GREEN INNOVATION AND CIRCULAR ECONOMY. A CASE STUDY IN THE AUTOMOTIVE SECTOR

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BACHELOR'S DEGREE IN BUSINESS ADMINISTRATION

AE 1049 - UNDERGRADUATE FINAL PROJECT

ACADEMIC YEAR 2022 - 2023

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1 INTRODUCTION

Over the past few years, sustainability has become an increasingly important issue in society. Increasing concern for the environment and climate change have led to the need to adopt measures to reduce the ecological footprint and improve resource efficiency. In this context, green innovation and the circular economy are presented as key solutions to these problems and promote sustainability in the global economy (Cerdá and Khalilova, 2016).

The work here presented will be based on a literature review of studies and reports related to green innovation and circular economy. In addition, data analysis of the automotive sector in Spain during 2022 will be carried out, as a case study where green and circular economy is growing quickly.

Throughout this work, the automotive sector industry in Spain will be analyzed from an economic and environmental point of view, in addition to a case study on the reuse of lithium batteries from electric cars and the techniques to achieve it through the ReCell center.

First, the theoretical framework discusses the concept and benefits of green innovation and the circular economy. By developing the benefits of the models in depth, the ability to provide a solution to the problems generated by the linear model is shown. However, despite the benefits offered by the circular model, it is also important to address the limitations it faces. This leads to the analysis the relationship between both concepts studied during the work.

After this, it is observed that the traditional linear economy model presents irregularities and it is shown that it is outdated in today's society, maintaining a very close relationship with the recent socioeconomic environmental and resource scarcity crises, which makes the solution to this to be the circular economy model explained throughout the work.

This is followed by an analysis of the situation in Spain and how it influences both its economy and environmental situation and the success stories of implementing green innovation and circular economy in companies.

In addition, the automotive sector in Spain is analyzed with data obtained from the last year, i.e., 2022. This is followed by explaining how the models described in the theoretical framework are implemented in the automotive industry. This is of great interest since this sector requires many natural resources for production and is in

constant change. The latter is encouraged by the emergence of policies aimed at reducing greenhouse gases, CO2 emissions and waste generation.

Subsequently, the usual techniques for recycling lithium batteries are analysed, as well as the research of the company ReCell, which focuses on the growth of a sustainably advanced battery recycling industry through an economical and environmentally sound recycling process that can be adopted by the industry for lithium-ion and future batteries. Some of the techniques currently employed include pyrometallurgical and hydrometallurgical processes. But there are also ongoing developments in direct recycling techniques.

Furthermore, the future European plans for the manufacture of batteries for electric cars are presented, as well as the four projects underway in Spain to produce these batteries. Finally, conclusions are drawn and the author's opinion on the most important concepts addressed in the work is highlighted, as well as a reflection on the economic future.

1.1 Objectives

The main objective of this work is to shed some light on the importance of the circular economy model and green innovation. Additionally, we intend to show the importance of this model in the case study of the automotive sector, analyzing how it affects companies and their consumers. To this end, the automotive sector will be analyzed to present techniques and projects that provide solutions to the current problems faced by the industry.

In addition, the following secondary objectives will be addressed:

- To recognize the main benefits and limitations to which the companies that use the mentioned models are exposed.
- To identify the relationship between both concepts, green innovation, and circular economy.
- To analyze the Spanish automotive sector and how these models are being implemented.
- To study techniques and projects capable of reusing lithium batteries in electric cars.

To achieve the objectives and move towards a circular economy and green innovation model, it is necessary, in addition to carrying out important structural changes at the production level, to offer consumers accurate and precise information on the real impact on the environment and health of the goods and services they consume (García, 2022).

1.2 Justification of the topic

I have decided to do my final thesis on green innovation and the circular economy in the automotive sector because of my deep interest in environmental sustainability and the impact that the automotive industry has on the environment. This topic has motivated and captivated me for several reasons.

First, I believe that green innovation and the circular economy are key to addressing the environmental challenges we face today. The automotive sector is known for its high environmental footprint, and the adoption of more sustainable practices and technologies is essential to reduce greenhouse gas emissions, improve air quality and preserve natural resources.

In addition, the topic of the circular economy in the automotive sector has been particularly interesting to me because it goes beyond simply reducing negative impacts. It is about rethinking and redesigning the entire value chain of vehicles, from their manufacture to their final disposal, with the aim of closing material cycles and minimizing waste. This perspective has led me to understand the importance of circularity in the economy and how it can generate both environmental and economic benefits.

1.3 Motivation of green innovation and the circular economy

Green innovation and the circular economy are motivated by several key factors and objectives such as environmental sustainability, scarcity of natural resources, changes in consumer demand and expectations, economic and competitive benefits, social responsibility, and corporate reputation (Bocken et al, 2014).

In summary, the motivation behind green innovation and the circular economy lies in the need to address environmental challenges, optimize resource use, respond to market demands, and promote more sustainable and responsible economic growth. These approaches offer long-term environmental, economic, and social benefits, generating a positive impact on the environment and society (Bocken et al, 2014).

2 THEORETICAL FRAMEWORK

2.1 Green Innovation

2.1.1 Concept and benefits

Green innovation arises as a proposal to address any form of integration between products, processes, technologies, management decisions and the development of distinctive capabilities of organizations to issues involving society and the environment. This concept is related to three other concepts of its terminologies, which are: Sustainable innovation, environmental innovation, and eco-innovation. The term we are going to study, in turn, is intrinsically related to the environmental dimension of sustainability (Romani-Dias et al., 2018).

This is a key factor in maintaining environmental management, as in recent years it has become a major threat to human survival. Today, many organizations are turning to green innovation as a strategy to achieve environmental protection and economic growth. It has also become a strategic tool for companies as they use it to increase their market share and sustain themselves in the long term. When green innovation is successful, it enables companies to improve their market position, attract potential customers, offer environmentally friendly services, and thus gain competitive advantages. Because it can bring all these benefits, green innovation is on the agenda of many managers of organizations and researchers; green innovation helps to meet the demands generated by customers for the protection of the environment in which they are located and contributes to the creation of new production and technologies with the aim of reducing environmental risks (Takalo & Tooranloo, 2021).

One way of encouraging innovation is based on financing various projects through governmental, corporate, or private sector policies. In this way, it is essential to create an innovation department to develop future projects in the public and private spheres. But today, producing innovation without considering the environment is counterproductive from various points of view. In this context, disseminating the benefits of highly sustainable innovation projects has become imperative. Besides, it is also important to promote public awareness that vital resources are limited and will soon run out. The Earth is the most precious thing that humans have, and it must be taken care of. Therefore, it is time to be extremely careful and creative and implement projects to ensure sustainable economic growth and development while protecting the environment. At present, the most developed countries in the world are betting on innovative policies that allow them to emerge as strong and capable countries in the face of increasingly

existing international markets. But they do so with a focus on the world's citizens, which primarily tests their ability to protect and improve the health of the environment (Lin et al, 2014).

Regarding the definition of **green innovation**, Aponte Figueroa (2021) suggests us that it is associated with the product of research and development, or initiatives aimed at sustainable and environmentally friendly solutions. Green innovation has had a great development in recent years, especially from the last ten years, particularly due to the need for organizations and countries to meet the Sustainable Development Goals, agreed in 2015 by the Member States of the United Nations (UN, 2021).

Therefore, nowadays, it is increasingly important for countries to determine indicators that standardize and monitor the efforts they make in the environmental area, with the purpose of achieving the planned objectives.

Przychodzen et al (2020) also defines green innovation as an invention that seeks to make the environment cleaner and safer.

Going green seems unimportant and is seen as an additional effort or a higher cost activity that no company or organization wants to take on; but in truth it is a good business opportunity and a great competitive advantage if done correctly.

Some of the benefits of going green can be (Przychodzen et al, 2020):

- Cost reduction, since green innovation reduces the use of natural resources, and thus costs.
- Customer attraction, because going green can help reduce environmental impact and thus attract the consumption of green brands, which would be accompanied by good marketing.
- Government incentives, in several countries, governments provide incentives in the form of tax initiatives to go green.

2.2 Circular economy

2.2.1 Concept and benefits

As for the **circular economy**, as described by the European Parliament (2022), it is defined as "a production and consumption model that involves sharing, renting, reusing, repairing, restoring and recycling existing materials and products as much as possible to create added value". In this way, the product life cycle is extended. In practice, this means minimizing waste. In other words, at the end of its useful life, a product retains its

available materials as economically as possible through recycling. These materials can then be used again for another product, thus creating additional value.

This contrasts with the traditional economic model based on the "use and throw away" concept. This concept comes from the so-called linear economy, which is based on acquiring, using, and then disposing of products completely, without the possibility of reusing all or part of the waste to make new products. It is only guided by economic profit and is a fast consumption model (Nygaard, 2022).

In contrast, the circular economy aims at the three R's: reduce, recycle, and reuse, in addition to the importance it gives to sustainability, also considering the economic benefit. The difference with the linear economy is that the circular economy tries to reduce waste as much as possible and seeks to remain in the production cycle for as long as possible (Figure 1).

Figure 1. Circular economy VS Linear economy.

Source: Own elaboration based on https://www.raeeandalucia.es/actualidad/economia-circular-vs-economia-lineal

In short, the main difference between the two models is that the circular economy does not eliminate the final product or turn it into waste but uses it as a resource for a new life cycle.

Figure 2. The three Rs of the ecology.

Source: https://www.olympiadgenius.com/study-material/grade-5-Science-3-Rs/?_id=488

Driving the circular economy means driving the three Rs, which correspond to reduce, recycle, and reuse. In Figure 2 we observe some brief descriptions on what the three "Rs" mean, and for further details we can see the work by Falappa et al (Falappa et al. 2019):

Regarding **reduce**, it refers to the reduction or reduction of direct products, which are those that are purchased and consumed. An example is the purchase of small bottles of water, in which, instead of buying three small bottles, a large bottle is purchased, which would be equivalent to the same amount, but with less packaging. Another prominent example is plastic bags in supermarkets, where a small amount is currently paid for each bag to encourage people to reuse them or bring them from home.

With the reduction of consumption, the impact on the environment is reduced, so this "R" is totally linked to awareness and education and can be done at two levels: energy consumption or goods.

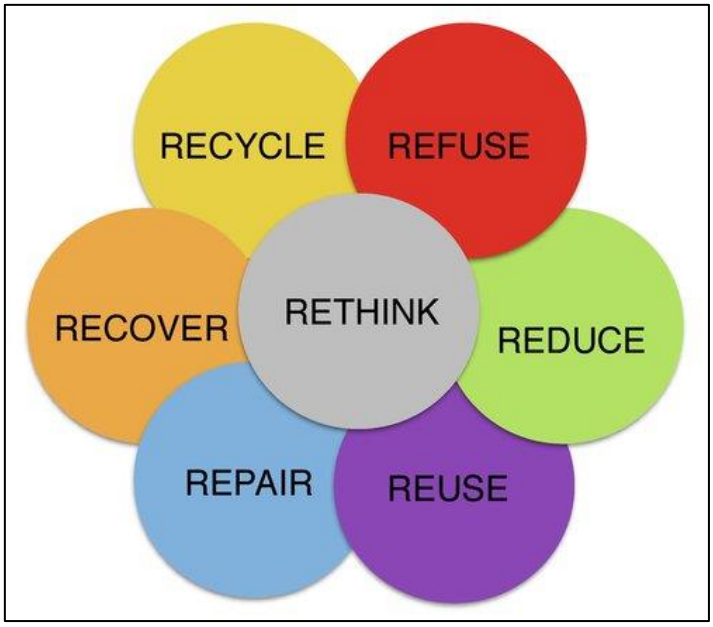
The second "R" is **recycling**, which involves taking advantage of the materials found in the waste generated. Recycling reduces the use of new materials and the production of new waste. Some of the materials that can be recycled and that we use daily are paper, plastic, glass, etc.

We also note that in the last "R", **reuse**, as the word itself says, the parts of the waste that can still be used to make new products and thus be reused. This word in fact means to be able to reuse things, giving them a second chance, thus reducing the amount of

waste, and reducing the impact on the environment. An example could be the reuse of one side of paper in the printer or the donation of clothes that you no longer use.

Some of the benefits provided by the three Rs are (Ramirez and Buitrago, 2022), the increase in soil quality, the reduction of both solid waste and greenhouse gas emissions and thus a better air quality, thus helping to stabilize the climate. In addition to economic benefits through the sale of solid waste to companies that recycle it.

Figure 3. The Rs.



Source: https://alimentaryinitiatives.com/blog/2018/10/21/remember-the-3rs-well-now-there-are-seven-know-them

But the 3Rs rule has been a very basic concept of sustainability at a global level for several years and has not proved to be effective enough for the sustainability problem be part of the Earth. This leads to the possibility of expanding the vision of the 3 Rs to the 7 R's, which form a more comprehensive initiative and complete the cycle with points that were not previously considered in the 3 Rs model. The 7 Rs (Figure 3) stand for redesign, reduce, reuse, repair, renew, recover, and recycle with the objective of extending the life of the product (Di Vaio et al, 2023).

The three Rs: reduce, recycle, and reuse, have been explained at length previously, and the remaining four are explained below (Moreno Inocencio, 2022):

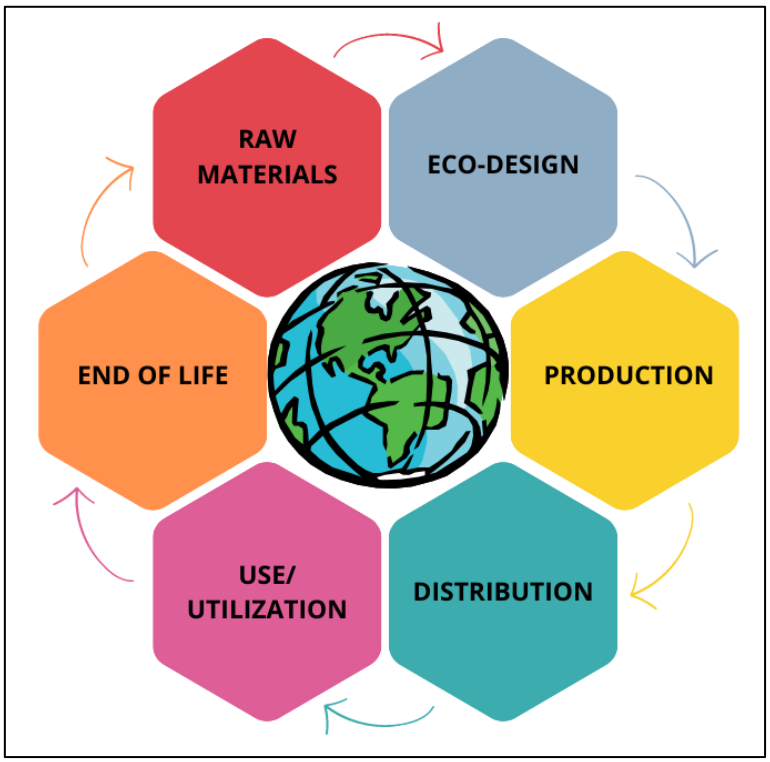
As for **redesign**, it is a concept that refers to the introduction of ecology in the world of design. Which implies designing or manufacturing products considering the possible environmental consequences.

We consider **repairing** to be fixing something damaged before throwing it away or buying a new one. Today's population tends to throw away broken products immediately without worrying about whether they can be repaired and reused, but the option of repairing is cheaper and saves raw materials and energy, as well as helping to reduce waste.

Renovate is like the previous case, we all have old products that we do not use in our homes, so it would be very useful to try to update these products to give them a new function and can be useful.

Finally, **recover** materials that have already been used to reintroduce them as raw material in the production process, and thus create new products.

Figure 4. Cycle and stages of the circular economy.



Source: Own elaboration based on http://www.symbiex.es/fases-de-la-economia-circular/

The main stages of the circular economy are shown in Figure 4, which are also described in (Cerdá and Khalilova, 2016):

1. **Raw materials**: the increased use of different raw materials such as fuel, metals, fossil, or other materials lead to the overexploitation of material resources. Therefore, for a more circular production, we will opt for strategies such as eliminating toxic compounds, using renewable energies and an efficient use of them, using raw materials that are already recycled and/or can be recycled, etc.
2. **Eco-design**: This is based on incorporating criteria for evaluating the environmental impact of products during their life cycle and during the design phase, thus achieving improved efficiency in the consumption of resources during the production process.
3. **Production:** This stage has the capacity to offer many possibilities for a company to become sustainable. The vital objective in production is to reduce energy consumption or use cleaner energies, optimize the use of materials used and reduce waste production. All these objectives will be achieved through alternative production techniques or reduction of production steps.
4. **Distribution**: Making transportation from where it is produced to the end user as efficient as possible by obtaining recyclable or reusable packaging, more efficient transportation, and logistics.
5. **Use/Utilization**: Making a product sustainable at this stage requires avoiding wasteful consumption of energy and/or consumables, as well as attempting easy maintenance or repair so that its useful life lasts as long as possible.
6. **End of life**: When the useful life of the product is over, to make it sustainable we must try to reuse its components so that they can go through the whole production process again.

There are several reasons why there is a need to switch to a circular economy, and these are the increasing demand for raw materials and the scarcity of resources. As several critical raw materials are in short supply, and as the world's population grows, so does demand. Dependence on other countries, as several EU countries are currently dependent on others for their raw materials. And the significant impact of climate.

In its conclusions on the circular economy, the European Parliament (2022) states that a shift to the circular economy could lead to improved innovation, boost competitiveness, less pressure on the environment, and higher economic and employment growth.

Some of the benefits that the circular economy can produce according to del Pozo (2021) are:

- The decrease towards dependence on raw materials, since the constant and growing demand for some of them makes them tend to disappear. Therefore, the circular economy decreases the use of raw materials.
- Environmental protection. The circular economy generates less waste and less pollution.
- Saving money for consumers.
- Employment promotion. The International Labor Organization (2018) published an article stating that the circular economy can create up to 6 million jobs. It is true that some jobs in more linear companies would be lost, but new positions related to recycling, repair and rental or new opportunities to companies that are dedicated to reuse materials that are discarded would emerge.

2.2.2 Limitations

Although we have observed the benefits that the circular economy can achieve, there are also limitations why this model cannot be immediately implemented to companies. The three main barriers that slow down the implementation of this model are (del Pozo, 2021):

- At the **political and regulatory level**. There is not enough support for the implementation of circular economy models. According to a report prepared by the European Environment Agency (2020), regulation is used by countries especially for recycling, energy recovery and waste management. But as for eco-design, consumption, and reuse, these have less stringent policies and do not go beyond advertising and information campaigns. A stronger amortization of the different standards that currently exist is needed for the change to take place properly.
- At the **cultural level**. One of the major limitations are the consumers, since, as we have said before, they are used to the traditional "use and throw away" model and it is difficult to change this habit.
- At the **technological level**. The scarcity of the appropriate technological means to develop a circular economy is very noticeable. According to the aforementioned report by the European Environment Agency, a large investment is required to monitor the progress of the circular economy and to obtain relevant data at the different stages of a product. In other words, both technological elements and skills are needed to get the job done.

All the limitations observed above arise from the authorities, who are the ones who must consider a model of economy that provides benefits. To do so, they must work on effective policies, raise awareness among the population and invest in them.

2.3 Relationship between green innovation and circular economy

The relationship between green innovation and the circular economy is very close, as both are focused on creating a sustainable and more environmentally friendly future. Green innovation is essential to achieve the circular economy, as it enables the development of innovative technologies and practices that reduce the environmental impact of human activities and promote the sustainable use of natural resources. It is also considered an important tool for achieving a circular economy, as it can provide technological and practical solutions to close product and resource cycles. Green innovation also helps the circular economy achieve the highest possible efficiency in the use of natural resources. For example, green innovation can enable the creation of more efficient production processes and the use of renewable energy sources, which reduces the carbon footprint of the circular economy (Smol et al, 2017).

In short, green innovation and the circular economy are mutually reinforcing, and together they can create a sustainable and more environmentally friendly future. Green innovation provides technological and practical solutions to close product and resource cycles, while the circular economy creates the framework necessary for these solutions to be effectively implemented (Smol et al, 2017).

2.4 Green Innovation and Circular Economy in Spain

Spain is considered one of the leading European economies and its commitment to green innovation and the circular economy are key to the development of a successful EU policy.

According to Cuesta (2022), thanks to renewable energies, Spain is in the lead in terms of green technological innovation, with an overall share several times higher than 5%. Spain, together with the EU, seeks to be carbon neutral by 2050, and for this purpose medium and long-term strategic plans have been initiated.

Focusing on Spain, a medium-term plan is the National Integrated Energy and Climate Plan 2021-2030. And the European Commission's assessment of this plan has so far been highly positive. We are considered to have the second highest level of wind power capacity penetration behind Germany, with competitive solar photovoltaic energy and a developed gas transmission infrastructure.

The Spanish target is to reach 42% renewable energy by 2030, achieving 24% in the electricity sector, according to CSIC researchers. Although there are still many challenges to be met, according to a report prepared by the World Economic Forum, Spain would rank 17th out of 150 countries in terms of ecological transition.

Furthermore, according to the European Commission, the European Union is proposing the European Green Pact to overcome the challenges of climate change and environmental degradation. Thus, with this pact, the EU will be transformed into a modern, competitive, and resource-efficient economy. The EU also wants to become climate neutral by 2050. A European Climate Act has therefore been proposed through which this political commitment would become a legal obligation, including a target to reduce emissions by at least 55% by 2030 as a starting point.

Regarding the European Green Pact in Spain, the highest priority objective is the development of renewable energies for 54% of Spaniards according to the Euro barometer EB14 2021. As a second objective we would position the fight against single-use plastics and their waste, continuing to provide fair remuneration to EU farmers who produce safe and affordable food.

In our country, green jobs currently account for 2.4% of Spanish GDP, that is, around 500,000 green jobs. Among the green sectors with the greatest potential are, among others, the large-scale development of renewable energies, as well as the development of the circular economy and waste management, the rehabilitation of buildings, investment in sustainable mobility, and solutions for the adaptation and resilience of territories to climate change.

Linked to the circular economy, Spain has a **sustainability problem**, and the answer to this would be the Spain Circular 2030 strategy, approved by the Council of Ministers, which lays the foundations for the promotion of a new production and consumption model, in which the value of materials, resources and products is maintained in the economy for as long as possible, and in which the waste generated is reduced as much as possible and the few that are unavoidable are used. In this way, the strategy helps Spain to achieve a sustainable, efficient, and decarbonized economy.

This strategy, with a long-term vision, will be achieved with different circular economy action plans of the European Union, which are: "Closing the loop: an EU action plan for the circular economy" of 2015 and "A new circular economy action plan for a cleaner and more competitive Europe" of 2020, in addition to the European Green Pact and the 2030 Agenda for sustainable development.

Therefore, the objectives to be achieved by this strategy for the year 2030 are:

- First, to reduce by 30% the national consumption of materials in relation to GDP, with reference year 2010. Followed by the reduction of waste generation by 15% with respect to that generated in 2010.
- They also aim to reduce food waste generation by 50% per capita at the household and retail consumption level and by 20% in the production and supply chains as of 2020.
- Another objective is to increase reuse by up to 10%, together with a 10% improvement in water efficiency.
- Finally, all this will make it possible to reduce greenhouse gas emissions by less than 10 million tons of CO2 equivalent.

Based on the COTEC report (Jiménez et al., 2021), several authors provide data on the state of Spain, which is far from circular. The latest data for 2019 present that only 10% of the total material requirements were covered by recovered material. This figure is close to the average circular use of materials recorded by the EU-27 (11.8%) but is below other countries such as France (20%) or the Netherlands (30%).

The recycling rate in Spain in 2021 was 35%, which fell far short of the 50% target proposed by the European Commission for 2020. This percentage placed the country below the EU-27 average (48%) and far from the 2025 target of recycling 55% of municipal waste generated.

Finally, in terms of waste treatment in Spain, in 2019 the waste in landfill deposits was 54%, a percentage also far from the target proposed by the European Union of not exceeding 10%.

Currently, the situation of the Spanish circular economy requires an urgent transformation in favor of measures aimed at durability, reparability, product recycling, eco-innovation, advances in eco-design and that the citizenry is more sensitive. Therefore, the Circular Economy 2030 strategy is a key element of the Circular Economy Framework, as it is one of the projects for economic recovery after the COVID-19 health crisis. It also contributes to Spain's efforts to achieve a sustainable, clean, and efficient economy. Achieving this challenge not only requires the involvement of the Public Administrations, but also of the whole society and all economic sectors.

In conclusion, Spain Circular 2030 is defined as a document that will allow our country to move towards a circular economy through the implementation of various action plans. This will allow that, as the different actions are implemented, their effects will also be

evaluated and, if necessary, the appropriate adjustments will be made to achieve the objectives set out in both the action plans and the 2030 strategy.

2.5 Success cases in Green Innovation and Circular Economy

According to El Confidencial (2021), the third BASF 2021 awards recognize the companies that have best integrated the circular economy in their processes. These awards recognize those projects or research that, based on the circular economy, contribute, or have the potential to contribute substantially to the development of the country's business competitiveness, especially those projects that contain the perspective of environmental and social sustainability in their development and objective.

The award winners are classified by category, and they are shown below:

Public Administration: Ministry of Technology and Demographic Challenge.

The ministry developed the "Catalog of good practices in circular economy", which the jury considered to be an important tool for raising awareness and disseminating the principles of circularity in the productive sector. This allows to promote sectoral and intersectoral connection through success stories that can be transferred and scalable between companies and sectors, which would lead to a circular growth of the economy. It is a meeting forum for the productive sector that allows the creation of a network that strengthens value chains and systems by providing links between suppliers and customers who share the same circular economy criteria with which they work.

Large company: Calvo Group.

It was awarded the prize for the Calvo Zero Waste project, which was born in 2017 and had as its main objective the valorization of 100% of the waste generated in all offices and factories of Calvo Group. Once it was put into operation, it had the valorization of around 100,000 tons of waste, going from valorizing 57.7% in 2018 to 91.11% in 2020. In addition to the main objective, it also has other objectives such as the reduction and elimination of single-use plastics, that at least 95% of the packaging placed on the market is recyclable and that 85% of the materials have a recycled or certified sustainable origin.

SME: Too Good to Go.

It is an app that focuses on food waste in the world, with the goal of becoming a planet where food is not wasted, a problem that is not only economic and social, but also environmental.

It arrived in Spain in 2018 with the slogan #LaComidaNoSeTira and connected the population with thousands of producers, supermarkets and other types of food businesses that put their excess food on sale at a low price so that it is not wasted.

Startup: Gravity Wave.

A social and environmental startup founded in 2019 by two siblings, Amaia and Julen Rodríguez, in which the goal was to make the seas clean of plastics. That is, to prevent waste from ending up in the sea and give them a useful life by transforming them into new products and thus avoiding the demand for plastic.

Dissemination: Marynes Rojas - 'podcast' Circular Design.

It was the first podcast in Spanish about circular economy and design. The goal is that these concepts reach the largest number of people to stop being so scientific, technical, and abstract definitions and become something close and enjoyable for the population to see that we can all be part of improving the environment through the circular economy.

Academic world: Tecnum Navarra.

This is a group formed by students from different grades and courses of an engineering school of the University of Navarra, with the aim of achieving a more sustainable campus. The idea is to carry out different projects throughout the course autonomously, focusing on reducing the environmental footprint of the campus.

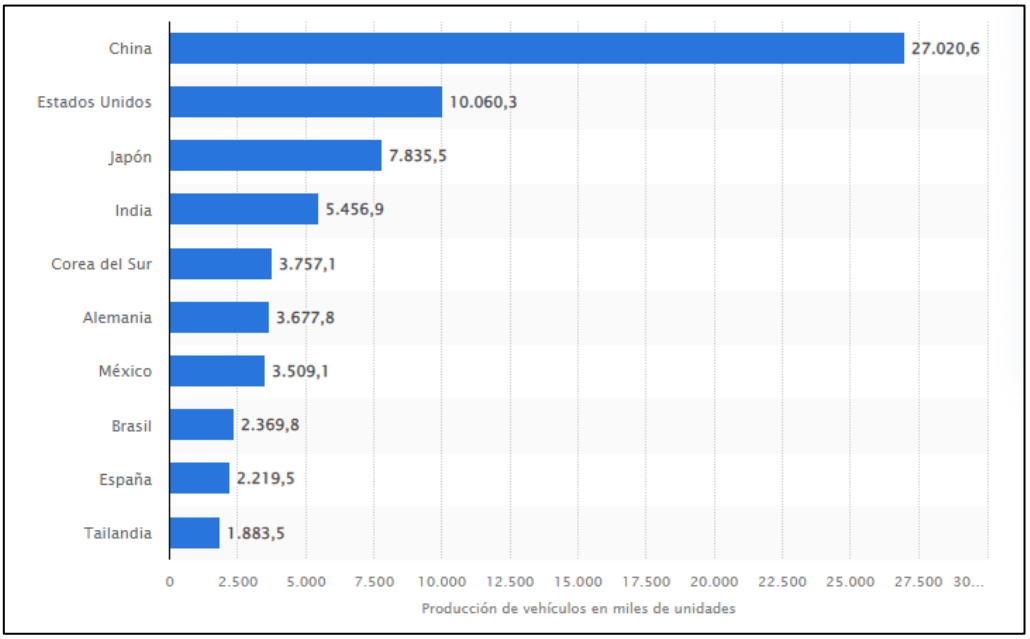
3 CASE STUDY

3.1 Analysis of the automotive sector

The automotive sector is one of the world's most important drivers of growth, thanks to the fact that it facilitates people's mobility in an efficient, safe, and affordable way, its social contribution, etc. It is considered an engine of innovation, a generator of quality employment and fundamental in international trade. In the case of Spain, thanks to the great production capacity and productivity it generates, it has become a mainstay of our industry and a worldwide reference. After the pandemic, the resulting economic crisis had a negative impact on the sector, as it was during a technological transformation

towards electrification. We will focus our study of the sector based on data and information from the last year, i.e., 2022, in which Spain ranked ninth in terms of the main vehicle producing countries, as it was also reported in 2021 (Garriga, J. M., 2021).

Figure 5. Global ranking of the top 10 automotive producing countries by number of vehicles produced in 2022 (in thousands).



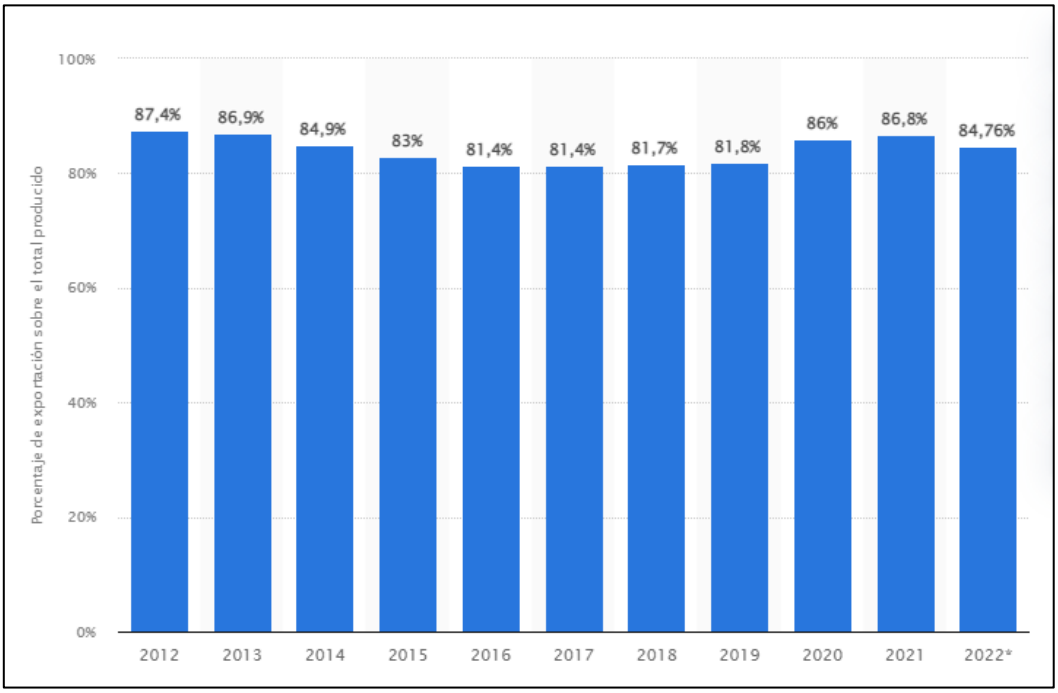
Source: *https://es.statista.com/estadisticas/611251/principales-productores-automovilisticos-del-mundo-por-vehiculos-fabricados/#statisticContainer*

As can be seen in figure 5, Spain ranked ninth with a production of approximately 2.2 million vehicles last year. Ahead of the Spanish industry were countries such as Brazil, Mexico, Germany, South Korea, India, Japan, the United States and China. And the difference with the latter was almost 25 million vehicles.

Spanish automotive production plants are positioned among the most efficient and automated in Europe, having 1,000 industrial robots for every 10,000 employees (ICEX Spain Data, 2019). In addition to the auxiliary industry, i.e., machinery, materials, components, etc. that contributes more than 75% of the value of the vehicle and it is considered very innovative, competitive and appreciated internationally. All this makes Spain to be considered as one of the most competitive in Europe in the automotive industry.

It is considered an export sector, since more than 80% of the vehicles manufactured in Spain are delivered abroad, reaching more than a hundred countries. Athough around 80% of these sales are destined to the EU, mainly finished vehicles, while components are sold to a greater extent to non-EU destinations (Garriga, J. M., 2021).

Figure 6. Annual evolution of the percentage of the Spanish vehicle manufacturing industry's total production that was exported between 2012 and 2022.

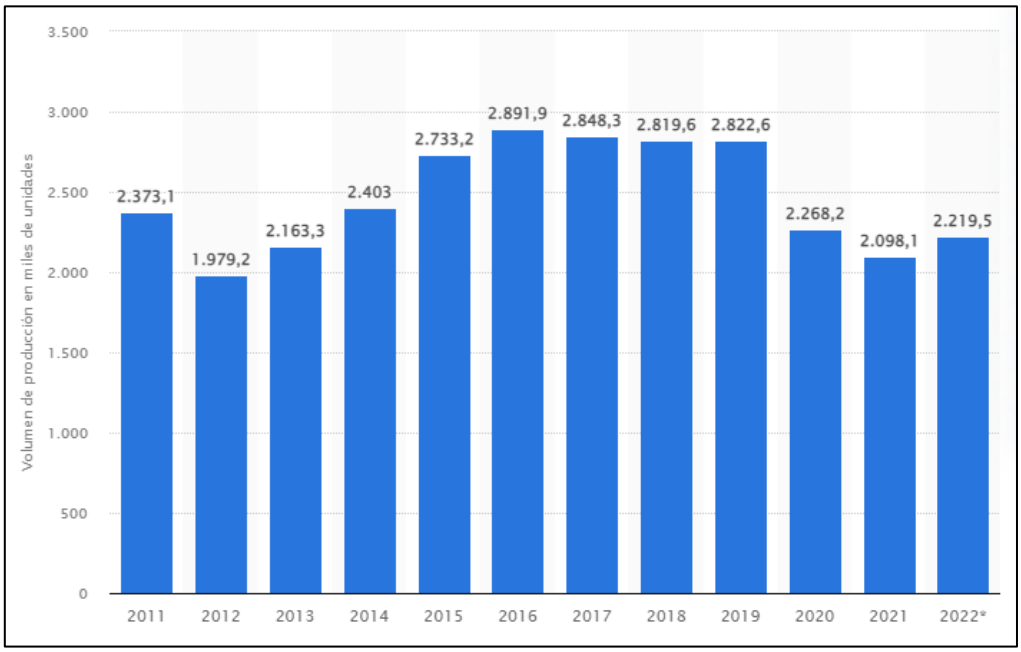


Source: https://es.statista.com/estadisticas/728544/porcentaje-de-exportacion-del-sector-de-automocion-sobre-produccion-total-espana/

As we can see in figure 6, it presents the annual evolution in percentage of the total production of vehicles in Spain that were exported between 2012 and 2022. These data support what it was said before, that is, more than 80% of the vehicles manufactured in Spain were exported in 2022, specifically 84.76%. Slightly less than in 2020 and 2021.

As for the sale of vehicles in Spain, only one out of four of the vehicles sold are manufactured in the country, the rest are imported from other European countries such as Germany, France, United Kingdom, Japan, or Korea. With all this into consideration, we can say that the trade balance of the sector is favorable to the Spanish economy (Garriga, J. M., 2021).

Figure 7. Number of vehicles produced in Spain from 2011 to 2022.



Source: https://es.statista.com/estadisticas/724444/produccion-anual-de-sector-de-la-automocion-espana/

According to data presented in figure 7, we observe that the halt in automobile production due to the COVID-19 pandemic negatively affected Spanish annual results, reducing automobile production to 2.27 million in 2020, half a million units less compared to the previous year. But in 2021 it declined even further due to a lack of components crisis, which caused production to slow down, making it even more difficult to increase output. In 2022 a different situation came up, and the annual production increased by 6% with a total of 2.2 million vehicles produced, which represented that the sector was starting to come out of the bad figures and the standstill produced by the pandemic.

But during the months that factories were closed, reduced production and sales caused employment to plummet. Companies were forced to resort to ERTE (*Expediente de Regulación Temporal del Empleo*), an instrument that cushioned the destruction of employment. Since then, there has been a gradual return of workers to their jobs. In addition to the negative impact on employment, the sector also suffered an intense loss of business network, which affected the automotive sector more than average (Garriga, J. M., 2021).

In 2022, this sector had 16 vehicle manufacturing plants of the main automotive brands in the world. These manufacturing plants are distributed among several autonomous communities such as those shown in the following illustration (figure 8), so that the sector is well established in the industrial network throughout the territory (Amaya, Á. P., n. d.).

Figure 8. Number of vehicle manufacturing plants in Spain in 2022.

Source: https://www.autonocion.com/fabricas-de-coches-en-espana/

Spain is considered a benchmark in the production and export of both vehicles and components for the automotive industry. As we said before, it ranked ninth globally. Around 3 million vehicles are manufactured annually, except for the year of the pandemic. The components sector must also be added to this echonomical impact. For all these reasons, the automotive sector is the second most important in Spain, behind only tourism. In 2022, Spain was at around 80% of its production capacity, a figure above the world average. Therefore, if it were at full capacity, production could reach 3.5 million vehicles per year (Amaya, Á. P., n. d.).

Table 1 shows a comparative list of the main vehicle factories in Spain.

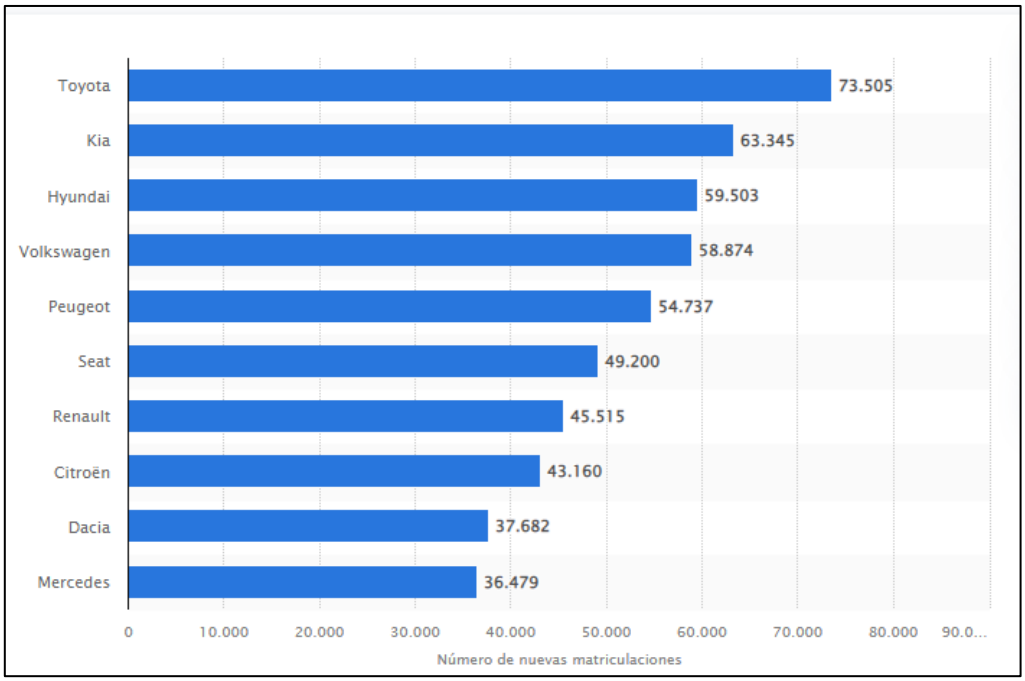
Table 1. Car factories in Spain.

Brand	Localization	Starting year	Type of production
FORD	Valencia	1976	Mean-high vehicles
IVECO	Madrid and Valladolid	1957	Madrid: heavy industrial and special vehicles Valladolid: Chasis Daily
MERCEDES-BENZ	Vitoria	1954	4 models for exportation Cantabria: Buses
NISSAN	Ávila and Cantabria	-	Cantabria: Foundry and mechanization Ávila: Big size van NT400
STELLANTIS (FCA-PEUGEOT-CITROEN-OPEL)	Zaragoza, Vigo y Madrid	Zaragoza: 1982 Vigo: 1958 Madrid: 1952	Zaragoza: Opel Corsa, Opel Crossland X, Citroen C3 and battery assambly Vigo: Brand models + electric versions Madrid: Citroen C4 and its electric model
RENAULT	Palencia y Valladolid Factoría en Sevilla	-	Sevilla: Gearboxes. Valladolid: Renault Captur, diesel engines 1.6 dCi 16V and blocks 1.3 TCe and battery pools. Palencia: Renault Megane and Austral
SEAT	Martotrell	1993	Gearboxes and models such as Audi A1, SEAT Ibiza, SEAT leon
VOLKSWAGEN	Pamplona	1965	Modelo V. Polo, Taigo and T-Cross

Source: Own elaboration based on https://www.autonocion.com/fabricas-de-coches-en-espana/

In addition to the vehicle factories in Spain, figure 9 presents the car brands that were the most registered in Spain in 2022:

Figure 9. Ranking of brands with the highest number of car registrations in Spain by 2022.



Source: https://es.statista.com/estadisticas/531854/automoviles-matriculados-en-espana-por-marcas-de-automovil/

As we can see, Toyota is the most registered brand in Spain with a total of 73,505 cars during 2022, followed by the South Korean Kia and in third position Hyundai, which is also South Korean.

In addition to the most registered brands in 2022, in terms of the types of vehicles registered, figure 10 shows the number of vehicles registered per year according to the DGT in its general statistical yearbook.

Figure 10. Registrations by vehicle type.

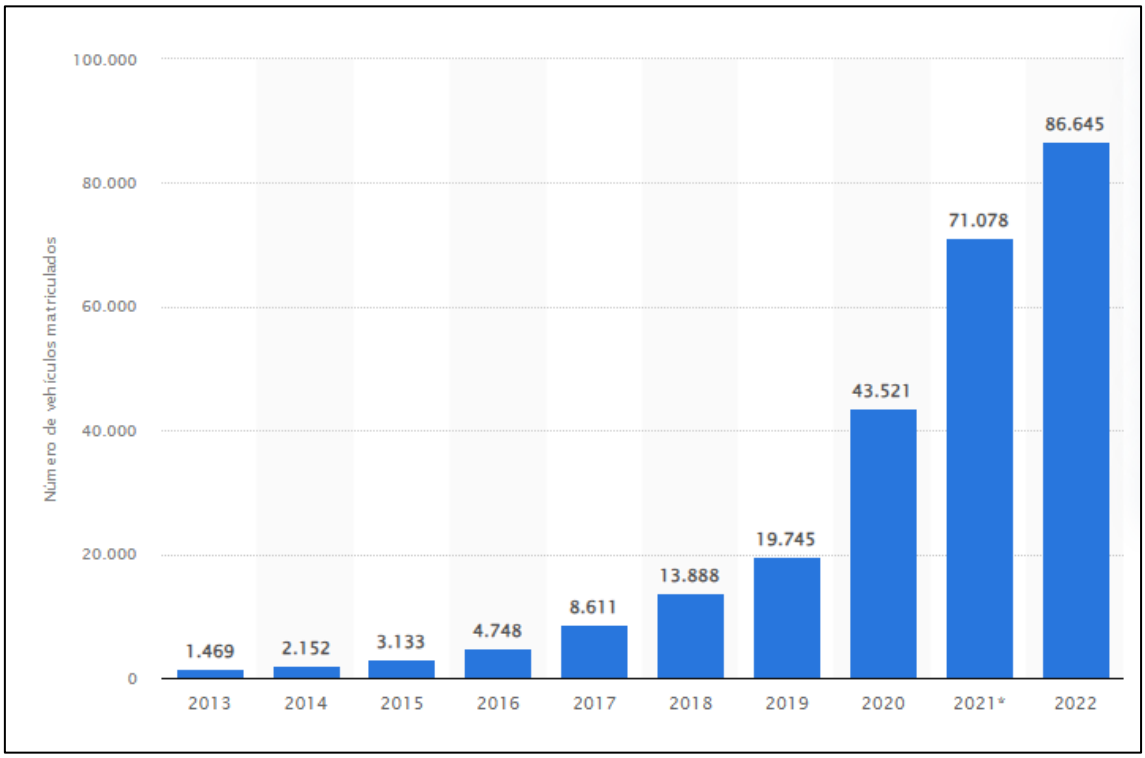
Años	Camiones y furgonetas	Autobuses	Turismos	Motocicletas	Tractores industriales	Otros vehículos*	Total
1990	255.984	2.829	1.007.014	118.525	8.894	-	1.393.246
1991	232.697	2.937	914.061	118.788	7.097	-	1.275.580
1992	234.385	2.775	1.008.454	100.596	5.630	-	1.351.840
1993	162.452	1.915	775.461	50.734	3.077	-	993.639
1994	172.520	1.853	938.971	35.150	4.928	-	1.153.422
1995	179.321	2.547	870.497	34.684	9.563	-	1.096.612
1996	197.364	2.866	968.363	31.217	9.387	-	1.209.197
1997	236.356	3.371	1.091.190	41.872	12.494	-	1.385.283
1998	267.650	3.657	1.282.970	56.152	14.952	2.518	1.627.899
1999	316.926	3.877	1.502.531	68.670	18.389	2.769	1.913.162
2000	305.547	3.365	1.467.160	72.075	19.256	2.859	1.870.262
2001	287.441	3.503	1.498.849	64.196	19.026	2.894	1.875.909
2002	273.127	3.145	1.408.426	63.416	18.423	3.320	1.769.857
2003	306.699	3.290	1.492.527	77.496	19.781	4.008	1.903.801
2004	343.978	3.659	1.653.798	123.195	20.618	4.458	2.149.706
2005	391.295	4.175	1.676.707	220.424	21.326	5.663	2.319.590
2006	397.561	3.847	1.660.627	274.918	21.088	6.615	2.364.656
2007	396.370	4.216	1.633.806	285.633	23.180	6.896	2.350.101
2008	220.539	3.869	1.185.438	221.772	16.343	3.052	1.651.013
2009	136.433	2.967	971.177	139.908	5.774	2.522	1.258.781
2010	145.093	2.593	1.000.010	141.030	7.196	2.887	1.298.809
2011	132.682	2.859	817.688	125.059	10.702	2.521	1.091.511
2012	97.905	1.777	710.638	102.603	9.632	1.755	924.310
2013	97.067	1.742	742.305	95.845	10.524	1.532	949.015
2014	123.111	2.115	890.125	114.600	14.431	1.743	1.146.125
2015	159.973	2.954	1.094.117	137.228	19.990	2.911	1.417.173
2016	170.041	3.760	1.230.104	160.978	20.858	4.135	1.589.876
2017	186.837	4.038	1.342.011	144.955	19.734	6.570	1.704.145
2018	211.372	3.848	1.424.758	165.194	17.944	8.440	1.831.556
2019	201.572	3.650	1.375.381	183.927	18.510	10.105	1.793.145
2020	154.188	2.268	939.096	162.260	16.225	9.509	1.283.546
2021	168.824	2.092	953.624	173.435	17.345	10.373	1.325.693
2022	147.367	2.853	914.835	183.353	19.006	8.980	1.276.394

Source: *https://www.dgt.es/menusecundario/dgt-en-cifras/dgt-en-cifras-resultados/dgt-en-cifras-detalle/?id=00854*

As we can see in figure 10, in 2022 there were a total of 1,276,394 registrations in Spain, with passenger cars topping the list with a total of 914,835, followed by motorcycles, trucks and vans, respectively. The least registered vehicles in that year were buses, with a total of 2,853 registrations.

Of the total number of vehicles registered in 2022 seen above, figure 11 shows that 86,645 were electric vehicles, the highest figure among recent years.

Figure 11. Total number of electric vehicle registrations in Spain between 2013 and 2022.

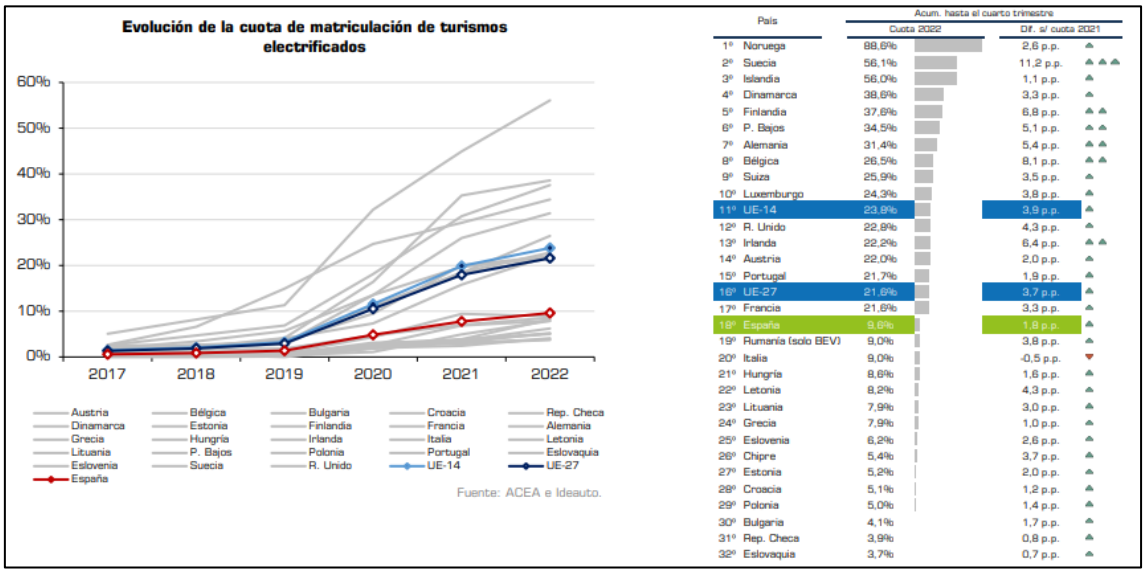


Source: https://es.statista.com/estadisticas/729638/numero-anual-de-vehiculos-electricos-matriculados-espana/

Figure 5 presents the annual evolution in terms of the total number of electric car registrations in Spain between 2013 and 2022. The high number observed in the last year represents an increase of about 15,570 vehicles registered compared to the previous year. The category of electric vehicles includes 100% electric vehicles (BEVs), extended range vehicles (REEVs) and plug-in hybrids (PHEVs).

According to ANFAC's 2022 annual report (ANFAC, 2022), this number of registered electric vehicles represented a 9.6% share in 2022, in which only 3.8% corresponded to BEVs (pure electric cars), and the rest, 5.9% were PHEV cars (plug-in hybrids). With these figures, Spain is still far from being one of the main European leaders in the share of electrified cars in 2022, with Germany in the lead with a share of 31.4%, followed by the United Kingdom, Portugal, and France. Results that can be seen in figure 12.

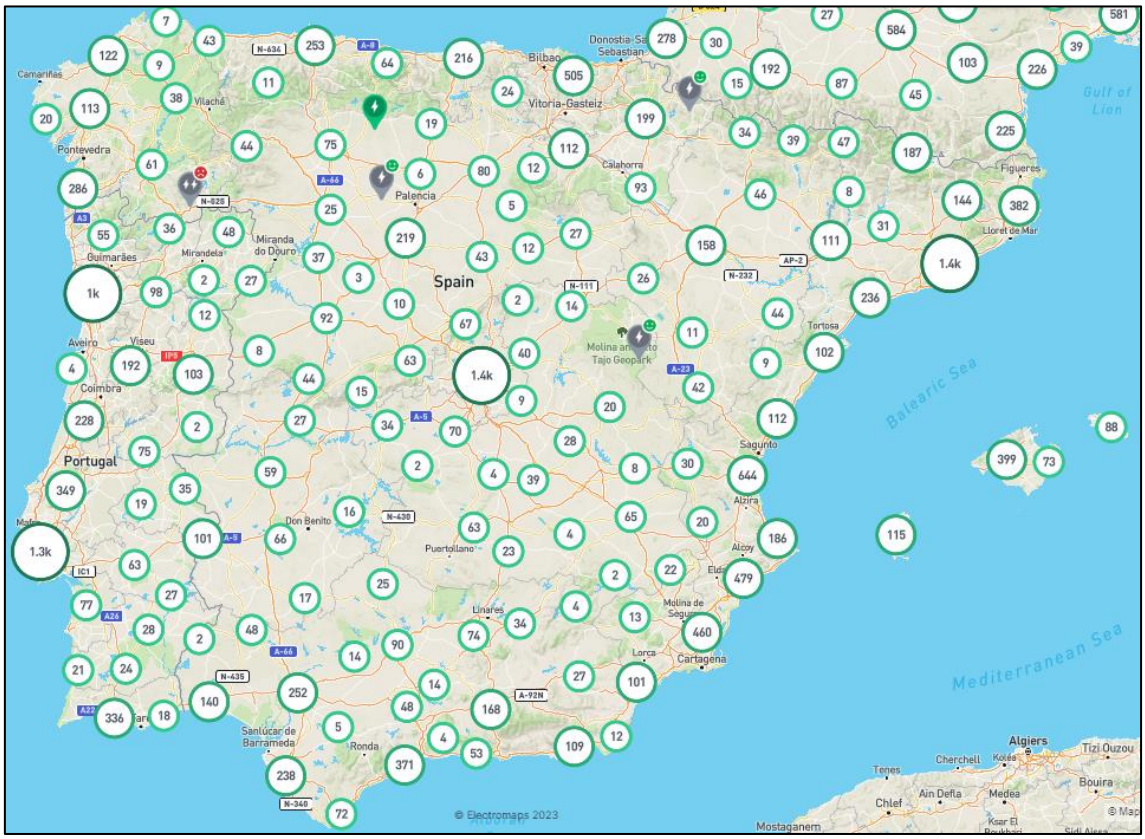
Figure 12. Evolution of the share of electrified passenger car registrations.



Source: https://anfac.com/wp-content/uploads/2023/04/2022_Informe_electrificados-Anual.pdf

Finally, as for the challenges of this sector, one is to achieve a greater weight of electric and plug-in hybrid vehicles. But for this increase to happen, it is necessary battery prices to be reduced and storage capacity to be increased to increase vehicle autonomy (Electromaps, n.d.). The latest available data show that Spain currently has a significant number of recharging points, as shown in image of figure 13.

Figure 13. Public access charging points in Spain.



Source:

https://map.electromaps.com/fr?gclid=CjwKCAjw4ZWkBhA4EiwAVJXwqUL2LE68iq5Age4y-A81N-ZkpaFcHasdoy7V8vVFPTgRUz-Sg0Ub5xoC9q0QAvD_BwE

Despite the existing number of charging points, one of the objectives is to reach 70,000 in 2023, 110,000 in 2025 and 340,000 in 2030, since the charging point infrastructure is currently poorly distributed and insufficient throughout Spain.

As a negative factor, we are currently facing insufficient power for the large future demand for electric vehicles (ANFAC, 2021).

3.2 Implementation of green innovation and the circular economy in the automotive industry

It is increasingly common to find the use of the circular economy in several aspects the automotive sector. Many of the elements manufactured in automotive companies are made with universal materials that can be reused.

We must consider that the manufacturing industry, including the automotive industry, accounts for 19% of the greenhouse gases produced in the atmosphere. Therefore, in

addition to energy efficiency, companies in the automotive sector must opt for the possibility of reusing components and waste generated throughout the manufacturing process. This is reflected in the analysis conducted by Accenture "Driving ambitions: the case for circularity in the automotive industry" (Accenture, 2022), as this sector has just started the path towards the implementation of the circular economy, and this analysis consists of extending the life cycle of products by repairing, recycling, reconditioning and reusing materials to reduce pollution and waste, i.e., using again the parts in the supply chain instead of throwing them to the landfill. European regulations will oblige large companies to fulfill with all the requirements and principles of this concept from 2035 with the aim of reducing carbon dioxide emissions by up to 75% (Kumar et al, 2019).

An example of including the circular economy in the automotive sector is to use products generated by the company Knauf Automotive, which focuses on the manufacture of plastic products for various industrial sectors, in which the automotive sector is included. These plastic products contain Expanded Polystyrene and Expanded Polypropene, materials that have unique properties and provide a versatile use in the industry. The Knauf company is committed to reverse logistics and circular economy principles, so using their products is an example to decrease negative environmental impact, as well as reduce the production of unnecessary waste (Kumar et al, 2019).

A few months after Accenture published the analysis cited above, in which it said that the automotive sector had barely started on the road to implementing the circular economy, Accenture's general manager of automotive and mobility in Spain, Portugal and Israel, Joan Cavallé said, "Increasing circularity in the automotive industry requires a major change in mindset among automakers and mobility providers; which would force them to collaborate more than ever with other players, including competitors."

According to the World Economic Forum and Accenture, full "circularity" would lead to a 50% increase in the profitability of the automotive industry's value chain, allowing automakers and their mobility providers to tap into new sources of value beyond the current ones and thus generate revenues 15 to 20 times higher than the initial selling price of the vehicle.

The analysis also points out some essential actions to achieve full "circularity" such as (Herrería et al., 2022):

- Vehicle manufacturers should not only focus on the sale of vehicles but should also consider the entire vehicle life cycle.
- All participants in the value chain will need to collaborate by exchanging information and data.

- These players will have to develop new capabilities and technology to lead, govern and manage collaborations, as well as transform their operating models and optimize the life cycle of both vehicles and their components.
- Strategic decision making by companies in line with the transformation of their core business.

This report points out that the transformation towards this circularity could be costly, but not doing so could generate an even higher cost (Accenture, 2023).

In recent years, the automotive sector has undergone one of the most profound transformations during difficulties such as the COVID-19 pandemic, the shortage of components due to the paralysis of the market because of the pandemic, problems in the supply chain since combustion cars will be banned from 2035, etc. Therefore, this sector seeks to make changes to achieve good sustainability through electric vehicles, digitalization, more responsible consumption, etc. (González Rodrigo, 2020).

Currently, the circular economy already allows the recovery of up to 95% of the parts of a car and several brands have launched several projects, for example (González Rodrigo, 2020):

- Renault, which has launched the Refactory project, focused on the circular economy.
- Ford, which, together with HP, is extending the useful life of 3D printed parts.
- Audi, which is studying how to reduce its environmental footprint.
- Hyundai, which has created the VIVe plan, the first 100% electric car-sharing service for rural areas in Spain.

According to Jan Amat, the co-founder of Recomotor (n.d.), a company specializing in engines and gearboxes that recovers car parts in good condition through a network of scrapyards to promote the circular economy and make them available to others, says: "All these actions show that sustainability has become an essential part of their organizational culture, and beyond these initiatives, recycling and reuse of components will prove key to achieving ambitious environmental plans."

3.3 Current movements and techniques for recycling and reusing electric car batteries.

As we have mentioned earlier in this project report, there is a possible ban on combustion cars that could be effected in 2035 throughout the European Union, so, if in the future we want a car, a combustion one will no longer be possible, and at present, an electric one with a lithium battery will be the most solution to reach the EU's 2050 climate neutrality target.

According to the European Parliament, road transport accounts for one-fifth of the EU's CO2 emissions, so in 2022 it supported the Commission's proposal for zero emissions from new cars and vans by 2035.

This ban will affect all new cars coming on the market from 2035, if you already had a non-electric car, you can continue to circulate with it, but if we want to buy a new one, it can only be electric from the established date. The productions of these electric cars in terms of waste generation of electric batteries will be neutral in CO2 emissions, and there are also several techniques and methods to reuse these batteries that have been produced after the development of an industry parallel to manufacturing (European Parliament, n.d.).

In Spain, BeePlanet was founded, a benchmark in the second life sector for lithium batteries, which, following the principles of the circular economy, focuses on giving a second life and covering the entire value chain of these batteries (Hantanasirisakul and Sawangphruk, 2023).

According to Di Persio et al. (2022), the processes of recycling lithium batteries are classified based on different criteria such as the metallurgical technique used in each process. The most important categories in this technique would be pyrometallurgical processes, in which the batteries are subjected to high temperatures prior to the metal recovery step, and hydrometallurgical processes, where metals are recovered through leaching at temperatures somewhat above ambient temperatures. Neither of these two processes is carried out in isolation, usually a combination of variants of them is carried out, together with pre-treatment or subsequent purification steps. In several instances, the methods employed are based on established industrial metallurgical processes to obtain metals present in such batteries.

Regardless of the classification generated from the recycling methods, all commercial recycling processes are based on the cost-effectiveness provided by the recovery of the most valuable materials from lithium-ion batteries (Di Persio et al., 2022).

3.4 ReCell center[1] and its process for lithium batteries

Once the automotive sector has been analyzed and it has been observed that electric cars with lithium batteries will be the next protagonists, it must be implemented how to extend their useful life to the maximum, and once it is finished, reuse both the batteries and all the other components to give them a new use.

That is why the ReCell center in U.S., which is one of the first advanced initiatives in lithium battery R&D, is a national collaboration of industry, academia and national laboratories working together to advance recycling technologies during the battery life cycle. Aiming at growing a sustainably advanced battery recycling industry through an economical and environmentally sound recycling process that can be adopted by industry for lithium-ion and future batteries.

This company's vision is to use science-based strategies to remove high-risk barriers to economical recycling of lithium-ion batteries, which would result in waste reduction, job creation, encourage greater adoption of electric vehicles, and reduce U.S. dependence on foreign supplies of citrus materials and mined metals used in battery materials (ReCell center, n.d.).

The main objectives of this company are:

- Recover high value materials to make battery recycling profitable.
- Optimize yield, productivity, and cost through process design.
- Increase national security by ensuring future supply of citrus energy storage materials.

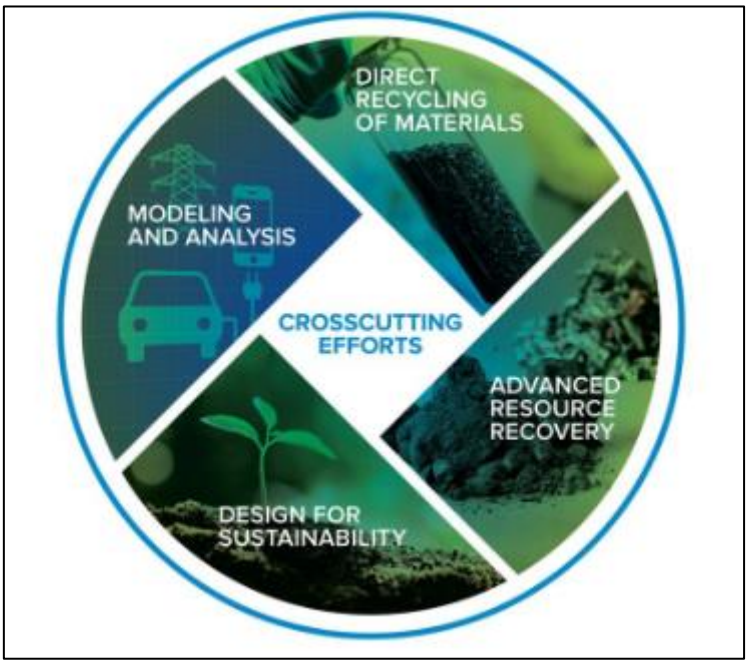
This company is comprised of leaders in key research and development areas such as Argonne National Laboratory, Renewable Energy Laboratory, Oak Ridge National Laboratory, Michigan Technical College, California State University San Diego, and Worcester Polytechnic Institute. In addition to an array of collaborators who bring expertise from all points of view along the battery production chain. It is also supported by an international non-profit industry consortium of more than 100 corporations, associations and research institutes called NAATBatt (ReCell center, n.d.).

In terms of their research, a cost-effective and environmentally friendly recycling process requires a complex set of techniques that require advances in separation, a thorough

[1] ReCell Center. (s. f.-b). Retrieved June 13, 2023, from https://recellcenter.org/

understanding of battery evolution, and the development of new electrochemical techniques for re-lithiation. Sometimes the process of recycling these batteries is more expensive than the battery itself, which is why ReCell is trying to develop an efficient process for this material recovery and be able to sell it to manufacturers. To do so, the Advanced Battery Recycling R&D Facility team has focused on solving four major research and development challenges for widespread adoption:

Figure 14. Cross-cutting R&D efforts.

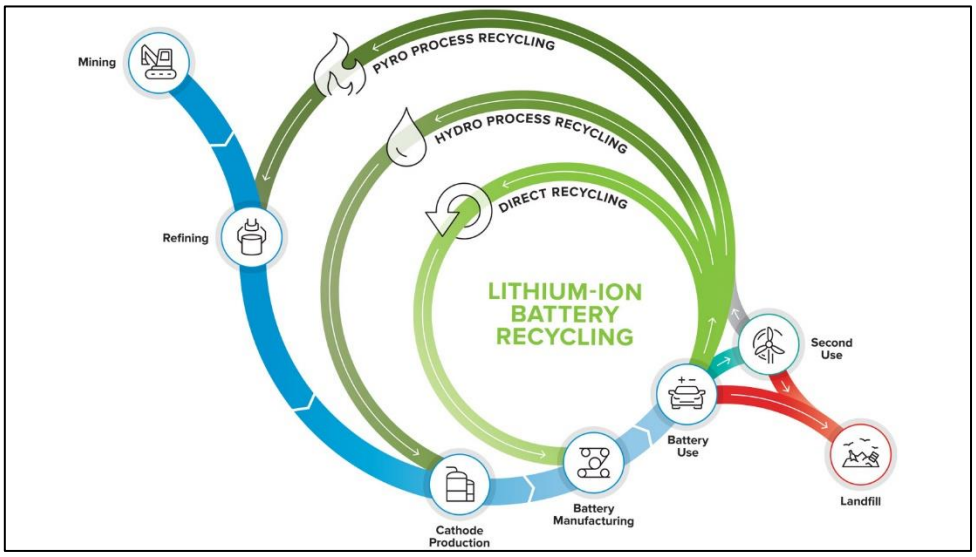


Source: https://recellcenter.org/research/

Of these four research parts that appear in image of figure 14, we will analyze two in depth: Advanced Resource Recovery and Direct Material Recycling.

ReCell's lithium-ion recycling practices are to drive recycling through a closed loop in which spent battery materials are directly recycled, in this process minimizing energy use and waste to the maximum after the elimination of the extraction and treatment phases.

Figure 15. Different lithium-ion battery recycling processes.



Source: https://recellcenter.org/research/

1. Advanced resource recovery:

Recycling processes that are not related to direct recycling are hydrometallurgical and pyrometallurgical recycling approaches (figure 15). Currently, these methods are used for recycling lithium-ion batteries and involve the decomposition of materials within a battery by heating them to a high temperature or dissolving them in acid. After this first step, a mixture of valuable metals is recovered in solid form or as a solution. These processes are effective, but only recover certain specific metals and in forms of little value to the manufacturers, so these processes would need to be improved to make recycling cost-effective. Research in this focus area focuses on two main topics, the first is the separation and recovery of citrus materials, and the second is the synthesis of cathodes using recycled materials.

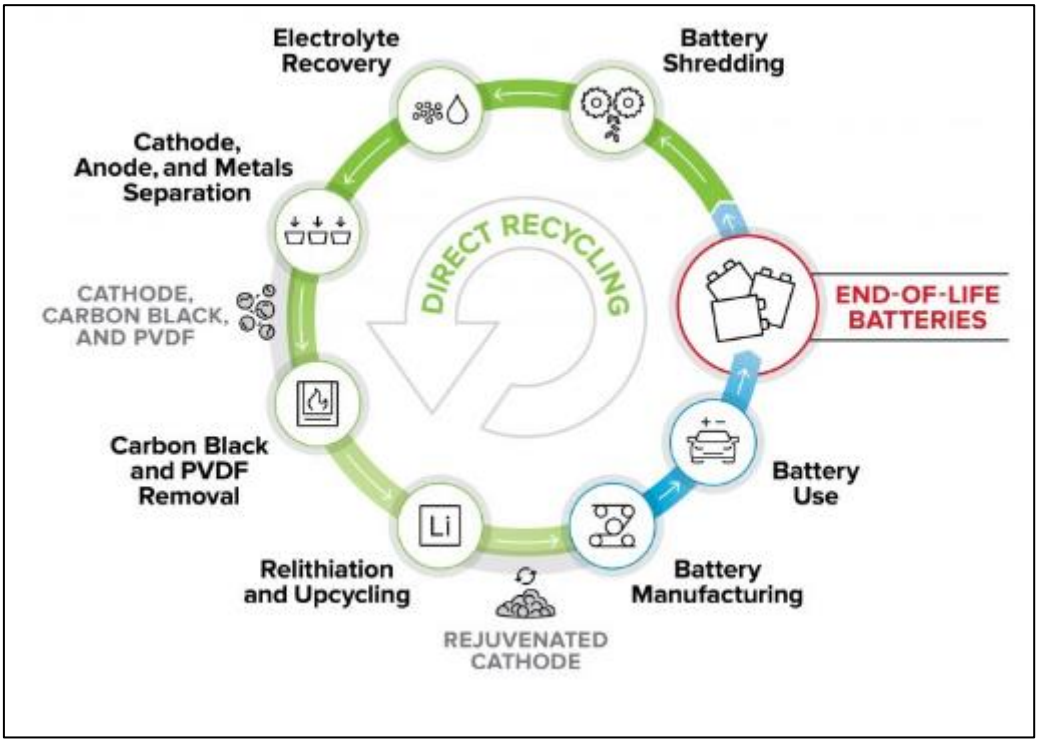
2. Direct recycling of materials.

Work is also being done on the development of direct recycling processes (figure 16), which is the recovery, regeneration, and reuse of battery components directly without decomposing the chemical structure, which would provide a lower cost to manufacturers by being able to maintain the value of the process in the original components. This recycling has been less studied than those seen above, hydrometallurgical and pyrometallurgical, but there has also been focus research in this area that focuses on (ReCell center, n.d.):

- Electrolyte recovery.
- Electrode separation and recovery.

- Binder removal.
- Cathode re-lithiation.
- Graphite recovery.
- Cathode recycling and impurity impact.

Figure 16. Stages included in a direct recycling process.



Source: https://recellcenter.org/research/direct-recycling-of-materials/

This program is funded through the Department of Energy's Office of Energy Efficiency and Renewable Energy and the Office of Vehicle Technologies.

3.5 Future European plans for battery manufacturing for electric cars

There are currently around 40 projects for future battery factories between 2021 and 2024, mainly in Germany and Norway, but also some plans in Spain (Beuse et al, 2018).

The map below, drawn up by the Basque research center CIC energiGUNE (figure 17), shows the different projects. As we can see, the activity is concentrated in the center of Europe, although it will eventually gain presence in the south.

Figure 17. European plans to manufacture electric car batteries.

Source: https://cicenergigune.com/en/blog/world-map-gigafactories

Germany, Norway, and Poland are the places where the main battery production plants are located. And as we can see, Germany is the country with the most factories, with up to 12 giga-factories. Its most prominent plant is the one Tesla has ready in Berlin, where up to 40GWh (gigawatt-hours) were produced in 2021. Norway also has an eager giga-factories development plan, with up to 4 factories and a total capacity of 50 GWh. Its most prominent plant is Freyr, which will produce 35 GWh, more than half of the country's total. But the plant with the largest battery factory in Europe will be Italvolt, located in northern Italy, with a target of producing up to 70 GWh per year (Martin, 2021).

Europe aims at stopping relying on Asia for battery manufacturing, as it is currently supplying us and sales of electric and hybrid cars continue to increase (Martin, 2021).

3.6 Projects in Spain

Thanks to CIC energiGUNE's map of battery factories, we can see that there are four projects underway in Spain (table 2). Note that most of the production will be in Sagunto (Valencia) and Barcelona. It is worth noting that the area of Badajoz has good prospects because it is a strategic location with nearby litium mines.

Table 2. The 4 ongoing lithium battery plant projects in Spain.

	Localization	**Production GW/hour**	**Kw/hour**	**Observations**
VOLKSWAGEN	Sagunto (Valencia)	24 GWh	400.000 packs of 60 KWh each year	
VOLKSWAGEN and SEAT	Barcelona	40 GWh	650.000 packs per year	Biggest facilities of this class in Spain. Own providers, which limits relationships with third parties, but warranty viability of the initial project.
Phi4Tech	Badajoz (Extremadura)	10 GWh	160.000 packs of 60 KWh per year	Strategic place, since there are nearby litium mines, which is an attractive factor for furture plants.
BASQUEVOLT	Vitoria-Gasteiz	10 GWh	160.000 packs of 60 KWh per year	Solid electrolite batteries.

Source: Own elaboration based on https://forococheselectricos.com/2022/08/gigafabricas-baterias-para-coches-electricos-espana.html and https://testcoches.es/actualidad/las-cuatro-fabricas-de-baterias-que-tendra-espana-para-responder-al-coche-electrico/

4 CONCLUSIONS

After the development of the theoretical framework and the application of green innovation and circular economy to the case study focused on the analysis of the automotive sector and lithium batteries for electric cars, the following conclusions can be drawn:

- The circular economy model is the correct model to reduce waste as much as possible, i.e., a product at the end of its useful life will preserve the materials available in the most economical way possible through recycling. These materials can then be used again for another product, thus creating additional value.
- This model contrasts with the traditional model based on the concept of "use and throw away", i.e., with the linear economy model, a system that was very successful in the past but has become obsolete over the years, as it does not provide for the possibility of reusing all or part of the waste to manufacture new products. It is only guided by economic benefit and is a model of rapid consumption, which makes the circular economy model the solution, since it seeks to remain in the production cycle as long as possible. This has been proven by analyzing the benefits of this, such as increased soil quality, reduction of both solid waste and greenhouse gas emissions and thus a better air quality, thus helping to stabilize the climate. In addition to economic benefits through the sale of solid waste to companies that recycle it.
- After this analysis, it is concluded that the circular economy model is much better adapted to the current context than the linear one, as it proposes a system that aims to maximize the useful life of the materials used, implementing as an objective the three R's explained in the theoretical framework, reduce, recycle and reuse, and in more depth the seven R's, which form a more comprehensive initiative and with which the cycle is completed with the points that were not previously taken into account, with the aim of extending the life of the product.

But despite the benefits of implementing this model, after checking with different sources, it has been concluded that there are different limitations which hinder the implementation of the model:

- At the political and regulatory level, there is not enough support for the implementation of circular economy models.
- At the cultural level, one of the major limitations are the consumers, since as we have said before, they are used to the traditional model of "use and throw away" and it is difficult to change this habit.

- At the technological level. The scarcity of the appropriate technological means to develop a circular economy is very noticeable.

These three limitations generate doubts in companies when it comes to making investments to provide the change of models.

This model implies a high investment with a long-term profitability that many companies do not dare or are not willing to make. After prior knowledge of the characteristics, benefits and limitations of the circular model, this concept has been related to that of green innovation, in which the relationship between the two is very close, since both are focused on the creation of a sustainable and more environmentally friendly future.

Spain is considered one of the main European economies and its commitment to green innovation and circular economy are the key to the development of a happy community policy, and that is why information has been collected on six successful cases of the implementation of green innovation and circular economy in Spain that have been explained in depth throughout the work.

Once all the necessary information on the models has been obtained, an analysis of the automotive sector in Spain has been carried out, focused on the last year, 2022, in which through an exhaustive research, data has been obtained about: Spain's position in the world ranking of producing countries in the automotive sector, the annual evolution of the percentage of total vehicle manufacturing production, the number of vehicles produced in Spain and the existing manufacturing plants, the car factories in Spain, which brands and types of vehicles are the most registered and the number of public access charging points for electric cars in the last year.

To verify the usefulness of the systems proposed in the theoretical framework, information has been collected on their implementation in the automotive sector, where it is increasingly common to find the use of the circular economy in this sector, since many of the elements manufactured in automotive companies are made with universal materials that can be reused. In addition to energy efficiency, companies in the automotive sector must opt for the possibility of reusing components and waste generated throughout the manufacturing process. This has been reflected in an analysis conducted by Accenture "Driving ambitions: the case for circularity in the automotive industry". In addition to developing current movements and techniques to recycle and reuse electric car batteries.

Following this analysis, the last part of this project report has focused on the analysis of the company ReCell, one of the first advanced lithium battery R&D initiatives that aims to grow a sustainably advanced battery recycling industry through an economical and environmentally sound recycling process that can be adopted by the industry for lithium-ion and future batteries. By delving deeper and searching for information about the company through its official website, the various common lithium battery recycling techniques have been developed, which are pyrometallurgical and hydrometallurgical techniques, as well as direct recycling techniques, which are not yet fully studied, but are in a period of transformation and improvement, which follow a process: Electrolyte recovery; Electrode separation and recovery; Binder removal; Cathode re-lithiation; Graphite recovery; Cathode recycling and impurity impact.

With the aim of manufacturing lithium batteries for electric cars to be recycled and reused and for Europe to stop depending on Asia in the manufacture of batteries, since it is who currently supplies us and sales of electric and hybrid cars continues to increase, Europe proposed future European plans for the manufacture of these batteries, in which Germany, Norway and Poland were the ones with the main battery production plants. It should be noted that four main projects were planned in Spain: The Volkswagen project in Sagunto (Valencia), another Volkswagen and SEAT project in Barcelona, the Phi4Tech project in Badajoz (Extremadura) and finally the Basquevolt project in Vitoria.

From my point of view, I consider that green innovation and circular economy are a current need to achieve a better use of the limited resources available to our planet and to build a stronger global economy without destroying the environment. After carrying out this project I have concluded that the biggest constraint to implement these models is the difficult change in consumer thinking. If consumers would change their way of thinking in terms of consumption trends and decide to use modular products, with a long useful life and ease of reuse and repair, it would be the companies themselves that would adapt to this.

After analyzing the situation in the automotive sector and the alternatives offered, I believe that it is the power entities, such as the EU, the Spanish government, and others, that are the main motivators for change, since they have the ability to mark a before and after in production and distribution by creating effective regulations and incentives. With the use of circular economy and green innovation models, recyclable lithium battery production plants such as the Volkswagen and SEAT project could be created.

In order not to harm the environment, in addition to producing recyclable batteries, this production should also be sustainable, installing renewable energy sources in factories to carry out the entire production chain, reducing greenhouse gases and the carbon footprint as much as possible.

As a conclusion, this project report has justified the need to apply green innovation and circular economy models both in the automotive sector and in other sectors. Therefore, this project tries to claim a greater support on circular products, to avoid in the future much more serious problems than the current ones related to the supply of raw materials for production and the disappearance of natural resources.

The study I have carried out has been analyzed at a specific time with conclusions in line with the current state of the topic addressed, so future lines of research could be to conduct the same study, but at another time point, as well as to explore the motivations and incentives behind the companies that decide to opt for the new circular economy model. Another future line of research could be to conduct research to improve electric vehicle charging infrastructure, including reducing charging time, increasing the availability of charging stations, and developing wireless charging technologies.

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ANNEXES

Reflection on the relationship between the Sustainable Development Goals (SDGs) and the Final Degree Project

During the present work, an analysis of the automotive sector, a sector that presents a high volume and impact on economies, has been carried out. Several problems of the sector are addressed, and solutions rigorously related to the SDGs are proposed. In 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development, an action plan that would benefit the planet, people, and prosperity. This agenda proposed 17 Sustainable Development Goals with 169 indivisible and integrated targets comprising economic, social, and environmental spheres (Mendoza Caballero, 2019).

Throughout the work, several SDGs have been addressed, but SDG number 12, responsible production, and consumption, is the main SDG of the project. The objective of this SDG is to ensure sustainable consumption and production patterns. The other goals that could have a bearing on the sustainability of the automotive sector are developed below (Mendoza Caballero, 2019):

- SDG 7: Affordable and clean energy → Ensures access to affordable, safe, sustainable, and modern energy for all.
- SDG 9: Industry, innovation, and infrastructure → Develops resilient infrastructure, promotes inclusive and sustainable industrialization and fosters innovation.
- SDG 13: Climate Action → Takes urgent action to combat climate change and its impacts.

These four development goals reflect the national motivation to achieve the targets set responsibly and as quickly as possible. In addition, they have been addressed throughout the work on green innovation and the circular economy in the automotive sector.