DIPARTIMENTO DI ECONOMIA E MANAGEMENT

Corso di Laurea Magistrale
in Green economy and Sustainability

Tesi di Laurea

SUSTAINABLE MOBILITY TO REDUCE EMISSIONS: CIRCULAR ECONOMY, ELECTRIC MOBILITY AND UNCERTAINTY

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Anno Accademico 2020/2021

To my mother and all her sacrifices,
To my brothers, Davide and Pietro, who have always believed in me,
To my angel, my father Francesco, who protects me every day.

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INTRODUCTION

For several years, all European countries and most countries in the world have been working to reduce polluting emissions in order to combat global warming and safeguard the future of our planet's ecosystem. The cause of global warming is due to the increase in the concentration of greenhouse gases, which are those gases present in the atmosphere whose function is to regulate the temperature of the planet in order to favour the development of life. The greenhouse effect is an entirely natural phenomenon, but human activity, particularly that of the last two centuries, has caused an unnatural increase in this effect, which is leading to a worrying and vertiginous rise in planetary temperatures and an increasingly uncontrollable mutation of atmospheric phenomena. The main contributor to global warming is carbon dioxide (CO_2), which accounts for more than 75% of emissions caused by human activity.

In this respect, the following paper focuses on the current transport sector and presents different methods to reduce CO_2 emissions and accelerate the decarbonisation process. The transport sector has a very high impact on the environment: about a quarter of CO_2 emissions come from the combustion of fossil fuels used to power the mobility system, which is mainly based on road transport.

The issue of sustainable mobility therefore plays a central role in the more complex and broader scenario of environmental sustainability, and the search for alternative, innovative and renewable solutions, with an increasingly low impact in environmental terms, is a point for reducing CO_2 emissions.

According to the Accenture, WEF and World Business Council for Sustainable Development report published in January 2020, the adoption of circular economy practices combined with electrification has the potential to reduce CO_2 emissions in the automotive sector by up to 75% and non-circular resource consumption by up to 80% per mile by 2030.

Circular cars appear to be a key element in serving the growing demand for mobility, reducing resource consumption and carbon emissions to a level that is truly sustainable. The term circular car denotes a theoretical vehicle that has maximised material efficiency and produces zero waste and zero pollution during production, use

and disposal. Although cars will never be completely circular, the automotive industry needs to increase its degree of circularity.
Circular strategies for the automotive industry can include the implementation of new business models such as shared mobility and buyback.
Product sellers should start to see themselves as service providers. If cars were increasingly shared as a service and designed for durability and reuse, there would be fewer cars on the road, each car would be in use for longer periods of the day, with benefits such as less congestion, lower maintenance costs, less land and investment used for parking and roads, less air pollution. A car remains unused for more than 90% of its life. A car sharing vehicle, on the other hand, is active for more than 40% of its time.
Secondly, how to extend the life of products? A company needs to be able to effectively recover and recondition its products after use and then put them back on the market for a second life: this is where the buyback process comes in.
This activity consists in the repurchase of cars by the manufacturer, after the end of the rental period by the rental company, and the subsequent remarketing through its dealers. This approach can be defined in line with the circular economy model as it is able to bring savings of 88% on materials, 56% on energy needs and 53% on CO_2 emissions, but it is also proven to be economically advantageous for both parties: manufacturers and dealers.
In this scenario, in addition to the circular economy, the focus should be on electric mobility, which represents an essential technological development for its important contribution to accelerating the decarbonisation process.
On a global scale, only 1 in 250 cars in circulation is electric. This means that electric vehicles account for only 2.2% of the global vehicle market share. Among the essential factors for the growth of electric cars, the measures taken by national governments to facilitate the transition play a very important role. More and more governments are stimulating the demand for electric mobility and the challenge they face is to find increasingly functional solutions that lead drivers to abandon their convictions and experience the benefits of sustainable, innovative and high-tech mobility. Specifically, demand stimulation initiatives are based on economic incentives (bonuses or discounts applied on the purchase price), fiscal incentives (exemption or reduction of the property tax, registration tax or VAT rate) and non-

economic measures (traffic management measures such as free and reserved parking spaces, access to preferential lanes and restricted traffic zones). These measures are often combined with bonus/malus mechanisms to encourage the purchase of low-emission vehicles and discourage the purchase of polluting vehicles.
Although the government's monetary incentives are key factors in accelerating sales, they are not by themselves sufficient to guarantee the expected growth volumes in the coming years. However, the transition from a conventional car to an electric car is far from easy: resistance is mainly related to the higher purchase costs of battery-powered cars, the limited mileage range (compared to conventional petrol or diesel cars) and the limited recharging infrastructure. A further barrier to the mass adoption of electric vehicles is misinformation, fuelled by fake news and the cognitive distortions to which our minds are subjected every day. Faced with these barriers, a number of measures have been put in place to further push the electric car market and drive change towards the mobility transition.
Cars and mobility, being pervasive in our daily lives and perfectly part of the macro-topic of sustainability, are fundamental pieces in the mosaic of the circular economy and future production and consumption patterns of goods and services. The shift towards more sustainable mobility is a fundamental change to which we are all called upon to contribute, and the transition is indeed possible.

The thesis is divided into three chapters:

The first chapter introduces the basic elements to understand the current global energy scenario, aggregate energy demand, mobility and electricity demand in the world. This is a very important chapter to assimilate the basics of the macro thematic area to which the automotive sector belongs.

The second chapter starts from the premise that the transition must not only concern the mobility model, but also the overall economic model: the transition from the current linear economy to a sustainable and highly innovative circular economy must be accelerated. Subsequently, the second chapter discusses the transition towards a more sustainable and flexible mobility, towards a conception of the car not only as a durable good but, often, as a real service. In this context, the circular economy approach in the transport sector is highlighted as a means to reduce CO_2 emissions. Short- and long-term rental and car-sharing strategies are therefore considered as models linked and relevant to the circular economy, thanks to the "reuse" philosophy. The discussion on vehicle "reuse" continues with an in-depth analysis of the sustainability and cost-effectiveness of a corporate buyback strategy, with the aim of answering the following question: "How can manufacturers use the rental channel to smooth out factory production without letting the resulting second-hand market negatively affect sales and dealer profitability?". Using a two-period economic model, the convenience for manufacturers and also for dealers is demonstrated.

In the third and last chapter, after an introduction to the great potential of the shift to electric mobility as a means to accelerate the decarbonisation process and a detailed description of the initiatives (incentives, tax breaks and non-economic measures) implemented by governments to accelerate the electric transition, the value of uncertainty, which plays a key role in the definition of incentives, is highlighted. Finally, an empirical study will be presented which was carried out on 325 people living in the United States to assess the social and cognitive barriers to the purchase of an electrified vehicle, with the aim of proposing a series of possible solutions to encourage the diffusion of electric mobility and trigger a behavioural change in consumers.

CHAPTER 1: INTRODUCTION TO THE GLOBAL ENERGY SCENARIO AND DEMAND FOR ENERGY AND MOBILITY

1.1. Introduction

In recent years, environmental issues have become daily news and there is not a news or newspaper that does not talk about weather events on a daily basis.
Sometimes the headlines are somewhat sceptical and provocative about climate change, associating unseasonal cold spells with the cancellation of the effects of climate change.
Very often people forget the difference between weather and climate. Weather events are local, time-limited episodes, whereas climate assesses the weather over a longer spectrum, over a region, over a nation, and in fact we talk about planetary warming.
Thanks to the demonstrations of young people, March 2019 can be seen as a clear demarcation line and a stance on the fact that action must be taken by making radical changes to the current system of development and energy consumption.
The events relating to climate change and the mobilisation of more and more people towards a different way of thinking make us aware of a huge problem: an environmental crisis that is now defined as irreversible.
This irreversibility must be seen in the order of magnitude of a human life. What can and must be done is to intervene to mitigate its effects because we do not have an alternative, we do not have a 'Planet B'.
The first awareness probably came in 1968 when Aurelio Peccei from Turin decided to found the Club of Rome, a non-profit association that at the time brought together scientists, economists and leading figures from all over the world; its mission was to identify the main problems that humanity would have to face, trying to identify alternative solutions to the various possible scenarios. After four years, in 1972 the
After four years, in 1972, the Club of Rome published a report entitled The Limits to Development, in which it highlighted the problems that would be encountered in the following decades if the development model did not change.
A year later, at the end of October 1973, there was a sudden rise in oil prices, and crude oil prices increased more than fourfold, resulting in what we all know today as

the 1973 energy crisis. That crisis stimulated the search for new energy sources as an alternative to crude oil. Governments in western industrialised countries began to take measures to reduce energy consumption, and over the next few years the efficiency of energy use began to increase, while at the same time awareness of environmental issues continued to grow.

In 1988 the IPCC, an intergovernmental group on climate change, was founded by two United Nations bodies: the World Meteorological Organisation and the United Nations Environment Programme.

The main purpose of the IPCC is to study climate change and global warming.

The warming of the planet is mainly due to the increase in the concentration of a gas considered to be climate-changing, the main greenhouse gas: carbon dioxide.

Carbon dioxide is not dangerous to humans; on the contrary, it enables life on earth and liveable conditions on the planet. The problem lies in the fact that when the concentration of this gas rises sharply it is correlated with an increase in temperature. And an increase in temperature leads to more intense and more powerful weather events.

In 2004, a European research project, EPICA (European Project Ice Core Antarctica) was completed. It reconstructed the concentration of carbon dioxide on earth over the last 800,000 years by drilling into the ice of the continent of Antarctica and measured the concentration of carbon dioxide in the air particles contained in the ice. As can be seen from the graph (Figure 1), the concentration of carbon dioxide had never exceeded 300 ppm (parts per million) in the last 800,000 years. In 2019 and even today we are above 400 ppm and this value is growing at a rate of almost 2 ppm per year. If we consider that Homo Sapiens appeared on earth about 300,000 years ago, we are now experiencing an earth with chemical conditions never seen before. In the last two centuries alone since the Industrial Revolution we have made a leap from 300 ppm to over 400 ppm of CO_2 in the atmosphere. We are mainly responsible for this increase, through the burning of fossil fuels.

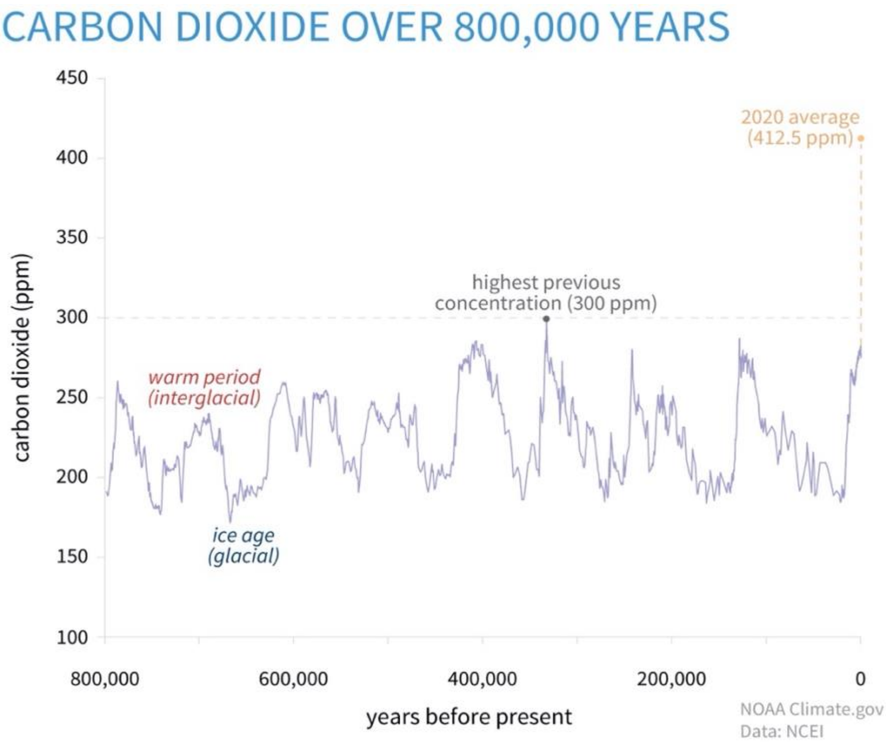


Figure 1: Evolution of CO_2 concentration in the atmosphere[1].

Let's think about our life: we live in a house that needs to be heated or cooled, we go to work or university, we move around and consume energy to work, study, eat; even just sitting down to write a document on the computer or to read it we consume energy. Our lifestyle influences our energy consumption. 40% of the energy consumed is consumed inside buildings and this portion is strongly influenced by our lifestyles. The fact that every action we take consumes energy is a reality and we need to be increasingly aware of this in order to undertake the best optimisation solutions to avoid waste and to avoid overloading and destroying our 'big house', the Earth, which we will sooner or later have to abandon to make way for those who will come after us.

Article 191 of the Treaty on the Functioning of the European Union (TFEU) of 2012 makes combating climate change an explicit objective of EU environmental policy.

In the absence of policies to reduce emissions, the average global temperature is expected to rise between 1.1 and 6.4 degrees Celsius during this century.

Global warming is responsible for:

[1]Source: Climate.gov. https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

- More frequent extreme weather phenomena;
- Forest fires;
- Scarcity of water resources;
- Disappearing glaciers and rising sea levels;
- Changing distribution patterns or even extinction of flora and fauna;
- Plant diseases and pests;
- Scarcity of food and drinking water;
- Intensification of photochemical smog, which causes health problems and migration of people fleeing these dangers.

Science shows that the risk of irreversible and catastrophic change would increase dramatically if global warming exceeds 2 degrees above pre-industrial levels. According to the Stern Report (Stern 2006), published by the UK government in October 2006, dealing with global warming would cost around 1% of global GDP per year, while the cost of inaction would be around 5% of GDP, rising to 20% of global GDP in the Stern scenario. global GDP in the worst-case scenario. Therefore, only a small fraction of only a small fraction of GDP to invest in a low a low-carbon economy emissions: the fight against climate change climate change would in return bring health benefits and greater and greater energy security would limit further damage to our ecosystem. Now let's think about the energy we use every day: petrol at the petrol station, gas, and electricity at home... how do they get where we find them?

First of all, energy has to be produced, and in the case of fossil fuels, it has to be extracted. Some 90 million barrels of oil are extracted every day and this fuel, along with natural gas, can be extracted from platforms such as those in Figure 2.

Figure 2: Oil and gas extraction platform[2].

As for coal, the extraction methods are different, but the effects of massive underground extraction can be as shown in the Figure 3:

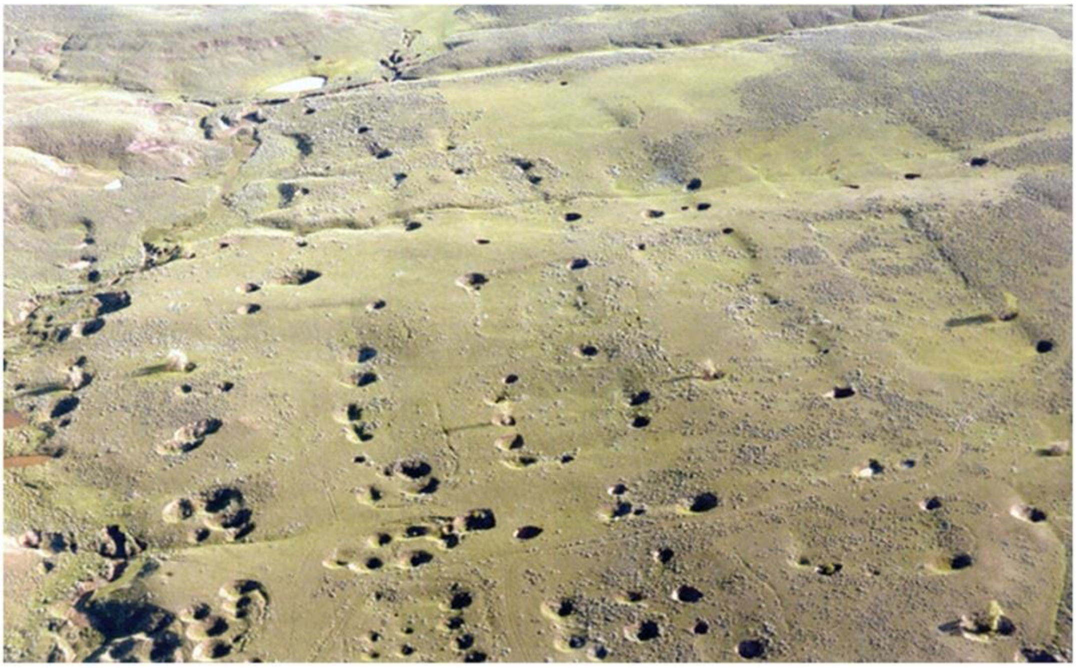


Figure 3: The effect of land sinking due to excessive coal mining a Sheridan, Wyoming (USA)[3].

[2] Source: GreenMe. https://www.greenme.it/informarsi/ambiente/piattaforme-gas-petrolio-co2/.
[3] Source: PNAS. https://www.pnas.org/content/118/20/e2107251118.

If we remove too much material from the subsoil, everything above it tends to sink until the soil collapses, with serious consequences for the life of flora, fauna and even humans.

Once the primary sources have been extracted, they need to be transported from places of production to places of use through pipelines, such as gas and oil pipelines, and stored until they are distributed to end users. In order for an energy system to be reliable, i.e., to guarantee a good energy supply, it is necessary to have energy reserves, both for environmental reasons (because there could be a particularly cold winter that causes us to consume more energy than we had planned to consume) and for supplier-related reasons, because if suppliers suddenly decide to cut off the supply they will put us in serious difficulty.

So, what about electricity?

You cannot extract it from the ground because it is a derived energy source. It can only be produced through the use of different primary sources: traditional fossil fuels and many others (sun, water, wind...). Electricity consumption is constantly increasing because it is easier to produce electricity from renewable sources than to produce fossil fuels synthetically, and because electricity is the 'noblest' form of energy that exists and the easiest to transform.

We can use electricity to generate heat through electric heaters and heat pumps, and we can use it to generate motion through electric motors to drive trains and cars.

However, electricity has a big problem: it cannot be stored as easily as oil or natural gas, which can be stored in reservoirs and re-injected underground in old, exhausted natural gas fields respectively. Electricity must be produced to be consumed when needed.

According to data updated daily by Terna[4], for the day of 7 July 2021, our national operator has forecast a total daily consumption of just over one million megawatts (MW).

Which means that at that moment there were hydroelectric and thermoelectric power stations producing exactly that amount of power.

[4] Source: (Terna S.p.A. 2021).

Right now, we all have an electrical energy accumulator in our hands or pockets: the mobile phone has one, the battery, but what accumulators does our national electricity system have?
At present, the national electricity grid owns the Alpine reservoirs. Pumped storage hydroelectric plants work like this: they have an upstream and a downstream reservoir and transfer water from the upstream reservoir to the downstream reservoir depending on whether the national grid needs to feed electricity into the grid or if the grid has a surplus, the excess energy is reabsorbed to transfer water from the downstream reservoir to the upstream reservoir.
Adding large new reservoirs can be very complicated, but what can be done more simply is to extend the distributed generation methodology that has become so popular with photovoltaic systems to distributed storage.
When the number of electric cars increases, as each electric car has a battery and that battery is an electrical energy storage device, it will be possible to make the exchange of energy between the cars and the system more efficient for a better distribution of loads. To do this, however, it will be necessary to implement the energy infrastructure to enable electric cars and also homes to exchange energy. In addition, our energy system, in order to increase its share of energy produced from renewable sources and to increase its reliability and safety, must necessarily increase its capacity to store energy produced from renewable sources and have an adequate generation mix.
The energy mix is very important because the fact of supplying energy from different sources, particularly renewables, seeks to reduce the problem of source uncertainty in a natural way. The biggest problem that needs to be solved is the discontinuity of energy production from renewable sources and the mismatch between supply and demand. The sun shines during the day, but we also want electricity at night or on a cloudy or rainy day. Thinking only about electricity consumption and it is necessary to source it from different sources: e.g., wind, photovoltaic, geothermal, hydroelectric. Having the possibility to schedule energy production is crucial. If it is not possible to do this by switching generation systems on and off - because the wind and sun are not always there - it is necessary to try to store energy when it is possible to produce it in order to use it when it is not possible to produce it at the expense of a loss of energy itself.

In any case, our electricity system already possesses a good percentage of energy produced from renewable sources historically based on hydroelectric plants and which has been boosted in recent years by photovoltaic and wind power plants.
The perception of many people who are skeptical about change is that solar panels or electric cars are more polluting technologies than those that use a non-renewable resource from the outset.
In fact, many studies have shown that solar panels generate all the energy needed for their manufacture in the first few years of life (Solar Bay 2020). As far as electric cars are concerned, for the same vehicle, changing only the power supply from, for example, diesel to electricity, purchased from the national grid and not produced by an internal combustion generator, can reduce emissions that are considered climate-changing: carbon dioxide emissions per kilometer driven are reduced by a third. Shifting energy consumption from fossil fuels to renewable sources and the electricity itself produced from renewable sources is absolutely feasible and less impactful on the environment. The energy system is complex to manage, but technology allows us to have high standards of well-being in a more sustainable way.
The approach towards sustainable development is now increasingly a benchmark for social, economic and environmental policies worldwide.
In 1987, "Our Common Future" was published, the final report of the World Commission on Environment and Development, established by the UN in 1983 and chaired by Gro Harlem Brundtland. That report is still a cornerstone of reflection on environmental issues and their connection to socio-economic imbalances on a planetary level. The report contains the definition of sustainable development that has become commonly used: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs".
Since then, the goal of sustainability has been high on the agenda of many countries, reinforced by the Rio de Janeiro Conference in 1992, which led in subsequent years to the drafting of documents regulating the measures to be applied to combat climate change. In 1997 the Kyoto Protocol was drawn up, which came into force in 2005, to seal the commitment of the industrialized nations to a reduction in climate-changing emissions, and in 2015 the UN further expanded the sustainability action plan by defining the 17 Sustainable Development Goals with the 2030 Agenda to homogenize

the targets and actions aimed at improving the lives of all the planet's peoples and safeguarding the environment. An unsustainable development would also be an uneconomic development and the price to pay would be too high.

And it is within the topic of sustainability that the important role of sustainable mobility comes in.

Sustainable mobility is understood as "A system of transporting people and goods that, while meeting the needs for movement or handling, does not generate negative externalities and contributes to a good quality of life (Ministry of the Environment 2017)".

Mobility involves all areas of the population's well-being and represents the importance of the interrelationship between the social, environmental and economic dimensions of sustainability. The sustainable and decarbonized mobility of the future is electric, and to promote its development it is necessary to leverage on the need to reverse the course of consumption of society and of the energy system in general and the electric one in particular, which is still too tied to dependence on fossil and highly polluting sources (Rigirozzo, 2020). We are the ones who strongly influence energy consumption and we need to use the opportunity we have to change as soon as possible. Everyone, within their means, must do their part to try to change the current paradigm. Niels Bohr used to say that making predictions is difficult, especially about the future, but what we do know is that if we continue with the massive use of fossil fuels, our planet will be increasingly ill and the consequences will be borne by us and above all by those who come after us (TEDxPavia 2019).

However, it is now certain that the electrification of transport, together with a circular economy, will have a positive impact on the climate and the environment in the future.

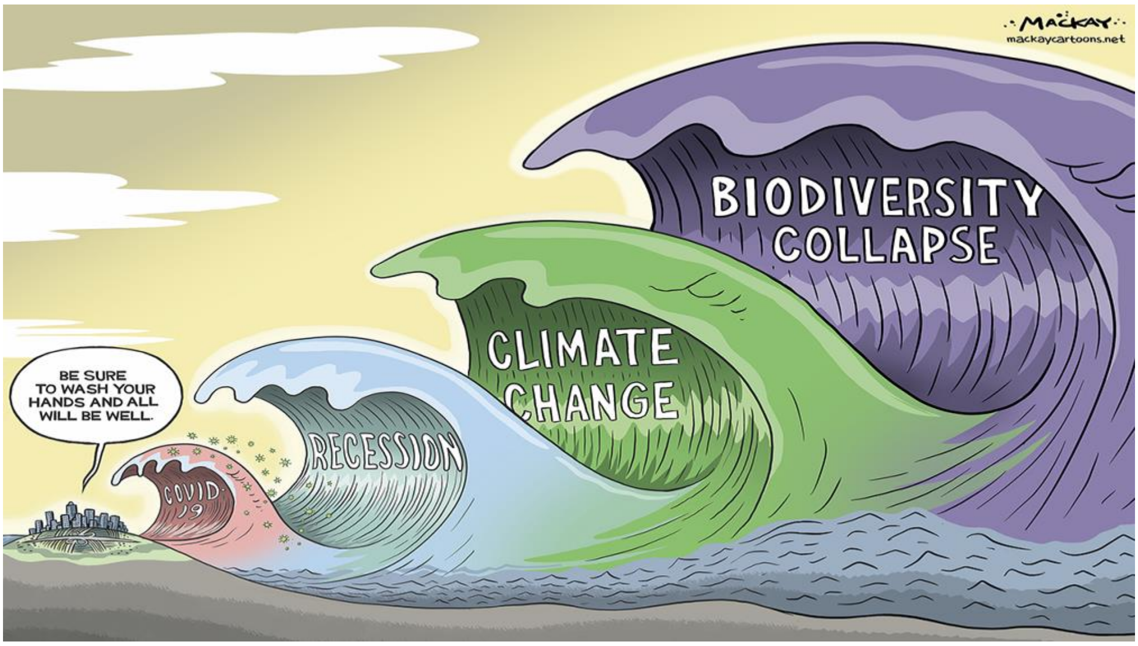


Figure 4: Impacts on the environment.

Electric mobility and decarbonization are not a question of "If..." but rather a question of "When".

According to that, the Paris Agreement of 2015 established a common and binding commitment by almost all countries in the world to halt the excessive advance of global warming and to keep the average temperature increase below 2 degrees Celsius compared to pre-industrial levels.

1.2. The demand of Energy

The previous century, and in particular the second half of it, saw an exponential growth in energy demand worldwide, with only sporadic contractions, most recently due to Covid-19. Measures to contain the pandemic health crisis, particularly in the first half of the 2020s, led to a significant drop in demand for electricity, and as a result, there was also a reduction in the use of coal, the world's largest source of energy.

According to estimates by the International Energy Agency (IEA), global coal demand shrank by around 5% in 2020 compared to 2019, the worst decline since World War II. However, lower electricity demand was not the only factor restricting coal consumption in 2020 as increased renewable energy supply and competition/convenience from natural gas also played a very important role (IEA 2020).

The graph below (Figure 5) shows how global demand for different energy has changed over the last two centuries.

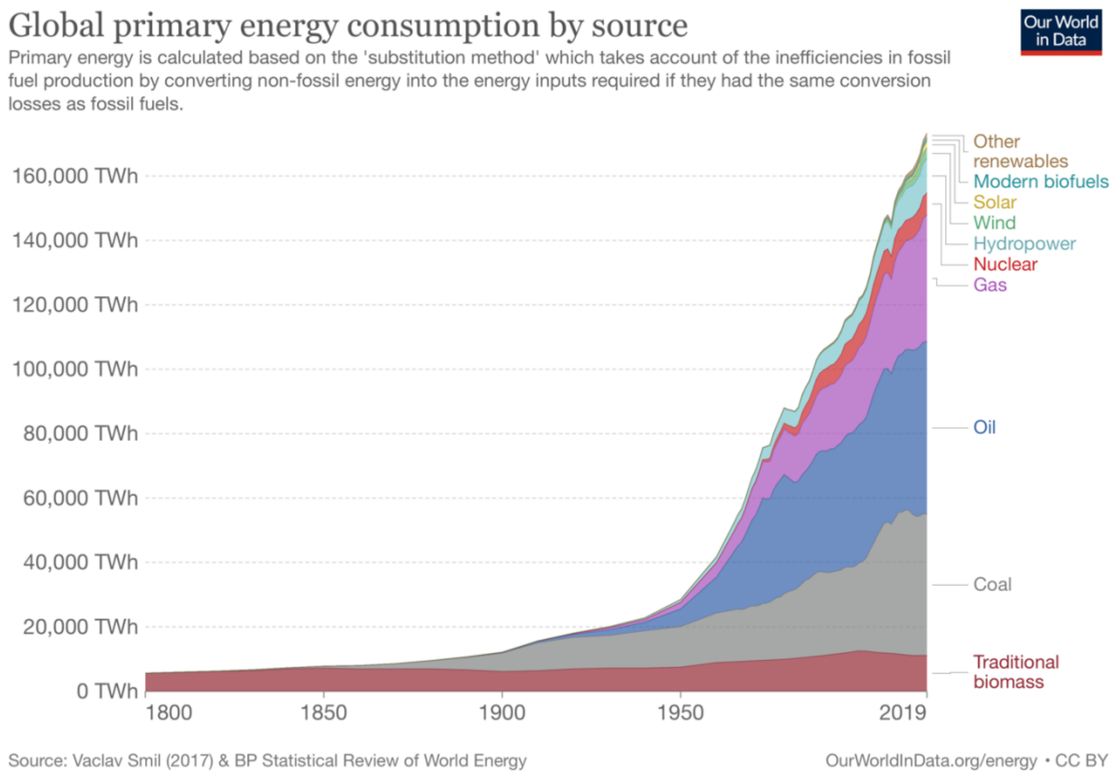


Figure 5: Evolution of global energy demand[5] .

It is clear that since the 1950s we have witnessed an exponential growth in energy demand, which has increased continuously without ever seeing significant setbacks, except for the temporary ones during the energy crises of the 1970s, the economic crisis of 2008 and lastly the Covid-19 pandemic crisis[6].

The global energy mix is dominated by fossil sources and in particular oil (31.2%), coal (27.2%) and natural gas (24.7%). The fall in global energy demand in 2020 mainly affected the followings: oil (down 8.8% compared to 2019) due to the collapse in transport, which accounts for more than 60% of total oil use; and coal (down 4% compared to 2019), due to the fall in electricity demand. The only energy sources that were not negatively affected were renewables and natural gas. In fact, renewables

[5]Source: https://ourworldindata.org/energy-production-consumption.
[6] Source: (BP 2021).

grew by 4%, mainly driven by Europe, the United States and China, with growth led by wind, hydro and especially photovoltaics.

The OECD[7] industrialised countries have an energy demand component that has grown, albeit at a not particularly high rate, and then stabilised from 2015 onwards, as shown in the graph in Figure 6.

All other countries, particularly China, India, other non-OECD Asian countries, and developing economies, have energy demand that is growing much faster than in OECD countries, and the trend is expected to continue. The measure of energy consumption is given here in billion tonnes of oil equivalent (BToe)[8] and is one of the standard measures of energy demand, along with the TWh.

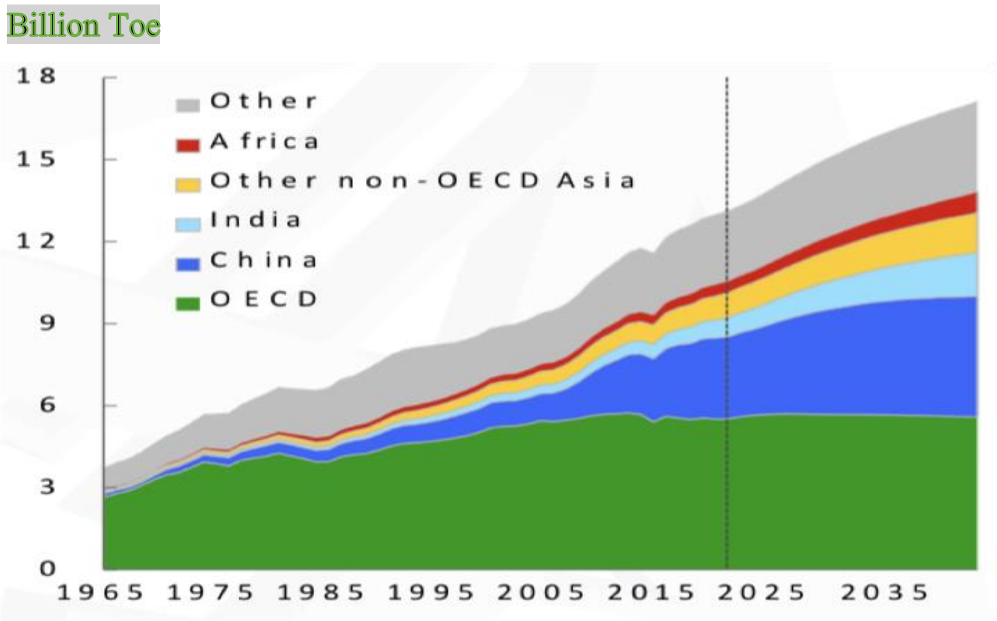


Figure 6: Energy demand by geographical area/country.

[7] The OECD, Organization for Economic Co-operation and Development, was founded in 1961 and currently has 38 member countries (Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Denmark, Estonia, Finland, France, Germany, Japan, Greece, Ireland, Iceland, Israel, Italy, Latvia, Lithuania, Luxembourg, Mexico, Norway, New Zealand, the Netherlands, Poland, Portugal, the United Kingdom, the Czech Republic, the Slovak Republic and the United Kingdom),
(Austria, Australia, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Latvia, Lithuania, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom). The mission of the OECD is to promote, at the global level, policies that improve the economic and social well-being of its citizens. The OECD facilitates the collection, dissemination and exchange of data and analysis by advising member governments on measures to support resilient, inclusive, green and sustainable growth.
Source: Ministry of Foreign Affairs and International Cooperation.
Cooperation. https://www.esteri.it/mae/it/politica_estera/organizzazioni_internazionali/ocse.html.
[8] Amount of energy produced with one ton of oil.

Energy demand is a derived demand: energy is demanded for uses that have to do with other forms of economic activity and in particular the production of goods and services, whether intermediate or final. Energy is needed: both to produce goods (energy as a production factor and therefore demand in an intermediate position along the supply chain of certain goods) and to satisfy the needs of final consumers (e.g., electricity to charge mobile phones or to start up and run household appliances or cars).

Energy is therefore both a production factor and a final consumption good. In general, we talk about goods and services with a high energy content (transport, heating, etc.) and goods and services with a low energy content (clothing industry).

Modern societies are based on energy input and we could not live without energy today.

The global energy demand is the sum of the energy demands of the different sources used and is mainly determined by three factors: population growth, economic growth, and improved standards of living, and technological development (Rigirozzo 2020).

Demographic and standard of living trends have a major influence on the level of demand and the structure of demand. According to the report presented by the UN Department of Economic and Social Affairs (United Nations 2019) and proceeding at current rates, the world's population, with an average growth rate of between 1.2% and 0.8% per year, is expected to increase by a further two billion over the next 30 years, reaching 9.7 billion and reaching almost 11 billion by the end of the century.

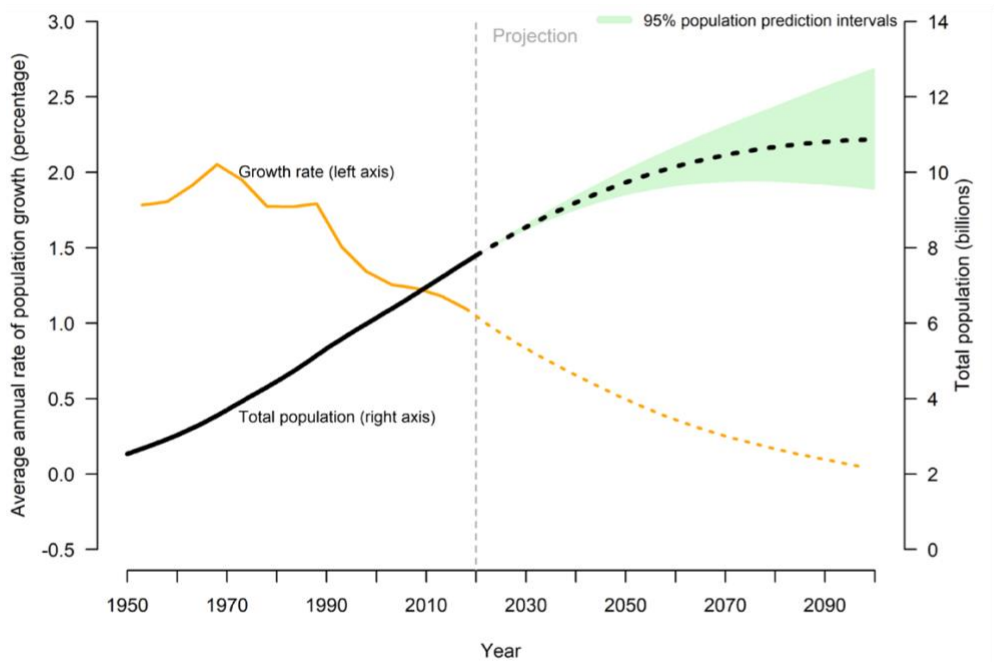


Figure 7: Global population growth[9].

The increase in population will mainly affect Africa, India, South-East Asia and the Middle East.

India will show the highest population growth by 2050, overtaking China as the most populous country on the planet, and the population of sub-Saharan Africa is expected to practically double by 2050.

[9] Source: United Nations, Department of Economic and Social Affairs, Population Division (2019), World Population Prospects 2019.

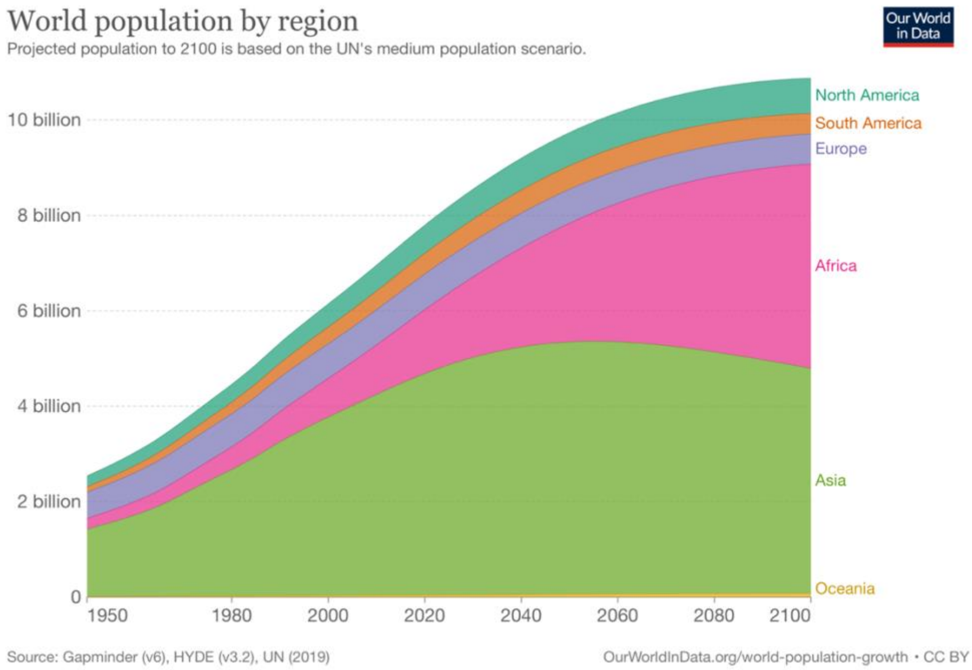


Figure 8: Geographical breakdown of population growth[10].

Such an increase in population will necessarily be followed by the need to improve the living standards of more and more sections of the population, and this will inevitably have an impact on the amount of energy demanded.

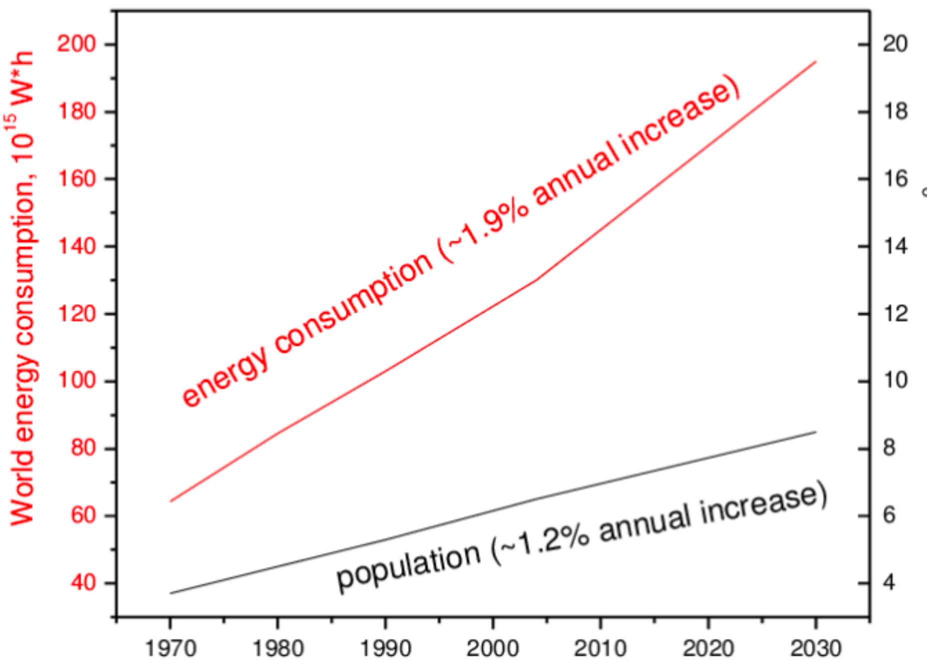


Figure 9: Comparison of the energy consumption and population growth in the world[11].

[10] Source: Grapminder (V6), HYDE (v3.2), UN(2019).
[11] The curves have been calculated based on the data of the International Energy Agency Report 2004.

The First Industrial Revolution paved the way for the phenomenon of mass society: mass production and the introduction of energy sources to replace labour, previously drawn from human and animal efforts, opened the door to the progress and change on which our society is based.

It was first coal that started the transformation process towards our current paradigms and then oil that turned the corner.

Production models changed, as did transport models: motorised transport, which was exclusive to sea and rail, was also developed on the road, with considerable economic and social consequences; similarly, the explosive rise in the use of natural gas - the last fossil energy source to become established on a global scale - from the 1950s-60s further renewed customs and consumption, especially at household level, in society (Eniscuola 2011).

The phenomenon of urbanisation, which started with the Revolution, is an evolutionary variable that must be taken into account in order to predict and interpret energy demand and its future developments.

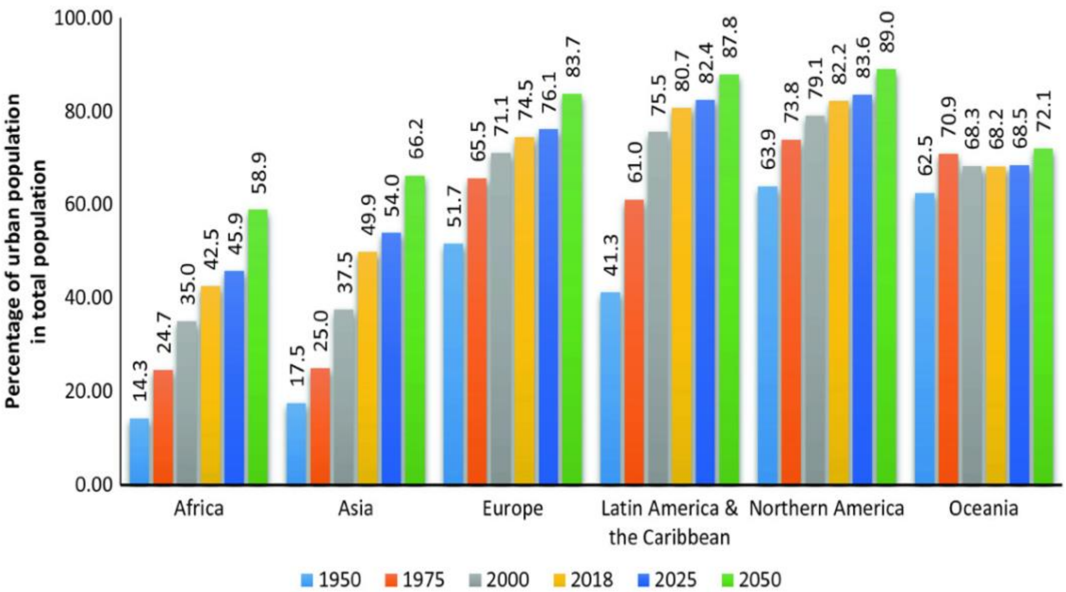


Figure 10: Global urbanization growth.

As can be seen from the graph (Figure 10)[12], between now and 2050 there will be a steady increase in urbanisation worldwide, with a marked trend in Africa and Asia, where people will tend to move from rural areas to large urban agglomerations in search of better employment and living conditions.

Thus, population growth and urbanisation will, as has happened on our continent and in the USA, lead to an exponential increase in energy demand, which is likely to be offset by a slowdown in energy demand from developed industrialised countries, which will reach ever higher levels of efficiency and start to demand less energy (from non-renewable sources), thanks to technological progress.

The second factor driving energy demand is economic growth.

It should be said that energy and economic growth are in fact closely related because it would be unthinkable to conceive of one without also considering the other. An indispensable prerequisite for economic modernisation has been the advancement of technical knowledge, particularly in the exploitation of energy. Energy change is a necessary condition for economic development and vice versa (Malanima 2009).

There is a close correlation between economic variables and energy consumption.

GDP is that measure of the well-being and health of the economic system because it measures, at market prices, the quantity of goods and services produced by an economy within a given unit of time. The rates of change in GDP from one year to the next are a measure of the economic growth of a system and it is evident that if energy is a fundamental factor in the production of goods and services, it is true that there must be a direct and important relationship between the production of goods and services, and therefore GDP, and energy demand.

Energy demand forecasts are closely correlated with GDP trends, and this can be observed very well in phases of crisis or GDP stagnation, in which a drop in energy demand can be observed, as was seen in the 1970s with the oil crisis, in 2008 with the economic crisis and finally in 2020. In fact, GDP and energy demand have a very similar pattern: when the GDP line increases or decreases, the annual rate of change of energy observes a very similar pattern (Figure 6).

[12] Source: (Kundu e Pandey 2020).

Global economic growth always requires more energy, even if technical efficiency means that less energy is needed to fuel more growth, so that energy intensity (defined as the amount of energy used per unit of Gross Domestic Product - given by the European Commission) is gradually decreasing over time. the ratio of Gross Domestic Energy Consumption to GDP - and which assesses the energy efficiency of economic systems[13]) as shown in Figure 11.

Technical progress means that GDP can grow with continuous efficiency gains (thus requiring less energy) because the energy intensity associated with economic growth decreases progressively over time (Figure 11).

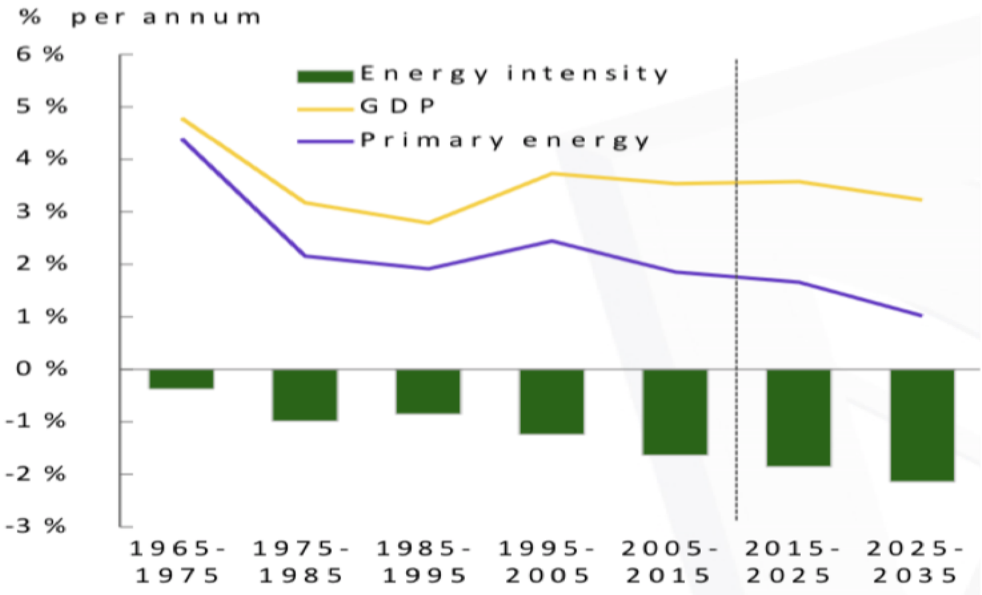


Figure 11: Percentage change in GDP and primary energy consumption[14].

As a result of this increased energy efficiency influenced by technological progress, an increasingly large deviation (or decoupling) over time can be observed between the percentage change in GDP and the percentage change in primary energy demand, The relationship between economic growth and energy demand is mediated by two important factors: technological progress and market price developments.

Technology influences both GDP and the quantity of energy demanded, and it does so because technological change defines the quantity and quality of the final product outputs that we can obtain given a certain availability of production factors.

[13] As a ratio, the lower the value of energy intensity, the higher the energy efficiency of the economic system.

[14] Source: World Energy Outlook 2019 data processing.

Technology also influences energy consumption because through new technological solutions we can obtain better performing products with lower energy consumption and consequently the advancement and progress of technology can help reduce energy demand and optimise consumption.

Changes in the price level determine the value of goods and services, and inflationary or deflationary phenomena can influence the demand for goods and services and thus GDP, which then also affects energy demand. In addition to the prices of goods and services on the market, the very price of energy sources also influences demand. Although energy demand is on the whole partially rigid in the long run, it depends on price changes.

Usually, an increase in prices for the same income will lead to a decrease in energy demand for two reasons:

- Consumers lose purchasing power and thus reduce the demand for energy;
- Consumers lose purchasing power and therefore reduce their demand for energy. As energy prices rise, consumers are driven to buy products that consume less energy to replace older, more energy-intensive products, in conjunction with technological advances in energy efficiency.

The first effect is short-term and leads to a reallocation of consumption within individual baskets in order to maximise utility.

The second effect is long-term and is much more significant than the first because it involves technological progress: technology has to develop new products that need less energy to function. When the oil crisis broke out in 1973, people reduced their consumption of petrol as much as they could, as the price of petrol had risen dramatically. Over the long term, car manufacturers had begun to invest in research and development and developed new cars that were more efficient and consumed less petrol, and the foundations were laid for experiments with electrically driven cars. As the car fleet was renewed, demand for petrol was reduced. The possibility of a reduction in an energy source also occurs in the hypothesis of competition between various alternative energy sources: if one source becomes more expensive, individuals tend to turn to another less expensive one, even if they are sometimes required to incur switching costs in order to change their current equipment to use another service or good that is more appropriate to their circumstances. Let us assume, then, that governments around the world, in order to promote the Let's assume, then, that the world's governments, in order to promote e-mobility, decide to raise the prices of diesel and petrol substantially.

The challenge for the future will be to try to decouple economic growth as much as possible from the amount of energy demanded in order to ensure sustainable development, and to do so requires (Sharma, Smeets and Tryggestad 2019):

- The progressive reduction of energy intensity: the economic structure of a country plays an important role in determining the relative energy intensity. In general, post-industrial economies, where the tertiary sector has a high weight in GDP, have in principle a lower energy intensity than economies characterised by traditional activities, with a large weight of heavy industry. The tertiarization of the economy should therefore lead to a decrease in national energy intensity.
- Improved energy efficiency: thus an increase in the efficiency of energy end-use resulting from both technological progress and consumer behaviour. In addition to the technology factor, which will undoubtedly bring increasingly energy-friendly products with reduced consumption onto the market, it is also necessary to work on changing the behaviour of consumers, who must be trained and educated to understand their consumption and to invest in improving and optimising it. By improving the energy performance of all buildings, both homes and businesses, and by improving the lifestyle and mobility habits of all citizens, significant results can be achieved in terms of reduced environmental impact, without compromising economic growth.
- The growth of electrification and the renewable energy mix: electrifying the energy system is key to meeting the decarbonisation challenge. Electricity, if produced with an energy mix increasingly fuelled by renewables, is a key energy vector and an opportunity to fuel the transition to clean energy on the way to a sustainable and reliable system.

1.3. Climate Changing- Emissions

Similarly, to energy consumption, economic growth has also been steadily increasing over time. Economic growth and energy consumption have been and still are strongly correlated, and if we consider that consumption has always been sustained by a strong demand for fossil fuels, it is clear that there is also a relationship between economic growth and CO_2 emissions into the atmosphere of the planet.

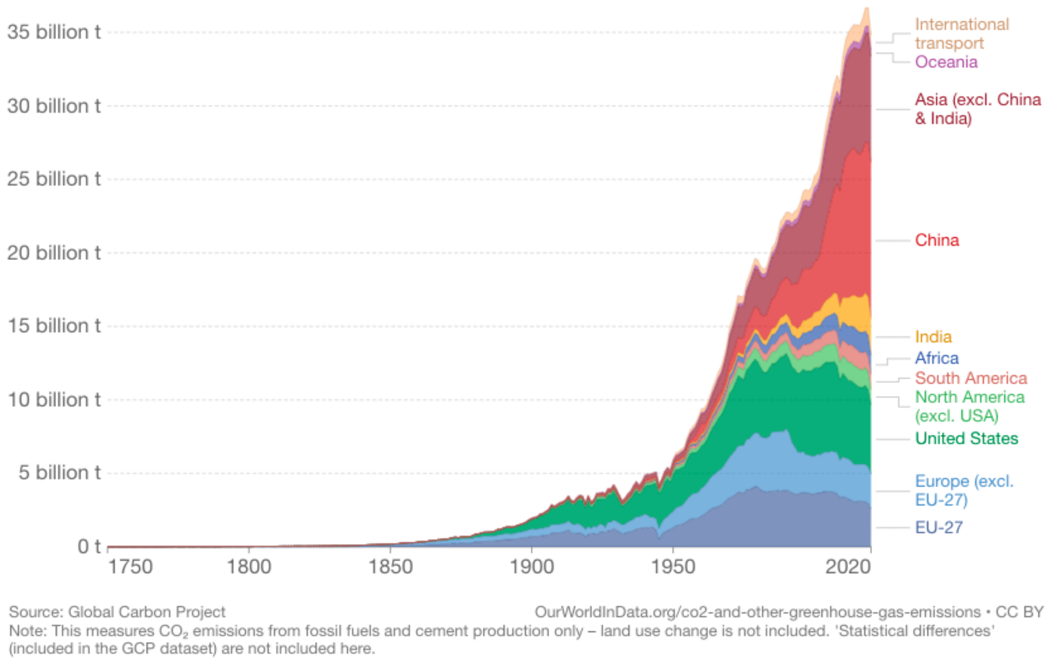


Figure 12: Annual CO_2 emission by World Regions[15].

The graph (Figure 12) shows how, since the second half of the 20th century, climate-changing emissions have increased across the planet as energy demand has grown.
Emissions are also affected by economic recessions: in recessions or when GDP is stagnant, consumption is reduced, fewer goods and services are produced and consequently there are fewer emissions. During the 2020s, as a result of the crisis and lower demand, global emissions were reduced by almost 6% compared to 2019 and five times more than in the 2009 crash of the subprime financial crisis. This 'the more you grow, the more you pollute' paradigm was logically and factually valid until the 1990s. From then on, the awareness of the main industrialised nations of the consequences of emissions on climate change, culminating in the Kyoto protocols, turned the system around and revolutionised the paradigm.
Thanks to energy efficiency, a reduction in the use of fossil fuels, a growth in renewables and new, more environmentally friendly production standards, the process of de-correlating the variable economy and the variable emissions has begun: since

[15] Source: (Ritchie e Roser 2020).

2000, it is possible to observe an increasing deviation between the change in GDP and the change in emissions, and since 2015, GDP has continued to grow, while CO_2 emissions produced annually have remained almost unchanged and have reached a plateau (albeit with a decrease in 2020 of 5.8% from 2019 levels due to the pandemic), but this trend is not strong enough to counteract the ongoing climate change.

Continuing the decoupling trend requires major efforts and even more stringent and binding legislation for countries across the planet. The demand for and production of renewable energies must be boosted, and investment must be made in the efficiency of both the energy production sector and the consumption and lifestyle of the entire population.

In the last 200 years the concentration of carbon dioxide on our planet has doubled and climate change is a global problem, but not all countries behave in the same way: China is now the most polluting country in the world, followed by the United States and the European Union. China's emissions were less than a quarter of those of all OECD developed countries until the 1990s, but in the last three decades they have more than tripled and now about 25% of greenhouse gas emissions come from the People's Republic.

China has promised to achieve zero emissions by 2060, yet the heavy use of coal in the People's Republic shows no sign of abating - in fact, it is increasing. Although China is the world's largest producer of renewable electricity, its reliance on coal remains the most worrying factor in its plan to become climate neutral in less than 40 years, and in the wider context of reducing emissions across the planet.

Without China, there will be no chance of achieving the targets set by the Paris Agreement to combat global warming. On the other hand, Europe, the United States, South Korea and many other nations around the world are aiming to achieve climate neutrality by 2050 in order to achieve a balance between emissions and removals. The European Union is aiming to get rid of coal by 2025, while China has announced that it will continue to increase coal use until 2030, when it is expected to phase out coal.

In the United States, the world's second largest producer of CO_2, emissions have been falling since the great crisis of 2008, and in 2020 40% of energy demand has been met by renewable sources, which have grown significantly in the last decade. And it is precisely on renewables that President Biden is focusing, allocating a good part of the

2 trillion dollars of the American Energy and Infrastructure Plan to them, to make photovoltaic and wind power the real protagonists of the energy transition from 2030. The USA has also announced that it intends to cut emissions by 55% by 2030, to honour the commitment made during the Paris Agreement (a commitment neglected by former President Trump) and to follow the good intentions launched with the Fit for 55% package by the European Commission.

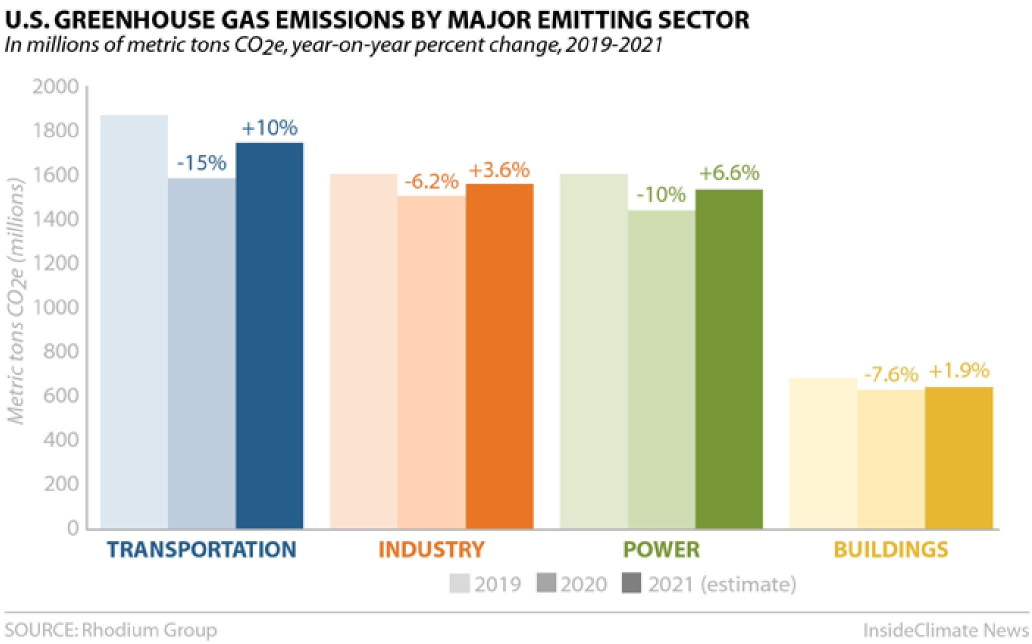


Figure 13: U.S. Greenhouse Gas Emissions and Sinks by Economic Sector,USA, 1990–2019[16].

In Europe, greenhouse gas emissions were reduced by 22% between 1990 and 2018[17] while economic growth continued to exceed 60%, proving that it is possible, through more sustainable development, to increase the differential between GDP and emissions.

Most of Europe's emissions come from combustion activities and since the 1990s there has been a gradual reduction of about 10%. The same cannot be said for the transport sector, which has seen its share of climate-changing gases increase by 10% over the last 30 years. Similarly, overall greenhouse gas emissions in Italy decreased by 24% between 1990 and 2018, while those from the transport sector increased.

[16] Source: U.S. EPA,2021.
[17] Source: (EUROSTAT), European emissions by sector (1990 and 2018 comparison).

The transport sector currently accounts for almost 25% of energy-related CO_2 emissions worldwide and is one of the sectors on which future policies and technological investments will have to focus to reduce its environmental impact.
Moreover, as Figure 14 shows, emissions fall fastest in the energy sector, while transport, buildings and industry see a steady decline until 2050. Reductions are helped by the increased availability of low-emission fuels.

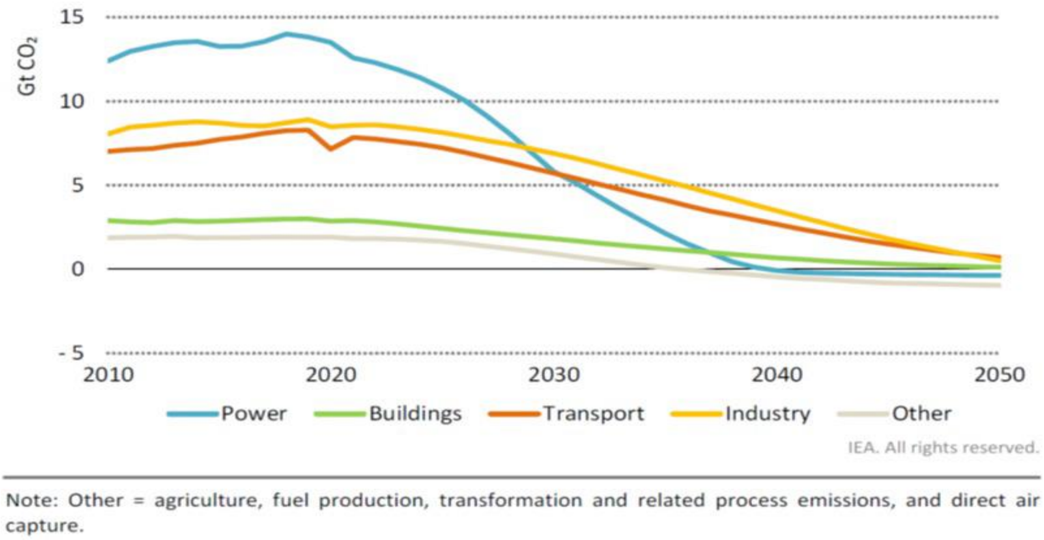


Figure 14: CO_2 emissions by sector.

According to analysis by the International Energy Agency, under current policies and without decisive action by governments, energy demand in this sector will double by 2050 and related emissions will grow at around twice current levels. To prevent this, we need to decarbonize the sector, focusing on electrifying mobility and generating energy from renewable sources. Even before the decarbonization targets were set, the European Union, which had already realized how dangerous the impact of transport on the air was, introduced a series of regulations in the 1990s (most recently in 2015) in which it set specific standards (Euro 1, 2, 3, 4, 5, 6) to regulate the maximum tolerable emissions thresholds for vehicles sold on European soil, thus imposing limits on car manufacturers to encourage sustainability and the ecological footprint of the market.
In addition, to combat climate change, Europe's institutional and economic response was the creation of the Emission Trading Scheme (ETS). This is the world's first CO_2 market and has the effect of limiting the emissions produced by more than 11,000

energy-intensive plants (power stations and energy-intensive industrial plants) and the airlines that link the 31 countries participating in this system. The current target is a 43% reduction in emissions from 2005 levels for all ETS participants.

The idea of creating an international emissions trading market was born in the context of the Kyoto Protocols, when an economic instrument was envisaged to direct the most polluting actors in the system to pollute less. The ETS was introduced and regulated in European legislation with Directive 2003/87/EC and came into force in 2005. The system is based on the "Cap and Trade" principle, which establishes an overall cap on the emissions allowed on European territory that is matched by an equivalent number of emission allowances, which can be sold. All industrial or aeronautical operators that fall within the subjects specified by the Directive are assigned a "cap", a maximum threshold of tolerable CO_2 emissions, and a maximum number of free allowances (free of charge to avoid the risk of relocating industrial production to countries with much more flexible environmental standards).

In order to emit climate-changing gases, the companies involved must obtain a permit from a competent national authority, which assigns them a number of allowances corresponding to the emissions calculated on the benchmarks of the most efficient plants (Viessmann Industrial 2019).

Every year, those obliged by the Directive have to communicate their emissions, calculated on the previous calendar year, and the most virtuous companies, i.e. those that emit less CO_2 than the allowances in their possession, can resell the surplus allowances on a specific market that works like the financial stock exchange or they can keep them to cover a possible increase in energy needs (and emissions) in the future; less virtuous companies, on the other hand, are forced to buy more allowances than they own to compensate for excess emissions, and companies that do not surrender the exact amount of allowances are subject to specific penalties for each ton of CO_2 not covered (Viessmann Industrial 2019).

The system has been modified over time and the maximum "caps" have been lowered in relation to specific continental emission containment targets and compensation mechanisms have been introduced to keep CO_2 allowance prices above a certain threshold to avoid penalising market performance.

The mechanism, which has worked well so far, is based on the principle of bonus/malus, which rewards the virtuous and penalizes the worst, and is the principle that more and more countries are adopting to encourage a reduction in the purchase of polluting vehicles in the car market.

1.4. The demand of mobility

In Europe, transport is responsible for a quarter of climate-changing emissions, caused mainly by road transport. Our society's demand for mobility is also very high and the use of the car as the preferred personal means of getting around has been the answer to this demand.

In our country, demand for mobility picked up between 2017 and 2019 after a long period of decline which, although varying from year to year, had taken hold since the economic crisis of 2008 onwards.

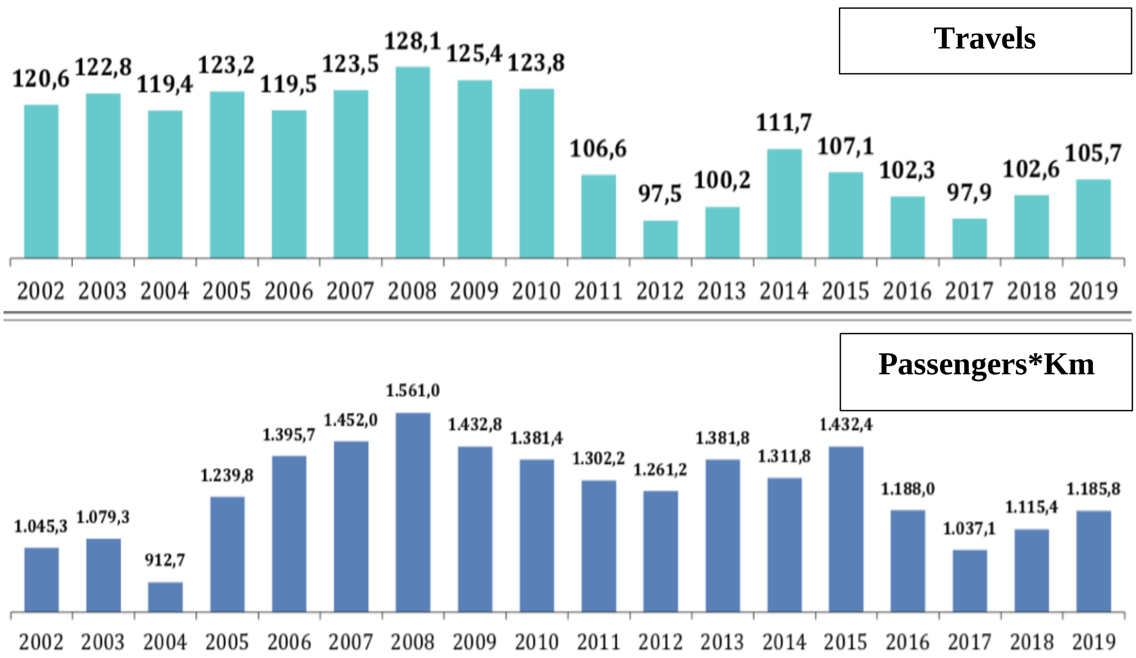


Figure 15: Number of total trips and passengers per km on the average weekday (in millions)[18].

According to data from the Audimob observatory, the demand for mobility has changed as follows:

	2002-2019	2008-2019	2017-2019	2018-2019
Spostamenti **totali** in un giorno medio feriale	-12,4	-17,5	+8,0	+3,0
Passeggeri*km **totali** in un giorno medio feriale	+13,4	-24,0	+14,3	+2,7

Figure 16: Evolution of Italians' demand for mobility from 2002 to 2017 (% changes)19.

[18] Source: (ISFORT 2020).
[19] Source: (ISFORT 2020).

The demand for mobility, just like the demand for energy, is also related to emission values, which in turn are related to the change in gross domestic product and thus to economic growth. The trend in GHG emissions in the transport sector follows the trend in mobility[20] and the whole is closely related to gross domestic product[21]. During recessions, crises limit consumption and also limit the need to transport goods, services and people. In a context in which the value of production falls, fewer goods are produced, many people lose their jobs and therefore mobility is also limited. This whole chain of consequences therefore leads to a reduction in emissions at both systemic and sectoral levels, including in the transport sector. Italy, which suffered severely from the 2008 crisis and then the sovereign debt crisis (Mario Draghi's famous "Whatever it takes" crisis) in 2011, has recorded negative falls in gross domestic product and this is reflected very well in the trend of average distances travelled by Italians and in mobility demand in general. The demand for mobility is more distributed among students and employees living in municipalities with more than 50,000 inhabitants, aged between 14 and 45, and the main reasons for travel are work, study and leisure.

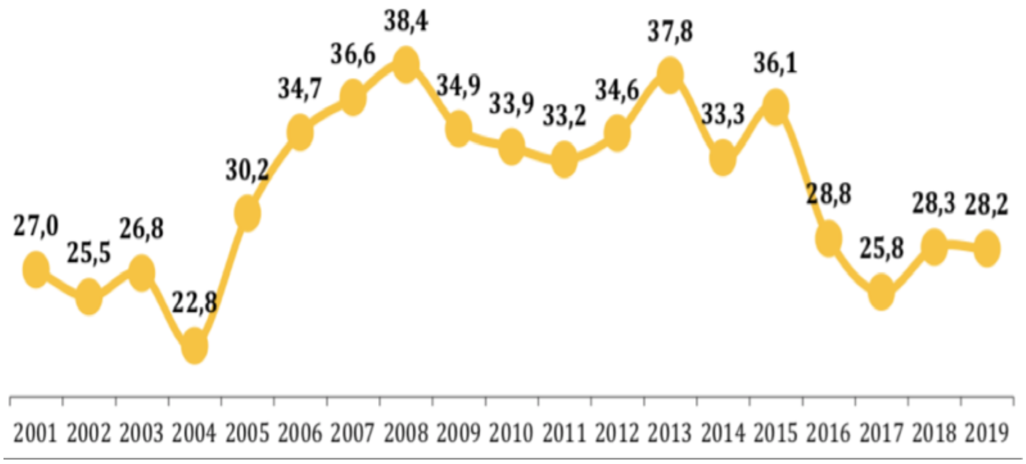


Figure 17: Average distance travelled per capita in kilometers (reference to average weekday)[22].

[20] Source: (EEA 2020).
[21] Source: (Terna S.p.A. 2020).

[22] Source: (ISFORT 2020).

Figure 18: Average per capita time spent on mobility in minutes per day (reference to average weekday)[23].

The backward trend in demand is clearly visible in the average distance travelled each day by citizens (28.2 km) and in the time spent travelling, which is by no means homogeneous because it is correlated with socio-ana graphic data: on average, men move more than women, younger people move more than the elderly and those who live in larger urban centers spend more time on mobility than those who live in less populous municipalities. Urban mobility, as a result of progressive urbanization, has been growing more and more: its weight has increased from 62.6% in 2008 to over 73.9%. The mobility rate, i.e., the percentage of citizens who made at least one trip on an average weekday, was 85.3% in 2019, a figure that fell sharply in 2020 due to the pandemic lockdown. If we look back over the last year and a half that we have all experienced, we can see that our lifestyles have changed considerably, just as our way of getting around has changed. The new organization of work and study with smart working and smart universities and the measures to contain them have affected mobility, which has been increasingly reduced even in the case of leisure-related travel. In a context of social distancing, home-working and fear of contagion, public transport took a hit, unlike the private car, which was perceived as safer. During the period of the first lockdown in our country (from mid-March until around mid-May 2020), there was a vertical drop in demand volumes compared to the ordinary 2019 regime, estimated to be over 65% fewer daily trips and over 80% fewer passengers per km. The effect of the travel-only rule has had a strong impact on daily travel per capita and average trip length. At the same time, the mobility rate decreased from 85% on average in 2019 to 32% in the lockdown period (ISFORT 2020). As a result of the pandemic, proximity and

[23] Source: (ISFORT 2020).

walking trips have grown much more, and this process has had a more pronounced impact in large cities than in small towns. Demand for mobility has dropped considerably as a result of the behavior of the elderly (the so-called at-risk individuals) and of young and very young students, due to the total closure of schools and universities, many of which have continued with distance learning after the openings**.** Just as the pandemic has affected travel, it has also had a significant impact on the automotive market: the crisis has led to a systemic collapse in registrations in 2020 of around 15% compared to the previous year's sales volumes, and the market in Europe has fallen by almost 24%. In spite of this hard blow, the only vehicles that have not been affected by the crisis at all have been electric vehicles, which, unlike petrol and diesel vehicles, which have fallen by up to 50%, have continued to grow, reaching unprecedented volumes, especially in China and Europe.

1.5. What solutions can be applied to the transport sector with a view to decarbonization?

Transport is responsible for 25% of the continent's emissions and to decarbonize the system, policy makers need to take measures to reduce mobility needs while opting for more environmentally friendly modes - such as cycling, walking, public transport, shared mobility and electric cars - and promoting the development of increasingly efficient technologies (Greenpeace 2020).

The Green Deal's targets include a 90% reduction in transport-related greenhouse gas emissions by 2050, which means focusing on clean electricity generation, green mobility, hybrid and full-electric technologies.

In order to combine the objectives of the PNIEC and the European Green Deal with a view to the future, traditional mobility must undergo an epochal change and be revolutionized. The PNIEC has set the following targets for 2030: the registration of 4 million electric cars to reach the quota of 6 million electrified cars in circulation, adding the 2 million plug-in hybrids. This is not an easy goal to achieve, since electric mobility requires not only constant technological development but also a cultural revolution in the minds and actions of citizens and consumers.

On 10 December 2020, the Commission presented a strategy for sustainable and smart mobility, which, together with regulations on limiting vehicle emissions, sets out a roadmap to put the European transport sector on the right track for a more sustainable future. The strategy's objectives include having at least 30 million zero-emission vehicles in circulation by 2030, as well as doubling the number of high-speed rail lines to keep freight traffic off the roads as much as possible, thereby reducing pollutant emissions from truck exhausts. The advance of electric mobility is certainly the future in the landscape of the coming years. It is inevitable and paradigmatic, starting now, since the European Commission has decided to accelerate the pace of change and has proposed a halt to petrol and diesel car sales from 2035.

The ecological, energy and vehicle transition will therefore be the basis of the new development model on a continental scale and has been identified as a priority by the whole world.

The legislative revisions introduced globally to reduce greenhouse gas emissions and to change the fuel mix represent a unique opportunity to take a step forward and win the race against time for the climate.

The pandemic has taught us how difficult it is to live in a sick and severely restricted world. To draw a parallel, the world we will face if we do not tackle the challenge of climate change with commitment and determination will still look like this: sick. Catastrophic weather events will become more frequent and cities will be so polluted that it will be impossible not to wear a mask to breathe. Although a mask is necessary today to avoid infection, it can also often be cumbersome and uncomfortable... so let's avoid prolonging its use because of excessive air pollution!

It is essential that each of us prioritizes any efficient and sustainable way to decarbonize the system and impact the planet as little as possible. Electric cars, car-sharing, public mobility, waste recycling... all small actions that when added together and proposed on a large scale can really make a difference in the long run. We are all aware of the change we are going to have to face and, since it is inevitable, we should start accepting it and maybe even ride the wave to understand it and accelerate it as soon as possible.

The revolution has begun, we are in it now.

The new millennium is not only a digital revolution, but also an environmental and energy revolution. Digitalization is a pivotal phenomenon that involves everything, including electrification of the system and decarbonization.

The behavioral revolution that will lead us all to become increasingly aware of the change is also taking place through the object we always hold in our hands: the mobile phone.

In a world where the majority of human beings in industrialized countries interface with life, studies, work and even love via social networks, it is important that all players in the system, including governments, work even harder to harness the potential of digital technology to communicate in real time with millions of users and raise awareness of change in the world.

In the following chapters, what has just been mentioned in this paragraph will be dealt with, in particular different methods will be proposed to reduce cCO_2 emissions: Circular economy, with a focus on car sharing and buy sharing; acceleration of the decarbonization process through incentives that favor the transition to the purchase of an electric car, focusing on the role played by uncertainty in the process of defining incentives; behavioral economics and a questionnaire aimed at analyzing the barriers to the purchase of an electric car, with the objective of proposing solutions that can reduce them.

CHAPTER 2: CIRCULAR ECONOMY IN THE AUTOMOTIVE SECTOR: THE ROLE OF BUYBACK. CAN BUYBACK REDUCE CO_2 EMISSIONS? IS THAT ENOUGH?

2.1. The important Role of Circular Economy

In this context of change, has to be stressed that the historical context in which we live is teaching us that we can no longer procrastinate and that has come the time to implement a change in both thinking and action.

The circular economy comes into play, enhancing the concept of reusing production waste, extending the life cycle of products, sharing economy, using recycled raw materials and energy from renewable sources. This new model of sustainability and development, this radical change in thinking, can be attributed to the need to react to the clear signs of crisis sent by the planet regarding the unsustainability of the linear economy model, oriented towards consumption, substitution and underuse of products.

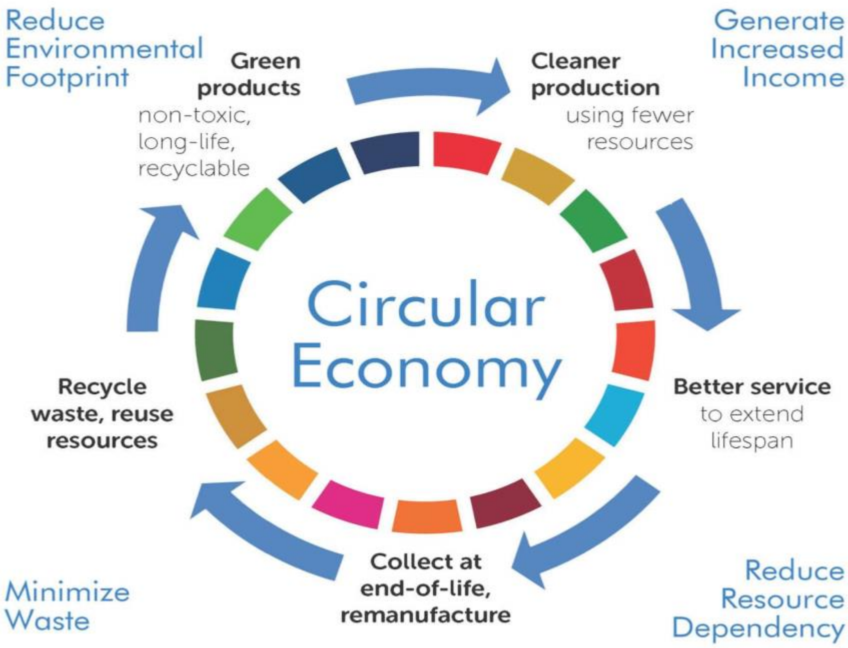


Figure 19: Model of Circular Economy.

2.2. The environmental unsustainability of the linear model

The growth model favoured by economies to date has been that of the linear economy, characterised by a "take - make - dispose" production process. This linear process has four stages: the first stage involves the extraction and/or acquisition of raw materials to be subjected to the second stage, the manipulation and transformation of production, in order to obtain the finished product to be marketed to the consumer; the third stage, consumption, precedes the end of the product's life cycle, which inevitably ends with its direct disposal in landfills.
The critical points of this type of supply chain can be summarised under the following headings:

- Economic inefficiency: the product is used at about 50% of its potential, as there is no valorisation of the good in the post-consumption phase, and for a substantially limited period of time. The life cycle of "linear products", in fact, is substantially linked to a single use or to a few consecutive uses, depending on the nature of the asset considered.
- Exposure to systemic risk: the over-dependence of the production process on supply markets results in complete exposure to price volatility and lack of availability of raw materials.
- Excessive landfilling and erosion of natural capital: the linear model, due to the short life span of goods and the lack of intrinsic predisposition of their components to reuse, significantly increases environmental pollution, mainly due to the excessive use of landfills. In addition, ever-increasing mass production with increasing efficiency demands is using the regenerative capacities of land, forests and water beyond their intrinsic limits.

It is clear, therefore, that the only context capable of making the linear model sustainable could be one in which resources are abundant and available at a good price on the market, so as to allow companies to transform, while maintaining high standards of efficiency, materials available in nature and on the market into goods that meet growing consumer demand and that can be disposed of at the end of their life cycle using environmentally sustainable methods.

The current context, characterised by rapid population growth, is very different from the above. According to estimates in the document "Towards the Circular Economy", drawn up in 2013 by the Ellen MacArthur Foundation, the linear "take-make-dispose" model will not be sustainable in the long term. The number of middle-class consumers is expected to increase by about 3 billion by 2030, most of whom will be Pacific Islanders, and this population growth will result in greater demand for consumer goods.

The growing demand from emerging or established economies could lead to an exponential increase in the demand for raw materials which, being limited on our planet, would cause greater price volatility and higher input costs, precisely because of their scarcity; all of which translates into lower product quality, due to the attempt to maintain an adequate profit margin for manufacturing companies despite everything.

- Resource scarcity: according to the projections in the "Global Resources Stock Check "[24] of 18 June 2012, the continued use of commodities crucial to modern economic growth, such as oil, copper, cobalt, lithium, etc., in the current manner is expected to lead to their inevitable depletion within 50-100 years.
- Increased price volatility in key supply markets: Linear business is set to produce an ever-widening imbalance between supply and demand for resources, which will put increasing pressure on both businesses and households by driving up prices. Accenture analyses show that the price index doubles even over limited time spans of about 10 years. In such a scenario, when resources are exhausted, companies that have remained tied to traditional production methods will be forced to stop production, leaving much of the demand unsatisfied. If, on the other hand, supply does not come to a complete standstill, the limited availability of resources could push up prices to prohibitive levels for certain categories of companies.
- Escalating geopolitical tensions: Acute resource scarcity has always been a source of tension between nations; suffice it to say that at least eighteen conflicts over natural resources, such as diamonds, timber, and cocoa, have occurred in the last twenty years. These conflicts have not only caused social

[24] http://www.bbc.com/future/bespoke/stock_check.html

unrest but have also led to the 'collapse' of many peace agreements, especially in regions with weak governance.

- Degradation of ecosystems: in 2009, a group of scientists quantified a new set of nine planetary boundaries,[25] exceeding which would result in irreversible and harmful damage to the environment. The Earth is already known to have exceeded three of them: the loss of biodiversity, the concentration of assimilable carbon dioxide and the fixation of atmospheric nitrogen. The current pattern of growth is producing irreversible impacts on climate and the ecosystem, from melting glaciers to the complete extinction of much of the marine ecosystem.

The Global Footprint Network, referred to in the previous section, has also explicitly stated that the world is using the equivalent of the resources of one and a half planets each year, using about 50% more resources than the Earth is able to regenerate and absorb pollution.
It is possible to conclude, after this brief analysis of the traditional economic system and its criticalities, that this is an economic model that is incompatible with the current availability of resources, and it is, therefore, necessary to develop and rapidly implement a new model of value creation such as the circular economy.

2.3. From Linear to Circular system: Implications

The circular economy is the new way of conceiving production characterised by the recovery and valorisation of waste. Following the definition of the Ellen MacArthur Foundation[26] (2012), the Circular Economy is precisely an "economy designed to regenerate itself where activities are organised so that someone's waste becomes a resource for someone else".

[25] Rockstrom, J., W. Steffen, K. Noone, A. Persson, F. S. Chapin, III, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. Schellnhuber, B. Nykvist, C. A. De Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sorlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Karlberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary boundaries:exploring the safe operating space for humanity. Ecology and Society 14(2): 32.
[26] Ellen MacArthur Foundation is an international organisation with the declared objective of accelerating sustainable transactions.

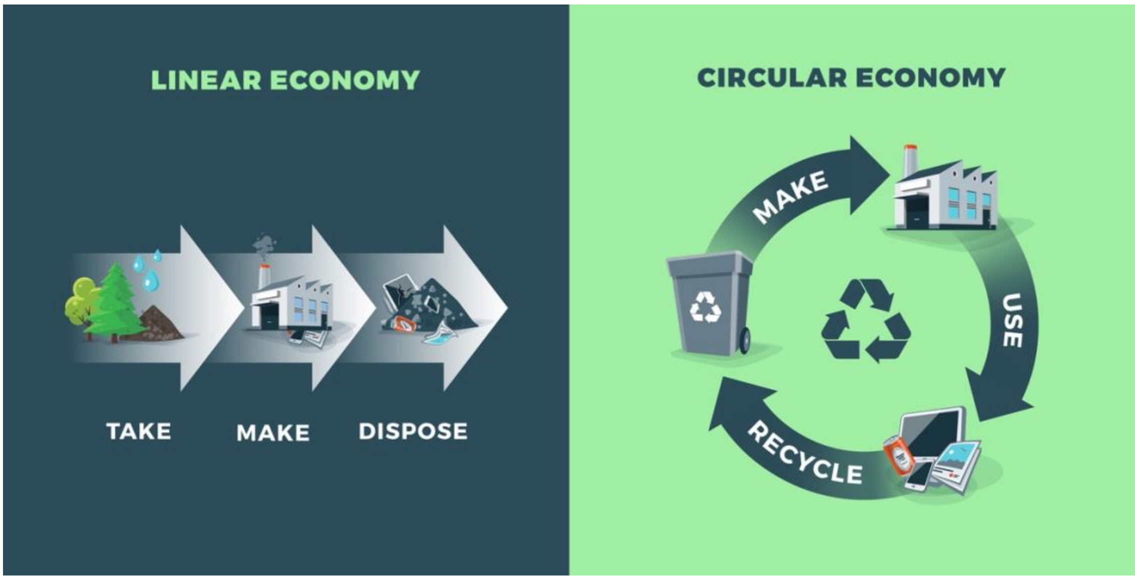


Figure 20: The transition from linear and circular economy.

In order to make a transition from linear to circular model, it is necessary to fulfil three basic principles, in order to move from the destruction of matter to the revalorisation of waste. These three principles are the following:

1. Use the discarded material as a source for new deposits, limiting processing as much as possible: in this context, one can distinguish between waste collection, recycling, management of production output, functioning objects thrown away due to incorrect stock management.
2. Put an end to wasteful use of the product even before it is discarded: eliminate the habit of not using products, such as in warehouses of discarded goods or items locked in boxes in the attic. This creates a useless collection of goods that have not been put to good use.
3. Stopping the premature death of matter: this step focuses on the disposal of products in which only one part is damaged. Theoretically it would be sufficient to repair that part, but in most cases it is cheaper to replace the whole object. This disposable use causes enormous damage to the environment as well as a waste of material and energy.

From these three basic principles, it is clear that the circular economy consists of a regenerative and reconstitutive industrial system, in terms of both ends and means, replacing the concept of end-of-life with that of transformation, valorising each of its components in a closed, efficient circle, broken down into its basic elements, using renewable energy, eliminating toxic elements, relaunching reuse or ensuring that its chemical elements can safely return to the biosphere.

In this way, the use of matter is maximised, exploiting it as much as possible, putting the unused and immobilised matter on a par with waste and scrap, making waste itself a new disassembled material ready to return to the industrial cycle. There are more and more products on the market made up of non-toxic biological elements and nutrients, which at the end of the product's life return to the natural cycles of the biosphere. On the other hand, products made of materials that cannot be reabsorbed by the biosphere must be designed from the outset for reuse, be easily upgradable and disassemble able into parts (Bompan and Brambilla, 2016).

Another very important factor is the type of energy used in the various processes. If fossil fuels were still used, the process would not be sustainable at all, so renewable energies provided by nature should be used, preferably avoiding the use of biomass as fuel, as this would still be combustion and would release greenhouse and toxic gases for the biosphere. This eliminates dependence on non-renewable energy sources and increases the resilience of the system to scarce sources. Using non-renewable energy and significant amounts of water for recycling or waste management is a fundamental violation of the principles of the circular economy. Therefore, using this economic model requires controlling any production process (Bompan & Brambilla, 2016).

From these concepts, it can therefore be summarised how production processes or activities can be considered circular. In order to implement the mechanisms of the circular economy and thus realise all the benefits outlined above, it must be possible to satisfy at least one of the following three principles, which encapsulate the very meaning of the circular economy:

1.Preserving and improving natural capital by controlling its finite endowments and choosing more efficient and environmentally friendly technologies and production processes, i.e. using renewable energy sources.

2.Optimising the profitability of resources by keeping products, components and materials at their highest value content at every stage of their life cycle.

3.Promote the effectiveness of the system as a whole through the identification and elimination of negative externalities. (Marchiori, 2017).

2.4. Benefits and limits of Circular Economy

Although the implementation of a circular model may initially entail a sharp increase in the costs of running circular loops, it has been amply demonstrated by international 'circle-jumpers' that the benefits to industry and consumers, as well as to the environment and society, outweigh the limits of applicability of the circular economy. From a purely industrial perspective, the adoption of a circular business produces substantial net material savings and the consequent reduction in the use of supply markets, which results in a mitigation of exposure to supply risk and price volatility. In addition, the adoption of a recycling supply chain and the increased focus on product design are driving companies to invest heavily in research, operating at increasing rates of technological development. A positive consequence of the increased propensity to innovate is an increase in the efficiency of resource use, which leads to a significant increase in productivity.

From a social point of view, the promotion of after-sales support to consumers for the maintenance of goods, the establishment of remanufacturing industries and the entire recycling chain, requiring specialised professionals, which stimulate job creation, restore vitality to the labour market.

Finally, in terms of environmental protection, it is believed that the valorisation of materials, as envisaged by the circular approach, the production of secondary raw materials to be reintroduced into production processes, and the increasing use of renewable energies, reducing the extraction of natural resources and the emission of harmful substances into the atmosphere, should slow down the degradation of ecosystems and reduce the associated meteorological consequences.

On the other hand, one of the main limitations of the circular economy is the need to 'close cycles' both physically and geographically to facilitate the smooth transfer of materials from one stage of the value chain to another. This distance, which is a direct consequence of the growing internationalisation of the main companies, can be overcome by creating an industrial district, i.e. by concentrating companies and skills in the area within a geographically limited area.

A further critical point linked to the circular model is the maintenance of high product quality standards, despite the irreversible loss of purity of the materials, which are

repeatedly subjected to the processing and enhancement of consecutive production cycles. In this case, there is no choice but to place trust and funds in investments aimed at improving techniques for the valorisation of production residues.
In addition to the main criticalities in the application of the new circular model, there is the inadequacy of policies to incentivise the transition, which are often insufficient and ineffective, since they involve only some stages of the value chain. It is therefore necessary for legislative bodies to intervene in order to overcome consumer and producer resistance to the adoption of the new business model.

2.4.1. The "Collaborative Consumption" model

One of the main foundations of the circular economy is the replacement of the concept of consumer by that of user (EMAF, 2010). In the model of the linear economy, the rational consumer buys goods and services under perfectly informed conditions and carries out the sorting and disposal of waste correctly. However, aspects such as hyper-consumerism, short product life cycles and planned obsolescence are the main shortcomings of today's consumer-side 'buy and consume' economic model.
In order to remedy these limitations, companies and customers need to bind themselves in contractual relationships based on product performance, and achievable through the introduction of new 'circular' business models that adopt products characterised by high durability, and that provide for the return of goods after use, thus also encouraging their reuse.
The transition from the concept of consumer to the one of user is marked by the introduction of "collaborative consumption" business models, in the wake of the "sharing economy". These models are based on the shared use of certain types of commodities, and determine a consumption based on sharing, exchange, barter, rent and loan of goods no longer useful to the consumer or underused, or other assets such as land, between groups or between individuals[27]. According to Rachel Botsman, author of "What's mine is Yours: The Rise of Collaborative Consumption", the phenomenon of the "sharing economy" has become more widespread in recent years due to a number of factors: online connectivity, which makes shared networks

[27] Botsman, R. (2010). What’s Mine Is Yours.

accessible everywhere, technology and environmental awareness. The sharing of information, photos and music is now extremely widespread, so it is not surprising that the digital sharing model has been applied to physical goods.

These forms of consumption already have a long tradition at the local level, but the advent of peer-to-peer platforms and clouding technologies has made it possible to carry out micro transactions (location-based) on a global scale, thus disrupting traditional patterns of production-consumption of goods and services (some of the best-known examples are Airbnb and Uber). Technology has substantially reduced transaction costs and has therefore made the sharing of goods easy and inexpensive, making it possible on a much larger scale.

The collaborative consumption models, therefore, are models that allow consumers, or rather groups of consumers and communities, to share the use of a service and the value of a physical product by coordinating (almost always) through a computer platform (digital economy). This is in total opposition to the classic model of individual consumption based on product ownership and exclusive consumption (until exhaustion).

The adoption of collaborative consumption models makes it possible to replace the consumption of products with the consumption of services, with the consumer becoming a user, i.e., one of the users of that product.

In other words, everything that one can live without on a daily basis can be provided by the "collaborative" networks when the need arises; while everything that is necessary for daily survival (washing machine, PC etc...) can be provided by the producer, who continues to maintain ownership of the good. Once again it emerges that the effort of the consumer, not to act as a buyer but as a user, is fundamental.

In this way it is possible both to limit the number of products of a certain type in circulation in the economic system (hence less consumption of resources, less waste produced etc...) and on the other hand it is possible to maximise the rate of use of the products and therefore of the materials used within the economic system.

Collaborative consumption models are seen as one of the main customer/consumer-side tools to achieve the transition to the circular economy. Botsman and Rogers (2010) define these models as potentially able to destroy the phenomenon of hyper-consumerism while favouring a fairer and more sustainable distribution of resources among the population. In addition, this consumption pattern is considered to have the

potential to reduce environmental impacts, reduce energy consumption and thus emissions directly or indirectly (FORA, 2010). Other co-benefits demonstrated by EEA (2016) are the creation of new jobs[28] and increased social interactions and cohesion.
In practice, consumers could access services offered by companies based on the use of physical products made by the company itself. Such a business model would incentivise companies to make more reliable, durable and repairable goods, thus aligning with the circular economy guidelines and still allowing companies to make profits on the services they offer rather than on the products they sell.

2.4.2. How a circular economy cuts greenhouse gas emission

Without a circular economy, there can be no ecological transition. And the chances of avoiding a climate catastrophe by honouring the 2050 commitments made at the 2015 UN summit in Paris are linked to relaunching the circular economy, on which 39% of CO_2 cuts depend. However, to achieve this goal, we need to double the current rate of circularity of goods from 8.6% to 17% at global level[29]. The focus of this year's National Report on the Circular Economy in Italy 2021, produced by the CEN-Circular Economy Network, is on the contribution of the circular economy to the fight against climate change. According to the Circle Economy's Circularity Gap Report 2021 - which measures the circularity of the world economy - doubling the current circularity rate from 8.6% (year 2019) to 17% could reduce material consumption from the current 100 to 79 gigatons and cut global greenhouse gas emissions by 39% per year.
A number of official European documents highlight the link between reducing emissions and the circular economy. The 2030 Climate Target Plan, a document supporting the introduction of the new European targets set in 2020, explains how

[28] Webster argues that the amount of labour input employed in the circular economy is higher because: a) economies of scale are limited (in terms of volumes and their geographical distribution); b) repair and reconditioning require additional steps that are not present in traditional processes (e.g. quality control, removal of defective parts, repair, etc.). However, there are currently no detailed estimates of the impacts of the circular economy on national labour markets. It should also be noted that employment is at the heart of the social dimension of sustainable development.
[29] Data identified by "Rapporto Nazionale sull'economia circolare in Italia 2021", now in its third edition, produced by the CEN-Circular Economy Network - the network promoted by the Foundation for Sustainable Development together with a group of companies and business associations - in collaboration with ENEA.

achieving circularity can lead to a reduction in the economy's dependence on primary resources and related industrial and energy emissions. In its Action Plan for the Circular Economy (2020), the European Commission focused on circularity as a prerequisite for climate neutrality.

In the Commission document 'A Clean Planet for All. Long-term European strategic vision for a prosperous, modern, competitive and climate-neutral economy' (2018) the circular economy is mentioned, together with lifestyles, as one of the most cost-effective policy choices to cut emissions. The document points out, for example, that every tonne of recycled plastic saves the equivalent of one car's annual emissions. That the use of materials can lead to a 28% reduction in global raw material extraction by 2050 and a 63% reduction in related emissions (which in 2015 were 23% of total global greenhouse gas emissions).

In addition a study commissioned by the European Environmental Agency EEA (Deloitte, 2016, Circular economy potential for climate change mitigation) concluded that circular actions in non-energy sectors "can have a modest but valuable impact on GHG reduction in all sectors and at different stages of the product life cycle in Europe".

By 2050, the report estimates that the GHG abatement potential is up to 550 Mt CO_2 eq (million tonnes of carbon dioxide equivalent) per year in Europe, equivalent to around 10-18% of total GHG emissions projected for that year (base case).

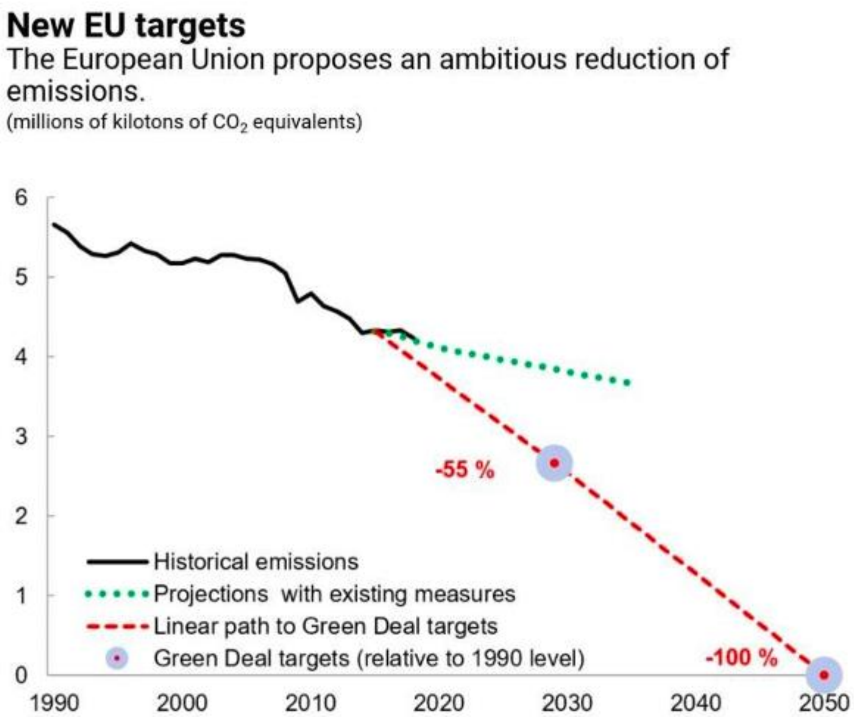


Figure 21: The European Union proposes an ambitious reduction of emissions (millions of kilotons of CO_2 emissions).

Actually, research on the climate mitigation potential of circular economy actions is growing; EEA has sought a more direct way to identify and compare which circular economy actions, individually or in combination, can provide the greatest climate benefits. Therefore EEA, together with a consortium of European experts, has developed a new methodology. It combines the advantages of various approaches to quantify the potential impacts of circular economy actions, requiring only limited investment in modelling. This methodology takes a step-by-step approach to identifying, prioritising and assessing the relative benefits of changes that can increase circularity and reduce GHG emissions in a given sector. The approach also links to European and international climate reporting frameworks and helps identify how emission reductions from circular economy actions can be accounted for in reporting on climate mitigation targets.

2.5. Circular economy in the automotive sector

An obvious example of adherence to the circular economy model in the automotive sector would clearly be short- and long-term rentals and car-sharing.

For all of these alternatives, it is possible to identify a phase of use by the consumer, who does not purchase the car and therefore does not assume ownership. Clearly, reference is made to very different services from one case to another, but the common factor is the return of the asset at the end of the service, an asset that can then be reused.

In the case of long-term rentals, the car is completely at the consumer's disposal for periods ranging from 12 to 60 months, at the end of which it is returned to the rental company, which can rent it again or sell it as a second-hand car. The main users of this type of service are small and medium-sized enterprises, which can thus save on their budgets by not having to write on their payroll all the costs of the staff who would eventually have to look after the car fleet, as well as of course saving on the actual purchase of cars for company or private use.

Short-term rental provides for very flexible formulas for the use and management of the car, with durations ranging from a minimum of one day to a maximum of six months. As will be seen later, at the end of the rental period these cars can be kept by the rental company, which can choose whether or not to sell them as used cars, or bought back by the manufacturer who can resell them as used cars through its dealers.

Car-sharing is a very different phenomenon, where the consumer can use the car even for a few minutes, by booking it through an app and, after the use is over, it can be used by whoever needs it at that moment. As an example, the utilisation rate of cars is less than 10%. Car sharing is an effective solution for increasing the utilisation rate of cars (as a physical product) by replacing car ownership with shared use by several individuals.

Businesses and consumers are increasingly moving towards the circular economy model.

2.6. Is the Buyback process a sustainable option?

2.6.1. Historical background

For years, car manufacturers and dealers have tended to exclude used cars from their business, thinking that their efforts should be concentrated on selling new cars, which have higher price levels aimed at wealthier buyers.

However, the importance of the used car market has grown significantly with the advent of the new millennium. In both the United States and France, for example, the used/new sales ratio, which shows the level of activity in the used car market, rose from 2.4 in 1999 to 2.6 in 2007, showing a steady growth in used vehicle sales by volume. This could be due to a reduction in consumers' willingness to pay for new cars, which in turn is a consequence of the economic contraction: already in the decade 1995-2004, the production of complete cars and chassis contracted by 20% compared to the decade 1985-1994[30].

The most important success strategy in the used car business was probably the development of initiatives that made the consumer more "confident", such as the certification programmes for used vehicles by the parent company. These programmes made companies more competitive and allowed dealers to significantly improve margins, while at the same time providing an additional source of profit for OEMs, who were able to market high-quality off-lease vehicles that were perceived as "better" by consumers.

With the improvement in the quality and perception of used vehicles and the popularity of certification programmes, used cars, especially newer models, increasingly became a viable substitute for new vehicles.

The used car market was no longer just one in which second-hand cars were sold by private individuals, but also included sales of vehicles by companies, previously used vehicles by manufacturers, rental and leasing companies.

2.6.2. Introduction to the model

It is a common strategy among producers of durable goods to meet consumer needs through different channels. For example, in order to meet the demand for daily or short-term rentals, car manufacturers sell some of their new cars to rental companies; in order to meet the need of consumers who want to own a car on a long-term basis, they sell new cars to dealers who in turn resell them to customers. It could therefore be said that car manufacturers sell their products through two main types of intermediaries, which serve two different and not competing consumer segments. However, the demand for short-term rentals has increased sharply over the years, while the average time for which rental companies hold cars has decreased. In the second period, however, these cars have to be resold on the second-hand market. Since

[30] Source: (Anfia).

there are some companies that sell their cars in lots that are often competitive with new car dealers, competition between the second-hand market and new car sales by dealers increases. This problem highlights the main critical issue facing car manufacturers in managing their sales channels: "how the rental channel can be used to smooth out factory production without letting the resulting second-hand market negatively affect dealers' sales and profitability?".

A two-period model can be used for the analysis, in which sales made in the first period compete on the second-period market with sales made in the second period (Purohit, Devavrat; Staelin, Richard; 1994). In the model proposed by Purohit and Staelin, in addition to the presence of the Manufacturer and the Customer, there are also two other figures: the Dealer and the Renter.

It is assumed that the renter is in charge of renting cars to consumers and the dealer is in charge of selling them. In the initial period, since dealers and renters serve different needs and therefore different customer segments, it is assumed that they do not compete. However, competition between these two players increases in the second period if the dealer decides to sell his used cars, at the end of the first period, directly to the consumer. This would change from a market without competition in the first period to duopolistic competition in the second period.

Finally, suppose that there is a possibility for the manufacturer to buy back some of the used cars from the renter's stock and sell them to the dealer in the second period. In this case, the dealer would have to sell, in the second period, two substitute products, one new and one "as new", for which he would have to define different prices.

2.6.3. The link with "Coase conjecture"

In this context, where reference is made to durable goods, it is essential to refer to the Coase conjecture (1972): consider a firm in a monopoly context, which sells a certain quantity of a durable good. Once the first quantity is sold, the firm will have an incentive to lower the price of the durable goods in order to attract more buyers into the market; this process may continue until the price of the durable equals the firm's marginal cost. In other words, the firm engages in intertemporal price discrimination, exploiting its monopoly position over time. However, Coase also considers the possibility that there are rational or 'strategic' consumers in the market, who might anticipate future price reductions and therefore wait for these to occur before buying. In this way prices would fall to the level of perfect competition in an extremely short time. This is the case when consumers have a zero discount rate, i.e. when it is indifferent in terms of utility for them to buy the good now or in the future.

2.6.4. The development of the model

The model starts from some fundamental assumptions, mentioned a few lines above, concerning the nature of the durable product, the decision rules used by each of the four "players" (manufacturer, dealer, renter and customers) and the structure of the market's sales channels.

Product: it is assumed that the product life cycle is two periods. It is also assumed that there can be three types of cars: new cars, used cars and programme cars. Program cars differ from used cars in that they have not been owned by anyone, but have been rented and are "as new". In the model, only new cars are available in the first period. In the second period, new cars from the current period, cars used in the first period by consumers and, potentially, part of the cars rented by renters in the first period are available.

Renter: It is assumed that the renter has determined the optimal amount of cars he needs $q_{1,r}$ and is not able to handle more than that level of stock. At the beginning of the first period, the renter does not own any cars and therefore buys $q_{1,r}$ from the manufacturer; in the second period; the renter can buy new cars only if he sells the corresponding amount of used cars, selected from those purchased in the first period. These "recycled" cars enter the consumer market as program cars.

Manufacturer: The manufacturer's main problem is to figure out how to manage its two distribution channels in order to achieve a given level of sales without affecting its relationship with the dealer. The interaction with the renter is simplified by the fact that the renter buys a certain amount of cars based on its needs at an exogenously determined price. It is assumed that price incentives offered to the renter to make him buy more cars are also exogenously determined. The relationship between manufacturer and renter can therefore be avoided. The control variables available to the manufacturer will therefore be the amount of cars sold to the renter in the two periods, the price offered to the dealer for the purchase of cars, and the type of distribution system used to manage the used car market.

Dealer: the dealer selling new cars and, when available, program cars, tries to make profit as great as possible. Although this figure is to all intents and purposes a "price follower", the dealer has complete autonomy on the quantity to be purchased from the manufacturer, for each type of car. It is therefore assumed that the dealer's decision variables are the quantities of cars purchased for each period.

Consumers: consumers are modelled in terms of demand for the three car types. In terms of the demand function, two basic assumptions are made. First, it is assumed that the price for each type of car is decreasing in quantity. Secondly, it is assumed that, given a certain quantity, the price of new cars is higher than the price of program cars and that this in turn is higher than the price of used cars. The latter assumption is compatible with the observation that competition between these three types of cars is asymmetrical. In terms of consumer perception, new cars and program cars are perfect substitutes for used cars, but the opposite is not true; used cars are imperfect substitutes for new cars and near-new cars. In the same way, a new car is a perfect substitute for an almost-new car, while an almost-new car is an imperfect substitute for a new car.

2.6.5. Further consumer considerations: Lemon problem and Moral Hazard

Considering the used cars, it is possible assume that due to the presence of information asymmetry, the quality of the product cannot be assessed by the consumer, the seller may have an incentive to emphasise the quality level. The buyer, on the other hand, takes this possible behaviour of the seller into account and determines that the actual quality of the proposed good remains unknown. He will therefore only acts on the basis of the average quality of the car. It follows that all those products whose quality level is above average will be excluded from the market.

This case refers to the so-called "Lemon problem"[31] (Akerlof, 1972). To give a concrete example, consider that second-hand cars are more likely to be sold for

[31]The lemons problem theory was described by George Akerlof in a 1970 paper titled "The Market for Lemons: Quality Uncertainty and the Market Mechanism." "Lemon" products, or products with bad performance and low durability, are often bought due to a lack of information that can lead people into bad

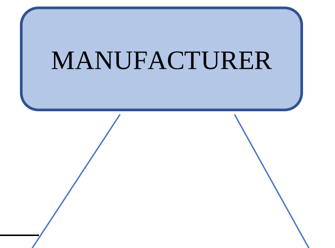
performance reasons than programme cars, which are only sold after the end of the rental period. Conversely, it can be argued that since program cars are driven by more customers than rental companies, potential buyers may be concerned about so-called 'moral hazard': since the previous drivers did not own the car, but used the rental service, they are likely to be less concerned about preserving it.

However, programme cars generally enjoy better maintenance by rental agencies and are covered by a full manufacturer's warranty. In addition, since both new cars and program cars are sold by a company, buyers might think that they have better assistance if something happens than a private seller. As a consequence, it can be expected that, on average, consumers perceive program cars as higher quality cars and that therefore the "Lemon problem" is more important than the "Moral hazard". Therefore, it is expected that program cars are better substitutes for new cars than used cars.

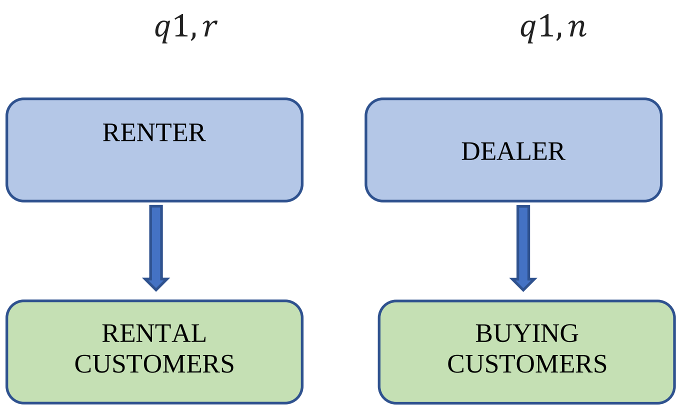
2.6.6. Distribution structure

As mentioned in the introduction to the model, customers of rental companies have very different needs from those who decide to buy a car from a dealer. Therefore, even if the basic product offered by these two markets is identical, the services that each market offers are different. Thus, short-term rentals are not a substitute for retail purchases. In the Figure1., this basic distribution structure is shown graphically in period 1, where the renter and the dealer do not compete, as they target different customer segments.

Figure 22. Period 1, Channel Structure



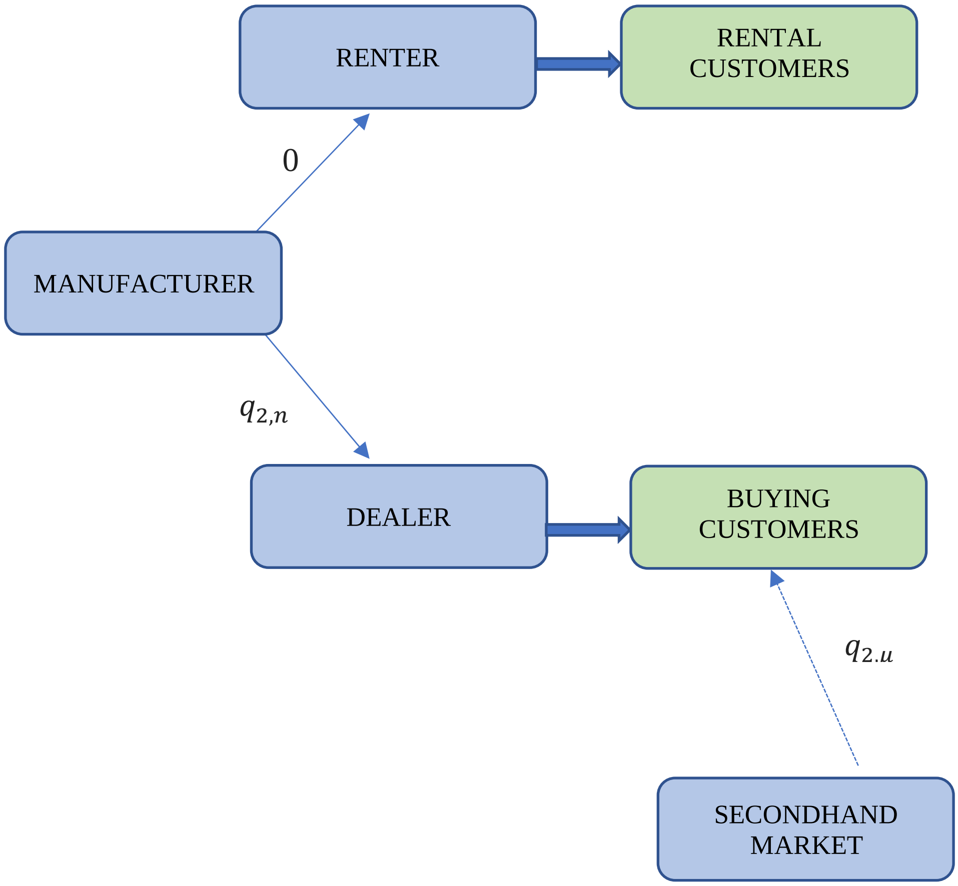
purchases and bad investments, instead of avoiding the product entirely. Timely, relevant information is crucial for functional, efficient markets. However, in certain industries and for some credence goods, consumers may not be able to thoroughly evaluate the goods or services they are thinking about purchasing. This leads to the possibility of consumers purchasing lemons.



If some of the renter's cars, in period 2, flow onto the second-hand market, which competes with the market for new cars sold by the dealer, then the independence of the channels will not persist and they will no longer be non-competitive. To model this change, three possible distribution structures are analyzed: separate structure, overlapping structure and buy-back structure.

In the separate channel case (Figure 23), the manufacturer, in period 2, does not sell cars to the rental company, and the renter does not sell program cars. Consequently, the only competition the dealer faces comes from the second-hand market, which consists of the cars sold by the dealer in period 1.

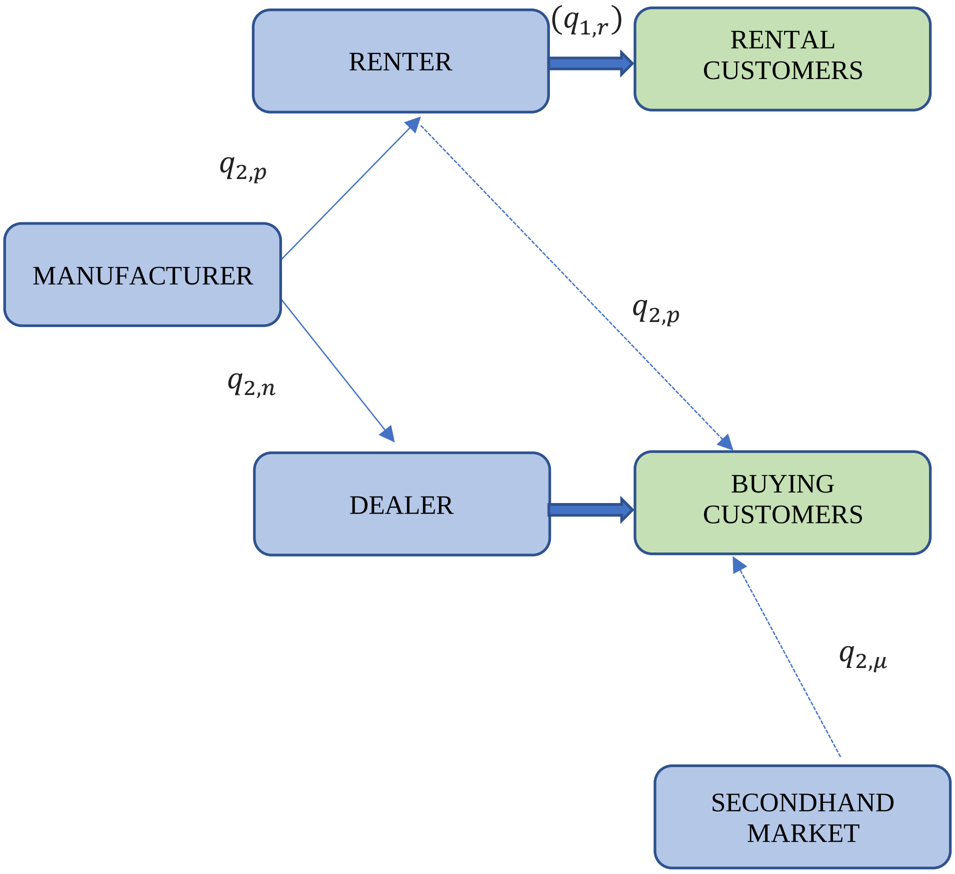
Figure 23: Period 2, separate channel structure



In the case of an overlapping channel (Figure 24), the renter sells its used product (i.e., program cars) in the same market as the dealer in period 2.

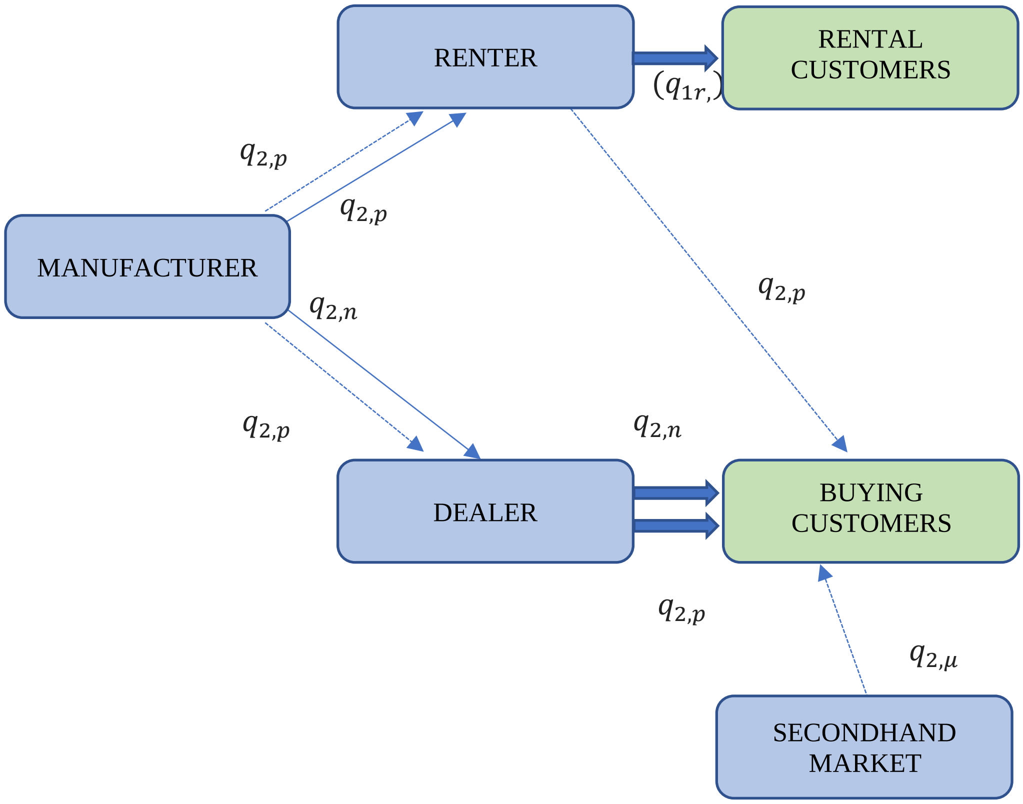
Consequently, the dealer faces competition on two fronts: used cars and program cars.

Figure 24: Period 2, overlapping channel structure



Finally, in a buyback channel (Figure 25) the manufacturer, in period 2, buys back the used product from the rental company and then sells it to the dealer. In this way, in period 2 the dealer sells new cars and program cars.

Figure 25: Period 2, Buyback channel structure



To solve the model, it is assumed that the manufacturer sets the price of the cars he sells to the renter and the dealer and that they react to the prices charged by the manufacturer.

2.7. Resolution of the model

An explicit assumption of the analysis is that consumer demand is not for the product itself, but for the services it provides. Furthermore, since a durable product is being considered, it is necessary to consider that consumers' expectations of future market actions may influence current prices. To do this, Purohit and Staelin developed a two-period model, in which the demand functions represent how much consumers are willing to pay to use the product for a given period (one-period price). However, the price paid by a consumer purchasing the product in period 1 reflects the consumer's potential use of the product's services over both periods. Therefore, it is assumed that the purchase price in period 1 is equivalent to the sum of the one-period prices.

Naturally, as period 2 is the last period, the selling price in period 2 is equivalent to the one-period price.

For the development of the model, it is also necessary to make explicit the asymmetric nature of consumer preferences. Since used cars are imperfect substitutes for new cars and program cars, it is represented the substitution rate of used cars for new cars and program cars with the parameter γ. Similarly, since program cars are imperfect substitutes for new cars, the substitution rate of program cars for new cars will be represented by the parameter θ.

Next, it is introduce the variable *Stock of relevant cars*, i.e. the stock that is considered relevant for the consumer.

Let $q_{i,j}$ be the quantity of the $j-th$ type of car in period i, where:

- i=1,2
- j = used (u), program (p), new (n).

Then the *Stock of relevan*t cars $S_{i,j}$ is defined as:

$$\begin{aligned} S_{1,n} &= q_{1,n} \ , \\ S_{2,\mu} &= q_{2,\mu} + q_{2,p} + q_{2,n} \ , \\ S_{2,p} &= \gamma q_{2,\mu} + q_{2,p} + q_{2,n} \ , \\ S_{2,n} &= \gamma q_{2,\mu} + \theta q_{2,p} + q_{2,n} \ , \end{aligned} \tag{1}$$

Where $0 \le \gamma \le \theta \le 1$ are the substitutability parameters. Since neither used cars nor program cars are available in period 1, stocks $S_{1,p}$and $S_{1,\mu}$ are not defined, nor are these two types of cars included in stock $S_{1,n}$.

Finally, the "Stock of relevant cars" is used to define the one-period price. Conceptually, this approach captures the belief that as the quantity of an available alternative increases, the prices of all alternatives should decrease to some extent. For example, consider that there is an increase in the quantity of new cars. This will not only decrease the price of new cars, but since new cars are assumed to satisfy the same needs as used cars and planned cars, the prices of the latter two alternatives will also decrease.

In particular, equations (1) are used to define the system of inverse demand functions as follows:

$$l_{i,j} = \alpha - \beta S_{i,j} \ , \tag{2}$$

Where:

- $l_{i,j}$ corresponds to the price in period i (i = 1,2) for the $j-th$ type of car;

- α and β are positive arbitrary constants expressing, respectively, the size of the potential market and the slope of the inverse demand function.

Since $S_{2,\mu} > S_{2,p} > S_{2,n}$, representing the demand function in this way ensures that the one-period price of new cars is higher than the price of program cars and that this in turn is higher than the price of used cars.
The basic demand system, represented by equations 1 and 2, has several interesting features. First, since the model does not expect used cars or program cars to be available in period 1, equations 1 and 2 do not define the one-period prices or relevant stocks of these cars in period 1. Second, new cars in period 1 become used cars in period 2, so that $q_{2,\mu}=q_{1,n}$. This implies that, although the equation does not define the price of new cars in period 1, it does not define the price of program cars in period 2. This implies that although equation 2 defines the prices of used cars in period 2, there is no corresponding demand function for used cars, since the quantity of used cars is predetermined by the number of new cars sold in period 1. Note that the price of used cars only depends on how many "relevant cars" exist in the market and not on how many consumers actually sell their used cars.
Given this framework, the following sections analyse the dealer and manufacturer problem in the three structures defined above.

2.7.1. Separate Channel

The demand system under the assumption of a separate channel have been developed. Considering this strategy, outlined by Figures (22) and (23), note that the renter does not purchase incremental cars in period 2, and thus $q_{2,p}$ = 0. Consequently, the price of a period $l_{2,p}$ and stock $S_{2,p}$ are not defined. From equation 1 and 2, it is obtain the following inverse demand functions, for a period, for available products:

$$l_{1,n} = \alpha - \beta q_{1,n},$$

$$l_{2,\mu} = \alpha - \beta(q_{1,n} + q_{2,n}), \tag{3}$$

$$l_{2,n} = \alpha - \beta(\gamma q_{1,n} + q_{2,n}$$

where 0 < γ < 1 reflects the degree of substitution of new cars by used cars.

Remember that, as mentioned above, if the consumer buys a product in period 1, the sales price in period 1 ($p_{1,n}$) depends on the current period price and the future one-period price on the second-hand market, i.e.

$$p_{1,n} = l_{1,n} + \rho l_{2,\mu}\ , \tag{4}$$

where ρ is the factor indicating the discount rate.

In this way, consumers anticipate future actions that influence the current sales price. Similarly, since period 2 is the last period, the sales price of period 2 is equal to precisely the "one-period" price of period 2, i.e. $p_{2,n}$=$l_{2,n}$. Since the presence of a positive discount rate does not undermine the qualitative nature of the results, for simplicity it is assumed that the discount rate is zero and hence that ρ = 1.

The dealer's problem is to maximise profits in the two periods by choosing the optimal quantities $q^*_{1,n}$ and $q^*_{2,n}$.

The model is solved backward, starting in period 2, by placing conditions on some actions in period 1, then solving the problem considering the two periods. Suppose the dealer sells a quantity $q_{1,n}$ in period 1. Then, in period 2, all previous sales ($q_{1,n}$) represent a latent second-hand market that competes with the dealer's own new sales. Given the first sales $q_{1,n}$, the dealer's problem in period 2 is to maximise profits by choosing an optimal level of additional sales ($q^*_{2,n}$). In period 2, the dealer maximises his profit:

$$\Pi = q_{2,n}(p_{2,n} - c_n) \ , \tag{5}$$

where c_n is the dealer's marginal cost of buying a new car or, equivalently, the manufacturer's wholesale price for buying a unit.

The optimal profit-maximizing quantity is equal to the follows:

$$q^*_{2,n} = \frac{\alpha - c_n - \gamma\beta q_{1,n}}{2\beta} \ , \tag{6}$$

Note that, in equation 6, the demand for new cars in the second period decreases as the sales of new cars in the first period increase.

Equation (6) describes the optimal dealer behavior in period 2, given a certain quantity $q_{1,n}$. Therefore, at this point, must be chosen the quantity $q_{1,n}$ that maximizes the dealer's profit over both periods:

$$\Pi = q_{1,n}(p_{1,n} - c_n) + q^*_{2,n}(p_{2,n} - c_n) \ , \tag{7}$$

where $q^*_{2,n}$ is defined by equation (6) and $p_{1,n}$ is the purchase price for the consumer in period 1.

The optimal quantity that the dealer will buy in period 1 will then be the following:

$$q^*_{1,n} = \frac{\alpha(3-\gamma) - c_n(1-\gamma)}{\beta(8-2\gamma-\gamma^2)} \ , \tag{8}$$

So far, the optimal choices of the dealer have been determined, given a certain pricing strategy of the manufacturer.

The manufacturer's problem remains to be solved.

The manufacturer maximises its combined joint profits over the two periods, from sales through the dealer network, by choosing an optimal price at which to sell its product.

It therefore maximises the following function

$$\Pi = q^*_{1,n}\ (c_n \text{-}\ m\ ) + q^*_{2,n}(c_n \text{-}\ m)\ , \tag{9}$$

with respect to a wholesale price (c_n), where m is the constant marginal cost to the manufacturer of producing a new car. From the profit maximisation with respect to the wholesale price c_n is obtained the following function

$$c^*_n = \frac{7\alpha+5m}{10}\ , \tag{10}$$

Equations (6) and (8) set out the dealer's equilibrium sales levels in periods 1 and 2. Given the concerns of car manufacturers to exploit the full production capacity of their plants, it is logical to focus on the manufacturer's total sales of new cars to dealers and rental companies. The total amount of new cars sold by the dealer is given by Q^*_D=$q^*_{1,n} + q^*_{2,n}$, which is equivalent to the following function:

$$Q^*_D = \frac{7\alpha-5m}{4\beta(4+\gamma)}\ , \tag{11}$$

and the total number of cars sold by the manufacturer is Q^*_T=$Q^*_T + q_{1,r}$.

From equations (10) and (11), it can be seen that if there is an increase in the term α, which is the intercept of the demand function, wholesale prices and total dealer sales increase. Since there can be no program car in the used car market, the parameter θ has no effect on either of these decision variables. Interestingly, γ affects total dealer sales, but not the wholesale price. In other words, the manufacturer does not respond to changes in γ, because the dealer makes his own adjustments by changing quantities.

In particular, the dealer responds to increases in γ by increasing sales in period 1, but decreasing sales in period 2 to a greater extent.

2.7.2. Overlapping Channel

Consider now the case of a structure with overlapping channels: in period 2, the manufacturer sells $q_{2,p}$ incremental cars to the rental company, and the renter recycles $q_{2,}$ p from the stock he bought in the first period ($q_{1,r}$), selling these program cars directly and independently on the second-hand market. In this case, the reverse demand system becomes as follows:

$$\begin{aligned} l_{1,n} &= \alpha - \beta q_{1,n} \,, \\ l_{2,\mu} &= \alpha - \beta (q_{1,n} + q_{2,p} + q_{2,n}) \,, \\ l_{2,p} &= \alpha - \beta (\gamma q_{1,n} + q_{2,p} + q_{2,n}) \,, \\ l_{2,n} &= \alpha - \beta (\gamma q_{1,n} + \theta q_{2,p} + q_{2,n}) \,, \end{aligned} \tag{12}$$

where θ reflects the degree to which new cars are replaced by program cars.

Using the general analysis outlined in the previous section, the optimal dealer quantities is derived. Given quantities $q_{1,n}$ and $q_{2,p}$,in period 2, the dealer maximizes the profit by choosing an optimum $q^*_{2,n}$.

Having established the optimal by $q^*_{2,n}$=$q^*_{2,n}\left(q_{1,n}, q_{1,p}\right)$, in the period 1 the dealer maximizes profits over both periods by choosing an optimum $q^*_{1,n}$. Based on these optimal quantities chosen by the dealer, the manufacturer maximises its profits on sales to the dealer by setting its wholesale price, c^*_n. These results are shown in Tables 1 and 2. In this case, the total sales of the supplier's new car are represented by the following equation: Q^*_T=Q^*_D + $q^*_{1,r}$+ $q_{2,p}$.

Table 1: Quantity of equilibrium

	$q_{1,n}^{*}$	$Q_D^{*} = q_{1,n}^{*} + q_{2,n}^{*}$	$q_{2,p}$
Separate channel	q_1^S	Q_D^S	**0**
Overlapping channe	q_1^S-$\frac{q_{2,p}(18+2\gamma-13\theta-7\gamma\theta)}{10(4+\gamma)(2-\gamma)}$	$Q_D^S - \frac{q_{2,p}(2+3\theta)}{4(4+\gamma)}$	$q_{2,p}$
Buyback-transfer	q_1^{BT}	$Q_D^S - \frac{\theta q_{2,p}(14-4\gamma-y^2)}{4(4+\gamma)(2-\gamma)}$	$q_{2,p}$
Buyback-auction	$q_1^{BT} + \frac{\gamma\theta q_{2,p}}{(4+\gamma)(2-\gamma)}$	$Q_D^S - A - \frac{3\theta q_{2,p}}{4(4+\gamma)}$	$q_{2,p}$

Table 2: Price of equilibrium

	c_b^*	c_n^*
Separate Channel	-	c_n^s
Overlapping Channel	-	$c_n^s - \frac{\beta q_{2,p}}{10}$
Buyback-Transfer	$\frac{(1-\theta)(\alpha - \gamma\beta q_{1,n}}{2}$	$c_n^s - B - \frac{\theta\beta q_{2,p}}{10}$
Buyback-Auction	$\frac{2\left(\alpha - \gamma\beta q_{1,n}^*\right) + 2c_n^* - \beta q_{2,p}(3-2\theta)}{4}$	$c_n^s - B - \frac{3\theta\beta q_{2,p}}{10}$

Specifically:

$$q_1^s = \frac{\alpha(23-3\gamma)-5m(1-\gamma)}{10\beta(4+\gamma)(2-\gamma)}$$

$$q_1^{BT} = \frac{\alpha(3-\gamma)-c_n^*(1-\gamma)-\ \beta q_{2,b}(1-\theta)}{10\beta(4+\gamma)(2-\gamma)}$$

$$Q_D^* = \frac{7\alpha+5m}{4\beta(4+\gamma)}$$

$$A = \frac{q_{2,p(18-4\gamma-3\gamma^{2})}}{4(4+\gamma)(2-\gamma)}$$

$$B = \frac{\beta q_{2,p(2-2\gamma+\gamma^{2})}}{10(2-\gamma)}$$

$$c_n^s = \frac{7\alpha+5m}{10}$$

From the tables just shown, it is possible see the negative impact of incremental sales (q2, p), on the total sales of new cars through the dealer; in fact it results

$$\partial Q*/\partial q, < 0.$$

However, this is less than a one-to-one effect. If cars recycled by rental companies in the consumer market increase by one unit, Q_D^* decreases by (2+3θ) ⁄ 4(4+γ), which is less than one unit. Similarly, the wholesale price offered by the manufacturer to the dealer decreases as $q_{2,p}$, increases, i.e., $\partial c_n^* / \partial q_{2,p}$, < 0. Thus, with an increase in incremental sales to the renter, not only does the manufacturer sell fewer cars through the dealer channel, but it earns a lower unit profit per car sold to the dealer. However, provided that the growth in profits associated with incremental sales to the renter outweighs the loss associated with a decrease in sales to dealers, it would be better for the manufacturer to flow more cars through the secondary distribution system. Finally, an increase in the substitutability of new cars with program cars (θ) leads to a decrease in total sales at the dealer level, $\partial Q_D^* \ / \partial \theta$ < 0.However, note that $\partial q_{1,n}^* / \partial \theta$ > 0; this means that, in anticipation of the consequences that could be in the second period, the dealer finds his optimum by increasing sales in period 1.

2.7.3. Buyback Channel:

The final structure to be analyzed is the one involving the buyback channel. As in the case of overlapping, the manufacturer sells an additional quantity of new cars ($q_{2,p}$) to the rental company in period 2.

However, this time the manufacturer buys back a quantity of program cars from the previous period exactly equal to $q_{2,p}$ and sells them to the dealer.

As a result, in period 2 the dealer sells "buyback" cars ($q_{2,b}$) and new cars. The system of inverse demand functions derived from this distribution structure is as follows:

$$l_{1,n} = \alpha - \beta q_{1,n} \ ,$$

$$l_{2,\mu} = \alpha - \beta(q_{1,n} + q_{2,b} + q_{2,n})$$

$$l_{2,b} = \ \alpha - \beta(\gamma q_{1,n} + q_{2,b} + q_{2,n}) \ , \qquad (13)$$

$$l_{2,n} = \ \alpha - \beta(\gamma q_{1,n} + \theta q_{2,b} + q_{2,n})$$

where $q_{2,b}$, represents the sales of buybacks in period 2.

In this analysis, it is assumed that the manufacturer cannot record repurchase cars in the inventory.

A key constraint is therefore that all cars bought back by the manufacturer are sold through the dealer; i.e. quantity $q^*_{2,b}$ equals the additional cars sold to the rental company ($q_{2,p}$). The manufacturer can satisfy this constraint through two mechanisms: transfer pricing and auction pricing. According to the transfer pricing method, the manufacturer sets a price for the buyback cars (c_b) such that it generates demand $q_{2,p}$. In other words, the manufacturer uses c_b as a control variable to make sure that the dealer selects the quantity $q_{2,p}$ of program cars. According to the auction pricing method, on the other hand, the manufacturer holds an auction for buyback cars. In this case, the auction price exactly satisfies the demand for program $q_{2,p}$.

2.7.4. Transfer Pricing

Since the dealer sells both new and rental cars, the dealer's problem in period 2 is to maximize profits by choosing the optimal quantities $q_{2,n}$ and $q^*_{2,b}$conditioned by the manufacturer's wholesale prices for buyback (c_b) and new cars respectively (c_n).
Consequently, in period 2 the dealer maximizes the following function:

$$\Pi = q_{2,b}\ (p_{2,b} - c_b\ ) + q_{2,n}(p_{2,n} - c_n\ )\ , \tag{14}$$

choosing $q^*_{2,n}$, and $q^*_{2,b}$. This leads to obtaining:

$$q^*_{2,b} = \frac{(1-\theta)\left(\alpha-\gamma\beta q_{1,n}\right)+2c_b\ +(1+\theta)c_n}{\beta(3-2\theta-\theta^2)}\ , \tag{15}$$

$$q^*_{2,n} = \frac{(1-\theta)\left(\alpha-\gamma\beta q_{1,n}\right)+2c_n\ +(1+\theta)c_b}{\beta(3-2\theta-\theta^2)}\ , \tag{16}$$

Note that equations (15) and (16) represent the demand function with which the manufacturer interfaces at the beginning of period 2. To be sure to sell all buyback cars, the manufacturer must set a transfer price equal to c_b^* , so that it is $q_{2,b}^* = q_{2,p}$. This is possible by setting the demand for buyback cars (equation 15) equal to the quantity of cars bought back ($q_{2,p}$) and solving as a function of c_b . Therefore it is obtained:

$$c_b^* = \frac{(1-\theta)\left(\alpha-\gamma\beta q_{1,n}\right)+c_n\,(1+\theta)-\beta q_{2,p}\left(3-2\theta-\theta^2\right)}{2}\,, \tag{17}$$

From equation (17), it can be seen that the transfer price that satisfies the market, from the point of view of the program cars, is a decreasing function of $q_{1,n}$ and $q_{2,p}$and is increasing in c_n .

This means that if the wholesale price of a new replacement car increases, so will the transfer price of a program car. However, note that if c_n increases by one unit, the transfer price rises by an amount equal to $(1 + \theta)/2 \leq 1$, and if $\theta = 1$, then $c_b^* = c_n$.

Given c_b^*, $q_{2,p}$, and $q_{2,n}$, in period 2, the dealer maximizes profits in periods 1 and 2 by choosing the optimal level of new cars to sell in period 1. The function to be maximised is therefore as follows:

$$\Pi = q_{1,n}\,(p_{1,n} - c_n) + q_{2,p}\,(p_{2,b} - c_b^*) + q_{2,n}^*(p_{2,n} - c_n), \tag{18}$$

By choosing the optimal value of $q_{1,n}^*$.

The manufacturer's objective, on the other hand, is to maximize profits from sales through the dealer. Again, the marginal cost to produce a new car is represented by "m". However, the marginal cost of a program car is less easy to calculate, since the manufacturer sells these cars to the rental company, and then buys them back at the end of period 1. The marginal cost at the beginning of period 2 is therefore zero, since the manufacturer has already incurred the fixed cost of the buy-back. However, for the purpose of assessing marginal cost, the appropriate time is not the beginning of period 2 but of period 1, when the producer chooses the quantity $q_{2,p}$ that maximises his profit in the long run. The cost of producing a program car is then assumed to be m. The producer's profit maximizing function will be as follows:

$$\Pi = q_{1,n}^{*} \, (c_n - m) + q_{2,n}^{*}(c_n - m) + q_{2,p}(c_b^{*} - m), \tag{19}$$

choosing the optimal wholesale price, c_b^{*} .

The optimal solutions for the dealer's and the manufacturer's problems are shown in Table 1 and Table 2. As in the overlapping case, we show that an increase in $q_{2,p}$ leads to a reduction in total new car sales through the dealer ($\partial Q_D^{*} / \partial q_{2,p} < 0$), less than proportionally. Moreover, the price set by the manufacturer for new cars decreases as the sales of program cars increase ($\partial c_{,n}^{*} / \partial q_{2,p} < 0$). If the substitutability of new cars with program cars (θ) increases, the dealer reacts by shifting the emphasis to program cars, thus reducing new car sales ($\partial Q_D^{*} / \partial \theta < 0$). However, in the case of overlapping, in anticipation of an increase in future competition (caused by an increase in θ), the dealer increases sales in period 1 ($\partial q_{1,n}^{*} / \partial \theta > 0$).

2.7.5. Auction Pricing

Consider a market in which there are several dealers and a single manufacturer, which auctions its program cars: according to the rules of the auction, the dealers compete by offering higher and higher prices to buy the car. The auction continues until only one dealer remains, corresponding to the highest bidder and thus the winner of the auction. It is important to consider that a dealer's highest bid is the price which makes the dealer indifferent between winning (and thus being able to sell the car) and losing (letting the car be sold to a competitor). From the manufacturer's point of view, the advantage of using an auction is to be able to sell the car at a higher price than the transfer price.

Since the analysis assumes the presence of only one dealer, an auction such as the one described above cannot take place.

However, one could simulate the effect of the presence of multiple dealers by considering the situation of the dealer in period 2: the used car market has $q_{q,n}$cars and the manufacturer has $q_{2,p}$ cars not registered in the inventory. The dealer then has two options: to buy the buyback cars and resell them through his network or not to buy the cars and let the manufacturer resell them through an overlapping channel. Aware of this situation, the manufacturer sets a wholesale price (c_b), so that the dealer is indifferent between these two options. Formally, the manufacturer sets the wholesale purchase price in order to equate the dealer's profits, in the second period, under the overlapping hypothesis (equation 5), with the dealer's profits, in the second period; under the buyback hypothesis (equation 14). This procedure leads to the optimal price c_b^* and the optimal level of new car sales in the second period:

$$c_b^* = \frac{2\left(\alpha + c_n - \gamma\beta q_{1,n}\right) - \beta q_{2,p}(3-2\theta)}{4}, \tag{20}$$

$$q_{2,n}^* = \frac{\alpha - c_n - \beta[\gamma q_{1,n} + (1+\theta) q_{2,p}}{2\beta}, \tag{21}$$

Given these equations, in period 1 the dealer's problem, is to maximize profits over both periods by choosing an optimal $q_{1,n}^*$. Based on the dealer's optimal choices, the manufacturer maximizes profits through the dealer's distribution channel, by choosing the optimal price c_n^*. These results are displayed in Table 1 and Table 2. The static comparative of these solutions is similar to the transfer pricing case; total sales of new cars through the dealer channel and the prices that the manufacturer sets for the dealer decrease with $q_{2,p}$ ($\partial Q_D^* / \partial q_{2,p} < 0$), and ($\partial c_n^* / \partial q_{2,p} < 0$). Moreover, when θ increases and program cars become more and more substitutes for new cars, the dealer's new car sales drop ($\partial Q_D^* / \partial \theta < 0$).

2.8. Results and comments

As mentioned above, an important objective of the manufacturer is to maintain a level of sales close to its production capacity. When, in the short term, there is a drop in demand for cars from the dealer's customers, such that output falls below capacity, the manufacturer will be inclined to increase its sales through the rental channel. Although this strategy allows the manufacturer to increase its sales in the short term, it is less clear how it affects the dealer's sales and profits. It is therefore necessary to understand the implications that the use of different channels may have not only on the manufacturer's sales and production capacity, but also on the dealer's sales and profits. Using Tables 1 and 2, a number of results can be obtained.

2.8.1. Implications for the dealer

By comparing the sales and profits that the dealer achieves with separate and overlapping channel structures, the following result is obtained.

First result: dealer sales and profits are higher when there is a separate channel structure ($q_{2,p}$= 0) than when there is an overlapping channel structure ($q_{2,p}$ > 0). Moreover, this difference increases as the number of incremental sales to the rental company increases.

This result is quite obvious, as the dealer faces more competition in an overlapping channel structure. It is no coincidence that, in the 1990s, there were several complaints from dealers about declining profits due to the fact that rental companies were selling "nearly new" and therefore competitive cars.

In response to these complaints, some US manufacturers decided to move from an overlapping structure to a total buyback structure. To understand whether this strategy was useful, one can compare dealer profits under an overlapping channel structure with dealer profits under the two different buyback structures shown above, transfer pricing and auction pricing. The resulting result (from Table 2) is as follows:

Second result: for $q_{2,p}$> 0, dealer profits under both buyback structures are larger than the profits it would earn under an overlapping channel structure. However, total new car sales are lower under buyback structure than under overlapping structure.

It has to be taken into account that in the case of an overlapping structure the dealer has to compete with the program cars sold by the renter, which are good substitutes for new cars, so he will lower the price of new cars. Although this reaction leads to an increase in the number of units sold by the dealer, it also causes a decrease in profits. On the other hand, under a buyback structure, the dealer does not compete with program cars; rather, he has a wider product line to sell and replaces part of the new cars with program cars. Although this substitution leads to reduced sales of new cars, it also leads to increased profits for the dealer.

Finally, one has to consider how the dealer's profits might change if the manufacturer increases the number of units sold in the second period. In general, it can be seen that the dealer's profits decrease as the manufacturer increases its sales to the rental company. This is always true both in the case of overlapping and in the case of buyback.

However, if $q_{2,p} > q_{2,n}$ in order to induce the dealer to buy all program cars, the manufacturer has to reduce the wholesale price of the program cars substantially; in this condition, the dealer's profits may increase with increases in $q_{2,p}$.

2.8.2. Manufacturer's strategies and capacity considerations

It has just been shown how, when the manufacturer abandons the separate channel strategy, the dealer's profits and total sales unequivocally fall. However, from the manufacturer's point of view, the interesting question concerns what happens to total car sales if he increases sales to the dealer. The result is as follows.

Third result: by keeping the number of incremental sales to the renter fixed, the total amount of cars sold by the manufacturer follows the following order:
overlapping ≥ buyback ≥ separate.

This result is very important because it shows that the manufacturer can influence its sales by altering the nature of its distribution system. In particular, it can increase total sales by switching from a separate channel structure to a buyback structure and again to an overlapping channel structure. It should be noted that the competitive mechanism of the market in the sale of program cars (overlapping channel) actually leads to higher total quantities than the choice of buyback. To better understand these differences, one can compare the total sales of the manufacturer in case of separate channel and overlapping channel.

From table 1, the difference is as follows:

$$\Delta Q_T = Q_T^O - Q. = \frac{q_{2,p}(14 + 4\gamma - 3\theta)}{4(4+\gamma)}, \qquad (22)$$

From the manufacturer's point of view, total sales (Q_T^*) are higher in the overlapping case since the rental company buys an incremental amount of cars ($q_{2,p}$) and this increase is not completely cancelled out by the reduction in the dealer's sales. Note that equation (22) is independent of the parameters defining the demand function, α and β, and that it increases as $q_{2,p}$ increases, while it decreases as θ increases. However, if program cars were perfect substitutes of new cars (θ = 1), an overlapping channel strategy would lead to more total sales. This reflects the benefit of using a second distribution system in competition with the dealer.

Comparing overlapping and buyback strategies, it appears that the manufacturer achieves more total sales when opting for car buyback. However, the sensitivity to the parameter θ varies across the two structures. When program cars and new cars are perfect substitutes (θ = 1), under a buyback strategy with transfer pricing, the following result is obtained:

Fourth result: when program cars and new cars are perfect substitutes (θ = 1), buyback channel strategies with transfer pricing and separate channel strategies lead to the same number of sales for the manufacturer.

The reason of this result is related to the fact that under a buyback strategy, the dealer maximizes his profits on the product line comprising new and rental cars. When these products are perfect substitutes, the dealer simply replaces new cars with program cars. However, when θ < 1, the dealer cannot achieve a one-to-one substitution, so the use of a transfer pricing mechanism leads to higher total sales than the separate channel strategy. However, result 4 does not take into account the auction pricing strategy, where, even with θ = 1, sales exceed those in the separate channel case. Since the two different types of buyback differ only in the mechanism by which the dealer buys the car from the manufacturer, any differences in total sales of new cars by the manufacturer are directly related to the pricing mechanism for program cars.

It is also important to consider, however, that the manufacturer has to be concerned not only with total sales of new cars under the various distribution structures, but also with maintaining a good long-term relationship with dealers; he has therefore also to consider the effects which the choice of the manufacturer's new car pricing mechanism will have on the total sales of new cars. of the various strategies has on dealers' profits. The analysis is then continued by considering the total quantities sold under the different strategies.

It was initially assumed that car manufacturers find it economically useful to keep production stable even in periods of low demand, by using sales to rental companies as a flexible variable, so as to keep production at a level close to full capacity.

Note that Q_D^*(total quantities of new cars sold in the two periods by the dealer) decreases with q_{2p} in all cases, while Q_T^* (total quantities of new cars sold in the two periods by the manufacturer) increases with q_{2p}.

When there are no incremental sales to rental companies, for all distribution structures, the total quantities sold by the retailer and the manufacturer will be equivalent.

$$Q_D^* = Q_T^* = \frac{7\alpha}{4\beta(4+\gamma)}\,, \tag{23}$$

Suppose now that there is a reduction in demand at the dealer level, represented as an inward shift of the demand curve, resulting in a deficit of K units. One way to represent this deficit is to shift the intercept by a value of K, upwards. The higher intercept implies that in order to operate the plant at the previous level, the manufacturer has to sell a total of $Q*$ cars, such that

$$Q_T^* = \frac{7\alpha}{4\beta(4+\gamma)} + \mathrm{K}, \tag{24}$$

Fifth result: considering *Q_D^*(total quantities of new cars sold in the two periods by the dealer) decreases with q_{2p} in all cases, while Q_T^* (total quantities of new cars sold in the two periods by the manufacturer) increases with q_{2p}*, appears that keeping the total production level fixed, the optimal amount of incremental sales for the producer has the following ordering:

$$q_{2,p}^{transfer} > q_{2,p}^{auction} > q_{2,p}^{overlapping}$$

This result underlines that although all three distribution systems allow the manufacturer to reach its old production level, the two buyback strategies require more incremental sales.

However, from result 1, it was found that different levels of incremental sales ($q_{2,p}$) lead to different levels of dealer profits. Therefore, it is not sufficient to compare dealer profits while keeping $q_{2,p}$ fixed, but it is necessary to compare profits under different strategies, considering that the $q_{2,p}$ needed to compensate for a demand shortage varies depending on the distribution structure. This leads to the next result:

Sixth result: by keeping the total output fixed, the dealer's profits under both buyback strategies are higher than in the overlapping case, even though the buyback strategy requires the supplier to put more program cars on the market.

The latter result is interesting because it shows that the benefits for the dealer of being able to manage the product line outweigh the costs of having more program cars to put on the market through the buy-back.

Furthermore, it can be concluded from these results that the optimal solution that maximises the dealer's profits and the manufacturer's total sales is the buy-back strategy.

Combining the considerations and results of the model discussed above, it has been shown that the choice of buyback is not only in line with the circular economy model but is also economically sustainable: this choice in fact allows the manufacturer to align itself with the needs of the market, which increasingly demands "time-based cars", and at the same time with the needs of those who are not yet ready to consider the car solely as a service, but are beginning to reconsider the usefulness of buying a new one at full price; all this, of course, while managing to maintain the company's profit and sales targets.

2.9. Further considerations and introduction to the third chapter

The analysis of this thesis proceeds with a criticism of the buyback, being that on a global scale, only 1 in 250 cars in circulation is electric. This means that electric vehicles account for only 2.2% of the global vehicle market share. Meanwhile, in the US, plug-in electric cars account for less than 2% of the vehicle market. Based on these statistics, the transition to electric cars is clear, but the speed of adoption remains questionable.

After illustrating the role of the circular economy and highlighting its crucial importance in ensuring a reduction in CO_2 emissions, the next chapter will deal with a key driver in accelerating the decarbonization process: the measures taken by governments to promote the transition to electric mobility.

CHAPTER 3: IS THE TRANSITIONING TO THE ELECTRIC CARS SIMPLE? INCENTIVES, UNCERTAINTY, AND CHANGE ACCORDING TO THE BEHAVIOURAL ECONOMICS APPROACH

3.1. Incentives: role and limits in accelerating the decarbonization process

More and more governments are stimulating demand for electric mobility, and the challenge they face is to find increasingly functional solutions that get drivers to abandon their convictions and experience the benefits of sustainable, innovative and high-tech mobility. 2020 has been a watershed year for the electric vehicle sector and, according to the Global EV Report (IEA 2021), to maintain these growth rates, governments around the world must continue to both subsidies the purchase of greener cars and maintain and strengthen restrictive policies on CO_2 emissions and conventionally powered vehicles, at least until EVs reach price parity with ICEs and the recharging infrastructure becomes even more widespread. Demand stimulation initiatives are based on economic incentives (bonuses or discounts applied to the purchase price), tax concessions (exemption or reduction of property tax, registration tax or VAT rate) and non-economic measures (traffic management measures such as free and reserved parking spaces, access to fast lanes and restricted traffic zones). These measures are often combined with bonus/malus mechanisms aimed at encouraging the purchase of low-emission vehicles and discouraging the purchase of polluting vehicles. Purchase bonuses and traffic advantages bring immediate benefits to consumers, whereas tax deductions and tax exemptions are more beneficial in the medium to long term. The first forms of incentives, designed to reduce the price gap between electric cars and traditional vehicles and thus make EVs more economical, date back to the 1990s, when Norway - a country that has always been very sensitive to environmental and sustainability issues (suffice it to say that today about 98% of its electricity is produced from renewable sources) and has always been a pioneer of electric mobility - introduced a reduction in purchase and import taxes and an exemption from the annual road tax for battery - powered cars. In 2008, under President George W. Bush, the USA introduced a tax credit facility of up to $7,500 for the first 200. 000 cars sold by each manufacturer (a limit that was exceeded by

Tesla and General Motors, for which the threshold was raised to support US automakers); and in 2014, China began a direct purchase incentive scheme (Made in China 2025) that led to a +300% boom in BEV and PHEV car registrations between 2014 and 2015. China's policies on electric cars, with a view to achieving carbon neutrality by 2060, have a strong industrial policy connotation aimed at strengthening the national production chain. Already a leader in sales of EVs and battery production, China subsidises the purchase of electric cars made in China to keep domestic growth strong. Chinese incentives, unlike European ones which are all aimed almost exclusively at end users, are the prerogative of all players in the system: manufacturers, dealers and customers. Since 2017, government subsidies for users have been gradually decreasing as the number of electric vehicles has increased beyond expectations, and the Chinese government plans to eliminate the incentive mechanism by the end of 2022, when the market will become sufficiently mature due to the growth of both the charging infrastructure and public acceptance of electric vehicles. The natural evolution of government incentives is for them to end, once the objective for which they were established has been achieved; and in the case of electric cars, the objective will be achieved when they are fully accepted in their importance for a greener future, when they achieve a market share of probably more than 50%, and when economies of scale succeed in significantly lowering their costs. In any case, purchasers of electric vehicles in China enjoy incentives of between €3,300 and €2,400, calculated on the basis of the vehicles' declared range, power, car model and domestic manufacturers' production capacity, and are entitled to exemption from registration tax and value-added tax and a reduction in registration tax (only for vehicles on the list drawn up by the Ministry of Industry and Information Technology); buyers of foreign cars are only entitled to exemption from registration tax. One measure that fits into the framework of indirect incentives for e-mobility is the number plate lottery mechanism in the main cities of China, including Beijing and Shanghai. In order to reduce the number of cars in China's mega-cities and thus reduce air pollution, the government introduced a lottery in 2011 to obtain a number plate, which is needed to buy a car. Nowadays, for residents of the People's Republic's metropolises, driving is a matter of luck, and the only way to have a better chance of winning the lottery is to apply for an electric vehicle license plate, which accounts for about 70% of the licenses up for grabs. In terms of size and policies at state and federal level, the United States is one of the markets with the greatest potential for developing electric mobility. State policies have remained unchanged over the last ten years and mainly provide incentives in the form of tax credits and reductions in registration fees**;** under President Trump[32], there have been several attempts to abolish the incentives, but now, under President Biden, Congress is considering raising the tax credit threshold to $12,500 and raising the cap to 600,000 vehicles per manufacturer, as part of the new energy policy (CLEAN Future Act) aimed at cutting harmful emissions by 50% by 2030, which is being pursued by the new Democratic leadership.

Alongside the state's federal policies, the initiatives promoted by the Californian parliament are the most emblematic: since the end of the 1990s, California has launched a series of measures against air pollution, encouraging the adoption of the first battery-powered vehicles, and from 2016 it is aiming for 1.5 million electric vehicles registered by 2015. The direct incentives offered by the Republic of California, to which state incentives must also be added, are about $5,000 for BEVs and $1,500 for PHEVs, with an additional $800 if the old vehicle is scrapped and the insurance policy reduced by up to 10%. In addition, free parking and recharging are also provided at many hotel and commercial facilities and a pass for bus lanes (Enel S.p.A. 2017**.** Europe, with the Green Deal, is aiming at the full decarbonization of the system by 2050 and, with proposals to stop the sale of ICE vehicles from 2035 and the establishment of a 70 billion social climate fund, the EU aims to co-finance 50% of the incentives that Member States have made available to accelerate the electric transition. The regulatory framework for reducing emissions and the targets for stopping the sale of petrol cars all set between 2030 and 2040 have created a very favorable climate for e-mobility in the EU, and the generous growth of economic incentives (especially in France, Germany and Italy), combined with the massive expansion of charging stations, fueled the record-breaking escalation in EV sales in the pandemic year.

In 2020, the incentives to support the purchase of EVs for the main electric-committed countries of the Old Continent are as follows:

[32] Trump had declared in 2018 that electric mobility "is not going to work" and in 2019, in his Fiscal Budget proposal for 2020, he proposed to cut incentives to zero, again reiterating his skepticism about battery-powered cars, in order to increase savings in the country's public spending by around $2.5 billion over the next decade (Wool 2019).

France: since 2009, the French government has increasingly reinforced the environmental bonus-malus mechanism (eco-tax for first registration) aimed at penalizing the registration of new polluting vehicles, the amount of which (between €50 and €20. 000) varies more than proportionally as the amount of CO_2 emissions increases (on a scale ranging from 131 grams of CO_2 to over 225 grams per square kilometre), applying to vehicles registered for the first time after 1 January 2008; greener vehicles are incentivised by this mechanism as they do not pay the ecotax. Direct incentives for the purchase of EVs amount up to €7000 (for vehicles priced up to €45,000) and €3000 (for vehicles priced above €45,000), plus further incentives of up to €5000 for scrapping your own vehicle and local incentives (depending on your region of residence) of up to €5000. Both EVs and PHEVs are exempt from purchase tax, except in some where tax is paid, albeit at half the rate of conventional vehicles. Finally, on the level of non-monetary incentives, free parking spaces are provided for EVs throughout France (EAFO 2020; Wallbox Blog 2021).

Germany: The German government offers very high incentives of up to €9000 for EVs and up to €6750 for PHEVs costing less than €40,000, and for those costing more than €40,000, incentives of up to €7500 for full electrics and up to €5625 for plug-ins. In addition to these figures, regional and local incentives of up to €1,500 are also available, allowing a total discount of €10,500 on an electric car, making it truly competitive with other similar ICE models. In addition, EVs are entitled to reduced VAT (at 16% instead of 19%), a ten-year car tax exemption, free parking everywhere and free use of bus lanes (EAFO 2020; Wallbox Blog 2021).

The Netherlands: In the Netherlands, BEVs and PHEVs up to €45,000 on the list are eligible for a €4,000 discount (whether on purchase or lease) for new cars and a €2,000 discount for used cars. Despite the fact that monetary incentives for EVs are lower than in France and Germany, the Dutch government's initiatives to increase fuel prices and taxes for conventional vehicles have meant that the cost of ownership gap between a petrol/gasoline car and an electric car has almost disappeared in view of the 2030 scenario in which the country aims to run only electric vehicles. In addition, until 2024 owners of green vehicles are exempt from both registration and ownership taxes, and it is possible for all citizens to apply to local authorities for a free recharging point near their home, and several charging points in the country provide free energy (EAFO 2020; Wallbox Blog 2021).

United Kingdom: The UK government has launched a strategy [Road to Zero Strategy (Department for Transport | UK Government 2018)] for e-mobility that includes £290 million to accelerate the vehicular transition and V2G smart charging infrastructure, in view of the target of halting sales of conventional vehicles by 2040 (anticipated to be 2030 by PM Boris Johnson). Subsidies for the purchase of an electric car are a maximum of £3,000 (€3512) for cars costing less than 35,000 pounds (around €41,000) and are exempt from paying the UK's annual road tax. There are also local incentives such as interest-free mortgages for EVs in Scotland, additional subsidies of up to 5,000 pounds (about 5885 euros) in Northern Ireland, free access to London's Congestion Charge until 2025 and free parking and reserved lanes in many cities across the country (EAFO 2020; Wallbox Blog 2021).

Sweden: Sweden has a bonus malus system similar to the French one but with much lower thresholds: BEV and PHEV cars receive the purchase incentive[33] (up to a maximum of the equivalent of 6000), while all conventional cars an eco-tax each year starting from the base of the equivalent of 35 € to which is added 10 €, for each gram of CO_2/km2 emitted above the threshold of 90 g CO_2/km2 (up to 130 g CO_2/km2), and 13 € for each additional gram from 130 g CO_2 per square km of emissions. In addition, there is an additional tax for diesel vehicles only (Transport Styrelsen, 2021). In Sweden, there is a tax deduction for the purchase and installation of a home charging wallbox; many public parking areas are free for EVs and those with a charge allow charging for free (EAFO 2020; Wallbox Blog 2021).
Norway: In Norway, the suspension of the sale of thermal vehicles is even expected to be brought forward to 2025, given the remarkable results in the diffusion of electric cars (in 2020, 54% of all cars sold are electric); unlike many other European countries, there are no direct economic subsidies for the purchase of EVs. electric cars because

[33] Interestingly, in Sweden the user pays for the car in full at the time of purchase and after 6 months receives the bonus in the bank account from the state. The deferred incentive policy is designed to avoid opportunistic behavior: paying the bonus 6 months after registering the car can avoid the potential risk of the car owner reselling the car immediately after buying it to pocket the bonus and make a small profit at the expense of the state (Wappelhorst and Tietge 2018).

the demand for EVs is already at a much more mature stage compared to other international realities. However, the government has planned to continue to incentivize electric mobility through some tax breaks, including exemption from registration tax, exemption from VAT for the purchase and leasing of BEVs, reduced property tax (around €50 compared to €300 for thermal cars) and reduced price taxes for company vehicles. In Norway, electric cars enjoy additional indirect benefits such as free parking, free motorways, free tunnels and free ferries and the possibility to travel on bus lanes (EAFO 2020; Wallbox Blog 2021).

In Italy, until 2019, the EV incentive policy was very weak and backward compared to other European countries and in the world: the only benefits promoted were free parking, access to some urban LTZs without paying a ticket (like in Milan) and exemption from the payment of the vignette for the next 5 years after vehicle registration and, for the years after, the payment of 25% of the amount of a corresponding conventionally fueled vehicle. The only way to enjoy discounts on EVs was through promotions by manufacturers and dealers.

After a heated political debate, Italy passed the 2019 Budget Law ("Legge di Bilancio 2019" or Law 145/2018[34]), which introduces bonus-malus legislation from April 2019**,** as France had done ten years earlier - for the purchase of new cars, based on CO_2 emissions. It introduces a staggered ecotax on new vehicles with emissions above 190 g/km from €1100 up to a maximum of €2500 and an Ecobonus for vehicles emitting less than 60 g/km (electric and plug-in hybrids). The 2019 Ecobonus, financed by 60 million euros made available by the State until it is exhausted, envisaged: for those buying an electric car, a €4,000 discount, extendable up to €6,000 in total, by scrapping their old petrol/diesel Euro 0, 1, 2, 3, 4 car; for those buying a plug-in hybrid car with emissions of up to 60 g/km, the discount was €1,500, extendable up to €2,500 in total in the event of scrapping the old vehicle**.**

The BEV and PHEV incentive had only one limit: the expenditure threshold of €54,900 including VAT could not be exceeded for the purchase of the car.

[34] Paragraphs 1042 to 1046.

From January 2020, the Ecobonus for green vehicles has been financed with an additional €40 million until June, with plans to refinance it again in the second half of the year, given the launch of several electric models in 2020.

After the advent of the Covid-19 crisis and the consequent shock to the car market, the Government decided, with the Relaunch Decree, to increase the funds for incentives, allocating an overall increase of 400 million euro also for 2021, and to extend the bonus to newer and less polluting (Euro 6) petrol and diesel models up to 135 g/km to avoid aggravating the situation in the market - hard hit by the crisis - of traditional fuels still chosen and purchased by most Italians. From the second half of 2020, the "**Decreto di Rilancio**"[35] will extend the possibilities for low-emission vehicles: up to €8,000 can be discounted on the purchase of an electric car if it is scrapped (of a vehicle registered before January 2011) and up to €5,000 without scrapping.

The Ecobonus is complemented by a €2000 discount (down to €1000 without scrapping) granted by car dealers: the government and dealers have reached an agreement to facilitate sales and accelerate the electric transition.

For PHEVs, the total discount amounts to €6500 (€4500 incentive and €2000 dealer discount) in case of scrapping, which drops to €3500 (€2500 incentive and €1000 dealer discount) in total without scrapping the previous vehicle. New, 'cleaner' petrol and diesel vehicles are instead subject to the scrapping of a vehicle more than ten years old, if they want to benefit from the state eco-incentives of 3500, otherwise there is no incentive[36].

The limits for benefiting from the incentives are linked, also in 2020 (albeit with a higher threshold of about 11% for electrics compared to 2019), to a maximum expenditure ceiling for the car: for BEVs and PHEVs a maximum of €61,000 including VAT and €48,800 for traditional drive vehicles.

[35] "Decreto Legge Rilancio" - Conversion Law 17 July 2020, n.77 (art. 44 and 44-bis); subsequent decree for funds: Decreto Legge - 14 August 2020, n.104 (art.74).

[36] The objective of the incentive plan is to encourage as much as possible the generational replacement of the circulating car fleet in a direction that is as green as possible: the cars that benefit most from the incentives and those on which the Government has placed the emphasis for future development are BEVs and PHEVs, which provide incentives even without scrapping, unlike ICEs, which unlock the bonus only with scrapping

There are also incentives for the purchase of used cars of up to €2,000 with scrapping for plug-in hybrids and pure electrics and up to €1,000 for hybrids, petrol and diesel with scrapping (Automobile.it 2020).

In addition to state incentives, there are also regional and municipal incentives to further reduce the purchase price of a new car. Lombardy was one of the first Italian regions to make incentives available to its residents (from €2000 up to €8000) for the purchase of low-emission cars, and has allocated 18 million for 2019-20, but these have been exhausted very quickly due to the high number of requests from users. The incentives promoted by the Veneto Region for all vehicles (from €3,500 to €8,000) and by the provinces of Bolzano (€4,000 for EVs and €2,000 for PHEVs) and Trento (€4,000 for electrics and €1,500 for plug-in hybrids, plus €2,000 and €1,000 respectively for scrapping a polluting vehicle (Automobile.it 2020) are also very high. The most emblematic case from a municipal point of view is that of the Municipality of Milan which, for almost fifteen years now, has been committed to progressively reducing CO_2 emissions and the volume of traffic[37], has chosen to make available from 2020 for resident owners the possibility of enjoying a significant local incentive, which can be cumulated with the state Ecobonus, worth as much as 9600 € for electric cars and 6000 € for hybrids with scrapping of petrol cars up to Euro 2 or diesel cars up to Euro 5 (Automobile.it 2020).

To conclude this long and hopefully exhaustive overview, it can be seen that forms of direct or indirect incentive for the uptake of electric vehicles are widespread throughout the world and very effective, in some countries to a greater extent and in others to a lesser extent.

In Europe, national governments, guided by EU policies geared towards sustainable mobility and with increasingly stringent emissions targets, have taken up the challenge of electric vehicles, increasing, particularly during the 2020s (France,

[37] In 2008, during the Moratti mandate, the Municipality of Milan introduced the Ecopass, a toll for all vehicles not resident in the city center, proportional to the level of emissions of incoming vehicles, and the revenue was used to finance a number of sustainable mobility initiatives, including the municipal bike-sharing project BikeMi. Subsequently, in 2012 the Pisapia council created in the city center, in place of the Ecopass, what is now Area C, again with a toll for all vehicles, except hybrid, plug-in and electric cars. In 2019, Mayor Sala, with the establishment of the Climate Air Plan and the aim of reducing climate-changing emissions in the city of Milan by up to 45% by 2030, established Area B (without tolls), outside the perimeter of Area C, effectively banning the oldest and most polluting petrol and diesel vehicles from entering the city.

Germany, Italy) and despite the economic crisis, measures to support growth in the electrification of individual transport.

In the race to go electric, European nations are making significant inroads to catch up with China's growth trends, and leading the revolution are mainly Norway, the Netherlands, France, Germany, the United Kingdom and also Italy, which, although still lagging behind its continental brethren, has made (compared to 2019) giant strides in installing new charging points and selling BEV and PHEV vehicles, with a truly noteworthy incentive programme that can guarantee increasingly competitive end-user prices.

3.1.1. Policy makers have many reasons to be concerned about uncertainty

Considering Moretto's analysis: " Partecipation in accelerated vehicle-retirement programs: an option value model of the scrappage decision".

"The owner's decision to scrap a car is part of the net benefits of transportation services' maximization problem. We assume, as in Albertini et. al., 1995 a stationary world, an individual who "buys a car holds on to it for an optimal period of time, scraps it, and purchases another identical car". This ownership cycle lasts for the owner's life which, for simplicity's sake, is assumed to be infinite. Let π_t be the value of the car's driving services net of the costs of running the car per unit of time. We assume that these net driving services are described by a geometric Brownian motion:

$$d\pi_t = \alpha\pi_t d\mathrm{t} + \sigma\pi_t dz_t \ , \alpha{<=}0, \qquad \pi_0{=}\mathrm{c} \tag{25}$$

where dz is the increment of a standard Wiener process satisfying the conditions E(dz_t) = 0 and E (dzt^2)= dt. Some remarks about [25] are in order. First, as the above formulation implies E (π_t| c) = ce^{at}, a <= 0, means that the expected net value of driving services declines as the car ages because it gradually wears out and/or requires more maintenance. Second, there are random shocks to future evolution of the net value due to environmental factors (i.e. physical deterioration) as well as market conditions (i.e. operating costs and/or fuel price). Third, zero is an absorbing state for π . Finally, c stands for the value of the driving services of a car which is new to the individual. Therefore, every time the individual decides to change his vehicle a new car-life-cycle begins with a starting value of benefits expressed by c. Because the cycle is repeated indefinitely, by [25] the expected present value of the stream of the net benefits given by car ownership, starting at time t with a car of "status" π, can be written as follows:

$$B\ (\pi) = E\ \{\int_t^{\infty} \pi_s\, e^{-p(s-t)} ds - \sum_i\ K e^{-p(s_i - t)}\ |\pi_{t=}\ \pi\ \} \qquad (26)$$

where K is the cost of a new car net of the scrapping (resale) value, and r is the individuals discount factor. Yet s_i denotes the moments when a new car is bought, and the cost K is paid.

Since the state variable π jumps to c when a new vehicle is bought, the owner's problem resembles the one of impulse control analyzed by Harrison, Sellke and Taylor (1983) (a simplified exposition can be found in Dixit 1993, p. 26). In the course of its evolution π reaches a lower level of benefits b < c where it is no longer optimal to keep the car. Then π is instantaneously moved up to c at the cost K, i.e., the owner replaces the old car with a new (identical) vehicle. This ensure that the lump-sum cost K is not incurred too frequently and the owner's problem is to choose optimally the lower barrier b to maximize [26].

Like the decomposition of an intertemporal objective in dynamic programming, we can obtain the expected present value of benefits B (π) of an individual owning a vehicle of status $\pi \in$ [b,∞) by solving the following differential equation (Dixit 1993, p. 14-15) :

$$\frac{1}{2}\sigma^2\pi^2 B''(\pi) + \alpha\pi B'(\pi) - \rho B(\pi) = -\pi,\ for\quad \pi \in [b,\infty) \qquad (27)$$

with boundary $B\,(+\infty) = 0$, and B' , B'' as first and second derivatives of B with respect to π. By the linearity of [27] in B and making use of the above boundary condition, the general solution takes the form:

$$B(\pi) = A\pi_2^B + \frac{\pi}{\rho-\alpha}\ , \text{ for } \pi \in [b,\infty) \qquad (28)$$

where B_2 is the negative root of the quadratic equation

$$B_2 = \frac{1}{2}\sigma^2 B(B-1) + \alpha B - \rho = 0 \tag{29}$$

As the term $\frac{\pi}{\rho-\alpha}$ represents the present value or the (net) driving benefits obtained if the owner sticks with the same car forever, the term $A\pi_2^B$ must stand for the increase in benefits due to the cycling change of the car. Therefore A should be positive. The constant A as well as the lower barrier b are determined by imposing some boundary conditions on [27]. Considerations on optimal car retirement require a value matching condition which states that at the switching time the owner must be indifferent between being stuck with an old car or buying a new one, i.e. $B\ (b) = B(c)$ - K and a smooth pasting condition, i.e. $B'(b)$=0 to rule out arbitrary exercise of the option to change car a different moment. That is:

$$A(\ b_2^B - c_2^B) = \frac{c-b}{\rho-\alpha} - K \tag{30}$$

$$A ß_2\ b_2^B + \frac{b}{\rho-\alpha} = 0 \tag{31}$$

Note that, with $ß_2 \leq 0$, from [31] results $A > 0$. Also, as b<c the expression in brackets on the l.h.s. of [30] is positive, which implies that $\frac{c-b}{\rho-\alpha} > K$ or b < b_c = c-$(\rho-\alpha)K$.

That is, the value of driving services that triggers the car's change under uncertainty is lower than the one under certainty, where the latter is expressed by the value of driving services of a new car minus the annuity value of the cost (rental price) of investment. In short, the owner will abandon the old car for a new one every time the state variable π hits for the first time the lower the level b obtained solving the above system. Given the uncertainty, the owner should wait to obtain more information about the decline of his car s driving services before committing himself to buying a new one.

3.1.2. Capital Cost Subsidy and Participation rate

As in Alberini et al. (1995), let us consider the possibility that, at some point during a cycle, the car owner may be offered a subsidy on the cost of a new car to give up his old vehicle. By our setting, while B (b) indicates the value of the stream of net benefits that triggers the substitution, B (π) is the car's value when current driving services n are within the operating interval [b,∞). Then, to induce an individual who owners a car with status $\pi \in [b,c]$ to retire it now instead of waiting to reach the lower barrier b, the offer must be such that: $B(b)$+Offer = B (π), or:

$$\text{Offer} \geq \Omega(\pi;b) \equiv B(\pi) - B(b) > 0 \;, \tag{32}$$

where Q (n; b) can be interpreted as the owner's reservation price or the willingness to accept (WTA) price for the car. This reservation price depends, besides the current status of the car, on the lower barrier b which in turn depends on the level of uncertainty, G, the cost of capital, K the discount factor, p, and on the trend parameter, a. By simple substitution we obtain:

$$\Omega(\pi;\, b) = \mathrm{A}\,[\,\pi_2^{\mathrm{B}} - \mathrm{b}^{\beta_2}] + \frac{1}{\rho-\alpha}(\pi\text{-b}), \tag{33}$$

In addition, if the current status of the car falls to b, we get $\Omega(b;b)$ = 0; the owner decides to change car even without an incentive. On the other hand, if the car is new or by exogenous shocks π hits c, $\Omega(c;\mathrm{b}) = K$. Finally, if σ^2 –> 0, the above WTA reduces to

$$\Omega_c(\pi;\, \mathrm{b_c}) = \frac{1}{\rho-\alpha}(\mathrm{c}\text{- }\mathrm{b_c}), \tag{34}$$

where:

$$\mathrm{b_c} = c - (\,\rho - \alpha)\mathrm{K}, \text{and } \Omega_c(\mathrm{b_c};\mathrm{b_c}) = 0, \Omega_c(c\mathrm{b_c}) = K$$

To summarize, the consequence of uncertainty over future driving services is to slow down the scrapping cycle and then to reduce, ceteris paribus, the effect of a subsidy on the cost of capital to attract old cars and to induce earlier retirement.
That is, the uncertainty lowers the participation rate in programs of accelerated retirement "(M.Moretto, 2000)[38].

If one way to accelerate the decarbonization process is to encourage car switching, as can be seen from M. Moretto's study just proposed, in the automotive sector, switching depends very much on uncertainty.
It is appropriate to identify what uncertainty is holding back the process of scrapping and buying electric cars, in order to find suitable solutions.

3.2. "What are the main barriers to buying an electric car in the U.S.?" Research Model and Research questions

The development of electric cars worldwide is a major challenge. However, today there are some relevant obstacles that prevent the massive diffusion of battery-powered vehicles.
A quantitative survey was carried out to answer this question: "What are the barriers to e-mobility perceived as most relevant by people and how can these be overcome?". The questionnaire, in English, was made available on a voluntary basis to all persons without socio-demographic constraints, except for residence in the United States; respondents had to be 21 years of age or older[39]. A total of 325 people responded to the questionnaire.
In particular the first part of the questionnaire section consists of demographic and socio-demographic questions (gender, age, size of municipality of residence, geographical area of residence, educational qualification, occupation, annual household income, type of dwelling, availability of a garage, availability of a car). While the second section of the questionnaire is based on the assessment of barriers to buying an electric car. For this section, 5-point Likert scales (Not at all important, Not very important, Somewhat important, Very important, Extremely important) were used. Each barrier was crossed with each of the socio-demographic variables and the

[38] Source: International Journal of Transport Economics.
[39] The age of majority was considered to be 21, as this is the age set by most American states.

chi-square test was used to check whether or not there was independence between them. The data collected were grouped and catalogued using Microsoft Excel. The research was carried from 23 February to 3 March.

3.2.1. Analysis and Proposal of Interventions

From the literature review (Egbue and Long, 2012; Biresselioglu, Demirbag Kaplan and Yilmaz, 2018; Berkeley, Jarvis and Jones, 2018) 6 barriers, considered relevant to e-mobility, were extracted and then submitted to the evaluation of the questionnaire respondents to appreciate their significance.
Table below summarizes the barriers administered and the average score given to each of them by the users.

Table 3.1.: Barriers to electric car purchase and average valuation values.

BARRIERS	AVERAGE VALUATION VALUES (1-5)
Vehicle cost	4,07
Charging Infrastructure	4,25
Driving range	4,32
Environmental impact due to the production of research electricity from coal-fired power plants	3,55
Uncertain battery life (approx. 8 years)	3,61
Engine silence (dangerous for pedestrians and cyclists)	3,30

The six proposed barriers received mixed evaluations and two of them (engine silence as an accident hazard and uncertainty about battery life) were not considered as such. It can be observed that the most important barriers are the belief that the recharging infrastructure is still too scarce[40] and that this may affect the possibility of making long journeys, given the problem of the insufficiency of slow and especially fast recharging stations along the entire motorway network. Another barrier of considerable importance is the purchase price[41] , which receives an evaluation that is not too far removed from that of the recharging infrastructure, and finally, a barrier of considerable importance is the vehicle autonomy[42].

The remaining barriers all present a value of less than 4 (Very important), which was considered the barrier value for carrying out an in-depth behavioral analysis of the barrier under investigation.

However, the rating given to each barrier was analyzed on the basis of some socio-demographic variables to assess the degree of dependence between the barriers and the social and demographic factors. By means of the chi-square test performed on SPSS, it was possible to verify where there is independence or dependence between the variables considered. In order to determine whether or not there is significance between the dependency relationship between the variables, Pearson's chi-square test returns a measure of the significance measure: values less than or equal to 0.05 are significant and therefore, in this case there is an association between the variables and conversely, values greater than 0.05 are not significant. For convenience and practicality, only significant summary p-values of less than 0.05 and not all values of the test statistic for the individual modes of each variable were reported in Table 3.2. More specific results for the categorical modes are summarized in the discussion of results below the table. The barriers, which can be read in the rows of the table, are rated on a Likert scale of 1 to 5. Each barrier was cross-tabulated with each of the socio-demographic variables and the chi-square test was used to test whether or not there is independence between them.

[40] As observed in the following studies: (Lane and Potter 2007), (Browne, O'Mahony and Caulfield, 2012), (Axsen and Kurani, 2015), (Wan, Sperling and Wang ,2015).
[41]As observed in the following studies: (Diamond, 2009), (Egbue and Long 2012), (Carley et al., 2013), (Aretè Methodos ,2021).
[42] As observed in the following studies: (Priessner, Sposato and Hampl, 2018), (Aretè Methodos, 2021).

Table 3.2 : Significance values (p-value) less than or equal to 0.05 of the chi-square test between EV purchase barriers and socio-demographic characteristics.

BARRIERS	Sex	Education	Income	Employment	Size city of Residence	Age
Vehicle cost	-	0,02	0,024	0,034	-	-
Charging Infrastructure	0,08	-	-	0,01	0,02	-
Driving range			0,025	0,001	0,02	
Environmental impact of electricity production from coal-fired power stations	0,05	0,019	-	-	-	0,05
Uncertain battery life	0,05	-	-	-	-	-
Engine silence (dangerous for pedestrians and cyclists)	0,01	-	-	-	0,018	-

The analysis of the statistical test shows that female subjects attach greater importance to infrastructure barriers, negative environmental impact, uncertain battery life and the quietness of the engine as drivers of accident hazards. As far as education is concerned, subjects with a lower level of education (middle school certificate, high school diploma) attach a higher value of importance to the higher purchase price of electric cars, while in contrast, subjects with a higher level of education (university degree) attach much higher values to the environmental impact. It appears, therefore, that educational qualifications and higher environmental awareness are positively correlated (Meyer, 2015). Increased environmental awareness also affects those under 36 years of age, millennials and Gen Z. As far as income level is concerned, it can be seen that the latter is significantly associated with vehicle price and range: the higher the household income, the lower the perceived concerns and assessments about vehicle price, and the lower the income, the greater the concerns about vehicle range over driving distances.

As far as employment is concerned, it is good to say first of all that the majority of the respondents to the questionnaire are students and working students, but, in any case, those who work and study attribute a lower value to the barriers. Concern about vehicle autonomy seems to be of particular interest to people who study or work and live in smaller municipalities. It is therefore conceivable that these are people who, for study or work, move daily to municipalities larger than their own, which offer more opportunities and, consequently, the need to make longer journeys that involve leaving the municipality of residence affects their perception of the autonomy they feel they need from a vehicle.

In addition, the size of the municipality also influences assessments of recharging infrastructure and engine quietness: recharging infrastructure is nowadays more widespread in large and medium-sized cities and in the most populated, industrialized urban centers or at points of major interest (shopping areas, tourist spots...), and therefore those living in a smaller municipality are likely to perceive the lack of recharging infrastructure as strong. Therefore those who live in a smaller municipality are likely to perceive the insufficiency of the network of recharging stations as strong; those who live in a larger municipality, on the other hand, are more concerned about the quietness of the engine as a risk factor for accidents because, since traffic and car jams are mainly concentrated in larger cities or municipalities, it is very likely that in the middle of urban chaos or due to distraction or not having heard a car passing by, they will find themselves involved in an unpleasant accident.

3.2.2. Purchase price

According to research (YouGov, 2020) conducted in 9 European countries, more than 6 out of 10 Europeans are concerned that the initial cost of the car, which varies according to the tax breaks and incentives available in each country, is too high. In line with the results of other noteworthy research conducted in the field of barriers to electric mobility (Giffi et al., 2010), (Element Energy, 2013), (Adeptu and Keshar, 2015) also the analysis of the questionnaire showed that the purchase price is a barrier of significant importance also in U.S. In particular, according to an attitudinal study carried out in 17 countries worldwide (Giffi Vitale Jr et al., 2011), it was shown that if electric cars cost exactly (or even less) than conventional petrol and diesel cars, most people would be more than willing to seriously consider buying a battery car.

3.3.2.1. Cognitive biases related to purchase price

Why is the purchase price of cars considered a barrier? most people, when buying a vehicle or another type of good, do not consider or marginalize most of the cost items related to the product (the Total Cost of Ownership), discounting the immediate costs and benefits and underestimating the benefits and cost savings that can be obtained in the future over time.

- Hyperbolic discounting: one of the biases most related to the perception of the purchase price of electric cars has to do with organizational myopia and the limited ability to frame potential future opportunities in the context of present choices (Catino, 2009). Hyperbolic discounting is a behavioral dynamic that may explain it. It is a typical cognitive bias that frames the human tendency to prefer immediate rewards over future rewards, even when immediate rewards are drastically lower in terms of benefits and rewards when compared to future rewards (Thaler, 1980; Loewenstein and Thaler, 1989; Frederiks, Stenner and Hobman, 2015; Harris and Laibson, 2001; Green et al., 2014). Hyperbolic discounting often leads towards quite limited and poor decision making because it incentivizes impulsivity (Kahneman's System 1) and immediate gratification instead of the achievement of certainly more complicated but also more satisfying conditions and goals.

- Fallacy of sunk/unrecoverable costs: A sunk cost is an investment that has already been made. This bias occurs when people insist on continuing a certain activity or behavior at all costs, even when it is clear that it is no longer profitable, because they have already invested a lot of mental and economic resources in it. The sunk cost fallacy is a mental mechanism that leads people to think that they cannot stop what they are doing and what they have done, however profitable or harmful it may be, otherwise what they have invested in terms of time, energy and money up to that point would be irretrievably lost and wasted (Thaler, 1980; Arkes and Blumer, 1985).Most people are prone to the choices they have made and the efforts they have made to go along with them and therefore tend to focus more on the past than on the future. In the research context of this paper, it can be assumed that many people therefore find it difficult to justify the relatively higher price of electric cars for the following reasons: They have already spent a lot of money on their petrol/diesel car; they have been driving conventional cars all their lives and, regardless of fuel consumption and maintenance. Habit leads them to think that "good old classic motorization" is still the best (status quo bias), or because they feel they do not trust electric cars (familiarity bias, which leads them to invest in something known and familiar, despite the possibility of investing in something less known but which would bring more benefits). Decision-making is influenced by many factors and habit is only one of them: other types of bias, age, experience, income, education, beliefs and cultural identity, social group dynamics and the inertial force of past choices. The fallacy of sunk costs, however, seems to have little hold on those people who are vocationally very curious and enthusiastic about novelties: in the field of new technologies and new products these individuals are called "early adopters" (Rogers, 1962) and are extremely strategic potential trendsetters for the market, as they see novelties as potential opportunities and are willing to experiment a lot. Yet, they make up only about 10% of the population (Zarazua de Rubens, 2019).

3.3.2.2. Interventions

1) "Labelling

Hyperbolic discounting and the fallacy of sunk costs, which lead to short-sighted decisions limited to a very short time horizon, are two significant biases that strongly undermine the intention to purchase an electric car. Recognizing cognitive biases is the first starting point for proposing interventions to overcome them, and it has been shown that simply providing detailed and clear information about the total cost of owning an electric vehicle, compared to that of a similar petrol-powered vehicle, goes a long way to reducing uncertainty and making a more informed choice (Zhu, 2016). Labelling is the naming of specific activities or the provision of salient information (such as that contained in product labels) to encourage certain behaviors (e.g. a sign on a bin explaining how waste should be sorted for recycling).

Labelling important information about the maintenance and refueling costs of electric cars and making it visible, compared with information about conventional cars, is one possible intervention that can be very effective in trying to remove the cognitive barrier and increase consumer awareness of the economic advantages of owning an electric car in the long run. An effective labelling operation must be simple and straightforward: the cost items must be neat, to the point and easily identifiable so that cognitive efforts in searching for and interpreting them are minimal. Clear indications, bright colors, appealing images and immediacy are key elements in the design of a successful information intervention (Kahneman, 2017), (Environmental Protection Agency, 2010).

Providing information on the cost of ownership can therefore be very useful in educating consumers to make more responsible choices, and now more than ever, thanks to social networks and the vastness and convenience of the web, an investment in web and label design can really be an extremely relevant turning point in getting consumers on their side and directing them towards a certain choice.

Suggestions for implementing electric mobility

For dealers:

- Effective label design can help to limit the effects of decision myopia and hyperbolic discounting. Myopic decision making and hyperbolic discounting: Dealers' websites could introduce on the web pages of individual vehicles, next to the final purchase price, a supplementary table showing the total costs of owning the car for five years.
- Exploiting the psychological influence of loss aversion: Since individuals perceive losses more than gains, car salesmen can use this psychological mechanism to their advantage to highlight the greater economic impact of the cost of ownership of a conventional car compared to an electric car. Dealers interested in driving up sales of EVs can therefore communicate to potential customers that a petrol car costs more than €1,000 per year (and thus more than €5,000 over five years) in terms of maintenance, tax and refueling than an electric car.

According to research conducted by Greenpeace (Gehrs, 2020), it has emerged that one of the serious problems afflicting the end market for EVs is a problem that also pervades the electric supply chain itself: misinformation. The lack of knowledge among salespeople about the characteristics of battery-powered cars, the incentive mechanism and the recharging operation contributes to discouraging the sale of EVs. It is therefore urgent that dealerships, as for-profit enterprises, invest in training human capital: the salesperson has always played a key role, as he or she is the link between the customer and the car to be sold. To sell successfully, it is not enough just to be empathetic and persuasive, because the conviction of the goodness of a purchase also passes through knowledge and the degree of perceived control over the goods one intends to sell.

It is therefore imperative that car dealers are thoroughly prepared to be at the forefront of the battle against misinformation and a general sense of ignorance. It is therefore imperative that car dealers are carefully prepared to be at the forefront of the battle against misinformation and the general sense of disorientation that EV-interested customers may perceive in the sea of fake news, unfounded clichés and general news about the electric world.

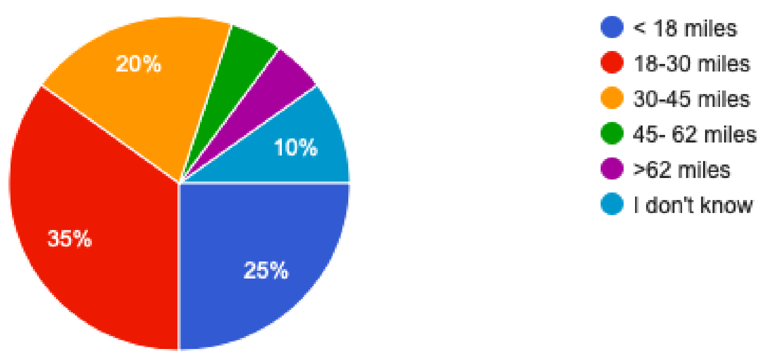
3.3.3. Autonomy

A major barrier faced by potential buyers of an electric vehicle is electric autonomy. This barrier in the market is known as "range anxiety" and has a significant influence on individuals' utility judgement about electric cars (Giffi et al., 2010). People want to be confident that they can drive from point A to point B without worrying about running out of charge and having to stop at the edge of the road with dead batteries and not being able to do anything (Tannahill, Muttaqi and Sutanto, 2015).

Research (Franke and Krems, 2013) shows, however, that this barrier is the result of an overestimation that is not at all proportionate with the reality of the facts: according to data from the Audimob observatory (ISFORT, 2020) on mobility in our country, Italians travel on average about 30 km a day by car and, according to research carried out on behalf of the European Commission (Pasaoglu et al., 2012), commuters throughout Europe drive an average of 40-80 km a day and make about 2 car journeys a day.

With an average range of about 250 km (155 miles) , practically all electric vehicles on the market today are already perfectly capable of covering the average daily distances travelled by most users.

The research questionnaire also investigated the mobility habits of the American users interviewed, and the results obtained are in line with the trends of studies on the average driving range of most people 8 out of 10 users declared that they drive less than 45 miles a day, so theoretically, an average electric car would be more than suitable for most people's daily needs, and all the anxiety about range would therefore be just a psychological construct that is not really justified.



Graph 1: results of the questionnaire survey to the question " Thinking about your habits, how many miles do you usually drive on an ordinary day when using your car?".

Some scholars have even put forward the hypothesis that limited autonomy and related worries are nothing more than an excuse to avoid serious consideration of a major change in purchasing decisions (Noel and Sovacool, 2016; Kirsch, 2000) and that autonomy anxiety is the tip of the iceberg of a much more deep-rooted problem in people's minds, namely misperception of their driving habits, which the mind tends to overestimate (Jensen , Cherchi and Mabit , 2013).

3.3.3.1. Cognitive biases related to driving range:

- **Status Quo Bias and loss aversion:** Status quo bias is a cognitive error consisting of a preference for the current situation over other possible situations. The current situation is taken as the reference point and any situational change is perceived as a loss. This bias is strongly linked to the choice of buying an electric car: people compare a new product, such as the electric car, with another that serves as a reference, namely the traditional car, and in the specific case of this barrier, the terms of comparison are on the one hand the autonomy of the battery-powered vehicle (the novelty, considered inferior and immature) and on the other hand the autonomy (greater and more established) of the petrol or diesel car. People are resistant to change because anything new generates upset and the fear of not being able to cope optimally. Change requires effort, and it is not hard to imagine that someone who has always been used to driving a petrol-powered car would be reluctant to switch to an electric car, which, moreover, gives them a shorter range in terms of kilometers - even if this is in line with their needs - than they have always been used to. Change is often perceived as a loss, and no non-pathological masochist likes to lose. Psychologically, the pain of loss is almost twice as great as the joy of gain because people are naturally averse to loss (Kahneman and Tversky, 1992). Range anxiety and misperceptions about driving range are a very serious problem for potential buyers and will be as long as there is a significant gap between the expectation of driving long distances on a single charge and the actual ability of EVs to do so. The most intuitive and reasonable solution would be to equip electric cars with even larger batteries, but without the cost of producing these batteries being so high as to raise the purchase price of the vehicles even further. The answer to this problem will surely come in the future with technical progress and economies of scale, which will enable electric and ICE vehicles to compete on equal terms in the market. ICE vehicles are the current benchmark for consumers, so it seems inevitable that they will consider the switch to an electric car as a significant loss, and although the benefits for green drivers in terms of cost savings and traffic advantages (free blue parking etc.) are very tempting, escaping the loss trap is extremely complicated at present.

- **Anchoring effect:** The anchoring effect is closely related to the status quo bias and is a very powerful cognitive distortion that occurs when people, in making decisions, are unconsciously influenced usually by the first environmental factors and information that are provided to them or that are immediately available by chance. This information, whether relevant or irrelevant, is called an anchor and serves as a yardstick for evaluating all other information and stimuli processed at a later time (Tversky and Kahneman, 1974 ; Strack and Mussweiler, 1997).This distortion affects, to a greater or lesser extent, essentially anyone, but especially those who lack a certain level of knowledge and expertise on the subject in question; on the other hand, more informed and more experienced people are more insensitive to the effect of anchors (Wilson, Houston and Etling, 1996), but it is worth remembering that anchoring can still deceive even the most attentive and competent subjects (Mussweiler, Strack and Pfeiffer, 2000).
- **Choice-supportive bias:** Choice-supportive bias is very similar to confirmation bias, which is the cognitive error that leads us to give more credibility to information that confirms our beliefs, while ignoring or downplaying information that contradicts them. Choice-support bias also has a confirmatory nature: when we make a choice we are inclined to overestimate the benefits we gain from it. The memory of past purchase choices is better than the memory of discarded purchase options: to support and corroborate the past decision, the mind retrieves every advantageous memory of that choice, removing or omitting any unpleasant memories, so as not to diminish it in comparison with the other discarded options. Choice-supportive bias can

support the choice of a petrol car by making us label the mileage as a negative feature of the alternative choice, i.e. the electric car, and thus making our mind succeed in supporting the idea that a correct choice (though perhaps not the best one) has been made, by virtue of the debasement of the alternative. In other words, this is - as they say - pulling the wool over one's own eyes to support what may be a mere justification for not having to adapt to change, even though change is in fact more than feasible.

3.3.3.2. Interventions

1) Perspective-taking

Perspective-taking refers to an individual's ability to understand the feelings, thoughts, and opinions of others (Carpendale and Lewis, 2006) and to adopt the perspective of others, interpreting their behaviour and thinking according to the context.

Adopting a perspective other than one's own greatly helps to broaden the view of one's own reality and to make better decisions that take into account a much wider and more articulated range of options and patterns of reasoning. The richness of cross-sectional and multifaceted thinking can therefore be a solution to reduce the effect of loss aversion on our decision-making ability (Sokol-Hessner et al., 2009). According to the research conducted by Sokol-Hessner et al., "thinking like a financial trader would" can be a strategy to overcome the psychological impact of loss aversion: financial traders are aware that loss is an essential part of their trade and are therefore prepared to accept it and limit its influence on subsequent investment choices.

To overcome the obstacle of range anxiety in battery-powered cars, adopting the financial trader's "modus cogitandi" means seeing things from a different perspective and interpreting what might be considered a loss as an opportunity: it's about striving to see the glass as half full rather than half empty and broadening your vision. Reduced mileage can be seen in the perspective of considering other means of transport for travel. To contribute to CO_2 reduction, more and more people should switch to a modal shift, i.e. change their transport choice: where possible, moving on foot and by bicycle is definitely the best alternative both for one's own health and for the environment; using public transport (which is increasingly electrifying in large Italian cities) improves urban traffic, reduces road congestion, allows less pollutants to enter the air and, through subscription formulas, saves absolutely no small amount in comparison to the costs incurred for refueling a car (EEA, 2020). Travelling on public transport is also safer than driving a car: a bus is 79 times safer than a car, and subways and trains are even safer, and trains are now the most environmentally friendly means of public transport in terms of emissions (EEA, 2020). Of course, the change of mentality and the consideration of other mobility options have a long-term effect if and only if accessibility to these options is guaranteed and is beneficial: if the transport systems are difficult to access (distant and inconveniently located bus stops, lack of cycle paths, impossibility of buying tickets online) or unreliable (transport delays, strikes, cancellation of services, dilapidated means of transport, poorly supervised and dirty stations (which at certain times of the day may also become drug dens or theatres of violence and theft) (Pietroni and De Rosa ,2021).

As already seen in the second chapter, other solutions that have a positive effect on the greater environmental sustainability of transport concern the spread of shared mobility choices and alternatives to public transport such as car sharing and carpooling.

To sum up, accepting other mobility options and broadening one's perspective in a direction that is certainly more ecological, and in some cases also more economical, can certainly help to make the impact of the limited autonomy of electric cars less noticeable.

2) Point of reference reframing

An alternative to perspective-taking to better manage autonomy anxiety is point of reference reframing.

Often, people consider the prima facie reference status quo as a correct and safe situation, without however caring about the actual goodness and reasonableness of the situation. All evaluations of a choice start from the reference point and the status quo with the assumption that the reference point is right and so well established that there is no point in questioning it. But are we really sure that this is the case?

The hard core of marketing theory is the needs and wants of consumers, which are the starting point on which products are created and subsequently placed on the market (Fahy and Jobber , 2019). Just as marketers investigate and assess consumer needs in order to formulate a winning product strategy, so too must those who want to trigger behavioral change in a certain direction: focusing first on actively assessing the goodness of the reference point, since this will influence the final choice, is the first fundamental step in harmonizing subsequent assessments and making them more considered and conscious (Bostrom and Ord, 2006). It is therefore necessary to first rethink the reference point itself.

Since the reference point of consumers in the automotive market is the traditional internal combustion car, potential buyers of an electric car tend to make an assessment for a possible change of power supply from the customary reference point of traditional vehicles, without really assessing the characteristics of the reference point.

An example of reformulating the reference point is to shift the starting point of the choice to buy a vehicle to one's own needs. In order to arrive at an optimal solution, it is essential to identify and understand and then communicate one's needs.

One of the first questions a consumer asks about an electric car is: "How many kilometers/miles does it do?". The right question an attentive consumer should actually be asking is: "How many kilometers/miles do I do?". It is a question of answering fire with fire: to defeat one status quo you need another status quo. So, setting one's own individual mobility needs (and habits) as a benchmark can allow a fairer assessment of the various options on the market. One of the most common mistakes told by car salesmen is the fact that customers very often do not express their needs because they apparently do not seem to be aware of their own needs and driving habits (DriveK, 2018).

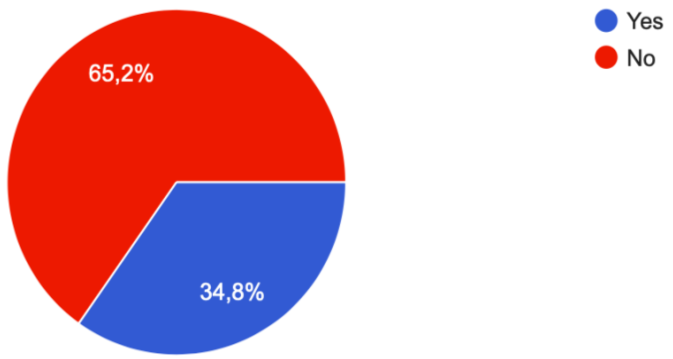
Therefore, for dealerships interested in increasing sales of EVs, it would make sense to educate salespeople to investigate customers' needs and habits and, once they have verified that these are potentially in line with what an electric car offers, to make them opt for the green solution. Questions such as "How many kilometers/miles do you drive in a day? How often do you go on long journeys (>100 km / 62 miles)?" and questions that draw on the influence of the Subjective Social Norm are simple examples of how a cognitive effort can be triggered in the consumer that can lead to greater awareness of their needs and formulate considered decisions based on them.

Another strategy that EVs sellers could adopt is that of "considering the opposite" (Mussweiler, Strack and Pfeiffer, 2000) to reduce the influence of anchoring bias which is simply to trigger critical reasoning about why the first impression that strikes us might not be true. It may seem trivial, but asking ourselves about the real reasons why we feel so anxious about the autonomy of electric cars is by no means self-evident, and the question may lead us to realize that the fear is greater in the head than in the reality of the facts.

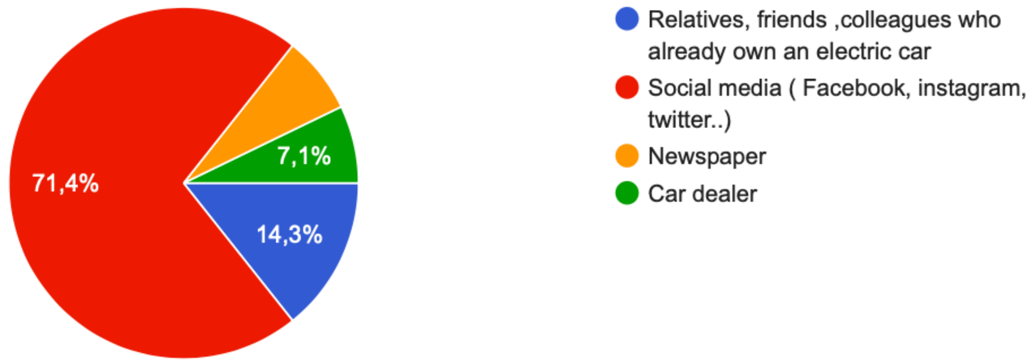
3) Test drive

Prejudice alters the perception of things and only fuels a series of fears and anxieties about something. It may make sense to justify the existence of range anxiety when compared to the reference point of the range of a petrol car, provided, however, that you have actually tried driving an electric car and been disappointed or distressed.

According to the data from the research questionnaire, as shown in the graph below almost 70% of the 325 respondents to the survey said they had never tried driving an electric car:



Graph 2: Results of the questionnaire survey to the question " Have you ever driven an electric car?".



Graph 3: Results of the questionnaire survey to the question " Which sources did you find more useful when getting information about electric car?.

So most thoughts on electric cars are based on hearsay and the odd piece of news they happen to read online in the newspapers or on social networks, with 7 out of 10 people saying that all they know about battery-powered cars comes from Instagram and Facebook. This leads us to conclude that the web is the most interesting and powerful source of information on which to focus in order to do "electric evangelism", but that at the same time much of the news disseminated online is often incomplete and in some cases completely wrong or, worse, fake... fake news.

In any case, in order to bring people closer to zero-emission mobility and defeat their skepticism and rampant anxieties about the car's mileage and operation, the most direct solution to the problem is to kick-off with a test drive.

Studies confirm that it only takes three days of practice with an electric car to significantly reduce fears about range per Kilometers/miles and that in less than a month, mental barriers to e-mobility can be almost completely eradicated (Nilsson, 2011; Bühler et al., 2014; Ryghaug and Toftaker, 2014). Furthermore, given that almost 9 out of 10 users who have chosen to switch to an electric car are fully satisfied and would never go back to a conventional vehicle (YouGov, 2020), it seems logical to infer that the comparatively low range is not actually limiting and unsatisfactory in actual usage practice (McKinsey, 2017).

The electric test drive requires a new and different approach to that reserved for internal combustion cars: awareness is required first and foremost, and this is required of the personnel involved in running the test. The disseminator must be thoroughly informed about the timing of the vehicle supply, the functioning of the charging infrastructure, maintenance and the service network.

The electric car is a highly technological and hyper-connected product, and approaching it requires a certain degree of innovation and digital openness.

A study by New Zealand's National Research Council (2015) revealed that 21st century consumers are no longer as likely to go to dealerships to see vehicles in person because almost all dealership websites now offer virtual tours and remote advisory services (including via Skype) that are so detailed and specific that most of the steps in choosing a vehicle are done mainly from the comfort of a computer or mobile phone at home. In the face of this new, mainly telematic mode of vehicle 'experience', the best solution for approaching people and inviting them to a more evident physical contact with drive tests can be encapsulated in the following saying: "If the mountain doesn't go to Mohammed, then Mohammed goes to the mountain". So, if buyers are going to dealerships less and less, except to finalize the sale and collection of the vehicle, then it must be the dealerships that go to potential customers: open-air ride and drive events, in city squares and streets, can be very valuable opportunities to arouse the interest of passers-by in the cars on display, and the chance to test drive the vehicle without obligation, with the support of an informed consultant, and immediately, can certainly contribute to raising awareness of electric cars. At these major events, not only the world's most famous and luxurious cars are on display, but also electric vehicles, which are made available to the public in order to put into practice the approach to mobility transition that the world needs to undergo. Some car manufacturers such as Hyundai and Nissan, who are among the leaders of electric in the international scene, aware that practice in some cases is much more useful than theory (Li et al., 2017) have launched initiatives that allow people to get behind the wheel of their EVs for several consecutive days to discover the benefits and advantages of the new mobility of the future.

4) Gamification

Gamification is an activity that involves doing something, exploiting game design and video game techniques to motivate people to achieve a certain goal. In the perspective of behavioral economics, gamification and nudge are two sides of the same coin: gamification aims at pushing individuals to make better choices for their lives according to a game logic, nudge aims at changing choices into real habits of change. It has been demonstrated that the game dynamic is capable of actively involving users and of orienting behaviour in a very interesting way: to give a practical example, the steps of a Stockholm underground station were transformed into piano keys and since then about 70% of travelers have chosen to use the stairs instead of taking the lifts (Corazziari, 2017); or, very much in vogue in the fitness world, Fitbit and Apple have developed smart wristwatches that send notifications and pulses to encourage users to stand up, if they spend too much time sitting, by encouraging competition between users (by displaying others' fitness results) and awarding virtual bagdies and trophies upon reaching certain exercise goals. The approach to change through play is very functional in activating and maintaining users' interest and reducing stress and psychological barriers of resistance to change and laziness (Horne-Moyer et al., 2014).

This approach can also be very useful for the green mobility sector. Toyota in 2020 launched Kinto, an app-based system that allows people to plan their journeys via a car sharing service and to take advantage of long-term rental formulas for Toyota-Lexus vehicles. The turning point of this major service: a dynamic reward system that rewards those who commit fewer offences and frequently recharge their battery-powered vehicles with discounts on the monthly subscription. In order to encourage the use of electric traction, BMW has set up a loyalty program for drivers of plug-in hybrids that rewards users who cover the most kilometers in electric mode only, and the rewards consist (once a certain number of points have been accumulated), for example, in free recharges for their vehicles. Interestingly, BMW has created e-Drive Zones within that program: these are 'virtual enclosures' (they work a bit like the maps of a video game in exploration mode) that define certain areas in which the car automatically activates electric mode and in which points are worth double.

In conclusion, the gamification approach can be a very useful ally for electric mobility: it can help to perceive mechanical and repetitive actions such as driving and recharging in a more interesting way and can contribute in a fun way to the growth of users' motivation and commitment in driving a battery-powered car, making the driving experience more complete and certainly more original.

Suggestions for the implementation of electric mobility:

- Car manufacturers and dealerships in partnership could organize more visible events open to the public to inform potential customers about battery capacity (and ongoing technological improvements) and to give more people the opportunity to discover the products more closely and test them themselves.
- Car manufacturers and public charging station operators should implement the functionality of their smartphone applications by adding reward or recognition systems, following the gamification approach, to reward, stimulate and intrigue (and even educate) EV users and give them the opportunity to experience electric driving in a more fun and authentic, experiential way;
- Salespeople should insist, without being intrusive, on potential customers to try driving a battery-powered car and possibly give the car on trial for a few days or a whole week (trial period);
- Salespeople need to be adequately trained on the products and to communicate, both telematically and live, in an effective and educational way the importance of knowing one's own mobility habits and needs, using de-biasing behavioral strategies;
- Public administrations and the government need to finance and promote sustainable mobility events to raise the image of sustainable mobility and demonstrate that public support for the electric transition is primary.

3.3.4. Charging infrastructure

Among the main criticisms levelled at the world of electric cars and perceived as obstacles are the difficulty of finding charging stations, the difficulty of using them and the charging times, which are still perceived as too long (Giffi et al., 2010; Pierre, Jemelin and Louvet, 2011).

Recharging times depend on many factors (the kW power being charged, the maximum power accepted by the vehicle charger, the type of cable being used and the capacity of the car battery and its level of charge at the time of the energy refill operation) and are related to the problem of vehicle autonomy: a slow recharging column (usually with 7 kW power) transfers enough energy to the vehicle to allow a car to gain about 25 km of range for every hour of recharging, and so to fully recharge, from zero (although it is almost impossible in practice for a user to bring the battery state of charge to zero[43]), an average electric car would take about 8 hours.

The problem of charging time and the problem of range are therefore extremely interlinked and both appear to be influenced by what is a very common error of judgement in EVs: the constant and incessant comparison with the conventionally powered car (Graham-Rowe et al., 2012). The negative perception of slow recharging times is mainly due to the fact that almost all people take the speed and immediate convenience of refuelling a petrol or diesel vehicle at the pump as a yardstick for making their judgement. The mechanism of comparison is also triggered by the perception of the number of charging stations available: although, as in Italy[44], the number of public charging stations in U.S. has grown exponentially in recent years and in January 2022, the U.S. had almost 113,600 charging outlets for plug-in electic vehicles (EVs).

[43] Although human beings are rationally limited, every individual has, to a greater or lesser extent, a certain degree of common sense and, because of loss aversion, which is surely a psychological reflex common to all people, no one would be so clueless as to consciously drain the vehicle battery and then find himself in the unfortunate situation of being 'stranded' and having to call a breakdown truck or mobile charging service to resume his journey. In addition, all electric cars are equipped with an electronic system that promptly alerts the driver when it is time to recharge, and the most sophisticated cars by default map out the shortest route to the nearest charging station for refueling. So, apart from some exceptionally rare cases, the problem of running out of autonomy is basically non-existent and is merely a prejudice that has little to do with the actual practical reality of things.

[44] In Italy the number of public charging stations has grown exponentially in recent years: there are now more than 11,000 across the country, EV stations, compared to the number of petrol stations (around 21,000), are still few in number, although fully sufficient for the electric fleet currently in circulation; information provided from the latest update on Motus-E's electric charging infrastructure (2021).

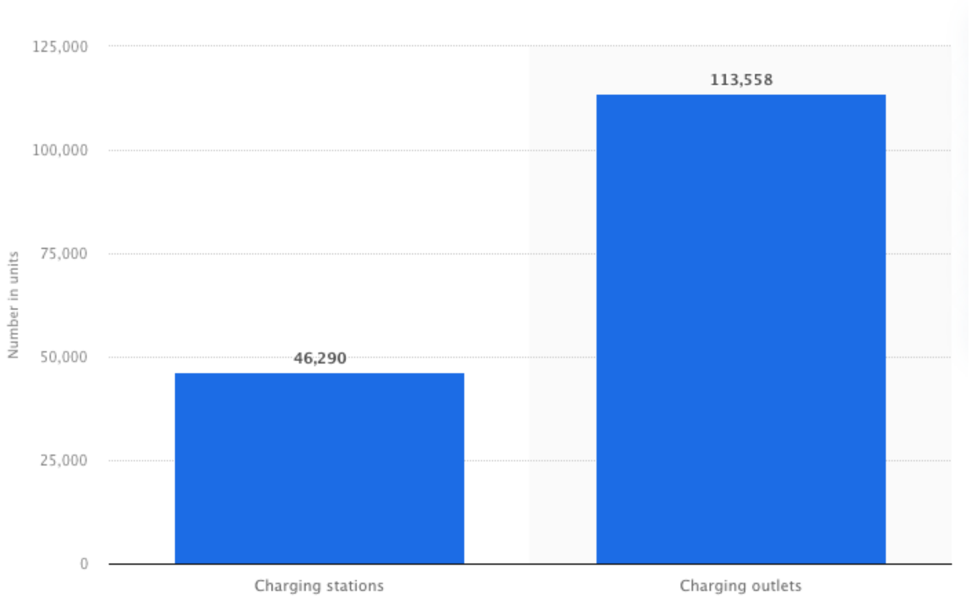


Figure 26: Electric vehicle charging stations and outlets in U.S. - January 2022

However, the number of columns appears to be perceived as lower than it actually is, both because electric charging stations are much less visible and usually less strategic (in terms of location) in their arrangement on urban, suburban and residential territory than the traditional and well-known petrol and diesel pumps[45] both because there are many charging points that are not operational because they are still waiting for bureaucratic approval for the operation of connection to the electricity grid and therefore to the final set-up.

3.3.4.1. Cognitive biases related to charging infrastructure

- **Status Quo Bias:** the status quo bias here relates to the cognitive mental scheme of approach to the EV charging process. Many users think that recharging an EV works in exactly the same way as refuelling a petrol car (Kyne, 2020), whereas in reality things are very different: recharging, rebus sic stantibus, does not involve the use of cash and is a highly digitalised operation that requires the use of a smartphone app or a specific card from the operator of the refuelling point from which one intends to refuel. The status quo is also evident with regard to the belief that there are far fewer refuelling

[45] Source: (QuiFinanza 2019).

stations than there are: according to research conducted by the multinational Ipsos in New Zealand (2017), the reference point of all people is the petrol station, whose presence is almost impossible to miss due to the huge gaudy signs surrounding it and the bright colours and height of the shelters, and most individuals are convinced that if charging stations looked more like stations in the current fuel distribution model the degree of positive perception of charging points would probably increase significantly.

- **Attentional bias:** attentional bias refers to selective attention, which is the ability to focus on a target stimulus and to process in a privileged way information relevant to the achievement of a given goal, while inevitably neglecting or considering only marginally many other types of stimuli that the environment provides (Chun and Johnson, 2011). Attentional bias is a cognitive distortion that involves an unconscious attentional bias related to the tendency to pay attention to some things while ignoring or marginalising others (Marois and Ivanoff, 2005). Like all biases and heuristics, it is a shortcut that optimises information processing time, but often leads us into the trap of making a judgement that leads to a suboptimal choice. The heuristic of availability inevitably leads to deciding often on the basis of the first image or the first piece of information that comes to mind and people, due to the effect of attentional bias are usually pushed to give greater importance to those stimuli with which they are more familiar and which are widely present in their minds: in the case at hand, the image of petrol pumps is certainly much more salient and familiar than that of a charging station and therefore it will be much more immediate and easier to recognise and notice a gas station than a charging station and to assume that the number of charging stations - since these are generally out of the attentional focus of the non-electric-committed - is much lower and insufficient when compared to that of the dear old petrol pumps (Tversky and Kahneman, 1974; Kliger and Kudryavtsev, 2010).
- **Bounded rationality and cognitive load theory:** Attentional bias and availability heuristics are both related to the concept of bounded rationality developed by Herbert Simon. The human mind has limits in terms of attention, memory and information processing capacity and these limits determine the effectiveness of learning and consequently of the implementation of certain

behaviors' 1991, psychologist John Sweller developed the theory of 'cognitive load', the basis of which is the concept of cognitive load, which refers to the amount of mental activity imposed on working memory (i.e. the ability to retain and manipulate information in the mind) at a given time, and when the cognitive load on memory is too high and we have to process either too much information or very complex information, the risk is that we learn very little or nothing at all and therefore experience frustration, boredom and, in the case of decision-making, rely even more on heuristics in making choices (Sweller and Chandler, 1991).The vastness and complexity of information and opinions, both correct and incorrect, circulating about electric cars make the choice of buying an EV very complicated, since the potential buyer is subjected to a not insignificant mental effort regarding the planning of trips, the search for charging points, the management of battery autonomy and the possible installation of a domestic wall box. Too much information can send people into crisis and paralyze them momentarily. Too many choice options can also lead to that outcome: the paradox of choice is that too much choice generates in individuals rising expectations, stress, anxiety, worry (Schwartz 2004). When information overload is very high, people tend to settle, for convenience and economy of decision-making effort, for 'sufficiently satisfying' solutions rather than trying too hard to find the optimal solution (Kahneman, 2003). Bounded rationality often leads to this: to avoid cognitively burdensome and demanding decisions and to turn to much more disengaged choices, however much they may not actually be the best in a long-term perspective (Kool et al., 2010). This trend is reflected in the decision-making process of many shoppers on a daily basis: too many choices and information overload are often too difficult to manage, and it is not uncommon that people are unable to make a properly motivated purchasing decision. Occam's razor, or the principle of parsimony, suggests that sometimes the simplest solution is also the most effective one, so it is necessary to limit the amount of information about the charging process and electric cars to the most salient and to strive to simplify as much as possible the stages of the charging process, the location of the columns and how to drive an EV, in order to make the transition more attractive and less demanding.

3.3.4.2. Interventions

1) Reformulation of the reference point

Also for the charging infrastructure issues, reformulating the reference point to counteract the effects of the current status bias can be very helpful.

Consumers should be educated to think that e-mobility is not a petrol-driven mobility with a charging plug, but a new and different mobility that loses its meaning and value, if considered and analysed exclusively from the point of view of a comparative comparison with traditional mobility (Hidrue et al., 2011).

Let's think about the mobile phone revolution: the first portable mobile phones were very expensive compared to traditional landline phones (a bit like electric cars compared to ICE cars), very bulky and not immediately easy to use, and it was hard to understand why a 'normal' person, who was not a businessman, a politician, a banker or a celebrity, should need to own one. Who would have thought 40 years ago that mobile telephony would be the future? Or how about the ATM? When it was introduced in the early 1980s, the Italian public was very cold to the use of a magnetic card to pay instead of money, and yet now it is a major milestone in the history of consumer spending.

To understand the benefits and scope of electric mobility, therefore, it is necessary to think outside the traditional box and see this paradigm as an evolution of mobility - logically and historically in line with the upward trend of electrification of consumption - and not as an alternative. The point of reference should no longer be the petrol or diesel car, but the electric car itself, which is as high-tech and rechargeable as the object we use most every day, the smartphone.

One of the most interesting and advantageous aspects of electric vehicles is that they can be recharged directly at home. With petrol or diesel cars we are used to refueling mostly when we see that the fuel gauge on the dashboard falls below a certain threshold, which means that refueling is not done on a daily basis (at least for the majority of people who drive less than 30 km a day). The electric car requires a change of mentality and a different approach: the electric car, just like your smartphone or tablet or PC, should be left charging when not in use so that it is fully ready when needed (BeCharge, 2020). You don't want to run out of batteries before looking for a charging solution. The reference point should therefore be modelled on the charging scheme for mobile phones and the electronic devices that we have been using massively every day for at least a decade now.

Public DC or AC charging is essential for those who need to refuel more quickly and for those who travel many kilometers in a day or do not have a home space in which to recharge their vehicle. The vocation behind the electric car is the possibility of recharging the vehicle in the comfort of one's own home, at lower costs and charged on a single bill (that of the utilities), with a view - as well as environmental and sustainable - to self-sufficiency. The columns are designed for longer journeys, for topping up while people are working or running errands and only in extremis for those who cannot recharge from home. Combating range and charging time anxiety therefore requires abandoning the status quo approach of 'fill up when you need it' and simply plugging the car into a home charging socket or column where possible. The charging stations are all equipped with a dedicated vehicle parking space, so it is as if you somehow always have a reserved parking space that can be easily identified via apps and websites. Instead of paying for the parking space, you pay for the recharge and everything via the app, without having to carry lots of bulky and heavy coins in your wallet.

2) More visible charging stations

The attentional selection bias prevents people from observing the rapid spread of e-mobility and charging infrastructure. So how can we attract people's attention? The solution may be to make charging stations more visible, and prominent signs indicating their presence may be a good first start (Bunce, Harris and Burgess 2014).

The important function of the signs would be twofold: to make it easier for EV drivers to find the stations without having to use online maps or the charging operators' apps; and, most importantly, to inform drivers of thermal cars that there are not as few charging stations as people think and perhaps, seeing that this is the case, more people might consider giving electric a chance in the near future. This would be both informative and promotional advertising (Taylor, Franke and Bang, 2006). Online advertising through sponsorships on Facebook and Instagram or LinkedIn should also be considered by charging service operators to promote the presence of the charging stations (Lee, Kim and Sundar, 2015).

Another step could be to equip traditional fuel stations and service stations with specific stations for electric cars, so that both traditional and electric refueling can be combined in one solution. In addition, while many users would like to see charging stations more like traditional petrol pumps (Ipsos, 2017), it would be very useful to start equipping the charging infrastructure with a number of amenities, most of which are currently lacking: canopies to protect users from the weather and strong sunlight, snack, drink and tobacco dispensers, and possibly even toilets (Carney, 2016).

A possible and very interesting solution to make electric car recharging both more visible and more practical is the one that the municipalities of Rome and Milan are currently experimenting with the companies E-Gap and Free2Move: mobile recharging on demand. A valid alternative to fixed charging stations, mobile recharging stems from the need to balance the location of fixed charging stations and to increase the possibility of access to electric mobility for users who do not have a place to recharge their car at home or nearby charging stations (Centenari, 2021).

Mobile recharging refers to a recharging service made up of fleets of pick-up trucks (similar to those used by the urban refuse collection service) equipped with a large battery which act as mobile 'power stations' and which, at the request of users (via a smartphone application or a phone call), go and recharge the batteries of electric cars wherever they are. To draw a parallel with the world of smartphones, mobile charging (off-grid) is to the electric car in the same way as the portable power bank (the external emergency battery) is to the mobile phone.

If this type of service were to become widespread, as well as being convenient, it would also be a useful way of publicizing electric mobility itself: just think of the logoed pick-up trucks as large travelling billboards, which as well as doing their job, advertise the service and consequently the frontiers of the electric car.

In order to make the electric car more visible in general, one could also opt for an option that the United Kingdom has recently adopted: a specific plate for electric vehicles. The "green plate" serves to distinguish battery-powered cars from all others at a glance and to identify them immediately. The green plate can be a very useful nudge on several fronts: it makes the vehicles more easily identifiable to police officers and roadside cameras with regard to soft incentives for e-mobility (exemption from paying for blue striped parking and access to restricted traffic zones); it can represent a kind of recognition status/bags (in the perspective of the competition and reward system of gamification) for EV drivers; finally, it can represent an opportunity for traditional drivers to notice and appreciate the spread of mobility change (Gasparini 2020).

3) Simplifying and enhancing relevant information on charging and infrastructure

Excessive cognitive effort and limited rationality are major obstacles to the uptake of e-mobility. The complexity and vastness of information, combined with false myths and fake news, contributes to anxieties and skepticism towards battery-powered cars and therefore it is necessary that all actors working on the rise of green mobility make an effort to simplify the whole information load and to direct it into a few clear recommendations or tips for the whole community.

Car sellers need to be prepared to explain in an understandable and comprehensive way how the charging process works, which operators are present on the market and which subscription and tariff plans they apply, and how to locate charging stations. The infrastructure can be easily identified both from the digital infotainment screen of one's own car and from smartphone applications[46]. Educating people to actively use their smartphones as a tool to support and monitor the state of the battery and vehicle recharging is crucial, just as it is crucial to explain to consumers that to pay for recharges it is necessary to register on an energy provider's app, subscribe or choose consumer tariffs, and pay for recharging services via an app linked to an ATM or credit card or via specific magnetic credit cards (issued by the operators themselves when stipulating the terms of service provision).

It is also important for anyone who provides information on vehicle recharging to reassure users that recharging times are shorter than they may seem: people often make an error of judgement when calculating the time needed to recharge a battery because they start from the wrong assumption, i.e. they consider the capacity of their car's battery and make an elementary mathematical calculation that consists in dividing the total capacity by the kWh of power of the column, thus obtaining the number of hours needed for a complete recharge. The calculation is correct, but this is another reference point error: the reference should not be the battery capacity with the assumption that the battery is at zero, but the percentage of battery charge at the time of charging and reasoning in terms of "How much more range do I need and up to what percentage do I want the car battery to be charged?". Promoters and salespeople need to educate people that the way to fill up at the filling stations, unless you have a domestic socket to charge your car or a wall box, is by topping up. It is essential to inform people as much as possible that it is important and above all economically advantageous for them to equip themselves with intelligent recharging systems (wall boxes) to refuel their vehicles at home. The great novelty and convenience of the electric car is recharging at home, and so vendors, domestic energy suppliers, electricians, technicians at the relevant municipal offices and publicists must be able to inform people of all the safety and operational measures for assessing the home provision of sockets and wall boxes for recharging the vehicle. The assessment of upgrading the domestic electrical installation and increasing the power of

[46] To name a few: JuicePass from EnelX (the leading operator in Italy), NextCharge (which also includes useful functions for planning longer trips and charging stops), EVWay and PlugShare.

the meter must be indicated and submitted to the awareness of the users by all the actors just mentioned.

Clear, precise, and reassuring information is the key to increasing positive Attitude (Ajzen, 1991) towards electric cars and to fostering an exchange of opinions and comparisons that positively influences as many people as possible on all fronts (and thus Subjective Norms).

Suggestions for the implementation of electric mobility

For dealers and salesmen:

- Careful preparation of salespeople on the operation and management of the various phases of the charging process.
- Sell, in addition to the vehicle, the domestic charging wall boxes (also in partnership with the Sell, in addition to the vehicle, the domestic recharging wall boxes (also in partnership with suppliers of the various brands of wall boxes): these are cross-selling operations or cross-selling of complementary products to the electric car in order to increase the profitability of overall sales and to build user loyalty. It would also be very useful for dealers to provide technical assistance on home charging solutions and possibly also direct installation of products at home.
- Equipping the physical facilities of the dealerships (the stores) with highly visible electric vehicle charging stations to show potential customers first-hand and in detail how charging is done.

For operators of charging services:

- It is of utmost importance that energy players in the national market establish Interoperability agreements between them: in order to make the process of charging outside the home more convenient and easier, it is imperative that service providers (whether operating domestically or internationally) enter into agreements whereby users of one company can use the network of the others without having to take out multiple subscriptions. The future of charging, apart from on-demand charging, depends very much on interoperable roaming.

- The future of recharging infrastructure depends very much on interoperable roaming, in addition to on-demand roaming. Equipping recharging infrastructures with signs indicating their presence and adding amenities to make the time spent recharging more pleasant (canopies, benches, snack machines, cigarette machines... the canopies could also be equipped with photovoltaic panels to make the structure energy self-sufficient, in the direction of greater sustainability).

3.3. Conclusions and Nudge Service Design Strategy

The transition from a conventional car to an electric car is not straightforward, especially if end-users are not properly involved in the process and if they are not assisted in understanding the economic and environmental advantage and benefit of this 'new' technology.

The development of e-mobility depends not only on the adoption and improvement of specific technologies and infrastructures, such as batteries and public and domestic recharging stations, but also on the ability to organise and manage certain information activities, aimed at developing individuals' social responsibility, positive attitude and active discussion and word of mouth among the community about the choice of zero-emission mobility for the future of the planet.

The pandemic, despite the economic and social disasters it has caused, has led to unexpected and dramatic growth in the battery car market, and it is necessary for all stakeholders in the supply chain and institutional players to support this growth by providing the right economic and information support tools, through the provision of services focused on overcoming barriers to electric power and spreading a participatory culture of environmental sustainability and concrete individual actions to achieve it.

Sustainability is an extremely rich field of opportunity to propose nudge service design interventions designed to simplify information, reduce individual cognitive load and mental barriers that hinder environmental-friendly behaviour.

In the light of the barriers identified, the design of the integrated website for the understanding and promotion of electric cars should be developed on the following points:

- A preliminary interface that allows users, by entering their driving and mobility habits data anonymously, to check their current consumption with their vehicle, to compare it with those declared by car manufacturers and with those recommended by an algorithm of the platform that would suggest how to pollute less, save more fuel (exactly as the MILE21 web platform of Altroconsumo.it does) and evaluate the possibility of buying a vehicle with a more ecological and alternative power supply to the traditional car.
- Highlight the opportunity cost of petrol-powered vehicles, comparing it with that of electric vehicles, highlighting the long-term disadvantage of buying an ICE car (create a loss frame - also acting as a "cognitive anchor" - within which the loss resulting from the purchase of a petrol/diesel vehicle is evident to activate the loss aversion mechanism in users).
- Add a vehicle search menu (with advanced search forms: filtering elements such as maximum price you intend to spend, car segment...) containing all the main models of battery-powered vehicles on the market and provide each model with a summary information sheet (range, battery capacity, price, incentives and reviews) to help users identify their ideal vehicle and thus overcome choice overload and confusion.
- Add fact sheets with clear and simple keypoints on how the Ecobonus for electric cars works and how to access government incentives. Illustrate the road signs of car parks and charging stations for electric cars in such a way as to stimulate attentive selection in users and make them pay more attention to the presence of car parks and EV charging stations when driving (also to overcome the belief that the charging infrastructure is inferior to what it is).
- Add an up-to-date map of all charging points (indicating the charging service provider, tariff applied and current output) in the regional and national territory. In the infrastructure map section, it would also be useful to explain how the recharging process and payment for the service works, and to design a "trip planning" feature: enter the car model and the desired destination and get a complete trip plan that also includes stops for recharging to give users a way to counteract autonomy anxiety.

- Point out the presence of dealers, in the vicinity of the user, that sell battery-powered cars and provide contact information (phone number and website) to further facilitate the choice phase at the point of direct contact.
- Create a Q&A section on the main concerns of drivers thinking of making the electric transition and open forum pages for discussions among website users in order to activate an active peer-to-peer discussion about their car mobility experiences, doubts about EVs and curiosities. Dialogue between users can also be a form of feedback to investigate both the level of knowledge about EVs and personal opinions about them. In the discussions, potential negative aspects or malfunctions of the platform can also emerge and based on the negative comments, very interesting insights into the evaluation of the service can arise which can lead the platform to change its information or content delivery strategy. A nudge tool must be adaptive and attentive to user feedback in order to generate the desired effects, reduce cognitive complexity and be able to keep up with the change it wants to trigger.

A website structured in this way could be a very valuable potential resource to improve the process of building shared and reliable information (even more so if promoted by a public body) on electric mobility. Digital platforms have revolutionized the online economy and new business and knowledge management models, which harness the power of the Internet, find fertile ground in the service design approach to users.

Behavioral service design can help both organizations and consumers to better understand behaviour and attitudes to change and develop promotional strategies and information campaigns.

Nudges are those implicit suggestions that guide purchasing behaviour to help consumers have more positive and sustainable shopping experiences and service design is the design of value change in relationships and approaches between people and choices.

Service designers and choice architects are called upon to bring innovation into the system, with the understanding that there is no perfect strategy for communicating a goal and getting people to achieve it: today the most popular solution may be the internet with nudge marketing campaigns, but tomorrow who knows what the most effective strategy will be?

Human beings' behaviour is dynamic and sometimes very unpredictable, and equally dynamic must be the response of the architects of choice and service providers to push for change.

Behavioral economics studies are particularly important in providing alternative models to classical economic theory and in showing in a comprehensive way how human judgement is formed and what factors influence decision-making capacity and guide the behaviour of individuals.

The conclusion that derives from the analysis conducted in this research is the need to have an increasingly robust educational and informational structure to support the incentives proposed by nudge and service design, where individuals are helped in their choices by a specific and accurate design of the decision-making context but, despite the guidance, are able to evaluate autonomously and respond negatively to a poorly structured decision-making context.

The environmental challenge now concerns each and every one of us and information is the most powerful weapon we have to embrace change and not be crushed by it. Knowledge is power and the tools provided by behavioural economics to understand our ways of thinking (and acting) and nudge - discreet and effective intervention - really have the potential to play a key role in the whole system of ecological transition, electrification of consumption and sustainable mobility.

CONCLUSION

After a thorough examination of circular economy issues in relation to the automotive sector, e-mobility and their importance in reducing CO_2 emissions, it can be said that cars and mobility are pervasive in daily life and perfectly integrated parts of the macro-topic of sustainability. They are fundamental pieces in the mosaic of the circular economy and future production and consumption patterns of goods and services.

The circular economy, as well as the shift to electro-mobility, require a change in thinking patterns in order to develop the necessary skills to change entire structures and value chains, and thus develop sustainable solutions. Playing our part in making up for man-made damage is innovation: from innovative corporate practices to innovative business models. Car-sharing, the buy-back strategy, electric mobility, are important solutions that if added together and proposed on a large scale can really make a difference in the long run. It's all about believing in them and seizing them, changing the general economic system. Each of us has a decisive role in the success of future policies and initiatives, and without individual response and responsible behaviour, success remains limited. The impetus must come from governments and institutions that, at least in the initial phase, must support the change with initiatives that incentivize the environmental transition. In addition to having understood that for investments involving the decision to scrap old cars, policy makers have many reasons to be concerned about uncertainty, and having defined what the main barriers to purchase are, I have come to a conclusion: the problem of misinformation, fake news and the cognitive distortions to which our minds are subjected every day can play a fundamental role in the willingness to take part in a change through responsible and farsighted individual actions. A food for thought that I would like to raise is the following: changing the cultural and production paradigm of the planet is possible, institutions could adopt a coercive and tough approach to repress undesirable behaviour and impose a single path of choice on all citizens. Repressive coercion is certainly the quickest alternative for levelling as much as possible the paths of action of the entire community, but, as history teaches us, the step from a very harsh coercive approach to a dictatorship of thought and action is very short indeed, and for the democracies of our planet a 'totalitarian' approach is completely out of the question. Imagine that, in order to accelerate the transition to electric mobility, a sudden and drastic stop is decreed on the sale and circulation of combustion vehicles. In practice, such a course of action - assuming it is implemented - would lead to a very serious systemic market shock: the entire transport sector, the automotive sector, the fossil fuel extraction and sales industry and the entire global energy system would enter a crisis phase that would drag the entire global economy into the abyss. Renewable energy sources and the global electricity system would not be able to cope with the energy demand needed to power fully electrified mobility. Fossil fuels would have to be relied on even more heavily to produce the electricity needed to power the millions of electric vehicles on the road. The supply of car manufacturers could not meet demand and the industry would collapse. Hundreds of thousands of jobs in the automotive and energy industries would be lost. Consumers would be poorer. There are hundreds of negative consequences that an ill-considered and abrupt coercive approach could cause, regardless of the "good intentions" that may motivate it from the outset. The guidelines on which the institutions and the system should move to drive change are awareness-raising, education and training to trigger a change in the socio-cultural paradigm of approach to mobility and sustainability, and finally the design of policies and tools to guide collective action in favor of sustainability (Berardi Ivoi and Tettamanzi, 2021). Careful design of policies, communication campaigns and initiatives aimed at citizens, consumers, industry and - in general - the whole community can also contribute to the design of individuals' behaviour, so that they are kindly encouraged to pursue, in their choices, 'the care of the common home' which is the protection of the environment and the customer. The theory of gentle nudging provides very interesting insights into changing the context and stimulating social confrontation between people in an attempt to harmonies individual behaviour and channel it more or less consciously - and never coercively and manipulatively - towards a more socially and ecologically responsible collective action. The empirical and literature work in this thesis has mainly focused on designing solutions to encourage the decarbonization process, as well as on raising awareness of the shift towards the electric car and overcoming barriers to it; other relevant aspects of the paradigm shift could not be thoroughly explored: the acceleration of the switch of the entire energy system to renewable sources, battery recycling solutions, installation of photovoltaic panels to achieve greater energy self-sufficiency, and many others. What is clear is that sustainability is the future and change will happen, we just need to insist that as many people as possible understand this and embrace a new perspective. Each of us has a decisive role in the success of future policies and initiatives, and without individual response and responsible behaviour, success remains limited.

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ACKNOWLEDGEMENTS

My dearest thanks go to my thesis advisor, Professor Sergio Vergalli, without his help I would not have had the chance to carry out these 6 months of thesis research at Barnard College in New York, a city that I will always carry in my heart. I would like to thank Professor Nicola Comincioli, and my foreign tutor Anja Benshaul-Tolonen, who were always available to help me.

A big thank you goes to my mother, who with love, sacrifice and patience, has always supported me and put up with me until this achievement.

I would also like to thank my two brothers, Davide and Pietro, who have always shown that they believe in me; between a joke, and some particular anecdote, they have always added vitality to my life.

A special thank you goes to Beppino, who with the extreme care and attention that distinguishes him has always been able to make everything easier.

Thanks to my grandmother, Rosanna, who between study and leisure time, has always been able to pamper me with her delicious dishes. Thank you also for reminding me how important it is to take time for oneself.

Thanks to my uncle Roberto and my aunt Cinzia, who since I was a child have always been there for me, and have given me memories of light-heartedness and happiness, even with the birth of Leonardo.

Thank you to Riccardo and his family, from whom I have learned so much and who have always been close to me over the years, both in happy and sad moments, and for giving me the most precious gift of all: time shared together.

Thanks to Dimitri with whom I have shared good and bad moments since I was 19. Time may have changed us both, but the spark that lights up when we are together remains the same. Thank you.

I would also like to thank Manuel with all my heart, a pure friend that for years has continued to show me the true meaning of the phrase " who finds a friend, finds a treasure".

Special thanks to Nadia: Brescia, Milan, Alicante, Hasselt, Paris and finally New York, over the years they have tried to divide us, but it was obvious that they would always fail miserably. Thank you for all these years.

I thank Sara for the true and special friendship she gave me between a Geko and an Iguana, breathtaking beaches, stray dogs, car trips from north to south and, taste of all the dishes of New York and funny and unimaginable situations. What we share cannot be explained. You are special.

Thank you, Jessica, for being the most beautiful and unexpected gift of the lovely month of February. Maybe it's because everything goes faster in New York, and maybe that's why I feel like I've known you for so much longer. Thank you for the person you are.

I thank Matteo for being the best promoter I could party with and for becoming the American "socio" I wouldn't change for anyone else. As you know among "angioletti" we understand each other.

Thanks to all my classmates and "Green" friends who, between an exam, excursion, and a party, made me appreciate university life even more, even during the pandemic.

I would also like to thank all those people who have been there for me, and given me the opportunity to be 100% myself; and for being and continuing to be essential parts of my training and growth in all aspects.

Thank you.