value system.* • *Dematerialization: Reduce the weight, size, and number of materials you use in your design.*	• *Designing for inner loops: Materials in your product should maintain the highest value during- and after the end of its life.* • *Moving from products to services: Shifting from ownership to access. Instead of purchasing, you offer your product as a service.* Ecochain

3.7 BASIC PRINCIPLES OF CIRCULAR PRODUCT DESIGN

In circular economy, product design is of crucial importance, because adequate design can preserve natural and unused resources, extend the product lifespan, and facilitate its recycling and remanufacturing. Even if products and materials are designed in a "smart" way, if resources are not used efficiently, waste will be generated throughout the entire production process.

Circular product design is the initial, crucial phase for implementing the circular economy principles. This is because it sets up the preconditions to achieve the full potential of circular economy in other phases too – production, use and waste management.

These are the **TEN BASIC PRINCIPLES** of circular economy: ***Selection of materials; use of materials; circularity of materials; simple dismantling; quality and longevity; green technologies; adaptability and multifunctionality; design-to-last; circular distribution; and innovative models.***

The implementation of circular economy principles in product design entails the following: use of easily renewable resources; combining the resources in a way that allows easy separation; maximum efficiency in the use of resources; minimal amount of generated waste; minimal amount of waste that cannot be reused; use of generated waste in the remanufacturing process for identical or different products; maximum extension of value provided by a product or a service; sharing a product or a service instead of purchasing it; option to repair the product or to return it to the market; recycling to bring back resources in the production process and create new values in the most efficient way; and establishing networks between those that generate waste and those that use it as a resource.

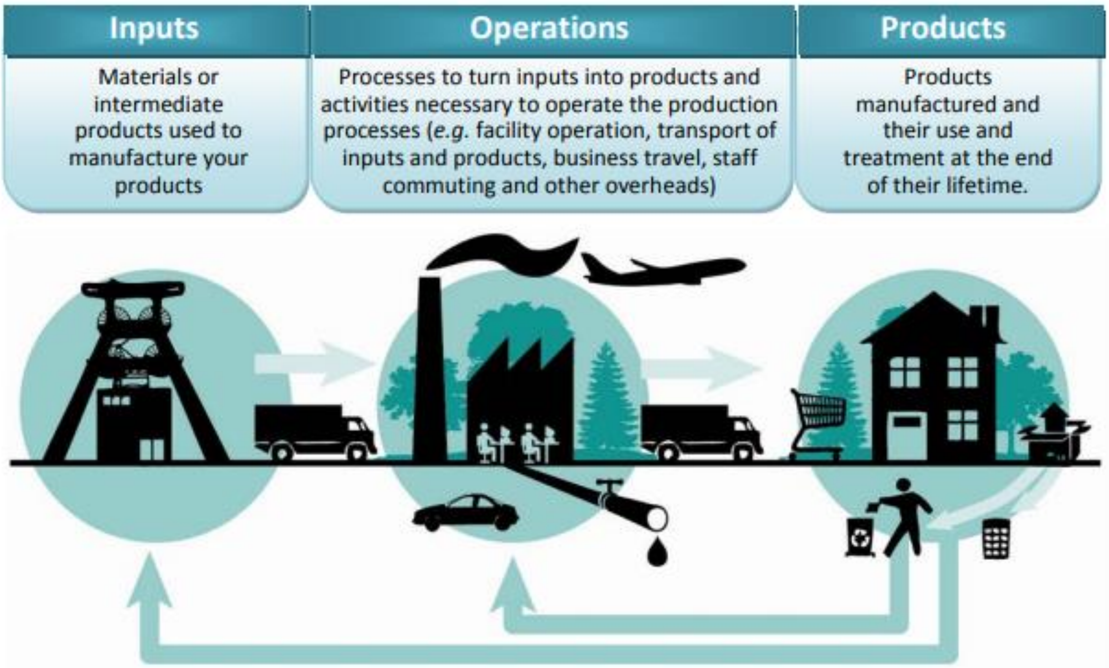
Implementing the circular economy principles when designing and manufacturing products, materials and components that can be reused, remanufactured and recycled, opens a wide range of opportunities for the private sector to speed up the innovations and jump start development without jeopardizing the environment. For this, the contribution of all direct stakeholders in the circular process is of utmost importance [[31]].

3.8 Environmental strategic visions of automotive companies:

Environmental strategic visions and plans of automotive companies are generally based on the following key objectives [[32]]:

- ☑ non-waste production technologies,
- ☑ reduction of emissions throughout the life cycle,
- ☑ reduction in fuel consumption and alternative sources of propulsion,
- ☑ replacement of non-recyclable materials,
- ☑ reducing the consumption of energy and water in the production process.

Even though the actual production processes are far more sophisticated, the environmental impacts are principally formed in the following three stages: inputs, operations, products [33]. The figure below indicates the basic interaction between bussines facility and the environment and the impact it may have on the environment throughout the 'lifecycle' of the products that it produces.



3-9. Figure Basic relationships between manufacturing and the environment

[The OECD Sustainable Manufacturing Toolkit, 2011]

3.9 THE ECO-INNOVATION DYNAMICS IN THE AUTOMOTIVE SECTOR

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

The automotive sector traditionally has been pointed out as one of the clearest examples of a mature industry, as well as a "successful" case of co-evolution between technologies, routines and structure.

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:

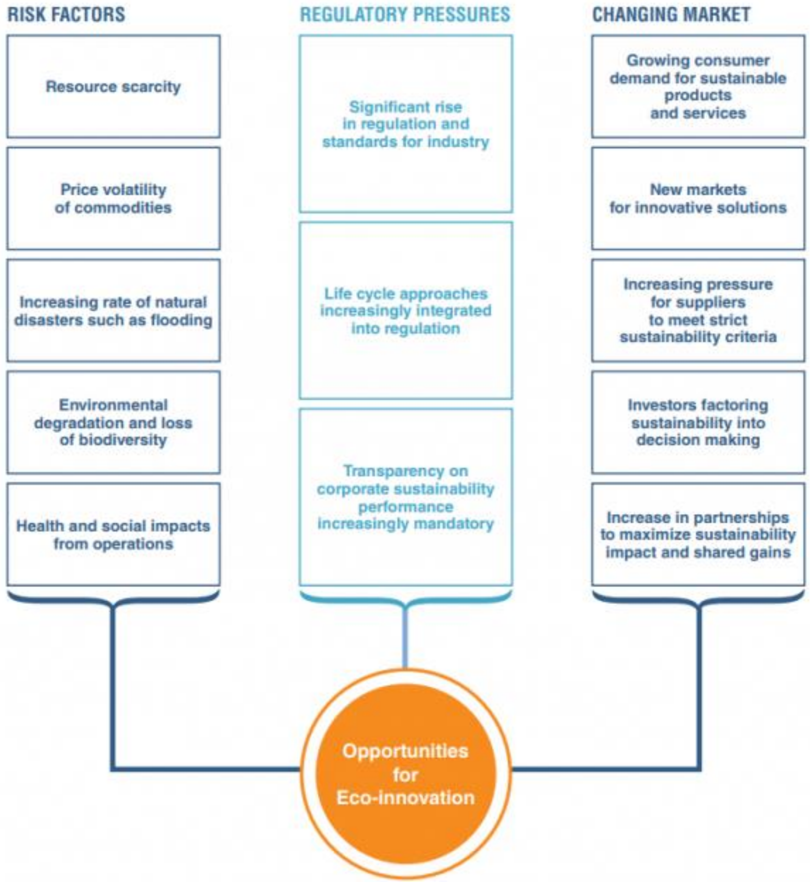
- internal combustion engines (ICE),
- all-steel car bodies, multi-purpose character, and
- fully integrated productive processes.

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 being 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.

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. The growing concern for the environment and the need for sustainable transport, the automotive industry is now focusing on eco-innovation (the process of developing environmentally friendly and sustainable products, services, and technologies).

There are several challenges that the industry is facing, such as increasing fuel prices, unpredictable demand, supply chain challenges, and growing concerns about air pollution. The semiconductor shortage alone resulted in a production loss of 1.5 million units in 2021.



3-10. Figure_ Increasing pressures on business are creating favourable conditions for eco-innovation [https://www.unep.org/eco-innovation]

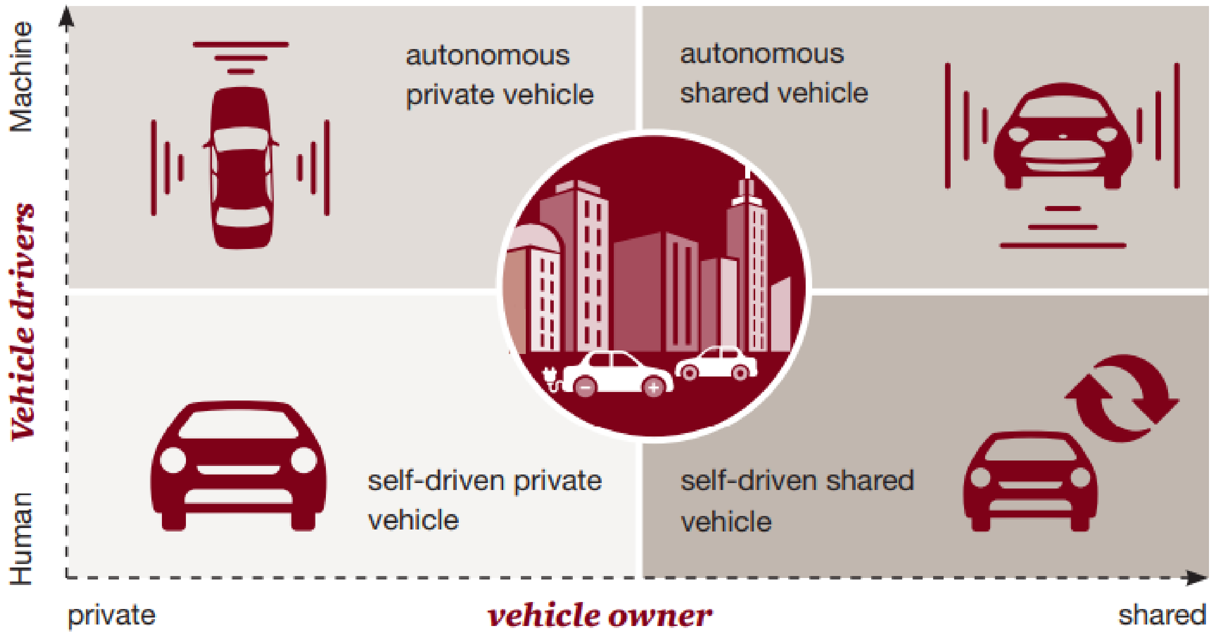
Eco-innovation practices have a positive influence on both sustainable performance and business performance in the automotive and auto parts industry [34].

Environmental protection is one of the basic pillars of the carmaker's sustainability and the automotive industry has the opportunity to shape this fundamental restructuring.

The automobile changed from a technical to a social commodity: it guarantees the personal mobility and social participation, shapes the cities and landscapes, and structures the temporal and spatial thinking. This is why it have to rethink the whole automotive industry – with the focus on the use rather than the production of vehicles, in order to make the lives of individual users more enjoyable, more efficient and safer.

The car of the future is **ELECTRIFIED, AUTONOMOUS, SHARED, CONNECTED AND YEARLY UPDATED: "EASCY"** [35].

Five of the top 20 companies with the highest R&D investment are vehicle manufacturers, but they do not feature among the 10 most innovative enterprises. Between 2020 and 2025 the industry will have to find ways of compensating for falling margins and rising investment. Manufacturers and suppliers should put users at the heart of their business model and offer them "eascy" mobility solutions. Implications will be the rapid redistribution of investment in research and development. Decisions regarding the long-term structure will be made between 2020 and 2025 and an illustrative representation of the mobility of the future is given in 3-11. Figure.



3-11. Figure_ Manifestation of the mobility of the future

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

Environmental strategic visions and plans of automotive companies are generally based on the following key objectives [36]: non-waste production technologies; reduction of emissions throughout the life cycle; reduction in fuel consumption and alternative sources of propulsion; replacement of non-recyclable materials; reducing the consumption of energy and water in the production process.

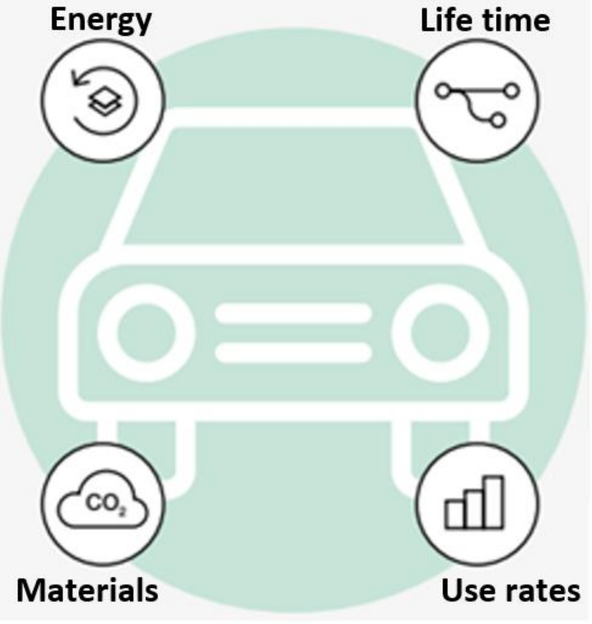
3.10 CIRCULAR CAR - VALUE AND EFFICIENCY

THE "CIRCULAR CAR", as a strategic concept, adopts a circular flow in the whole product lifecycle: reduction, recovery, repair, renovation, reuse, and recycling of all components. These processes are a part of the value chain, and the reason is to increase value and the circularity of materials.

A circular car maximizes value to society, the environment and the economy while efficiently using resources and public goods. Its value is measured in terms of its ability to provide mobility, and its efficiency is measured in terms of carbon emissions, non-circular resource consumption and use of public goods, such as space or clean air [37].

The definition focuses on the relevant variables [38]: energy, materials, lifetime, and use (3-12. Figure).

ENERGY is used efficiently (per km of movement) and renewable; **LIFETIME** of the vehicle and components is optimized for resource efficiency (by emphasizing efficient design, modularity, purpose-built vehicles, reuse, repair, remanufacturing, etc.). **MATERIALS** are used without waste (reduced, reused, recycled and/or renewed). **USE RATES** are optimized (accounting for resiliency requirements).



3-12. Figure_ The circular economy value chain for automotive companies

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

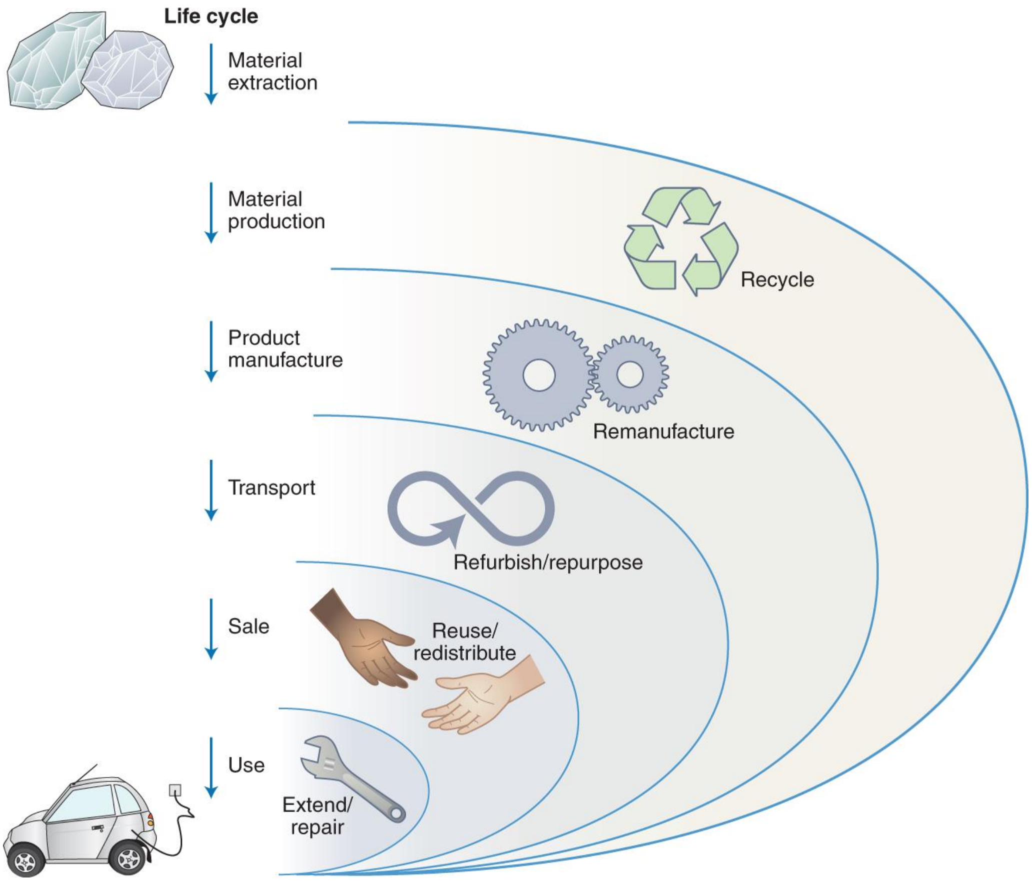
A circular car maximizes the value from resource consumption.

To measure progress over the five levels of circularity, is used carbon efficiency and resource efficiency as primary measures. Efficiency is increased by reducing carbon emissions and non-circular resource consumption, as well as by increasing the service delivered by a vehicle – mostly in the form of passenger kilometres.

Carbon efficiency: life-cycle CO2 emissions per passenger kilometre

Carbon efficiency takes a holistic view of a vehicle's carbon footprint – not merely exhaust emissions or carbon intensity of materials. This methodology accounts for both: a) total life-cycle emissions, including materials, production, use phase and end of life; and b) service delivered (as opposed to kilometres driven). The entire automotive fleet's carbon efficiency should align with a 1.5°C climate scenario.

The useful lifetime of electric vehicles can be extended through repair and reuse. Refurbishing and remanufacturing can have lower environmental impact compared with manufacturing, and recycling materials can decrease the demand for mining of new primary materials [39]. The circular strategies for electric vehicles are represented in 3-13. Figure.

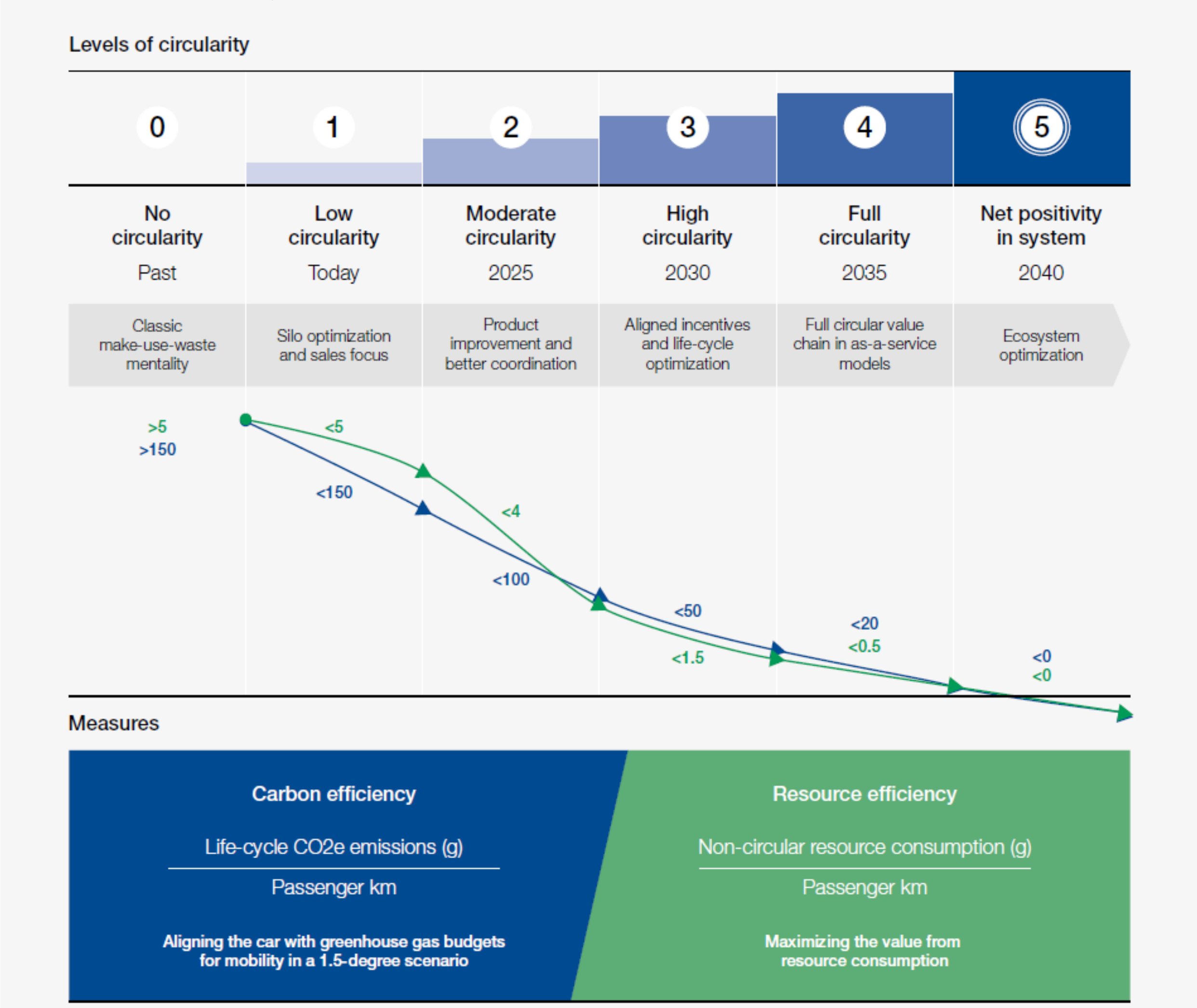


3-13. Figure_ Circular strategies for electric vehicles

[[40]Richter, J.L. A circular economy approach is needed for electric vehicles. *Nat Electron* **5,** 5–7 (2022). https://doi.org/10.1038/s41928-021-00711-9]

Accenture proposes a taxonomy with five levels of circularity based on two primary measures (carbon and resource efficiency) to evaluate and improve the circularity of cars [41]. The proposed levels range from single owner use and disposal (Level 0) to an aspirational goal of an automobility ecosystem that has net positive impacts (Level 5).

The levels describe vehicles that are part of an increasingly circular automobility system. Each level can be determined based on the characteristics of both the product and its use, so the producer and the owner of the car are responsible for achieving circularity.



3-14. Figure_ Levels of circularity

[Source: Accenture Strategy]

4 ECOINNOVATION – CASE OF ELECTRIC VEHICLES

4.1 BASICS OF ELECTROMOBILITY

The topic of "electromobility" basically refers to all vehicles that are driven by means of electrical energy. This includes both battery-powered vehicles and hybrid vehicles (full hybrid vehicles) or vehicles with a fuel cell. Electric vehicles are categorized primarily according to concept and their names indicate how the electrical energy is supplied [42].

The Electric vehicle is the most representative variety of the existing eco-friendly vehicles, because it does not use fossil fuel. With global warming becoming a serious problem and consumers opting for eco-friendly cars more than ever, the time will come soon when the global EV market share exceeds that of the internal combustion engine vehicles (ICEVs). According to Bloomberg NEF's 2019 report on EVs' prospects, 30% of all cars in the world will be EVs by 2040. And with increasing battery capacity, more charging infrastructure, and improving performance, modern-day EVs will not only help the future environment but also provide satisfying performance for all—they are indeed a core of future mobility [43].

Nearly the whole world is setting rigorous regulations to come closer to the emission-free "Zero-Carbon Age," and global manufacturers are diligently engaging in R&D to respond to this trend. EVs, which do not emit any exhaust, have emerged as the major environmental solution for the automotive industry.

Hyundai Motor Group declared 2021 as the year when its journey to global leadership in vehicle electrification begins. By 2025, the Group states, it will have released 23 eco-friendly vehicle lines and sold more than 1 million vehicles (or the market share of 10%). A concerted effort will be made to electrify the South Korean, U.S., Chinese, and European markets by 2030; developing markets like India and Brazil will have 2035 as the equivalent target.

These ambitious objectives are made plausible by the E-GMP (Electric-Global Modular Platform), Hyundai Motor Group's first EV-exclusive platform.

Platforms designed for EVs have serious ramifications on the EVs' cost-efficiency and quality assurance, which explains why many global manufacturers have been focusing their R&D capacity to develop a single platform. The E-GMP is a culmination of all Hyundai Motor Group's long-accumulated know-how in vehicle electrification.

Compared to existing platforms—which were mere redesigns of ICEV platforms—the E-GMP is distinguished by many advantages: flexibility in development, EV-optimized structural design, standardized high-capacity battery system, longer range, futuristic aesthetics, and revolutionary cabin spaciousness.

Vehicles that do not require fossil fuels to operate and do not emit CO2 are major concerns for car manufacturers. The introduction of environmentally friendly technologies in the manufacturing chain aims to improve the functionality of cars, such as safety and comfort while reducing pollution and fuel consumption.

Different types of electric cars changed and are developed continuously giving users and potential users choices. Today the world is increasingly familiar with the terms BEV, HEV, PHEV and FCEV. How an electric vehicle works is depend on the type.

An electric car is a vehicle that is fully or partially propelled by electric motors, using energy stored in rechargeable batteries. The first practical electric cars were produced in the 1880s. Electric cars were popular in the late 19th century and early 20th century.

Innovation and advanced development in internal combustion engines (ICE) and mass production of cheaper gasoline vehicles has led to a decline in the use of electric vehicles.

The development of energy storage technology, especially battery technology, makes electric cars become more popular again at this time.

THE MAIN COMPONENTS OF AN ELECTRIC VEHICLE

The electric vehicle drive system includes:

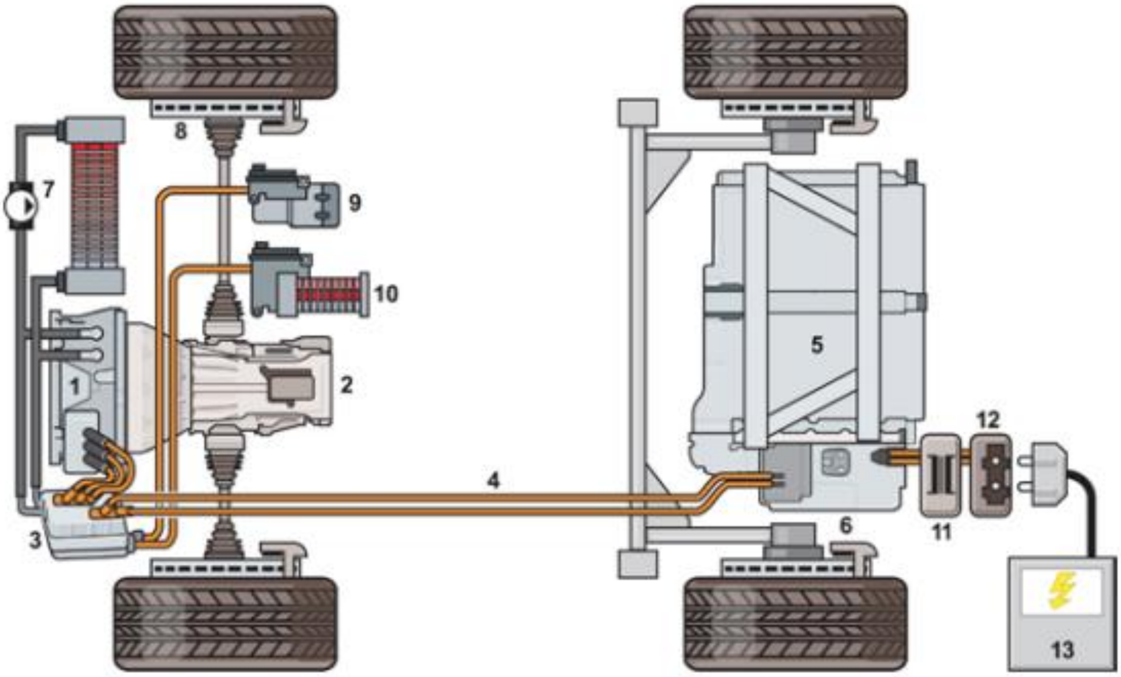
• High-voltage battery with control unit for battery regulation and charger

• Electric motor/generator with electronic control (power electronics) and cooling system

• Transmission including the differential

• Brake system

• High-voltage air conditioning for vehicle interior climate control



4-1. Figure_ Main Components of an Electric Vehicle

[Design-and-Function-Basics-of-Electric-Vehicle

https://electrical-engineering-portal.com/res3/Design-and-Function-Basics-of-Electric-Vehicles.pdf]

1 Electric motor/generator;
2 Transmission with differential;
3 Power electronics
4 High-voltage lines
5 High-voltage battery
6 Electronics box with control unit for battery regulation
7 Cooling system
8 Brake system
9 High-voltage air conditioner compressor
10 High-voltage heating
11 Battery charger
12 Charging contact for external charging
13 External charging source

4.2 ADVANTAGES OF ELECTROMOBILITY

- ☑ Electric drive motors run quieter than internal-combustion engines. The noise emissions from electric vehicles is very low. At high speeds, the rolling noise from the tires is the loudest sound.
- ☑ Electric vehicles produce no harmful emissions or greenhouse gases while driving. If the high-voltage battery is charged from renewable energy sources, an electric vehicle can be run CO2 -free.
- ☑ In the near future, if particularly badly congested town centres are turned into zero-emissions zones, we will only be able to drive through them with high-voltage vehicles.
- ☑ The electric drive motor is very robust and requires little maintenance. It is only subject to minor mechanical wear.
- ☑ Electric drive motors have a high degree of efficiency of up to 96% compared with internal-combustion engines that have an efficiency of 35–40%.
- ☑ Electric drive motors have excellent torque and output characteristics. They develop maximum torque from standstill. This allows an electric vehicle to accelerate considerably faster than a vehicle with an internal combustion engine producing the same output.
- ☑ The drive train design is simpler because vehicle components like the transmission, clutch, mufflers, particulate filters, fuel tank, starter, alternator and spark plugs are not required.
- ☑ When the vehicle is braked, the motor can also be used as an alternator that produces electricity and charges the battery (regenerative braking).

- ☑ The high-voltage battery can be charged at home, in a car park and by using any accessible sockets. The blue charging connector on the vehicle and on public charging stations has been standardized across Germany and is used by all manufacturers.
- ☑ The energy is only supplied when the user needs it. Compared with conventional vehicles, the electric drive motor never runs when the vehicle stops at a red light. The electric drive motor is highly efficient particularly in lines and bumper-to-bumper traffic.
- ☑ Apart from the reduction gearbox on the electric drive motor, the electric vehicle does not require any lubricating oil.

4.3 DISADVANTAGES OF ELECTRIC VEHICLES

• Electric vehicles have a limited range due to battery size and construction.

• Charging a high voltage battery can take a long time, depending on the battery cahrge and power source.

• The network of electric charging stations is sparse.

• If the destination is beyond the range of the electric vehicle, the driver will need to plan the journey. “Where can I charge my electric vehicle on the road?”

4.4 THE WORKING PRINCIPLE FOR BATTERY ELECTRIC VEHICLE (BEV) TYPE

EV’s Basic Working Principle [https://tech.hyundaimotorgroup.com/electrification/evs/]

When the driver turns on the car, the electricity in the high-voltage battery boots the vehicle and the systems power on in standby. When the gas pedal is pressed, the motor rotates and produces maximum torque. Then the EV transmission delivers the power to the wheels in accordance with the motor characteristics.

4-2. Figure_ Principal Parts of EV

[https://tech.hyundaimotorgroup.com/electrification/evs/]

PRINCIPAL PARTS AND TECHNOLOGIES

1. PE SYSTEM

1-1. MOTOR

The equivalent of the engine in an ICEV, the motor produces the power by which the vehicle can run by converting the electrical energy in the battery into mechanical energy. The motor also serves as a generator during reduction, per the regenerative braking system*.

**regenerative braking system: converts the kinetic energy from elastic running (e.g. running downhill) into electrical energy, which is then stored in the battery. The system basically recoups, or regenerates, some of the energy spent during braking.*

1-2. EV TRANSMISSION

The equivalent of the transmission in an ICEV, the EV transmission adjusts the number of revolutions by the motor, so that the electric vehicle can attain higher torque.

**EV Transmission Disconnector: the world's first adaption on an EV vehicle, in which the motor and the drive axle can be connected or disconnected as needed. The mechanism enables free shifting between 2WD and 4WD.*

1-3. INVERTER

The inverter converts DC-power in the battery to the AC-power used for torque control in the motor. The inverter power module comes with Silicon Carbide (SiC) semiconductors* that are more efficient than the existing semiconductors made with Silicon (Si).

*SiC semiconductors: Power semiconductors that use cutting-edge material Silicon Carbide (as opposed to Silicon) to convert/process/control electricity. They are sturdier, higher in thermal conductivity, and better conserves energy than the previous-gen Si semiconductors.

2. VEHICLE CHARGING MANAGEMENT SYSTEM (VCMS)

A central component of V2L* along with the ICCU, The Vehicle Charging Management System oversees all vehicle functions related to charging.

*V2L (Vehicle to Load): A technology that enables the electrical energy from the battery to be used by external devices. The maximum power output is set at 3.5kW due to certain parts specifications. If an In-cable Control Box (ICCB) is used, the system can also slow-charge another vehicle's battery (V2V; Vehicle-to-Vehicle).

3. INTEGRATED CHARGING CONTROL UNIT (ICCU)

The ICCU is an upgrade over the OBC, which only allowed one-directional charging from an external source to the battery. It now allows bi-directional charging, enabling the aforementioned V2L function.

4. VEHICLE CONTROL UNIT (VCU)

The VCU is responsible for controlling most vehicle functions dependent on electricity, including the control of the motor, regenerative braking, climate control, vehicle electronics, and power supply.

5. HIGH-VOLTAGE BATTERY

The battery stores and supplies the electrical energy needed to power the car. Inserting more battery cells into the battery increases the vehicle range, but it also makes the vehicle heavier and more expensive. Finding the point of compromise that best fits the vehicle model is key. Recent advances in battery technology have seen the gradual rise of battery energy density.

6. 400/800V MULTI-CHARGING SYSTEM

This patented system, applied to the E-GMP, is the first charging system in the world to allow seamless multi-charging between 400V and 800V. The default 800V Ultra High-Speed Charging requires 18 minutes up to 80 percent of capacity, yielding 500 km of range; just a 5-minute charge can yield 100 km. The system also supports the still-mainstream 400V High-Speed Charging, in which case it uses the motor and the inverter to convert the voltage from 400V to 800V before battery storage.

When pedal of the car is pressed, then [44]:

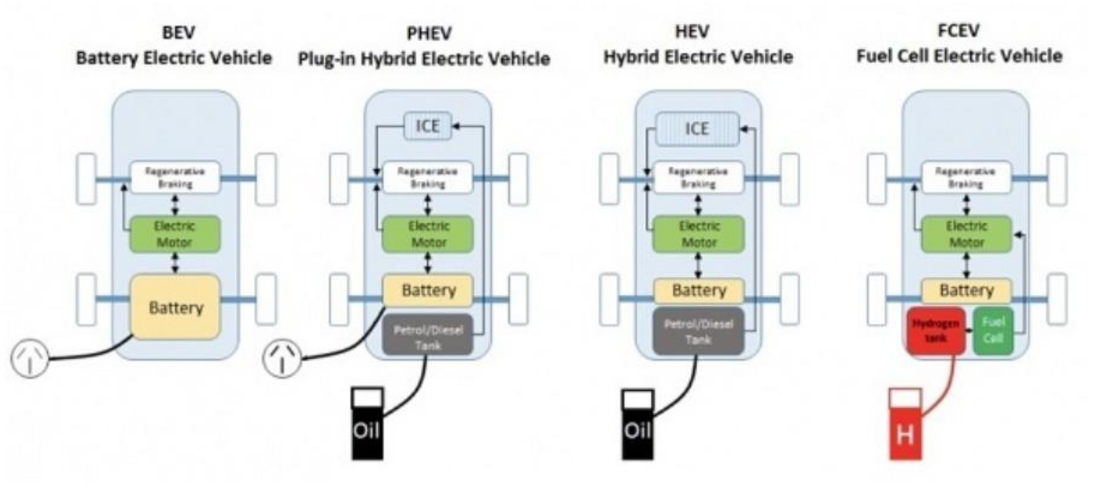
- Controller takes and regulates electrical energy from batteries and inverters
- With the controller set, the inverter then sends a certain amount of electrical energy to the motor (according to the depth of pressure on the pedal)
- Electric motor converts electrical energy into mechanical energy (rotation)
- Rotation of the motor rotor rotates the transmission so the wheels turn and then the car moves.

4.5 TYPES OF ELECTRIC CARS

There are 4 (four) types of electric cars, with the following outline:

1. Battery Electric Vehicle (BEV)
2. Hybrid Electric Vehicle (HEV)
3. Plug-in Hybrid Electric Vehicle (PHEV)
4. Fuel Cell Electric Vehicle (FCEV)

The system architecture of the four types of electric cars above can be seen in the following figure:



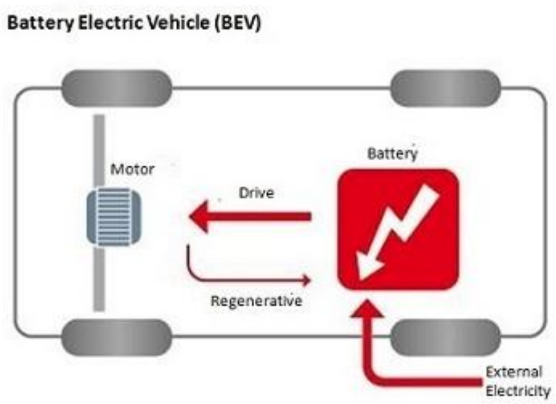
4-3. Figure The system architecture of the four types of electric cars [https://www.omazaki.co.id/en/types-of-electric-cars-and-working-principles/]

4.6 BATTERY ELECTRIC VEHICLE (BEV)

A Battery Electric Vehicle (BEV), also called All-Electric Vehicle (AEV), runs entirely on a battery and electric drive train. This types of electric cars do not have an ICE. Electricity is stored in a large battery pack that is charged by plugging into the electricity grid. The battery pack, in turn, provides power to one or more electric motors to run the electric car.

4.6.1 COMPONENTS OF BEV

- Electric motor
- Inverter
- Battery
- Control Module
- Drive train



4-4. Figure Architecture and Main Components of BEV [https://www.omazaki.co.id/en/types-of-electric-cars-and-working-principles/]

4.6.2 WORKING PRINCIPLES OF BEV

- Power is converted from the DC battery to AC for the electric motor
- The accelerator pedal sends a signal to the controller which adjusts the vehicle's speed by changing the frequency of the AC power from the inverter to the motor
- The motor connects and turns the wheels through a cog
- When the brakes are pressed or the electric car is decelerating, the motor becomes an alternator and produces power, which is sent back to the battery

EXAMPLES OF BEV: Volkswagen e-Golf, Tesla Model 3, BMW i3, Chevy Bolt, Chevy Spark, Nissan LEAF, Ford Focus Electric, Hyundai Ioniq, Karma Revera, Kia Soul, Mitsubishi i-MiEV, Tesla X, Toyota Rav4.

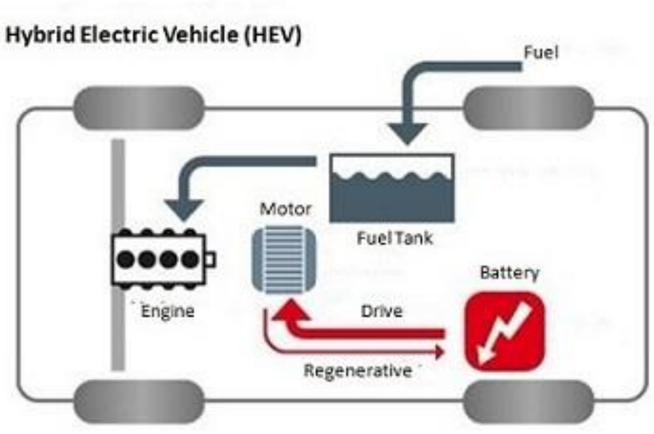
4.7 HYBRID ELECTRIC VEHICLE (HEV)

This type of hybrid cars is often called as standard hybrid or paralel hybrid. HEV has both an ICE and an electric motor. In this types of electric cars, internal combustion engine gets energy from fuel (gasoline and others type of fuels), while the motor gets electricity from batteries. The gasoline engine and electric motor simultaneously rotate the transmission, which drives the wheels.

The difference between HEV compared to BEV and PHEV is where the batteries in HEV can only charged by the ICE, the motion of the wheels or a combination of both. There is no charging port, so that the battery cannot be recharged from outside of the system, for example from the electricity grid.

4.7.1 COMPONENTS OF HEV

- Engine
- Electric motor
- Battery pack with controller & inverter
- Fuel tank
- Control module



4-5. Figure Architecture and Main Components of HEV [https://www.omazaki.co.id/en/types-of-electric-cars-and-working-principles/]

4.7.2 WORKING PRINCIPLES OF HEV

- ⇨ Has a fuel tank that supplies gas to the engine like a regular car
- ⇨ It also has a set of batteries that run an electric motor
- ⇨ Both the engine and electric motor can turn the transmission at the same time

EXAMPLES OF HEV Honda Civic Hybrid, Toyota Prius Hybrid, Honda Civic Hybrid, Toyota Camry Hybrid.

4.8 PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)

PHEV is a type of hybrid vehicle that both an ICE and a motor, often called as series hybrid. This types of electric cars offers a choice of fuels. This type of electric cars is powered by a conventional fuel (such as gasoline) or an alternative fuel (such bio-diesel) and by a rechargeable battery pack. The battery can be charged up with electricity by plugging into an electrical outlet or electric vehicle charging station (EVCS).

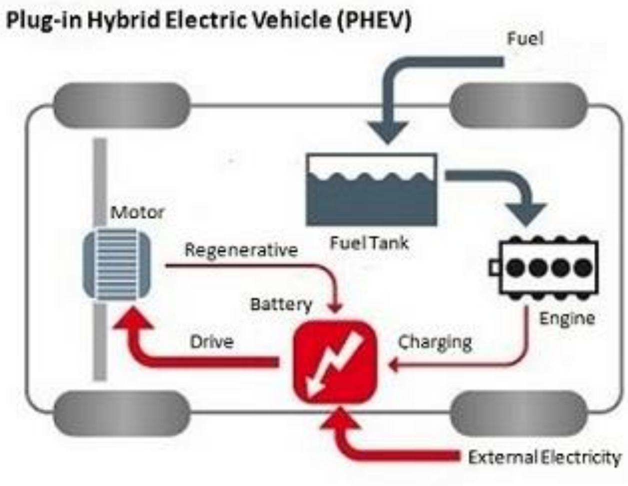
PHEV typically can run in at least two modes:

- All-electric Mode, in which the motor and battery provide all the car's energy
- Hybrid Mode, in which both electricity and gasoline are employed.

Some PHEVs can travel more than 70 miles on electricity alone.

4.8.1 COMPONENTS OF PHEV

- Electric motor
- Engine
- Inverter
- Battery
- Fuel tank
- Control module
- Battery Charger (if onboard model)



4-6. Figure Architecture and Main Components of PHEV
[https://www.omazaki.co.id/en/types-of-electric-cars-and-working-principles/]

4.8.2 WORKING PRINCIPLES OF PHEV

- ⇨ PHEVs typically start up in all-electric mode and operate on electricity until their battery pack is depleted.
- ⇨ Some models shift to hybrid mode when they reach highway cruising speed, generally above 60 or 70 miles per hour.
- ⇨ Once the battery is empty, the engine takes over and the vehicle operates as a conventional, non-plug-in hybrid.
- ⇨ In addition to plugging into an outside electric power source, PHEV batteries can be charged by an internal combustion engine or regenerative braking. During braking, the electric motor acts as a generator, using the energy to charge the battery. The electric motor supplements the engine's power; as a result, smaller engines can be used, increasing the car's fuel efficiency without compromising performance.

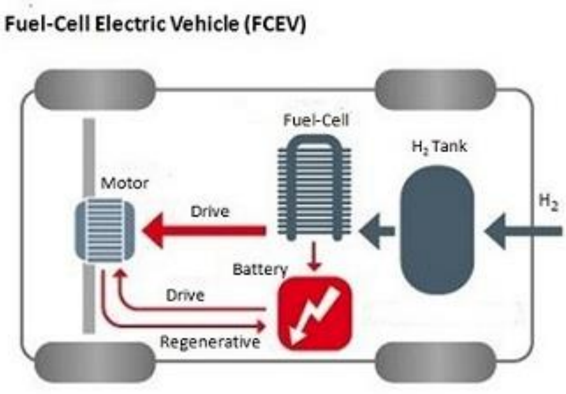
EXAMPLES OF PHEV: Porsche Cayenne S E-Hybrid , Chevy Volt, Chrysler Pacifica, Ford C-Max Energi, Ford Fusion Energi, Mercedes C350e, Mercedes S550e, Mercedes GLE550e, Mini Cooper SE Countryman, Audi A3 E-Tron, BMW 330e, BMW i8, BMW X5 xdrive40e, Fiat 500e, Hyundai Sonata, Kia Optima, Porsche Panamera S E-hybrid, Volvo XC90 T8.

4.9 FUEL CELL ELECTRIC VEHICLE (FCEV)

Fuel Cell Electric Vehicles (FCEVs), also known as fuel cell vehicles (FCVs) or Zero Emission Vehicle, are types of electric cars that employ 'fuel cell technology' to generate the electricity required to run the vehicle. In this type of vehicles, the chemical energy of the fuel is converted directly into electric energy.

4.9.1 COMPONENTS OF FCEV

- Electric motor
- Fuel-cell stack
- Hydrogen storage tank
- Battery with converter and controller



4-7. Figure Architecture and Main Components of FCEV

[https://www.omazaki.co.id/en/types-of-electric-cars-and-working-principles/]

FCEVs share many of the same components as BEVs, such as electric motors and power controllers or inverters; however, the major difference is the main energy source. While BEVs use energy stored in the battery, FCEVs use fuel cells as they are superior to batteries in many ways. The major advantages are that fuel cells are lighter and smaller and can produce electricity as long as the fuel is supplied. Due to the clear similarities between batteries and fuel cells, both these technologies will coexist in the future, while the BEV is suitable for short range and small vehicles, the FCEV is suitable for medium-large and long range vehicles [45].

4.9.2 WORKING PRINCIPLES OF FCEV

The **principle of how FCEVs work is simple**, since they use low temperature fuel cells to generate electricity from hydrogen; the electricity is then either used to drive the vehicle or stored in an energy storage device, such as batteries or ultra capacitors. Since fuel cells generate electricity from chemical reactions, they do not combust fuel and therefore do not produce pollutants and produce much less heat than an ICE. The by-product of a hydrogen fuel cell is water. Fuel cells have no moving parts or irregular shapes, so they have the potential for high reliability and low manufacturing cost.

Although FCEVs possess many advantages, they also have certain limitations, relating to the fuel cell stack itself and its fuel, hydrogen production, transportation and storage.

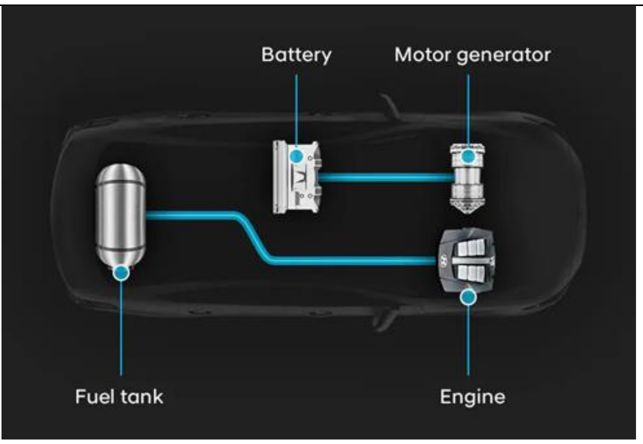
The working principle of a ‘fuel cell’ electric car is different compared to that of a ‘plug-in’ electric car. This types of electric cars is because the FCEV generates the electricity required to run this vehicle on the vehicle itself.

Examples of FCEV: Toyota Mirai, Hyundai Tucson FCEV, Riversimple Rasa, Honda Clarity Fuel Cell, Hyundai Nexo.

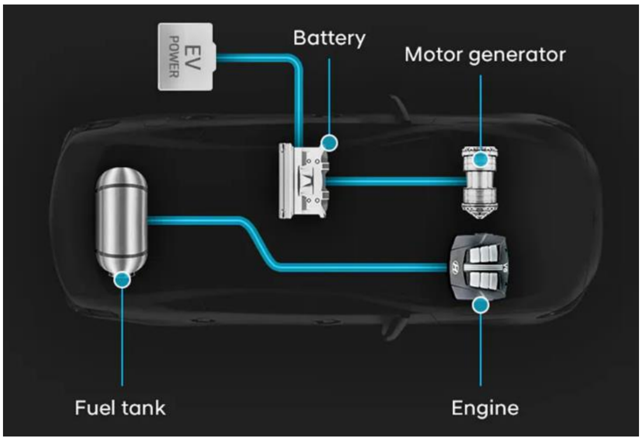
4.10 MOTOR’S GREEN TECHNOLOGY VEHICLE FROM HYUNDAI

Hyundai Motor has introduced several green technologies and developed green cars with the guidance of the ‘Blue Drive’ strategy [46]. Hyundai Motor’s green models include a Hybrid Electric Vehicle (HEV), a Plug-in Hybrid Electric Vehicle (PHEV) which can be charged using grid electricity, a zero-emissions battery Electric Vehicle (EV) and a Fuel Cell Electric Vehicle (FCEV) which is regarded as the ultimate green car.

HYBRID ELECTRIC VEHICLE (HEV) combines two power sources of an internal combustion engine and an electric motor. As Hyundai's innovative development of parallel hybrids achieves better fuel economy with improved packaging efficiency, the Hybrid Starter Generator control technology further assists the engine clutch control and reduces the tension between the EV mode and the engine mode for smoother hybrid driving.



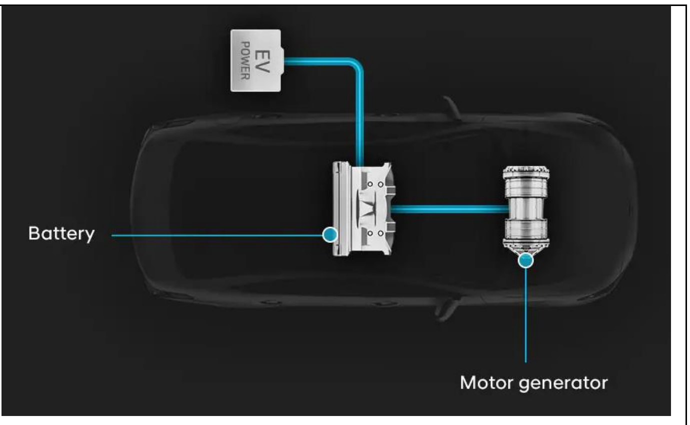
4-8. Figure HYBRID ELECTRIC VEHICLE



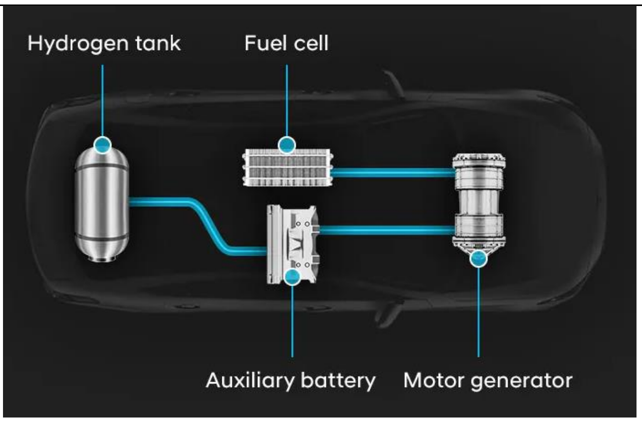
4-9. Figure PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV)

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) is an advanced hybrid vehicle with extended battery life and greater energy density for more fuel-efficient and long-distance driving in all-electric mode. Whether driven on EV mode or HEV mode, PHEV has a significant advantage of providing greater driving performance while reducing levels of emissions by restoring the energy from an external electric power source.

ELECTRIC VEHICLE (EV) uses electrical energy sources of electric motors and rechargeable high-density battery for propulsion. Powered by an external source of electricity, EV helps reduce carbon emissions. Equipped with a 27kWh lithium-polymer (Li-Poly) battery pack, Hyundai's EV provides optimized solutions for better performance, higher energy density and speed.



4-10. Figure Hyundai ELECTRIC VEHICLE (EV)

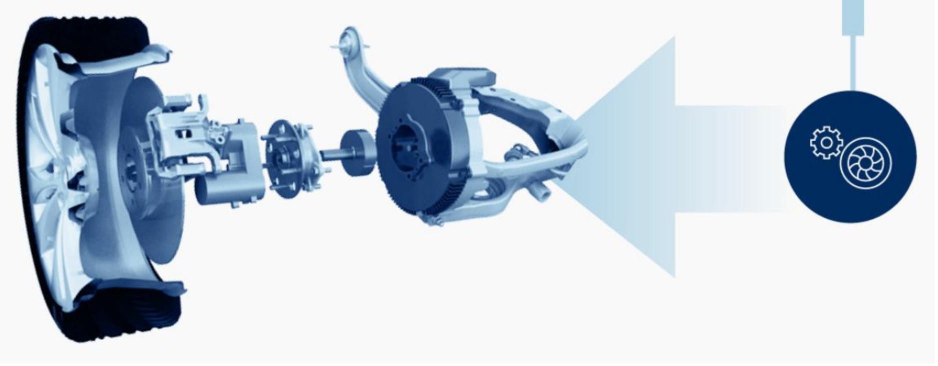


4-11. Figure FUEL CELL ELECTRIC VEHICLE (FCEV)

By combining Hydrogen and Oxygen atoms in a fuel cell stack, **FUEL CELL ELECTRIC VEHICLE (FCEV)** stores compressed hydrogen under high pressure in tanks and produces its own electricity for power with zero exhaust emissions. As the first developer of the world's first mass-produced fuel-cell vehicles, Hyundai continues to lead the future of sustainable motoring technology.

4.11 ENERGY-EFFICIENT IN-WHEEL MOTOR

The in-wheel motor system enables an independent driving and braking with an electric motor equipped inside the wheel. It is a future-oriented, eco-friendly system that does not require an internal combustion engine, gearbox, or drive shaft. The motor and the brake are attached to each wheel, maximizing energy-efficiency and cabin space.



4-12. Figure_ The in-wheel motor system

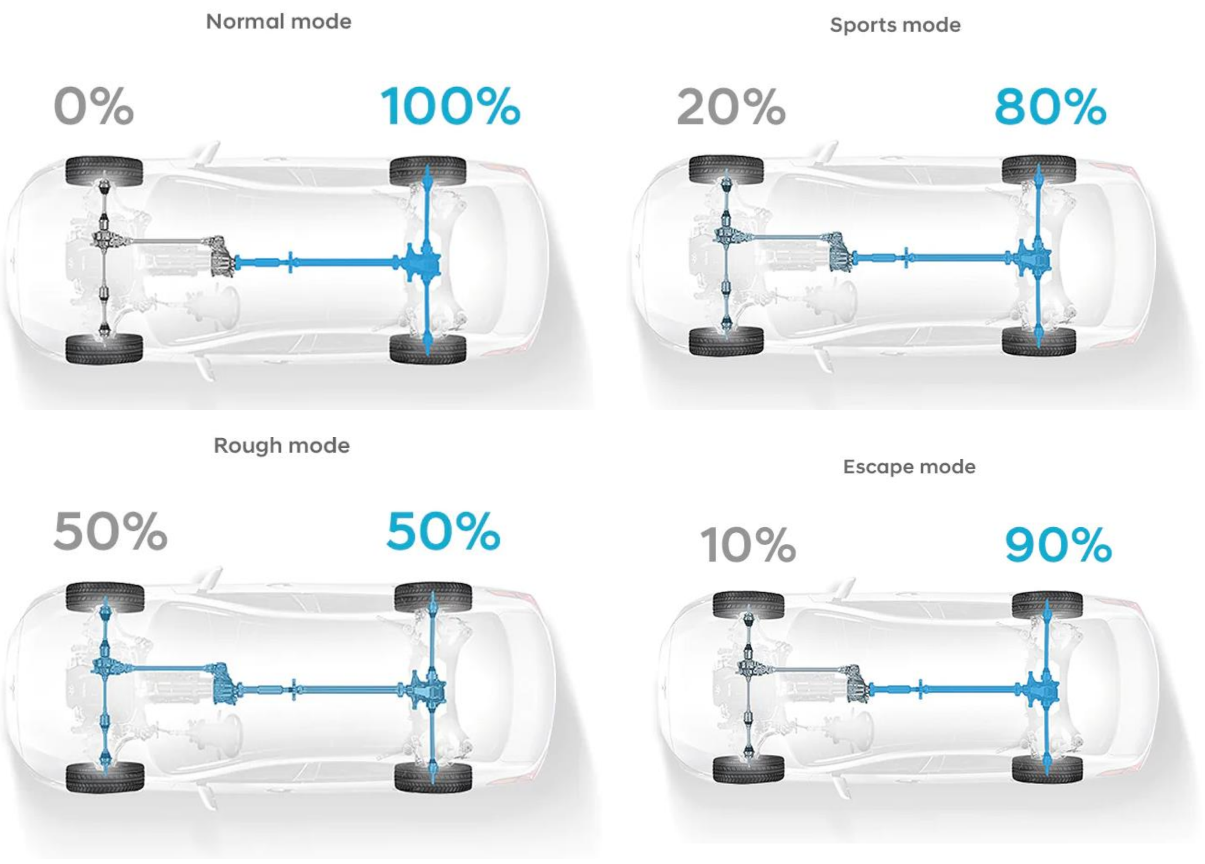
https://tech.hyundaimotorgroup.com/article/ev-a-to-z-encyclopedia-tech-features/

Automakers in Germany, Japan, and the U.S. are also working on developing the system. Hyundai showcased its concept model with the in-wheel motor in it through the Hyundai N 2025 Gran Turismo design back in 2015. The system will be widely used in other electricity-powered, eco-friendly vehicles, such as FCEVs.

4.12 INNOVATION TECHNOLOGY: ELECTRONIC ALL-WHEEL-DRIVE SYSTEM

A new value proposition for automobiles

HTRAC from Hyundai is an electronic all-wheel-drive system that makes it possible to allocate freely the distribution of traction between the front and rear wheels of the vehicle depending on driving conditions. It provides dynamism and stability to enhance the pleasure of driving or to help maneuver out of difficult road conditions.



4-13. Figure_Electronic all-wheel-drive system

[https://www.hyundai.com/worldwide/en/company/innovation/technology/performance]

4.13 Eco innovation for the powertrain

The engine is the heart of a car and having a great engine is essential for making a great car

4.13.1 ENGINE

Hyundai Motor has focused its research and development efforts on creating engines that can achieve high efficiency during everyday use. Good performance characteristics, higher efficiency and cleaner emissions are achieved and an attempt is made to achieve the perfect balance between power and efficiency, with special attention to the environment.

	Tau engine 5.0 V8 GDi gasoline engine Honored as one of Ward’s 10 best engines in the U.S., the Tau engine is an independently developed engine that represents the culmination of Hyundai Motor Company's engine development know-how and optimized tuning technology.
	Lambda engine 3.8 V6 GDi gasoline engine Introducing the improved version of the world-renowned V6 engine. Now a 3.8 GDi unit, it's as durable, fuel-efficient, and lightweight with minimum noise and vibration levels also delivering more impressive low rpm torque (334 ps at 6,400 rpm and 40.3 kg·m at 5,100 rpm).
	Theta engine 2.0 T-GDi gasoline engine Lightweight and reliable, this high-spec unit delivers a maximum torque 36.0kg·m at 1,350 ~ 4,000 rpm. Theta engine provides dynamic driving performance, with its Theta 2.0 T-GDi gasoline engine taking you from 0 to 100 kph in 7.5 sec.
	Nu engine 2.0 GDi gasoline engine With Gasoline direct injection (GDi), the maximum power is 164 ps at 6,200 rpm while torque peaks at 20.7 kg·m at 4,700 rpm.

4-14. Figure_Engines

4.13.2 TRANSMISSION

8-SPEED AUTOMATIC REAR WHEEL DRIVE TRANSMISSION

4-15. Figure_ 8Speed automatic rear wheel drive transmission from Hyundai

HYUNDAI is the first carmaker in the world who develop this cutting-edge technology. Compared to the 6-speed gearbox, the 8-speed automatic RWD transmission delivers better fuel economy and power performance while boasting a unique structure that is more compact than the 6-speed unit.

7-SPEED DOUBLE CLUTCH TRANSMISSION (DCT)

4-16. Figure_ 7-Speed double clutch transmission (DCT) from Hyundai

Hyundai's 7-speed Double clutch transmission (DCT) provides exceptional fuel economy and low CO_2 emission while impressively increasing acceleration performance.

4.14 ELECTRONIC CONTROL SYSTEMS

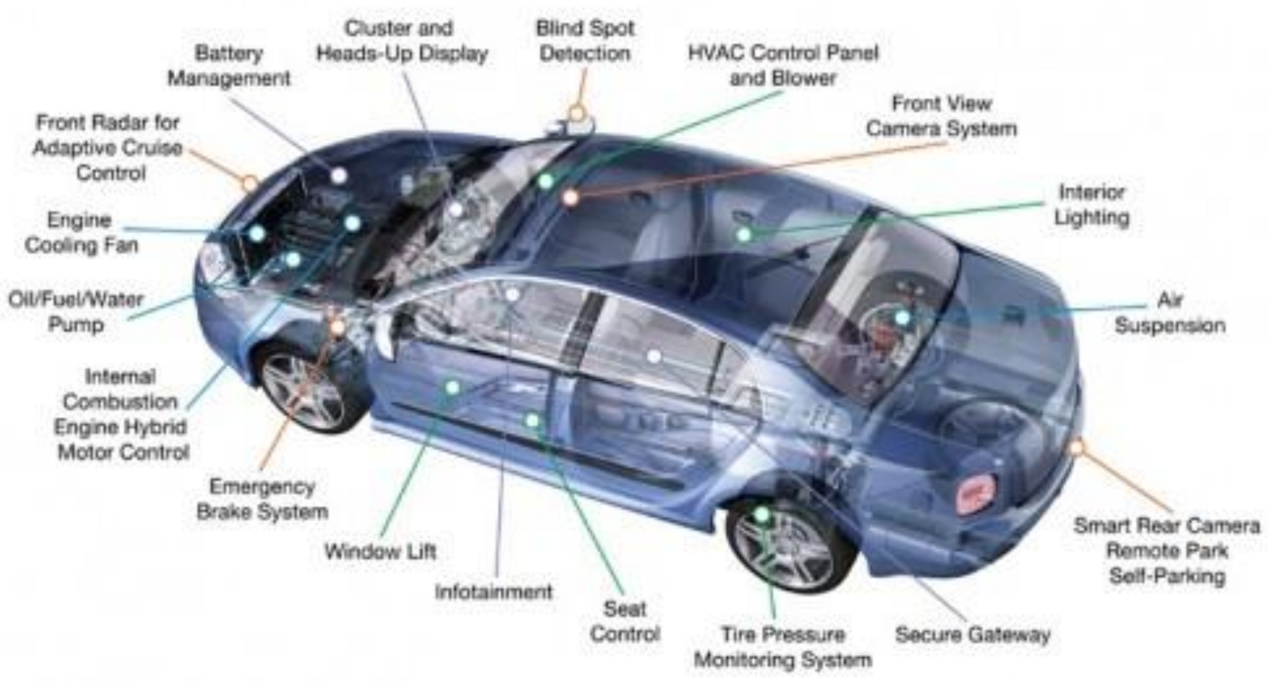
Better Fuel Efficiency, Safety, Convenience & Tighter Emission Control can only be achieved by Electronic Control Systems. More Electronics are adopted for luxury car which is followed by low-end car. More intelligent and highly integrated ECUs needs more custom ASICs.

Automotive Requires More Stringent Standard

Reliability is the most important factor in Automotive Semiconductors.

All requirements such as Temperature, Product Life Span, Humidity, Defect rate, Supply Commitment, and etc are much strict than one of Consumer, or Industrial.

A in-depth understanding about the circuit and semiconductor devices is a must.



4-17. Figure_ Automotive Electronic Systems & Semiconductors

[https://aesl.unist.ac.kr/]

Broad Area of Research On Automotive Semiconductors

Automotive Electronics : Sensors, ECUs, Actuators

Sensors - Pedal Detection Sensor, Radar, etc.

ECUs - MCU, Analog IC, ASIC, etc.

Actuators - Injector, Brake Booster, HVAC, etc.

Wide understanding at mechanical, analog, digital, power circuits is very important.

4.15 ELECTRONIC CONTROL UNIT

An Electronic Control Unit (ECU) is an embedded system that controls various functions of a vehicle, such as engine management, transmission control, braking systems, climate control, and more.

The ECU acts as the brain of the vehicle, processing and interpreting data from various sensors to control the operation of different components and subsystems. It collects information from sensors and makes real-time adjustments to optimize vehicle performance, enhance safety, and improve fuel efficiency.

This important information is stored in the control unit's data, so it is necessary to protect such confidential data. Therefore, consumers are increasingly inclined to data security.

Automotive World, Power Electronics

4-18. Figure_Role of Electronic Control Units in vehicle performance

Common types of ECU:

ENGINE CONTROL MODULE: Also known as an engine control unit. Responsible for assessing the load of the engine and tuning the ignition, fuel delivery and more to deliver optimum performance and economy.

TRANSMISSION CONTROL MODULE: These control the way, and when, an automatic gearbox shifts. Besides being fed with sensor data from the transmission itself, TCMs may also take data from the engine control unit to deliver more suitable, precise shifts.

SUSPENSION CONTROL MODULE: Sometimes dubbed a ride control module and common in active, adjustable or air suspension set-ups. These adjust the suspension to suit the current driving conditions, or work to maintain the correct ride height.

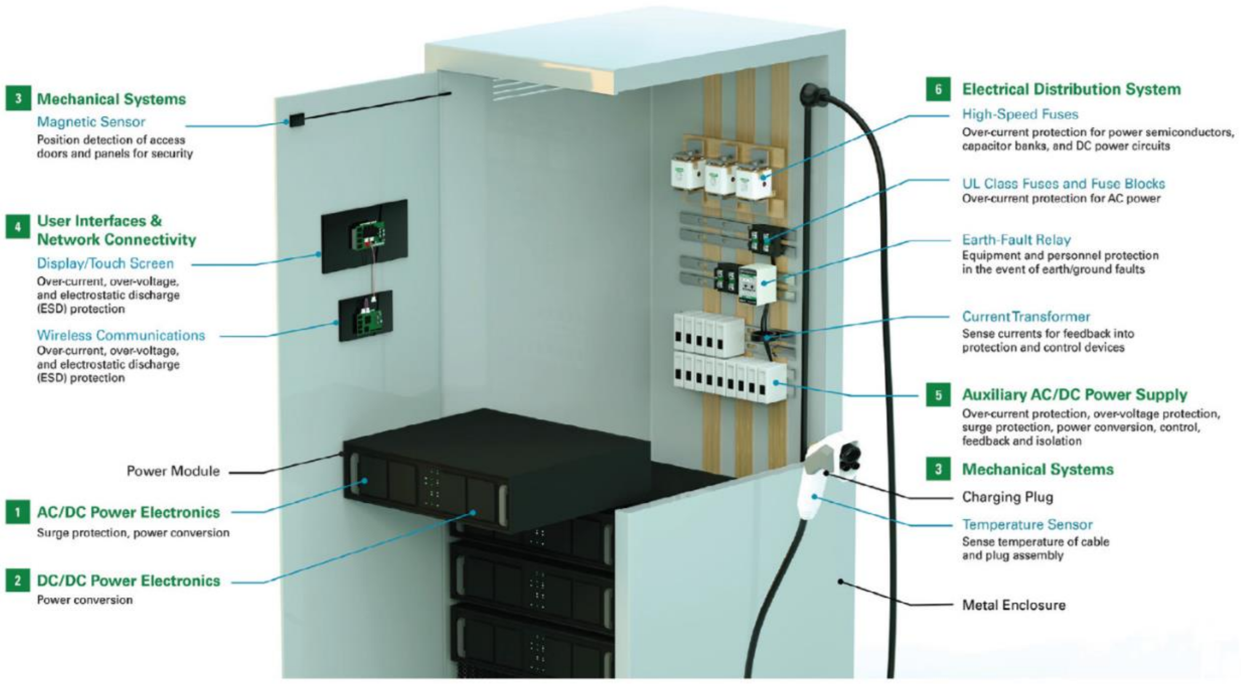
BODY CONTROL MODULE: This unit is typically responsible for controlling the car's myriad electrical access, comforts and security features. Common features it controls include door locks, electric windows and climate systems.

TELEMATICS CONTROL MODULE: Typically offers internet and phone connectivity for the car's on-board services. May also include a GPS receiver for navigation services.

4.16 DESIGNING OF THE EV CHARGING STATIONS

Tackling the triple challenges of safety, efficiency and reliability is key to the EV revolution.

https://www.engineering.com/story/how-to-design-ev-charging-stations-the-right-way?utm_source=engineering.com&utm_campaign=61b5ea9a9f-



4-19. Figure_ Inside an EV charging station. (Source: TTI.)

4.17 WIRELESS CHARGING FOR XEV

Wireless charging of an electric vehicle or a plug-in Hybrid is not a dream. Electricity is transmitted by magnetic induction between the transmitting coil on the ground and the receiving coil in the car. This technology is a crucial step forward to cable-free electro mobility.

4-20. Figure_ Wireless parking charge

[https://www.toyota-europe.com/news/2016/wireless-charging-for-xev]

xEV –refers to pure electric vehicle (EV) or plug-in Hybrid (PHV) – is one of the hot areas of industry studies.

An alternative solution, able to simplify and optimize the charging process, is wireless charging, which can be used both with the vehicle in motion and with the vehicle parked.

The possibility to charge a vehicle without a cable would generate a number of advantages: automatic 'hands-free' charging, cable-free clean look of charging stations, and so on.

Electricity is transmitted by magnetic induction between the transmitting coil on the ground and the receiving coil in the car. This technology is a crucial step forward to cable-free electro mobility.

Halo technology — which Qualcomm has been developing since before 2012 — is an entire system for charging an EV, enabling drivers to recharge simply parking over wireless charging ground pads [[47]].

THE TECHNOLOGY INVOLVED INCLUDES: power conversion, tuning, wireless power transfer, magnetics, control, communications and safety systems.

WiTricity (Watertown, Mass.) said the acquisition would simplify the ratification of a standard to help ensure wireless charging interoperability across automakers. EV drivers will be able to use any standards-compatible pad to charge their vehicles [[48]].

A partnership between Qualcomm, automaker Renault and a French R&D institute have been developing an "electric road" technology based on Halo that is capable of recharging an EV while the vehicle is in motion.

4-21. Figure_ Wireless EV charging technology

https://www.eetasia.com/qualcomm-sells-wireless-ev-charging-technology-to-witricity/

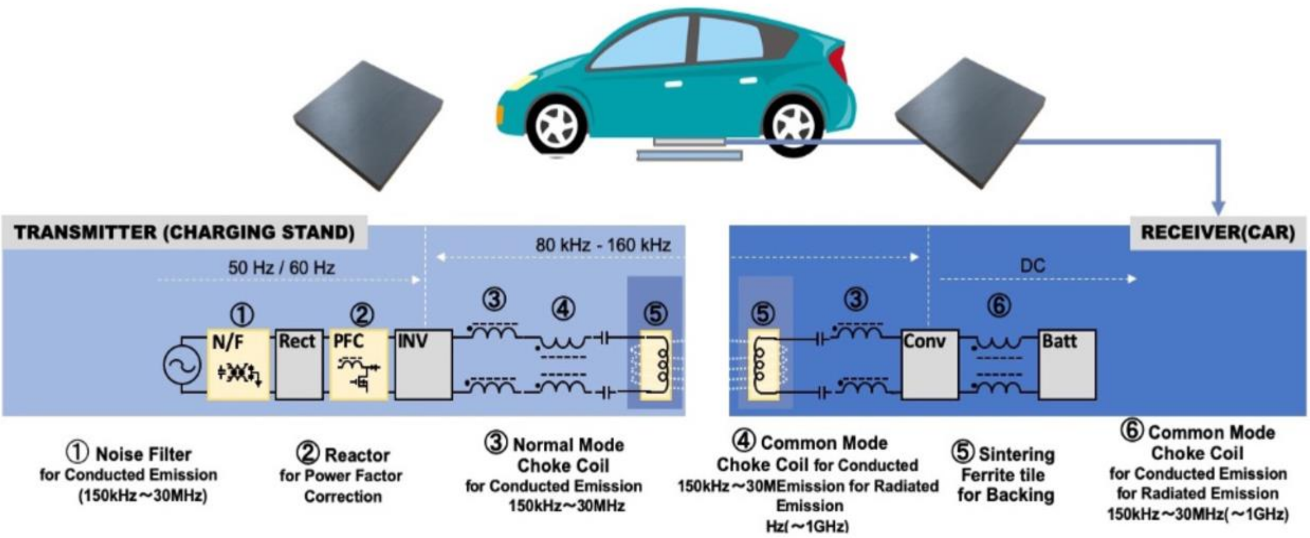
The latest technological advances made by two companies operating in the wireless charging sector, demonstrating how this technology is ever closer to achieving large–scale adoption.

ELECTREON’S TECHNOLOGY

Electreon, a provider of wireless charging solutions for EVs, has successfully tested its dynamic wireless charging technology at the “Arena of the Future” test track powering a Fiat 500 EV and an Iveco electric bus.

Fiat 500 EV was able to travel at a typical highway speed without drawing energy from its battery pack, thus extending its range. Similarly, driving at a lower speed, the vehicle might be able to restore some of its charge.

The Dynamic Wireless Power Transfer (DWPT) technology developed by Electreon is based on conductor loops that are deployed under the asphalt and transmit the energy to the receiver plates of the EV using the principle of magnetic induction. The receiver plate can be installed indifferently on an EV, an electric bus, or an electric truck. To limit power losses and facilitate integration with renewable energy sources, the technology uses DC electricity. Compared to AC charging, this solution allows to use thinner cables, reducing costs and simplifying the thermal management.



4-22. Figure_ The Dynamic Wireless Power Transfer (DWPT) technology developed by Electreon []

5 ORGANISATIONAL ECO-INNOVATION - AUTOMOTIVE SMART FACTORY

Organisational eco-innovation - new organisational methods and management systems for dealing with environmental issues.

A SMART FACTORY is a digitised manufacturing facility that uses connected devices, machinery and production systems to continuously collect and share data. This data is then used to inform decisions to improve processes as well as address any issues that may arise [[49], [50], [51]].

The **SMART MANUFACTURING PRACTICES** used by a smart factory are enabled by a variety of technologies including: artificial intelligence (AI), big data analytics, cloud computing, and the industrial Internet of Things (IoT).

5.1 DIGITALIZATION OF AUDI GLOBAL PRODUCTION

An element of the company's digitalization efforts is the Automotive Initiative 2025 – AI25 for short– which was launched in early 2021. The goal of the initiative is to create a global network of expertise for digital factory transformation and sustainable innovation.

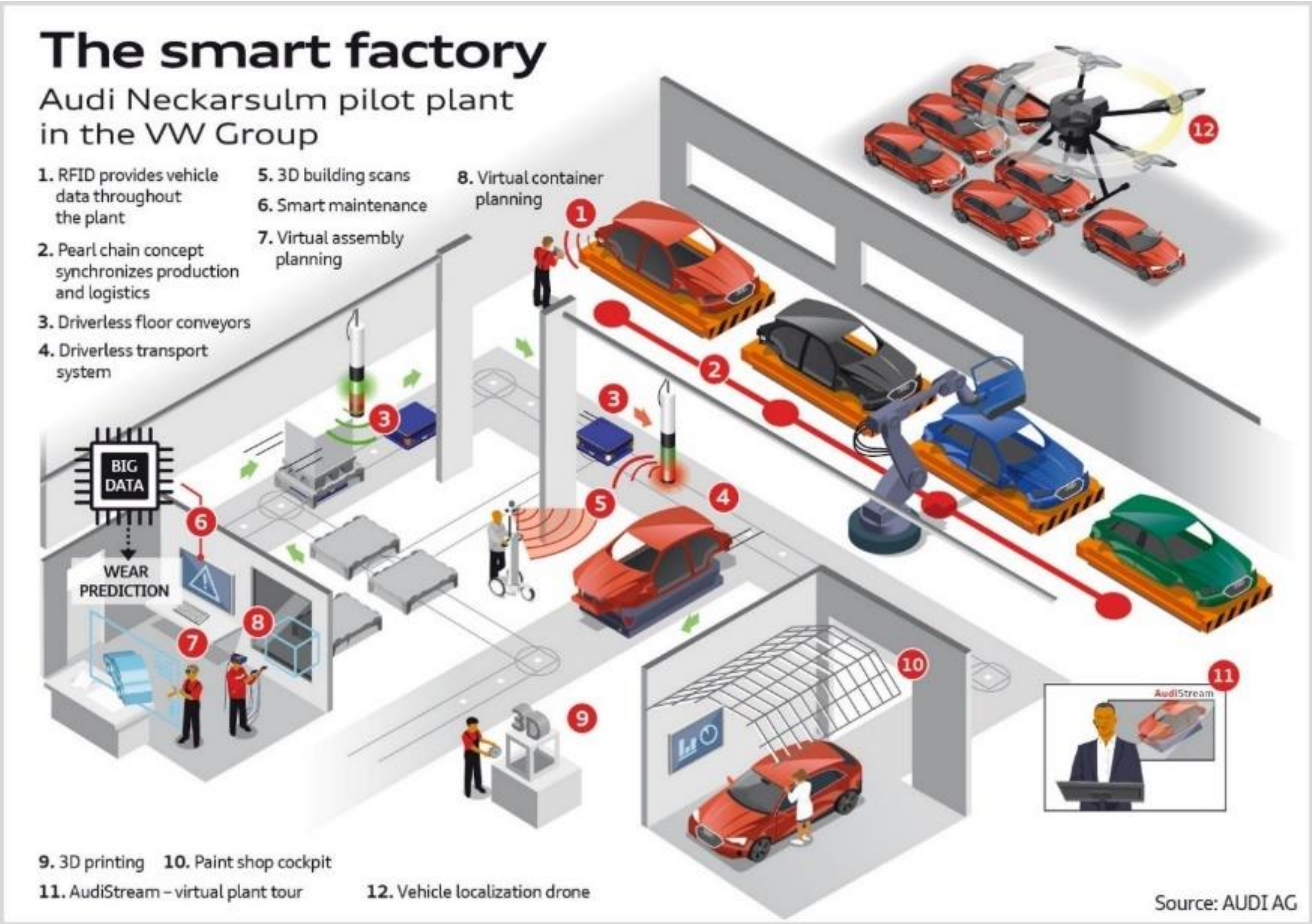
To this end, Audi Neckarsulm will play a pivotal role as a pilot factory and real-world laboratory. The long-established site already has extensive expertise in production IT for both high-volume and small-scale production. In addition, the initiative is intended to serve as a source of ideas and inspiration for the transformation of production and logistics throughout the Volkswagen Group. Over the next five years, digital solutions for vehicle production and the supply chain will increasingly be tested and developed through to full-scale production via AI25. The development of IT solutions for the smart production is being supported by academic institutions such as the Fraunhofer Institute for Industrial Engineering and the Technical University of Munich, as well as technology partners Amazon Web Services (AWS) and SAP. Custom-developed solutions and ideas are also expected to come from the joint venture "XL2" based in Heilbronn, which was founded last year together with Capgemini. This independent unit is focusing on SAP projects for production, master data management, and the development of cloud-based applications.

AUDI [[52]]

- Audi using digital solutions to make production more flexible and efficient
- Audi Production Lab and Automotive Initiative 2025 integral part of the group's digital strategy
- Audi's global production network will be part of Industrial Cloud in the future
- 5G, 3D printing, RFID, machine learning, and AI – cutting-edge technologies leading the way to the smart production
- Audi is working at full speed to digitalize its production and, as a result, the working environment in areas such as planning, assembly, logistics, maintenance, and quality assurance at the five production facilities the company operates itself around

the world. A number of groundbreaking projects with technologies such as 3D printing, 5G, apps, and virtual reality are already revolutionizing operational processes and creating synergies and new forms of global networking.

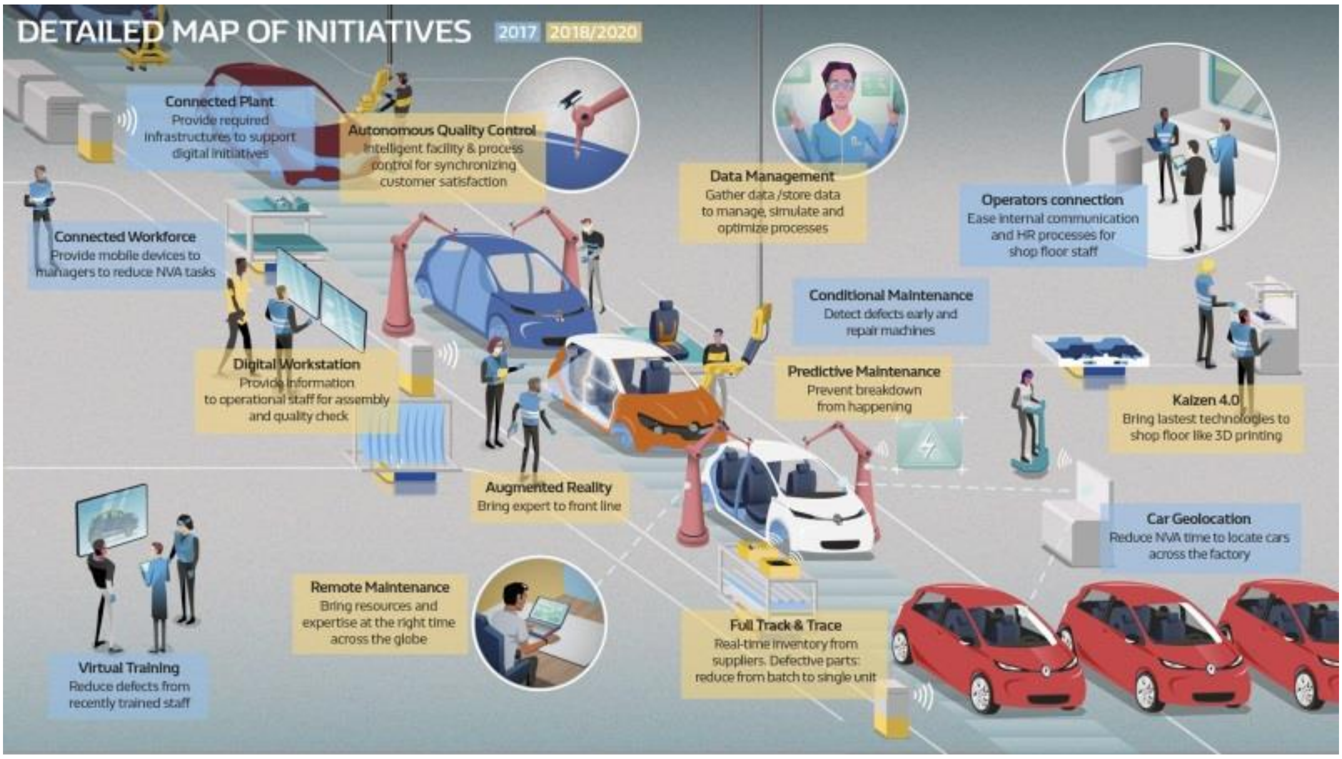
Efficient systems and new high-tech solutions are the basis for fully connected, digitalized production operations. With this clear vision, Audi is strategically aligning its processes with the future. The Audi Production Lab is instrumental in the development of many forward-looking projects. The P-Lab, as it is known at the company, was set up by Audi in 2012 and is a kind of think tank for all topics related to production. Here, a core team of 30 employees develops ideas and tests new approaches together with their coworkers from production and logistics in order to further optimize efficiency, precision, and quality at the plants. The P-Lab has played a key role in helping technologies such as 3Dprinting, human-robot collaboration, automated guided vehicles, and augmented and virtual reality make their way into large-scale production at Audi.



5-1. Figure_AUDI Smart factory

1.RFID provides vehicle data throughout the plant; 2. Pearl chain concept syncronizes prodiction and logistics; 3.Driverless floor conveyors; 4.Driverless transport system; 5. 3D building scans; 6. Smart maintenance; 7. Virtual assembly planning; 8.Virtual container planning; 9.3D printing; 10.Paint shop cockpit; 11.AudiStream – virtual plant tour; 12 Vehicle localization drone

5.1.1 Renault: The Manufacturing Plant Of The Future



5-2. Figure_Renault: The Manufacturing Plant Of The Future [https://www.renaultgroup.com/en/innovation-2/industry-4-0-production-plants-shaped-by-the-future/]

Renault's Industry 4.0, production plants shaped by the future

4 KEY INITIATIVES to drive digital transformation:

- ⇨ **REAL-TIME SUPPLY MANAGEMENT** As soon as a customer orders a vehicle, suppliers are informed, raw materials are prepared and logistics flows are established.
- ⇨ **REAL-TIME SUPPLY MANAGEMENT** As soon as a customer orders a vehicle, suppliers are informed, raw materials are prepared and logistics flows are established.
- ⇨ **CONTINUOUS TRACEABILITY** Vehicle parts, assembly and packaging are tracked in real time, so customers can follow the progress of their order.
- ⇨ **DATA FOR PLANNING** Data are sent and analyzed continuously to conduct remote operations and simulations as well as to optimize maintenance.

RENAULT GROUP LAUNCHES THE FIRST INDUSTRIAL #METAVERSE IN THE AUTOMOTIVE INDUSTRY.

100% of the production lines, i.e. 8,500 pieces of equipment, have been connected to collect more than 1 billion data every day! The industrial Metaverse is a true digital replica of the Renault Group's physical industrial ecosystem, controlled in real time to improve both production efficiency and the reduction of the industrial carbon footprint.

To achieve these objectives, it relies on 4 dimensions: massive data collection, digital twins of processes, connection of the Supply Chain ecosystem and a set of advanced technologies.

5.1.2 VOLKSWAGEN GROUP’S DIGITAL PRODUCTION

AUDI is part of the Volkswagen Group’s digital strategy. Volkswagen is currently building one of the world’s largest cloud projects of its kind: the Industrial Cloud.

The technological heart of this system is the Digital Production Platform – or DPP for short. In the future, the platform will be used to bring together and analyze the data from all of the machines, production lines, and systems in use at the group’s factories around the world. In its final stage of development, the amount of data that will be analyzed on the platform every day is likely to be in the order of magnitude of the quantity of data generated by a small German town.

It is being built on technologies from fields such as the Internet of Things (IoT), machine learning, data analytics, and computing services that have been developed to meet the specific needs of the automotive industry.

Each site will be able to download applications for its machines, tools, and systems directly from the Industrial Cloud and thereby produce even more efficiently (i.e., an “app store approach”).

Neckarsulm and Ingolstadt are the first two Audi sites already connected; the remaining three will follow. As a result, the sites will become part of an open platform that will also gradually integrate the global supply chain and industrial partners.

Furthermore, Volkswagen is also working with partners to create a marketplace for industrial applications. This would allow all of the participants to share applications with each other as well as purchase and use the applications they need. Audi can then share best practices and deploy them itself.

5.1.2.1 5G TECHNOLOGY OPPORTUNITIES FOR PRODUCTION

A high-performance network infrastructure that can respond in real time plays a critical role in the agile and flexible production environment of the future. Audi is therefore focusing on the use of 5G technology in smart production processes. Network operators promise fast data speeds of more than ten gigabits per second and minimal latency rates of no more than one millisecond.

The cellular connections are considered robust, they consume very little power, and reliability stands at nearly 100 percent. In addition, 5G offers the ability to wirelessly connect a large number of industrial devices.

A machine connected via 5G can respond in real time to inputs from the control system. The company recognized these advantages early on and has already launched several pilot projects. Automated guided vehicles are already in use, which deliver materials and components for production just in time and exactly where they are needed.

This is just one example of what high-speed 5G technology will make possible at Audi in the future.

In the Audi Production Lab (P-Lab) [53], several applications are currently being tested under real production conditions in order to formulate the requirements that 5G technology will have to meet in Audi's production environment.

An exclusive frequency spectrum – a 5G campus network within the factory – has been in use in Ingolstadt since mid-2020. This local frequency is an important condition for successful 5G deployment in production.

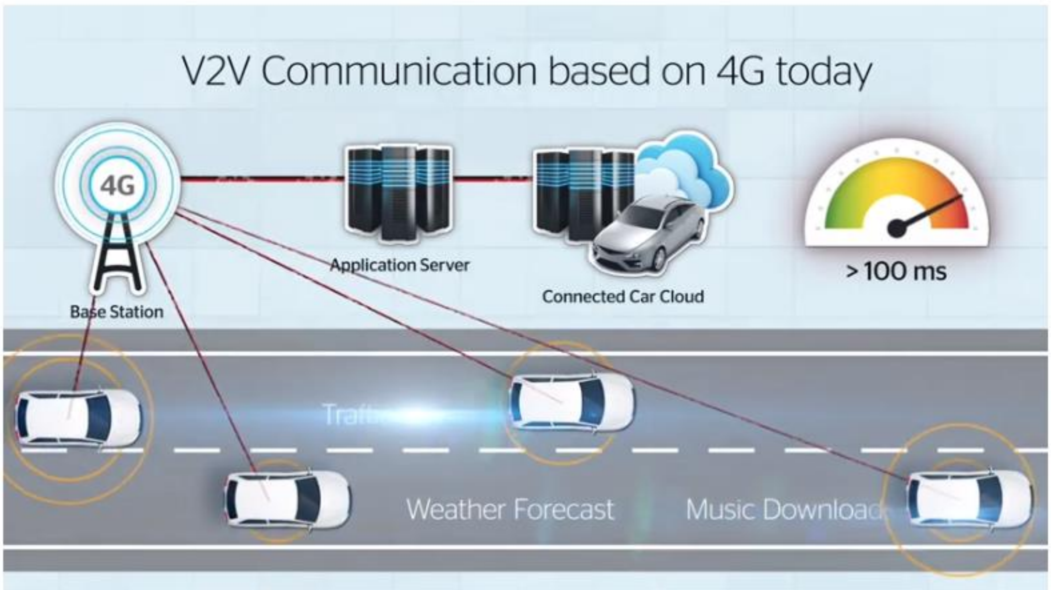
5.1.2.1.1 5G CONNECTIVITY

The new mobile network standard 5G will enable completely new functions in the vehicle and beyond. It will pave the way for future mobility and automated driving, but also for enhanced multimedia and infotainment features in the car.

For future mobility 5G means for example vehicle-to-vehicle communication in real-time, due to higher bandwidths of up to 10 Gbit/s and an estimated latency in data transmission of less than 1 millisecond. But also over-the-air updates of applications and software in the vehicle are possible almost in real time. Infotainment solutions with 5G connectivity will allow for seamless and delay-free video and music streaming for example, as well as for the integration of weather forecasts, or information on the current traffic situation.

5-3. Figure_Holistic Connectivity

[https://www.continental-automotive.com/en-gl/Passenger-Cars/Technology-Trends/Holistic-Connectivity-(1)/5G-Connectivity]



5-4. Figure_ V2V Communication

[[https://www.continental-automotive.com/en-gl/Passenger-Cars/Technology-Trends/Holistic-Connectivity-(1)/5G-Connectivity]

5.1.2.1.2 ADVANTAGES OF 5G TECHNOLOGY

Using 5G makes the communication faster and offers three main advantages:

FASTER DOWNLOAD - Fast Internet - for example for map downloads, online music and videos in the car.

DIRECT COMMUNICATION - With 5G, vehicles can communicate directly to each other without any detour (until now, vehicles had to communicate via a server) and thus inform each other about dangerous situations (e.g. accidents, black ice) in almost real-time.

INVOLVEMENT OF ALL TRANSPORT USERS - Pedestrians and cyclists are also part of the network. This means more safety, for example when turning right at crossroads with a cyclist approaching quickly from behind.

5GAA (Automotive Association) is intensively pushing the development of the new standard for the automotive sector.

5GAA was founded in 2016 to test, standardize, commercialize the new mobile radio standard 5G. It unites interests and members from the fields of mobile technology and the automotive industry, such as AUDI AG, BMW Group, Daimler AG, Ericsson, Huawei, Intel, Nokia and Qualcomm.

5.1.2.2 3D PRINTING IN PRODUCTION

Audi has been using digital 3D printing in production processes for more than 20 years. Originally, the process was mainly used to produce visual models.

In recent years, the share of components created using the technology for the company's own production tools and vehicle models has increased significantly. In the meantime, plastic and metal 3D printing is capable of producing larger and larger parts. A number of different competencies and resources for Technical Development and Production are pooled at the Ingolstadt site. This is where technology scouting and the development of new applications with various departments takes place.

The metal 3D printing center located in Ingolstadt specializes in producing complex steel and aluminum parts as well as tool inserts for forming tools weighing several tons, for example for pressing car body parts or for die casting, which are manufactured from metal powder using the laser melting process. This makes it easier to implement unusual designs because 3D printing supports open shapes, i.e., all conceivable organic forms. This is a major advantage for tool inserts with cooling channels close to the edge, for example.

A second center of excellence for 3D printing using plastics is located at the Neckarsulm site. In close collaboration with coworkers from Production, 3D printing specialists there design customized assembly aids that make work more ergonomic. If employees have optimization ideas, they can simply contact the in-house 3D printing center. Together with a start-up from Berlin, Audi has developed software that reduces the time required to design preassembly devices by 80 percent. A sketch is usually all that is needed, and the desired part is available in just a few hours.

3D printing was first incorporated into the preparations for the high-volume production of the Audi e-tron GT[1]. More than 160 different printed aids are now in use at the location today. One of these, for example, is used in the preassembly of air-conditioning compressors as well as cooling lines.

The assembly aid with a built-in clamp was designed in-house and holds all of the components in the exact position.

5.1.2.3 PREDICTIVE MENTENANCE: HOW ARE SENSORS AND APPS REVOLUTIONIZING MAINTENANCE AT AUDI

The company-wide "PREDICTIVE MAINTENANCE" flagship project makes the maintenance of production equipment at the Neckarsulm site in the body shop more efficient, thereby minimizing downtime.

Special sensor technology in a joining system that rivets various car body components together uses data, algorithms, and measured values to detect traces of wear in plastic hoses. Sudden system failures have been virtually eliminated as a result, and maintenance work can be carried out during non-production time. This makes maintenance work easier and production more efficient. Processes are currently being standardized in order to connect multiple systems and machines to databases. After a successful pilot phase, Predictive Maintenance is set to enter high-volume production and will also be used in other areas.

Audi's maintenance staff receive further support from **the "iMaintenance" app**. This app contains a knowledge database with around 5,000 pages on materials science and recommended actions. If a machine displays an error code, the user simply enters the code into a tablet and then receives step-by-step instructions. Via another app, "Audi Mobile Maintenance," experts in assembly at the Ingolstadt site and in the paint shop at the Neckarsulm plant receive immediate information about system errors.

The app displays all of the relevant information via a push notification

- ➔ Which system in which hall is affected?
- ➔ Which warehouse has a replacement available?
- ➔ Are coworkers possibly already taking care of the situation?

This increases transparency, reduces trips, speeds up processes, and enhances data quality. Everything is documented digitally and can be accessed by the entire team from anywhere using a mobile device. Audi plans to roll the app out to other factories in the near future.

5.1.2.4 RFID FOR PRODUCTION AND LOGISTICS

The Audi Neckarsulm site was the first automotive plant in the VW Group to use radio-frequency identification (RFID) technology for digital vehicle identification – throughout the entire production process. To this end, every Audi manufactured at the plant receives an RFID tag consisting of a chip and an antenna during the very first production step in the body shop. This tag then accompanies each vehicle from there to the paint shop, to assembly, and all the way to delivery. The chips contain a unique identification number. With the help of a reader, important vehicle information such as body design, paint finish, engine, and features of the respective car can be accessed in the various production areas.

Among other benefits, this guarantees that every single Audi rolls off the production line exactly as it was configured. Since the start of production of the all-electric Audi e-tron GT[1] at the end of 2020, Audi has also been using “RFID on metal” tags.

This innovative data storage device uses direct contact between the vehicle and the tag to the benefit of transmission quality by using the body of the e-tron GT[1] itself as an extended antenna. In addition to the production areas, other areas also benefit from the use of this technology.

For example, vehicle logistics uses the RFID tag to track individual vehicles moving around the factory premises. Likewise, future loading records, such as those used when loading vehicles onto cargo trains, will be processed via dedicated reading stations by simply scanning the tag. RFID technology is set to become the standard in all areas of Audi’s global production network in the coming years.

5.1.2.5 MACHINE LEARNING AND AI IMPROVE PRODUCTION QUALITY

Increasing demands in terms of design, lightweight construction, and functionality are constantly presenting the press shop with new challenges. Sharper lines for the exterior as well as the increasing complexity of the components lead to narrow process windows that can occasionally result in cracks during the production of body components. In order to keep product quality as high as possible, a cross-functional team at Audi is developing a solution to visually detect quality defects with the help of artificial intelligence.

The methods used mimic the human ability to reliably detect cracks in sheet metal parts. An algorithm based on deep neural networks, also known as deep learning, operates in the background. This enables it to reliably detect defective parts automatically, in seconds, and with maximum precision. To this end, the software is continuously trained and improved with sample images. For this purpose, experts from production marked cracks by hand and photographed them.

The process is carried out at the Ingolstadt press shop with the help of several cameras in the system that take photos of newly produced deep-drawn parts. The images are then evaluated in real time by the algorithm. If a crack has been identified, a visual signal alerts the employees. The pilot solution from 2019 is currently being refined and enhanced for use in high-volume production, including at other sites, and is gradually being implemented with the group’s partners.

A key technology in this context is the VW Vision Workbench (VW^2) group platform, which lays the technical foundation for and expands the use of new AI-based approaches at all plants worldwide. This is also intended to intensify cross-location collaboration, which can lead to further synergy effects. By working together more closely, several locations have already been identified for possible roll-out projects.

5.1.2.5.1 VIRTUAL REALITY SUPPORTS DIGITAL PRODUCTION PLANNING

The Audi e-tron GT[1] is the first model from the brand with the four rings whose assembly and logistics processes were tested entirely virtually and without physical prototypes.

This was made possible by innovations such as three-dimensional building scans, machine learning, and virtual reality. All of the assembly sequences and the associated logistics processes were tested and optimized in virtual rooms, such as the exact arrangement of machines, racks, and components along the assembly line or ergonomic aspects. To achieve this, the conditions in the production hall had to be precisely reproduced to scale. This is where 3D scans came into play. They create a virtual image of the production facility including all of the systems, tools, and shelves.

At the same time, the scanning process generates a three-dimensional point cloud that can be used to virtually recreate machines and infrastructure.

Audi employees can digitally update their layout and planning systems, thereby saving time and cutting costs. Thanks to the digital likeness and a VR solution developed by Audi, coworkers from all over the world now meet in virtual rooms. Here they can look over the shoulders of computer-generated workers as they carry out the planned workflows and experience and optimize the planned processes for any component versions in the application itself. Audi developed the software based on artificial intelligence and machine learning in-house.

Virtual planning and production preparation is now used across locations and allows employees to work digitally and collaboratively with far fewer business trips – and not just during the coronavirus pandemic.

How important is training in the course of this transformation

Audi will not rely only on technologies alone in the future. Instead, the company understands Vorsprung durch Technik to also mean connecting people and machines in the factory of the future in the best possible way. Innovative technologies support Audi employees in production, relieving them of strenuous physical tasks or monotonous manual labor. As a result, employees can better focus on value-adding activities. Within the framework of various programs, Audi is therefore training its workforce for digital tasks.

For example, in order to make 3D printing better known and to teach relevant basic and expert knowledge, Audi has been promoting the topic in training for several years. Among other qualifications, aspiring mechatronics engineers can complete additional training in 3D printing. Trainees and employees from plant logistics learn how to carry out what is known as the pick-by-light process using VR headsets and controllers. For this purpose, a typical workplace was recreated virtually and accurate down to the last detail. In it, the trainees practice various work routines. This gamified approach is designed to make the training fun. The basis of this solution is a modular VR system that can be used to create training programs for all operational and process-oriented workflows in production. At a higher level, the Audi Academy offers a wide range of training courses in the future field of digitalization, thereby preparing employees for the future.

All of these examples clearly show that Audi's transformation into a digital car company is in full swing.

6 DIGITAL TRANSFORMATION IN THE AUTOMOTIVE INDUSTRY

Digital transformation is a means for automotive OEMs and tier suppliers to modernize their processes to increase operational efficiencies, create sustainable products, and provide new experiences that consumers expect. Digital Transformation is a leading force in today's competitive market and a key factor to innovation.

With increased use of modeling and simulation, data science, analytics and other technologies in product design, companies are now linking these technologies with product lifecycle management (PLM) and virtualization to create partial or full digital twins of products. In turn, this can lead to further digitalization of the manufacturing chain.

A digital thread creates a closed loop between digital and physical worlds to optimize products, people, processes, and places. With the technologies available today, a holistic digital thread spans the entire product lifecycle that takes place within a company and extends outward to suppliers, customers, and products and people in the field.

6.1 BENEFITS OF DIGITAL THREAD

ENGINEERING EXCELLENCE Improve quality, reduce rework, and expedite new product development and time-to-market.

MANUFACTURING EFFICIENCY Drive process effectiveness with greater insight into assets, throughput, and worker productivity.

PRODUCT & SERVICE INNOVATION Enable (and uncover) new business models and opportunities that impact top-line revenue.

SERVICE OPTIMIZATION Improve technician effectiveness and reduce asset downtime.

digital-thread-enhances-sales-marketing-experience

SALES & MARKETING EXPERIENCE Enrich the customer experience with new ways to engage and drive customer loyalty.

digital-thread-whitepaperdigital-thread-whitepaper

6.2 THE BENEFITS OF DIGITAL TRANSFORMATION IN AUTOMOTIVE

As digital technologies evolve all around us, manufacturers are increasingly coming to crossroads: to transform and develop or stick with the tried, tested, and true methods [[54]]. Digital transformation offers many **BENEFITS IN THE LONG TERM**, including:

- Streamline the supply management in automotive manufacturing and facilitate a connected supply chain
- Innovate vehicle performance and design
- Expand into new markets with auto parts or supply sales
- Offer omnichannel experiences in sales and customer care
- Provide post-sales support and monitor customer satisfaction

6.3 INTERNET OF THINGS in automotive industry

IoT applications in the automobile industry are virtually endless, thanks to Industry 4.0 and artificial intelligence. Automotive industry leaders can use IoT solutions to improve vehicle efficiency and reduce the environmental impact of their products. Incorporating IoT monitoring systems increases vehicle efficiencies and enhances precision around maintenance, driver behavior, and navigation [[55]].

THE INTERNET OF THINGS (IOT) is a term used to describe a network of gadgets communicating online. This enables sophisticated automotive technology, such as electronics, actuators, and sensors, to communicate with one another and with other online-connected vehicles.

With many uses to emerge as technology develops, modern WiFi capabilities, engine performance data, and temperature control systems are only the tip of what IoT solutions can provide for automobiles.

The automotive industry is developing cutting-edge solutions using IoT technologies, including connected car solutions, ADAS, in-car infotainment systems, navigation & telematics solutions, predictive maintenance solutions, and Vehicle-to-Vehicle (V2V) applications, Vehicle to Infrastructure (V2I) applications, and Vehicle to Everything (V2X) communication applications.

How we interact with and utilize the cars will change due to IoT connection, smart sensors and devices, edge computing, mobile apps, and cloud services. Implementing IoT applications in the automotive sector improves performance, lowers costs, and facilitates quality control in design.

APPLICATIONS OF THE AUTOMOTIVE IOT

1) DRIVER AND FLEET MANAGEMENT: The most recent IoT use case in the automotive sector, the fleet management solution, provides fleet operators with many advantages throughout their lives. The critical advantage of IoT applications in the automobile industry is compliance with environmental and safety requirements, starting with improving maintenance and logistics to monitor driver performance.

In addition to vehicle tracking, monitoring fuel consumption, sharing statistics on driver performance and health, sending idle alarms, preventative maintenance, and integrating a service condition monitoring system are all extended uses of IoT in fleet management.

IoT sensors integrated into automobiles give signals and set off warning alarms for low battery, coolant temperature, or engine maintenance with reliable communication to the cellular networks through multiple networks, including 2G, 3G, and 4G/LTE.

IoT solutions for the automotive sector enable fleet management to automate various procedures, including trip planning. Additionally, this aids the fleet management sector in enhancing client satisfaction through punctual delivery and superior service.

2) ACTUAL TELEMATICS FOR VEHICLES

The position, movement, condition, and behavior of a vehicle within a fleet may all be tracked via vehicle telematics. A significant development in IoT in the automotive sector is the smart cloud-connected IoTboxes that link telematics devices to offer real-time data on vehicle status, driver health, and transportation optimization.

Vehicles may be improved with electronics, connections, and hardware that enable them to talk and interact with other devices when IoT and telematics come together.

The use of telematics has several benefits, such as remote access to vehicle operating data, remote speed limit limits, turn-by-turn directions with enhanced third-party information, and vehicle collision warnings to third parties and emergency responders.

3) CELLULAR VEHICLE TO EVERYTHING (CV2X)

These services require a connection, including mapping, entertainment, and remote access to emergency services. A cellular vehicle-to-everything (CV2X) network is used in the IoT use case in the automobile industry to link cars. With CV2X, there are two operating modes: device-to-device and device-to-network.

Vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) communications are made possible via device-to-device (V2P). Through developments like collision avoidance, data sharing concerning speed, position, and the route over a single network, alerting the driver about traffic signal priority/timing, and safety alerts for pedestrians and cyclists, V2V, V2I, and V2P enable linked highways.

Real-time traffic reporting and routing are made possible by device-to-support networks for vehicle-to-network (V2N) communication through cellular networks, enabling cloud services to be incorporated into these end-to-end systems.

4) IOT-BASED PREDICTIVE MAINTENANCE

Big data, cloud computing, edge computing, and sensors work together to provide data collection, analytics, and predictive technologies based on IoT connection tools. It assesses the vehicle’s likelihood of malfunctioning, communicates the data via the cloud, and alerts the user by lowering breakdowns and simplifying maintenance.

The following are the primary benefits of automotive IoT systems with predictive maintenance.

- ☑ Determine any component failures before they happen.
- ☑ Determine the remaining usable life and any potential repairs up to 75 percent.
- ☑ Measures the electrical system’s performance, navigation route, temperature, and speed.
- ☑ Lower operating expenses while improving safety

5) IN-VEHICLE INFOTAINMENT SYSTEM

The mobile networks and intelligent apps provide a broad spectrum of infotainment in cars, starting with entertainment, telematics, and navigation, just as many automakers are working with Google and Apple to deliver IoT use cases like in-vehicle infotainment.

Examples: Apple Carplay for high-end automobile entertainment, Google Maps for navigation, and Google Assistant for hands-free driving assistance. With a linked network certifying the car to open, close, and self-start, the owner's expectations for the vehicle's entertainment are now available on the owner's smartphone.

6.3.1 Ways IoT technology is aiding sustainability efforts in the automotive sector

Monitoring Vehicle Location and Driver Behavior [[56]]

Using IoT sensors to track vehicle location and monitor driver behavior can yield insights over time along with instant alerts that let managers address problems and optimize routes, helping to minimize gas consumption and time stuck in traffic.

For example, fleet management and software provider Astrata Europe created a solution called VanLinc to provide real-time tracking and monitoring for all vehicles in a fleet. Each vehicle is connected to the cloud using cellular IoT SIM technology. Beyond GPS location tracking, VanLinc can provide various services depending on a company's individual needs—for example, integrating with refrigeration systems to maintain cold chain requirements or monitoring driver behavior and vehicle performance to ensure compliance with regulatory standards.

Keeping an eye on the details is key to maximizing sustainability efforts in fleet management. Events such as high-speed turns and unexpected braking can be programmed to trigger alerts in most IoT driver behavior management systems, letting managers and drivers know when there's a problem. The data also sheds light on gas mileage and energy consumption, helping managers understand their fleet's footprint and informing sustainability efforts.

Enabling Predictive Maintenance

Installed in vehicles, IoT sensors can monitor the status of various parts and systems, providing data that allows fleet managers or manufacturers to anticipate mechanical problems and take a proactive approach to maintenance.

The fleet operations arm of a global sales and service organization, Scania Trucks uses IoT sensors to track a range of vehicle data, allowing for remote diagnostics when a problem is detected or predicted. Fleet owners or drivers access diagnostic information through a mobile app or a web portal, where they receive alerts and review data to plan a service. Having access to this information helps minimize downtime and keep vehicles running smoothly and efficiently, reducing fuel consumption by up to 10 percent and lowering cost and emissions as a result.

Innovating Practical Electric Alternatives

Concerns over climate change are motivating vehicle manufacturers to replace gas-powered vehicles with electric ones. The growing number of electric vehicles on the market creates the need for adequate numbers of vehicle charging stations, located both in urban and rural areas. Providing IoT connectivity for these stations is essential for oversight and maintenance, but broadband connectivity is often limited in rural areas—and isn't necessary to transmit the small amount of data these devices generate.

Germany-based IONITY is building out a network of 7,000 EV charging stations across 24 European countries, with the goal of having a station every 150-200 kilometers. Using cellular IoT connectivity, IONITY stations provide GPS location information and other details to customers via their smartphone app. IoT connectivity also allows users to process secure payments and track their vehicle's progress as its battery charges. With reliable charging stations available, more individuals and fleet managers are likely to choose electric over gas-powered vehicles, helping to reduce CO2 emissions.

Painting a Clear Picture

IoT connectivity is an incredibly valuable tool for implementing environmental sustainability in the automotive sector, empowering efforts at every level. Connected sensors provide a spectrum of data that, combined with the power of AI and predictive analytics, provides drivers with a precise, accurate picture of a vehicle's performance. That knowledge can maximize efficiencies and reduce emissions in fleets of traditional vehicles—and sway consumers away from gasoline-powered engines by revealing exactly what type of performance they can expect from electric alternatives.

The IoT has become a fundamental technology for next-generation vehicles.

You can manage and access your vehicle's statistics with only one swipe on the app. The Business Insider forecast estimates that use cases for the automotive IoT will have a spending potential of $267 billion.

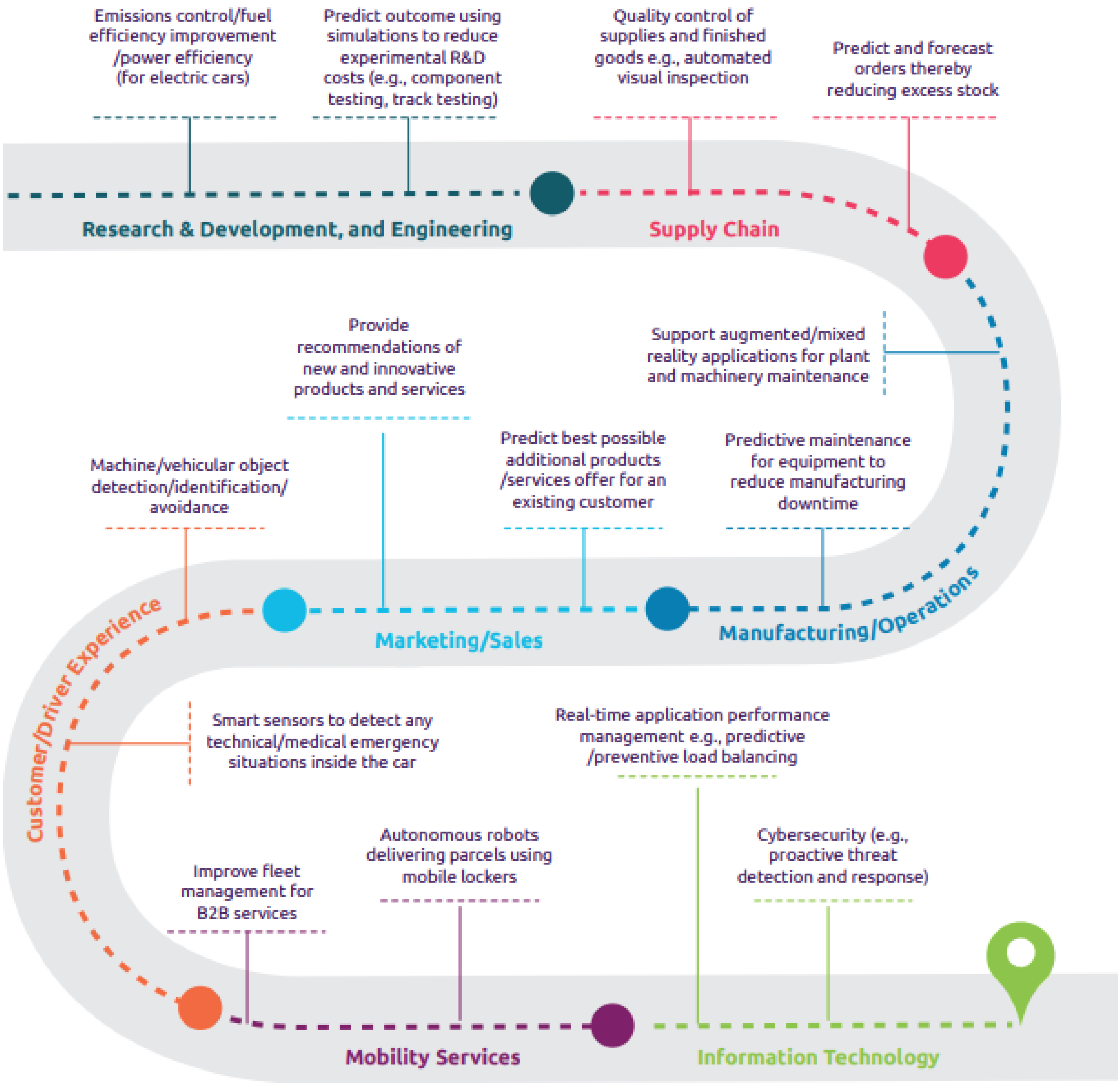
With IoT and WiFi capabilities supported by 3G/4G/5G functionality, the automotive industry is entering a new phase and creating space for more extensive adoption.

7 AI USE CASES FOR THE AUTOMOTIVE INDUSTRY

Since 2018, BMW has been using various A.I. applications in series production.

One focus is automated image recognition: In these processes, artificial intelligence evaluates component images in ongoing production and compares them in milliseconds to hundreds of other images of the same sequence. This way, the A.I. application determines deviations from the standard in real time and checks, for instance, whether all required parts have been mounted and whether they are mounted in the right place.

The innovative technology is fast, reliable and, most importantly, easy to use.



7-1. Figure_High-benefit AI use cases for the automotive industry – by function

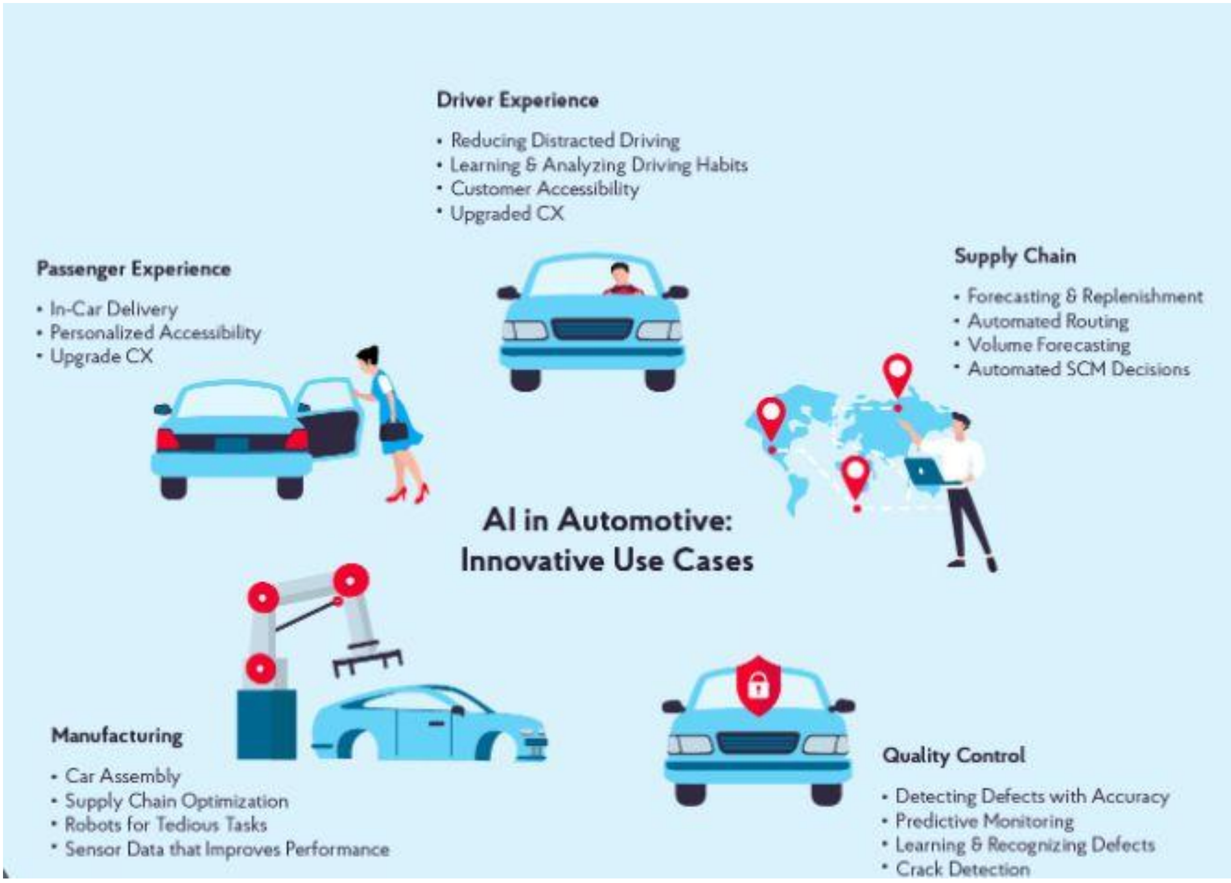
[Source: Capgemini Research Institute survey of automotive executives (N=503) and sustainability experts (N=317), November–December 2019]

7.1 AUTOMOTIVE ARTIFICIAL INTELLIGENCE

ARTIFICIAL INTELLIGENCE (AI) is one of the most progressive technologies in computer science. It is associated with human intelligence through similar characteristics such as language understanding, reasoning, learning, problem solving, and others.

Manufacturers in the market witness enormous underlying intellectual challenges in the development and revision of the technology. In addition, the growth in automotive industry is expected to drive the automotive artificialintelligence market.

Automotive industry has experienced the promise of artificial intelligence and is among the major industries using AI to augment and mimic the action of humans. Furthermore, emergence of standards such as advanced driver assistance system (ADAS), adaptive cruise control (ACC), blind spot alert, and growth in demand for convenience features attract automotive vendors towards AI [57].



7-2. Figure_ AI in Automotive
[https://nix-united.com/blog/ai-in-automotive-a-new-edge-of-the-automotive-industry/]

Table 7.1_AI in Automotive: Innovative Use cases

Supply Chain	Forecasting Replenishment Automated routing Volume forecasting

	Automated SCM decisions
Quality Control	Detecting defects with accuracy Predictive monitoring Learning and recognizing defects Crack detection
Manufacturing	Car assembly Supply chain optimization Robots for tedious tasks Sensor data that improces performance
Driver experience	Reducing distracted driving Learning and analyzing driving habits Customer accessibility Upgraded CX

AI-POWERED VEHICLE PROTOTYPING

Like any other industry, the automotive industry suffers from cut-throat competition that necessitates rapid prototyping. But creating rapid prototypes that are not functional would not be feasible for car manufacturers. The new-age AI-powered prototyping uses innovative product development processes that eliminate several pain points present in the traditional prototyping and streamlines the entire process.

The usage of AI enables better CAD rendering and improves the prefabrication efficiency. In addition, it also helps enhance the quality of the product by allowing ML to point out design anomalies while supercharging the simulation process. In addition, artificial intelligence also helps automate repetitive tasks, enabling designers to focus on the more critical tasks [[58]].

MONITORING EMISSIONS.

With the AQI (Air Quality Index) of several cities in the world already beyond alarming levels, there is a drive to control or improve automotive emission levels and reduce the overall carbon footprint. AI and ML can lead to a major turnaround for the vehicle industry.

As per a BCG study, applying AI to corporate sustainability can increase savings and revenue to the tune of USD 1.3 trillion to USD 2.6 trillion by 2030 [[59]].

7.2 REDUCE CARBON AND COSTS WITH THE POWER OF AI

It would require vehicle companies to employ AI-powered data engineering that helps in automated emission tracking. It can also collect data from several operational activities throughout the value chain. It can also source data from other sources, such as satellites, layer them up to find missing data, and undertake meaningful emission monitoring actions.

The great strength of AI lies in its ability to learn by experience, collecting massive amounts of data from its environment, intuiting connections that humans fail to notice, and recommending appropriate actions on the basis of its conclusions. Companies looking to reduce their carbon footprint should turn the AI spotlight on all three components of the effort:

Companies can use AI-powered data engineering to automatically track emissions throughout their carbon footprint. They can arrange to collect data from operations, from activities such as corporate travel and IT equipment, and from every part of the value chain, including materials and components suppliers, transporters, and even downstream users of their products. AI can exploit data from new sources such as satellites.

By layering intelligence onto the data, AI can generate approximations of missing data and estimate the level of certainty of the results.

PREDICTING EMISSIONS. Predictive AI can forecast future emissions across a company's carbon footprint, in relation to current reduction efforts, new carbon reduction methodologies, and future demand. As a result, they can set, adjust, and achieve reduction targets more accurately.

REDUCING EMISSIONS. By providing detailed insight into every aspect of the value chain, prescriptive AI and optimization can improve efficiency in production, transportation, and elsewhere, thereby reducing carbon emissions and cutting costs.

AI IN MANUFACTURING

AI tools can process and interpret vast volumes of data from the production floor to spot patterns, analyze and predict consumer behavior, detect anomalies in production processes in real-time, and more. These tools help manufacturers gain end-to-end visibility of all manufacturing operations in facilities across all geographies. Thanks to machine learning algorithms, AI-powered systems can also learn, adapt, and improve continuously.

Such capabilities are crucial for manufacturers to thrive in the aftermath of pandemic-induced rapid digitization.

ARTIFICIAL INTELLIGENCE IN SUPPLY CHAIN MANAGEMENT

AI-enabled systems can help manufacturers assess various scenarios (in terms of time, cost, revenue) to improve last-mile deliveries. AI can predict optimal delivery routes, track driver performance in real-time, and assess weather and traffic reports besides historical data to forecast future delivery times accurately.

AI can also give manufacturers greater control over their supply chains from capacity planning to inventory tracking and management. They can set up a real-time and predictive supplier assessment and monitoring model to get notified the moment there's a supplier failure and assess the extent of supply chain disruption immediately.

One example is that of the carmaker Rolls Royce. It uses advanced machine learning algorithms and image recognition to power its fleet of self-driving ships, which in turn improves its supply chain efficiency and safely transports its cargo.

McKinsey predicts that AI-enhanced supply chains will reduce:

- ☑ Forecasting errors by 20-50%

- ☑ Lost sales by 65%
- ☑ Over-stocking inventories by 20-50%

7.3 DIGITAL ENTERPRISE

Benefit from the opportunities of Industry 4.0 accelerate the digital transformation in order to become a Digital Enterprise [60].

Digital Enterprise – combining the real and digital worlds: The industrial world is facing rapidly changing challenges, including geopolitical tensions, technological changes, shifts in global markets, and the impact of climate change. Digitalization and automation are the game changers to meet these challenges. It is essential to collect, understand and use the massive amount of data created in the Industrial Internet of Things (IIoT). The Digital Enterprise is doing exactly this by combining the real and the digital worlds.

EXAMPLE SIEMENS XCELERATOR

Combine the real and digital worlds to collect, understand and use the generated data meaningfully. The infinite amount of data allows to use our finite resources efficiently and drive sustainability and flexibility in the industry.

Integrating the lifecycle of product and production: Combining the real and the digital worlds makes it possible to seamlessly integrate the entire value chain from design to realization, while optimizing with a continuous flow of data. A true Digital Enterprise is able to harness the unlimited power of data by gaining valuable insights to make fast and confident decisions – and to create best-in-class products through efficient production.

Siemens Xcelerator is an open digital business platform that helps to innovate faster and ultimately become a Digital Enterprise.

able to integrate the entire product lifecycle with the factory and plant lifecycle, along with performance data, with the comprehensive Digital Twin approach. The result is a continuous open loop of optimization, both for the product and the production.

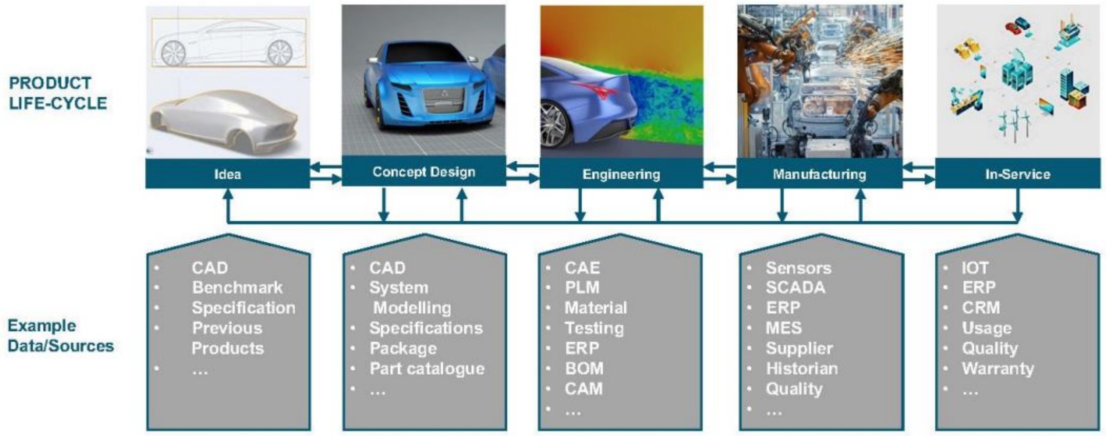
7.3.1 DIGITAL THREAD IN ACTION

Real-world enterprises are leveraging digital technologies and driving business value.

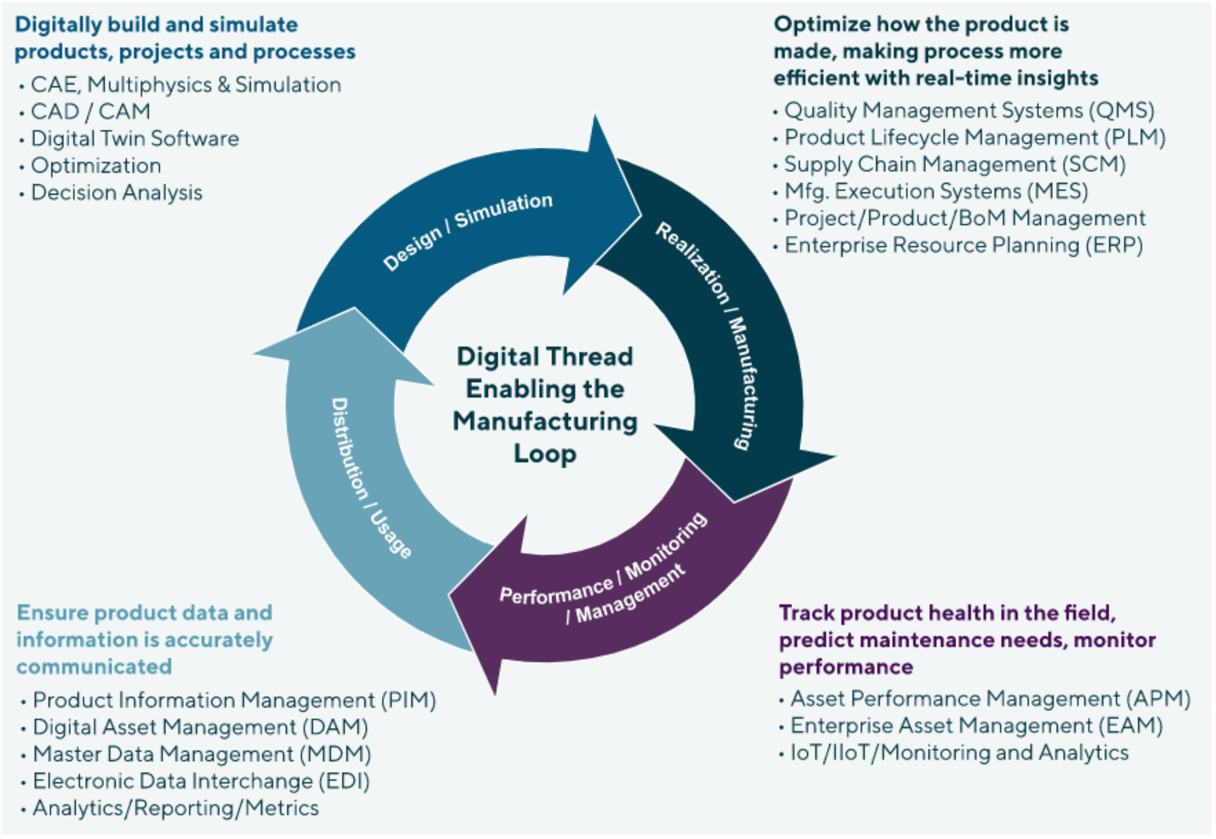
- ➔ Volvo CE How Volvo CE Moved from PDM to PLM: A unified product lifecycle management system provided a product-centric information backbone for the extended enterprise.
- ➔ VCST Creating a Product-Driven Digital Thread: VCST created digital continuity from engineering to manufacturing by linking PLM & IoT solutions.
- ➔ Groupe Beneteau realizing value across the enterprise with digital thread. This recreational boat leader is using this cutting-edge framework to drive innovation and enable mass customization of their products.
- ➔ Volvo Group optimizes quality assurance process with digital thread. This global manufacturer is leveraging a suite of PTC technologies to improve product quality and worker productivity.

7.3.2 ENGINEERING DATA ACROS THE PRODUCT LIFE-CYCLE

To successfully apply analytics to digital thread data, companies must think of the whole process as a system, not as a series of individual functions.



7-3. Figure_ Engineering Data Across The Product Life-Cycle
[Altair Engineering]



7-4. Figure_ The Digital Thread Enabling the Manufacturing Loop

https://www.lincolninternational.com/perspectives/articles/private-equity-pursues-investments-in-engineering-and-manufacturing-software-sector/

Historically, companies designed a product, physically built a variety of samples, stress tested the samples, maintained various data silos across the development and manufacturing process and manually collected maintenance and performance data once the product was in the field, before refining it over time to make design or manufacturing enhancements.

Today, software can digitize many of these processes across each of the four stages in the product lifecycle. When connected, the various software capabilities can form a digital thread that enables real-time insights across the manufacturing loop to continuously improve a product.

Software that connects data and insights across multiple stages of the product lifecycle creates greater efficiency, better products and designs, and can lead to cost reduction and optimization. Investors are prioritizing opportunities for consolidation across the manufacturing loop to create a stronger end-to-end offering.

7.3.3 DATA ANALYTICS FOR ENGINE AND VEHICLE DESIGN

Automotive companies are looking to **use vehicle data** for increasingly important applications such as **real-world emissions**, **fuel economy and driving patterns, and prognostics**. Working with this big engineering data requires systems that can handle the sheer volume, variety, and velocity of that data [[61]].

These systems must include flexible, scalable algorithms deployed in a production environment so engineers can derive insights from the data.

For example, **MATLAB®** can be used to extract key insights for improving engine and vehicle design, including:

- ➔ Understanding real-world brake-specific fuel consumption
- ➔ Identifying problematic traffic patterns in which fleet vehicles are consuming the most fuel
- ➔ Run closed-loop system simulation by connecting your PID Controller block to the plant model
- ➔ Visualizing, optimizing, and analyzing vehicle fleet performance characteristics with MATLAB and Hadoop

Across industries, **BIG DATA** is commonly described in terms of the three Vs: *volume, variety, and velocity*. (A fourth V, *veracity*, is frequently included) .

In engineering applications, the term “big engineering data” is used to characterize data that exhibits these qualities while presenting a subtly different set of problems. The data is typically better structured and more varied, and it has the potential to grow much faster than big data in other industries.

For example, when dealing with fleet data:

• **Volume refers to the scale of the data**.

For automotive OEMs, it is not uncommon to work with data sets of up to 20 TB at once and collect more than 30 GB of data per car per day. At these rates, the data can easily grow to sizes in the order of petabytes and sizes that cannot be analyzed at once in memory. Even the relatively modest demonstration system we constructed was capable of collecting 25 MB of sensor data per day, per car, and it produced almost 2 GB of data over several months with just a few drivers. These figures do not include video data, commonly used in advanced driver assistance systems, which can amass at a rate of several gigabytes per hour.

• **Variety reflects the recognition** among analysts that including data from many sources can lead to more valuable and unexpected insights. Today's vehicles are equipped with dozens of sensors— and instrumented fleet vehicles have many more—all generating a variety of signals including speed, fuel consumption, and temperature.

Different vehicles produce different types of data. For example, hybrid and electric vehicles may report battery charge information rather than fuel flow. In our system, data from the vehicle is combined and time-aligned with data from other sensors, including GPS devices. Lastly, all of this time-series data can be complemented by simulation, audio, video, and CAN log data, among other types.

7.3.4 SUSTAINABLE SIMULATION - ANSYS

Ansys develops, markets and supports engineering simulation software used to predict how product designs will behave in real-world environments. They continuously advance simulation solutions by developing the best technologies, integrating them into a unified simulation platform capable of complex operations, multiphysics solutions and providing system services, including high performance computing (HPC) and cloud solutions, to manage simulation processes and data.

Ansys Mechanical [62] is an integrated platform that uses finite element analysis (FEA) for structural analysis. Mechanical is recognized for its complete range of analysis tools from preparing geometry for analysis to connecting additional physics for even greater fidelity. Its intuitive and customizable user interface enables engineers of all levels to get answers fast and with confidence. AMD and Ansys have an ongoing collaboration to deliver exceptional performance for customers.

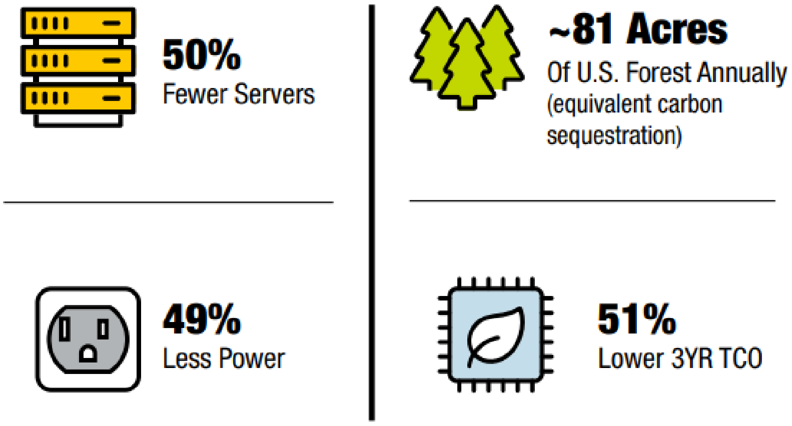
ACCELERATED HPC, SIMULATION PERFORMANCE

Engineers need access to powerful compute resources to simulate and analyze large, complex models, and do so faster and with greater frequency [63].

High-Performance Computing (HPC) infrastructure based on new 3rd generation AMD

EPYCTM processors with 3D V-CacheTM technology can increase productivity and efficiency.

SUPPORTING SUSTAINABILITY Compared to competitive environments, it is estimated that running Ansys CFX on an AMD EPYC platform can reduce energy consumption and carbon emissions:



7-5. Figure_ Running Ansys CFX on an AMD EPYC platform can reduce energy consumption and carbon emissions

[https://www.digitalengineering247.com/download/ansys-infographic-sustainable-simulation/simulate]

7.3.5 DRIVING MANUFACTURING INNOVATION

Driving manufacturing innovation with next-gen solutions for Ansys CAE workflows

The new age of manufacturing:

- Manufacturers are struggling to maintain or re-gain competitive advantage as they navigate post-pandemic economic and socio-political headwinds.
- customers become more demanding, anas products become smarter and more complex, advanced
- computer-aided engineering (CAE) simulation is essential to get quality products to market faster.

The need to design for sustainability, artificial intelligence (AI), and machine learning (ML) workloads, and a desire to improve the world's environmental and social footprint are putting a strain on engineering productivity and compute-intensive resources.

These trends are fueling the need for innovation.

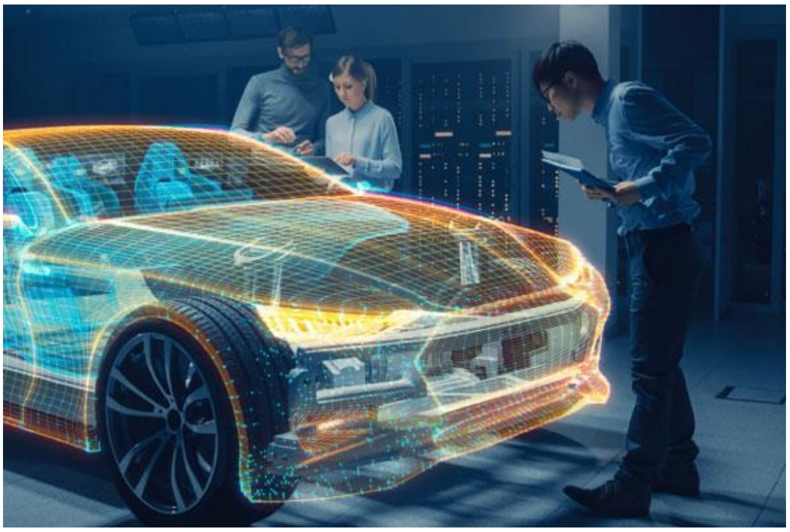
7.3.6 METAVERSE

GridRaster Inc., a provider of cloud-based XR platforms that powers high-performance and scalable AR/VR/MR experiences on mobile devices for enterprises, has shared results of its latest survey addressing where and how enterprise-level businesses and manufacturers have an interest in leveraging the Metaverse for their operations.

IT leaders are building the **METAVERSE**—knowledge workers and things being represented by "digital twins"—a virtual world where people, consumers, workers all gather to communicate, collaborate and share through a virtual presence on any device.

This means companies will build immersive virtual spaces, aka “metaverses,” and it will allow employees to virtually collaborate using their digital twin through chats, emails, video calls and face-to-face meetings [64].

GridRaster commissioned an online survey to more than 3,000 business leaders and manufacturing executives across a number of industries from February 14-18, 2022. The purpose of the survey was to gauge activity in using AR/VR in their operations, as well as their interest and plans for leveraging the metaverse in their operations.



7-6. Figure_ IT leaders are building the Metaverse

[https://www.digitalengineering247.com/article/survey-shows-how-manufacturers-plan-to-leverage-metaverse/virtual-reality-and-augmented-reality]

IT leaders are building the Metaverse, a virtual world where people, consumers, workers all gather to communicate, collaborate and share through a virtual presence on any device. Image courtesy of GridRaster.

8 DIGITAL TWINS

8.1 Digital TWIN CONCEPT

The concept and model of the digital twin was first publicly introduced in 2002 by Michael Grieves, at a Society of Manufacturing Engineers conference in Troy, Michigan. Grieves proposed the digital twin as the conceptual model underlying product lifecycle management (PLM) [65]. The digital twin concept, was subsequently called the "digital twin" by John Vickers in a 2010 Roadmap Report of NASA [66].

The digital twin concept consists of three distinct parts: the physical object or process and its physical environment, the digital representation of the object or process, and the communication channel between the physical and virtual representations. The connections between the physical version and the digital version include information flows and data that includes physical sensor flows between the physical and virtual objects and environments. The communication connection is referred to as the digital thread.

The International Council of Systems Engineers maintains in its Systems Engineering Book of Knowledge that: "A digital twin is a related yet distinct concept to digital engineering. The digital twin is a high-fidelity model of the system which can be used to emulate the actual system." [67].

The US Department of Defense's evolving Digital Engineering Strategy initiative, first formulated in 2018, defines a digital twin as an integrated multiphysics, multiscale, probabilistic simulation of an as-built system, enabled by a Digital Thread, that uses the best available models, sensor information, and input data to mirror and predict activities/performance over the life of its corresponding physical twin [68].

THE AUTOMOBILE INDUSTRY HAS BEEN IMPROVED BY DIGITAL TWIN TECHNOLOGY.

Digital twins in the automobile industry are implemented by using existing data in order to facilitate processes and reduce marginal costs. Currently, automobile designers expand the existing physical materiality by incorporating software-based digital abilities. A specific example of digital twin technology in the automotive industry is where automotive engineers use digital twin technology in combination with the firm's analytical tool in order to analyze how a specific car is driven. In doing so, they can suggest incorporating new features in the car that can reduce car accidents on the road, which was previously not possible in such a short time frame.

Digital twins can be built for not just individual vehicles but also the whole mobility system, where humans (e.g., drivers, passengers, pedestrians), vehicles (e.g., connected vehicles, connected and automated vehicles), and traffics (e.g., traffic networks, traffic infrastructures) can seek guidance from their digital twins deployed on edge/cloud servers to actuate real-time decisions.

8.2 DIGITAL TWIN FOR EVERY STAGE

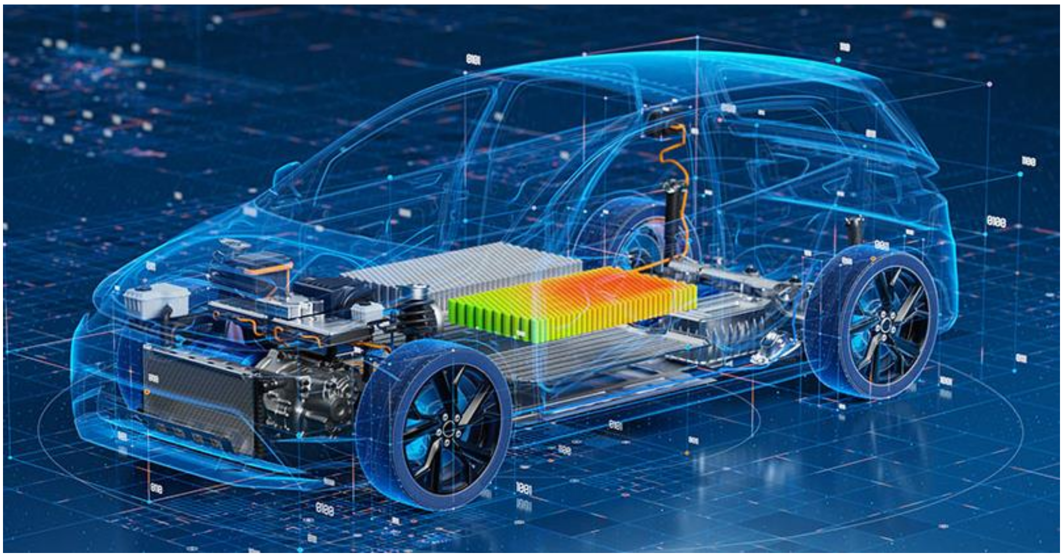
Altair's one total twin solution empowers organizations to transform their products, systems, and processes.

With features that combine leading simulation, high-performance computing (HPC), artificial intelligence (AI), data analytics, and Internet of Things (IoT) capabilities, teams can design, build, test, optimize, evaluate what-if scenarios, perform predictive maintenance, and extend the remaining useful life (RUL) of their products—without the need of physical prototypes. Altair's flexible, connected capabilities and smart product development solutions also enable comprehensive cross-functional system evaluation, which eliminates information silos and communication bottlenecks during product development. With these capabilities, organizations become more efficient and can deploy digital twin technology when and where they need it — through any or all lifecycle stages — from pre-production conceptual design through in-service performance.

8.2.1 PRE-PRODUCTION TWINS

DESIGN CONCEPT In the pre-production stage, organizations can deploy the as-specified twin, which covers specifications and requirements, development, and simulation. These twins help teams design, analyze, and optimize performance in the earliest stages of the system lifecycle without requiring expensive prototypes.

DETAILED DESIGN As system concepts mature into detailed designs, organizations can deploy the as-designed twin for validation studies, real-world performance prediction, and streamlined mechatronic product development. Teams can also converge multiphysics simulation with advanced HPC, AI, and data analytics capabilities in a unified, cohesive environment.



8-1. Figure_ Designed twin for validation studies, real-world performance prediction, and streamlined mechatronic product development [https://altair.com/product-showcase]

Products for pre-production include Altair Activate®, Altair® Inspire™, Altair Drive, Altair® HyperWorks®, Altair® PollEx™, Altair® Flux®, Altair Compose®, Altair® Feko®, Altair® PSIM™, Altair® EEvision™, XLDyn (via the Altair Partner Alliance), and Altair consulting services.

8.2.2 POST-PRODUCTION TWINS

BUILT SYSTEMS

For systems that have reached the production stage, the as-built twin helps teams evaluate advanced virtual system dynamics under what-if scenarios, deploy reduced order modeling (ROM), detect design sensitivities, and resolve test failures. Organizations benefit from capabilities that enable mixed-reality simulations that lead to optimal designs — especially concerning very large structures or situations that are otherwise impossible to evaluate in the real world. Teams can also resolve test failures with multibody and controls simulation, and real-time visualization.

INTEGRATED DEVICES OF BUILT SYSTEMS

Organizations can use the as-manufactured twin to evaluate integrated software, processors, and hardware involved with system controls, such as human-driver, ergonomics, immersion, and virtual reality. Teams can simulate realistic and unexpected events, improve workability and operation windows, and produce high-fidelity displays of innovations in interactive, realistic environments.

Products for post-production include Altair Embed®, Altair® MotionSolve®, Altair® HyperStudy®, Altair® Panopticon™, Design Explorer inside of Altair® DesignAI™, Vortex® Studio (via the Altair Partner Alliance), and Altair consulting services.

8.2.2.1 CREATING AN INTELLIGENT DIGITAL TWIN TO OPTIMIZE BATTERY PERFORMANCE

This presentation and live demonstration from Altair and battery specialist Danecca showcases a Digital Twin which presents a virtual representation of a physical battery pack subject to a transient duty cycle. The Digital Twin mimics the embedded control logic of the hardware to manage system heating and cooling during the event. Capturing the complex physics and system response with the Digital Twin in timescales commensurate with the physical hardware enhances the role of simulation within the UK battery development community. The battery Digital Twin presents new opportunities for rapid, holistic, design exploration and innovation. (This presentation was part of the 2nd Altair Northern UK Seminar and was filmed live in Newcastle, UK in December 2022).

8.2.3 SYSTEM-IN-SERVICE TWINS

The as-sustained twin handles predictive analytics and maintenance of systems that are in service. Teams can leverage real-time data stream analytics and machine learning to optimize system performance, deliver ideal maintenance routines, trigger insights based on anomaly detection, determine a system's RUL, and more. This capability delivers fast, real-time insights about system status, which helps organizations make optimal operational adjustments to maximize system life and avoid failures.

Products for systems-in-service include RapidMiner®, Altair® SmartWorks™, Altair SLC™, Altair® Monarch®, Altair® Knowledge Studio®, and Altair consulting services.

8.2.4 FLEXIBLE, OPEN, AND CONNECTED PLATFORM

At the core of our digital twin integration platform are our flexible, agile, and vendor-agnostic software capabilities for executing twins in production and connecting them to real-world data in real-time. This platform provides the essential building blocks for digital twin developers from various specialties to get started fast, scale efficiently, and streamline changes as systems evolve over time.

Learn how our platform and One Total Twin™ solution are helping numerous industries like yours:

8.2.5 DESIGNING WITH AUGMENTED/VIRTUAL REALITY

8.3 SOME WAYS AUTOMOTIVE BUSINESSES ENACTED DIGITAL CHANGE

The sector is full of excellent digital transformation examples in automotive, from product innovation to operational change to customer-facing improvements.

Some ways automotive businesses enacted digital change [[69]]:

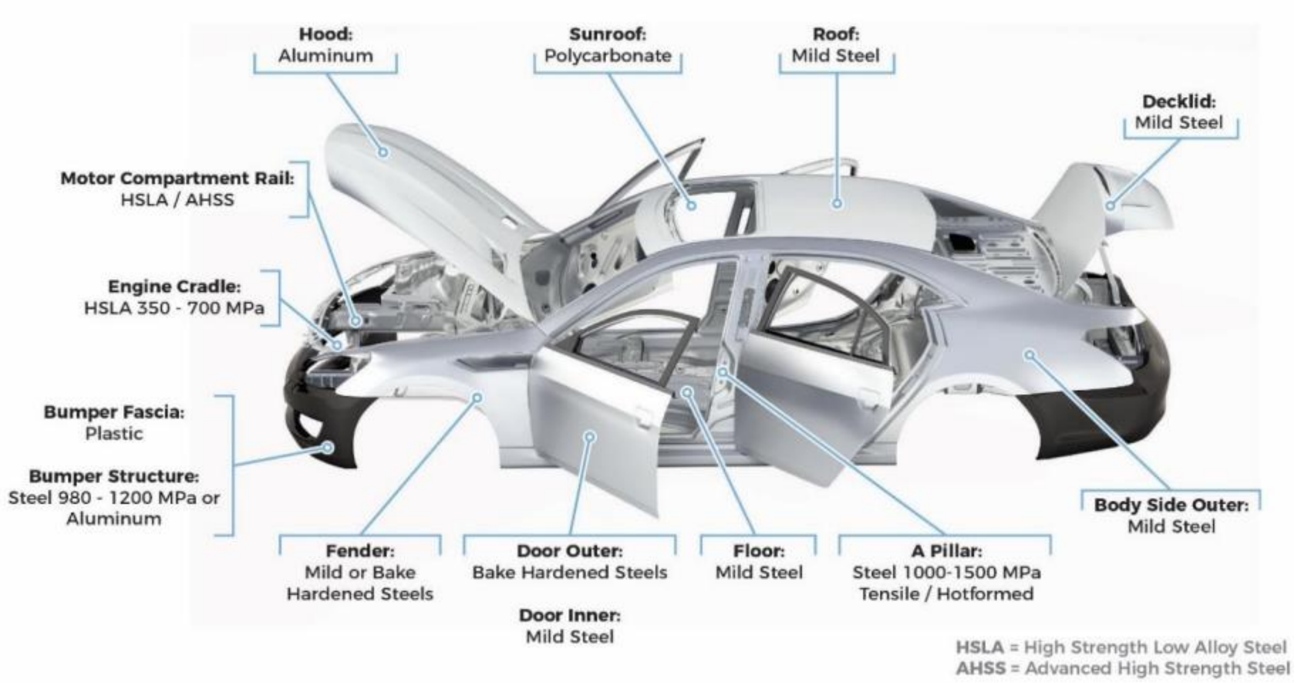
- Tesla long pioneered the use of artificial intelligence and big data. Since 2014, they've been gathering data from drivers using onboard sensors, which allowed them to push a wireless update that enhanced the accuracy of their autopilot software.
- Volvo's Polestar brand was named the best-positioned car brand for online sales. Like Tesla, Their Polestar 1 and Polestar 2 models are only available online. However, Volvo also maintains dedicated "spaces" at physical locations in partner dealerships.
- BMW deployed an IoT platform at its Regensburg plant to great success. It allowed them to reduce the time needed to deploy new applications by 80% and reduced quality control issues by 5%.
- Volkswagen partnered with AR-based application developers to label automotive parts with the correct tools to be used. Known as MARTA, this system increases efficiency for service technicians.
- Automotive supplies is a business traditionally limited to offline. TruPar, a wholesaler of forklift parts, future-proofed its operations with a unified eCommerce, CRM, and ERP integration.

9 SUSTAINABLE MATERIALS IN AUTOMOTIVE INDUSTRY

9.1 DESIGNING SUSTAINABLE VEHICLES WITH RECYCLED AND RECOVERABLE MATERIALS / SECOND LIFE

When we talk about the circular economy, the first thing we think of is eco-design, i.e. the use of resources which are renewable, sustainable and reusable in other forms. For the automotive industry the challenge is considerable [[70]]. For example, for Groupe Renault, it's a question of designing sustainable vehicles with recycled and recoverable materials. More specifically, for the electric vehicles, it's about finding a second life for batteries that are no longer usable, e.g. for storing renewable energy or providing power for buildings.

Theoretically, a material can be used to make vehicle parts if it is commercially available, can be manufactured with an available technology, and meets the performance requirements [[71]]. Cork, coconut fibre, coffee grounds – the automotive industry is moving away from traditional materials that are difficult to recycle. The focus is instead shifting to more sustainable resources. While electromobility is key to slashing carbon emissions, the products that go into a car also matter [[72]].



9-1. Figure_ Materials used most commonly for major vehicle structure components in the current fleet

[CAR Research-Automotive Technology Roadmaps (2017) https://www.cargroup.org/wp-content/uploads/2018/01/Technology_Roadmap_Combined_23JAN18.pdf]

Automotive lightweight material refers to materials that exhibit high strength-to-weight ratio, superior corrosion resistance properties, and substantial design flexibility, thereby finding its application in automotive system and components. In the recent years, requirement for weight minimization & higher fuel efficiency, adhering to environmental regulations.

SURGE IN NEED FOR IMPROVED SAFETY AND ENHANCED PERFORMANCE OF VEHICLE

Lightweight materials are having characteristics of low weight at a significant level along with high strength as compared to traditional materials, which are crucial factors in the vehicle manufacturing process. Furthermore, in the current era of advanced mobility solutions, several high-end technology-enabled devices to meet the changing needs of automotive consumers. Systems such as safety devices, advanced emission control systems, and integrated electronic systems uses lightweight materials to improve the operational efficiency along with reduction in overall weight of the vehicles.

HIGH COST OF MATERIALS

Increase in need for high-strength and fuel-efficient materials is boosting automotive development, owing to changing automotive design requirements, increasing adoption of connected technologies, and changing mobility outlook across the globe. To attain these changing requirements of automotive manufacturers, composites and carbon fibers are gaining traction in recent years. However, materials such as titanium, magnesium, and carbon fiber-reinforced composites are associated with high cost.

ENTERING INTO AGREEMENTS AND CONTRACTS WITH AUTOMOTIVE OEM

Automotive lightweight materials are widely and majorly demanded by automotive manufacturers and component manufacturers for automotive production activities. This material procurement witnesses open contracts and agreements between automotive OEMs and manufacturers of automotive lightweight materials. The commencement of the automotive lightweight materials solution is expected to be carried out through contracts and agreements between end users and developers of automotive lightweight materials.

Electrifying powertrains are one way to help decarbonise the lifecycle of a vehicle, but more needs to be done to reduce material emissions. Consulting firm McKinsey estimates that 60% of automotive-industry emissions by 2040 will come from materials used in production, so stepping up decarbonisation efforts in this area is key.

‘VEGAN’ LEATHER

Replacing leather with ‘vegan’ alternatives sits at the top of the list for many manufacturers. The idea is not new as carmakers have been using faux or synthetic leather for years. But automotive companies want to take this to the next level by offering greener options. The advantage is that vegan leather can be made from all sorts of natural resources, such as mushrooms or pineapple waste, so the sourcing potential is great.

Swedish carmaker Volvo has vowed to make its electric-vehicle range vegan-friendly by 2030 and other premium manufacturers are eager to explore sustainable leather alternatives as well. BMW is collaborating with Desserto, a company that creates a cactus-based biomaterial, which can replace leather in seats and panels. The material is cruelty-free certified and could help to reduce the environmental impact in product manufacturing, the company said.

The plant-based product, known as Deserttex, promises quality, and the company is targeting premium brands to provide them with a product that performs to the expected standards. Luxury automotive brands have taken notice as Dessertex can be found in the upholstery of Mercedes-Benz's Vision EQXX concept car.

The automotive industry is racing into a new world of possibilities around sustainability and mobility — and biotechnology applied to interior materials can significantly contribute. [Autovista24].

RECYCLED MATERIALS

Plastic – a material known for its environmental unfriendliness. So how can carmakers make this material more sustainable? Through recycling. Discarded polyethylene terephthalate (PET) bottles or plastic caps have found their way into vehicle interiors, from the dashboard to foam seats and air bags.

Plastic remains a popular material for car manufacturers as it reduces the weight and cost of vehicles while also increasing performance. Around a third of the 30,000 parts used in new vehicles are made from plastic, so recycling the product makes sense from an environmental point of view.

Audi is interested in recycling automotive plastic and last year got involved in a chemical-recycling pilot project in Germany. Considering that on average 250kg of plastic are used in an Audi model, the company sees the re-use of mixed plastic waste as promising.

Audi is aware of its responsibility when dealing with resources. This includes the entire lifecycle of a car, from the selection of materials in the design to the materials used in production and the use-phase to the recycling of raw materials. Environmentally friendly materials are already playing a major role in our series models, because a beautiful look and pleasant feel are no longer enough, [Autovista24].

The Audi Q4 e-tron boasts a high proportion of recycled materials, comprising up to 27 components that contain recycled material. Meanwhile, floor carpets and mats in the Audi e-tron GT are made from econyl, which consists of up of 100% recycled nylon fibres constructed from production waste or old fishing nets. In the Audi A3, up to 89% of the textile used originates from recycled PET bottles.

While recycling materials can initially be more expensive, this can be compensated for in the long run. The most valuable materials are those that can be recycled again and again with little or no loss of quality.

A PLASTIC ALTERNATIVE

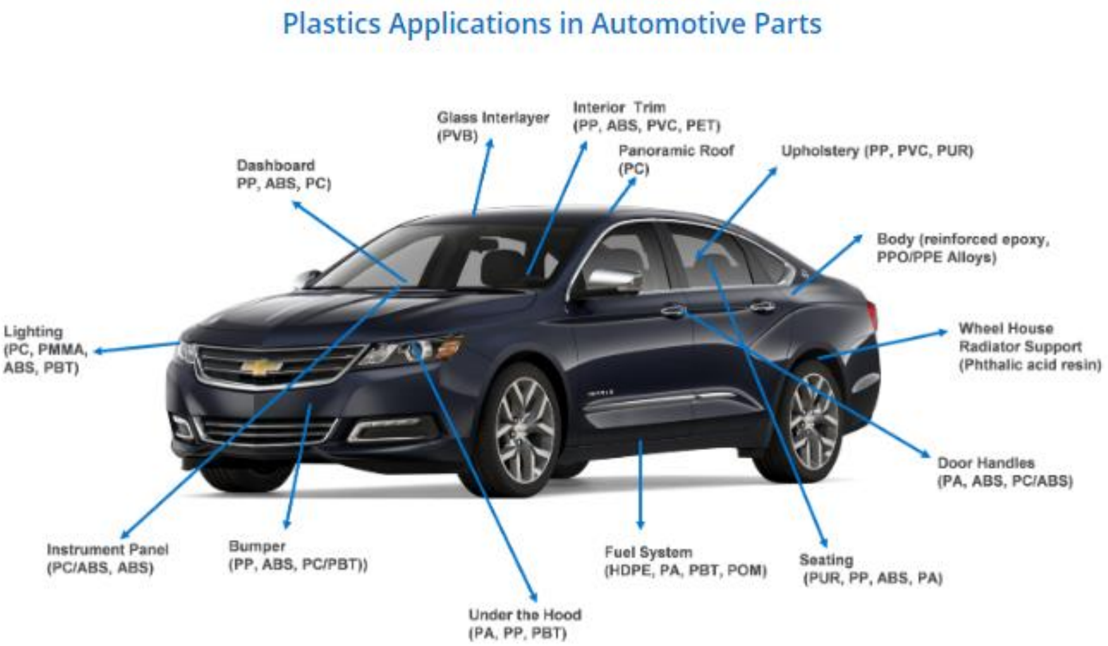
Car manufacturers are increasing their decarbonisation efforts with vigour, not least because consumers are demanding more sustainable products. But eco-friendly materials do not only have to be 'green', they also need to be appealing to the eye and do their job by being durable.

9.2 TRENDS IN PLASTICS CONSUMPTION IN THE AUTOMOTIVE INDUSTRY

The role of plastic in the design and manufacturing of automotive vehicles is essential, with stringent regulations and changing consumer habits driving demand for more affordable, lightweight, and fuel-efficient vehicles. Fuel efficiency has become one of the most important features in automotive vehicle design due to the rising fuel prices and stricter environmental regulations. This, combined with high demand for automotive vehicles as well as rising disposable income in emerging economies will continue to drive demand for plastics in the automotive industry. However, while some materials may win from recent changes in the automotive industry, others will find themselves on the losing side, spelling serious implications for plastic producers globally and in the GCC [73].

Currently, there are about 30,000 parts in a vehicle, out of which 1/3 are made of plastic. In total, about 39 different types of basic plastics and polymers are used to make an automobile. More than 70% of the plastic used in automobiles comes from four polymers: polypropylene, polyurethane, polyamides and PVC.

Plastic has become one of the key materials required for the structure, performance, and safety of automobiles in recent years, with growth in plastic consumption being driven by light weighting trends for fuel efficiency and consequently lower greenhouse gas emissions. The high absorption properties of plastics also allow the vehicle to meet stricter safety standards, while the use of engineering plastics allows for minimization of the mass of parts used in vehicles as they offer more design freedom compared to metals.



9-2. Figure_Plastics applications in automotive parts

[http://adapt.mx/plastics-in-the-automotive-industry-which-materials-will-be-the-winners-and-losers/]

9.2.1 IMPACT OF ELECTRIC VEHICLES ON POLYMER CONSUMPTION

The emergence and rapid growth of electrically-powered road vehicles have become a key issue for consideration when assessing the automotive outlook and for resulting polymer demand. While the overall number of electric vehicles (EVs) remains at a low level on a global scale, vehicle fleet electrification has gained significant momentum in recent years, supported by regulatory incentives, changing consumer perception, and the development of large numbers of affordable electric models by the auto industry. Despite the growth trend for electric vehicles, automobiles that are powered by Internal Combustion Engines (ICE) will remain a significant proportion of the vehicle fleet, with polymer innovation driven by increasing fuel efficiency.

The EV vehicle design is not radically different from a traditional ICE vehicle, with the main difference being in the design and use of materials under the hood. However, electric vehicles will not have fuel system, pump, tanks, connecting cables, etc. As the market penetration of electric vehicles increases, polycarbonate (PC) consumption is expected to grow at a faster rate, as PC will be used in sensors and in LEDs in the car.

The application of polymer components within engine transmission will become more common as manufacturers seek to squeeze costs and weight. But, the consumption of engineered polymers will be counterweighed by the industry’s emphasis on light weighting, resulting in smaller and lighter components. The light weighting of the battery pack in electric vehicles is viewed as another important trend that will allow EVs to compete with cars using an internal combustion engine. The entire structure of the battery pack offers opportunities of light weighting with the use of engineering polymers and composites.

9.2.2 CHANGES IN POLYMER DEMAND PATTERNS

The increase in consumption of plastics such as polypropylene (PP) and polyurethane (PU) in recent years has partially been offset by the decline in consumption of engineering plastics, with PP and PU accounting for about 50% of total plastic consumption in vehicles. The consumption of engineering plastics is expected to decline due to lesser requirement of these plastics in under-the-hood applications for electric vehicles, as the high temperature resistance of engineering polymers is not required to the same extent as with internal combustion engines. Instead, polyamides will be used for battery brackets and housings in the EVs.

Polypropylene demand will continue to grow as it finds new applications in car interior and exterior, and under the hood replacing some metal parts. In addition, growth will also be spurred by increased production of EVs, which will require lighter parts to help offset the weight of the heavy batteries. PE consumption has also stayed flat as HDPE gas tanks have already penetrated into the gasoline tank market, displacing steel in developed countries. Electric vehicles may use more PE in the engine parts as the high temperature performance of engineering polymers is not required in electric battery engines.

ABS consumption is expected to decline as polystyrene and PP composites with improved properties continue to replace ABS in decorative parts in the interior, which was traditionally dominated by ABS, especially in the United States, due to the material's gloss. The high price of ABS has also supported the substitution with lower priced polypropylene.

In some high-end automobiles, the consumption of ABS will increase for the interior with consumers requiring a higher quality design. However, the overall consumption, particularly in North America and Western Europe, will be counter-weighed by a reduction in the size of certain modules, such as the front grill, in turn decreasing the consumption of ABS.

The growth in polycarbonate will be driven by the emerging application in car sensors (lenses) in autonomous vehicles, supported by continued electrification and lighting requirements in traditional vehicles.

9.3 Virtual sensors

Today, vehicles are full of electronics and thus with sensors that provide information well beyond speed and fuel levels. They deliver a limitless amount of information about the vehicle's condition, whether this applies to parking assist, tire pressure, engine performance, fuel consumption, vehicle dynamics, thermal management, and many more.

CAR SENSORS ARE DIVIDED INTO SEVERAL CATEGORIES, depending on the role they play in the operation of the vehicle. There are several types of sensors used in automation - which can be considered essential, as well as monitoring sensors, without which the car can function, but which improve the driving experience [[74]].

OXYGEN SENSORS: These sensors help control pollutant emissions and fuel consumption by measuring the level of oxygen in the exhaust gases. In modern vehicles, one such set of sensors is mounted on the exhaust manifold, and another set after the catalytic converter. Depending on the oxygen level detected, the on-board computer will increase or decrease the amount of fuel pumped into the injection system.

BENEFITS:

- ensures optimal fuel consumption;
- prevent the failure of the catalyst and other engine components;
- reduce polluting gas emissions by up to 90%.

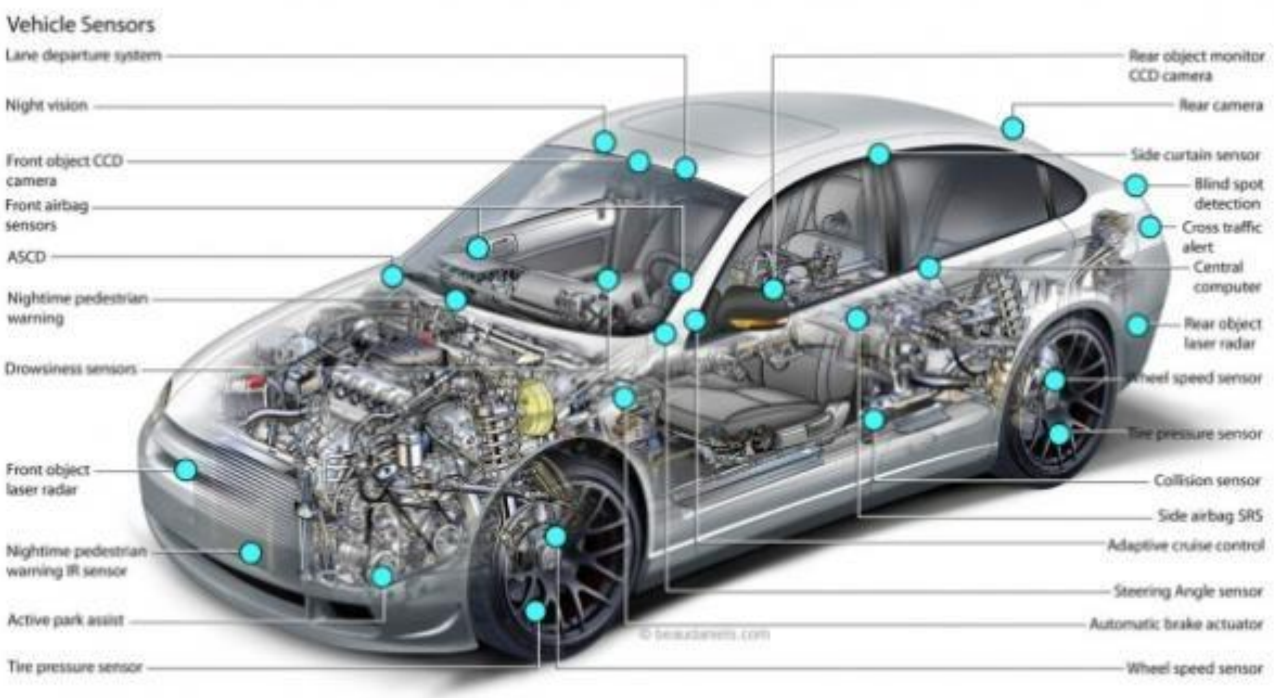
FUEL TEMPERATURE SENSOR

The fuel pumped into the injection system must be at a certain temperature, and this sensor tells the on-board computer if the optimum value has been reached. Too low a temperature causes slow burning due to increased fuel density, while too high a temperature causes rapid burning. The sensor constantly monitors the fuel so that it is pumped at the optimal temperature.

BENEFITS:

- prevents increased fuel consumption;

- avoids the failure of some engine components;
- allows a constant supply of fuel.



9-3. Figure_ Sensor locations of a vehicle of today (Image courtesy of Car from Japan)

Currently, each vehicle has approximately 60 to 100 sensors on board and this number is expected to rise. As cars get smarter, analysts are predicting that the number of sensors is projected to reach more than 200 sensors per car by 2020. (Source: Automotive Sensors and Electronics 2017).

200 sensors per car represent 22 billion sensors used in the automotive industry per year. No wonder that physical sensing technology is about to reach its limits.

Hardware sensors are often deemed expensive, and have a reduced life expectancy when exposed in a hazardous environment (for example in an engine).

In addition, physical sensors are costly to design and install due to the extreme conditions they must withstand, such as borderline temperatures or hard-to-reach locations. Consequently, sensors may fail to guarantee reliable output.

Virtual sensors offer a valuable alternative in this respect.

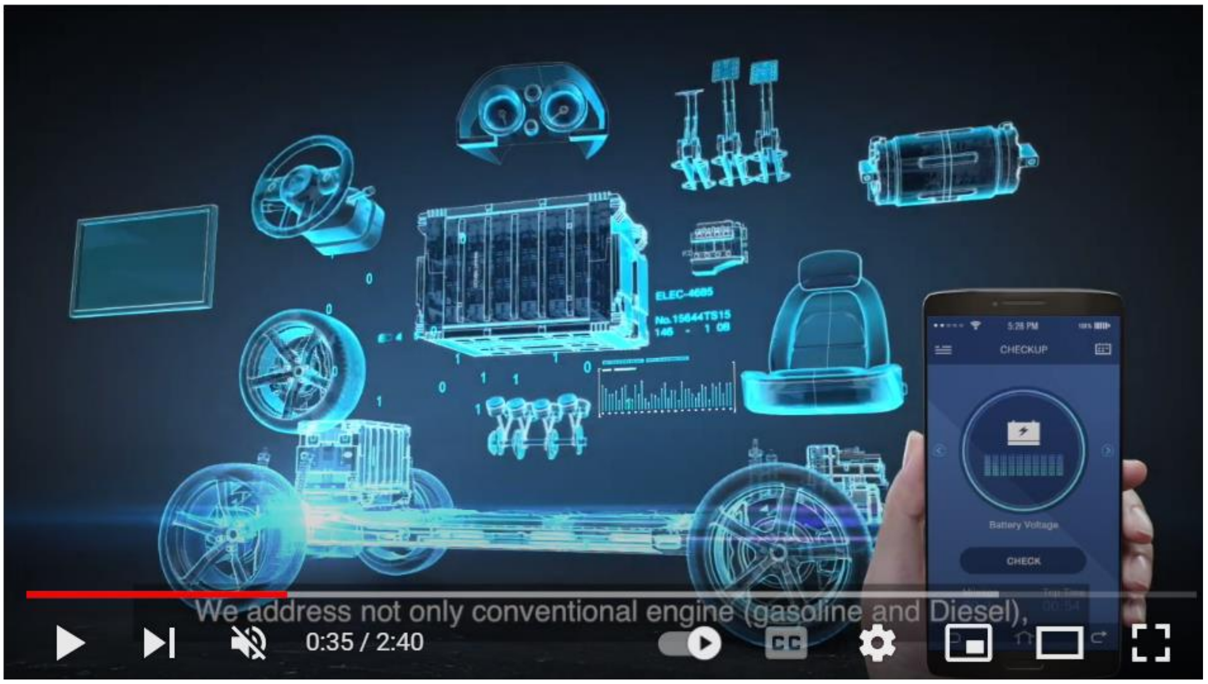
At the powertrain controls department of Renault-Nissan, in order to comply to Euro 6 and Euro 7 standards, the car manufacturer has made technical decisions with regards to the engine architectures and its controls strategies.

Together with the Simcenter Engineering and Consulting services team, Renault-Nissan performed a synthesis of virtual sensors and controllers at the same time, to get ready for next generation powertrains (hybrid, electric and internal combustion engines).

The Simcenter Engineering experts used artificial intelligence methods, and more specifically neural networks, to automatically select the most informative signals and combining them in a virtual sensor.

9-4. Figure_ Workflow for virtual sensor & controller synthesis

[https://blogs.sw.siemens.com/simcenter/the-sense-of-virtual-sensors/]



9-5. Figure_ Renault | *Coupling virtual sensors with artificial intelligence* | *Simcenter Amesim*

[https://blogs.sw.siemens.com/simcenter/the-sense-of-virtual-sensors/]

Using Simcenter Amesim for closed-loop simulation of plant models and controller executable specifications, Renault-Nissan is now able to verify and validate control systems against functional requirements early in the design process.

10 ECO-INNOVATIVE TECHNOLOGY IN THE AUTOMOTIVE INDUSTRY

10.1 ENVIRONMENTAL TECHNOLOGIES:

Environmental technologies refer to process technologies (including energy conversion technologies) and measurement technologies used for environmental purposes (to measure pollution or to identify toxics).

- Pollution control technologies
- 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
- Noise and vibration control

The automotive industry as a whole has developed a variety of green technologies to ensure sustainability and to lower the negative effects of the industry on the earth [75].

Going green in any industry is incredibly important for the future of the environment. The automotive industry might be most important because of just how much of effect cars and vehicles have on the environment. Historically, the earth has been damaged by the production of cars and by the vehicles themselves.

Innovative green technology is associated with Tesla first, which is the accelerating transition to sustainable energy.

After launching the first electric car, Roadster, in 2008, Tesla officially presented its cutting-edge battery technology and electric powertrain.

10.1.1 INNOVATIVE BIPOLAR NICKEL-HYDROGEN BATTERIES FOR HYBRID VEHICLES

Toyota Industries establishes on-board battery production line at its new Ishihama Plant, increasing production of bipolar nickel-hydrogen batteries for hybrid vehicles [76]

Toyota Industries Corporation has established its new Ishihama Plant. The plant will start production of bipolar nickel-hydrogen batteries for hybrid vehicles in October 2022.

The new plant is expected to operate at a production capacity of 20,000 units per month, and, together with the Kyowa Plant (Obu-shi, Aichi) that started battery production in May 2021, this will boost total capacity to 40,000 units per month.

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.

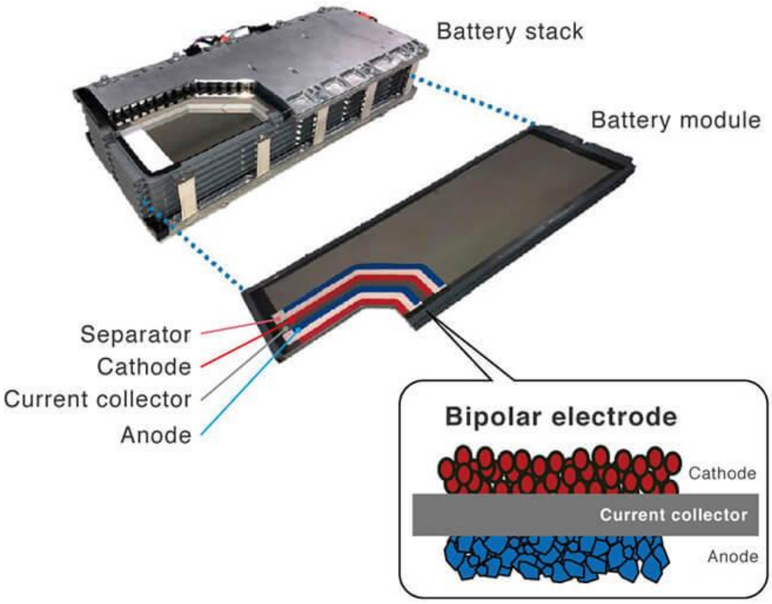
In this **INNOVATIVE BATTERY**, a cathode is applied to one side of a metal component called a current collector and an anode to the other. Several of these structures, which are known as "bipolar electrodes," are stacked together to form a battery.

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.

10-1. Figure_ The bipolar nickel-hydrogen battery

[https://www.toyota-industries.com/news/2022/08/30/005417/]

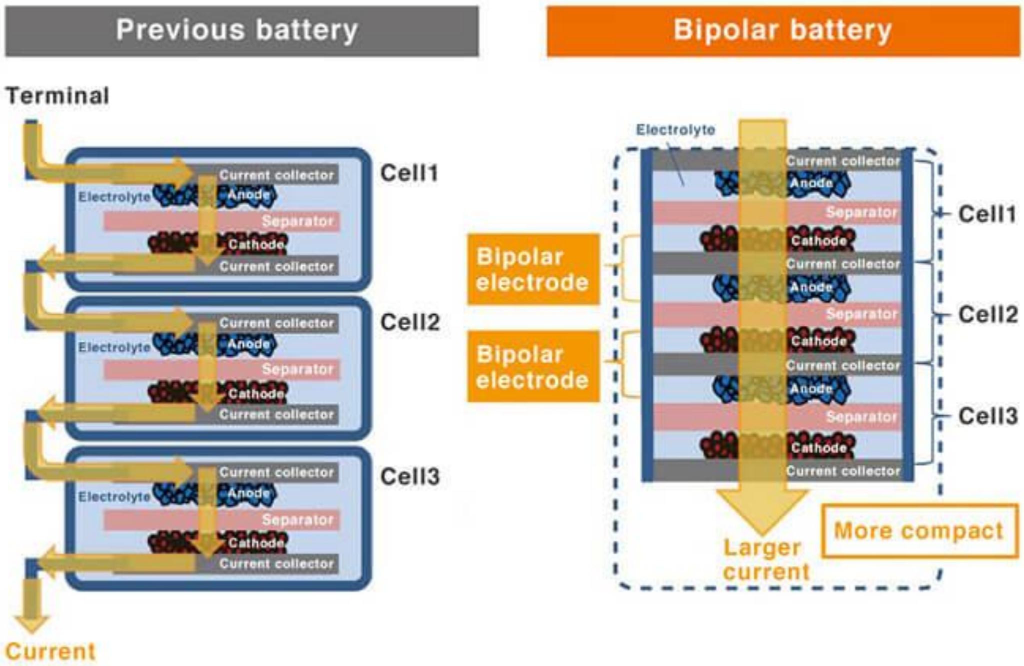
In bipolar nickel-hydrogen batteries, a cathode is applied to one side of a metal component called a current collector and an anode to the other; several of these structures, which are known as “bipolar electrodes,” are stacked together to form a battery. The Aqua is the world’s first vehicle to use a bipolar nickel-hydrogen battery as an electric drive battery.



10-2. Figure_ The bipolar nickel-hydrogen battery

[https://www.toyota-industries.com/products/automobile/battery/]

Achieving Compactness and Higher Output: 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.



10-3. Figure_ The bipolar nickel-hydrogen battery

https://www.toyota-industries.com/products/automobile/battery/

The bipolar nickel-hydrogen battery, which achieves both superior driving performance and environmental performance, is scheduled to be used in the Lexus RX unveiled in June 2022 and the Toyota Crown unveiled in July. The Ishihama and Kyowa plants are prepared to handle future increases in demand. To contribute to the expansion and spread of electrified vehicles and work toward carbon neutrality, Toyota Industries is both working on stable supply as well as to enhance its lineup of batteries so that they can be used in a range of electrified vehicles.

10.2 PIONEERING USE OF BIOSYSTHETIC 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.

The first vehicles to use the new vacuum sensing hoses was produced in May 2016, with usage expected to be rolled out to all models manufactured in Japan by the end of the year. Toyota plans to expand the use of biohydrin to other high performance rubber components, such as brake hoses and fuel line hoses.

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.

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.

The bio glycerin can be used to manufacture bio epichlorohydrin. (Roundtable on Sustainable Biomaterials certification as a plant-derived raw material has been confirmed.)

10-4. Figure_ Toyota became the world's first automaker to use biohydrin rubber

[https://global.toyota/pages/global_toyota/sustainability/report/kururisa_en.pdf]

10.3 NEW PROCESS TO PRODUCE BETTER, CHEAPER CATHODES FOR USE IN LITHIUM-ION BATTERIES

Oak Ridge National Laboratory (ORNL) engineers have developed a new process to produce better, cheaper cathodes for use in lithium-ion batteries. It enables a way to make more affordable batteries from a faster, less wasteful process that uses less toxic material.

Traditional processing presents numerous challenges. One big obstacle is a reliance on cobalt, a rare metal mined and refined abroad. The balance of other metals common in cathodes can also make the manufacturing process longer and more hazardous. For example, high nickel concentration has led to the widespread use of a chemical mixing method for cathode production that requires large quantities of ammonia for corrosive reactions. Using this toxic chemical increases costs, heightens health and environmental concerns, and wastes large amounts of water to reduce acidity.

Instead of continuously stirring cathode materials with chemicals in a reactor, the new ORNL method uses a HYDROTHERMAL SYNTHESIS APPROACH. It crystalizes the cathode using metals dissolved in ethanol. The ethanol is safer to store and handle than ammonia, and afterward it can be distilled and reused.

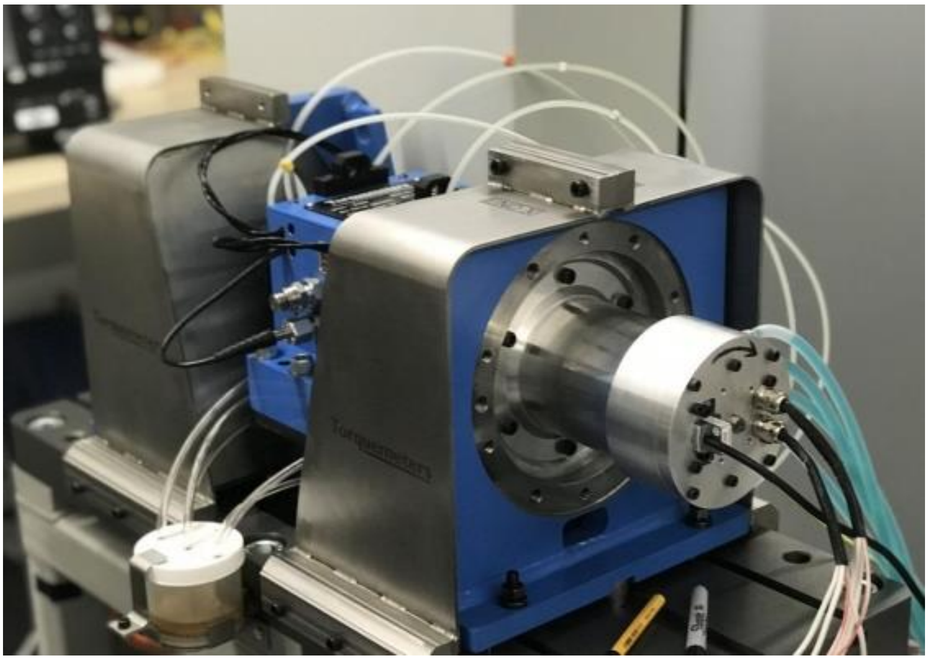
The hydrothermal synthesis method is also much faster. The time required to make particles and prepare for the next cathode batch drops from as many as a few days to 12 hours.

“In addition, the material produced has more uniform, round, tightly packed particles that are ideal for a cathode,” explains Rachid Essehli, ORNL lead researcher. “Because its properties are similar to those of today’s cobalt-based cathodes, the new material can be seamlessly integrated into existing battery manufacturing processes. This cathode material can give more energy and decrease the cost of electric car batteries.”

A new hydrothermal synthesis method makes a cobalt-free cathode material with more uniform, round, tightly packed particles (right) than is common in today’s cathodes (left), maintaining more stability throughout the battery charging cycle. Illustration courtesy Oak Ridge National Laboratory

10.4 HIGH-SPEED EV MOTOR FEATURES IMPROVED POWER DENSITY

The **MAGNETICALLY DRIVEN MOTOR** was developed by the University of New South Wales (UNSW Sydney) and **SIGNIFICANTLY REDUCES THE USE OF RARE-EARTH MATERIALS** such as neodymium. The high-speed device has the potential to increase the range of electric vehicles.



10-5. Figure_ High-Speed EV Motor

[https://newsroom.unsw.edu.au/news/science-tech/new-very-high-speed-motor-offers-improved-power-density-use-electric-vehicles]

The new motor designed and built by the team at UNSW is an improvement on existing IPMSMs (Interior Permanent Magnet Synchronous Machine Motor), which are predominantly used in traction drive of electric vehicles.

The design of the prototype interior permanent magnet synchronous motor (IPMSM), inspired by the shape of the longest railroad bridge in South Korea, has achieved speeds of 100,000 revolutions per minute. The maximum power and speed achieved by the motor have exceeded the existing high-speed record of laminated IPMSMs, making it the world's fastest IPMSM ever built with commercialized lamination materials.

The motor is able to produce a high power density, which is beneficial for EVs in reducing overall weight and increasing range for any given charge.

An IPMSM has magnets embedded within its rotors to create strong torque for an extended speed range. However, existing designs suffer from low mechanical strength due to thin iron bridges in their rotors, which limits their maximum speed.

The UNSW device features a new rotor topology that significantly improves robustness, while also reducing the amount of rare-earth materials per unit of power production. It is based on the engineering properties of the Gyopo rail bridge, a double-tied arch structure, as well as a compound-curve-based mechanical stress distribution technique.

This research project tried to achieve the absolute maximum speed, with a peak power density that is around 7 kilowatts per kilogram, For an EV motor, it would actually reduce the speed somewhat, but that also increases its power.

The project can scale and optimize to provide power and speed in a given range, for example, a 200-kilowatt motor with a maximum speed of around 18,000 rpm [would] perfectly suit EV applications.

The new motor also offers a significant cost advantage over existing technology and uses less rare-earth materials. Most high-speed motors use a sleeve to strengthen the rotors and that sleeve is usually made of high-cost material, such as titanium or carbon fiber.

The sleeve itself is very expensive and also needs to be precisely fitted. That increases the manufacturing cost of the motor.

Rotors have very good mechanical robustness, so that sleeve is don't need, which reduces the manufacturing cost. It only use around 30 percent of rare earth materials, which includes a big reduction in the material cost, thus making our high-performance motors more environmentally friendly and affordable.

This high-speed magnetically driven motor significantly reduces the use of rare-earth materials such as neodymium. [University of New South Wales].

11 3D PRINTING FOR THE AUTOMOTIVE INDUSTRY

11.1.1 3D PRINTING GENERAL ASPECTS

The 3D printing technology, often referred to as additive manufacturing, is used across many industries and an increasing number of companies adopt to this future enabling technology.

Additive manufacturing is a specific 3D printing process. This process builds parts layer by layer by depositing material according to digital 3D design data.

The term “3D printing” is increasingly used as a synonym for additive manufacturing. However, “additive manufacturing” better reflects the professional manufacturing process that differs significantly from conventional, subtractive manufacturing methods.

For example, 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.

Additive manufacturing is relevant in many areas and for numerous industries. Whether used for building visual and functional prototypes or small and medium series - and increasingly for series production.

This method offers convincing advantages conventional methods cannot achieve. Product development and market entry can be significantly accelerated, agile product customization and functional integration can be achieved more quickly and at a lower cost. In this way, additive manufacturing gives large OEM manufacturers from a wide variety of industries the opportunity to differentiate themselves on the market in terms of customer benefits, cost reduction potential and sustainability targets [[77]].

Growth Drivers:

- Ability to develop more complex and higher quality products
- Cost effective, fast customization and faster time to market
- Supportive government initiatives
- Decline in the price of desktop printers

Pitfalls & Challenges:

- Inability to manufacture larger parts and components
- Lack of skilled professionals
- Intellectual property concerns

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 [78].

The role of 3D printing in the automotive industry is huge.

In the past decade, more car companies are throwing their hats into the 3D printing ring.

The role of 3D printing isn't obvious to the everyday consumer since we don't see 3D printed cars on the road. The real role comes when look at the production and testing processes.3D printing is the right manufacturing process for every car company.

11.2 3D PRINTED AUTO PARTS

There aren't a ton of 3D printed parts that make it into a final production run. That's not to say 3D printed parts are bad, it's just hard to print them at the scale that auto manufacturers are looking for.

IN THE TEST LAB

Most of the printed parts are showing up during the prototyping and testing phases. For example, Alfa Romeo's F1 team 3D prints scaled-down models of their final production car. They take the miniature parts to a wind tunnel to see how aerodynamic the car would be.

This option is a lot cheaper, faster, and easier than manufacturing a full-scale model, then testing it. The same can be said for stress testing, assembly testing, and dynamic situations for car parts.

TOOLING, JIGS, AND FIXTURES

Ford use 3D printers to make tools, jigs, and fixtures for their vehicles. They're used as peripheral steps in the ultimate production process.

Making a car could require a lot of unique, one-off tools. Rather than paying an over-priced third party, these teams are deciding to print their own tools in-house.

REPLACING OBSOLETE PIECES FOR CLASSIC CARS

The Chevelle, for example, hasn't seen a production line since 1977. Owners have to cross their fingers and hope to find a replacement for their broken window crank handle.

Alternatively, the part could be 3D printed using OEM dimensions resulting a quasi-OEM part that it's much cheaper than a true OEM part [79].

11.3 EXAMPLES OF USING 3D PRINTERS

As 3D printers get cheaper, faster, and more accurate to operate, more industries find a use for them. One of the big industries that have been in love with 3D printers over the past decade is the automotive industry. Some of the biggest names in the world of auto have been using this technology to get an upper hand on their competitors [80].

The most trustworthy and quality-focused automotive manufacturers are using 3D printing. Some of the major companies using 3D printers are: BMW, Audi, Porsche, Ford, Volvo, Bugatti, GM, Rolls Royce, Daihatsu, VW, Alfa Romeo's F1 team.

SAUBER is able to print parts like front wings, brake ducts, suspension and engine covers much faster, with greater design flexibility than traditional manufacturing would allow [81]

BMW is one notable example: the German automaker used Fused Deposition Modelling to produce hand tools for assembly and testing as an alternative to traditional metal-cutting manufacturing methods like milling or turning. Thanks to 3D printing, the weight of the ergonomically designed tools has been reduced by 72%, making it easier to use for workers and enhancing the device's functionality.

With 3D printing, OEMs are able to use CAD software to design parts and then print a prototype themselves, saving them both time and money. Previously, OEMs outsourced the process of prototyping to machine shops, which not only resulted in additional costs but also took weeks to produce a part. Moreover, if the produced part needed modification (which in most cases it did), then the modified blueprint was sent to the machine shop again for production, resulting in a repeat of the entire process.

Due to lower costs and turnaround time, this technology has given OEMs the flexibility to use a fleet of printers to try out multiple designs at once, rather than being limited to one design and then restarting with another in case the first result did not meet expectations. This has largely helped OEMs boost quality levels as they do not waste too much time applying modifications to their designs and then testing them.

GM uses 3D printing technologies of various kinds, such as selective laser sintering (SLS) and stereolithography (SLA), across its design, engineering, and manufacturing processes and rapid prototypes for about 20,000 parts. **CHRYSLER** uses 3D printing for prototyping a wide variety of side-view mirror designs and then selecting the one that looks and performs the best. **FORD**, on the other hand, has been one of the earliest adopters of 3D printing technology. It runs five 3D prototyping centres, of which three are in the US and two are in Europe. The company churns out about 20,000 prototyped parts per annum from just one of these centres (Michigan, USA).

Other OEMs, such as **MITSUBISHI** – which bought its first 3D printer in 2013 – have been late adopters of the technology.

While 3D printers continue to be widely used for rapid prototyping across the industry, several large vehicle manufacturers have advanced into the next stages of 3D printing technology adoption. Although still in nascent or experimental stage, these OEMs have applied 3D printing to produce hand tools, fixtures and jigs to enhance production efficiency at floor level. Ford, which is one of the most advanced users of 3D printing, uses this technology to produce calibration tools.

Leaders in the use of 3D printing, such as **FORD**, also apply the technology to prototype parts that are of such strength that they are installed on running test vehicles. The company uses engine parts, such as intake manifolds, from 3D printing white silica powder, to install it in its running test vehicles. With the use of 3D printed prototypes of components such as cylinder heads and intake cylinders in test vehicles, Ford is successful in avoiding the requirement of investment castings and tooling, and in turn saving significant amount of time and dollars.

11-1. Figure_ Ford's Jigs and Fixtures for The Production Line

Another advancement in 3D printing encompasses the use of new and innovative materials. While most companies use silica powder, resin, and sand, few OEMs are innovating with forming test parts out of clear plastics. This allows them to validate designs as the team can visualise what is happening inside the part.

CHRYSLER uses transparent plastic in 3D prototyping their differential and transfer cases. By inserting oil, they can monitor whether the gear stays well-lubricated under the prototyped design/model.

The use of metal as a printing material is an innovation that, although still in its nascent stage, is being used by OEMs such as **BMW** to 3D print (using SLM technology) a metal water wheel pump for its DTM racing car.

Auto-parts manufacturer, **JOHNSONS CONTROLS AUTOMOTIVE SEATING**, also uses 3D printers to print metal parts that have complex shapes and are difficult to produce using traditional welding.

With these new applications taking the industry by storm, several OEMs are increasingly investing in and exploring the uses of additive manufacturing. While few companies have been slow in adopting to 3D manufacturing initially, it is expected that they will soon come up to speed with the advances in the use of this technology, given the holistic benefits it offers.

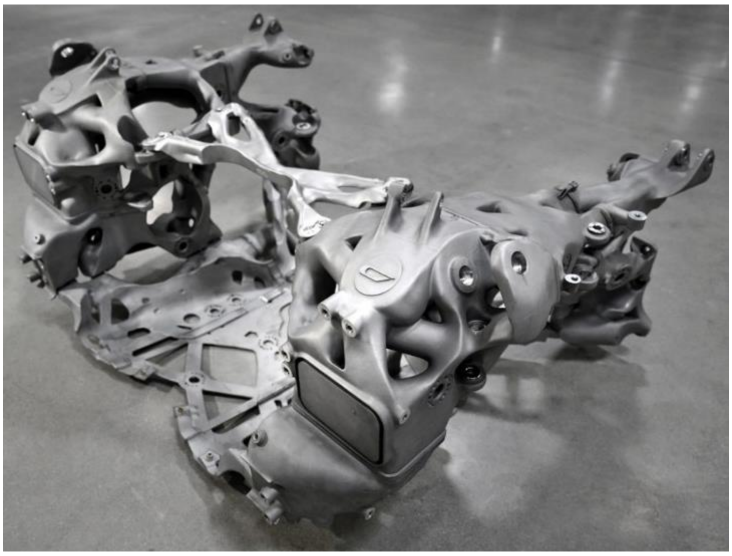
BUGATTI'S eight-piston monobloc brake caliper is a key example. Bugatti favors titanium for certain components due to the material's high performance characteristics, but processing the metal with conventional methods is costly and challenging. The use of 3D printing not only enabled Bugatti to produce the caliper at the required scale, but 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).

11-2. Figure_ Bugatti's eight-piston monobloc brake caliper is the world's largest functional titanium 3D printed car part.

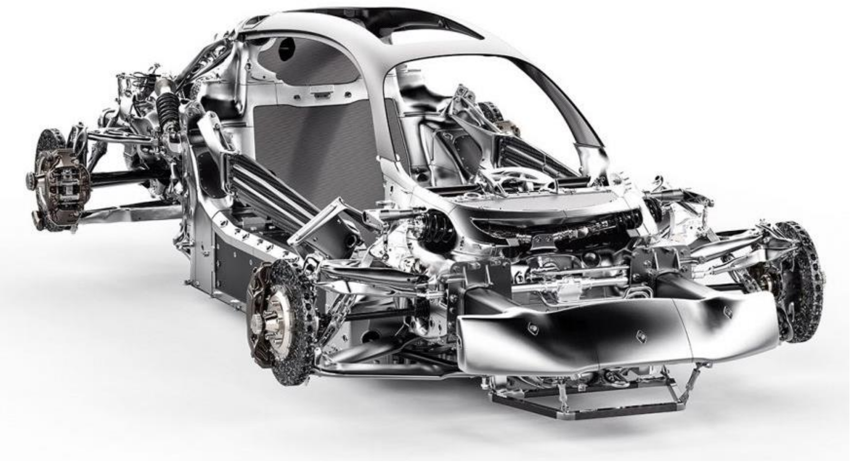
https://www.bugatti.com/media/news/2018/world-premiere-brake-caliper-from-3-d-printer/]

Another example [82, 83] is the 3D printed **CZINGER 21C**. In the 11-3. 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 (Courtesy Czinger Vehicles).

11-3. Figure_ View inside the engine bay of the Czinger 21C [Source: Czinger Vehicles]



*11-4. Figure_ The assembled rear structure,
showing the extent to which metal Additive Manufacturing has been used on the 21C
[Source: Czinger Vehicles]*



11-5. Figure_The front safety structures, suspension and braking systems, all of which leverage AI to optimise component designs for performance whilst taking advantage of the opportunities presented by AM

[Source: Czinger Vehicles]

11.3.1 DIGITAL FACTORY SOLUTION FOR COMPLEX STRUCTURES

Designing for Automotive [84]: Divergent Technologies Inc. has introduced a ground-breaking digital factory solution for complex structures that the firm touts as a replacement method for traditional vehicle manufacturing. The Divergent Adaptive Production System (DAPS) is a modular digital factory solution that aims to transform auto manufacturing economics and environmental impact.

The **FULLY-INTEGRATED SOFTWARE AND HARDWARE SOLUTION** and patented process combines AI-optimized generative design software, 3D printing, and automated assembly to build lightweight automotive parts and frames.

DAPS takes a data-driven approach to designing and building vehicle structures with the goal of minimizing material usage and reducing total system cost. Based on a set of digital requirements as input, the design software optimizes the weight, strength and cost of vehicle models, and parts are 3D printed and assembled autonomously, reducing manufacturing time and the need for human intervention. The system essentially delivers a tool-free approach to car making, leveraging the same hardware infrastructure to enable quick design iterations or seamless switches between different car models without downtime.

Divergent officials tout DAPS' design-agnostic process as less energy- and resourceintensive, delivering more efficient structures faster. The process can also promote weight reductions on vehicles of between 20% to 70%, officials claimed, leading to improvements in vehicle efficiency

11.3.2 HOLISTIC DESIGN OF AN EPOWERTRAIN SYSTEM

Hexagon's powertrain engineering experts have been active in the design and development of Electric Vehicle ePowertrains for over a decade, working with Automotive OEMs, Tier 1s and Start-ups as electrification has developed in the sector from hybrid to pure electric solutions. Hexagon will explain how taking an analysis-led Systems Engineering approach to the design of Electric Vehicle ePowertrains allows the optimum overall solution to be identified and developed from the outset and helps engineering teams understand the implications of design decisions on the whole product through the development process to mitigate the risks of system integration issues in the later stages.

This process will be explored through an indicative real-life project that Hexagon's experts have delivered, illustrating why decisions were made and their outcomes.

11.4 ADVANTAGES OF 3D PRINTING FOR THE AUTO INDUSTRY

There are a number of reasons why 3D printers are so useful in this industry:

THE PRICE

First and foremost, manufacturing low-run or one-off parts is incredibly expensive if you use traditional machining.

There's a cost associated with buying raw material, setting up machines, learning about the part, and finally making it. With traditional machine shops, the "per unit" cost goes down as you make more and more. One-off parts have the highest possible "per unit" cost.

For most production cars, they'll use bulk manufacturing to knock out hundreds of thousands of parts. Before the final production run, during the initial stages, these manufacturers might just need 10 or 20 parts to play with.

Rather than spending an outrageous amount on a machine shop, these companies can use a 3D printing shop. A part that costs $5,000 to machine might only cost $500 to 3D print.

SPEED OF MANUFACTURING

Not only are 3D printed parts cheaper, but they're faster to make. Car parts can be really complicated which means machining them can take a lot of time, energy, and a talented machinist. Instead of waiting for the long lead-times of traditional machining, an automotive company can turn to a 3D printing shop. For especially complicated parts, they might save weeks or months in lead-time.

EASE OF ITERATIVE DESIGN

During the prototyping stage, there's a lot of iteration that goes on. The designers might go through a dozen prototypes, each with small tweaks from the previous version. These tweaks happen after holding the prototype in their hand and physically testing it.

Each of these iterations results in more money and time spent waiting for a machinist to finish the part. With a 3D printer, a designer can make changes and have the new part start printing within the same day.

It's easy to make changes on a 3D CAD model and ship it over to a 3D printing shop.

VALIDATING A PROOF OF CONCEPT

Sometimes, an auto designer has an idea and isn't quite sure how it will work out. It'd be hard for them to ask their boss for thousands of dollars to test an idea that might not even work.

It's a lot easier for them to ask for tens or hundreds of dollars to 3D print the same piece.

This is one way that someone like BMW can stay ahead of their competitors with their M Performance line. If someone has an idea for a new, lightweight, high-performance door panel, they can test it and prove it out before going to full-scale production.

LIGHTWEIGHTING

Designing a part for a 3D printer is very different than designing it for a CNC mill. With a 3D printer, you have more design freedom. One avenue of freedom is the ability to lightweight a piece. Bugatti wanted to make a lighter brake caliper, so they 3D printed one it was featured in headlines across the world.

3D PRINT FOR A WHOLE CAR

3D printers can use multiple different materials and can print almost anything that can be otherwise manufactured. Through a combination of carbon fiber, plastics, and metals, it's easy to visualize how someone might 3D print a whole car.

The only place where 3D printing falls short is in the electrical components, tires, engine, and suspension. For now, it's probably easier just to buy and install those components into an otherwise fully 3D printed car.

LOCAL MOTORS STRATI

A company Local Motors 3D printed their Strati. The only non-3D printed parts are the motor, battery, suspension, and lights. The whole thing can be printed in less than 24 hours, with the goal being a sub-10-hour print time.

3D PRINTED CONCEPT CAR

Another 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 that look great [85].

11-6. Figure_ The EDAG Light Cocoon

https://www.digitalengineering247.com/article/edags-light-cocoon-is-a-metamorphosis-for-car-design

The selling point is how lightweight 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 weather proof textile outer skin panel [86].

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 a weight savings of approximately 25% thanks to the approach.

11.5 MATERIALS USED IN AUTOMOTIVE 3D PRINTING

PLASTICS is the material people think of when they imagine 3D printing. Massive pieces up to 60″ x 29″ x 22″ can be made. They aren’t as strong as metals, but they’re less expensive.

STAINLESS STEEL offers high strength, low flexibility, and corrosion resistance. These are reasons why so many people in the auto industry love stainless steel. The stainless can be 3D printed, and, from a materials perspective, the final product is identical to raw stainless steel. It can use this material to make molds for casting products.

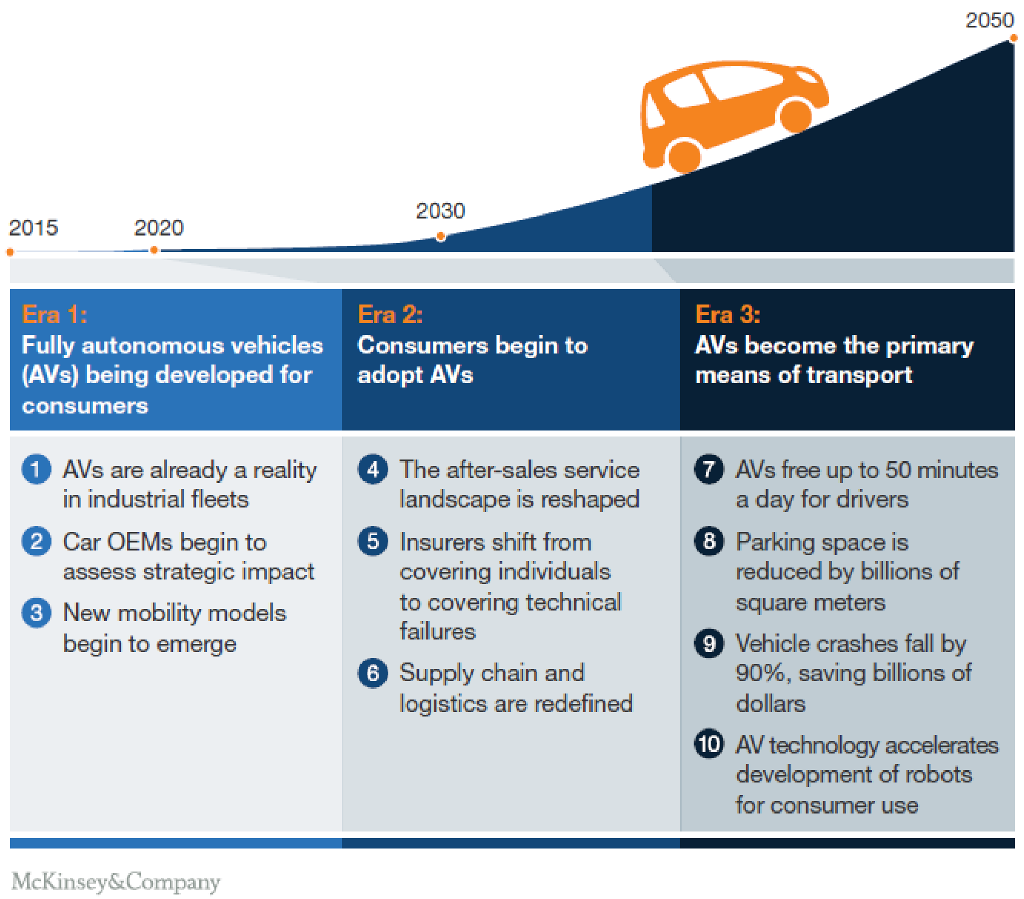
MARAGING STEEL is typically used for injection molding tools. These help auto manufacturers produce plastic parts in bulk. It's typically less expensive and quicker to make the mold via 3D printing instead of traditional machining.

BLUESTONE Bluestone it's a construction material that is a stable engineered nano composite. It's perfect for prototyping for aerodynamics or drag on a scale model for the automobile or bike.

3D printing is a shoo-in for the automotive industry. Companies can prototype, test ideas, and make small-batch runs cheaper, faster, and more accurately than with a traditional machine shop.

12 AUTONOMOUS DRIVING

An autonomous car is a vehicle capable of sensing its environment and operating without human involvement. A human passenger is not required to take control of the vehicle at any time, nor is a human passenger required to be present in the vehicle at all. An autonomous car can go anywhere a traditional car goes and do everything that an experienced human driver does. Autonomous driving could redefine the automotive world [[87]].



12-1. Figure_ Potential growth of the self-driving vehicle
[McKinsey&Company, 2015, Ten ways autonomous driving could redefine the automotive world]

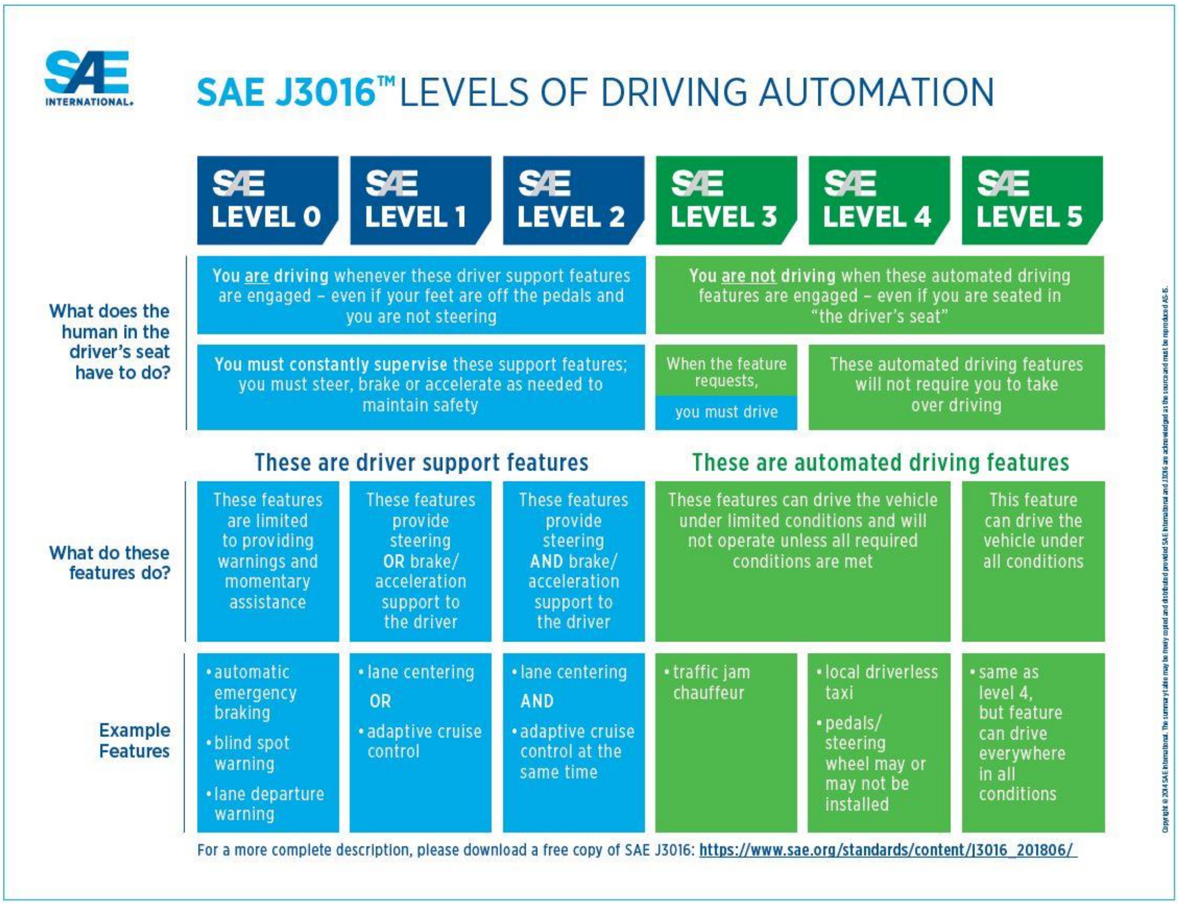
In addition to transforming the automotive industry, the rise of autonomous vehicles will likely have a profound impact on society. The ten developments described here provide a snapshot over the wide spectrum of possible outcomes linked to the increasing penetration of AVs in the market, offering industry leaders a look forward at this evolving landscape as it unfolds before them. Defining how to shape this landscape effectively represents a significant strategic challenge for the industry and regulatory authorities.

The design and development of autonomous vehicle systems is one of the fastest-growing fields in engineering and data science, and one that is at the leading edge of technology.

An autonomous vehicle in itself is not a standalone entity; rather, autonomous vehicles are a collection of systems for sensing and operation which work together to safely navigate and operate the vehicle.

These systems include sensors such as LiDAR, radar, cameras and computers to process and make sense of sensor data. Today, many algorithms running on those computers also use artificial intelligence.

The Society of Automotive Engineers (SAE) [J3016 "Levels of Driving Automation" standard]defines 6 levels of driving automation ranging from Level Zero which can include basic driver assistance but no autonomy to Level 5 which involves full autonomy of the vehicle under all conditions [88]. These levels have been adopted by the U.S. Department of Transportation.



12-2. Figure_ Levels of driving automation

[J3016 "Levels of Driving Automation" standard]

Currently, most commercially available vehicles are still in the range of Level 2, with driver assistance packages such as lane monitoring and adaptive braking or adaptive cruise control. However, the march toward Level 5 continues, being led by startups and large automotive OEMs alike, which means an increasing need for automotive engineers with the skills and knowledge to develop the future of autonomous mobility and transportation.

To achieve these skills, new types of training are needed for automotive industry professionals to ensure they understand the rapidly changing technologies available for the development of autonomous vehicles.

Professional development training through SAE International ensures engineers are training on the most recent technologies for automotive vehicle systems. Those who participate in SAE courses learn from established subject matter experts and professionals in the field and have the opportunity to meet and collaborate with peers in their field or industry. SAE courses also enable engineers to earn certificates and the CPU/PDU credits required to maintain their licensing and further their professional development.

Researchers forecast that by 2025 we'll see approximately 8 million autonomous or semi-autonomous vehicles on the road. Before merging onto roadways, self-driving cars will first have to progress through 6 levels of driver assistance technology advancements [[89]].

Level 0 (No Driving Automation)

Most vehicles on the road today are Level 0: manually controlled. The human provides the "dynamic driving task" although there may be systems in place to help the driver. An example would be the emergency braking system—since it technically doesn't "drive" the vehicle, it does not qualify as automation.

Level 1 (Driver Assistance)

This is the lowest level of automation. The vehicle features a single automated system for driver assistance, such as steering or accelerating (cruise control). Adaptive cruise control, where the vehicle can be kept at a safe distance behind the next car, qualifies as Level 1 because the human driver monitors the other aspects of driving such as steering and braking.

Level 2 (Partial Driving Automation)

This means advanced driver assistance systems or ADAS. The vehicle can control both steering and accelerating/decelerating. Here the automation falls short of self-driving because a human sits in the driver's seat and can take control of the car at any time. Tesla Autopilot and Cadillac (General Motors) Super Cruise systems both qualify as Level 2.

Level 3 (Conditional Driving Automation)

The jump from Level 2 to Level 3 is substantial from a technological perspective, but subtle if not negligible from a human perspective.

Level 3 vehicles have "environmental detection" capabilities and can make informed decisions for themselves, such as accelerating past a slow-moving vehicle. But—they still require human override. The driver must remain alert and ready to take control if the system is unable to execute the task.

Audi (Volkswagen) announced that the next generation of the A8 —would be the world's first production Level 3 vehicle and they delivered. The 2019 Audi A8L arrives in commercial dealerships this Fall. It features Traffic Jam Pilot, which combines a lidar scanner with advanced sensor fusion and processing power (plus built-in redundancies should a component fail).

However, while Audi was developing their marvel of engineering, the regulatory process in the U.S. shifted from federal guidance to state-by-state mandates for autonomous vehicles. So for the time being, the A8L is still classified as a Level 2 vehicle in the United States and will ship without key hardware and software required to achieve Level 3 functionality. In Europe, however, Audi will roll out the full Level 3 A8L with Traffic Jam Pilot (in Germany first).

Level 4 (High Driving Automation)

The key difference between Level 3 and Level 4 automation is that Level 4 vehicles can intervene if things go wrong or there is a system failure. In this sense, these cars do not require human interaction in most circumstances. However, a human still has the option to manually override.

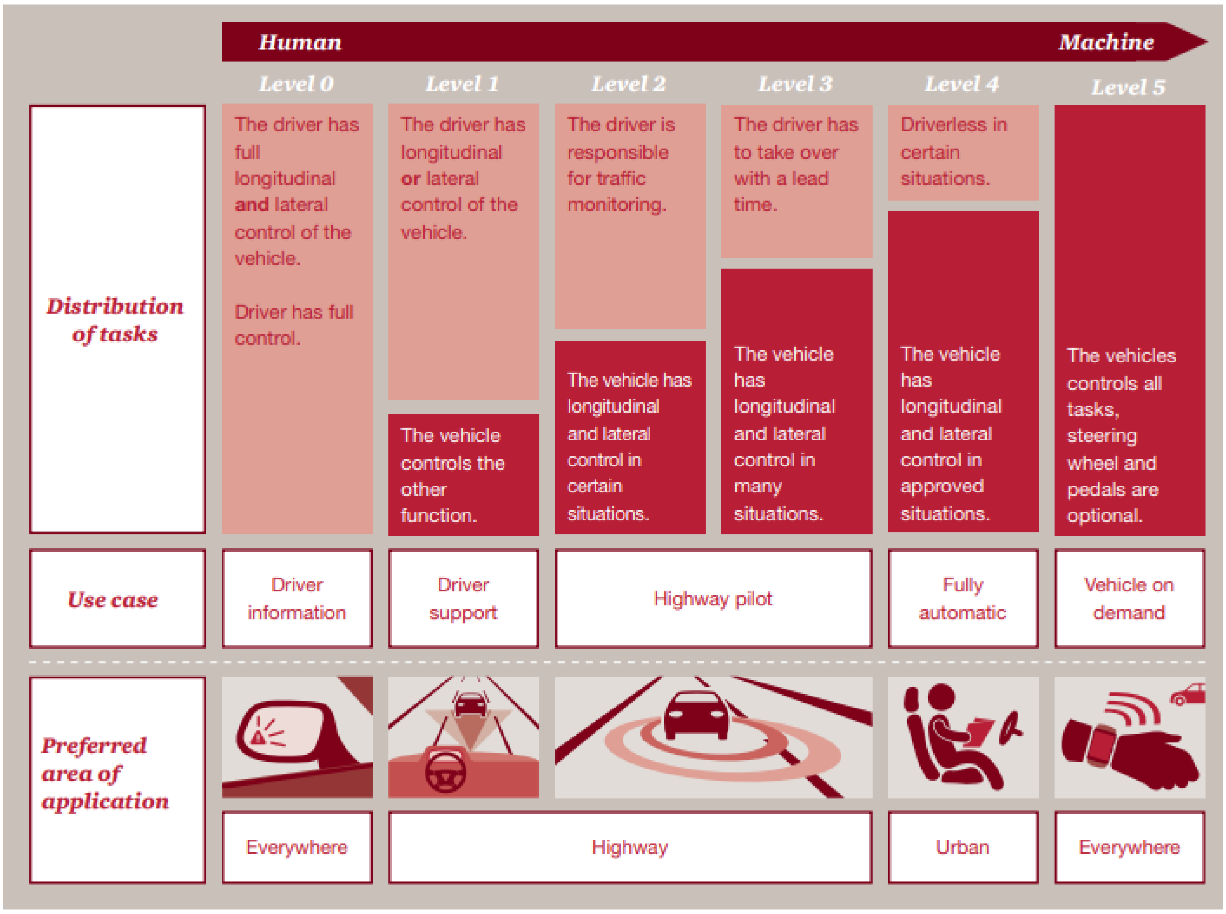
Level 4 vehicles can operate in self-driving mode. But until legislation and infrastructure evolves, they can only do so within a limited area (usually an urban environment where top speeds reach an average of 30mph). This is known as geofencing. As such, most Level 4 vehicles in existence are geared toward ridesharing.

EXAMPLES:

- NAVYA, a French company, is already building and selling Level 4 shuttles and cabs in the U.S. that run fully on electric power and can reach a top speed of 55 mph.
- Alphabet's Waymo recently unveiled a Level 4 self-driving taxi service in Arizona, where they had been testing driverless cars—without a safety driver in the seat—for more than a year and over 10 million miles.
- Canadian automotive supplier Magna has developed technology (MAX4) to enable Level 4 capabilities in both urban and highway environments. They are working with Lyft to supply high-tech kits that turn vehicles into self-driving cars.
- Volvo and Baidu announced a strategic partnership to jointly develop Level 4 electric vehicles that will serve the robotaxi market in China.

Level 5 (Full Driving Automation)

Level 5 vehicles do not require human attention—the “dynamic driving task” is eliminated. Level 5 cars won’t even have steering wheels or acceleration/braking pedals. They will be free from geofencing, able to go anywhere and do anything that an experienced human driver can do. Fully autonomous cars are undergoing testing in several pockets of the world, but none are yet available to the general public.



12-3. Figure_ Levels of autonomous driving

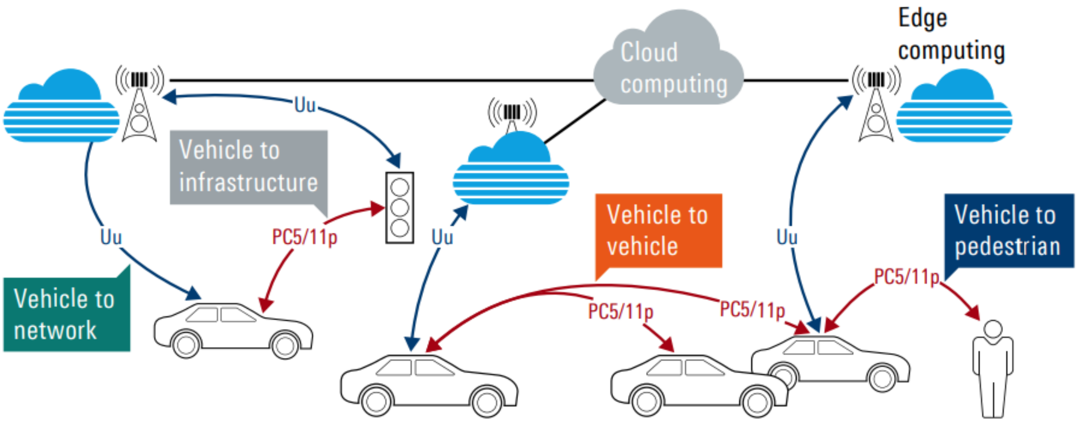
https://www.pwc.com/gx/en/industries/automotive/assets/pwc-five-trends-transforming-the-automotive-industry.pdf

13 VEHICLE TO EVERYTHING (V2X) COMUNICATION

13.1 V2X OPPORTUNITY AND CHALLENGES

Current developments in the automotive industry highlight an increased interest in connected and autonomous vehicles that offer many benefits, such as improved safety, less traffic congestion and implicitly less impact on the environment. A key driver of this evolution is vehicle-to-everything (V2X) communication, which allows a vehicle to communicate with other vehicles, pedestrians, roadside equipment and the Internet. With V2X, critical information can be exchanged between vehicles to improve situational awareness and thus avoid accidents. V2X also provides reliable access to the vast information available in the cloud. For example, real-time traffic, sensor and high-definition map data can be made available, which is not only useful for today's drivers, but will be essential for self-driving vehicle navigation in the future [[90]].

V2X includes networks, devices and data shared via V2V (vehicle-to-vehicle), V2N (vehicle-to-network), V2P (vehicle-to-pedestrian), V2D (vehicle-to-device) and V2I (vehicle-to-infrastructure) connectivity.



13-1. Figure_ Vehicle to everything (V2X) infrastructure and examples

[https://www.rohde-schwarz.com/cz/solutions/test-and-measurement/automotive/automotive-connectivity-and-infotainment/vehicle-to-everything/connectivity-v2x_231776.html#media-gallery-7]

Automotive V2X Hardware: On-board Units (OBU); Roadside Units (RSU); Antenna; Evaluation Kits; Other Hardware.

Automotive V2X Software: V2X Software Stack; V2X Software Development Kit; Automotive V2X Service

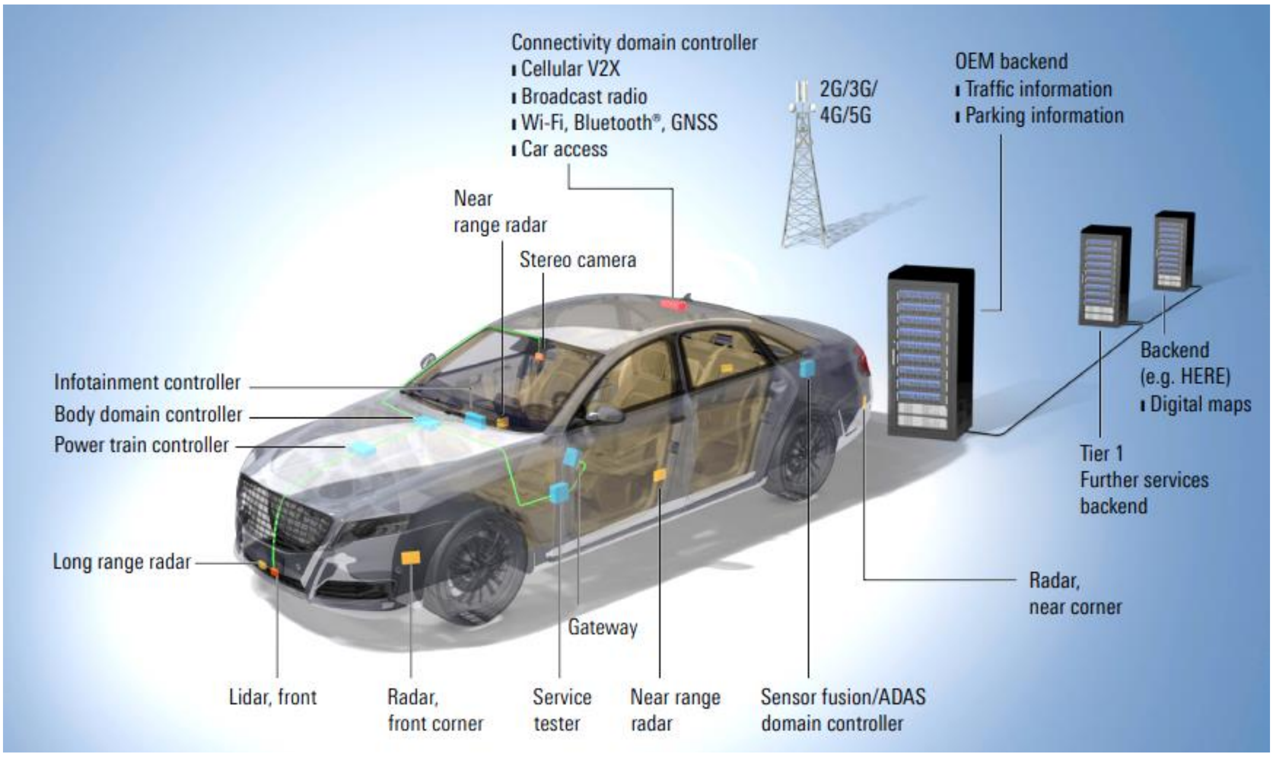
Communication Type: Vehicle-to-Pedestrian (V2P); Vehicle-to-Grid (V2G); Vehicle-To-Cloud (V2C); Vehicle-to-Infrastructure (V2I); Vehicle-to-Device (V2D); Vehicle-to-Vehicle (V2V).

Connectivity: Dedicated Short-Range Communication (DSRC); Cellular-V2X (C-V2X); Other Connectivity Types.

Technology: Emergency Vehicle Notification; Automated Driver Assistance; Passenger Information System; Line of Sight; Other Technologies.

When specifying connections there are further standardized references:

- V2V (Vehicle-to-Vehicle) is the connection between all vehicles either moving or parked.
- V2I (Vehicle-to-Infrastructure) is the connection to roadway infrastructure. This ranges from traffic signals and road signs to temporary fixtures such as roadworks and construction.
- V2P (Vehicle-to-Pedestrian) is the connection to all other road users, which could be pedestrian smartphones or other devices connected to the network.
- V2N (Vehicle-to-Network) is the connection of the device to the supporting mobile network.



13-2. Figure_ Vehicle architecture with domain controllers [91]

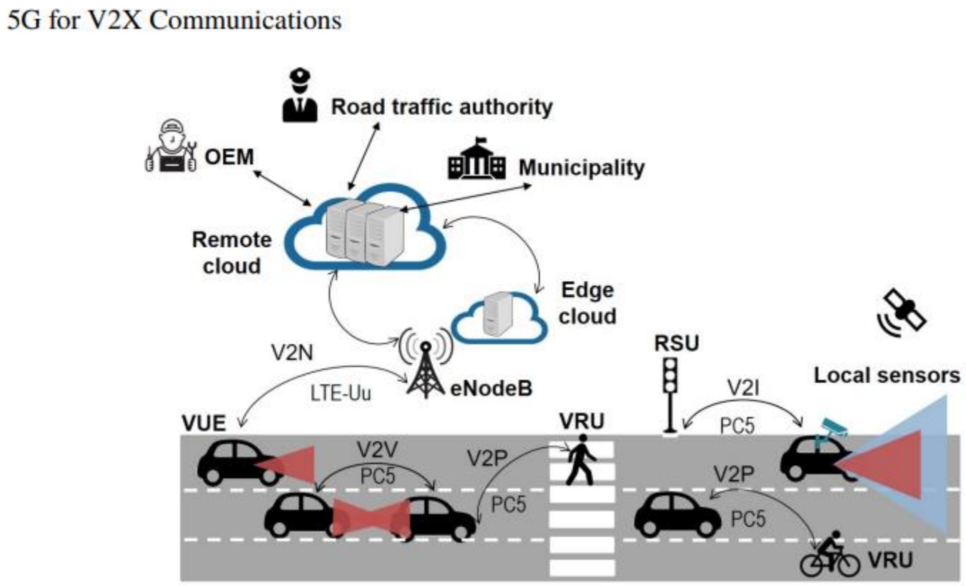
V2X was first introduced to cellular networks with 4G, although deployment has been relatively limited. There are a number of factors that contribute to why deployment has been slow, ranging from the demand from industry (vehicles rely on sensors on the vehicle rather than input from elsewhere) coupled with the readiness of the 4G infrastructure (investment won't be made if the business case is not there).

V2V, V2I and V2P scenarios typically involve a direct connection termed "SL" (Sidelink). The V2N relies on the cellular connection, i.e., LTE or 5G.

3GPP Release 16 in 2019 saw the introduction of NR-V2X, (New Radio V2X) allowing V2X services access to the 5GS (5G System). This included not only key support for autonomous vehicles, but also the delivery of media services to vehicles. It is worth noting that LTE-V2X and NR-V2X are not capable of communicating with each other, however they can co-exist. This enables vehicles to operate V2V LTE-V2X and N-V2X radios simultaneously, enabling backward compatibility to LTE-V2X-only devices.

Release 17 added additional NR-V2X features enhancing the V2X application layer support and Sidelink operation, as well as support for additional use-cases. 5G Release 17 also introduced MBS (Multicast Broadcast Services), which can be incorporated into the V2X data delivery mechanism [92].

V2X uses 5G to transmit signals to and from automobiles, pedestrians, and traffic cameras/sensors to make driving safer and more convenient. 5G will make connectivity—from cellphones to traffic lights to onboard navigation systems—the future of transportation.



13-3. Figure_ V2X communication modes, interfaces and entities [93]

13.2 V2X APPLICATIONS AND REQUIREMENTS

V2X applications cover a wide range of use cases, which can be clusterized based on their purpose and requirements.

The 5G Automotive Association (5GAA) is a global, cross-industry organisation of companies from the automotive, technology, and telecommunications industries (ICT), working together to develop end-to-end solutions for future mobility and transportation services [94]. The 5GAA has grouped V2X use cases in four categories: **Safety** aimed at reducing the frequency and severity of vehicle collisions; **Convenience** managing the vehicle health and offering services like diagnostics and software updates; **VRU** targeting safe interactions between vehicles and non-vehicle road users; **Advanced driving assistance sharing** similar objectives with the safety use cases, but treated separately for their close relationship with (semi-)autonomous vehicle operation.

Specifically, V2X technology can solve the issue of sensors that can't detect objects outside the line of sight by enabling cars to wirelessly communicate with connected devices on other cars, pedestrians, and roadway infrastructure.

When devices are connected to the same wireless network, V2X enables cars to detect the movement of objects outside the field of vision, ensuring safety beyond the traditional line-of-sight sensors. By sharing data, such as position and speed, to surrounding vehicles and infrastructure, V2X communication systems enhance driver awareness of potential risks.

V2X technology can enhance traffic efficiency by providing warnings for upcoming traffic congestion, alternative routing, and reduced CO2 emissions through adaptive cruise control. Such technology will help mitigate traffic and minimize fuel costs for individual vehicles.

The V2V communication segment, with its focus on safety measures, is predicted to have the largest share of the automotive V2X market. The Cadillac CTS and Mercedes Benz E-Class vehicles are already on the road and equipped with V2V technology.

Adoption of V2X is still in its early stages; few corporations and startups are working on the technology, and even fewer are testing it.

The main drivers of market growth in V2X are increasing concerns about transportation pollution and the growing trend toward safe, connected vehicles.

Along with a variety of hardware and service providers, OEMs are working to develop their own V2X protocols, data, measures, and processes as part of their own ADS or ADAS platforms.

14 DISRUPTION IN THE AUTOMOTIVE INDUSTRY

What are the latest vehicle electrification trends?

How will the automotive industry contribute to the global goal of carbon neutrality?

The auto industry's transition to EVs is accelerating. The year 2026 has emerged as a tipping point for an acceleration in EV adoption that will drive automotive electrification trends ahead [[95], [96]].

By 2030 over one in four new passenger cars sold will be an electric vehicle. Many major vehicle manufacturers worldwide have signaled the end of an era of internal combustion engines (ICE) as the transition to zero emission vehicles (ZEV) is ramped up.

The top automakers are expected to account for more than 70% of global EV production by the year 2030 (compared to 2022 when they represented only 10% of all EV manufacturers). But despite the rapidly growing choices EV consumers have, and the unprecedented loyalty rates among EV return buyers, the industry as a whole still needs to tackle consumers range anxiety, particular for those without a garage or those traveling long distances.

The solution needs to be a joint effort between multiple industries: automotive, utilities, government, and private property owners such as shopping malls and apartment complexes. As these paths converge, vehicle electrification trends will increase exponentially. And we may, indeed, see the end of the ICE-age.

New disruptive technology is evolving and impacting the automotive and transportation industry.

Automotive innovations are driving the logistics and transportation industry into a new era filled with autonomous vehicles and electric vehicles. The pandemic has disrupted how people drive and buy their vehicles. And, supply chain disruptions such as the semi-conductor shortage are making a huge impact on current production capabilities. Stay connected on the technology, supply chain and retail disruption in the automotive industry with our latest news and industry reports.

14.1 AUTOMOTIVE INDUSTRY TRENDS

- Autonomous Vehicles (AVs)
- Vehicle Connectivity.
- Electrification.
- Shared Mobility.
- Artificial Intelligence.
- Big Data & Analytics.
- Human-Machine Interfaces.
- 3D Printing.

Automotive IoT uses sensors on vehicles to monitor and collect data about vehicle performance. OEMs can use this information to improve the reliability, compliance, and safety of their cars.

Enabling positive impacts through portfolio-As a company, SIEMENS supports the customers in generalizing carbon-neutral passenger and freight transport, from door to door, in cities, and in-between: With rolling stock, rail infrastructure, intermodal solutions, rail services, and turnkey solutions.

utilizing energy-efficient products and accelerating alternative propulsion systems that use battery or hydrogen technology. ~~The customers~~ also enjoy the benefits of increased asset value through the lifecycle management strategy; this in turn reduces the ecological footprint of their operations.

14.2 DATA AND DIGITIZATION CAN REVOLUTIONIZE PRODUCT DESIGN AND DEVELOPMENT

Insights: Re-Engineering Engineering, How data and digitization can revolutionize product design and development [97]

The numbers of sensors and digital systems collecting data on aircraft, railway cars, locomotives, and 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. And customers, recognizing the possibilities, are demanding ever more customized equipment and intelligent interfaces reflecting the most current capabilities.

But the new components and technologies are also reshaping the way engineers design and develop this equipment. They create opportunities that, when used to full potential, can contain research and development (R&D) costs and substantially speed up the incorporation of innovations – allowing manufacturers to better adapt to rapidly changing customer demands.

In the past, inventing transportation equipment required a trial-and-error process and multiple prototypes. For instance, developing a new model of car typically took close to four years, with the model staying on the market for seven years. For aircraft and rail rolling stock, the combined timetable for development and the equipment's time in service can be three to four times longer than for autos. Given the current pace of technological change and adoption, that's too long.

REAL-TIME INNOVATION

Digitization is changing the playing field for engineers. It alters the culture by providing more real-time data on the performance of equipment in the field today, allowing engineers to consider improvements that can be achieved in months through data algorithms rather than years or decades. Instead of focusing only on breakthrough technologies and new models, engineers can significantly expand the capabilities of equipment already in service through incremental upgrades in software downloads or the incorporation of new sensors.

Transportation manufacturers can operate more like an Apple or Microsoft, sending software updates to improve performance or security. Regular upgrades and the flexibility that digital systems provide are revolutionizing what original equipment manufacturers can offer customers – and what engineers can develop.

Exemple: Tesla with its electric vehicles and their substantial digital content. Since its inception, the electric car company has let customers incorporate technology upgrades through simple downloads while vehicles sit in the garage or parked on a street.

The pressure to keep technology cutting edge is even more intense for aircraft and rail equipment manufacturers whose products remain in service for decades. Public transport authorities are beginning to demand faster turnaround on new trains and trams to provide riders the latest comforts and conveniences; airlines want to distinguish themselves in the market with more customization of their planes and the customer experience through advanced connectivity.

THE REALITIES OF BUDGETS

Making sure that products keep up with technological advances costs money at a time when most manufacturers are forced to look for cuts. As a result, engineering departments are transferring funds from traditional R&D to digital in an impossible race to reduce both the cost and time to reach market with new products.

Annually, equipment makers budget more than $814 billion (€700 billion) on R&D and engineering – a significant cost of operation. Adopting data-driven engineering could shave up to 10 percent off these budgets, with the savings likely to increase as transportation equipment becomes more digital, autonomous, and electric.

To accomplish this, engineering departments will have to change how they work.

14.2.1 TRENDS IN DESIGN AND DEVELOPMENT OF TRANSPORT EQUIPMENT

TREND ONE. TWO TYPES OF ENGINEERS

The biggest challenge facing transportation companies is finding candidates with the right combination of engineering skills required by the increasing technical sophistication of transportation equipment. Thus, expertise is needed in narrow scientific fields such as artificial intelligence, but their complexity also creates a need for system engineers and architects. These specialists must master multiple engineering disciplines and can approach a product holistically, understanding how different systems interact and support each other.

Information technology tools and artificial intelligence systems will take over some engineering tasks, primarily simple design tasks. It is estimated that robots will eventually take over as much as 25 percent of the work of engineers, as they have replaced production workers in factories and changed the required human skill set.

TREND TWO. OPEN ENGINEERING ECOSYSTEMS

Outsourcing has transformed from a means of reducing costs to one that enables access to new skills in areas such as artificial intelligence, so that in-house engineers can focus on new technologies. This involves collaborating with tech startups. The technology industry is used to refining systems over time based on usage data, but for transportation equipment manufacturers, issues in the field can threaten more than reputation and customer relationships.

However, the two types of engineers must work together, which will require more alignment between engineering processes, approval procedures, and validation requirements, among other things.

Companies can use ecosystems made up of internal and outsourced engineering teams from multiple companies working together, but there can be problems in finding the right ecosystem for software development, maintaining control over design methodologies, lack of standardized IT systems, and mitigating attack potential cyber when working with third party providers.

TREND THREE. OPTIMIZING DESIGN WITH PRODUCT DATA

New engineering initiatives are arising from the growing pools of data supplied by aircraft, automobiles, and railway cars themselves. Manufacturers have added more and more sensors to their products as the cost has come down and advanced analytics become available to interpret the data. Oliver Wyman believes equipment manufacturers could gain $10 billion annually from improvements based on such Internet of Things data.

For automakers, the problem has been the fact that data rarely makes it back to the engineers. Vehicle internal error codes are tracked and used by repair shops to diagnose problems but often deleted after the car is fixed. If they were fed into a database, engineers could track frequently recurring problems with, for instance, navigation and infotainment systems, and find the root causes. They could then fix them in subsequent designs.

TREND FOUR. CUSTOMER-CENTRIC PRODUCT DESIGN

Demand for customization means that engineering companies are working closer than ever with their customers. Sixty percent of top performing companies now collaborate intensively with their customers to get feedback on products and understand what they want next. Equipment makers do not involve their customers in the technical design, but smart ones use them as integral parts of the testing process for new technologies.

In automobiles, by monitoring drivers' habits digitally, automakers might identify driving patterns that cause higher emissions and adjust the exhaust systems' control algorithms for individual drivers.

TREND FIVE. PROJECT DATA MANAGEMENT AND OTHER IT TOOLS

Project data management (PDM) tools are one way to cope with the growing complexity. PDM arranges a technology system into a connected library of subsystems, a bit like LEGO blocks, and allows data sharing across a company, removing functional silos. It can speed up development and cut the design cycle in half. PDM could be particularly useful for the rail industry, where there's more scope for customization than in automotive or aerospace, and where the need to limit complexity makes data about every variable easily accessible. Rail manufacturers have initiated the journey to modularization of sub-systems, and automakers are using similar parts on multiple platforms. Engineers are often reluctant to adopt new IT tools like PDM, with their rigidity and poor user interfaces that are often a struggle to use.

TREND SIX. IMPLEMENTING FULLY AGILE DEVELOPMENT

Traditional engineering development was based on a steady sequence of steps from concept to implementation. Sometimes engineers wouldn't know a system wasn't working until far into the testing process, forcing them to lose time as they go back to re-engineer it. Today, software uses agile processes in which teams quickly iterate, test, and gather feedback on a product. Big tasks are divided into smaller ones, and teams tend to work in sprints. As the digital content of engineered products grows, companies will increasingly turn to agile methods. The result is much faster product development cycles, with estimates that agile processes will deliver faster results in over 90 percent of projects. Even with this impressive number, it may not be easy to get engineers to give up their traditional development process.

14.2.2 DEVELOP DATA-ENABLED ENGINEERING AND VIRTUAL-ENGINEERING CAPABILITIES

Automotive OEMs are undergoing an essential transformation from experience-based engineering toward data-driven, virtual engineering. This development is strongly integrated and will affect automotive suppliers in the same way. The goal is to improve the product by developing new features (such as SAE Level 4 and Level 5 autonomous-driving capabilities) and increase R&D efficiency [98].

Traditionally, OEMs incorporated engineering capabilities based on the collective experience of their engineers and experts with only limited data on customer behavior and product performance in the field. They made limited use of testing fleets or static hardware-in-the-loop or software-in-the-loop testing environments. OEMs need to adopt data-enabled engineering and virtual-engineering capabilities to understand the value drivers of automotive customers in today's new ecosystem, which includes autonomous driving and data services. Automakers should also increase their engineering efficiency and use their limited R&D resources most efficiently. The adoption of these capabilities will also be pushed toward suppliers.

TWO PRODUCT-RELATED USE CASES ILLUSTRATE POTENTIAL CHANGES IN THIS AREA. The first use case takes advantage of advanced simulation techniques to improve multiphysics simulations via surrogate models or virtual testing with an AI-based driver in the loop.

The second use case involves data-driven development based on a state-of-the-art big-data architecture. This architecture consists of a big-data stack in the backend, broad OTA capabilities, and a protected mode in the vehicle stack for in-vehicle simulations. It's paired with algorithms based on machine learning to intelligently collect data at scale and identify "interesting situations" to propel the development of Level 4 and Level 5 autonomous-driving features or optimize driver-assistance features. It represents a critical enabler and precondition for leaping into Level 4 and Level 5 autonomous driving.

Implementing big-data infrastructure and architecture is an essential requirement for driving data-enabled engineering and virtualization. Elements of these include the data backbone; the backend or big-data stack; in-vehicle architecture; technology such as machine learning algorithms and simulation techniques; and governance, including data governance, legal framework, and consent management processes.

14.3 SEVEN FUNDAMENTAL TRENDS DRIVE THE AUTOMOTIVE INDUSTRY UNTIL 2030

In the third edition of the FAST study, created every five years in collaboration between Oliver Wyman and the German Automotive Association (VDA) was identified seven fundamental trends that drive the automotive industry until 2030, enabled and accelerated by digitization, AI and machine learning. The simultaneous "Mighty Seven Industry Trends" is a perfect storm of transformative technologies and changing customer behavior – which challenge the core business pillars the industry is built on.

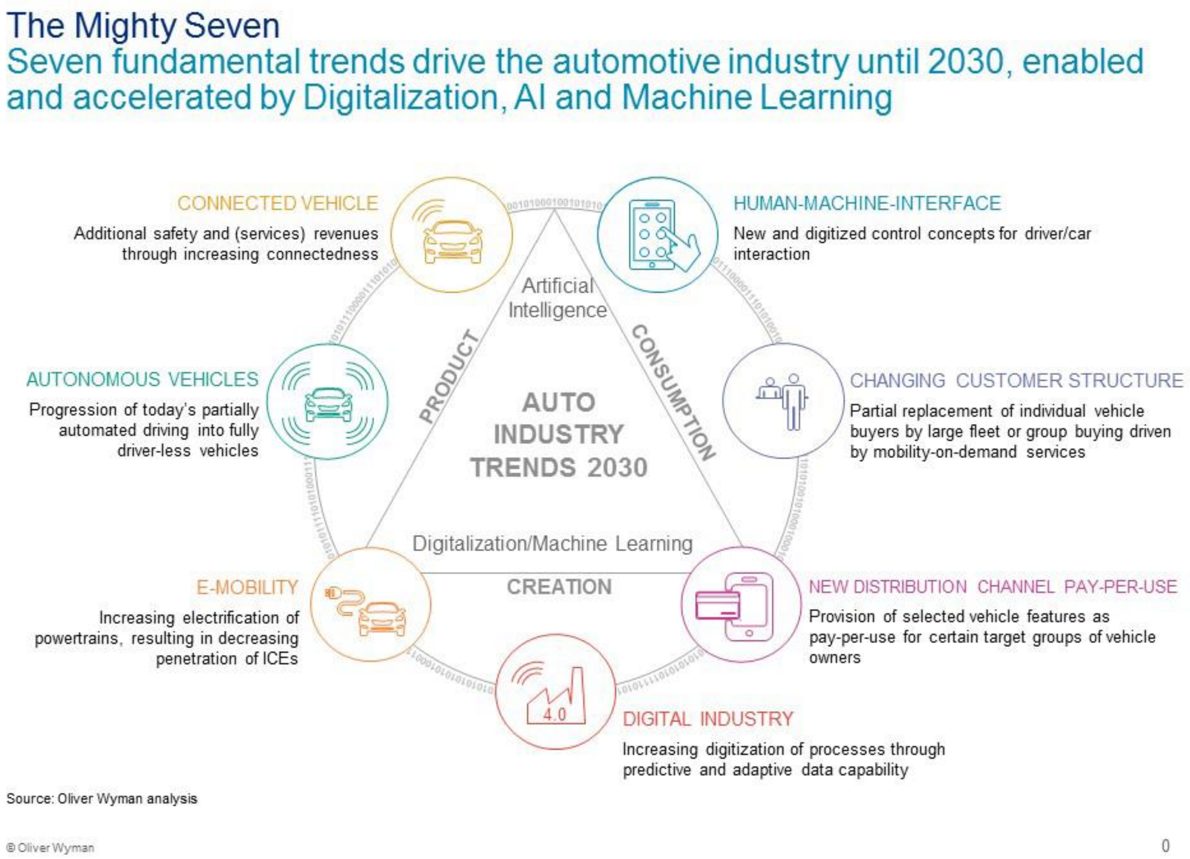
As a consequence, the shape of automotive value creation is expected to simultaneously shift in three dimensions until 2030:

- horizontally between vehicle systems,
- vertically between industry players, and
- regionally.

NINE NEW BUSINESS MODELS EXPECTED TO EMERGE

With shifting value pools across the field of vehicle components, nine new business models for auto suppliers are emerging, creating a need to re-define their role and operating model in order to retain competitive.

In parallel, both suppliers and vehicle manufacturers will have to foster holistic performance improvements to offset the needed investments and absorb other looming externalities.



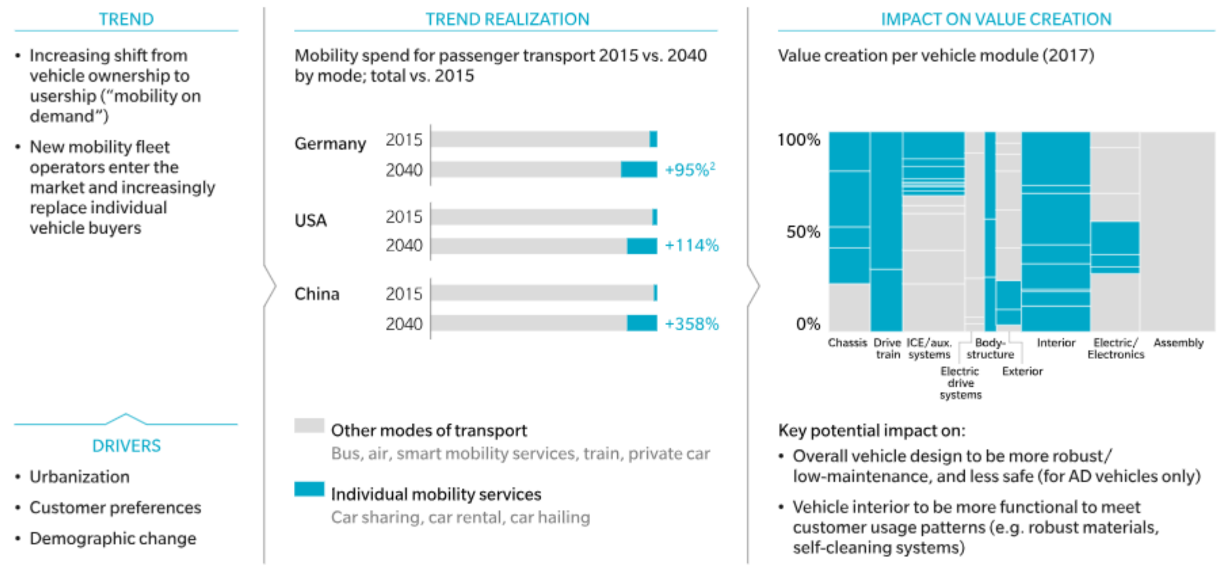
14-1. Figure_ The Mighty Seven: Seven fundamental trends drive

[https://www.businesswire.com/news/home/20180621005944/en/Turbulent-Times-Ahead-for-Global-Automotive-Industry-According-to-New-Oliver-Wyman-Report]

STRATEGIC OPTIONS FOR AUTOMOTIVE SUPPLIERS

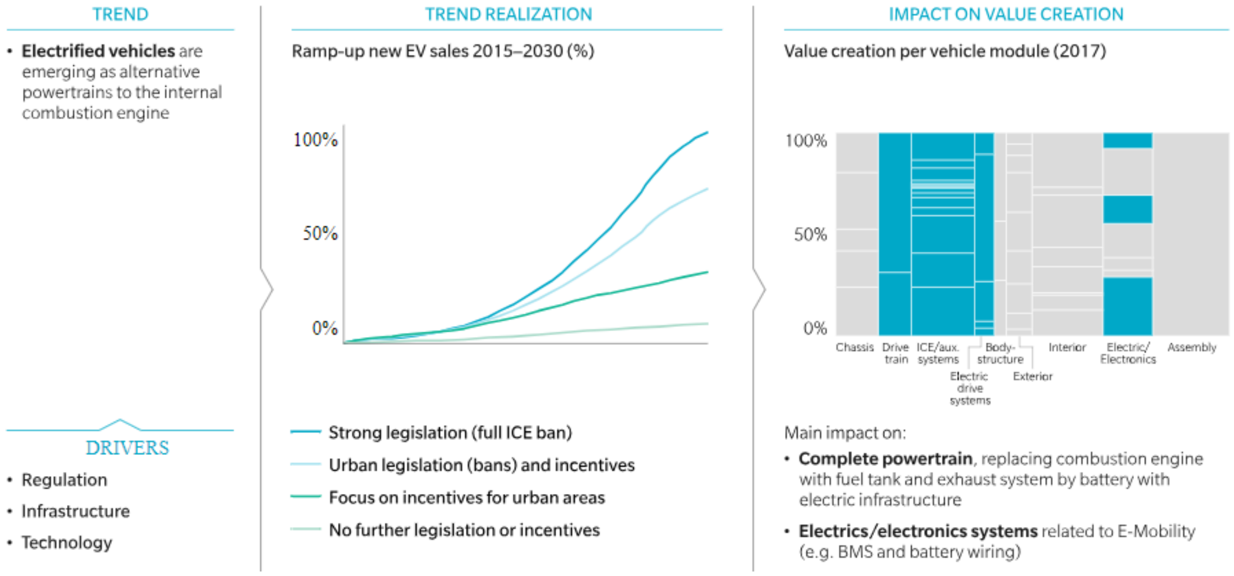
- Cross-functional transformation of business operations
- Business models 2030
- *Digitizer:* Specialists for smart components and smart mechatronic
- *Digital integrators:* Delivering digital modules and systems
- *E-Driver:* Specialists for the E-powertrain
- *Ramp-downer:* Specialists for the winding up of dated technology
- *Tier-0.5-Supplier:* Between OEM and premium supplier
- *Direct sales:* Direct selling specialist in the aftermarket
- *White-Label-contract manufacturer:* Everything except branding
- *Digital service provider:* Supplier of digital, data-based services

- *Hardware-Software-development service provider:* The best out of two worlds



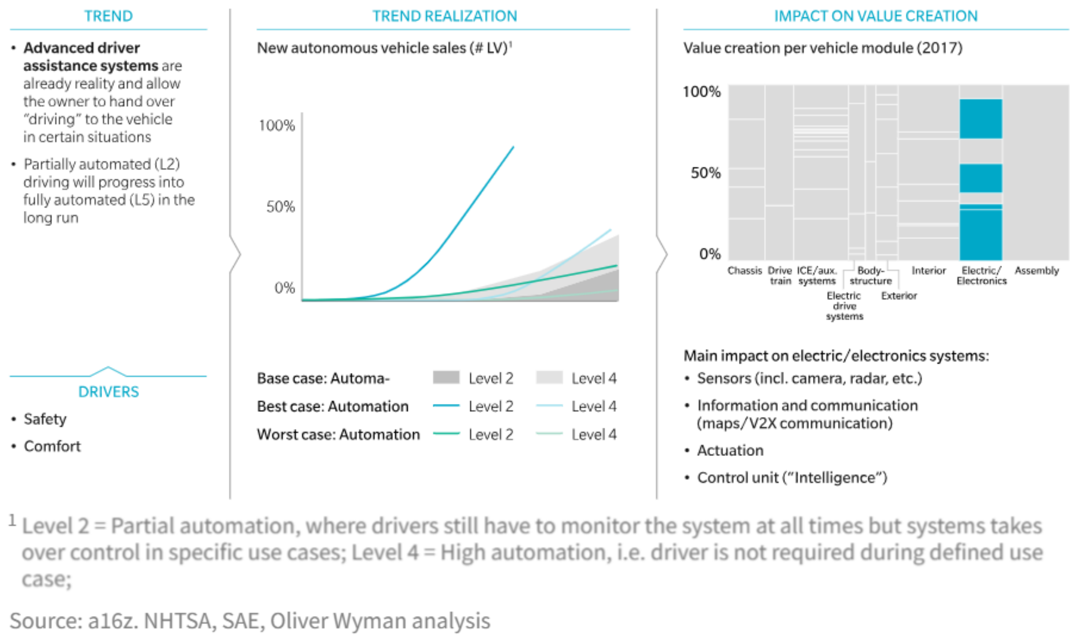
14-2. Figure_ Trend Changing Customer Structure

[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]



14-3. Figure_ Trend E-Mobility

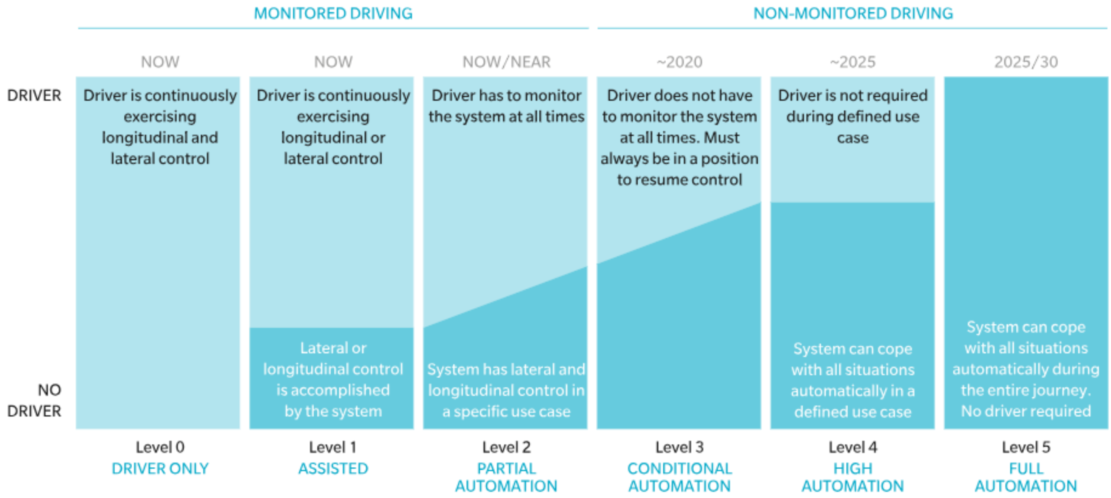
[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]



14-4. Figure_Trend Autonomous Vehicles

[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]

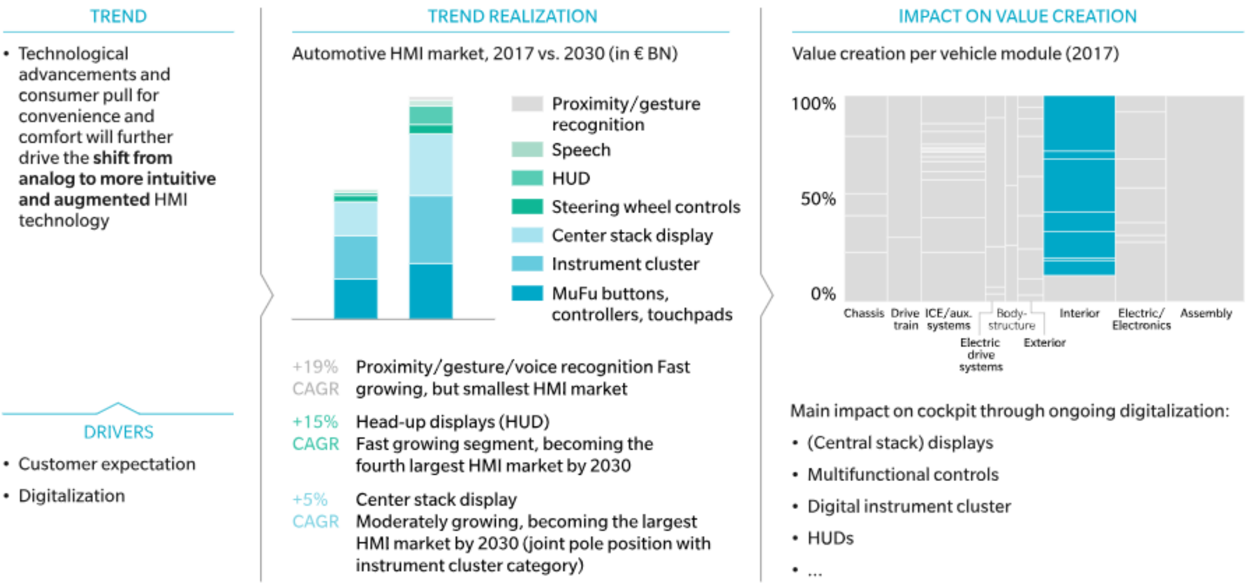
Autonomous driving is still in early stages but is expected to reach full automation levels between 2025 and 2030.



14-5. Figure_ Autonomous Vehicles – The Evolution Has Already Begun

[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]

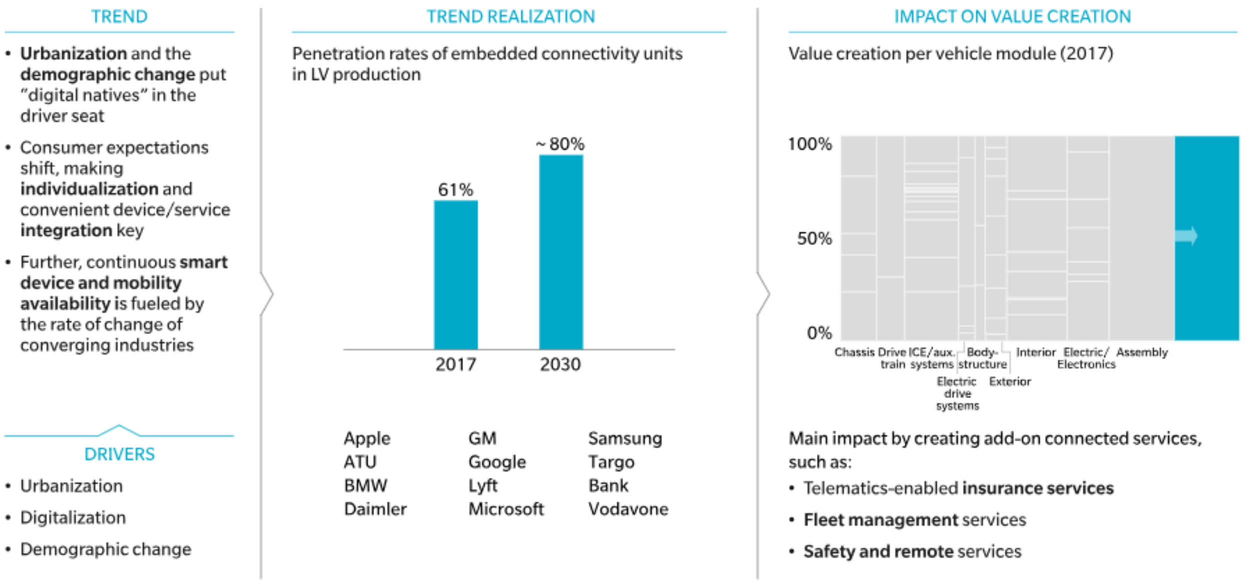
Trend Human-Machine-Interface (HMI)



14-6. Figure_Trend Human-Machine-Interface (HMI)

[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]

Trend Connected Vehicle

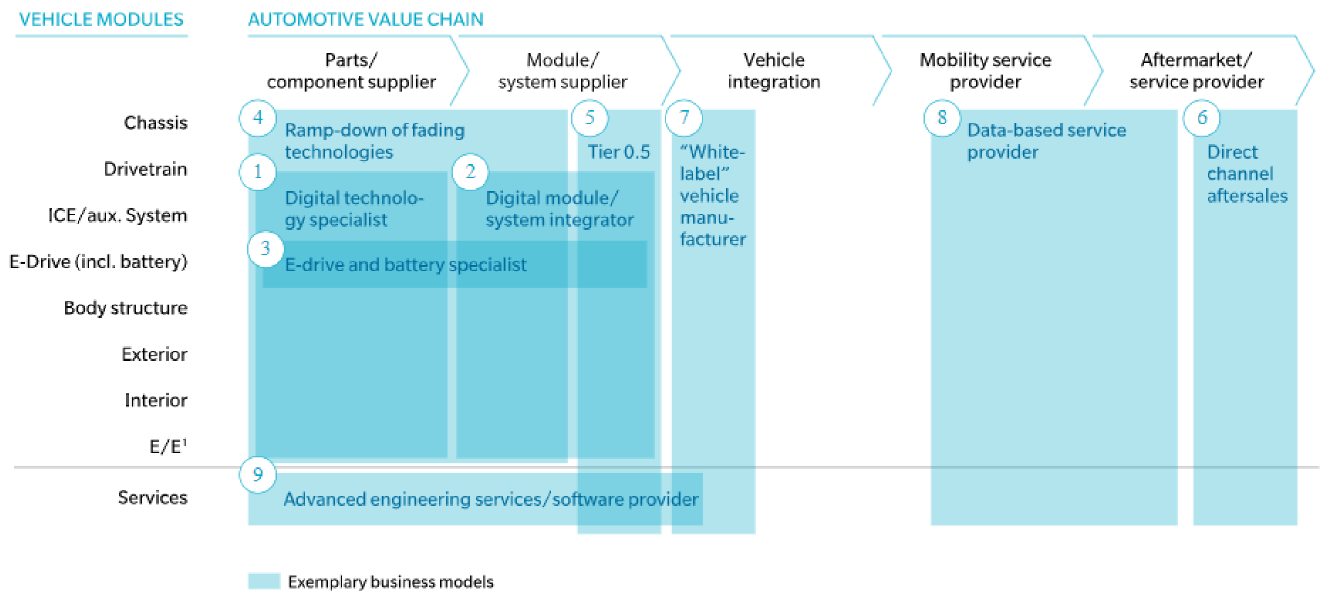


14-7. Figure_Trend Connected Vehicle

[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]

Supplier Business Models 2030

Driven by the current and emerging trends, new supplier business models are being established along the automotive value chain



14-8. Figure_ Supplier Business Models 2030

Driven by the current and emerging trends, new supplier business models are being established along the automotive value chain

[https://www.oliverwyman.com/media-center/2018/june/turbulent-times-ahead-for-global-automotive-industry-according-t.html]

15 SKILLS, KNOWLEDGE, AND COMPETENCIES REQUIRED TO SUPPORT ECO-INNOVATION

Providing eco-innovation implementation services will require people who are Service Providers to have a variety of skills, knowledge and competencies or at least know how to acquire skills, knowledge and competencies when needed [[99]].

The focus is on the skills, competencies and, knowledge that are likely to be new or may require further development for the eco-innovation.

Business management – Two key aspects of business management are essential for eco-innovation: business strategy development (defining strategic goals, creating a long term vision) and business model innovation (the process of defining and testing a scalable, repeatable business model that will help a company to achieve its strategic goals).

Sector-specific knowledge - It is the technical and commercial knowledge of the sectors in which eco-innovation services are offered. Technical knowledge requirements include specialist knowledge of how the product is produced, the processes involved, who is involved in producing the product and the technical threats facing the sector. Business knowledge requirements include specialist knowledge of the main markets for the product, key customers, business strategies and business models commonly used in the sector as well as key business threats facing the sector.

Life cycle thinking – This is a mostly qualitative approach to understand how the choices made influence what happens in the life cycle stages of an industrial activity: from the acquisition of raw materials to manufacturing, distribution, product, use and disposal. This approach is necessary to balance the trade-offs and to have an effective impact on the economy, environment and society (UN Environment, 2004).

Design for Sustainability – Pro-active approach to the integration of environmental, social, and economic sustainability issues into the product development processes, without compromising the traditional requirements for a product, such as quality, cost and performance.

Creative thinking tools – Approaches that help identify opportunities for innovation and new solutions to problems by encouraging people to think about a problem in different ways and from different perspectives.

Innovation management – Provides management guidance that can support the implementation of innovations such as new product development (eg structuring the development process), introducing new ways of working (introducing a sustainable solution) green procurement system and new models of business (eg how to move to a product-service system).

Organizational change management – Organizational change management – guides and supports the implementation of changes in organizations, such as new business processes and structures, as well as new/adapted cultural behavior and social norms.

Marketing – is the set of activities that are designed to help the company understand the type of product it should offer to a market and communicate the benefits and value of the product to the intended consumer. Marketing focuses on product, promotion, price and distribution channels.

Technology transfer – SMEs often lack the resources and capacity to develop new ground-breaking technologies, but can benefit from the adoption and adaptation of technology developed outside the company. A strong network of contacts spanning different sectors, business and research institutes, together with good technical knowledge and appreciation of the local context are required to support this type of activity. Further information on the role of the Service Provider in supporting technology transfer is provided in the publication Technologies for Eco-innovation (UN Environment, 2016).

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Module 9

Ecodesign and Ecoinnovations

Simona ISTRITEANU

Ecoinnovations of products offering environmental benefits

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