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Toward lower emissions: how smart mobility can decarbonize transportation

TESI DI LAUREA MAGISTRALE IN
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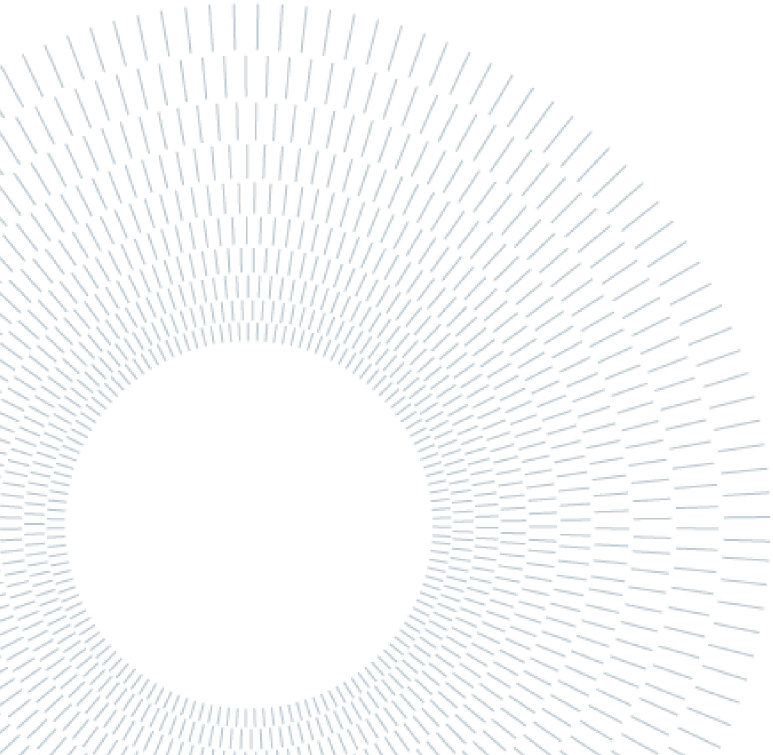


Abstract

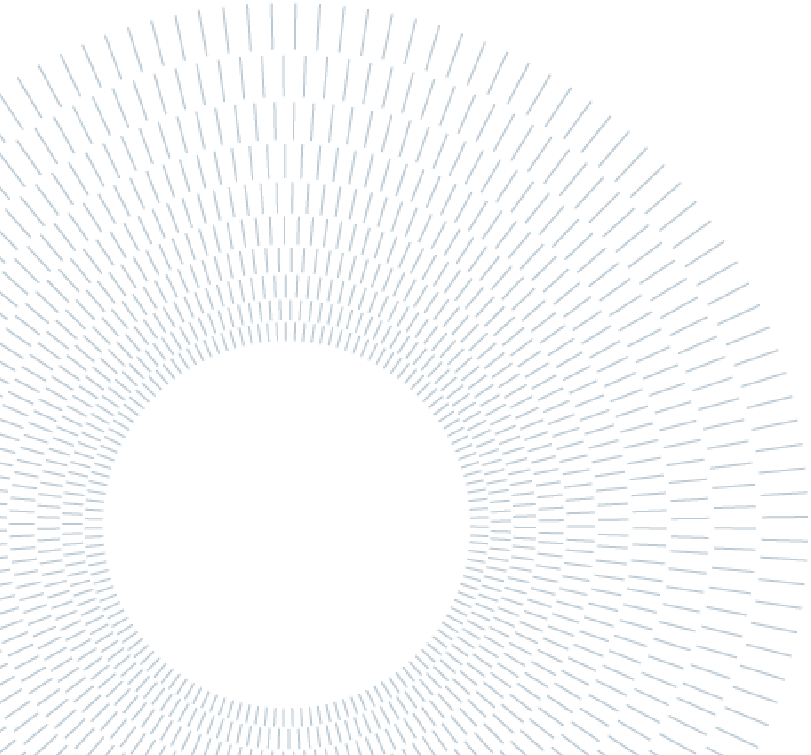
This thesis aims to illustrate how transports' decarbonization is the fastest and most effective means of reducing GHG emissions in order to meet global, but especially European, targets. Indeed, in order to be able to reduce emissions by 55 percent by 2035 and 100 percent by 2050, European Union member countries are implementing major decarbonization measures. In this context, smart mobility enters the picture as an alternative to fuel retail. While to date traditional fuels cover more than 90 percent of consumption in the transportation sector, this figure is set to change in the near future. Indeed, consumers are increasingly concerned about the environmental impact of their travel. Most oil consumption will be offset by electric and hydrogen. In cases where these energy carriers cannot be used, such as in aviation and marine transportation, however, traditional fuels will be replaced by biofuels or LNG. The real focus of the discussion is therefore electric cars, as they are considered the fastest, most efficient and immediately available means of decarbonizing ICEVs. Electric cars will be analyzed in terms of their emissions, to verify that they are actually lower than the corresponding ICEVs; prices and costs, to ensure that they are sustainable for possible consumers; the fleet on the road, to assess their diffusion; and finally the batteries, with their respective components and costs. In addition, the electric supply chain will be explored in depth, comparing how the current supply can cope with an increasing demand for electricity. Considerable weight is also given to the analysis of charging infrastructure, as its adequacy determines the spread of electric mobility. Charging stations in the discussion are analyzed according to their accessibility, costs, regulations, charging technology trends, and location.

Key-words: decarbonization, transportation, emissions, smart mobility, electric vehicles, charging infrastructure

Abstract in italiano

La tesi ha l'obiettivo di illustrare come la decarbonizzazione dei trasporti sia il mezzo più veloce ed efficace per ridurre le emissioni di GHG, in modo da rispettare gli obiettivi mondiali, ma soprattutto europei. Infatti, per poter ridurre del 55% entro il 2035 e del 100% entro il 2050 le emissioni, i paesi membri dell'Unione Europea stanno attuando misure di decarbonizzazione importanti. In questo contesto, entra in gioco la smart mobility come alternativa al fuel retail. Se ad oggi i carburanti tradizionali coprono più del 90% dei consumi nel settore dei trasporti, questo dato è destinato a cambiare nel breve termine. I consumatori sono infatti sempre più interessati all'impatto ambientale dei propri spostamenti. La maggior parte dei consumi petroliferi saranno compensati dall'elettrico e dall'idrogeno. Nei casi in cui questi vettori energetici non possano essere utilizzati, come ad esempio nell'aviazione e nel trasporto marittimo, i carburanti tradizionali verranno comunque sostituiti da biofuels o GNL. Il vero focus della trattazione sono dunque le macchine elettriche, in quanto ritenute il mezzo più veloce, efficiente ed immediatamente disponibile per decarbonizzare le ICEVs. Delle macchine elettriche verranno analizzate le emissioni, per verificare che siano effettivamente inferiori alle corrispettive ICEVs, i prezzi e i costi, affinché siano sostenibili per i possibili consumatori, il parco circolante, per valutarne la diffusione, e infine le batterie, con i rispettivi componenti e costi. Inoltre, verrà approfondita l'electric supply chain, comparando come l'attuale offerta può far fronte ad una sempre maggiore domanda di elettricità. Peso notevole viene anche dato all'analisi dell'infrastruttura di ricarica, in quanto la sua adeguatezza determina la diffusione della mobilità elettrica. I punti di ricarica nella trattazione vengono analizzati in base alla loro accessibilità, ai loro costi, i regolamenti, i trend tecnologici di ricarica e il loro posizionamento.

Parole chiave: decarbonizzazione, trasporti, emissioni, smart mobility, veicoli elettrici, infrastrutture di ricarica



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Introduction

In a context of climate change awareness, world governments have committed to the Paris Agreement to keep the planet's temperature rise below +2°C. In order to accomplish this, efficient and effective policies are needed to reduce emissions and decarbonize the most polluting sectors. The European Union is a world leader in energy policies to limit global warming. It is also a virtuous example as it has put in place measures to achieve climate neutrality by 2050. Among the most important ones there are the European Green Deal, Next Generation EU, European Climate Law with the resulting Fit for 55. In particular, the Fit for 55 is aimed at the intermediate steps needed to achieve climate neutrality, and achieves this by proposing to reduce emissions by 55% by 2030. In this context, Italy also has several plans in place to reduce emissions, including the PNEIC and, a hot topic at this time in our country, the PNRR to address the post-pandemic economic, political and energy crisis.

In addition to these energy projects, the past year has also featured the need to cope with the Russia-Ukraine war crisis, with the resulting problems due to European dependence on gas imports from Russia. Consequently, the need for energy decarbonization to become independent from politically unstable countries becomes even more imperative.

The discussion will focus precisely on transports' decarbonization for several reasons. To date, it is one of the more polluting sectors, if not the most polluting one in some areas of the world such as Italy. Moreover, dercarbonizing transportation is one of the most efficient ways of actually reducing GHG emissions by 55 percent by 2030, thus going to meet the targets imposed by the European Union. Indeed, there are existing, established and usable alternatives to polluting vehicles. In order for these solutions to actually be considered to replace internal combustion ones, they must make transportation more sustainable and efficient, while also decarbonizing vehicle production and the infrastructure itself. For this reason, the energy that powers the alternative solutions must also be decarbonized, with a strong focus on renewable sources as well.

Currently, the solution that seems to be able to replace internal combustion quickly is electric, although there are other interesting energy carriers within sustainable and smart mobility.

1 Climate Change and the Actions in Place to Mitigate it

Scientific research has long shown that to mitigate the effects of climate change, it is necessary to keep the Planet's average temperature growth between 1.5 and 2.0°C (Accetturo et al., 2022, MISM). In 2019, a temperature of +0.98°C above pre-industrial levels was detected. If no action is taken, the temperature could rise to +1.5°C between 2030 and 2050. For this reason, in 2015 with the Paris Agreement, signatory governments pledged to limit global temperature rise below +2°C compared to pre-industrial levels (Enel Green Power, n/a).

In IEA's energy scenarios, there is a very wide gap between the Stated Policy Scenario and the Net Zero Emission Scenario[1]. Only in the latter, it can be expected to keep the rise in average global temperatures within +1.5°C. In order to close this gap and thus manage rising temperatures, there are four priority actions to be implemented (IEA, 2021b):

- Realize increased clean electrification;
- Realize the full potential of energy efficiency;
- Prevent methane leakage from fossil fuel activities;
- Promote clean energy innovation.

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[1] Stated Policies Scenario and Net Zero Emission Scenario are part of IEA's World Energy Outlook Scenarios.

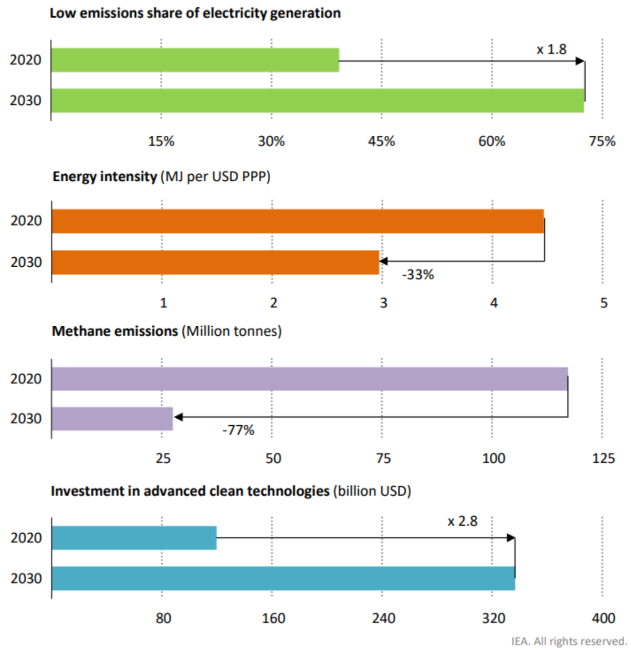

Figure 1: Four key priorities to keep the door to 1.5 °C open in the Net Zero Emissions by 2050 Scenario (IEA, 2021b)

More and more extreme events are happening that demonstrate the fact that climate change is already underway. The heat waves of recent summers have highlighted how the effects of global warming are already leading to major issues, such as wet bulb temperature. Wet bulb temperature is defined as a combination of temperature and humidity such that the human body can no longer handle its sweating and evaporation, so it has no way to cool itself (Horton et al., 2020, Science Advances). This occurs when the combianation of heat and humidity exceeds the human body temperature, i.e., 36°C (Chow, 2022). This situation can potentially lead to death. In order to prevent the establishment of bulb temperatures in different areas of the planet, international efforts must be imposed to stay within +1.5°C (Enel Green Power, n/a).

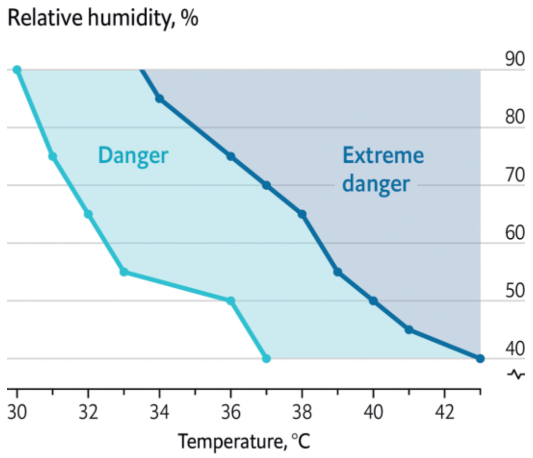

Figure 2: Combinations of temperature and humidity that determine the wet bulb temperature (The Economist, 2022)

1.1. European Union Decarbonization Policies

In the landscape of actions to reduce emissions, the European Union is a world leader in energy policies aimed at containing global warming. Over the past decade, the EU has introduced increasingly challenging decarbonization targets, complemented by supporting instruments for member States. The targets set to date to achieve climate neutrality in 2050 are the following (Boccardo et al., 2021, ES):

- "2020 Climate & Energy Package", approved in 2007;
- "2030 Climate & Energy Framework", updated in 2014;
- "A Clean Plan for All, 2050 Long-Term Strategy", issued in 2018;
- "European Green Deal", approved in 2019;
- "Next Generation EU", approved in 2020;
- "European Climate Law", "Fit for 55" and "AFIR", issued in 2021.

In addition, on May 18, 2022, the "RePowerEU" plan was presented to answer to the global energy market challenges caused by the Russian invasion of Ukraine (European Commission, 2022b).

1.1.1. 2020 Climate & Energy Package

The "2020 Climate & Energy Package" consisted of a set of measures to ensure that the EU achieved the following targets by 2020 (Boccardo et al., 2021, ES):

- 20% reduction from 1990's levels in greenhouse gas emissions;
- 20% improvement over the PRIMES[2] 2007 scenario in energy efficiency;
- Meeting 20% of energy needs with renewable sources.

1.1.2. 2030 Climate & Energy Framework

In 2014, the goals stipulated by the "2020 Climate & Energy Package" were updated, aiming for a longer time horizon, i.e., up to 2030. The proposed targets were (Boccardo et al., 2021, ES; Chiesa et al., 2021, ES):

- Reduction of at least 40% from 1990 levels in greenhouse gas emissions;
- Improvement of at least 32.5% in energy efficiency;
- Share of renewable energy at least 32%.

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[2] PRIMES is a "partial equilibrium model of the European Union energy system used in the development of forecasts, scenarios and impact analysis of policies and measures in the energy sector up to 2030" (ENEA, 2020).

1.1.3. A Clean Planet for All, 2050 Long-Term Strategy

"A Clean Planet for All" is a long-term European vision, aiming to be a climate neutral economy by 2050. According to this strategy, climate neutrality is achievable through several building blocks, including energy efficiency, renewable energy development, and smart mobility (European Commission, 2018).

1.1.4. European Green Deal

The European Green Deal advocates the need to become a climate-neutral economy by 2050. This is only possible, according to the European Union, by reducing greenhouse gas emissions from transport by 90 percent. The three pillars identified by the EU to accomplish this systematic change are (European Commission, 2020):

- Making all forms of transport more sustainable;
- Make sustainable transport alternatives available with a multimodal transport system;
- Implement the right incentives to drive the transition.

The specific goals of the Green Deal are further listed in the image below:

Figure 3: European Green Deal Objectives (Casetta & Zocchi, 2020)

1.1.5. Next Generation EU

In November 2020, 1.8 trillion euros of funding has been allocated. This package was allocated for the economic recovery of EU member countries after the Covid-19 pandemic. 750 billion of the 1.800 allocated fueled the Next Generation EU. Thus, the Next Generation EU is a temporary recovery tool to quickly repair the damage from the pandemic, creating a greener, digital and resilient EU. Approximately 90 percent of these funds (672.5 billion out of 750) went to the European Recovery and Resilience Facility (Boccardo et al., 2021, ES).

1.1.6. European Climate Law, Fit for 55 & AFIR

In July 2021, the European Commission issued “Climate Law”. “Climate Law” aims to reduce emissions in Europe by at least 55% below 1990’s levels by 2030. In this way, Europe could become the first carbon-neutral continent in 2050 (European Commission, 2021b).

On July 14, 2021, the European Commission also presented the “Fit for 55”. “Fit for 55” is a package of proposals that is meant to update the European Union's policies in order to make them consistent with the new interim 2030 emission reduction targets. Specifically, it aims to (Boccardo et al., 2021, ES; Bibra et al., 2022, IEA):

- Increase to 40% renewables in the European energy mix, with a total new capacity to be installed by 2030 of approximately 660 GW for photovoltaics and 450 GW for wind;
- Increase to 36% energy efficiency on final energy consumption;
- Increase to 39% energy efficiency on primary energy consumption;
- Upgrade at least 3% of the floor area of public buildings each year;
- Reduce the emissions of new cars by 55% and those of trucks by 50% compared to 2021, which will become 100% by 2035 due to the ban on the sale of ICE[3] cars, excluding hybrid vehicles;
- Revise the ETS[4] mechanism;
- Revise the Effort Sharing Regulation.

Thus, the 2030 Climate Targets updated with the Fit for 55 can be summarized as follows:

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[3] ICE is the acronym for Internal Combustion Engine.

[4] EU ETS is an international emissions trading system and operates on the "Cap and Trade" principle. In other words, a cap is set on the maximum amount of emissions from installations in the system of reference. Within this cap, companies according to their needs, can buy or sell quotas (ISPRA, n/a).

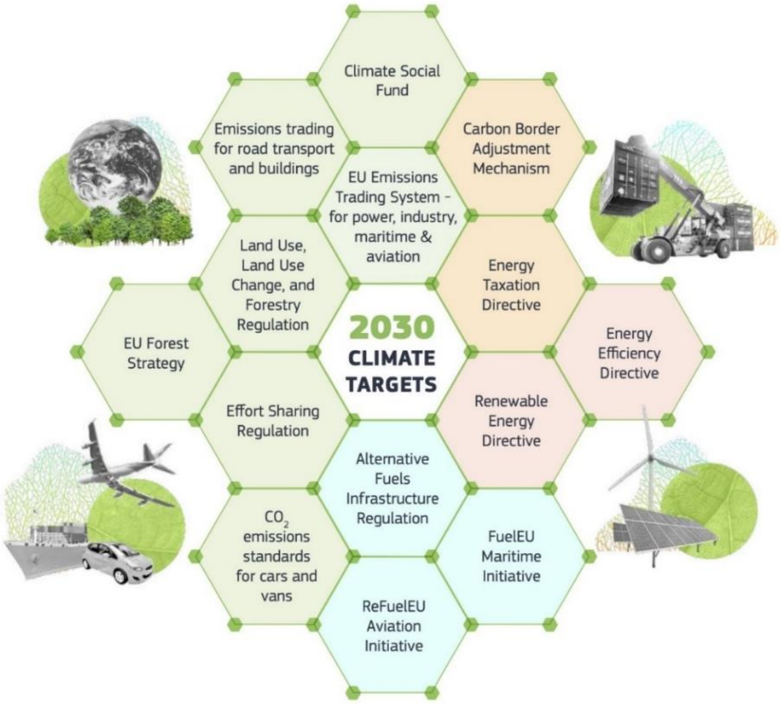

Figure 4: 2030 Climate Targets, updated with Fit for 55 proposals (Bellini, 2021)

Within the Fit for 55 package, special emphasis should be given to the Alternative Fuel Infrastructure Regulation (AFIR) (European Commission, 2021a). This regulation automatically forces all member states to meet three main objectives (Motus-E, 2021):

- Presence of an infrastructure to support the growth of alternative fuel vehicles;
- Interoperability between infrastructures;
- Total transparency and appropriate payment options for the end user.

1.1.7. REPowerEU

The Russian invasion of Ukraine has caused an international crisis, highlighting the important critical issues related to European dependence on fossil fuel supplies from countries with non-democratic regimes. As a result, the EU is now preparing for a total disruption of gas flows from Russia (Staffetta Quotidiana, 2022c). The EU has responded decisively to Russia's attack to Ukraine by implementing several restrictive measures against Russia in order to increase economic pressure on the country and threaten its ability to carry out the war. Specifically, the sixth sanctions package, adopted on June 3, 2022, includes a total ban on imports of Russian crude oil and petroleum products transported by sea. These imports cover 90 percent of current European oil imports from Russia (European Commission, 2022b; 2022c). This choice must come to terms with the fact that Russia is the EU's largest supplier of oil and gas. Therefore, the EU urgently needs to reduce its dependence on energy imports from Russia. Consequently, to address the energy and climate crisis, on May 18, 2022, the European Commission adopted the REPowerEU plan. REPowerEU argues that it is necessary to accelerate the decarbonization steps set by the European Green Deal, as the climate emergency has been paralleled by the need for energy independence and security (Armaroli et al., 2022, MISM).

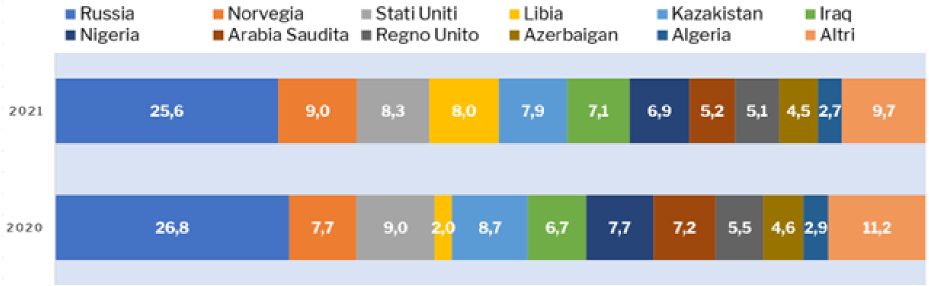

Figure 5: List of countries on which the EU depends for oil imports in percentage terms (Rivista Energia 2022)

1.2. Decarbonization Policies in Italy

The Italian State, being a member of the European Union, has also developed several plans to cut carbon dioxide emissions in order to align with the decarbonization trend taking place in Europe. The main actions to mention in the Italian context are:

- Integrated National Energy and Climate Plan, also known in Italian as Piano Nazione Integrato per l'Energia e il Clima (PNIEC);
- National Recovery and Resilience Plan, also known in Italian as Piano Nazionale di Ripresa e Resilienza (PNRR).

1.2.1. PNEIC

The Integrated National Energy and Climate Plan 2030, also known as PNIEC, marked the turning point in Italian energy and environmental policy. At the national level, to date it is the only official and binding document for the energy sector (Boccardo et al., 2021, ES). The plan has five main objectives (Ministero dell'ambiente e della tutela del territorio e del mare et al., 2018; Parlamento Italiano, 2021):

- Decarbonization, with a share of energy from RES[5] in final energy consumption of 30%. In particular, for transportation the percentage stands at 22% compared to the EU target of 14%. In addition, there is the goal to reduce GHGs for the non-ETS sectors by 33% compared to 2005, 3% higher than the EU target percentage;
- Energy efficiency, with the reduction in primary energy demand estimated at 43% in 2030 for Italy against an EU target of 32.5%;

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[5] RES is the acronym for Renewable Energy Sources.

- Energy security, with improving security of supply, obtained by increasing renewables and diversifying sources of supply;
- Internal energy market, to ensure greater flexibility of the electricity system, with actions addressing transmission grid developments, electricity market coupling and the central role of consumers;
- Research, innovation and competitiveness, to introduce and develop technologies, systems and organizational-management models to achieve a safe energy transition.

As a result of the Fit for 55 package proposals, Italy's 2030 targets will need to be updated to meet new decarbonization targets at 2030 and climate neutrality targets by 2050 (Boccardo et al., 2021, ES).

1.2.2. PNRR

On April 30, 2021, the Italian government submitted to the European Commission the National Recovery and Resilience Plan, also known as PNRR, i.e., the Italian plan for spending Next Generation EU funds for post-pandemic economic recovery. The plan cubes a total of 191.5 billion euros (Boccardo et al., 2021, ES). The plan is divided into six missions (Governo Italiano, 2021):

- Digitalization, innovation, competitiveness, culture and tourism;
- Green revolution and ecological transition;
- Infrastructure for sustainable mobility;
- Education and research;
- Inclusion and cohesion;
- Health.

Figure 6: Six PNRR's missions and allocation of funds (Cataldi & Gualco, 2022).

In particular, the purpose is to invest in the development of the renewable fleet and distribution network in such a way that it becomes resilient, digital and flexible, thanks also to the strengthening of smart grids (Boccardo et al., 2021, ES).

2 Decarbonization of the Energy System

Regarding 2022, the energy market in Europe is facing an unprecedented crisis: gas prices in the first quarter in major European markets were on average five times higher than the previous year. The conflict in Ukraine is not the only cause, but it is aggravated by trends that have been in place since before the war, including decarbonization policies and the management of global supply chains after Covid-19. Therefore, even if the conflict is solved soon, the effects will be prolonged in time, for at least three years. Economically, energy-intensive industries are greatly affected, as these price increases have primarily impacted their production costs. To survive, companies will have to develop new energy procurement models, focusing on making their processes efficient and decarbonized (Crispeels et al., 2022, McKinsey & Co.).

As discussed in the previous chapters, decarbonization is therefore one of the trends at global level, but especially at European level, on which governments are focusing the most. In order to decarbonize the global energy system, there are a few key issues to be addressed: energy efficiency, behavioral changes, electrification, renewables, hydrogen, bioenergy and CCUS[6]. Efficiency improvement allows, among other things, to reduce the vulnerability of companies and consumers to potential electricity supplies disruptions. On the other hand, to make a massive transition, there must be convinced participation of the population (Bouckaert et al., 2021, IEA).

2.1. Emissions

Globally, there was a major increase in GHG emissions from 1990 to 2018: CO2eq tons increased by 40%, with energy industries accounting for the largest contribution, +81% over the reported period. In second place for GHG emissions, there is the transportation sectors with 8.5 billion CO2eq tons in 2019, +79% compared to 1990, of which 75% refers to road transport (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES).

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[6] CCUS stands for Carbon dioxide Capture & Utilization or Storage.

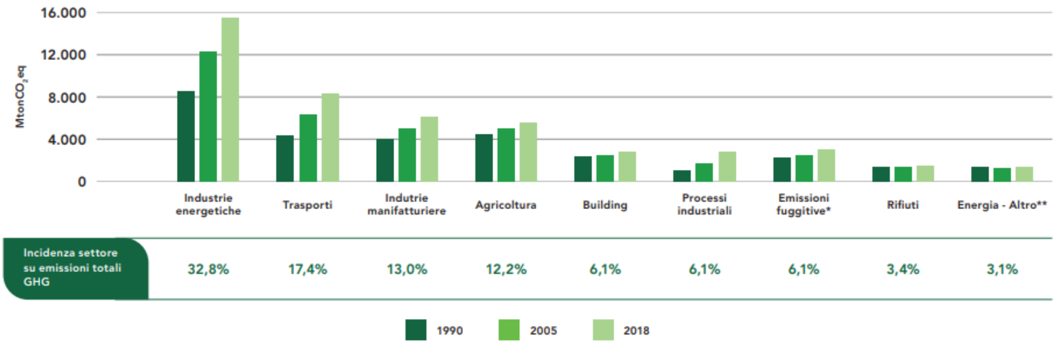


Figure 7: Global GHG emissions trends by sector (Chiesa et al., 2021, ES, p. 39)

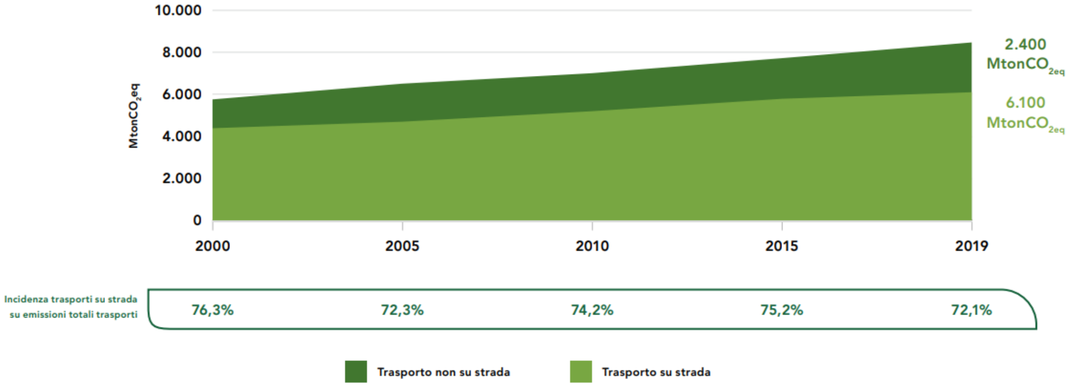
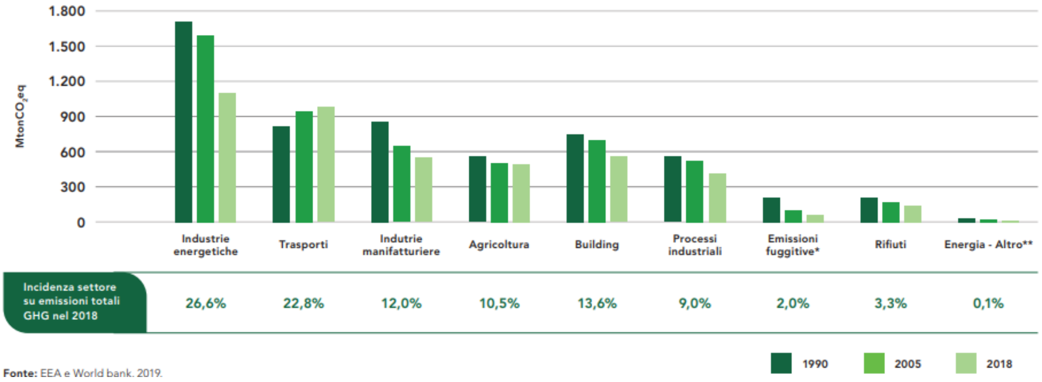


Figure 8: Global GHG emission trends in the transportation sector (Boisrond et al., 2022, ES, p. 41)

For this reason, transport decarbonization is part of the United Nations 2030 Agenda and the 17 Sustainable Development Goals (SDGs) (Armaroli et al., 2022, MISM). Instead, the trend at the European level is the opposite: emissions have been declining over the past three decades. The only sector that has seen an increase in emissions, about 20% from 1990, is transportation, of which almost all is related to road transport (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES). Therefore, to achieve the 55% emission reduction by 2030, more drastic measures are needed, especially in the transportation sector (Conzade et al., 2021, McKinsey & Co.).



Fonte: EEA e World bank. 2019.

Figure 9: European-level GHG emission trends by sector (Chiesa et al., 2021, ES, p. 42)

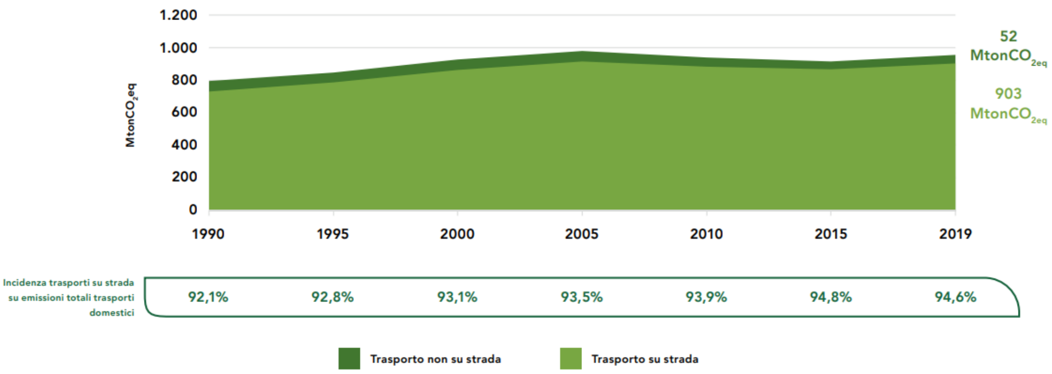
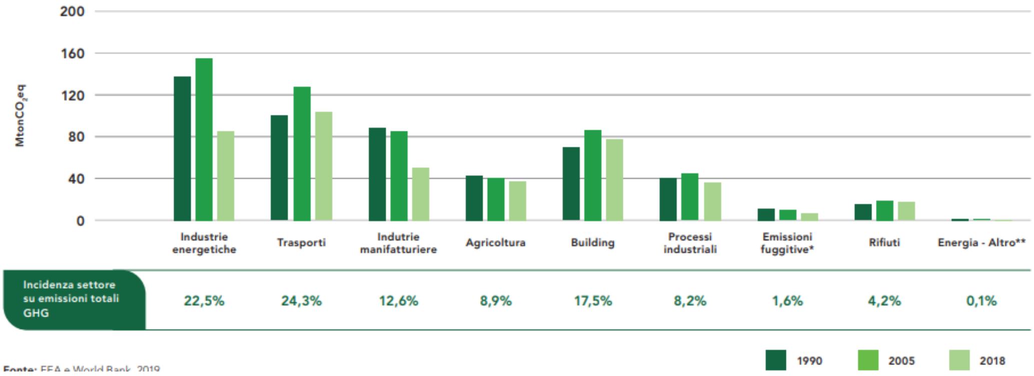


Figure 10: European-level GHG emission trends in the transportation sector (Boisrond et al., 2022, ES, p. 43)

Italy, in line with the rest of Europe, has reduced its emissions from 1990 to 2019. The top sector by emissions is transportation, with a +2% compared to 1990 values, with a total of over 100 million tons of CO2eq. Again, almost 93% of the GHG emissions related to this sector are from road transportation, with cars in particular accounting for about 68% of emissions, followed by heavy-duty vehicles and light trucks (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES).



Fonte: EEA e World Bank, 2019

Figure 11: Italian-level GHG emissions trends by sector (Chiesa et al., 2021, ES, p. 45)

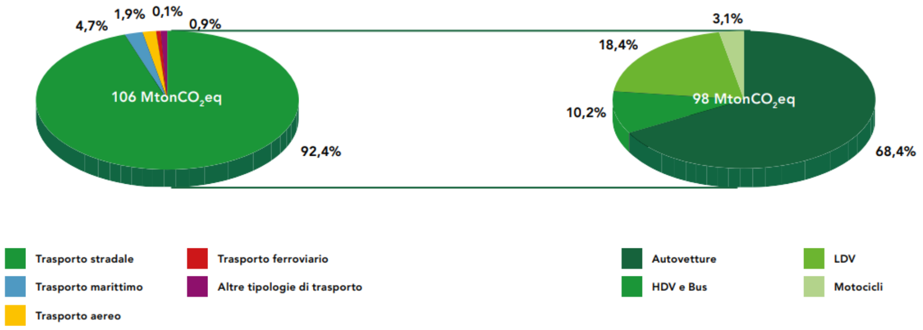


Figure 12: Distribution of GHG emissions by type of transportation (left) and by road transport (right) (Boisrond et al., 2022, ES, p. 47)

In addition, transports also generate emissions of other pollutants, including 40.3% of nitrogen oxides (NOx), 11.4% of non-methane volatile organic compounds (NMVOCs), 10.1% of particulate matter (PM) and 18.7% of carbon monoxide (CO) (Armaroli et al., 2022, MISM).

2.2. Transports Decarbonization

Priority in this thesis is given to the decarbonization of transports, both because of its relevance to the current discussion and because of its priority in emission reduction contexts. Indeed, the transports sector cubes several negative externalities, including climate change, air, landscape, and noise pollution, supply dependence on geopolitically unstable countries, and traffic congestion. These externalities translate into 800 million euros per year in mobility costs within the European Union (Accetturo et al., 2022, MISM). In a more national view, in Italy the transportation sector causes 24.3% of total GHG emissions and 30.7% of CO2 emissions (Armaroli et al., 2022, MISM).

Therefore, the transports decarbonization process can be seen as a series of growth opportunities and risks related to the transformation of production processes. Capturing these opportunities requires important industrial, technological and market choices. Therefore, congruent policies are needed (Armaroli et al., 2022, MISM). To achieve the Net Zero Emission scenario, policies need to promote modal shift and efficient integrations between passenger transportation modes. Transports decarbonization must be helped by technological transitions, such as electric mobility both with pure electric vehicles (BEVs and hybrids) and fuel cell vehicles (FCEVs), and with the use of low-emission fuels such as, for example, biofuels or hydrogen fuels (Bouckaert et al., 2021, IEA).

Considering also the new European targets, decarbonization of vehicles is one of the most efficient ways to reduce GHG emissions by 55% by 2030. Already with the current energy mix, replacing internal combustion vehicles with electric vehicles would result in a 50% reduction in light-duty transportation emissions by road. Moreover, the advantage of this sector is that there are already usable alternatives, which can at least partially replace current ICE solutions. According to this point of view, technologies that have less environmental impact need to be optimized to minimize costs and improve the economic productivity of the system. However, decarbonizing the transports sector is a complex activity that requires to (Armaroli et al., 2022, MISM):

- Making sustainable transport alternatives to traditional road transportation available and enhancing them to manage mobility demand;
- Improve energy efficiency;
- Decarbonize vehicles and energy carriers;

- Reduce emissions required for vehicle production and infrastructure construction.

Analyzing the specific situation in Italy, the transportation system has structural deficits: it is the second country in Europe in terms of the number of cars per inhabitant, there are gaps in local public transport networks and a clear territorial unevenness in terms of infrastructure. In fact, the South lacks the presence of high-speed rail and adequate highways, making mobility very difficult. All this results in the prevalence of road transport over more environmentally sustainable alternatives (Armaroli et al., 2022, MISM). For this reason, the Italian climate neutrality strategy to 2050 includes two evolution scenarios: the reference scenario and the decarbonization scenario. In the reference scenario, the PNIEC targets are met in 2030 and the same trends are pulled until 2050. In this scenario, in 2050, the transportation sector is still the one with the most emissions due to the persistence of a large share of fossil-fueled circulating carriers. Clearly, climate neutrality in 2050 cannot be achieved in this way. On the other hand, in the decarbonization scenario there is a radical transformation of the energy mix in favor of renewable sources, with the total reduction of transportation emissions. To achieve this, the scenario uses technologies such as electrification of vehicles, with a focus on cars, the use of hydrogen, reducing the need for daily polluting transport of people, and enhancing rail transport. With these measures, Italy can effectively aim for climate neutrality in 2050 (Chiesa et al., 2021, ES). The PNRR has also intervened in the issue of Italian infrastructure and mobility: €33.7 billion out of the €61.4 billion of PNRR and National Complementary Plan resources allocated to the Ministry of Infrastructure and Sustainable Mobility are intended for southern Italian regions. Clearly the intention is to recover as quickly as possible the territorial gap regarding the infrastructures, since it burdens southern areas (Ministro per il Sud e la coesione territoriale, 2022).

2.3. Renewables

As evident from both Italian and European decarbonization policies, increasing renewable sources on the energy mix is imperative for green transition projects. In IEA's various scenarios, although different in terms of exponential growth, by 2030 solar PV[7] and wind generation are expected to grow (IEA, 2021b).

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[7] PV stands for photovoltaic

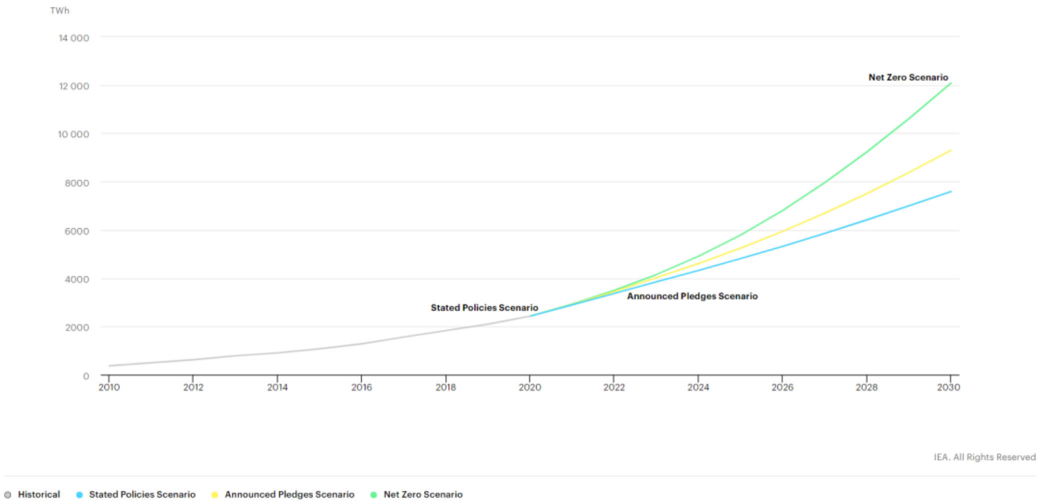

Figure 13: Solar PV and wind generation by scenario, 2010-2030 (IEA, 2021b)

Globally, 80 to 90% of the power generated is expected to come from renewable sources in 2050. Most of this power will come from onshore solar and wind power due to lower costs for these technologies, while offshore wind will make up only a small percentage due to policy hurdles. Thermal power plants will continue to be an important part of energy use. Insted, when it comes to nuclear power plants there is still a heated debate about whether or not they can be considered clean energy sources (Gruenewald et al., 2022, McKinsey & Co.). To decarbonize the transports sector, renewables play a central role, as they allow to generate clean energy to be used to power electric cars.

Italy's electricity system has evolved in recent years to align with decarbonization trends thanks to the reduction of thermoelectric power, but especially to the spread of renewables. The installed capacity from renewable sources in Italy is 60.58 GW, mainly due to solar and wind power. On the other hand, thermoelectric power currently has a capacity of 60 GW, down 22% from 2012. To date, the largest amount of energy, about two-thirds of current capacity, is produced by natural gas-fired plants. Coal-fired plants count for 17% of thermoelectric generation capacity, but they clearly need to be decommissioned by 2025, following PNIEC guidelines. Finally, biomass and oil-fired plants count for the 3% (Boccardo et al., 2021, ES).

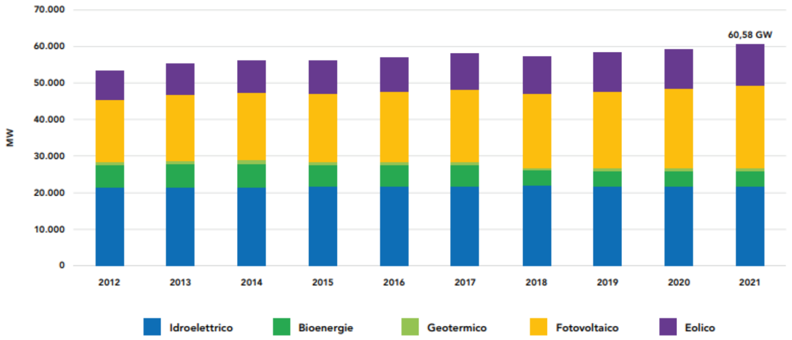

Figure 14: Total installed power from renewable sources in Italy (Boccardo et al., 2022, ES, p. 31)

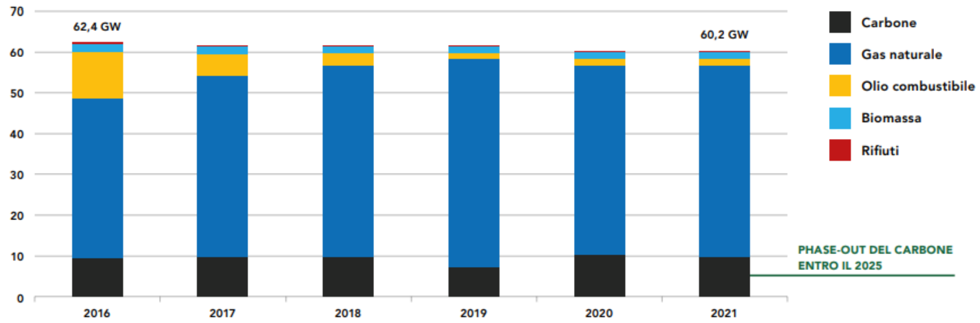

Figure 15: National generating capacity in GW (Boccardo et al., 2021, ES, p. 11)

Analyzing in more detail at the Italian renewable fleet, it is immediately evident that the installed power is mainly concentrated in the North, with 48% of the total. The only exceptions is Puglia: the region alone produces 10% of the installed power. The main source of renewables is photovoltaics, with about 69% of the installed power, followed by wind power at 30%. The rest can be largely attributed to hydroelectric power, with a smaller contribution from bioenergy and geothermal sources (Boccardo et al., 2021, ES).

Looking more at the economic part, greater penetration of renewables would cause competitive energy prices. Even now, the presence of renewables allows market prices to be contained. Although the influence of offers from traditional sources is still strong, as is shown by the increase in energy prices during times of crisis for the gas cost (Boccardo et al., 2021, ES). Therefore, enriching the energy mix with renewable sources is not only necessary to accelerate climate neutrality goals, but also to achieve greater energy independence, which would cause more stability both in terms of energy supply and of end-customer costs.

Italy historically has a higher cost of energy than the European average and it is heavily dependent on gas imports. However, in order to be in line with European targets, it should install at least 65 GW of new capacity from renewable sources by 2030. On the one hand, these actions are aimed at achieving energy independence, resulting in competitive energy costs. On the other hand, they clearly involve a planning effort both at a temporal and geographic levels. The plan should be supported by a substantial investment, in order to strategically position Italy in the future global economic system. In this scenario, there is the need of policies in order to attract the financial market and international investors, since the can play an active role in the development of the sector (Boccardo et al., 2021, ES).

2.4. Energy Infrastructures

The energy transition and decarbonization have also affected energy infrastructure management. In general, the macro trends that are shaping the sector are (Accetturo et al., 2022, MISM; Boccardo et al., 2021, ES):

- The globalization of markets;
- The spread of ICT and mobile telecommunications systems;
- The introduction of smart paradigms, such as smart grids and smart cities;
- The rise of web-based services;
- The increase in the share of renewables in gross domestic consumption;
- The spread of RES, especially from non-programmable sources[8];
- The development of energy communities;
- The electrification of consumption.

The main effects of these new trends can be listed as follows (Boccardo et al., 2021, ES):

- Reduction of system inertia;
- Increased reserve energy requirements;
- Periods of overgeneration;
- More complex management of distribution networks;
- More grid congestion;
- Fewer resources for frequency regulation.

This has led to the re-regulation of the industry. Energy infrastructures have been shifted from monopolistic to open-market, resulting in industry efficiencies, reduced costs, and increased user focus. However, energy infrastructures in this way have been exposed to the effects of cascade events that can occur in the market (Schaeffer, 2012, quoted by Accetturo et al., 2022, MISM). To protect critical infrastructure, the European Union stipulated the European Program for Critical Infrastructure Protection (EPCIP) back in 2006. However, in 2013 this framework was revised to take into account new pilot projects, such as the EU electricity transmission and gas transport network, Eurocontrol and the Galileo satellite system (Accetturo et al., 2022, MISM). In Italy, the PNRR in the second mission has a component for the renewable energy, hydrogen, grid and sustainable mobility. This component includes some measures for the development of a digital, flexible and resilient distribution network. In particular, the investment lines for networks concern (Boccardo et al., 2021, ES):

- Strengthened smart grids, to increase grid capacity by 4 GW from renewable sources. This allows to power the electrification of energy consumption in highly concentrated metropolitan areas;

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[8] According to GSE's definition, non-programmable renewable sources are those that are used by "hydroelectric, wind, photovoltaic, and biogas production facilities”.

- Grid climate resilience interventions.

Finally, in order to answer to the aforementioned macro trends, Terna[9] introduced the Capacity Market in Italy. The Capacity Market mechanism, on the one hand, allows Terna to procure capacity through long-term contracts and auctions, while, on the other hand, ensures the suitability of the Italian electricity system at competitive prices. This is possible since power producers submit bids, with a discount compared to a given cap (Terna, n/a a). The objectives of the Capacity Market can be summarized as follows (Boccardo et al., 2021, ES):

- Phase-out the most polluting plants, especially coal-fired plants;
- Develop non-programmable renewable plants;
- Stabilize prices in the long run.

From a more technical point of view, the energy supply chain needs to be evaluated both in terms of the risk of single parts of the infrastructure and by considering the combinations of fuel and energy supplies, in order to identify which bottlenecks are potentially critical to infrastructure resilience. Since energy supply disruptions are still possible, smart meters can be used to secure supplies to consumers, since they can balance the demand in times of grid stress (Accetturo et al., 2022, MISM). Load balancing considering power availability can be managed through storage systems, which are crucial in a scenario of increasing electric vehicles. Smart IT systems allow batteries to be charged during off-peak periods of power demand. In addition, the resilience of the electricity generation infrastructure can also be strengthened by creating a large portfolio of generating capacity, with the integration of even renewable sources (OECD, 2018, cited by Accetturo et al., 2022, MISM).

2.5. Electric System

One of the main factors that will cause emission reductions in the Net Zero Emission scenario is the replacement of fossil fuels using electricity. Specifically, a 20% reduction is expected by 2050. Therefore, global electricity demand is expected to more than double between 2020 and 2050, especially in the industrial sectors. In further detail, demand in 2020 was 23,230 TWh, while in the net zero emission scenario in 2050 global electricity demand is expected to be 60,000 TWh, with an average growth rate of 3.2% per year. Of this projected demand, it is plausible that 75% will come from emerging markets and developing economies. On the other hand, strong demand growth is also expected in advanced economies due to end-use electrification and hydrogen production (Bouckaert et al., 2021, IEA).

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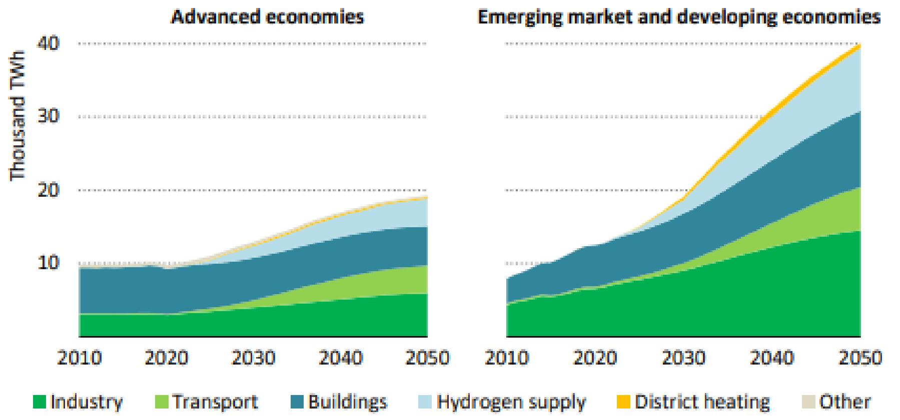
[9] The Terna Group owns Italy's national high- and extra-high-voltage electricity transmission grid, and is the largest independent grid operator for electricity transmission in Europe (Terna, n/a b).



IEA. All rights reserved.

Figure 16: Electricity demand by sector and regional grouping in the Net Zero Scenario (Bouckaert et al., 2021, IEA, p. 114)

The rate of consumption electrification has remained constant over the past decade, on average the 20% of final consumption, with significant variations by sector. Regarding the electricity demand coverage, traditional thermal sources declined from 74% in 2005 to 51% in 2021, while RES increased from 14% to 36% driven by wind and photovoltaics (Boccardo et al., 2022, ES).

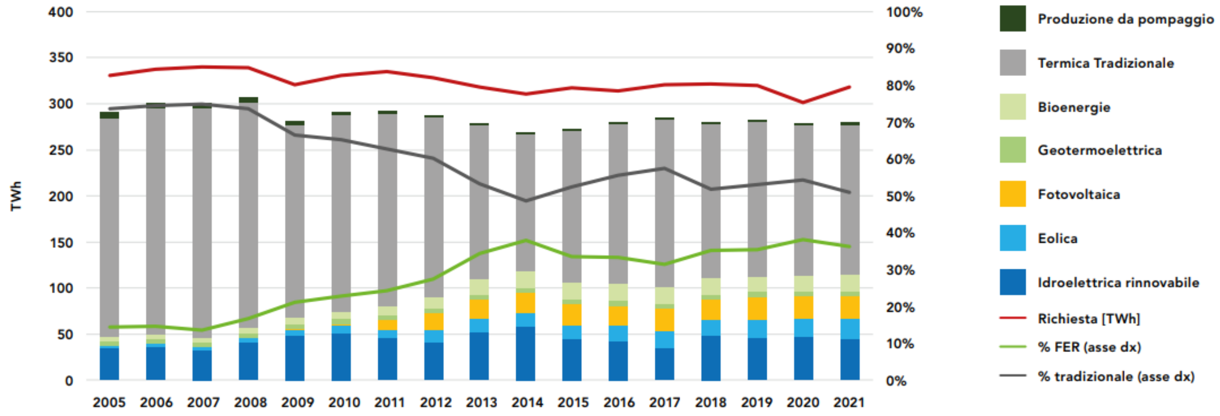


Figure 17: Electricity demand coverage (Boccardo et al., 2022, ES, p. 35)

2.5.1. Electricity Price

Within the European Union there is the pay-as-clear marginal price system. According to this system, all electricity producers must offer the same price for the power sold at a given time. Power producers set the price based on their own costs. The bidding order ranges from the cheapest to the most expensive. Since RES are produced at zero cost, they are always the cheapest and, as a consequence, the ones bought first. Once the entire demand has been met, the price settles at the price of the last producer from whom the electricity was purchased (European Commission, 2022a). Therefore, since producers offer a price that reflects for each technology the marginal costs of generating electricity, the electricity price is determined by the technology that leads the cleaning price (Boccardo et al., 2022, ES). This model was already widely used in the EU even before it was part of the legislation, as it is considered to be the most efficient for the free electricity market, as it is transparent, and it lowers costs. (European Commission, 2022a).

In Italy, gas-fired plants represent the marginal technology. The outbreak of Ukrainian war has caused gas prices to soar, with a cascade effect on electricity prices. Renewables partly succeed in lowering prices at certain times of the day, but with current electricity consumption RES are not enough to give up plants with high generation costs. In the spring of 2020, with the lockdown restrictions, there had been a sharp decrease in electricity demand, and renewables had reached 48% of demand, causing a major price reduction. In order to achieve a similar result, renewable installations must be done at a steady pace (Boccardo et al., 2022, ES).

The reference price of wholesale electricity purchased on the Italian Power Exchange market is called PUN, an acronym that stands for Prezzo Unico Nazionale, which means Single National Price in Italian. After the liberalization of the electricity market, the Italian Power Exchange has been regulating the buying and selling of electricity between producers and suppliers since 2007. Most transactions take place during the buying and selling session referred to as the Day-Ahead Market (MGP - Mercato del Giorno Prima), which allows to buy and sell electricity offers one day before the actual delivery of electricity. In the Day-Ahead Market, the selling price differs by zone while the buying price depends on the PUN. Specifically, the PUN is the result of the national weighted average of zonal electricity selling prices for each hour and each day. Changes in the PUN determine the final energy costs on the bill. During periods when the PUN rises, costs go up, and vice versa. End-consumer tariffs are divided between fixed-cost or indexed-cost in terms of the energy component price. The indexed energy component price implies the price change over time based on the performance of the PUN on the Italian Power Exchange. Instead, the fixed energy component price remains unchanged for a certain period of time, usually for one or two years (Enel Energia, n/a). The PUN in 2021 increased by 64.6% compared to 2019 and 121.3% compared to 2020. This growth was caused, as was explained earlier, by the steep rise in gas prices, once again highlighting Italy's heavy reliance on fossil fuels (Boccardo et al., 2021, ES).

In order to contain electricity and natural gas costs, the Decreto Energia (dl 17/2022), which stands for Energy Decree in Italian, was enacted. Indeed, there was an obvious urgency to take measures in order to manage the economic effects of the international crisis, caused by the war between Russia and Ukraine. The proposed actions involve an Electricity and Gas Social Bonus and the elimination of system charges in the electricity sector for the third quarter of 2022. Even if these actions represent only short-term measures, the decree also proposes long-term solutions, such as the development of renewable energy and the revitalization of industrial policies

(Gazzetta ufficiale della repubblica italiana, 2022a; 2022b). The measures in terms of renewables can be summarized as follows (Boccardo et al., 2022, ES):

- Simplify solar panel installations on roofs;
- Extend the “simplified single model”, also known as “modello unico semplificato”[10], which is used for reporting the installation of small photovoltaic systems on rooftops, to bigger installations between 50 and 200 kW (GSE, 2022);
- Extend the use of PAS[11] to authorize PV installations up to 20 MW on industrial land, quarries, and landfills which are connected to the high-voltage grid (GSE, n/a);
- Add new categories of areas automatically eligible for PV installation. To date, automatically eligible areas are, for example, agricultural areas that are a maximum of 300 meters away from industrial areas, quarries, or mines;
- Change the ban on incentives for photovoltaics on agricultural land in order to consider agrovoltaic systems, where modules can be installed high above the ground without compromising farming activities;
- Activate a purchase service for renewable electricity by the GSE, with the stipulation of long-term contracts.

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[10] The “modello unico semplificato” refers to the construction, connection and operation of small photovoltaic systems, integrated on the roofs of buildings. The measure aims to simplify the communication procedures and to reduce the charges on citizens and businesses for the construction of photovoltaic systems with a nominal power up to 50 kW (GSE, 2022).

[11] PAS stands for "Procedura Abilitativa Semplificata", which means “Simplified Enabling Procedure”, and it indicates an authorization process for the installation of a photovoltaic system (GSE, n/a).

3 Mobility Market

As previously mentioned, the energy transition must necessarily go through transports decarbonization. Accordingly, this section will analyze the mobility market in detail, discussing sustainable alternatives to the current fuel-based ones, leading up to the concept of smart mobility and how it can be declined in urban contexts.

In terms of systematic mobility, i.e., the type of mobility for work or study, its contraction for both short and long distance can be seen in countries with more advanced economies. The Covid-19 pandemic and digitalization have only accentuated a trend that had already been present for years due to (Accetturo et al., 2022, MISM):

- Aging of the population, since as age increases there is a decrease in systematic movement;
- Decrease in the working population, due to an increase in unemployed and retired people;
- Decreased travel and commuting for work-related causes, partly due to time flexibility and the spread of distance learning and remote work.

Furthermore, the demand for occasional mobility, although less significant than systematic mobility, has also had a decreasing trend, due to (Accetturo et al., 2022, MISM):

- Diffusion of e-commerce, which reduces shopping trips;
- Increased awareness of environmental sustainability, prompting people to reduce high-impact travel, favoring responsible tourism instead;
- Reduced travel for major events, including corporate ones, also accentuated by the effects of Covid-19.

3.1. Fuel Retail

Within the oil and gas industry, retail fuel distribution has always been one of the most resilient segments. This may seem unusual given that the industry was hit particularly hard by the Covid-19 pandemic. Especially in the first half of 2020, fuel volumes more than halved from the same period the previous year. However, as soon as it was possible to travel again, private mobility quickly recovered, settling at levels comparable to the pre-pandemic ones. In a no longer emergency situation, it can be seen that there are several changes in consumer habits. These new trends are destined to significantly change mobility and, consequently, fuel distribution as well. On one hand, it is clear the shift from public transports, as they are perceived as places with a high risk of infection, to private vehicles can fuel demand. On the other hand, trends such as remote working and online shopping will certainly tend to reduce it. It should be noted that the scenarios are different between more mature economies, such as the EU, the United States, and China, compared to emerging markets in Asia, Latin America, and the Middle East, where a slight increase in traditional fuel consumption is expected (Bau et al., 2021, McKinsey & Co.).

Within this context, fuel retailers have in fact been able to capture incremental value through non-fuel businesses as well. Within the various businesses revolving around fuel retail, three major macro areas can be identified (Bau et al., 2021, McKinsey & Co.):

- Services. Within services, we can find core businesses related to fuel retail that are tire changing, lubricant sales, and more generally car maintenance. There are also businesses considered natural adjacencies, such as parcel pickup services, or even emerging in the industry, such as postal services, ATMs, and ridesharing;
- Alternative fuels. Alternative fuels refer to the whole world of e-mobility, biofuels, and hydrogen fuels;
- Non-fuel retail. Non-fuel retail businesses range from more traditional businesses, such as car washes, to mid-market businesses, like fast dining, to businesses that are not yet widespread in this area, for instance, hospitality, last-mile delivery, and drive-through services.

The goal is to convert classic gas stations into mobility hubs, where it is possible to eat, shop, and relax while the car is recharged and taken care of by car care centers. To accomplish this, it is necessary to move beyond the concept of the gas station as simply refueling, coupled at most with some car repair and cleaning services. Gas stations should be conceived as "new mobility retail," as defined by Bau et al. (2021), in which the focus is no longer on the vehicle itself, but on the needs of consumers. In this scenario, electric vehicles are well suited, since they can be recharged by slow charging while consumers are busy with other chores.

Oil majors have also decided to diversify their businesses through non-fuel retailing. They are seeking to acquire more and more distribution networks that offer these alternatives (Bau et al., 2021, McKinsey & Co.). Oil companies need to improve their reputations to be economically resilient and they should consider how to reposition themselves in order to keep up and take advantage of new trends in emissions reduction. Some companies have announced goals to reach the Net Zero Emission scenario, decarbonizing not only their operations, but also their value chains. Moreover, low-carbon sectors represent fast-growing investments, particularly renewable energy, infrastructure electrification, hydrogen, bioenergy, and carbon capture, utilization, and storage (Beck et al., 2021, McKinsey & Co). Investing in low-carbon sectors is particularly necessary because, according to Gruenewald et al. (2022), oil demand will peak around 102 MMb/d[12] in the next 2 to 5 years. After that, oil demand will involve increasingly less gasoline and diesel. Gasoline and diesel in recent years to counted for 55% of total oil demand, but they are expected to reach a share of 15% in 2050. On the other hand, the share of natural gas and LPG will rise from current 20% to about 60% in 2020. This shift will cause a cascading 85% decline between the current situation and 2050 in refining activities, forcing the shutdown of those refineries that will not be able to shift to biofuel production (Bouckaert et al., 2021, IEA).

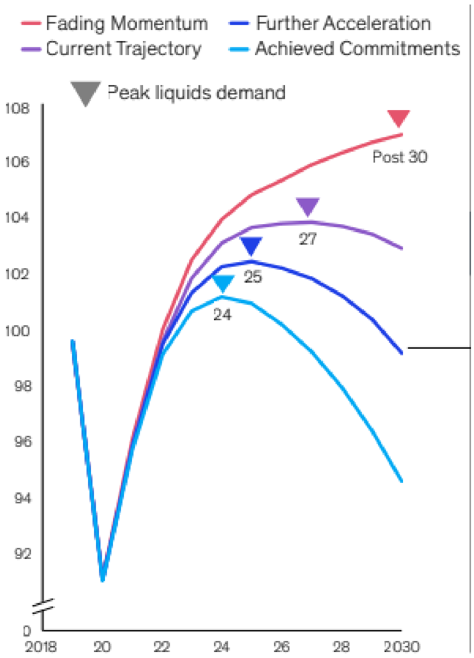

Figure 18: Liquids demand, MMb/d (Gruenewald et al., 2022, p. 14)

Instead, from the viewpoint of the different IEA scenarios, oil demand varies greatly depending on the scenario considered. In the Stated Policies Scenario, post-pandemic oil demand growth continues steadily, far exceeding pre-2020 levels. In the Announced Pledges Scenario[13], demand settles at pre-pandemic levels without ever fully recovering. Finally, in the Net Zero Scenario, demand collapses, nearly to zero in 2030, as conventional fuels do not allow emissions to be cut (IEA, 2021b).

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[12] MMb/d stands for million barrels per day and it measures oil output.

[13] Announced Pladges Scenario is part of IEA's World Energy Outlook Scenarios.

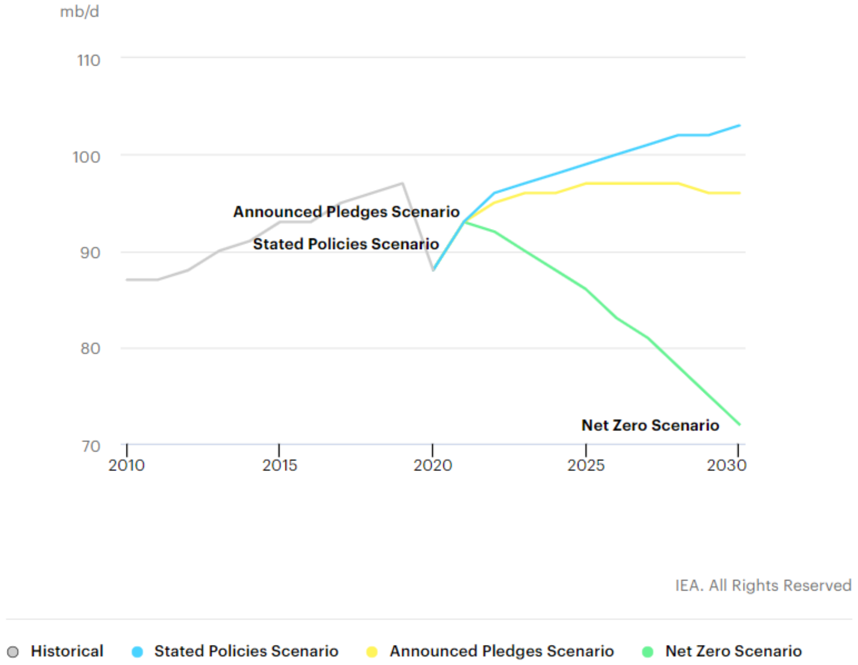

Figure 19: Oil demand by scenario, 2010-2030 (IEA, 2021b)

Forecasts in which oil demand falls dramatically imply a spread of electric vehicles. Indeed, the electric fleet expansion will reduce the use of oil, which currently fuels more than 90% of total consumption in the transportation sector (Bibra et al., 2022, IEA). This percentage is expected to drop to 75% in 2030, down to 10% in 2050. From 2040, electricity is expected to become the dominant fuel in the transportation sector, reaching 45% of final consumption in 2050. Instead, in sectors where the use of electricity and hydrogen is limited, such as aviation and transportation, biofuels are expected to be used more (Bouckaert et al., 2021, IEA). Indeed, consumer environmental awareness of transports air pollution is motivating governments to take action in order to reduce fuel consumption (Ghasemi-Marzbali & Shafiei, 2022). The EU Council of Environment Ministers has even accepted the European Commission's proposal to ban the sale of internal combustion cars from 2035. Although, cars with endothermic engines may also be sold after that date if they are powered by climate-neutral fuels, also known as e-fuels. In 2026 it will be evaluated whether hybrid or e-fuelled vehicles are really able to meet the EU's environmental standards (Staffetta Quotidiana, 2022b).

From an economic perspective, tax revenues will be greatly impacted by the substitution of petroleum products. Taxes on transport fuels feed significantly into government revenues in many countries and are used to invest in transportation infrastructure. The adoption of electric vehicles is the primary source of reducing these revenues, which are unlikely to be offset by taxes on electricity use. Indeed, electric vehicles are two to four times more efficient than internal combustion vehicles, causing lower overall energy consumption. To date, tax reductions are still small, but the projected 2030 electric fleet replaces about 3.4 MMb/d in the Stated Policies Scenario and 4.6 MMb/d in the Announced Pladges Scenario. This implies a net fuel tax loss of between $75 billion and $90 billion in the two different scenarios, with Europe suffering the largest loss of $35 billion. Governments need to anticipate the reduction of tax revenues in order to establish mechanisms to support the deployment of electric vehicles, while on the other hand limiting the fiscal impact (Bibra et al., 2022, IEA).

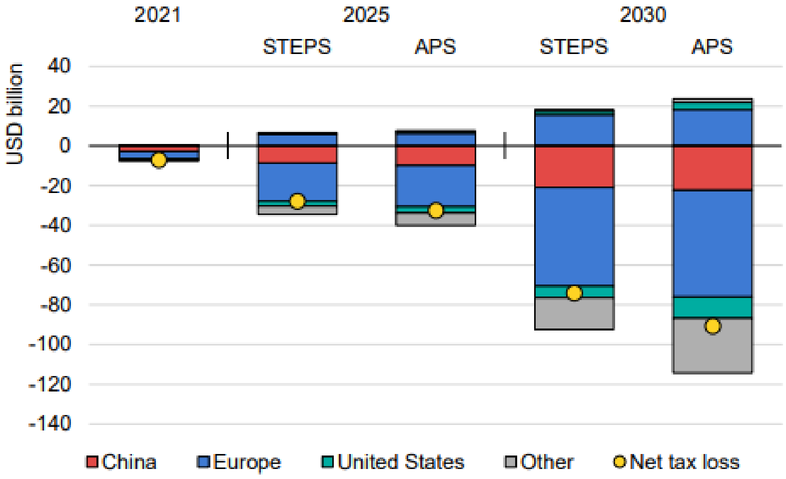

Figure 20: Additional tax revenue from electricity and tax loss from displaced oil products by region and scenario[14], 2021 – 2030 (Bibra et al., 2022, IEA, p. 130)

3.2. Technological Alternatives

This section has the task of comparing at a general level the different technological alternatives to ICE vehicles to date on the market. Then the section will go into detail of the analysis of the most relevant technologies. As advocated by the European Commission (2020), consumers and businesses need to be informed as clearly and transparently as possible about which is the most sustainable choice for their transportation. However, this discussion is not meant to define what that option actually is, but to compare the pros and cons of each alternative based on the transportation mode considered.

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[14] STEPS stands for Stated Policies Scenario, APS for Announced Pledges Scenario,

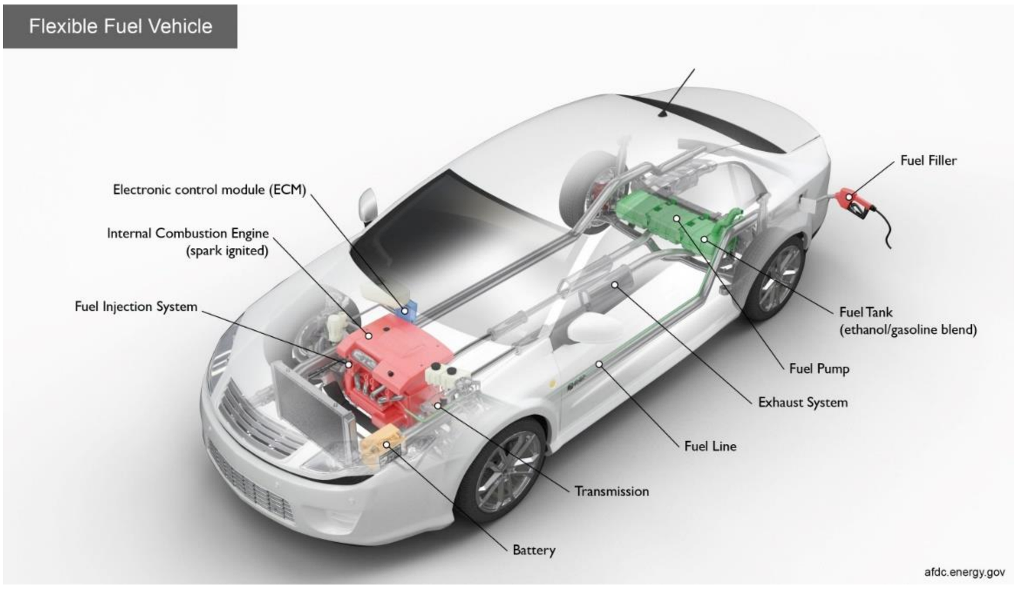


Figure 21: ICE diagram (U.S. Department of Energy, n/a)

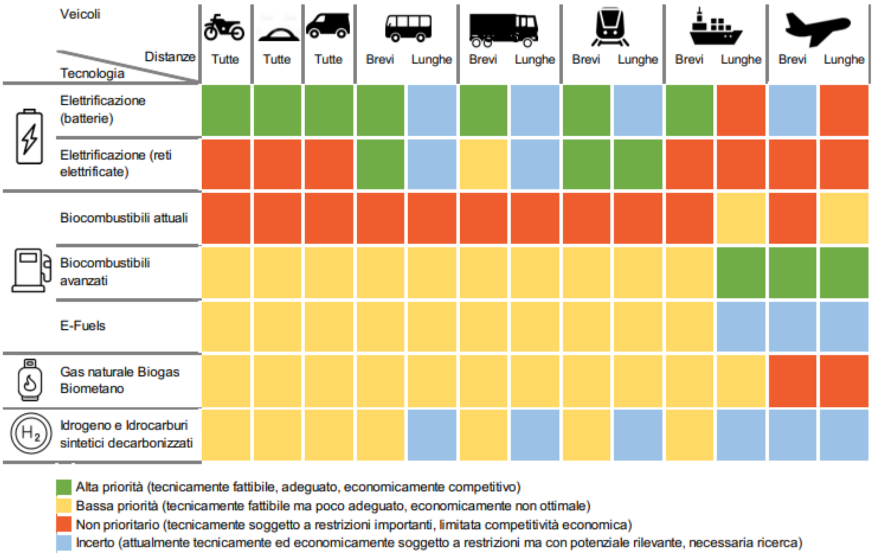
The alternative that seems most readily available to internal combustion vehicles for reducing greenhouse gas emissions and at low cost is the electric one. Direct electrification solutions (BEVs) are more energy efficient and have great potential for decarbonization if the electricity is obtained from renewable sources. Internal combustion vehicles (ICEs) have a larger material footprint than battery-powered cars. At the end of its useful life, an ICE car has burned and dispersed 5/10 times its weight in fuel into the atmosphere. The main cost component of electric cars is the battery. Indeed, they require the use of metals and graphite, but their production must be increased substantially to meet demand, as it is expected to grow greatly. As a result, raw material supply chains will change structurally, considering the switch in demand from fossil fuels to metals, such as lithium, nickel, and cobalt. The current limitations of electrification relate to long-distance vehicles, such as ships and airplanes: large storage systems are needed, as it is not possible in these cases to use charging systems during the operational phase. For shorter distances, the development of new battery technologies will enable the acceleration and expansion of transport electrification. Solutions are already being tested to double the energy density of batteries, considering that now the best ones have a weight of around 250 Wh/kg. Another limitation regarding electrification is the imbalance between electricity demand and supply, considering that the production of decarbonized energy carriers is more energy intensive than fossil derivation. This could result in the need for infrastructure investment, causing the total cost of electrification to increase compared to other solutions. However, by basing the electricity system on renewable energy, as has been done in several Scandinavian countries, there is actually no need to upgrade the electricity system. Certainly, it will still be necessary to regulate demand in order to increase the hosting capacity of electricity grids. This requires, as it will be explained in detail later, charging systems that can modulate themselves based on signals from the electric system (Armaroli et al., 2022, MISM).

However, there are also other solutions besides electrification: alternative fuels. Alternative fuels are defined as energy carriers that include LPG, methane, hydrogen, biofuels, and synthetic fuels. They are termed this way because they are alternatives to electric mobility and traditional fuels, i.e., gasoline and diesel (Chiesa et al., 2021, ES). Partial substitution of traditional fuels with biofuels does not lead to important decarbonization benefits, as the emission profile of biofuels is quite high and results in low efficiencies and high energy costs. On the other hand, synthetic fuels are at a level of technology where they are close to commercialization, although the levels of efficiencies and energy costs do not foresee their use in shipping and aviation. In general, the availability of hydrogen, biomethane, biofuels, and synthetic fuels will be limited, as there are constraints on the availability of sustainable biomass and renewable energy. These energy carriers can be used to lower emissions in situations where there are no alternatives at lower costs and environmental impacts (Armaroli et al., 2022, MISM).

In further detail, the next sections will analyze the main alternatives to traditional ICE motorizations identified by Armaroli et al. (2022), which are:

- Battery electric vehicles (BEVs);
- Hybrid vehicles equipped with both electric and thermal motor (HVE - hybrid electric vehicle);
- Hybrid vehicles with a directly chargeable plug-in battery (PHVE - plug-in hybrid electric vehicle);
- Fuel cell electric vehicles (FCEV or HFCEV - hydrogen fuel cell electric vehicle);
- Vehicles powered by natural gas and biomethane (CNG and LNG - Compressed & Liquefied Natural Gas);
- Vehicles powered by biofuels from dedicated crops or Generation II;
- Vehicles powered by synthetic hydrocarbons.

In a climate emergency situation, with the urgency of making an effective energy transition, distributing investments over many different solutions is a significant technological, economic and infrastructure maintenance effort. Consequently, it would be better to invest more on options with low risk of failure. Currently, the solution with the least risk is the expansion of public charging infrastructure for electric cars and the use of incentives for electrification, as these are already tested strategies that have proven successful. The major investment in this case involves building gigafactories in Europe to produce the best batteries on the market (Armaroli et al., 2022, MISM). Having said that, it is deemed necessary, for awareness of the existence of other options, which are especially necessary for sectors and situations where electric cannot be used, to illustrate the other options as well.



Veicoli / Distanze / Tecnologia	Tutte	Tutte	Tutte	Brevi	Lunghe	Brevi	Lunghe	Brevi	Lunghe	Brevi	Lunghe	Brevi	Lunghe
Elettrificazione (batterie)	🟩	🟩	🟩	🟩	🟦	🟩	🟦	🟩	🟦	🟩	🟥	🟦	🟥
Elettrificazione (reti elettrificate)	🟥	🟥	🟥	🟩	🟦	🟨	🟦	🟩	🟩	🟥	🟥	🟥	🟥
Biocombustibili attuali	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟨	🟥	🟨
Biocombustibili avanzati	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟩	🟩	🟩
E-Fuels	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟦	🟦	🟦
Gas naturale Biogas Biometano	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟥	🟥
Idrogeno e Idrocarburi sintetici decarbonizzati	🟨	🟨	🟨	🟨	🟦	🟨	🟦	🟨	🟦	🟨	🟦	🟦	🟦

🟩 Alta priorità (tecnicamente fattibile, adeguato, economicamente competitivo)
🟨 Bassa priorità (tecnicamente fattibile ma poco adeguato, economicamente non ottimale)
🟥 Non prioritario (tecnicamente soggetto a restrizioni importanti, limitata competitività economica)
🟦 Incerto (attualmente tecnicamente ed economicamente soggetto a restrizioni ma con potenziale rilevante, necessaria ricerca)

Figure 22: Evaluation of different technology options for different vehicle types and distances (Armaroli et al., 2022, MISM, p. 70)

3.2.1. BEV – Battery Electric Vehicle

The battery-powered car today is considered the fastest solution to decarbonize transportation. Moreover, it is a very effective solution due to the higher inherent efficiency of the propulsion, the lowering of lifecycle emissions, but most importantly considering the medium to long term, the opportunities to integrate through digital technologies BEVs into smart electric grids. However, there are currently still major barriers to the massive deployment of BEVs, first and foremost the purchase price. Without incentives, an average BEV costs at least 30% more than an equivalent ICEV. The price differential varies greatly depending on the size. For these types of vehicles, rather than the purchase price itself, it would be more correct to consider also the other costs incurred during the life of the car, such as depreciation, refueling, maintenance, and any resale proceeds. Considering these costs, BEVs can be compared with their ICE counterparts and, when this is not enough, incentives compensate for the remaining gap. Besides that, consumers are also being held back by the perceived inadequacy of charging stations. Thus, it is a priority to offer stations of different capacities according to the areas of interest. Specifically, it would be appropriate to install low-power stations, between 3 and 22 kW AC, in long-stay locations, such as residential and public garages, work and leisure places, or shopping malls. Whereas high-power stations, i.e., fast recharging of 50 kW and ultrafast recharging of at least 100 kW DC, are needed on major roads and highways. Limiting factors in this context are suburbs and city centers, where it is difficult to find houses with private garages. In such cases, solutions integrated into the urban context, such as public lighting poles, can be used, or multimodal mobility, based on public transport and micromobility, can be encouraged. Furthermore, charging stations can be seen as an opportunity for the creation of energy communities, resulting in lower costs for them. Another potentially critical issue, more for governments than for consumers, is the reduction in tax revenues from traditional fuels due to the spread of electric and other decarbonized energy carriers. To compensate for the taxation of fossil fuels, automobile taxes could be remodeled based on infrastructure use and distances traveled (Armaroli et al., 2022, MISM).

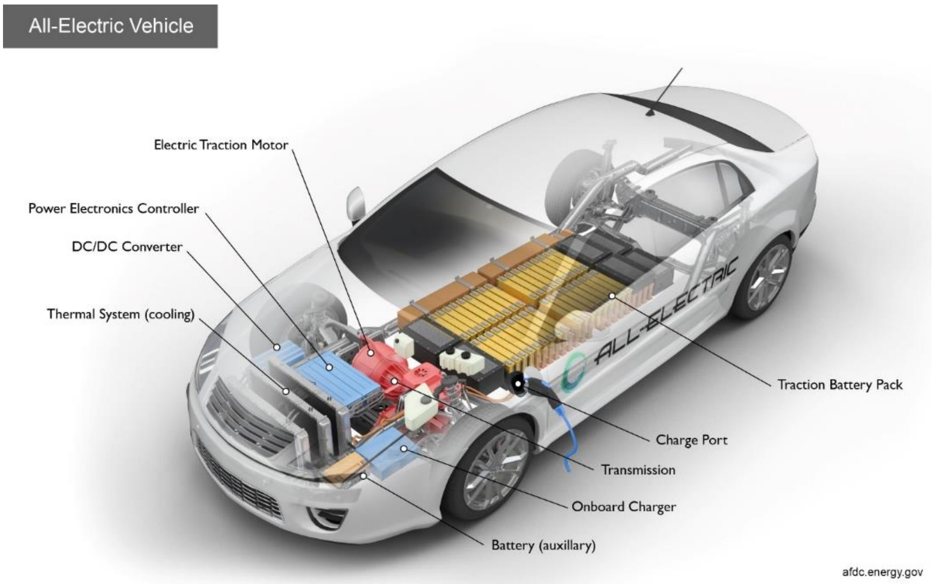


Figure 23: BEV diagram (U.S. Department of Energy, n/a)

Clearly, the whole discussion is aimed at cars for personal transportation, or at most for light commercial transportation, such as cabs and car shares. Instead, for heavy commercial transportation, especially over long distances, there are major limitations, such as the need for very high-powered charging infrastructure for fast refueling and battery size. There are proposals to solve these problems, although with obvious implementation difficulties. The first solution is to electrify the roads, as is already done for trains: the right lane could be equipped with overhead power lines to power the electric motor. Another solution could be to implement a network of very high-power charging stations, around 1 MW for heavy vehicles, but this requires significant storage capacity. Finally, as it is already being experimented in China, battery swap, i. e., fast replacement of batteries at gas stations, could be used. Basically, robotic stations would be needed, where discharged batteries are replaced by battery packs recharged at the same station. The latter solution is theoretically the most feasible, as it sets refueling times around the current 5 to 10 minutes. It enables the distribution of the energy load on the electric grid in a less impactful way than either electrified roads or power-lift recharging, both of which require an adjustment of the instantaneous supply. The problem with this solution is that, in order to robotize gas stations, a common battery standard is needed, thus encountering difficulties in finding agreement among different manufacturers (Armaroli et al., 2022, MISM).

3.2.2. PHEV & HEV – (Plug-in) Hybrid Electric Vehicle

Hybrid cars are called like this since the classic endothermic engine, the type found in ICE cars, is supported by an electric engine connected to a battery. The battery in HEVs is recharged only by the kinetic energy released in braking, thus it is highly dependent on the heat engine. The car is able to move using only the electric engine as well in this case, but only for short distances (Automobile.it, 2022b). HEVs have limited advantages in terms of energy transition, as they use the same energy carriers as conventional ICE vehicles. However, an improvement in energy efficiency can be seen, resulting in a reduction in GHG emissions, for the same size and performance, of about 20-25% compared to gasoline vehicles and 5% compared to diesel vehicles (Armaroli et al., 2022, MISM).

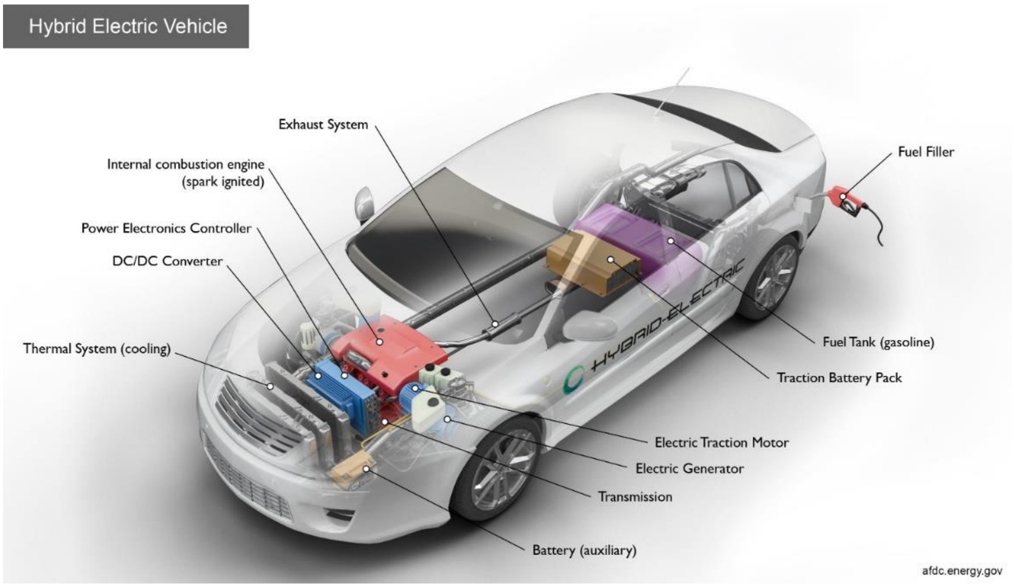


Figure 24: HEV diagram (U.S. Department of Energy, n/a)

On the other hand, there are also PHEVs, which are an evolved form of hybrid technology. PHEVs always take advantage of kinetic energy regeneration under braking, but they differ from HEVs in being able to recharge the vehicle while plugged in as well. For this reason, the battery has greater capacity and allows medium distances to be covered in all-electric mode (Automobile. it, 2022b). PHEVs are an interesting transitional solution because they involve much less impactful changes to industrial production, as the combustion engine is retained and smaller batteries than BEVs are needed. However, they have a higher construction phase emission impact than ICEVs and HEVs and higher maintenance costs than BEVs, as they require the components of both electric motors and combustion engines. In order to effectively exploit their advantages, electric use in cities must be maximized, thereby lowering pollutant emissions in the most densely populated places. Obviously, this always entails the need to install easily accessible charging stations in urban settings (Armaroli et al., 2022, MISM).

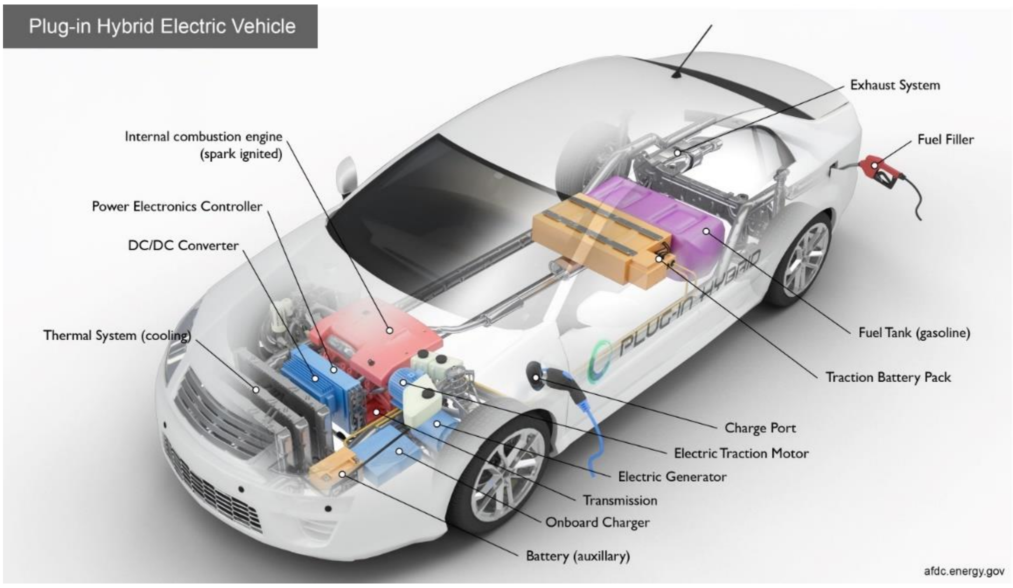


Figure 25: PHEV diagram (U.S. Department of Energy, n/a)

3.2.3. FCEV – Fuel Cell Electric Vehicle

Hydrogen fuel cell vehicles can be considered electric, as they have the electric engine and a battery, although smaller in size than BEVs. FCEVs have two very important components: high-pressure tanks, where hydrogen is stored, and the fuel cell, which is a combustion battery. The fuel cell receives hydrogen from the negative pole and oxygen present in the air from the positive pole. The catalyst causes an electrochemical reaction that separates the electrons from the nucleus, and thus electricity is released. Afterwards, the electrons move to the positive pole, joining oxygen atoms. This results in water, which is released into the atmosphere as water vapor (Automobile.it, 2022a).

Looking forward, hydrogen cars do not represent a consistent alternative to electric cars. Firstly, FCEVs require a complex design at the production level. Secondly, hydrogen produced with electricity is obviously more expensive than the direct use of electricity for batteries. Finally, hydrogen refueling stations, with the resulting transportation, distribution and storage systems for centralized production, require investment with a much higher level of risk than electric charging stations. Indeed, there are few FCEV models on the market, with a negligible presence on the road, and the situation does not seem to be improving, given the reduced presence of hydrogen distributors on the road network. Therefore, for light vehicles, hydrogen does not seem to be a priority alternative (Armaroli et al., 2022, MISM).

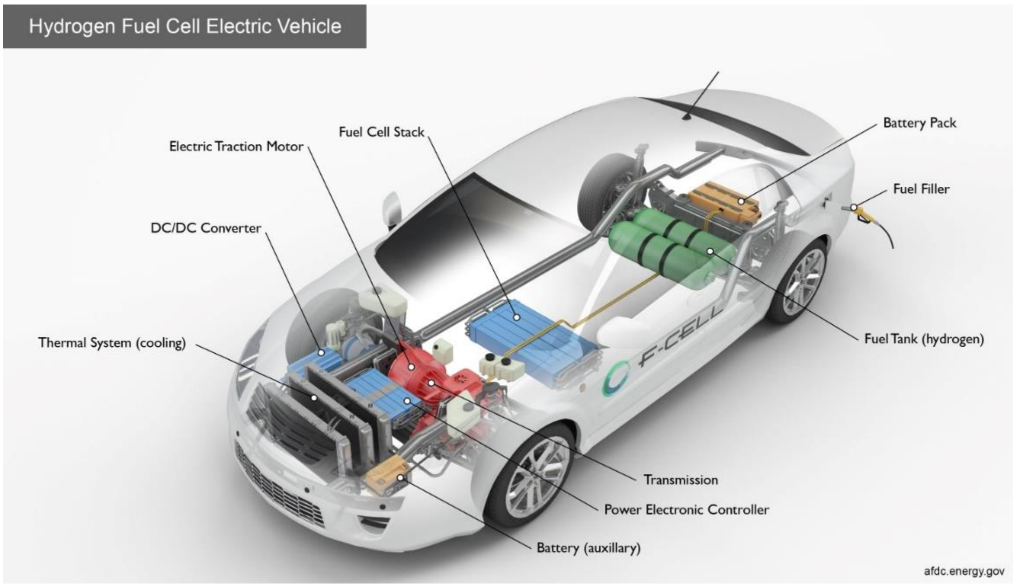


Figure 26: FCEV diagram (U.S. Department of Energy, n/a)

3.2.4. LNG & CNG – Liquefied & Compressed Natural Gas

Natural gas vehicles have a combustion engine in which CNG and air are burned. Usually these cars have a dual tank: one of CNG and one of gasoline in case the first one becomes empty. Natural gas is effectively a fossil fuel, consisting of 90% methane. However, it has significant advantages over traditional fuels. Namely, CNG reduces emissions of (Snam, 2021):

- CO2 by about 33%;
- NOx by about 75%;
- Particulate matter by about 97%.

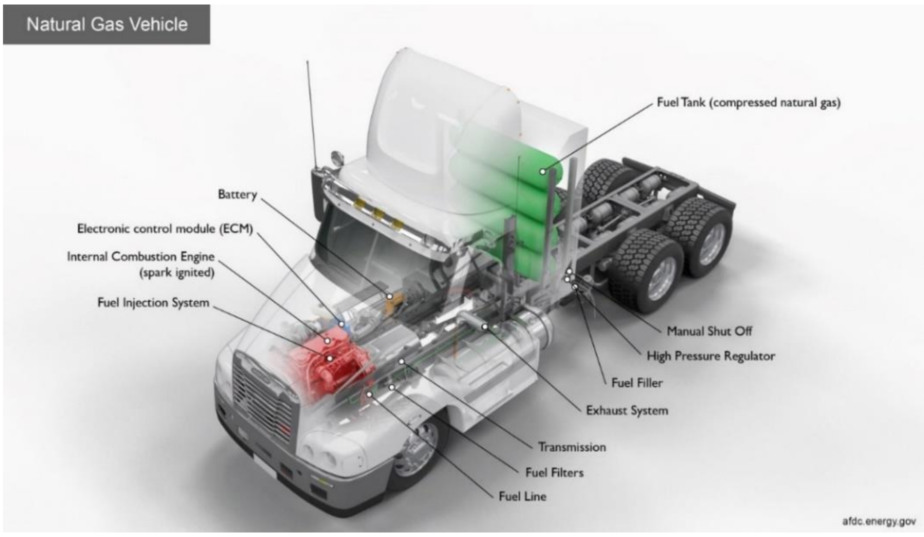


Figure 27: CNG vehicle diagram (U.S. Department of Energy, n/a)

The climate impact is even less when it comes to biogas. Biogas is still composed of methane, but compared to natural gas, it differs in origin. In fact, biogas is produced by fermenting biogenic waste, thus making it a renewable energy source (AutoScout24, 2019).

LNG is simply natural gas in a liquid state. To reach a liquid state, natural gas must be brought between -120°C and -162°C, depending on the pressure.

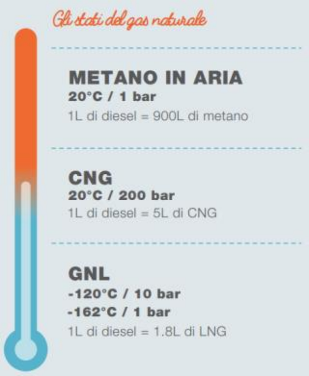


Figure 28: Natural gas states (TotalEnergies, n/a)

LNG-fueled vehicles must have a cryogenic tank to keep the gas at those temperatures. The natural gas is then gasified to be introduced into the engine. LNG is well suited for heavy-duty vehicles and buses for two main reasons. First, it is suitable for vehicles that travel long distances, as LNG offers up to 1500 km of autonomy. Furthermore, LNG vehicles must continuously consume product, as although the tanks are made of insulating materials, if the vehicle is not refueled for a few days, the LNG inside the tank will begin to return to gaseous form, creating excessive pressure (TotalEnergies, n/a).

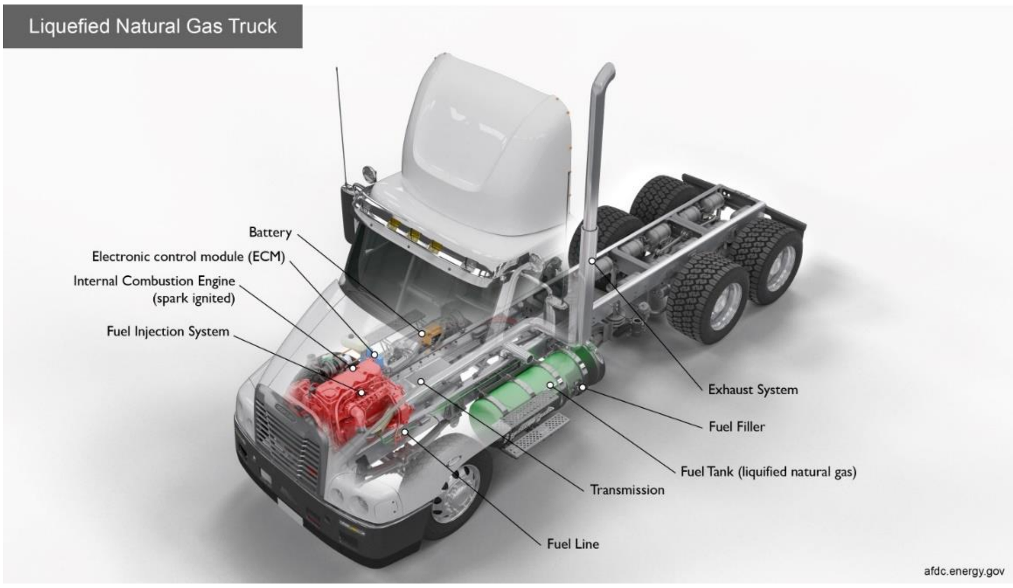


Figure 29: LNG vehicle diagram (U.S. Department of Energy, n/a)

Italy is well ahead in the use of natural gas, as it is the leading European market for automotive methane consumption, with nearly 800 thousand cubic meters consumed in 2020 and about 1 million vehicles currently on the road (Snam, 2021). Nevertheless, in the perspective of climate neutrality by 2050, natural gas numbers are probably not enough. For example, a significant amount of energy is needed to bring natural gas to its liquid form. In the IEA Net Zero Emission scenario, its demand is expected to drop significantly (IEA, 2021b). This does not change the fact that it can be considered as an alternative to decarbonize sectors for which direct electrification is not a feasible solution (Armaroli et al., 2022, MISM).

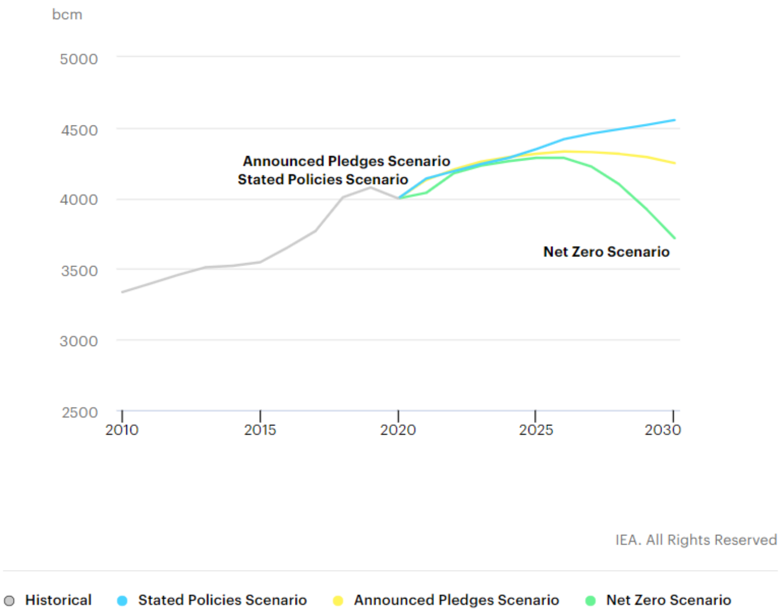


Figure 30: Natural gas demand[15] by scenario, 2010-2030 (IEA, 2021b)

Currently, a major limitation in terms of natural gas use is the dependence it entails on Russia. In fact, Russia is the EU's main natural gas supplier. In 2021 alone it accounted for 44.5 percent of EU gas imports, thus the dependence is even greater than on oil (Rivista Energia, 2022).

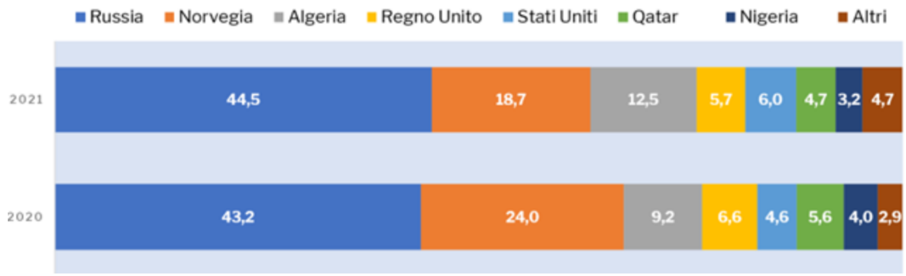


Figure 31: List of countries on which the EU depends for natural gas imports in percentage terms (Rivista Energia, 2022)

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[15] Bcm stands for billion cubic metres and it is a measure of natural gas production and trade.

3.2.5. Biofuels from dedicated crops or Generation II

Using dedicated crops, liquid fuels, including mainly bioethanol and biodiesel, can be obtained through industrial processes. These fuels can also be used pure, but they are usually mixed with their fossil analogues. There are several limitations to this solution. First of all, the net energy gain is very low, as the initial stages of the supply chain, including planting, fertilization, irrigation, harvesting, transportation and production, require high energy consumption, reducing the ability to mitigate emissions during the life cycle. Furthermore, energy efficiency is low: 1 m2 of dedicated crop produces in one year enough biofuel to power an average car for 2 km, whereas a photovoltaic panel of the same size in one year powers an electric car for 900 km. Finally, the use of land for dedicated crops can cause environmental problems such as deforestation and competition with agricultural crops (Armaroli et al., 2022, MISM).

Generation II biofuels are those derived from waste products, such as waste edible oils. For this reason, they able to cut emissions more effectively than Generation I biofuels and have less impact on food prices and land use. Therefore, these fuels have priority in cases where direct electrification is not possible. Indeed, they are particularly suitable for aviation and marine transportation (Armaroli et al., 2022, MISM). Nevertheless, in the current emergency situation of shorting petroleum products from Russia, biofuels from wastewater and municipal waste are being strongly considered as a sustainable alternative, partly due to the presence of virtuous examples in Northern Italy, which can become an example for the rest of Europe (Staffetta Quotidiana, 2022c; 2022e).

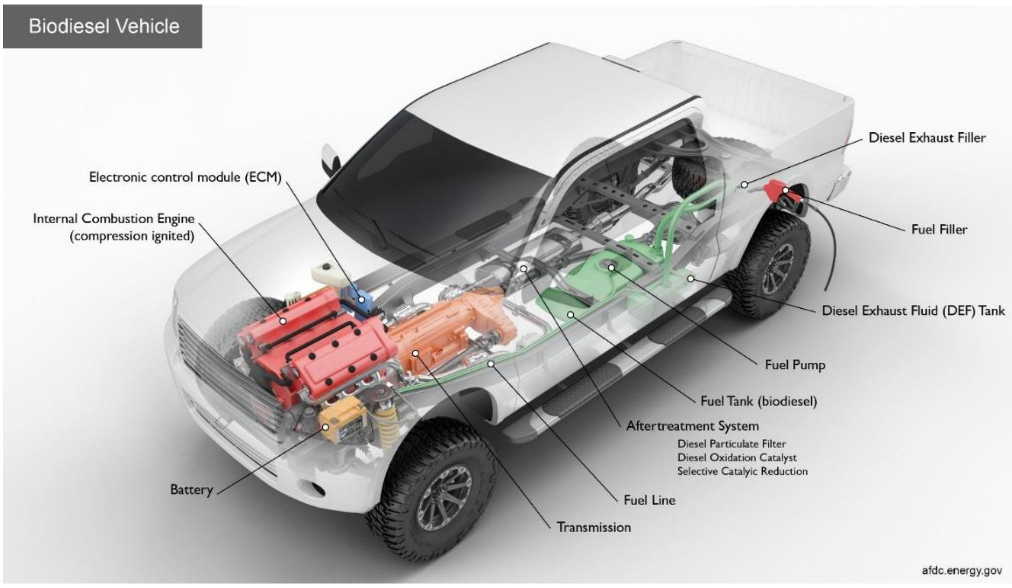
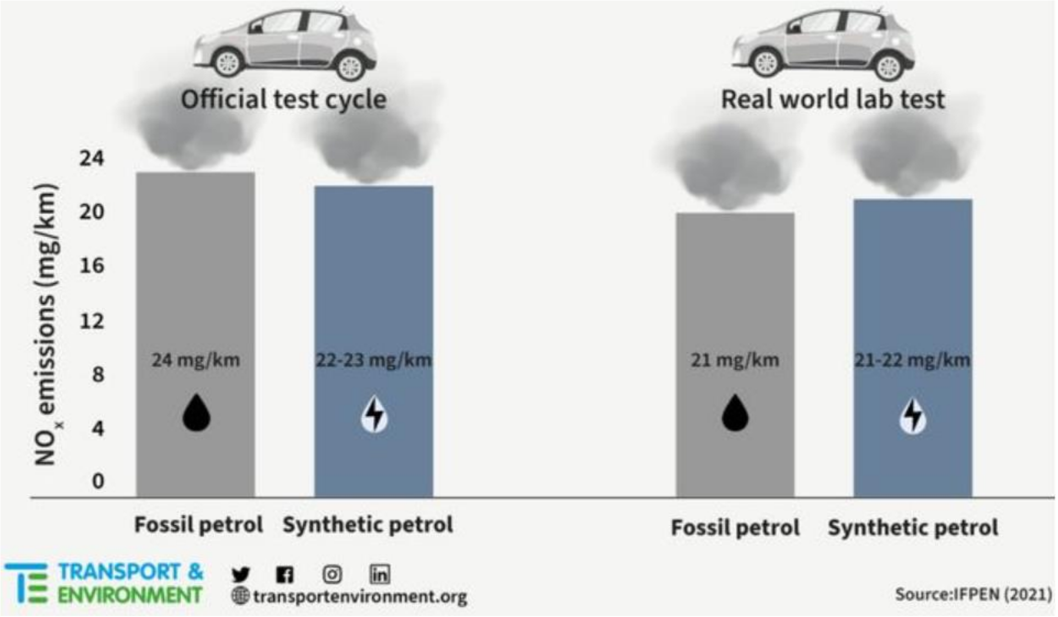


Figure 32: Biodiesel vehicle diagram (U.S. Department of Energy, n/a)

3.2.6. Synthetic Fuels

Synthetic fuels are industrially produced hydrocarbons and have the same carbon- and hydrogen-based composition as fossil fuels. Synthetic hydrocarbons originate from the intention to create carbon-neutral fuels. To achieve this, carbon is taken from atmospheric CO2 and then combined with hydrogen. They are called carbon-neutral fuels because the engines will release the same amount of CO2 into the atmosphere as they take, while the hydrogen should be generated from renewable sources. However, the Transport & Environment association noted that synthetic-fueled cars emit the same amount of NOx as fossil-fueled cars. It is also true that synthetic fuels emit 97% less particulate matter than their fossil counterparts, but at the same time they produce more carbon monoxide and ammonia (Angì, 2021).



Source:IFPEN (2021)

Figure 33: Tests compare car powered by 3 synthetic fuels to fossil petrol (Transport & Environment, 2021, quoted by Angì, 2021)

In addition, there are major barriers to the production of synthetic fuels. Therefore, it is difficult to imagine producing them on a large scale and at a low price, except in some areas such as the Middle East and North Africa that have the potential to generate low-cost renewable energy (Armaroli et al., 2022, MISM).

3.3. Sustainable & Smart Mobility

Sustainable mobility can be defined as a set of solutions which support a type of mobility that benefits the environment and people. This ideal transportation system promotes more efficient and faster travel through innovation, technology, and most importantly, citizen behavior. In order to achieve this, mobility, in addition to being sustainable, must also be Smart. Indeed, mobility infrastructure, such as parking, charging networks and vehicles, and the mobility solutions themselves must succeed in providing a flexible, efficient, integrated, clean, accessible, safe, on-demand and convenient experience for the consumer. Smart Mobility is strongly linked to the environmental aspect, as the ultimate goal is always to reduce traffic, air and noise pollution by improving the use of public land. Urban mobility must be improved to make it accessible to all by developing more resilient infrastructure that can integrate public transport, ride sharing, bike lanes, and electric cars in (Maci, 2022). In order to fully analyze this topic, it is important first to analyze the current Italian vehicle fleet, including for commercial transportation, to assess the situation now. Then, the proposals in place to make mobility sustainable and smart should be evaluated. Finally, there will be an analyzis of the smart mobility alternatives that can be implemented. Among the sustainable and smart alternatives, there are also electric cars, which, however, will be explored in a separate section, given their importance within this discussion.

3.3.1. Italian Vehicle Fleet

The Italian road fleet from the latest MISM[16] data (Armaroli et al., 2022) amounts to 52.7 million vehicles. These are divided into:

- Passenger cars, 39.8 million;
- Motorcycles, 7.2 million;
- Light commercial vehicles, 3.7 million;
- Heavy goods transportation vehicles, about 700,000;
- Buses, about 100,000;
- Motorcars, about 200,000;
- Special vehicles, about 900,000.

Of these, 99% have internal combustion engines, powered by gasoline, diesel, LPG and natural gas. Gasoline and LPG are entirely obtained by refining fossil oil, while only 5% of diesel is obtained from biofuels (Armaroli et al., 2022, MISM).

Overall, a 5,5% increase in car registrations in Italy in 2021 compared to the previous year can be observed. At the same time, there was a reduction of gasoline (-10%) and diesel (-8%) car registrations, as they respectively weigh 23% and 30% of total registrations. Instead, positive trends were recorded in terms of growth in registrations of electric cars, BEVs and PHEVs, amounting to 9.3%, and HEVs amounting to 29%. Although these cars still account for a small share of total registrations, it is evident

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[16] The Ministry of Sustainable Infrastructure and Mobility (MIMS) replaces the Ministry of Transport (MIT) in Italy from 2021. The MISM has jurisdiction over national infrastructure networks serving transport modes and over land, sea, and air transport.

that there is a shift underway, though slow, toward greener and more sustainable mobility (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES).

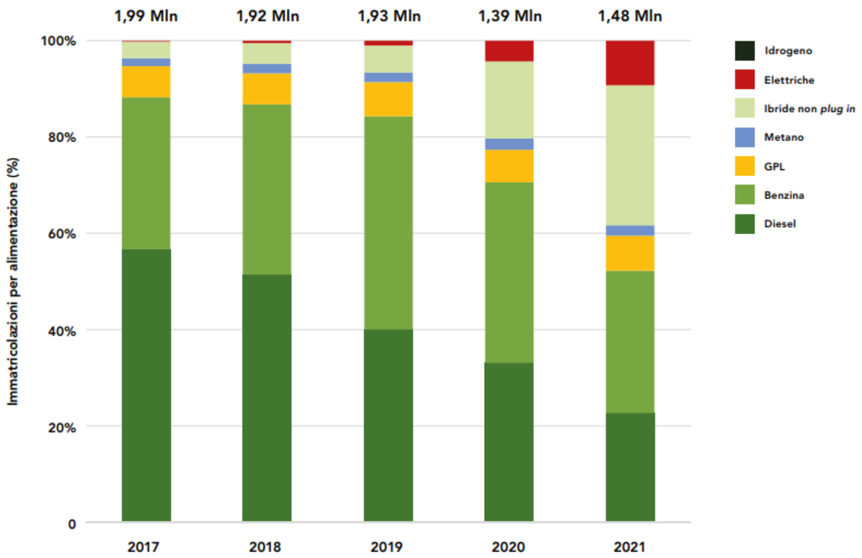

Figure 34: Registrations by power supply in Italy (Boisrond et al., 2021, ES, p. 105)

Regarding the utilization, Italy is on track with other European countries, as 75% of cars drive less than 60 km per day and 9% less than 100 km per day (Armaroli et al., 2022, MISM). This figure is useful to highlight the fact that most consumers do not use their cars intensively, leaving room for more convenient and sustainable Smart Mobility solutions.

3.3.2. Proposals for implementing Smart Mobility

In 2006, the European Council defined sustainable mobility as transport systems that correspond to the economic, social and environmental needs of society while minimizing their negative impacts on the economy and the environment. Therefore, to be sustainable, mobility must improve the quality of transportation, such as availability, frequency, speed and comfort (Accetturo et al., 2022, MISM).

The EU Green Deal is also based on sustainable mobility: the goal is to reduce greenhouse gas emissions in the transport sector by 90% by 2050. This can be accomplished by acting on several factors, including digital mobility, transport types and prices, alternative fuels, and, consequently, the decarbonization of transport. Digital mobility refers to automated mobility with intelligent traffic management systems made possible by digitization. Different types of transportation refer to the possibility of implementing multimodal transportation in a way that increases efficiency. Proposals in place include:

- The adoption of an EU Common Aviation Area to reduce emissions from the industry by up to 10%;
- The shift to rail of the majority of domestic goods transported by road nowadays.

The price of transport should reflect its impact on the environment. Therefore, according to the EU Green Deal, all fossil fuel subsidies should be ended, the maritime sector should be included in the ETS, and the share of free ETS emissions for the aviation sector should be reduced. Regarding alternative fuels, about 1 million charging stations and refueling stations for zero- or low-emission vehicles need to be installed in the EU by 2025. Thus, the decarbonization of transport sets increasingly stringent standards for both internal combustion vehicles, but also for aviation and maritime transport (Chiesa et al., 2021, ES).

In December 2020, the European Commission issued the Sustainable and Smart Mobility strategy, whose goal is to reduce emissions with a smart, competitive, safe, accessible, and affordable transport system. The milestones are divided between 2030, 2035 and 2050 (Chiesa et al., 2021, ES):

- By 2030, it is expected at least 30 million zero-emission vehicles, 100 zero-impact cities, doubled high-speed rail traffic, zero-emission collective travel under 500 km, zero-emission ships brought to market, and large-scale implementation of automated mobility;
- By 2035, large zero-emission aircraft are expected to be ready for the market;
- By 2050, nearly all cars, buses and heavy vehicles are expected to be zero-emission; doubled rail freight traffic; a developed multimodal trans-European transportation network with high-speed connectivity.

The Sustainable and Smart Mobility strategy is divided into 10 key action areas, which aim to make transport more sustainable, smart and resilient (Chiesa et al., 2021, ES):

- Making mobility multimodal, connected and automated;
- Making freight transportation greener;
- Making urban and intercity mobility sustainable;
- Make mobility accessible to all;
- Promoting zero-emission vehicles, ships, and planes, using low-emission fuels and charging infrastructure;
- Promote innovation and the use of data and AI for smart mobility;
- Create zero-emission ports and airports;
- Determine the cost of carbon and provide better incentives for consumers;
- Strengthen the market, increase safety and security for all categories of transport.

In Italy, the PNRR aims to reform mobility in order to make it environmentally sustainable and socially equitable. Sustainable mobility projects aim to (Armaroli et al., 2022, MISM):

- Strengthen the presence of local public transport by renewing, upgrading and decarbonizing the fleet;
- Reduce polluting transport in the city, using bike lanes, micro electric mobility and intermodality;
- Develop a public fast-charging network to encourage the use of electric cars;
- Favor rail instead of airplanes and cars for passenger and freight transports, also developing high-speed rail in the South.

3.3.3. Smart Mobility Solutions

Smart mobility, to be defined that way, must embrace current evolutionary trends in transport, such as electrification, use of alternative fuels, x-sharing, vehicle-grid integration, and autonomous driving. An extraordinary event such as the Covid-19 pandemic has accelerated pre-existing trends regarding mobility, while bringing new ones to life. First of all, the massive spread of smart working during lock-down is persisting despite the fact that there is no longer an emergency situation and will consequently cause a decrease in travel for working reasons. Due to the pandemic, public transport is perceived as unsafe since there is no social distancing; thus, private mobility, if possible, is preferred. For this reason, there has been a boom in urban micro-mobility and sharing as an alternative to public transport.

The trend of vehicle rental and sharing has roots that go far beyond the pandemic emergency. The trend arise from the observation that an owned vehicle is actually used for only 5-10% of its useful life, while for the majority time it remains stationary parked, often occupying land that could be used for other purposes (Chiesa et al., 2021, ES). Shifting from ownership to user, with the consequent shared use of vehicles, is already a widespread practice for freight transportation by logistics operators and it is now being attempted for passenger transportation as well (Accetturo et al., 2022, MISM). This allows greater utilization of the vehicle by using it either simultaneously or in succession. Simultaneous use is often referred to as carpooling and involves the use of a single car by a group of people who have to travel more or less the same route. In this manner, an often underutilized resource, namely empty car seats, is exploited. Carpooling would be very attractive especially for commuters, in order to save money for the commute and time to find parking, while also decreasing traffic and pollution due to the lower number of cars used (Maci, 2022). Instead, sequential use refers to the ability to rent third-party vehicles for limited times, especially in cities. Car sharing has spread widely since digitization made it possible to rent cars for hours or minutes at affordable costs. In Italy, car sharing has faced four years of continuous growth, from 2015 to 2019, only to have a slight setback in 2020 and 2021. The incidence of electric cars over the entire fleet is around 27% (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES).

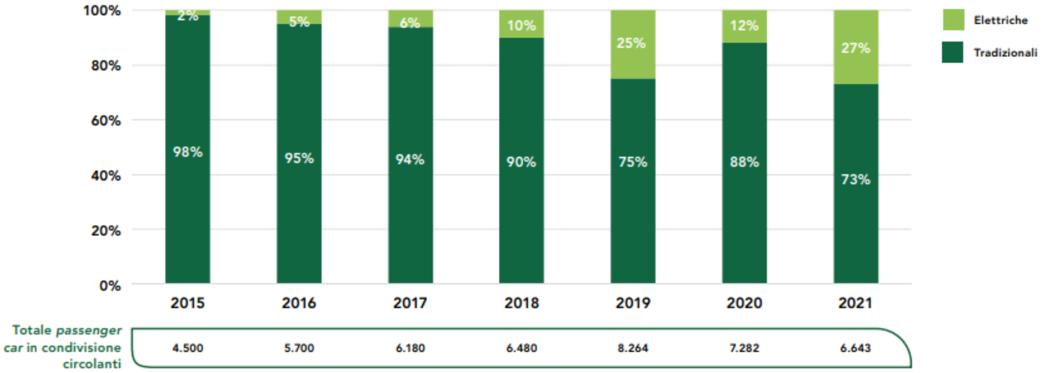

Figure 35: Car sharing fleet in Italy (Boisrond et al., 2021, ES, p. 129)

X-sharing is also very well connected with the concept of micromobility, defined as the set of means for last-mile mobility. Micromobility does not refers only to scooter sharing, but also to bicycles, electric scooters, hoverboards, skateboards, and many others. Therefore, moving around within the city becomes increasingly quiet, environmentally friendly, and agile in traffic, saving time and improving air quality (Maci, 2022). The circulating fleet of scooter sharing in Italy has grown enormously, in particular between 2019 and 2021 it increased by 19% and finally the totality of them is electric (Boisrond et al., 2022, ES).

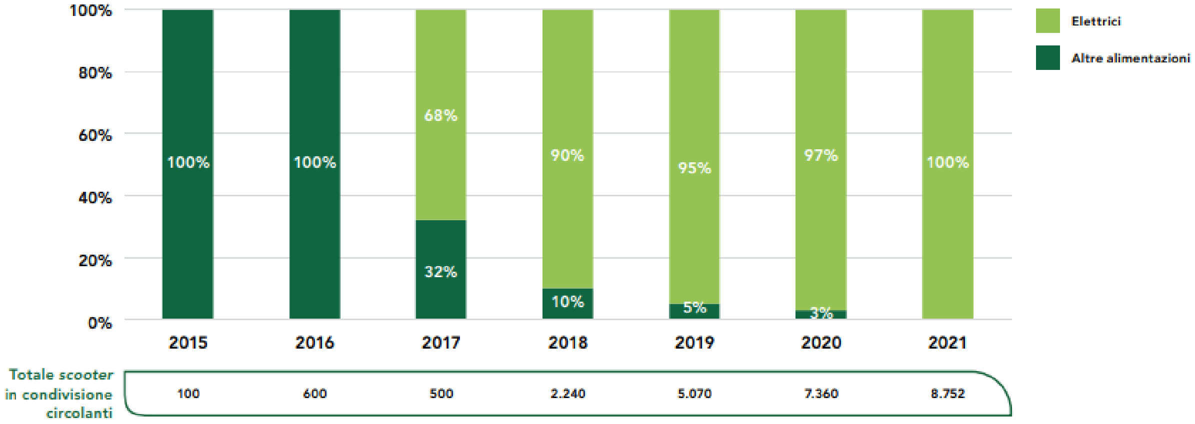

Figure 36: Scooter sharing fleet in Italy (Boisrond et al., 2022, ES, p. 130)

There were about 27.6 thousand shared bikes in Italy in 2021, decreasing by 20% compared to 2020, and about 43% of these are electric (Boisrond et al., 2022, ES). An analysis by Deloitte showed that e-bikes have become a key means of electric mobility. Especially within cities, they exhibit characteristics that lead consumers to prefer them over e-cars and e-scooters, such as usage rates and average distances traveled (Staffetta Quotidiana, 2022b).

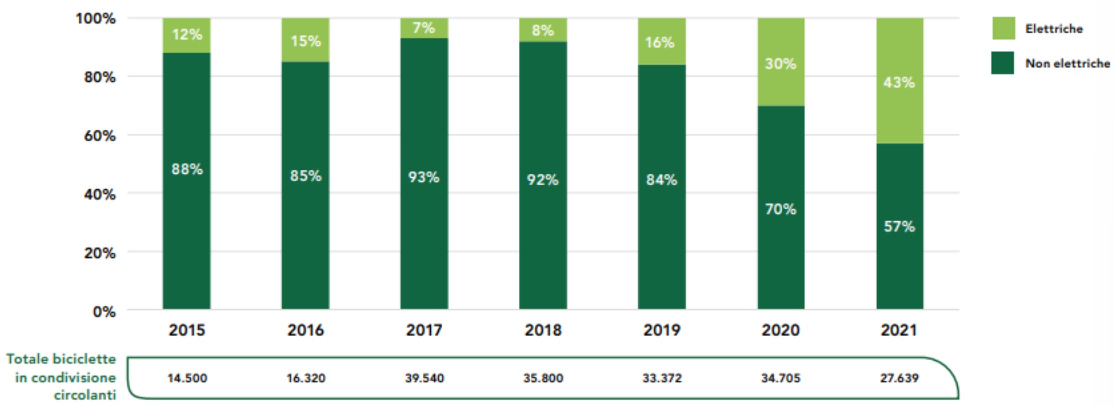

Figure 37: Bike sharing fleet in Italy (Boisrond et al., 2022, ES, p. 131)

The phenomenon of electric scooters is more recent than others, at least in Italy, as it has taken off since 2019, only to explode in 2020 thanks in part to the electric scooter bonus given by the government. In 2021 electric scooters became the most widely available means of sharing in Italy, with 64 kick-scooter sharing services in 30 Italian cities. Such astounding growth, +26% over 2021, has not been seen in any other type of sharing vehicle. This is an indication of a strong ecological turn, considering also that these vehicles are only powered by electricity (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES).

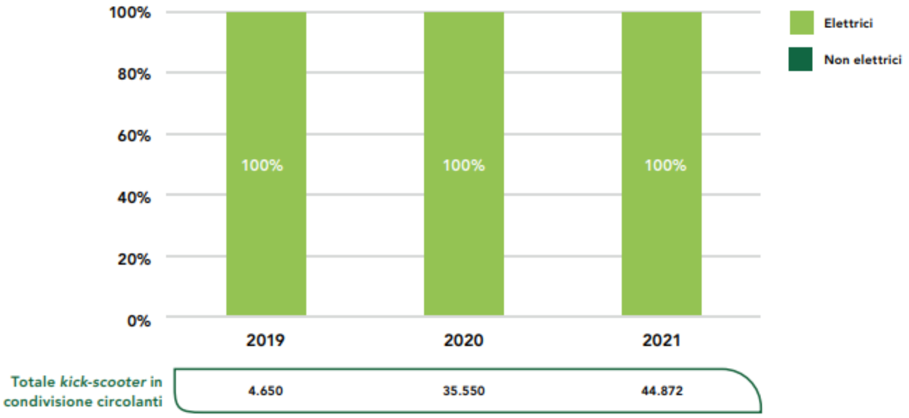

Figure 38: Kick-scooter sharing fleet in Italy (Boisrond et al., 2022, ES, p. 132)

Another example of Smart Mobility, as has already been mentioned and will be discussed further, are electric vehicles. The most interesting aspect here is not the vehicle itself, but more the concept of Vehicle-Grid Integration (VGI). VGI refers to the electric vehicle's ability to provide grid services and still arises from the fact that an owned vehicle often remains parked for more than 90 % of its useful life. During this "dead" time, the vehicle can be used as a resource. As will be explored later, VGI can be understood in two ways, either as smart charging, also known as V1G, or as vehicle-to-grid, better known as V2G. V1G involves supply with only one-way flows of energy, from the grid to the vehicle, modulated over time. Instead, in V2G, supply is managed with bi-directional flows of energy between vehicle and grid (Chiesa et al., 2021, ES).

There are also Smart Mobility trends not yet as widespread as those already mentioned, but on which high expectations are placed in the near future. These include the shift from human driving to autonomous driving using vehicles connected to each other and to the surrounding infrastructure (Accetturo et al., 2022, MISM). There are very different companies in this market: there are both tech giants such as Google, but also private transportation companies such as Uber and Lyft and automakers such as Ford and General Motors. They all aim to realize a commercial transportation service, following the business model similar to one of Uber and Lyft, but without the driver (Maci, 2022).

The concept of Smart Mobility fits very well with city life, and especially with Smart Cities. Smart Cities are cities able to keep up with innovations and digitization and to provide smart and green infrastructure and mobility solutions, in order to reduce traffic, reduce pollution levels, and create smart and continuous mobility flows, thus going on to improve the quality of life of its citizens (Maci, 2022). Smart Cities are also being characterized by the shift from analog to digital mobility through the concept of Mobility-as-a-service (MAAS). MAAS allows the integration of traditional and innovative transportation services through digitization and smart use of data (Accetturo et al., 2022, MISM). Essentially, with MAAS, the user no longer has to organize his or her own route to get around, but can rely on a multimodal service with subscription or pay-per-use (Maci, 2022). Conzade et al. (2021) argue that the implementation of smart mobility solutions can actually lead to traffic-decongested smart cities in 2030. The landscape of cities in the near future is expected to change in the following way:

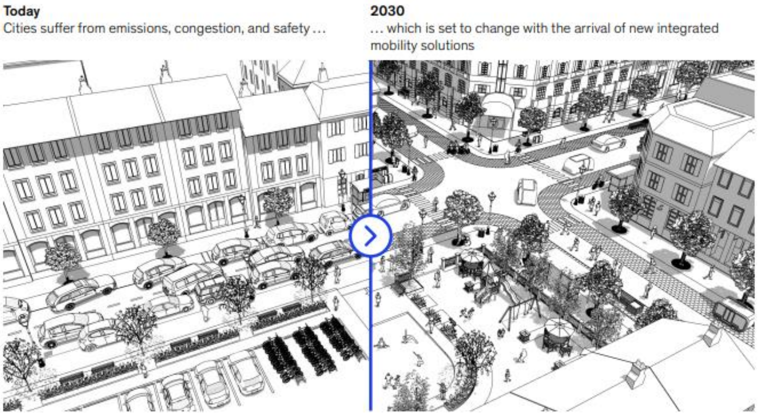

Figure 39: City landscape between today and 2030 (Conzade et al., 2021, McKinsey & Co.)

4 Electric Vehicles

This section serves to review in detail the various information gathered in the previous chapters and to introduce new information about electric vehicles. Electric vehicles represent the fastest and most cost-effective opportunity to achieve transports' decarbonization, due to several factors, including the greater inherent efficiency of propulsion, life-cycle emissions reduction capabilities, and opportunities to integrate BEVs into smart electric grids through digital technologies. This has also been realized by governments and institutions, which are pushing to facilitate the penetration and diffusion of electric vehicles. Indeed, without supportive regulations, the electric market is dominated by affluent early adopters and government fleets. These segments alone cannot aim to expand into the mobility market in a way that can decarbonize it. The first responses to regulations encouraging electric cars were seen in 2020, when sales of PHEVs and BEVs fared proportionately better than those of ICEVs (Bau et al., 2021, McKinsey & Co.).

The following chapter will therefore go into the following characteristics of electric cars:

- Emissions, since the adoption of electric cars is aimed at reducing GHG emissions, but emissions from the production of the vehicle itself and the electricity must also be considered;
- The electric supply chain, to investigate whether the electric infrastructure can fuel the demand for electricity and whether it can actually become a market tool. There will be a special focus on the Italian supply chain in terms of turnover and revenues;
- The prices and costs of EVs compared to market alternatives, as these factors are currently perceived as strongly limiting the choice of purchasing an electric car;
- The electric vehicle fleet, considering both current and future fleets under different scenarios;
- A study of battery costs and components, a key part of any BEV;

Instead, charging infrastructures and the consumer perspective will be analyzed in subsequent chapters.

4.1. Emissions from Electric Vehicles

For the transportation sector in Italy, the PNIEC has set a target for the RES share, achieved through the contribution of different types of fuels generated from renewable sources. Specifically, the renewable share of electricity in road transport covers almost

6% of the RES-transport target to 2030, which is around 22%. As a result, important increases in BEVs and PHEVs are expected in 2030 (Chiesa et al., 2021, ES).

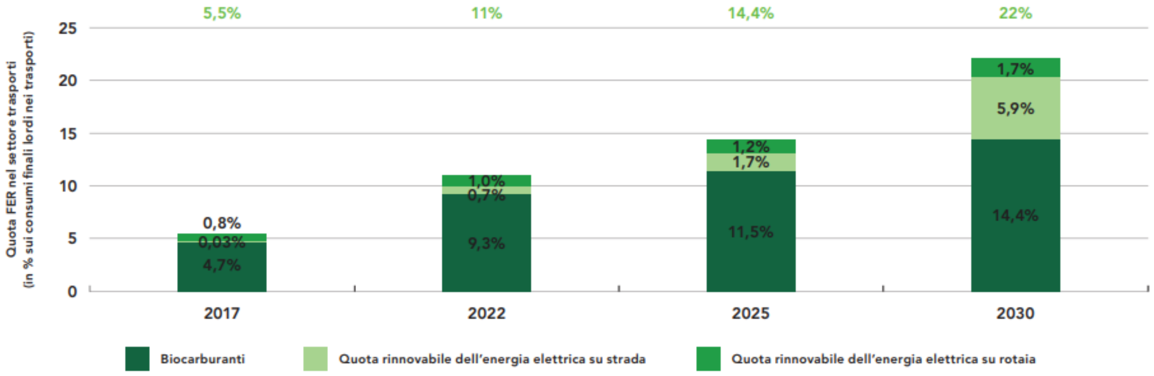

Figure 40: RES share in the Italian transport sector, as a % of gross final consumption in transportation (Chiesa et al., 2021, ES p. 61)

Therefore, the electrification of the vehicle fleet, combined with the decommissioning of polluting vehicles, has an important effect on reducing CO2 emissions. To assess the actual impacts to 2030 of the diffusion of electric cars in Italy, Energy & Strategy[17] (2021) developed three development scenarios (Chiesa et al., 2021, ES):

- Business-as-usual, which represents an inertial scenario. The scenario assumes that no additional policies are enacted to boost the sustainable mobility market. In this scenario, only a 30% reduction in CO2 emissions is expected in 2030, as no emission limits are imposed on new registrations;
- Policy-driven, a scenario in which current trends are further developed. This implies legislative support for the spread of sustainable mobility in Italy. In this scenario, following the targets set by the PNIEC, a 35% CO2 reduction could be achieved in 2030, but by imposing emission limits on vehicle manufacturers this reduction could be as high as 40%;
- Full-Decarbonization, a scenario that pursues challenging decarbonization goals supported by legislation entirely aimed at the deployment of sustainable mobility. If legislation were to impose emission limits, the reduction in CO2 emissions in this case would be as high as 42% in 2030.

In all these scenarios, a massive replacement of ICE vehicles with BEVs is assumed in order to make the green transition and consequently decarbonize transportation, reducing emissions. However, it should be pointed out that to date, BEVs do not allow these emissions to be completely zeroed out. In order to effectively assess the GHG

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[17] Energy & Strategy is a multi-disciplinary team of the School of Management of the Politecnico di Milano, whose goal is to establish a permanent Observatory on markets and industrial chains pertaining to different sectors, including renewable energy, energy efficiency and Smart mobility.

emissions of a BEV, a Life-Cycle Assessment must be conducted, "from cradle to grave," as Armaroli et al. (2022) suggest. With this modality, all effects of a vehicle's production are taken into account, starting from the extraction of materials to the end of its useful life. By conducting a Life-Cycle Assessment on the emissions of endothermic and battery-powered vehicles in Italy, MISM obtained the following results (Armaroli et al., 2022, MISM):

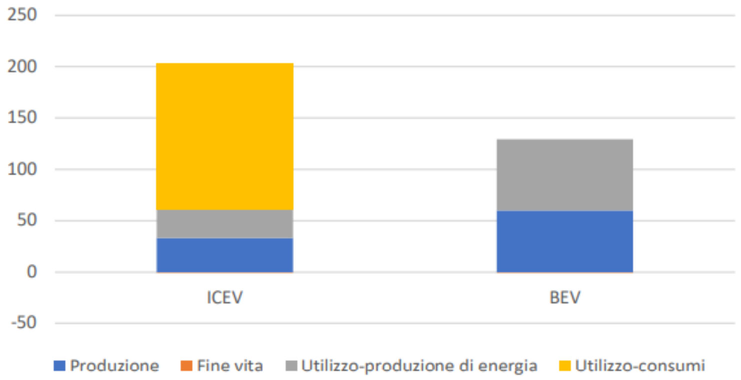

Figure 41: Life cycle emissions of ICEVs and BEVs, measured in grCO2/km (Armaroli et al., 2022, MISM, p. 61)

In general, electric vehicles allow for a 37% reduction in emissions, thanks to the zeroing of emissions caused by their use in terms of fuel consumption. However, immediately it can be seen that a BEV produces almost twice as many emissions, about 60 grCO2-eq/km, during its production than an ICEV, which are around 33 grCO2-eq/km (Armaroli et al., 2022, MISM). Indeed, metals, such as aluminum, and other resources are used especially in the construction of batteries, which have high environmental impacts.

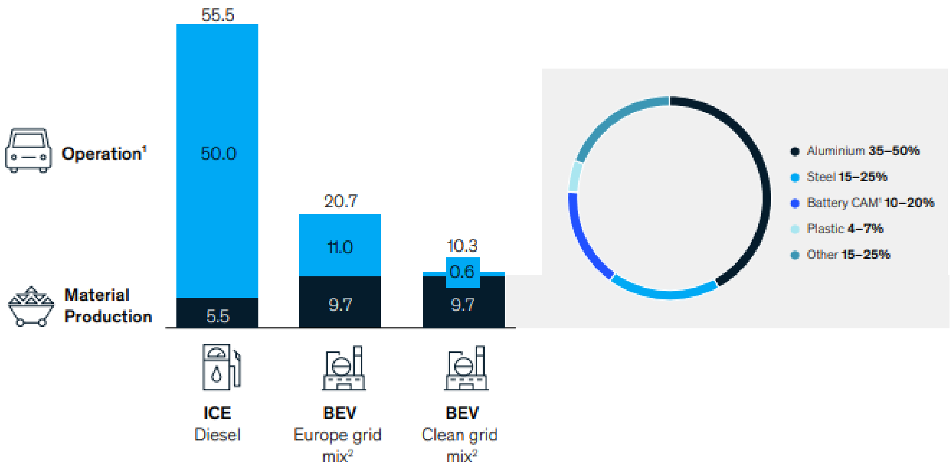

Figure 42: CO2-eq emission over lifecycle mileage of a lower-medium segment passenger car and the proportion of polluting materials (Conzade et al., 2021, McKinsey & Co., p. 15)

There are two ways of trying to reduce material emissions (Conzade et al., 2021, McKinsey & Co.):

- Replace virgin materials with recycled alternatives. This can save most of the emissions from raw material generation. Indeed, replacing 30 percent of virgin raw materials with recycled materials can reduce production emissions by 15 to 25%. However, there are some limitations to this solution. First of all, the end-of-life collection is still underdeveloped and of poor quality for the automotive sector. Moreover, other industries have also decided to use recycled materials to achieve decarbonization goals. As a result, significant supply bottlenecks have been created, causing prices of recycled materials to rise;
- Use green raw materials, i.e., produced by processes with low or no carbon emissions. This solution seems more feasible in 2030, as about 80-90% of emissions from materials production are expected to be eliminated through new production technologies.

Combining these methodologies could reduce the production emissions of BEVs between 10 and 30% by 2030. On the other hand, decarbonization of the production process necessarily implies an increase in vehicle costs, whereas currently the goal is precisely to reduce the prices of BEVs to stimulate consumer interest (Conzade et al., 2021, McKinsey & Co.).

Emissions from power generation also weigh heavily in the Life-Cycle Assessment of a BEV. However, CO2 savings under this heading are expected to gradually increase due to the decarbonization of electricity, with the prospect of being half of an ICE vehicle in 2030 (Armaroli et al., 2022, MISM). Thus, on one hand it is true that possible future designs of electric cars could cause an increase in GHG emissions, as battery enlargement is expected, but on the other hand the more the energy system is decarbonized, the emissions from BEVs overall decrease (Bibra et al., 2022, IEA).

MISM also noted how there are actually quite similar CO2 reduction results with both BEVs and FCEVs, as long as the hydrogen is produced with low emissions. Actually, the two types of vehicles experience different levels of energy efficiency, as hydrogen needs more primary energy to provide the same end service as electric cars (Armaroli et al., 2022, MISM).

4.2. Electric Supply Chain

4.2.1. General Considerations

As it has been evident from the previous chapters, the discussion is aimed at the in-depth analysis of sustainable mobility, particularly electric mobility. Consequently, it is appropriate to analyze how the electric system can support the energy transition. The first important clarification is that current electricity demand for electric vehicles is a small part of overall electricity consumption. Although the electric vehicle fleet is expected to grow rapidly, different scenarios claim that by 2030 electricity demand for electric vehicles will account for about 2% of global consumption. However, this should not underestimate the implications that electric vehicles will have on peak demand and transmission and distribution capacity. To effectively and efficiently manage the demand from these vehicles, smart charging systems must be used and slow charging encouraged.

First of all, speaking of mass adoption of electric vehicles, the main concern for those in charge of electric infrastructure relates to the charging of the vehicles themselves. Indeed, the question is whether power systems can actually handle the increased demand for electricity due to the spread of more electric vehicles. Electric system operators must be able to balance supply and demand on the grid at all times. To accomplish this, they need sufficient energy resources to generate or store ample grid capacity. The two factors that need most attention are bulk energy and network capacity. Regarding bulk energy, sufficient energy resources are needed to meet the increased load of EVs. To date, in the leading EV deployment economies, such as Europe, China and the United States, EVs account for less than 5% of total electricity consumption in the Announced Pledges Scenario by IEA in 2030 (Bibra et al., 2022, IEA). Instead, in terms of network capacity, properly sized and equipped transmission and distribution networks are needed. The relationship between electric vehicle deployment and the need for upgrading is often complex. Indeed, a distribution system may have high levels of electricity demand, but some lines may be sized for reduced capacity due to low loads and low expected load growth, such as in rural versus urban areas. In addition, grid upgrades are expensive, thus maximizing their use during the day is often cheaper than upgrading facilities only to handle short peak periods. It must also be taken into account that it is not only vehicle charging that is increasing the pressure on power grids. The process of electrification of consumption is increasingly widespread and also affects heating, air conditioning, the high range of plug-in devices, and so forth. In addition to managing rising demand, energy system operators must balance an increasing proportion of variable renewable sources in the bulk energy supply and at distribution level.

Current networks should be able to handle the additional demand in major markets by 2030. Indeed, network simulations show that until electric vehicles reach about 20% of the entire vehicle fleet, the upgrade requirements are rather scarce and focus on transformers in order to handle voltage control. Therefore, there is a need to move from passive to active transformers that can control voltage levels on the low-voltage side, so-called smart transformers. Rural areas usually have weaker grids and consequently may be the first to require upgrades. According to the simulations, line upgrades, which are the most complex and costly operations, are likely to remain limited to less than 2% of total line assets even with a 40% EV [18]share. There are three

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[18] EV stands for electric vehicle

reasons why network upgrade needs are relatively low for moderate levels of EV penetration (Bibra et al., 2022, IEA):

- The load of a single EV is usually higher than typical household loads, but when multiple EVs are present in a system, not all their loads match. When enough users are considered, the actual maximum load is only a fraction of the maximum possible load;
- By 2030, current distribution networks will need to keep expanding in order to serve additional loads from the installation of solar PV systems and the electrification of heating;
- In most industrialized countries, distribution networks have historically been overdesigned, and many retain significant spare capacity.

The most significant investments in upgrading the network are needed to enable fast highway charging for electric cars and trucks. Indeed, while existing networks can handle the increase of electric vehicles in urban and rural areas until 2030, highway charging still presents challenges. If the highway in question is not located in areas with existing networks, there is no problem in installing charging stations, as long as the network is not already congested. Instead, for charging vehicles in remote locations, network upgrade costs are an obstacle. To charge heavy-duty vehicles, operators are considering installing chargers of up to 4.5 MW, more than ten times faster than those currently installed for Ligh-Duty ones. However, to charge multiple trucks at the same time, a connection capacity of more than 10 MW to a high-voltage grid is needed, with significantly higher costs. On the other hand, technological progress, especially with regard to fast charging of light commercial vehicles, has already made it possible to largely reduce costs; consequently, the same result is hoped for electric trucks. Instead, with regard to power lines, cost reduction is unlikely as these are mature technologies. Alternative solutions can be used to alleviate costs, such as the installation of batteries or the inclusion of distributed renewable capacity in charging stations (Bibra et al., 2022, IEA).

4.2.2. Italian Supply Chain

Regarding the Italian electricity sector, the RSE[19] has planned infrastructure investments to be able to meet the Fit for 55 goals (Armaroli et al., 2022, MISM):

- Cumulative investments for renewables, as solar and wind need €85 billion versus €25 billion projected without the Fit for 55 legislation;

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[19] Ricerca sul Sistema Energetico – RSE SpA is a joint-stock company of the GSE SpA Group, which develops research activities in the electro-energy sector, with reference to national strategic projects of general public interest financed with the Electricity System Research Fund.

- Strengthening of the transmission and distribution network, with investments up to 2030 of €37 billion compared to €22 billion in the base case;
- Diffusion of charging infrastructure, requiring €3 billion of investment by 2030.

However, it must also be taken into account that the reduction in fossil fuel consumption resulting from the increase in renewables will allow repositioning the considerable economic resources that are now being paid abroad for the import of gas, oil and coal. In recent years this expenditure has been around 40 billion euros, but at current prices the expenditure could more than double (Armaroli et al., 2022, MISM).

The electric car supply chain in Italy is divided into four stages: manufacturing, distribution and sale, utilization and after-sale, recycling and second life. The supply chain in 2020 generated a turnover of about 1 billion euros, with an EBITDA of 200 million euros. The manufacturing phase is the one that weighs most heavily on turnover, with vehicle manufacturing activities alone generating between 125 and 310 million euros in turnover, while the manufacture of parts and accessories for motor vehicles and their engines generates between 245 and 260 million euros in turnover. The second most profitable stage is the distribution and sales stage, where the business of trading in passenger cars and light motor vehicles generates between 295 and 330 million euros in turnover. Next, there is the utilization and after-sale phase, which through car and light vehicle rental activities cubes a turnover between 310 and 330 million euros. Finally, the turnover from recycling and second life is neglectable. From 2018 to 2020 there has been significant growth in economics, an indication that the Italian supply chain is facing a prosperous period, with an average annual turnover increase of 67.5% (Chiesa et al., 2021, ES).

Instead, regarding the supply chain for electric vehicle charging infrastructure in Italy, there are currently only two stages: manufacturing, distribution and sales. In 2020, the supply chain generated a total of €0.22-0.34 billion in sales, with an EBITDA of €24 - 37 million. The companies that helped generate these results are very heterogeneous among themselves, but can be divided into three categories (Chiesa et al., 2021, ES):

- Generalist companies, for which the share of turnover related to electric mobility and charging infrastructure does not reach 5%, of total one;
- Diversified companies, for which the share of turnover is between 15% and 35% of total one;
- Specialist companies, for which the share of turnover is between 70% and 100% of total one.

In terms of total turnover, Generalist companies prevail, accounting for about 40% - 45% of total turnover. This is followed by Diversified companies (about 30%) and Specialists (with 25% - 30%). For all categories, there was a growth trend of 2.2% in

EBITDA Margin[20] between 2018 and 2020, but with a slight decrease of 0.4% in EBIT Margin[21] over the same time frame (Chiesa et al., 2021, ES).

4.3. Price and Costs of Electric Vehicles

4.3.1. Acquisition Price

One of the factors currently severely limiting the transition to electric is the purchase price of cars. Indeed, for a mid-size BEV, without incentives, the price compared to an equivalent diesel or hybrid ICEV is 30% higher, up to 50% higher for a gasoline ICEV. These price differences change considerably according to vehicle size and are more pronounced for small cars, in which the cost of batteries has a large impact. Instead, for luxury cars, the price differential is very small, if not almost completely zero (Armaroli et al., 2022, MISM). Energy & Strategy in 2022 analyzed the supply of pure electric BEV cars in Italy, particularly the price per segment. The results confirm the data reported above. Electric cars are fairly distributed among the various segments, but with some polarization on intermediate segments B and C, for which they together cover 50% of the total supply. The price remains more or less unchanged, with slight variations in the range of 3 to 4% points (Chiesa et al., 2021, ES; Boisrond et al., 2022, ES).

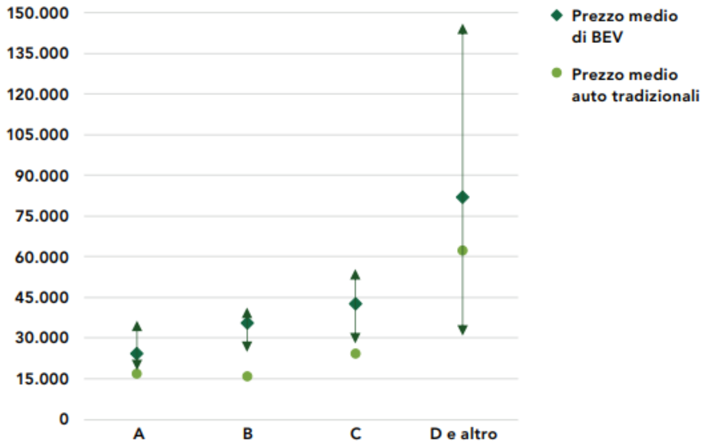

Figure 43: Minimum, average and maximum price [€] by segment of BEVs, with comparison to ICEVs average price, 2020 (Boisrond et al., 2022, ES, p. 178)

Therefore, BEVs are for many consumers out of their reach. A survey conducted in Italy by the consulting firm Areté showed that 56% of respondents are unwilling to pay an average of more than €30,000 for an electric car. Thus, the gap between the

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[20] $EBITDA\ Margin = \frac{EBITDA}{Revenues}$

[21] $EBIT\ Margin = \frac{EBIT}{Revenues}$

current market price and consumers' willingness to spend absolutely must be bridged somehow, and as of today the most immediate solution is incentives (Staffetta Quotidiana, 2022a). The limiting action of car prices is very clear when comparing the market share of electric car registrations and GDP per capita in different European countries in 2020, as a significant correlation emerges (Chiesa et al., 2021, ES):

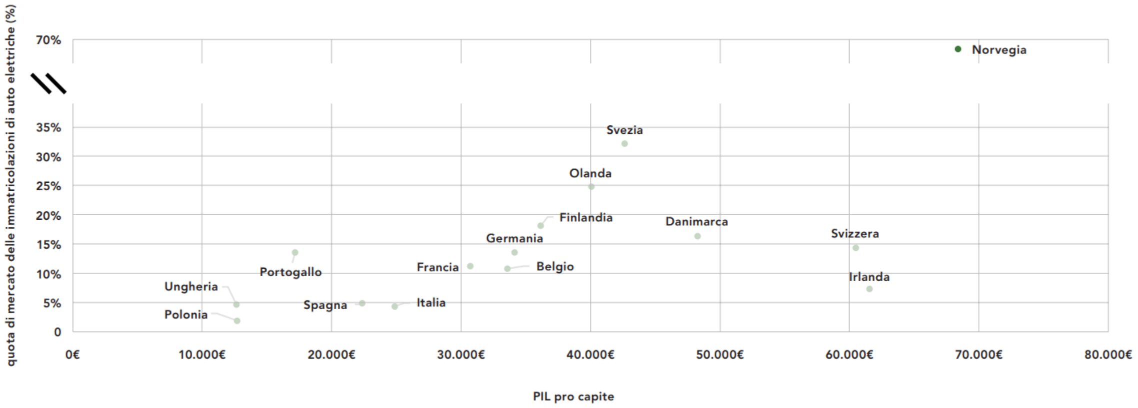


Figure 44: Relationship between GDP per capita and BEVs market share in European countries, 2020 (Chiesa et al., 2021, ES, p. 102)

4.3.2. Total Cost of Ownership

In order to assess the true cost of an electric car, it is not correct to consider only the purchase price, but the Total Cost of Ownership per km driven, which allows to evaluate the overall cost involved in owning and using a car throughout its useful life. Indeed, consumers who buy a BEV at acceptable prices thanks to incentives are concerned that they will subsequently have higher costs than a gasoline or diesel vehicle. This concern is not always well-founded, as the costs of a BEV depend on various factors, including the aforementioned vehicle size, usage profile, and the emission intensity of the national electric system. To account for all these aspects, the Total Cost of Ownership includes both the purchase cost, called CAPEX, and the usage cost, called OPEX, of the cars, as well as any subsidies and incentives. Consequently, Total Cost of Ownership also depends on energy costs, especially in differential terms between the costs of petroleum products, electricity and hydrogen. MISM attempted to estimate the Total Cost of Ownership for different types of private cars under two different energy price scenarios (Armaroli et al., 2022, MISM):

- Energy prices in line with historical values: 1.6 €/l gasoline, 0.21 €/kWh domestic electricity, 0.4 €/kWh public charging, and an optimistic assumption of 5 €/kg hydrogen;
- Prices updated to recent shocks: 2 €/l gasoline, 0.25 €/kWh domestic electricity, 0.8 €/kWh public charging, 13 €/kg hydrogen.

MISM also assumed 15,000 km/year, a car life of 10 years, no incentives, and a uniform depreciation rate for all engine types. The results show that the Total Cost of Ownership in the segments considered for BEVs and ICEVs are comparable under both energy price scenarios. For BEVs with an average battery size of 58 kWh and charging over 80% domestically, the Total Cost of Ownership is competitive with that of conventional vehicles. It is clear, as was already anticipated, that the charging mode and battery size strongly influence the price. However, in general, electric vehicles can be considered much more competitive than FCEVs, which cost on average 60 to 80% more than internal combustion cars (Armaroli et al., 2022, MISM).

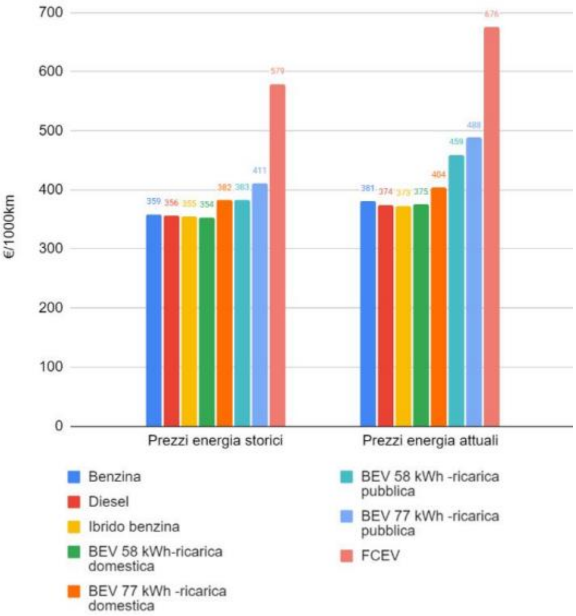


Figure 45: Total Cost of Ownership of Passenger Vehicles, 2020 (Armaroli et al., 2022, MISM, p. 59)

To summarize, to date, the Total Cost of Ownership for BEVs with intensive use profiles is lower than the corresponding ICEVs, as long as electricity prices and the differential with fuel prices are not subject to increases beyond the conditions that have characterized them in the past. Clearly, in an energy emergency situation, these considerations will have to be further reevaluated. Instead, in the presence of incentives the gap closes even for BEVs with usage profiles comparable with European averages. Beyond that, prices for BEVs may fall further by 2030 due to improvements in battery design and manufacturing process. Indeed, batteries themselves have demonstrated extraordinary cost performance. Over the past 10 years, battery production costs have decreased by 80%, surpassing even the modeling predictions of experts. This is especially exceptional when taking into account the rising prices of raw materials needed to manufacture batteries (Armaroli et al., 2022, MISM).

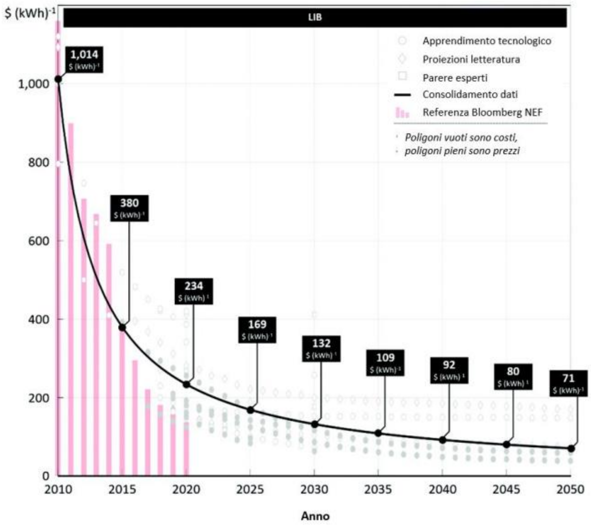


Figure 46: Historical evolution of battery cost, in pink, and forecasts based on expert studies, in gray and black (Mauler et al., 2021, quoted by Armaroli et al., 2022, MISM, p. 66)

4.3.3. Incentives

Since the Total Cost of Ownership is almost comparable, the initial purchase price may be a limit for many consumers. As a result, European governments have decided to provide incentives, in order to help the effective diffusion of electric cars. In addition to Italy, the major EU member countries are analyzed below.

In France, regions provide 100 or 50% exemption from registration fees for electric cars and electrified hybrids, CNG, LPG and E85 alimented vehicles. There is a 6,000 euro rebate for cars and vans with less than 20 g CO2/km and price below 45,000 euros, or 1,000 euros with emissions between 21 and 50 g CO2/km and price below 50,000. The bonus drops to 5,000 euros when the old vehicle is scrapped and a new or second-hand vehicle is bought (Ciriaco, 2022). There is also a malus related to the purchase of polluting vehicles: the minimum is 50€ for vehicles with emissions of 133 gCO2/km, but increases exponentially as emissions increase, peaking at 30,000€ for vehicles emitting 219 gCO2/km and above (Chiesa et al., 2021, ES).

In Germany, there is a 10-year exemption, capped at 2030, from property taxes on pure electrics and fuel cells registered by December 31, 2025. Also excluded is the road tax for vehicles with less than 95 g CO2/km (Ciriaco, 2022). There is also a €5,000 bonus for used BEV and FCEV cars, while for used PHEVs the bonus is €3,750 (Chiesa et al., 2021, ES).

In Spain, there are some incentives such as exemption on registration taxes for vehicles with less than 120 g CO2/km and 75% reduction in property taxes on BEVs in major cities, such as Madrid, Barcelona, Valencia, and Zaragoza. In addition, for electric and hydrogen cars, there is also an incentive of 4,500 euros without scrapping and 7,000 euros with scrapping; while for plug-in hybrid cars, there is an incentive of 2,500 euros without scrapping and 5,000 euros with scrapping (Ciriaco, 2022).

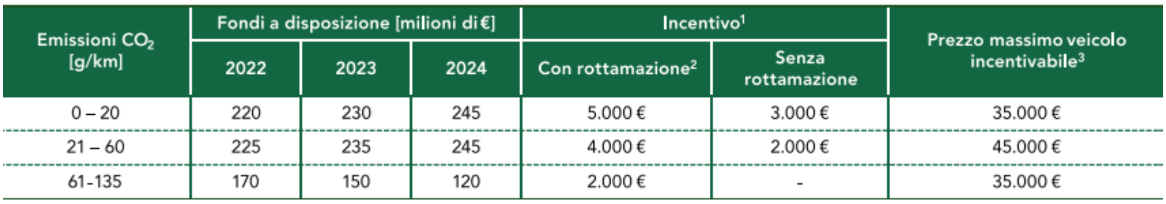
Having analyzed incentives in other major EU countries, the focus of the discussion turns to Italy. In particular, through the Legge di Bilancio (Budget Law) 2019, the Ministry of Economic Development introduced an Ecobonus. The Ecobonus consists of giving grants for the purchase of reduced-emission vehicles. The resources available in the three-year period 2019-2021 for financing the Ecobonus are €60m in 2019, €262m in 2020, and €283m in 2021. The amount of bonus received for the registration of a new vehicle depends on CO2 emissions and whether or not there is a vehicle to be scrapped. To qualify for the incentive, the emissions of the vehicle to be registered must not exceed 60 g/km and the list price of the vehicle must be less than €50,000, excluding VAT (Chiesa et al., 2021, ES).

Furthermore, in 2020, the Decreto Rilancio, in English Relaunch Decree, was issued for registrations occurring between August 1 and December 31, 2020. The Decree provided an incentive that could be combined with those under the Ecobonus and was accessible if the seller applied a discount of at least €2,000 for purchases with scrapping and €1,000 for purchases without scrapping (Chiesa et al., 2021, ES).

In 2021, the Legge di Bilancio 2021 provided an additional bonus for purchases and subsequent registration from January 1 to December 31, 2021. This bonus is also combinable with Ecobonus resources and is also subject to the seller's rebate of €2,000 if the purchase is with scrapping and €1,000 if the purchase is without scrapping. To qualify for the incentive, the list price of the vehicle must be no more than €50,000 (excluding VAT) for the 0-60 gCO2/km emission range and no more than €40,000 (excluding VAT) for the 61-135 gCO2/km range. Finally, from August 2021, through the law converting the Decreto sostegni bis, there was an additional €350 million in funding for incentives for low-emission vehicles, of which (Chiesa et al., 2021, ES):

- 200 million is for the purchase, exclusively with scrapping, of vehicles with emissions between 61-135 gCO2/km;
- 60 million, called extrabonuses, are for vehicles with emissions between 0-60 gCO2/km;
- 50 million is reserved for commercial and special vehicles, of which 15 million is for electric vehicles only;
- 40 million has been allocated for the purchase of used cars of class not less than EURO 6 and with emissions up to 160 gCO2/km.

Under Decreto Legge 17/2022, the Ecobonus was reshaped to incentivize the reconversion of the automotive industrial supply chain, with a fund of 700 million euros for 2022 and 1 billion euros per year from 2023 to 2030 (Boisrond et al., 2022, ES).



Emissioni CO_2 [g/km]	Fondi a disposizione [milioni di €]			Incentivo[1]		Prezzo massimo veicolo incentivabile[3]
	2022	2023	2024	Con rottamazione[2]	Senza rottamazione	
0 – 20	220	230	245	5.000 €	3.000 €	35.000 €
21 – 60	225	235	245	4.000 €	2.000 €	45.000 €
61-135	170	150	120	2.000 €	-	35.000 €

Table 1: Amount of Ecobonus based on CO2 emissions and whether or not there is a vehicle to be scrapped (Boisrond et al., 2022, ES, p. 242)

Moreover, in all regions of Italy, BEVs are exempt from paying road tax for 5 years from first registration. At the end of this period, the tax is still reduced, amounting to about a quarter of the amount for gasoline cars. However, there are regions for which this exemption period is longer, such as Campania and Valle D'Aosta where the periods are 7 and 8 years respectively, and regions where the exemption is permanent, such as Lombardy and Piedmont. There may also be local incentives that are responsibility of municipalities, such as free parking on blue lines and free access to restricted traffic zones. In the chart below, Italian regions are scored according to the facilities available for BEVs, from which a heterogeneous picture emerges across regions, with a significant north-south disparity (Chiesa et al., 2021, ES):

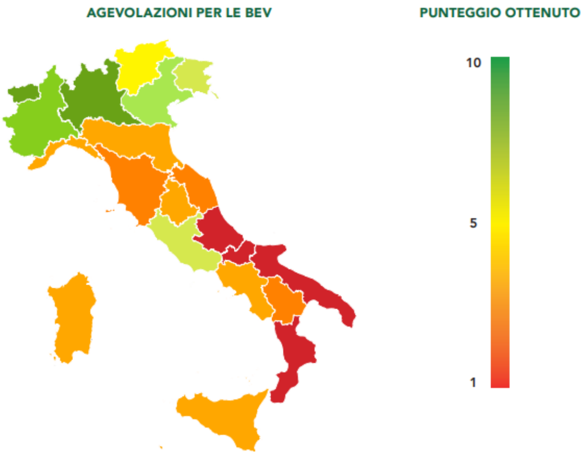


Figure 47: Measures to support BEVs in Italy (Chiesa et al., 2021, ES, p. 270)

4.4. Electric Vehicle Fleet

This section is meant to analyze the world's electric vehicle fleet, and then explore the situation within the European Union, with a particular focus on the Italian market.

4.4.1. Global Electric Vehicle Fleet

Globally, IEA claims that EVs in the short term will capture a major share of sales, with obviously different speeds depending on development scenarios (Bibra et al., 2022, IEA):

- In the Stated Policies Scenario, the global stock of electric vehicles in all road transport modes expands from about 18 million in 2021 to 200 million by 2030, with an average annual growth of more than 30%. Two- and three-wheeled vehicles are excluded in this context. As a result, electric vehicles account for about 10% of the circulating fleet in 2030. In 2030 alone, a total sale of 30 million electric vehicles is projected, representing more than 20% of all road vehicle sales that year;

- In the Announced Pladges Scenario, the global stock of electric vehicles reaches 270 million vehicles in 2030, again excluding two/three-wheelers. The share of electric vehicles in the vehicle fleet reaches 14% in 2030. Electric vehicle sales in this scenario reach over 45 million vehicles in 2030, with a market share of 33%;
- In the Net Zero Scenario, the global EV fleet stands at 350 million vehicles in 2030, not counting two- and three-wheelers. Therefore, these constitute 20% of the total circulating fleet in 2030. In 2030 alone, EV sales will reach more than 65 million vehicles, with a market share of nearly 60%. Comparing these numbers with those of the Announced Pledges Scenario, it is clear that the government's current commitments are not sufficient to achieve net zero emissions by 2050.

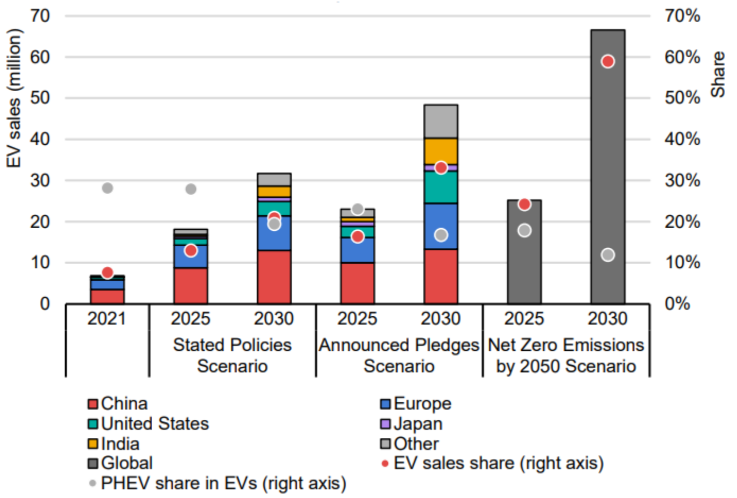


Figure 48: Global EV sales by scenario, 2021 – 2030 (Bibra et al., 2022, IEA, p. 99)

The deployment of EVs will consequently be paralleled by an increase in global electricity demand, which differs according to the scenarios. Electricity demand in the Announced Pledges Scenario is about 50% higher than in the Stated Policies Scenario, despite the fact that the EV fleet is only 35% higher. This is due to the fact that in the Announced Pledges Scenario there is an acceleration of electrification in countries with high average mileage, such as the United States. Furthermore, in this scenario there is a higher share of BEVs in total EVs, but even for PHEVs it is assumed that most of the energy consumed comes from electricity instead of diesel and gasoline (Bibra et al., 2022, IEA). Instead, for the Net Zero Scenario, the share of electricity in transportation reaches 45% in 2050, as the global car fleet is almost completely electrified, while the rest instead use decarbonized vectors, such as hydrogen (Bouckaert et al., 2021, IEA).

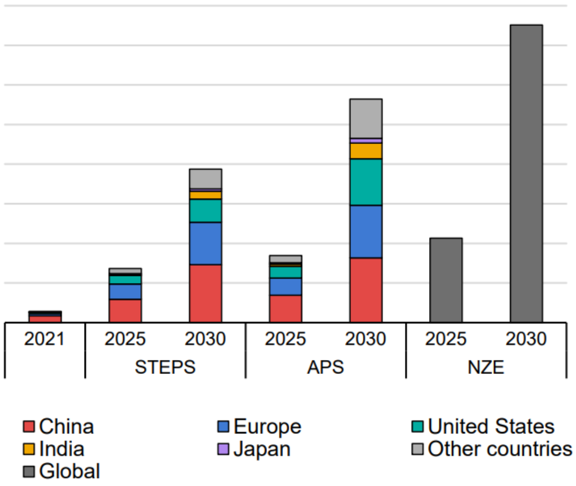


Figure 49: Electricity demand by country/region from the global EV fleet by scenario, 2021-2030 (Bibra et al., 2022, IEA, p. 112)

Therefore, vehicle electrification plays a key role in decarbonizing road vehicles and thus achieving Net Zero Emissions by 2050. Nearly 6.75 million electric passenger cars and Light Duty Vehicles were registered globally in 2021, a growth rate of 108% over the previous year. Electric vehicles weigh in at 8.3% of total passenger car and Light Duty Vehicle registrations globally in 2021, up sharply (+4.1%) from 2020 (Boisrond et al., 2022, ES). Looking forward, light duty vehicles are being electrified faster than advanced economies in the medium term, accounting for 75% of sales by 2030, while in emerging and developing economies only 50% (Bouckaert et al., 2021, IEA).

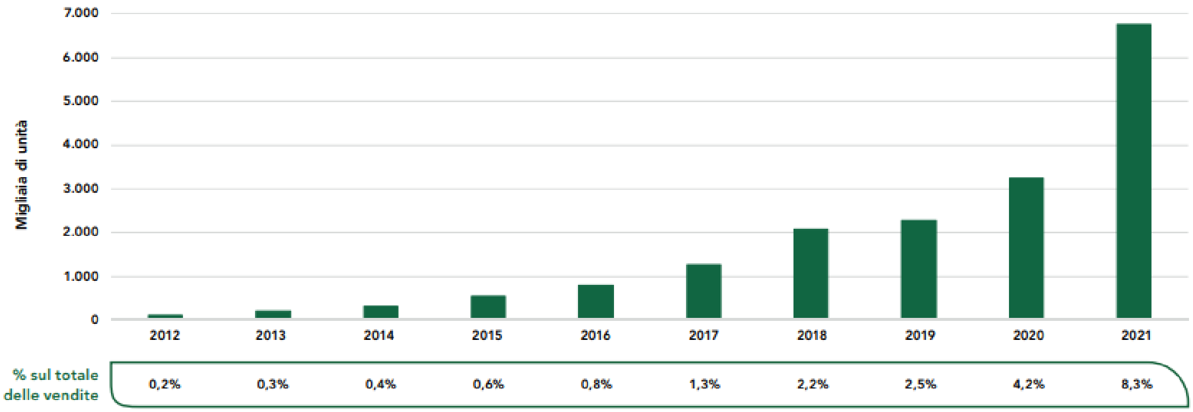


Figure 50: Global registrations of EVs, 2012-2021 (Boisrond et al., 2022, ES, p. 82)

While the electrification of cars, and Light-Duty-Vehicles (LDVs) in general, is expected to follow a fast and linear path, the electrification of trucks will certainly be slower. Indeed, trucks need heavy and higher-density batteries than those currently available on the market, especially for long-haul transportation, and high-power charging infrastructure. For this reason, electric trucks even in the Net Zero Scenario account for only 25% of total global heavy truck sales by 2030 and about two-thirds by 2050 (Bouckaert et al., 2021, IEA).

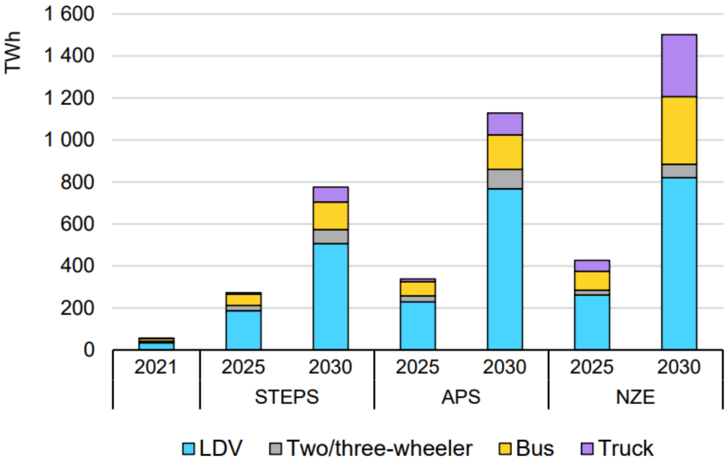


Figure 51: Electricity demand by mode from the global EV fleet by scenario, 2021-2030 (Bibra et al., 2022, IEA, p. 112)

4.4.2. European Electric Vehicle Fleet

The electrification of road transport is accelerating in major areas of the world, but at different speeds. As was explained extensively in section 1.1., the European Union is imposing increasingly stringent CO2 emission standards for light and heavy commercial vehicles. The European Commission has intentions to make all transportation modes more sustainable, but it argues that, although it is growing rapidly, the percentage of low- and zero-emission vehicles in the fleet today is far too low. For this reason, standards are necessary, as they are the main policy drivers in the transition to zero-emission mobility in transportation by road (European Commission, 2020). These policies should promote the adoption of electric vehicles, consolidating Europe's position as one of the most advanced EV markets in the coming years.

Indeed, Europe is currently the world's largest market, with nearly 2.26 million electric vehicles registered in 2021, a whopping 66% more than in 2020. With these numbers it has overtaken China, which alone has more than 1.3 million registrations in 2020. Third on the podium is the United States, with nearly 330,000 registered electric vehicles. Within Europe, the top market is Germany with more than 680,000 registered electric cars, up 73% from 2020, followed by the United Kingdom with more than 305,000 registered electric cars and France with about 303,000 registered electric cars. Italy gained two positions within the European top-10 compared to 2020, thanks to the nearly 137,000 electric cars registered in 2021, representing 140% growth over the previous year (Boisrond et al., 2022, ES).

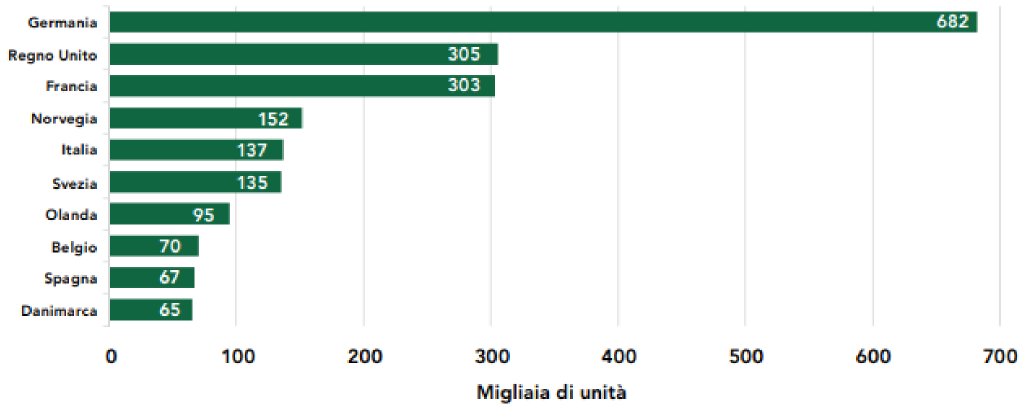


Figure 52: Electric car registrations in Europe in 2021 (Boisrond et al., 2022, ES, p. 91)

Analyzing electric car registrations in 2021 in major European countries, 3 clusters can be recognized based on technology (Boisrond et al., 2022, ES):

- BEV-oriented countries, including Norway, the Netherlands, and the United Kingdom;
- PHEV-oriented countries, including Belgium, Spain and Sweden;
- Countries with a balance between BEVs and PHEVs, including Denmark, Germany, France, and Italy.

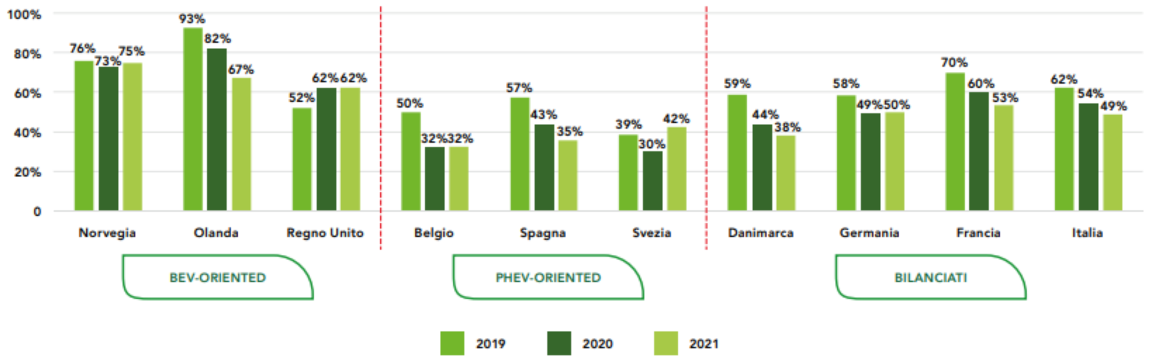


Figure 53: Percentage of BEVs in new EV registrations in 2019, 2020 and 2021 (Boisrond et al., 2022, ES, p. 92)

The RSE has developed scenarios consistent with Fit for 55 and confirmed by the European Commissions' models as well. These scenarios highlight that within the private car market, electric cars will play an important role, exceeding 6 million units in 2030. In these scenarios, PHEVs do not seem to play a major role, covering a small part of private passenger travel demand. However, the reduction in auto transport emissions envisaged by Fit for 55 implies a reduction in demand related to the modal shift from private transport to public transport and cycling (Armaroli et al., 2022, MISM).

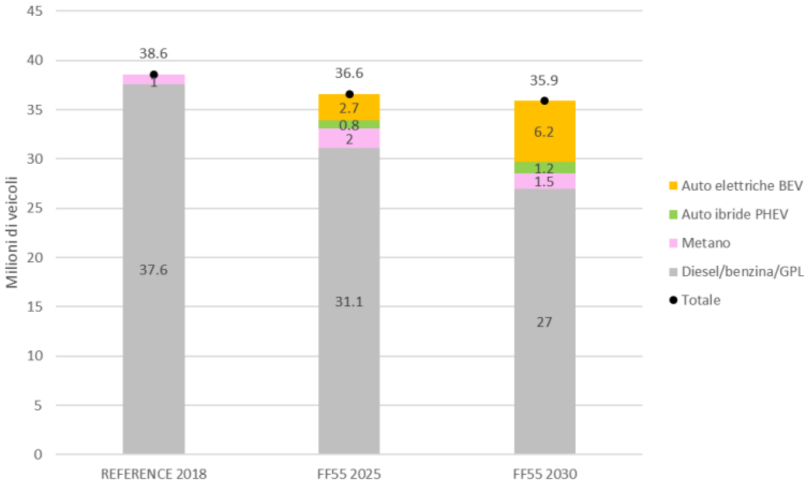


Figure 54: RSE scenarios on the road vehicle fleet (Armaroli et al., 2022, MISM, p. 63)

Finally, when it comes to heavy duty vehicles, according to IEA in the Stated Policies Scenario, the share of electric vehicle sales in Europe is nearly 55% for buses and 10% for trucks in 2030 in the European Union. Considering the commitment made by the Union to zero emissions by 2050, as well as the signing by some European countries of the Memorandum of Agreement on zero-emission for medium- and heavy-duty vehicles, these same shares in the Announced Pledges Scenario reach 60% for buses and 20% for trucks (Bibra et al., 2022, IEA).

4.4.3. Italian Electric Vehicle Fleet

As previously mentioned, Italy ranked fifth among European countries for electric car registrations in 2021. Specifically, 136,854 electric cars were registered, an incredible 128% increase over 2020, including 67,542 BEVs and 69,312 PHEVs. Of these electric cars:

- 38% were registered by private individuals;
- 35% of registrations are related to long-term rentals;
- 8% of registrations are related to corporate fleets;
- 19% of registrations related to short-term rentals and dealers.

These 136,854 electric cars weighed 9.3% of total registrations, amounting to about 1.46 million in 2021 (Boisrond et al., 2022, ES).

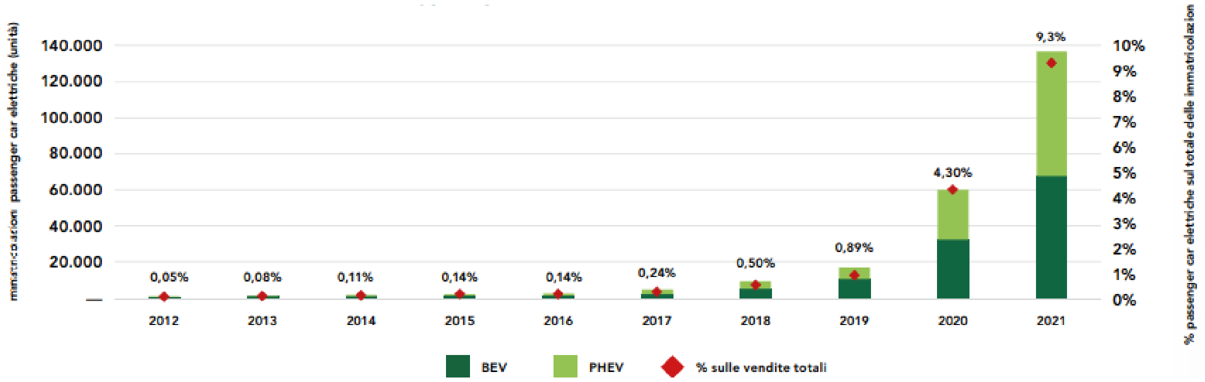


Figure 55: Electric car registrations in Italy, 2012-2021 (Boisrond et al., 2022, ES, p. 108)

Analyzing market segments, more than 70% of the BEVs registered between 2017 and 2021 in Italy belong to small- to medium-sized segments, i.e., segments A, B, and C. Specifically, in 2021 for BEVs, segment A made up 64% of the total, such that four of the five best-selling BEV models in Italy in 2020, namely Smart fortwo, Renault Twingo, Dacia Spring and Fiat 500, belong to segment A. Instead, the segment B decreased significantly in relative terms, reaching 18% (Boisrond et al., 2022, ES).

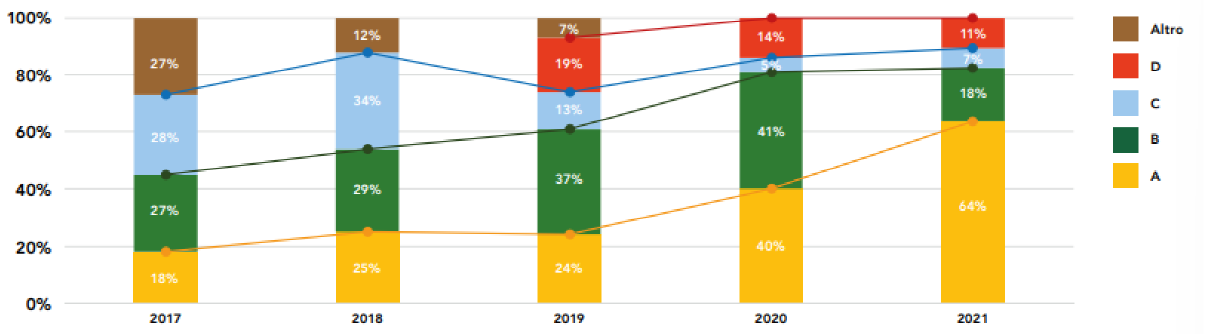


Figure 56: BEVs registrations in Italy by segment, 2017-2021 (Boisrond et al., 2022, ES, p. 111)

2021 was even more fruitful in terms of electric registrations in Italy. Indeed, there were 136,754 registered EVs, an increase of +128% over the year 2020 and a market share of 9.35%, +5% over 2020. This placed Italy fifth in the European context in 2021, gaining two positions. However, when analyzing the ratio of the number of charging infrastructures to the number of EVs, it is immediately apparent that Italy is above the European average and second only to the Netherlands. This shows that the long-term goal of achieving ubiquity of charging service is being pursued (Motus-E, 2021).

Driving the market is mainly Northern Italy, with more than 90,000 EVs registered, accounting for 65% of total registrations in Italy. Next come the regions of Central Italy with 26% of registrations and, finally, in Southern Italy and the Islands the percentage is around 9% (Boisrond et al., 2022, ES). Indeed, in 2021 ARERA[22]'s analyses attempted

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[22] Regulatory Authority for Energy Networks and Environment (ARERA) is an independent body that carries out regulation and control activities in the areas of electricity and natural gas, as well as in the areas of water services, and waste recycling. ARERA has the task of establishing every three months the cost of electricity and gas in the protected market

to assess the diffusion of electric cars in the different geographical areas of the Italian territory by analyzing the correlation between GDP per capita, number of registered electric vehicles and charging stations installed for public use. As evident from the graphs below, vehicle diffusion follows the trend of GDP (ARERA, 2022):

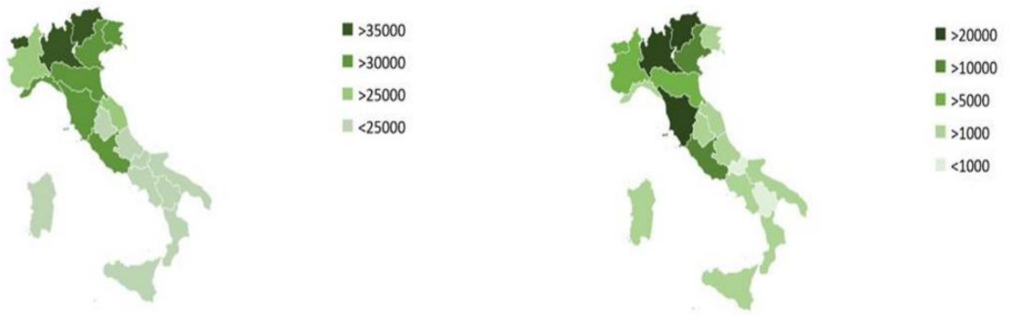

Figure 57: Relationship between GDP per capita (left) and distribution of registrations (right) by region, 2021 (ARERA, 2022, p. 27)

Projecting into the future, Energy & Strategy again uses its previously mentioned scenarios to assess the spread of cars in Italy to 2030. Certainly, regardless of the scenario, an 8% reduction in the circulating car fleet is expected compared to current values, primarily attributable to ICEVs. As for the adoption of electric vehicles (Chiesa et al., 2021, ES):

- The Business-as-usual scenario predicts a significant uptake of EVs, but without exceeding 4 million vehicles on the road by 2030. In addition, alternative-fueled cars, particularly CNG and LPG, are expected to grow by 32% in this contest compared to today's fleet;
- In the Policy-driven scenario, EVs reach 28% market share as early as 2025, rising to 55% in 2030 with a total of 6 million EVs on the road. These numbers are in line with the PNIEC, although PHEVs are still much more prevalent than BEVs. Again, alternative-fuel vehicles play a significant role;
- In the Decarbonization scenario, EVs are projected to have a 35% market share and more than 2 million total vehicles on the road as early as 2025, and then reach 75% in 2030 with 8 million vehicles. In this case, 85% of electric sales are accounted for by BEVs.

4.5. Batteries

4.5.1. Costs and Technologies

Batteries currently impact up to 40% of the price of an electric vehicle, despite a significant reduction in absolute value in recent years. The price of a lithium-ion battery, to date the benchmark technology, averaged 114€/kWh in 2020, 90% less than in 2010. By 2023 this value is even expected to reach 84 €/kWh, making electric vehicles competitive with ICEVs in terms of purchase price. Enabling factors include (Chiesa et al., 2021, ES):

- Expected development of the EVs market to decrease unit production costs through economies of scale, battery pack standardization, and technology process improvement;
- Adoption of new chemistries for cathodes.

The combination of these factors, together with efficiencies in the amount of materials used in batteries, could nearly halve current battery prices. Otherwise, a 40% reduction in cost compared to current lithium-ion batteries could be achieved through the production of solid-state batteries. Indeed, solid-state batteries are expected to achieve significant improvements in technical characteristics over current lithium-ion batteries, for example, in terms of the number of charge and discharge cycles[23], and mass energy density[24] (Chiesa et al., 2021, ES).

A key feature of nickel-based batteries is cathode chemistry, as it determines both the battery's performance and its material demand. To date, there are three major categories of cathode chemistry in the automotive industry: nickel manganese cobalt oxide (NMC); nickel aluminum cobalt oxide (NCA); and lithium iron phosphate (LFP) (Bibra et al., 2022, IEA).

In order to optimize battery management, batteries could be integrated with intelligent functions to improve their life and safety. Sensors, such as fiber optics, "plasmonics," and electrochemical and acoustic sensors could be introduced to track chemical and electrochemical reactions directly at the battery cell level. This would be made possible by monitoring parameters such as temperature, pressure, electrolyte state, potential difference, and heat flow. In addition, a self-healing feature could be implemented to restore any lost functionality within the battery cells. Research activities for battery self-healing mainly involve self-repair of electrodes to restore conductivity, as well as functionalization of membranes to regulate ion transport (Chiesa et al., 2021, ES).

4.5.2. Supply and Demand

In 2021, there was a 120% growth in EVs over the previous year. As a result, battery demand also doubled. Specifically, the demand for lithium-ion (Li-ion) automotive batteries was 340 GWh in 2021, more than double the demand in 2020. This increase in demand was met by the capacity of battery factories, whose global average utilization

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[23] A charge and discharge cycle is generally used to specify the expected life of a battery, since the number of charge cycles affects the life more than just the passage of time.

[24] In the field of energy storage, mass energy density is used to compare the performance of storage technologies. The higher the mass energy density, the more energy that can be stored or transported for a given mass.

rate in 2021 was 43% of nameplate capacity. The utilization rate of factories was calculated as the total demand for electric vehicles, consumer electronics, and stationary storage batteries compared to the nameplate capacity of all battery plants, where the nameplate capacity of a factory is defined as the expected output at full load. The utilization rate still seems low, but it is actually due to anticipated strategic investments in battery plant capacity to prepare for the expected growth in demand (Bibra et al., 2022, IEA).

Battery cell production is physically moving closer to vehicle assembly plants. By 2030, battery production capacity is still expected to be concentrated in China (70%), but investments are heading to other regions, with a quarter of battery production capacity expected in Europe and the United States by 2030. Indeed, whereas ten years ago almost all cells were imported from Asia, there are now regional manufacturing hubs, for example in Eastern Europe. In addition, several plants will be built in key vehicle manufacturing countries such as Germany, the United Kingdom, and France and in low-carbon environments such as Norway and Sweden. Battery sourcing is changing as OEMs[25] are integrating upstream, especially in joint ventures with cell manufacturers. These integrations arise from the growing demand for battery cells, the desire for supply control and certainty, and the ambition to keep a significant part of vehicle value creation in-house. In addition, OEMs also seek areas of differentiation, as battery technology, durability, and performance are key evaluation criteria for BEVs (Conzade et al., 2021, McKinsey & Co.).

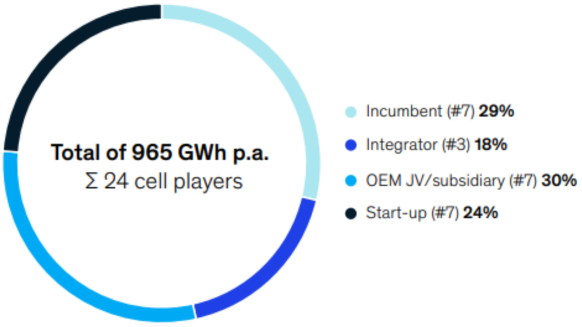

Figure 58: Battery cell players by archetype in Europe in 2030 (Conzade et al., 2021, McKinsey & Co., p. 15)

Globally, it is projected that battery factories may be able to meet the 2030 demand. To reach the required production levels, IEA forecasts an additional 52 gigafactories with an annual production capacity of 35 GWh in the Stated Policies Scenario and 90 gigafactories in the Announced Pledges Scenario. Demand for batteries is driven by electric cars, which account for 85% of the projected total by 2030 in both scenarios. It is plausible that vehicles will have increasing battery capacity due to the demand for

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[25] OEM stands for Original Equipment Manufacturer

longer driving range and larger vehicles. This trend contributes about one-third of the increase in battery demand and is particularly pronounced in North America. According to Benchmark Mineral Intelligence's analysis, the production capacity for batteries announced by companies for 2030 is 4.6 TWh, which is higher than demand in both scenarios mentioned earlier. If all of the announced capacity become operational by 2030, the utilization rate of battery production will be 47% (Bibra et al., 2022, IEA).

Looking forward, Europe is also expected to have a similar development by 2030. Indeed, it expects a 20-fold increase in generating capacity to 965 GWh by 2030. If this capacity is actually installed by that date, it should meet a projected demand of "only" 874 GWh. Out of this demand, BEVs make up 90%. However, while the forecasts claim that the capacity will be sufficient to meet demand, in reality it is likely that the process will be slowed down by several factors, including problems with giga-factory production, slow increases in yields, fragmented supply chains, and inflexible contracts with OEMs. Therefore, if demand for electric vehicles continues to grow at these rates, battery demand will exceed supply in the medium term. (Conzade et al., 2021, McKinsey & Co.).

Looking even further ahead, in order to achieve Net Zero Emission by 2050, more supply is needed than is currently projected. Thus, in order to meet the projected demand for electrification, large investments are needed in the supply of battery minerals, just as in all other clean energy technology sectors. On the other hand, efforts can also be made to reduce demand by acting on both the mineral intensity of batteries and the average size of batteries per vehicle. The average battery size is increased by 60% between 2015 and 2021 to raise the average driving range and to handle the rising average energy consumption as the share of electric SUVs increases. If current trends continue, battery sizes are expected to increase up to 30% in 2030. In order to manage demand, this trend could be slowed by adopting policies that discourage vehicles with extremely large batteries, such as linking incentives to battery size or, in the long run, taxing electric vehicles with large batteries. If by 2030 battery sizes remained the same as they are today, 16% of the incremental demand for battery metal could be avoided (Bibra et al., 2022, IEA).

4.5.3. Critical Raw Materials

Over the next decade, a slowdown in the mining industry and the outbreak of other geopolitical crises are expected. These factors will consequently weaken the supply chain, leading to price spikes in raw materials such as nickel and lithium (Conzade et al., 2021, McKinsey & Co.).

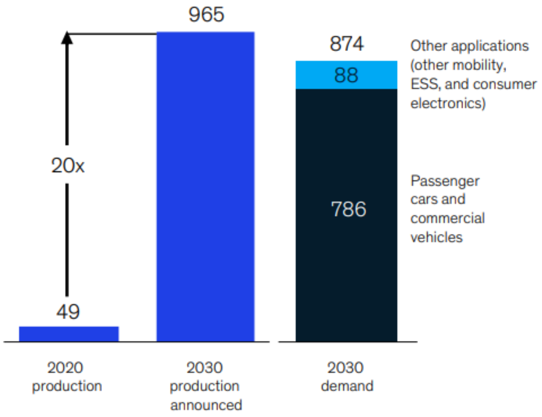


Figure 59: Battery cell demand and announced supply in GWh (Conzade et al., 2021, McKinsey & Co., p. 15)

Only some of the materials needed to make battery cells are available in Europe, including nickel, cobalt, lithium and graphite. As a result, companies must shop globally to secure the required volumes while following environmental, social and governance (ESG) sustainability principles. All of the above raw materials are likely to become more expensive in the short to medium term (Conzade et al., 2021, McKinsey & Co.). Indeed, battery metal prices around the world increased dramatically in early 2022, posing a significant challenge to the electric vehicle industry:

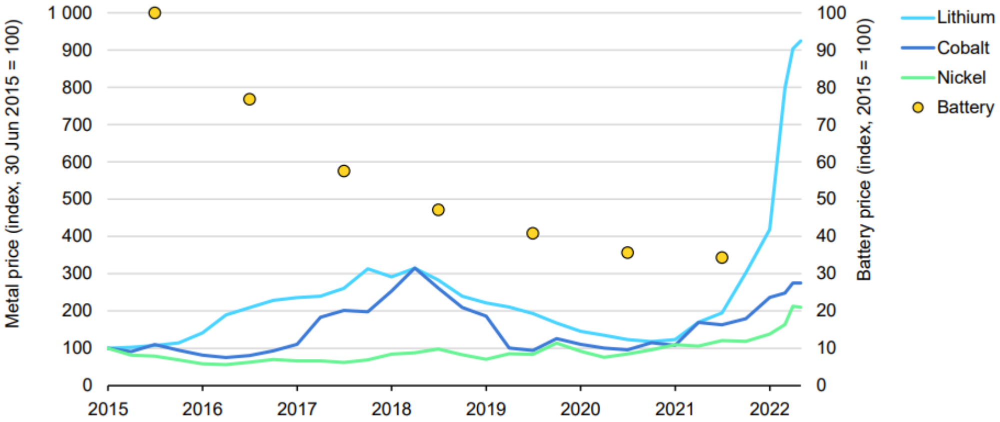


Figure 60: Battery metal prices, 2015 – mid 2022 (Bibra et al., 2022, IEA, p. 141)

In particular, the price of lithium has increased more than sevenfold and the price of cobalt has more than doubled. These unprecedented increases were caused by a number of combinations of factors, such as increased demand for batteries, increased pressure on supply chains, and concerns about supply tightening, further worsened by geopolitical crises. On the other hand, supply constraints have been driven by production challenges caused by the pandemic, concerns about nickel supplies from Russia, and a structural lack of investment in new supply capacity in the three years leading up to 2021, when metal prices were low. However, the impact of rising raw material prices has not yet fully materialized. Automakers are increasingly using contracts in which material costs are linked to raw material prices in the case of large battery orders, even if there is a time lag. Thus, the automakers themselves have yet to feel the result of the exceptional rise in raw material prices from the past few months. If metal prices remain at the levels shown before, it is estimated that the price of batteries could increase by up to 15% over the average price in 2021, all things being equal. This impact could be mitigated by OEM substitution of other, cheaper chemicals. However, these increases will still pose a major challenge for automakers, as they reduce manufacturers' margins and increase costs for consumers (Bibra et al., 2022, IEA).

4.5.4. Downstream Supply Chain

One of the doubts regarding the actual environmental sustainability of electric cars concerns the disposal of batteries after the end of the car's useful life. For example, the CEO of Redwood Materials, a lithium-ion battery and e-waste recycling company, claims that a Tesla's battery can last 15 years (Staffetta Quotidiana, 2022a). Indeed, batteries can be both reused and recycled. Reuse or repurposing involves refurbishing EV batteries for less demanding second-life applications, usually for stationary storage. Exhausted EV batteries typically still have about 80% of their usable capacity, therefore reuse generates additional value. In order to reuse them, the pack needs to be disassembled, the modules and cells verified, and finally repackaged for new applications. The main cost drivers of battery reprocessing involve the logistics required for collection, verification of remaining useful life, and physical disassembly and repackaging of cells and packs. Moreover, there are other economic and regulatory challenges to effectively reuse batteries, including ensuring reliable grading of cells and packs, but most importantly, being sure that cost of reconditioning is competitive with that of new batteries. Regarding recycling, there are three main methods for recycling lithium-ion batteries: pyrometallurgy, hydrometallurgy, and direct recycling. Pyrometallurgy involves melting the battery in a high-temperature furnace, recovering only part of the metals from the cathode. Hydrometallurgy involves a chemical leaching process to precipitate individual metals. Currently, most battery recycling uses a combination of these two methods to recover the more expensive metals, such as nickel and cobalt. Current global battery recycling capacity is about 200 kt/year, and China accounts for about half of that. In addition, China has announced that it will install additional recycling capacity in an effort to consolidate its dominant position.

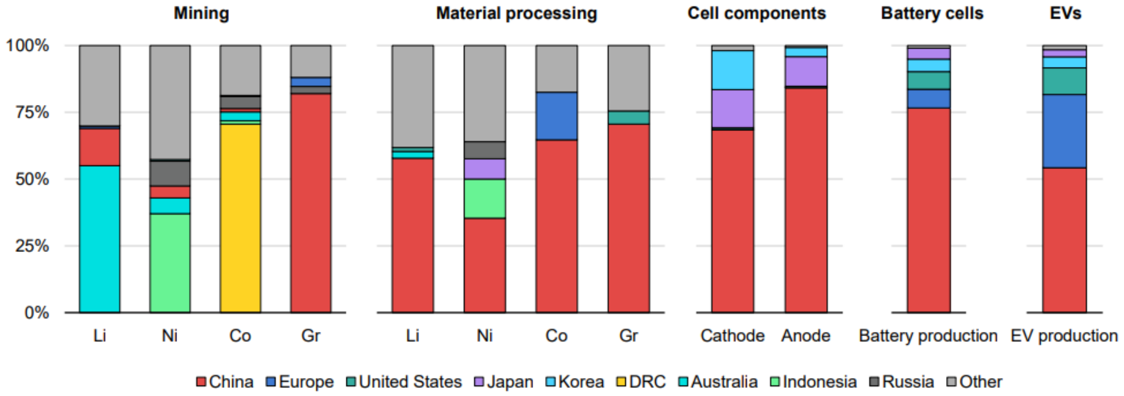


Figure 61: Geographical distribution of the global EV battery supply chain (Bibra et al., 2022, IEA, p. 154)

As of today, most battery recycling companies are independent recyclers, but OEMs, battery manufacturers, extractors, and processors are beginning to enter the market. Finally, direct recycling is an emerging process that offers greater recycling efficiency because it preserves the crystalline structure of the material by regenerating the cathode. This preserves the embedded energy and economic value of EV batteries and supply chains in processing the cathode, avoiding the need to resynthesize raw materials. However, it is a method limited by its inflexibility, as it must be tailored to each cathode chemistry and the recovered cathodes can only be fed into the production of the same type of battery (Bibra et al., 2022, IEA).

5 Charging Infrastructure

The aspect that most differentiates an EV from an ICEV for consumers is that, compared to traditional fuel retailing, drivers no longer have to go to a gas station to refuel, but can recharge their vehicles at home, at work, in shopping malls and parking lots, as well as on the road (Bau et al., 2021, McKinsey & Co.). All this is possible thanks to charging infrastructure. This chapter aims to analyze charging infrastructure in detail, exploring the following aspects:

- The differentiation of charging stations according to their power, their efficiency and their connectors;
- The technological trends for electric vehicle charging;
- The current regulations regarding the installation of the charging points;
- The differentiation of infrastructure based on the accessibility of the charging station, then a comparison between public and private charging;
- The costs associated with charging stations, thus not only the costs of charging itself, but also the costs of purchase and installation;
- The current and ideal location of the charging stations.

5.1. Power, Current & Connectors

Before analyzing the topic, it is appropriate to provide some background regarding the terms that will be used in the chapter.

A charging station is defined as an interface, corresponding to an electrical outlet or connector, capable of charging one electric vehicle at a time connected to it. Instead, a charging device is a device capable of delivering charging service through one or more charging stations, commonly referred to as a “charging column”, or, in the domestic context, a “wallbox”. Charging infrastructure is defined as the set of structures, works and facilities required to create parking areas equipped with one or more charging stations for electric vehicles. Specifically, the charging infrastructure is composed of one or more charging devices and related electrical interconnections. The Point of Delivery is the code used to precisely identify the user, i. e., the geographical point on the territory where electricity is taken from the user. There are essentially two actors in this context: the Grid Operator and the Charging Point Operator. The Grid Operator is the distribution company in charge of transporting energy on the grid (ARERA, 2022). Charging Point Operator instead is the entity that installs and operates charging infrastructure for electric vehicles (ARERA, 2021b).

After this overview of definitions, the focus returns to the charging infrastructure. Indeed, the charging infrastructure for electric vehicles can be classified, based on the accessibility of the charging station (Chiesa et al., 2021, ES):

- Public charging: charging stations installed on public land and therefore with non-discriminatory access;
- Private charging for public use: charging stations installed on private land but with non-discriminatory access, such as at shopping centers or other points of interest;
- Private charging: charging stations installed on private land and with private access.

Charging stations belonging to public charging infrastructure or private charging stations for public use can themselves be classified according to their main characteristics: maximum power output, in terms of kW, charging mode and current type, and connector type. It should be specified that the charging time of an electric car is determined by the power, in kW, at which this takes place, but also by the characteristics of the vehicle itself, such as the size of the battery pack and the maximum power accepted by the integrated charger.

5.1.1. Maximum Deliverable Power

In terms of maximum deliverable power, charging stations are divided into (Motus-E, 2021; Chiesa et al., 2021, ES):

- Standard power charging station allows the transfer of electricity to an electric vehicle at a power of up to 22 kW. However, devices with a power rating of 3.7 kW or less are excluded because they are installed almost exclusively in private homes or otherwise their main purpose is not to charge electric vehicles. These charging stations can be classified themselves into:
  - Slow charge, up to 7.4 kW;
  - Quick charge, up to 22 kW.
- High power charging station allows the transfer of electricity to an electric vehicle at a power output over 22 kW. They can be classified themselves into:
  - Fast charge, up to 50 kW;
  - Ultra-fast charge, over 50 kW.

5.1.2. Charging Mode and Current Type

Electric car chargers are classified by charging mode and to the current type. Regarding the charging mode, the different types are (Enel X, 2020):

- Mode 1: The battery is directly connected to the power grid. However, it is an obsolete system, as it has a high risk of overheating, since the current goes directly from the plug to the vehicle without a control unit between the two. Associated with this mode is the Schuko connector, which will be analyzed later;

- Mode 2: It involves the use of a control and protection module between the grid and the vehicle. This is the simplest way to charge an electric car at home without a permanent infrastructure such as Wallboxes. Mode 2 corresponds to Schuko or Type 1 connectors;
- Mode 3: It requires the use of fixed equipment, even if the infrastructure is domestic, such as Wallboxes. The connector used in this mode can be either Type 2 or Type 3. It should be specified that all three modes explained before are compatible that with hybrid cars;
- Mode 4: characteristic of fast charging stations, where direct current is delivered. Charging is done with CHAdeMO type or CCS COMBO1 and COMBO2 type connectors. It does not work with hybrid cars but only with electric cars. This is normally used in the chargers of public charging stations.

Regarding the current type, vehicle charging can be either alternating current (AC) or direct current (DC) and this distinction is strongly related to the charging mode. AC charging has the following characteristics (Enel X, 2020):

- It is used in domestic settings in Mode 2;
- It is mandatory in public or private environments for public use in Mode 3;
- For both Mode 2 and Mode 3, the type 2 connector is provided as the main type;
- Provides for two types of charging: a slow, single-phase (at 16 A and 230 V), and a fast, three-phase (at 32 A and 400 V);
- Charging is done by feeding the charger inside the vehicle, therefore the charging station is like a dispenser;
- The charging cable is an equipment of the electric vehicle; therefore, the charging station does not have the cables to connect different electric cars.

Instead, DC charging (Enel X, 2020):

- Occurs only in Mode 4;
- CHAdeMO and CSS COMBO type connectors are the two main standards;
- Charging is done by feeding directly to the vehicle battery, therefore the charging station acts as a true external charger;
- As a result, the limitation of the in-vehicle charger, which in the case of AC charging is a limitation on the power that can be delivered and thus the charging time, is exceeded. In DC, current is delivered at 200 V and 400 V, achieving ultra-fast recharging;
- DC charging stations have the cable directly connected to the charging station, following the model of gasoline pumps.

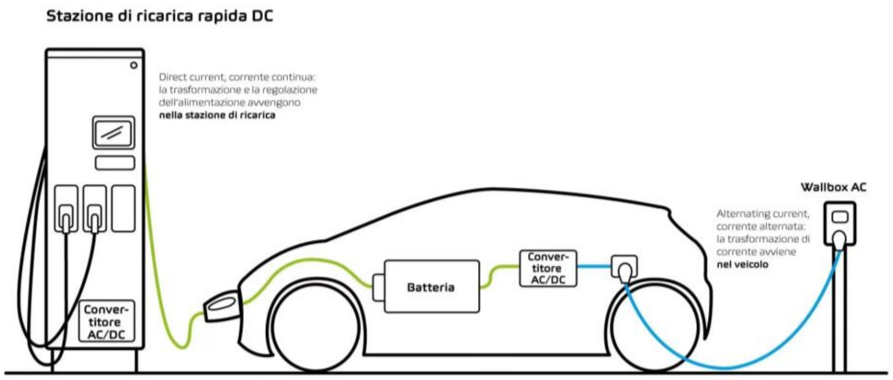


Figure 62: Difference between AC and DC charging stations (Salama, 2019)

5.1.3. Connector Type

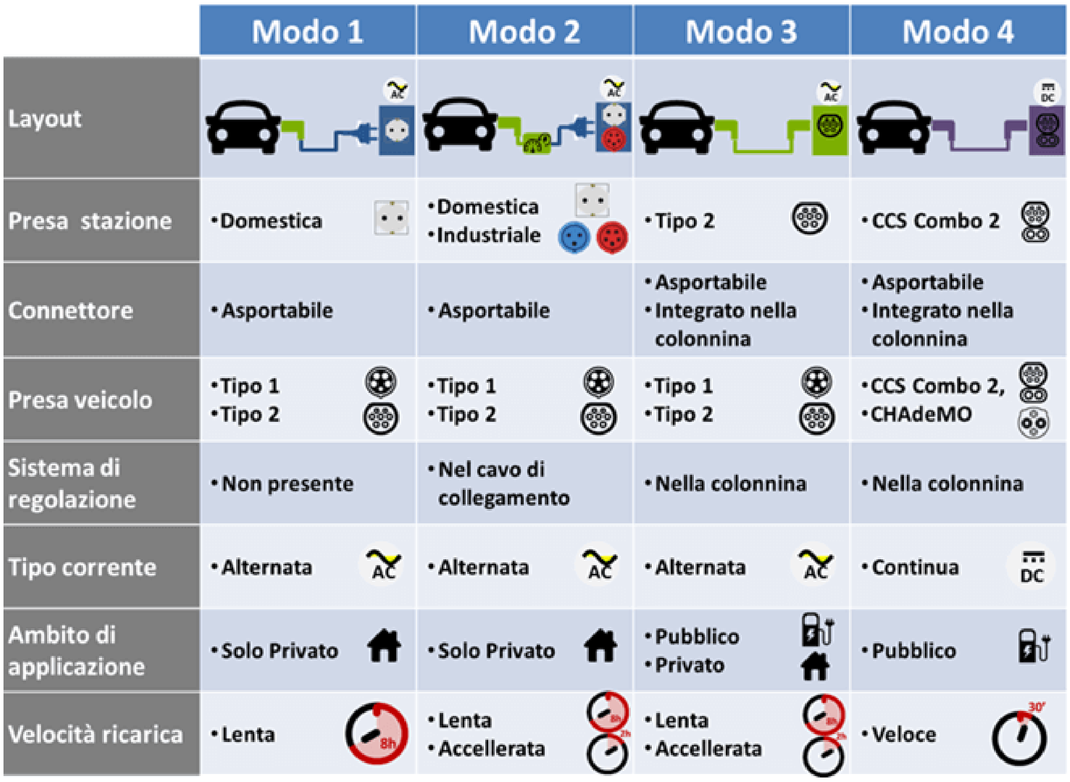
There are different types of cables for charging an electric vehicle. Each car model usually comes with a cable with a plug that connects to the charging station and a connector that connects to the car's inlet. The type of connector is strongly related to the charging mode and current type. There are different types of charging stations for electric cars based on the type of connector (Enel X, 2020):

- Schuko connector: this is the traditional plug of European houses, the same one used for household appliances. The main advantage of these plugs is that they are compatible with all electric cars. However, it is not the best way to charge a vehicle as charging is very slow;
- Type 1 connector: this is the first connector made specifically for charging electric cars. These connectors are single-phase and can support two levels of AC load;
- Type 2 connector: is the most widely used in Europe. These devices work with both single-phase and three-phase installations;
- Type 3 or single combined connector: unlike the other chargers mentioned before, this charger charges with both alternating and direct current;
- CHAdeMO (CHArge de MOve) connector: although less common, it is the most versatile of all. It is a three-phase charger that uses high-speed direct current. In addition, this connector is bidirectional, meaning that the car can become a power supplier if needed. It is the most widely used standard in Asia and America;
- COMBO1 and COMBO2 CCS (Combined Charging System) connector: this is the standard of European automakers. It allows both DC fast charging and AC slow charging.

Figure 63: Connector Types (Salama, 2019)

In addition to these chargers, there are emerging technologies in the field, such as wireless charging, in which the charging process is done by induction or magnetic resonance (Enel X, 2020).

Finally, the table below summarizes the information in this chapter:



	Modo 1	Modo 2	Modo 3	Modo 4
Layout	AC	AC	AC	DC
Presa stazione	• Domestica	• Domestica • Industriale	• Tipo 2	• CCS Combo 2
Connettore	• Asportabile	• Asportabile	• Asportabile • Integrato nella colonnina	• Asportabile • Integrato nella colonnina
Presa veicolo	• Tipo 1 • Tipo 2	• Tipo 1 • Tipo 2	• Tipo 1 • Tipo 2	• CCS Combo 2, • CHAdeMO
Sistema di regolazione	• Non presente	• Nel cavo di collegamento	• Nella colonnina	• Nella colonnina
Tipo corrente	• Alternata AC	• Alternata AC	• Alternata AC	• Continua DC
Ambito di applicazione	• Solo Privato	• Solo Privato	• Pubblico • Privato	• Pubblico
Velocità ricarica	• Lenta 8h	• Lenta • Accellerata	• Lenta • Accellerata	• Veloce 30'

Table 2: Summary of charging mode, current type, and connector (Giacometti, 2020)

5.1.4. Italian Market

In Italy, 91% of the charging stations present at the end of 2022 are AC, while the remaining 9% are DC. In terms of DC connector types, - CHAdeMO and CCS COMBO 2 dominate the market, weighing 75% of the total DC connectors, but Tesla's proprietary standard, which is called the Tesla SuperCharger, is also taking its place. As for BEVs in Italy in 2022, all of them have an AC charging connector, while 93% also have a DC charging connector, up from previous years. With respect to AC charging connectors, all BEVs have a Type 2 connector, while Type 1 has almost completely disappeared. Instead, for DC charging connectors, the Type CCS dominates the market since it is present in 80% of BEVs, while the ChaDeMo and Tesla SuperCharger account for only 4% and 9% of BEVs, respectively (Boisrond et al., 2022, ES).

Instead, analyzing public charging power in Italy in 2023, the most popular maximum AC charging power is between 3.7 and 7.4 kW with 53% of the market, while that below 3.7 kW has disappeared. On the other hand, the highest charging power, from 11 to 22 kW, is supported by a decreasing percentage of BEVs, going against the trend of charging infrastructure offerings going up to 43 kW (Boisrond et al., 2022, ES).

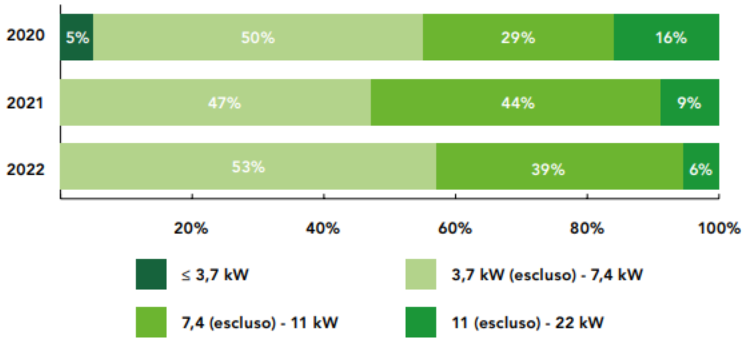


Figure 64: Maximum AC charging power in Italy, 2019-2022 (Boisrond et al., 2022, ES, p. 184)

As for DC charging connectors, the number of cars without any DC connectors has decreased sharply in the past years, while cars that can accept a maximum DC charging power of more than 100 kW have increased significantly. Specifically, they accounted for 37% of the market in 2022. This is in line with the development of high-power charging infrastructure. Forecasts claim that in the next three to five years almost all BEVs in Italy will be able to accept charging power above 100 kW (Boisrond et al., 2022, ES).

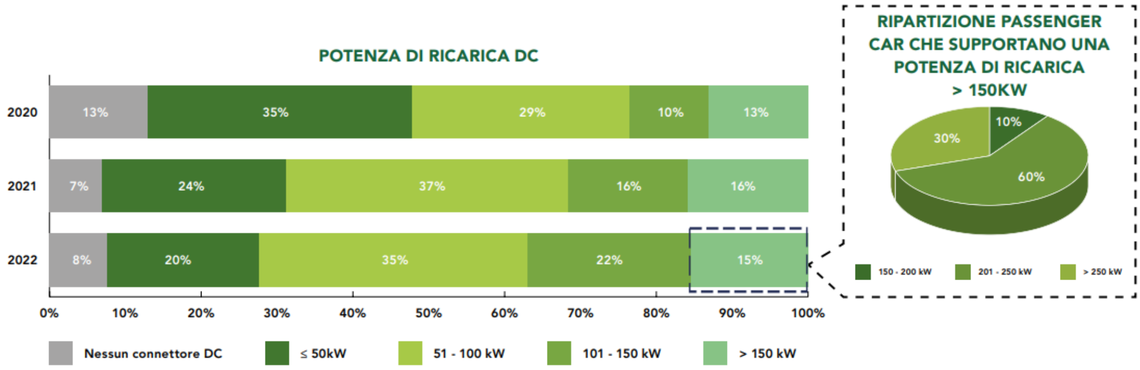


Figure 65: DC charging connector in Italy, 2019-2022 (Boisrond et al., 2022, ES, p. 186)

5.2. Technology Trends

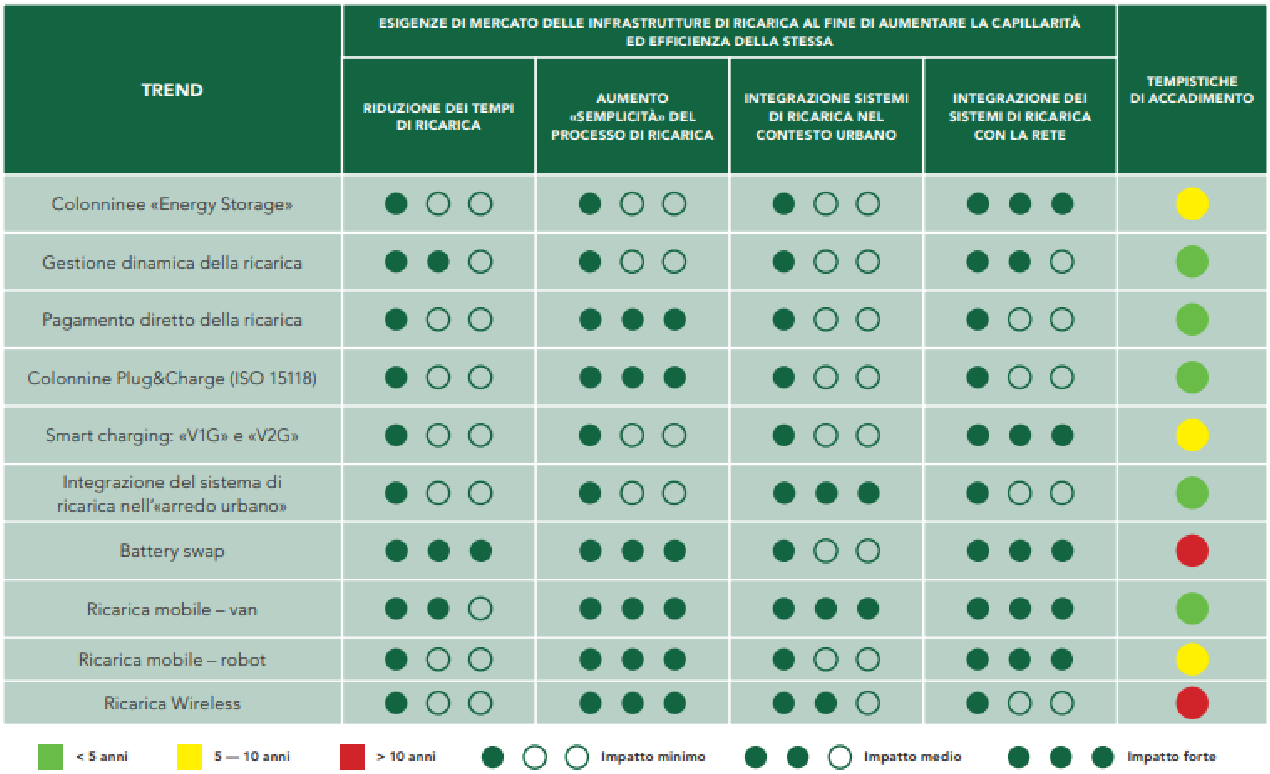
After analyzing the main characteristics of charging stations, the main technological trends regarding charging infrastructure for electric cars are discussed below. The following are the already existing trends for charging stations (Chiesa et al., 2021, ES):

- Energy Storage charging stations;
- Dynamic Load Balancing
- Direct charging payment;
- Plug&Charge charging stations;
- Smart Charging;
- Integration of the Charging System into street furniture.

Instead, new charging technologies include (Chiesa et al., 2021, ES):

- Battery swap;
- Mobile Charging;
- Wireless Charging;
- Solar Powered Vehicles.

A table comparing the various technology trends is shown below:



TREND	ESIGENZE DI MERCATO DELLE INFRASTRUTTURE DI RICARICA AL FINE DI AUMENTARE LA CAPILLARITÀ ED EFFICIENZA DELLA STESSA				TEMPISTICHE DI ACCADIMENTO
	RIDUZIONE DEI TEMPI DI RICARICA	AUMENTO «SEMPLICITÀ» DEL PROCESSO DI RICARICA	INTEGRAZIONE SISTEMI DI RICARICA NEL CONTESTO URBANO	INTEGRAZIONE DEI SISTEMI DI RICARICA CON LA RETE	
Colonninee «Energy Storage»	● ○ ○	● ○ ○	● ○ ○	● ● ●	🟡
Gestione dinamica della ricarica	● ● ○	● ○ ○	● ○ ○	● ● ○	🟢
Pagamento diretto della ricarica	● ○ ○	● ● ●	● ○ ○	● ○ ○	🟢
Colonnine Plug&Charge (ISO 15118)	● ○ ○	● ● ●	● ○ ○	● ○ ○	🟢
Smart charging: «V1G» e «V2G»	● ○ ○	● ○ ○	● ○ ○	● ● ●	🟡
Integrazione del sistema di ricarica nell'«arredo urbano»	● ○ ○	● ○ ○	● ● ●	● ○ ○	🟢
Battery swap	● ● ●	● ● ●	● ○ ○	● ● ●	🔴
Ricarica mobile – van	● ● ○	● ● ●	● ● ●	● ● ●	🟢
Ricarica mobile – robot	● ○ ○	● ● ●	● ○ ○	● ● ●	🟡
Ricarica Wireless	● ○ ○	● ● ●	● ● ○	● ○ ○	🔴

🟩 < 5 anni 🟨 5 — 10 anni 🟥 > 10 anni ● ○ ○ Impatto minimo ● ● ○ Impatto medio ● ● ● Impatto forte

Table 3: Comparison of various technology trends for charging infrastructure (Chiesa et al., 2021, ES, p. 232)

5.2.1. Energy Storage charging stations

Storage systems make it possible to decouple the energy delivery of the charging service from the energy withdrawal itself from the grid. In this way, they make it possible to reduce the impact of charging on the electricity grid. Thus, it is possible to install charging stations where the grid is at a weaker level. In this context, electric vehicle batteries can have a second purpose from the perspective of circular economy. In addition, storage systems integrated with the charging infrastructure can also be powered by locally produced green electricity plants, thereby reducing the environmental impact of powering electric vehicles (Chiesa et al., 2021, ES).

5.2.2. Dynamic Load Balancing

Dynamic load balancing involves modulating the power delivered by the charging station in a way that provides the fastest possible charging for multiple electric vehicles at the same time. By taking advantage of this system, electric vehicles can always be charged while respecting the power limits of the point of delivery. In this way, it is possible to achieve continuity of service, lower operating costs, as costs related to exceeding the contracted power are avoided, and lower installation costs. Dynamic load balancing can be used in two different situations: when there is the need to dynamically manage the charging on a single charging station or within a local network. Regardless of the situation, there is an even spread of power among the electric vehicles connected to the charging infrastructure. However, more advanced dynamic load balancing can be implemented, in which the power delivered is divided not only according to the number of vehicles connected to the infrastructure, but also according to the state of charge of the vehicles or particular needs of the owners of the vehicles themselves. Consequently, the available power will be automatically shared according to the individual demand of the electric vehicles, their state of charge and the time of arrival at the charging station, optimizing the charging time itself (Chiesa et al., 2021, ES).

5.2.3. Direct charging payment

The most popular payment methods for public charging involve the use of cards with RFID[26] technology or via APP through NFC[27] or QR code communication. These methods enable many useful features for authentication and charging measurement, which are essential for systems installed in publicly accessible locations. On the other

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[26] RFID (Radio Frequency Identification) is a technology that enables the unique, automatic and remote detection of objects, on which special electronic tags that can store data have been applied

[27] NFC (Near Field Communication) is a two-way technology that provides short-range wireless connectivity, which is integrated into a large proportion of commercially available cell phones today and is used to make various types of payments, including by virtualizing a credit card function.

hand, these functionalities are quite unnecessary in individual charging situations not accessible to the public, where there is no need to electronically authenticate or apportion consumption (ARERA, 2021b)

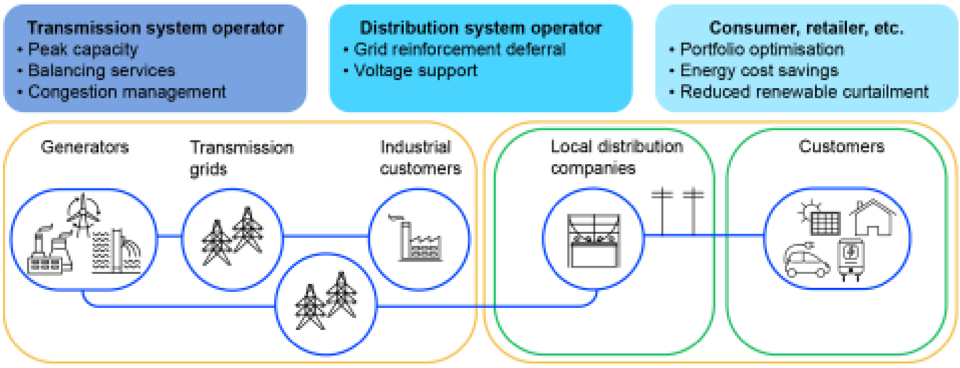
There are, however, also methods of direct payment by credit or debit card, called tap and charge, for example, which involve paying for charging by credit or debit card directly at the charging station when the charging itself is done. This payment method does not require signing a contract with a recharge service provider, but it is not yet a popular solution in Italy because of electronic invoicing. In Italy, one of the few operators that provides the possibility to pay for the charging service by credit or debit card at some of its charging stations is Neogy, which uses an electronic receipt and, in case the user requests it, also electronic invoicing upon data entry. Instead, this payment method is already active in some European countries (Chiesa et al., 2021, ES).

5.2.4. Plug&Charge Charging Stations

The Plug&Charge charging mode allows the charging process itself to be simplified, as the user does not have to identify himself at the charging station, but only needs to connect the vehicle to the infrastructure through the charging cable. Indeed, once connected, it is the vehicle that identifies itself on behalf of the user, initiates the charging process, and manages the connected invoicing. Enabling Plug&Charge functionality should be both infrastructure-side and vehicle-side. Infrastructure side, many market players have already enabled or are otherwise enabling their infrastructure to support Plug&Charge mode. Instead, on the vehicle side, only some car models, including Teslas, are already enabled, although many other automakers are working on its introduction (Chiesa et al., 2021, ES).

5.2.5. Smart Charging

Smart charging denotes a charging mechanism in which stations, operators, and electric vehicles communicate with each other, optimizing the charging process. In this way, electric vehicle charging can be adapted to the grid conditions at that time and to the needs of the vehicle users. For a charging device to be considered "smart," it must be able to measure the energy exchanged with the vehicle and then transmit the sensed data to an external subject and implement commands given by an external party in order to modulate the current during a charging session (ARERA, 2021b). The adoption of digital and smart charging technologies can reduce the need for grid reinforcement. On the other hand, smart charging of electric vehicles offers new opportunities for power systems. Markets and regulations should reward flexibility in order to promote the deployment of smart charging. Cost-sensitive consumer tariffs will incentivize drivers to charge their vehicles when the grid is not under stress or when renewable generation is high. This helps minimize the need for costly grid upgrades. Consumers alone cannot handle energy market signals, therefore there is a need for aggregators who contract with individual customers to provide flexibility services and manage a pool of flexibility providers to maximize revenues and benefits for participants and the system. The most appropriate way to incorporate electric vehicle charging flexibility will vary depending on the specifics of the electric system and the market. However, key aspects such as the right to participate, product specifications, and rules for monitoring and measuring flexibility need to be evaluated to ensure that excessive burdens are not imposed on distributed flexibility providers (Bibra et al., 2022, IEA).



IEA. All rights reserved.

Figure 66: Smart charging services along the power supply chain (Bibra et al., 2022, IEA, p. 205)

There are two main types of smart charging:

- Off-peak charging, which is incentivized with favorable tariffs to encourage users to recharge during off-peak hours or when there is surplus generation from renewable sources;
- Vehicle-to-grid.

V-to-G (vehicle-to-grid) is an integration system between electric vehicles and the electric system, which allows vehicles to deliver reserve, balancing, frequency and voltage regulation services, through the charging infrastructure to which they are connected. Thus, the charging device can dynamically vary the intensity and direction of the power flow exchanged with the vehicle (ARERA, 2021b). V-to-G is divided into V1G and V2G.

First, V1G is a type of V-to-G in which the flow of power from the power grid to the vehicle can be varied in intensity, interrupted or advanced/delayed, but not change direction, since it is one-way from the grid to the vehicle battery (ARERA, 2021b). To effectively implement V1G, the charging infrastructure must have power management systems to measure both the power delivered from the grid and the power absorbed by the vehicle during charging. Furthermore, a charging infrastructure control system must be installed in order to communicate with the grid and manage price trends and any changes in the grid frequency. Indeed, the charging infrastructure at the very beginning of the charge establishes the maximum current that can be delivered, but in case of sudden or transient events, it must be possible to modulate the current by allowing the car's Battery Management System to identify the combination of voltage and current that the vehicle can draw. These parameters with V1G can be modulated according to grid conditions (Chiesa et al., 2021, ES). V1G services are mostly specific, though not exclusive, to alternating current (AC) devices in the Slow and Quick segments. Indeed, vehicles remain connected to these devices clearly for longer and for this reason are more likely to offer useful services to the electricity grid (ARERA, 2021b).

Instead, in V2G the flow of power can be bidirectional, meaning that it also includes injections of power from the vehicle battery to the grid. Within V2G, there is the special example of V2H (vehicle-to-home), in which the energy contained in the vehicle battery flows only to the electrical circuit of the enabler where the charging device is installed, without reaching the electrical distribution grid (ARERA, 2021b). In order for bidirectional energy exchange to occur, the charging station must be equipped with a bidirectional inverter. In the case of AC charging, the charging stations are already capable of enabling bidirectional energy exchange. On the other hand, for DC charging, the protocol for V2G is CHAdeMO. In this case, the implementation of V2G is possible due to the fact that the inverter inside the vehicle is bidirectional. However, this results in higher vehicle-side costs (Chiesa et al., 2021, ES). In addition, another factor slowing the deployment of this technology is the difficulty of quantifying its actual benefits to the electricity system and, therefore, it is not possible to define an appropriate remuneration model for those who invest in this type of infrastructure. As a result, only a limited number of technology providers have implemented "V2G-compliant" solutions, both from the point of view of charging infrastructure and vehicles, although interest is growing significantly.

5.2.6. Integration of the Charging System into street furniture

The development of a widespread charging network often clashes with the desire to minimize the visual impact of charging infrastructure in the urban context. Therefore, to make their design more attractive, it was decided in some cases to integrate charging systems within elements of street furniture, such as street lighting lampposts and sidewalks. In addition, retractable infrastructure was developed to be visible only during use. In the case of charging stations integrated with lampposts, the existing street lighting infrastructure could be exploited, resulting in economic benefits from already being connected to the electricity grid. By contrast, during nighttime hours the use of the streetlight takes power away from charging (Chiesa et al., 2021, ES).

5.2.7. New Charging Technologies

Within the new technology trends there is the aferomentioned Battery Swap, which is the replacement of the discharged battery of EVs with a charged one in less than 5 minutes. This technology makes it possible to reduce the timing of the charging process, but at the same time it requires a highly automated infrastructure with high implementation costs. It also requires standardization of the battery module for the swap process to be effectively possible. However, the European market seems quite resistant to this initiative, while it is successful in the Asian market. Indeed, in China there are two major players operating in Battery Swap: NIO and BAIC (Chiesa et al., 2021, ES).

Another innovative trend is mobile charging, or off-grid charging, based on the temporal decoupling between the provision of the charging service and the withdrawal of electricity from the grid. As a result, this solution provides flexibility of charging location and charging time. To date, there are two main applications of mobile charging: vans and robots. The vans are equipped with an on-board battery and through a reservation system they reach the parked vehicle to dispense charging on site. This solution is especially useful in case of emergency charging, namely when the EV remains completely without range, or when the vehicle does not have enough remaining range to reach the nearest infrastructure. On the other hand, robots have a battery and can move autonomously within a limited context the provision of charging service and the withdrawal of electricity from the grid. Thus, it is as if they act as mobile charging stations with a storage system (Chiesa et al., 2021, ES).

New technology trends also include wireless charging, which can be either static or dynamic. Wireless charging is based on the use of magnetic resonance technology. The system consists of: a wallbox or a charging station and a Primary Coil placed inside the Ground Assembly that is responsible for transferring electricity from the wallbox/column to the car battery through the secondary coil placed inside the vehicle assembly (Bonalumi et al., 2019, ES).

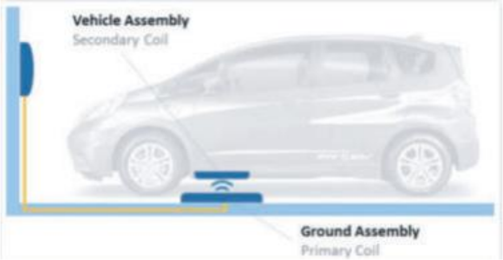


Figure 67: Wireless charging scheme (Bonalumi et al., 2019, ES, p. 250)

Finally, Solar Powered Vehicles are electric cars that use photovoltaic cells to convert solar radiation into electricity. Energy can be stored in the battery to allow the car to run even at night or on days with little sunshine. Solar panels can be installed on both the roof and hood of cars, substantially decreasing the amount of fossil fuels burned to produce electricity and reducing the amount of electricity for charging taken from the grid (Chiesa et al., 2021, ES).

5.3. Regulations and Investment

Investment in EV charging infrastructure and network planning must increase sharply to meet ambitious Net Zero Emission targets. China and Europe have the largest EV charging networks in the world. Their charging networks provide the highest percentages, 48% in China and 33% in Europe, of the global EV stock in 2021. This figure reflects the charging infrastructure improvements being pursued by China and Europe to meet growing consumer demand in areas, such as (Bibra et al., 2022, IEA):

- Standardization;
- Improved performance of charging stations;
- Wider coverage to include rural areas;
- Customer service;
- Greater flexibility to install technological innovations such as high-power chargers.

Indeed, mature markets must not only further expand the amount of charging stations to meet growing demand, but also ensure the development of a well-connected network even in rural areas. Usually, the lack of strategic infrastructure development, whether through central government planning or incentivizing policy mechanisms, tends to result in infrastructure being concentrated in only a few areas, often absent in remote regions. Furthermore, mechanisms such as access to property and network connections, supportive building codes, interoperability standards, and efficient permitting can be used to facilitate infrastructure development (Bibra et al., 2022, IEA).

Therefore, it must be ensured that the construction of charging infrastructure occurs in sync with the electric vehicle fleet to avoid becoming a potential bottleneck and limiting consumer adoption of electric vehicles. Four risks could turn charging into a bottleneck (Heldmann et al., 2021, McKinsey & Co.):

- Regulations: in many geographic areas, obtaining permits to build chargers, sites, and grid connection can take months or even years of planning;
- Power grid: especially in areas with high demand for charging, the power grid needs to be upgraded to adjust power capacity, resulting in costly and time-consuming interventions;
- Resources: there is a shortage of important resources, such as qualified technicians, manufacturing capacity for fast-charging hardware, and sufficient green power to make electric vehicles fully green;
- Costs: electric vehicle charging infrastructure is not cheap; in the European Union, a typical 350 kW charging station can cost $150,000, including hardware, installation and planning.

There are some actions that can be implemented to mitigate the threat of a shortage of electric vehicle charging infrastructure. All players in the electric ecosystem need to commit to this goal, but surely governments and charging companies are the ones who can make a difference. Governments can (Heldmann et al., 2021, McKinsey & Co.):

- Offer more incentives and warrants for the construction of private chargers;
- Subsidize public charging in needed locations, with subsidies for capital expenses for chargers, installation and distribution of power, as well as operating costs;
- Work with utilities providers to develop the electric grid;
- Link incentives and subsidies to green energy use;
- Simplify and standardize permitting to simplify and quicken procedures;

On the other hand, EV charging companies can (Heldmann et al., 2021, McKinsey & Co.):

- Invest in production capacity and a skilled workforce;
- Collaborate to finance public charging stations;
- Use data and analytics for network planning;
- Reduce autonomy anxiety among potential EV drivers by proactively addressing perceptions of potential problems associated with the transition from ICEV to EV.

Indeed, EV charging is a growing business opportunity. Electricity sales for EV charging currently account for about 55 TWh and are worth nearly $8.5 billion annually. In the Static Policy Scenario, the value of the electric charging market will increase to $135 billion per year by 2030, reaching nearly $190 billion if governments meet their national climate commitments (Bibra et al., 2022, IEA).

To create a global network of charging and refueling infrastructure to fully enable the widespread adoption of low- and zero-emission vehicles across all transportation modes, the European Union has proposed the Recharge and Refuel initiative as part of the Recovery and Resilience Facility. This initiative sets the goal of building half of the 1,000 hydrogen stations by 2025 and a third of the 3 million public charging stations needed by 2030 (European Commission, 2020). Bibra et al. (2022) estimate that 20 billion euros invested in charging infrastructure will be needed to achieve this goal by the target date. The European Commission has also proposed to transform the Alternative Fuels Infrastructure Directive into an Alternative Fuels Infrastructure Regulation (AFIR). Adoption of AFIR would automatically and uniformly oblige all member states to meet the targets set by binding legislation without having to transpose them into national laws. Under AFIR, member states will have to provide 1 kW of power for each light BEV registered in their jurisdiction and 0.66 kW for each light PHEV (Bibra et al., 2022, IEA).

Therefore, it must be considered that while first-generation EV buyers relied mainly on private charging, the next generation will depend on public charging. More than 50% of Europeans will live in multifamily houses without access to private chargers; thus, public chargers will need to ensure that EVs can make long-distance trips, as potential EV buyers still see this as the primary concern. Similarly, the regulatory processes for installing chargers in private homes require simplification, and the production capacity of wallboxes must increase. Increased production and simplified regulation are also needed for public chargers. Conzade et al. (2021) estimated that by 2030 the industry will need to install more than 15,000 chargers per week in the European Union. As a result, simplified regulations are needed to facilitate the placement of chargers, as it can currently take up to three years to obtain a network extension permit for a fast-charging station. Ensuring EU-wide coverage of public charging is essential to prevent chargers from being placed only in profitable locations (Conzade et al., 2021, McKinsey & Co.).

As for Italy, the PNRR promotes the development of electric mobility with 750 million euros in funding for the installation of 21,400 fast and ultrafast charging stations by the end of 2025 (Motus-E, 2021). RSE data show that by the end of 2021 in Italy there are (Armaroli et al., 2022, MISM):

- 26 thousand public charging stations;
- 13.2 thousand infrastructure, including stations and charging stations in 10.5 thousand sites;
- 24 thousand private charging systems.

In the different scenarios provided by the RSE, consistent with the Fir for 55 scenario, 45% of electric cars in 2030 will have to be recharged through public recharging. For this, 200 thousand charging stations will be needed, divided as follows (Armaroli et al., 2022, MISM):

- At least 4 fast charging stations, indicatively 100 kW, will be needed for each of the 462 service areas currently present on Italian highways, for a total of 1,850 highway fast charging stations;
- Italy's suburban roads extend for about 177,000 km. Charging stations on average are between 35 and 60 km away; therefore, 3,000 to 5,000 stations will be needed, with 2 to 4 fast charging stations each. This would require 10,000 suburban fast charging stations;
- For cities, 20 thousand fast charging points are assumed, but above all, conventional charging systems, i.e., up to 22kW AC, must be provided, which will amount to 81,500 charging stations with two charging points each.

Finally, again in line with the Fit for 55 scenario, 3.6 million private charging stations will need to be installed in both residential and business services (Armaroli et al., 2022, MISM).

5.4. Comparison between Public and Private Charging

As seen in Chapter 5.1, charging stations can be considered public or private based on their accessibility. This distinction is important because while the installation of private charging stations is prerogative of the individual consumer or at most the apartment building, public charging stations must be installed by companies and governments. A non-differentiated analysis of charging stations does not provide an effective understanding of the level of advancement of the charging infrastructure, whether at the global, European, or Italian level. Therefore, the following will analyze public charging stations first, and then end with private ones.

5.4.1. Public Charing

Globally, there will be at least 1,700,000 available public charging stations by the end of 2021, a 35% growth over 2020. New installations show a slight slowdown from the previous year. More than 67% of these charging stations are standard power, with the remaining being high power. This shows that public charging has expanded despite the slowdown in construction due to the pandemic (Boisrond et al., 2022, ES; Bibra et al., 2022, IEA).

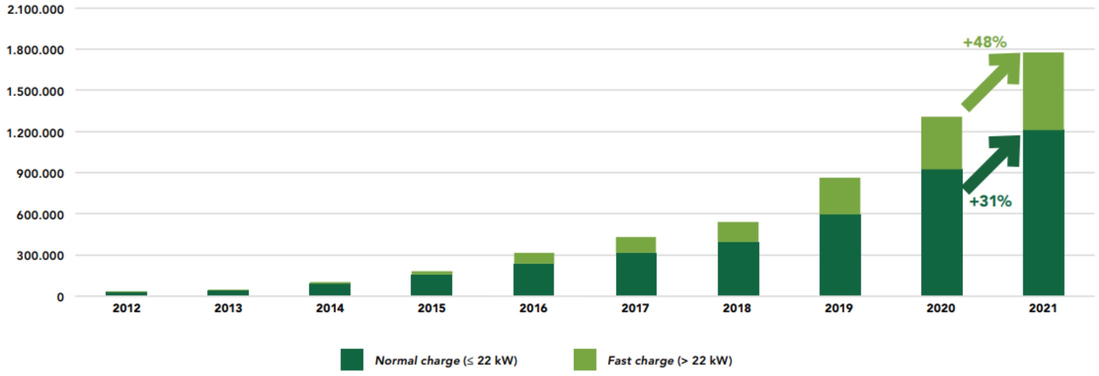


Figure 68: Public charging stations globally (Boisrond et al., 2022, ES, p. 147)

Moving on to analyze the geographic breakdown, China is still the world leader for both standard and high recharge, with 56% and 82% of the global market, respectively, due in part to its very densely populated cities. In second and third place, for both recharges, are Europe with 25% of the global market and the United States with 8% (Boisrond et al., 2022, ES). The problem in other world regions is the slow pace at which fast and ultra-fast public infrastructure is being developed, as this is a barrier in the adoption of electric cars. China is the only virtuous example in this direction, where more than 40% of publicly available charging units are fast chargers, well above other major EV markets. The factors behind the rapid spread of public chargers in China are government subsidies and active infrastructure development by utilities. Thanks to regulatory controls on electricity prices, the demand for public charging from urban residents and the increasing electrification of cabs, ride-sharing, and logistics fleets have improved the profitability of electric vehicle charging activities (Bibra et al., 2022, IEA).

Figure 69: Geographical distribution of charging stations with power less (left) and more (right) than 22 kW in 2020 (Boisrond et al., 2022, ES, p. 148)

Looking forward using IEA scenarios, public charging stations in 2030 will be less than 10%, confirming the trend whereby most charging takes place in private homes or at work. However, this 10% will constitute almost 40% of the installed capacity, due to higher powers (Bibra et al., 2022, IEA).

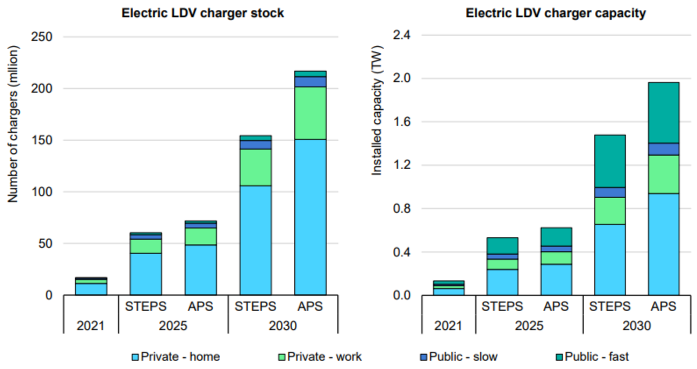


Figure 70: Electric Light-Duty-Vehicle (LDV) chargers and cumulative installed charger power capacity by scenario, 2021 – 2030 (Bibra et al., 2022, IEA, p. 119)

In terms of the countries involved, in 2030 Europe is expected to begin to have a significant weight in slow charging stations, but China will continue to dominate, especially in fast charging stations (Bibra et al., 2022, IEA).

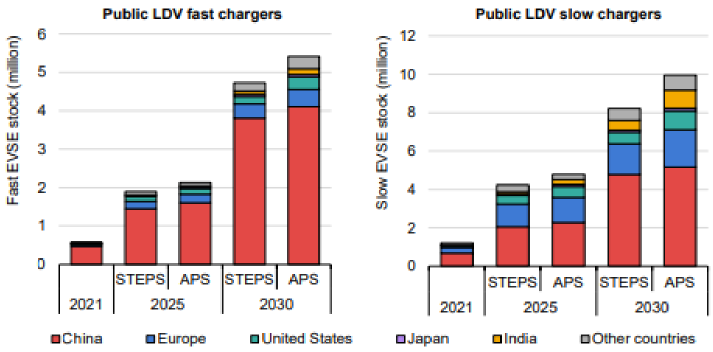


Figure 71: Public LDV chargers by region and scenario, 2021 – 2030 (Bibra et al., 2022, IEA, p. 123)

Furthermore, projecting to 2030, IEA argues that as the number of publicly accessible charging stations increases, installation costs will decrease due to economies of scale. In China, the cost of chargers decreased by 67% from 2016 to 2019 for example. On the other hand, these benefits may be offset by the large costs required for network upgrades. Moreover, it is assumed that as the share of electric vehicles increases, the number of public chargers per vehicle decreases. This may be a problem, but actually having a large number of charging stations per vehicle initially serves to encourage adoption, but until the number of EVs increases, the utilization rate of each charger may be low. A low utilization rate makes it difficult for operators to recover capital costs and make profits. Therefore, at this stage, the government needs to support operators by strengthening the affordability of public charging stations. Thus, in the long run, government support could still be helpful in ensuring that charging infrastructure is available to all citizens, including those in rural and low-income areas (Bibra et al., 2022, IEA).

Turning the analysis to a European level, there are at least 338,000 public charging stations at the end of 2021, 74% more than in the previous year. However, most of these, nearly 88%, are normal charge, while the remainder are fast charge. On the positive side, fast charge points have increased by 72% from the previous year (Boisrond et al., 2022, ES).

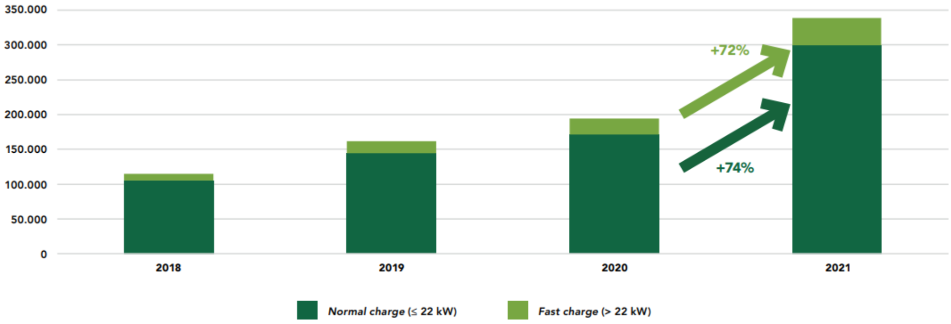


Figure 72: Public charging stations in Europe (Boisrond et al., 2022, ES, p. 149)

Moving on to analyze the density of charging stations and EVs relative to population, there is some unevenness among European countries. Norway and the Netherlands are at the top of the list, both for EVs, but especially for public access charging infrastructure, that they are out of scale in the graph below. Specifically, Norway has 350 charging stations per 100,000 population, while the Netherlands has 525 per 100,000 population. Instead, Spain, Italy and Portugal show the most limited uptake of e-mobility with a range of 25 and 45 charging stations per 100,000 inhabitants.

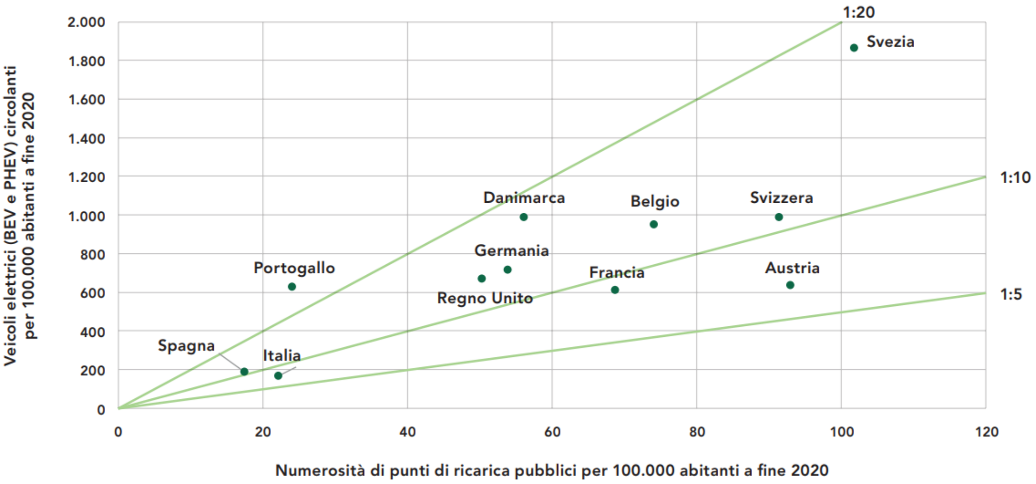


Figure 73: Ratio of charging stations to circulating EVs per 100,000 population in major European countries at the end of 2021 (Boisrond et al., 2022, ES, p. 154)

Instead, when analyzing the ratio of the number of charging infrastructures to the number of EVs, Italy is above the European average, second only to the Netherlands, demonstrating a capillarity of charging service. Indeed, when it comes to high-power charging stations, the percentage in the Netherlands is 3.8% while in Italy it is 9.7%. Norway is unexpectedly last in this ranking, but it has a large penetration of private charging infrastructure due to its different urban planning model, when compared with the one of Italy. However, if the number of electric vehicles per inhabitant in Italy does not start to increase, the growth rate could decrease since there would be no return on investment for the creation of public charging stations (Motus-E, 2021).

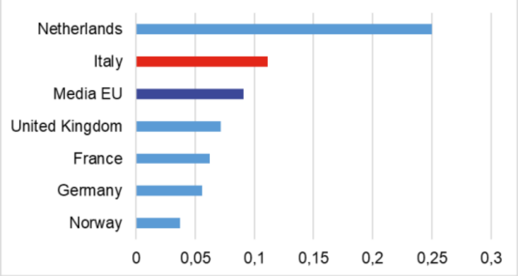


Figure 74: Charging stations for each EVs in different European countries (Motus-E, 2021, p. 6)

Looking in detail at the situation of public charging infrastructure in Italy, there are more than 26,860 public charging stations in 2021, an increase of 75% compared to 2020, in line with the European average. More than 86% of these charging stations have a power rating of less than 22 kW, although the growth of fast charge stations is 158%, compared to the 67% of the normal charge one (Boisrond et al., 2022, ES).

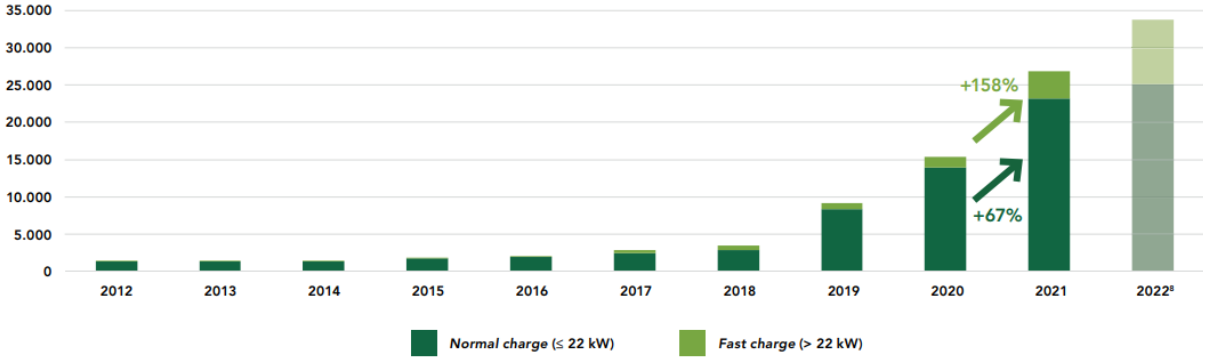


Figure 75: Public charging stations in Italy (Boisrond et al., 2022, ES, p. 159)

The positive trend continued in 2021, with a 35% increase in public charging stations and a 36% increase in charging infrastructure (Motus-E, 2021).

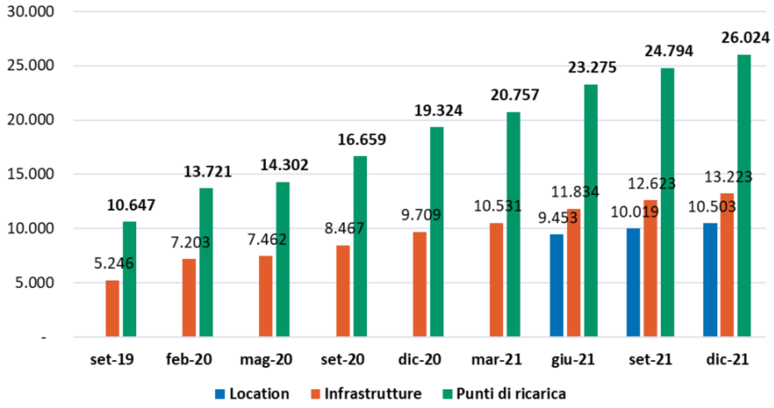


Figure 76: Evolution of infrastructure and charging stations in Italy (Motus-E, 2021, p. 9)

Among these infrastructures, 80% are on public land, with the rest located on private land for public use. The rate of inactive infrastructure decreased from 22% in 2020 to 12% in 2021, demonstrating the effectiveness of efforts to improve permitting processes by both local distributors and governments. However, there is still plenty of room for improvement in order to reduce the time required for activation as much as possible (Motus-E, 2021).

In terms of the number of public charging stations and EVs per 100,000 inhabitants in the regions, in 2022 Trentino Alto Adige has the highest uptake of e-mobility with 170 charging stations and 6,000 EVs per 100,000 inhabitants, significantly ahead of the other regions. Indeed, especially in southern Italy, there is limited uptake of e-mobility across the rest of Italy, with less than 40 charging stations and 200 EVs per 100,000 inhabitants. Tuscany shows the highest growth rate, with +320% compared to end of 2020. (Boisrond et al., 2022, ES).

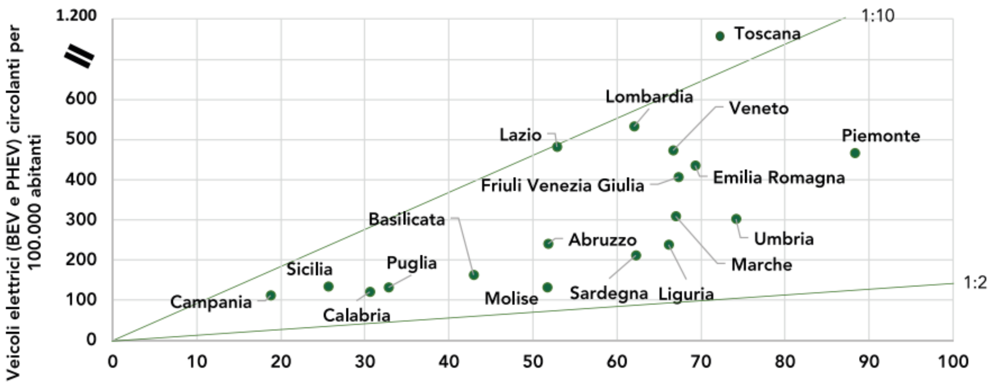


Figure 77: Ratio of charging stations to circulating EVs per 100,000 population in different Italian regions (Boisrond et al., 2022, ES, p. 162)

As far as highways are concerned, 118 public charging stations are installed in Italy in 2021, of which 78% recharge at powers greater than 43 kW (DC), while the remaining 22% have a charging power less than or equal to 43 kW (AC). To date, the absence of a sufficient number of charging stations in service areas or along highways is perceived as a user inconvenience. More widespread deployment of charging stations, especially at powers of at least 150 kW, would be needed (Motus-E, 2021). In general, the diffusion of ultra-fast charging in Italy is still marginal, with only 0.6% of the total. Most regions have less than 2 ultra-fast charging stations per 100,000 inhabitants. The only regions out of scale are again Trentino-Alto Adige and Valle d'Aosta, with about 4 and 12 ultra-fast charging stations per 100,000 inhabitants, respectively (Chiesa et al., 2021, ES).

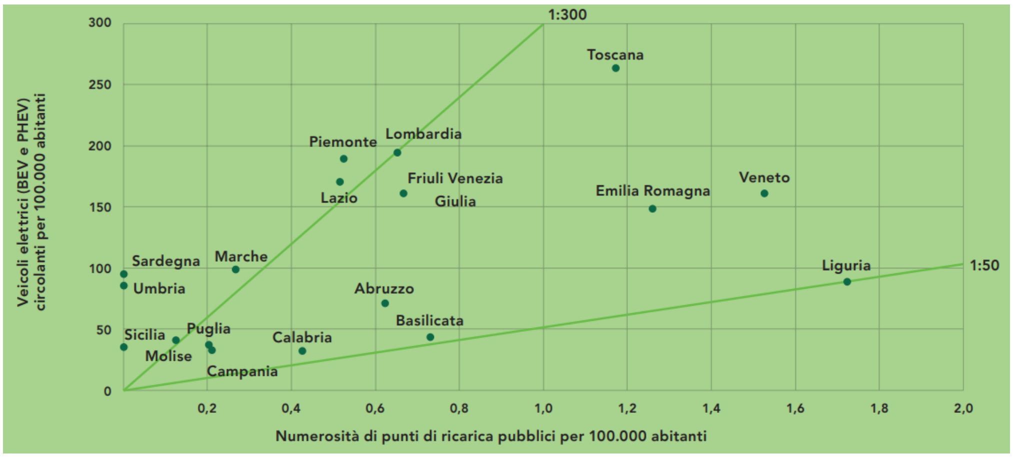


Figure 78: Ratio of numbers of ultra-fast charging stations per 100,000 population in different Italian regions (Chiesa et al., 2021, ES, p. 168)

However, significant growth of the ultra-fast infrastructure in Italy is expected in the coming years. Indeed, it is a strong stimulus to the spread of electric mobility, since more than 50% of electric car owners consider the presence of such points of paramount importance in promoting the spread of electric mobility. The availability of ultra-fast charging stations would also have a very positive impact on the propensity to make trips longer than 200 km. To actually analyze the use of charging infrastructure, market research by Energy & Strategy found that 72% of electric car owners use public charging stations, but the price of public charging is considered too high by 79% of the EV's owners who don't use public charing. Other barriers to utilization are the low speed of charging and the lack of coverage in the area, but also problems regarding the operation of the charging station itself, which is often found to be faulty, busy or otherwise difficult to use. For this reason, home charging is often preferred. Indeed, consumers argue that it is essential first and foremost to have effectively functioning infrastructure, but also that they are reasonably priced and adequately fast, all with easy-to-use technologies. As for future projections, according to Energy & Strategy's scenarios, in 2030 a minimum of 67,000 charging stations is expected in the Business-as-usual scenario to a maximum of 127,000 in the Decarbonization scenario. This wide spread in absolute value depends on a number of factors, such as new funds from the PNRR and the forecast of fast charge infrastructure growth (Boisrond et al., 2022, ES).

5.4.2. Private Charging

Moving on to private charging stations, globally in 2021 there are estimated to be more than 15 million charging stations with a growth rate of 58%, of which 70% represent domestic ones and the rest business ones. In absolute terms, this is 8.8 times that of available public and private public access charging stations and at about 0.91 times the number of electric vehicles on the road (Boisrond et al., 2022, ES).

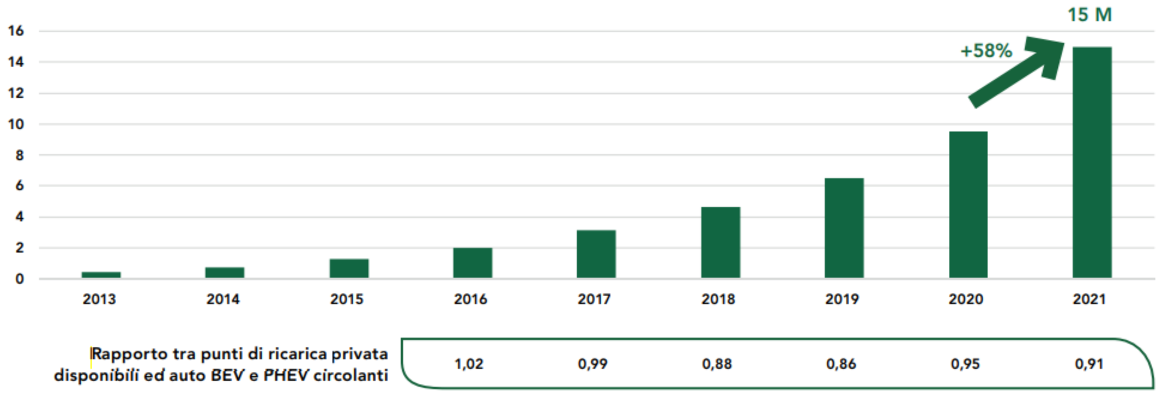


Figure 79: Private charging stations globally (Boisrond et al., 2022, ES, p. 167)

Therefore, it is clear that car charging is and will likely be dominated by private charging. Looking forward, in 2030 private chargers account for 90% of all chargers in the various IEA scenarios. However, they account for only 65% of installed capacity due to lower power compared to public chargers. Access to home chargers is the main determinant of private versus public charging behavior. Indeed, most people who buy EVs for the first time have access to and use their home charger as their primary source of charging, as they can benefit from lower electricity rates and are not dependent on a small public charging infrastructure. However, accessibility to residential charging varies significantly among population groups within the same country and across countries. Considering the current composition of household types and vehicle ownership, it is estimated that in Europe and the United States between 50% and 60% of all cars are owned by households with access to residential charging, while in China the same figure is less than 40%. Moreover, by 2030, according to IEA scenarios less than 15% of the car fleet will be electric in most countries, thus the majority of EV owners will plausibly continue to have access to a residential charger. The relatively low share of new construction in Europe means that upgrading buildings will also have to play an important role. Simultaneously, policies must ensure fair and affordable access for people who will rely primarily on public chargers to reduce charging barriers for apartment residents (Bibra et al., 2022, IEA).

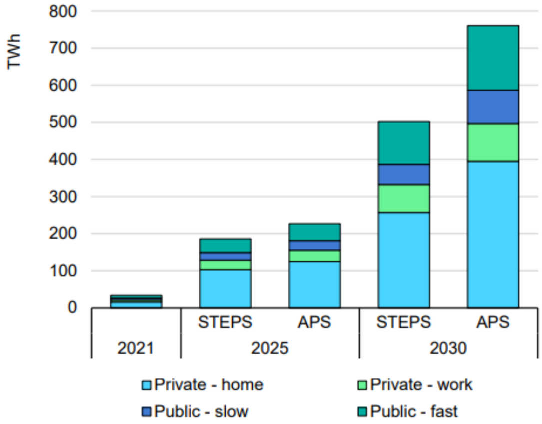


Figure 80: Electricity demand by charger type and scenario, 2021-2030 (Bibra et al., 2022, IEA, p. 122)

Regarding Italy, there are more than 88,000 private charging stations in 2021, more than triple the number in 2020. Of these, 90% are wallbows and the rest are charging stations. (Boisrond et al., 2022, ES).

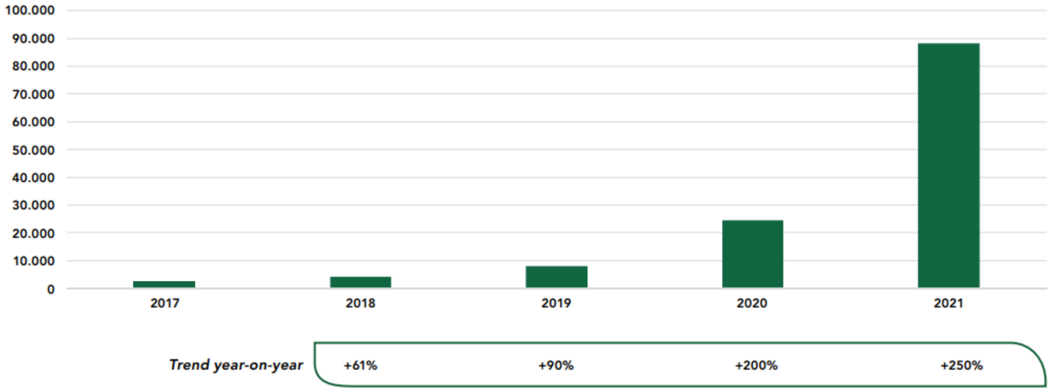


Figure 81: Private charging stations installed annually in Italy, 2017-2021 (Boisrond et al., 2022, ES, p. 168)

Among these private charging stations, 50-55% are installed in Northern Italy, 30-35% in Central Italy, and the rest in Southern Italy and the Islands. At the same time, the total charging stations are divided between the residential and business sectors, 60-65% and 35-40% respectively. It is clear, therefore, that home charging is critical. Energy & Strategy estimated that even nearly 38% of electric car owners recharge their cars with the home charging station in 80 to 100% of the total recharging done. In addition, 72% of electric car owners have installed a home charging station, of which more than 85% were installed at a private garage/space. Most of the installations, about 50%, are 3.7 kW or less and still all are below 22 kW. The most prevalent connector is Type 2, followed by the Schuko. Only 13% of electric car owners do not have and do not plan to install a private charging point, and the reasons lie mainly in the fact that they do not have adequate space in which to install the wallbox or they have the option of charging the car at their workplace or at public charging stations near their home. Instead, the drivers that guide the decision to purchase a home charging station are ease of use and cost, but also the ability to manage charging via an App, the availability of smart features, and the speed of charging. Looking forward, according to Energy & Strategy's estimates, private charging is and will continue to be a key asset for electric mobility diffusion. As for Italy, in the Business-as-usual scenario, the number of private charging stations in 2030 will reach 2.2 million. Instead, in the more optimistic estimates of the Policy-driven scenario and the Decarbonization scenario, the number stands at 3.2 and 4 million units, respectively (Chiesa et al., 2021, ES).

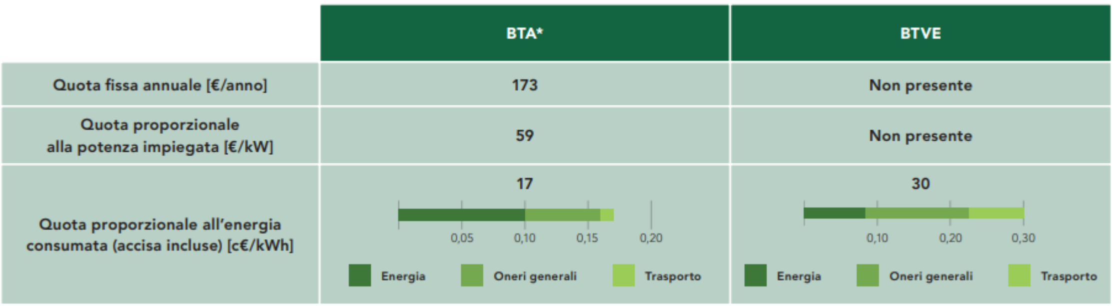
5.5. Costs

Consumers are very sensitive when it comes to the purchase price of an EV, but even if this were to be incentivized by economic bonuses, the issue of the cost of charging and, in more special cases, the purchase and installation of charging stations remains.

5.5.1. Cost of Charging

One of the factors that often frightens consumers is the uncertainty regarding the cost of charging for an electric vehicle. However, the price can vary greatly by charging. For example, residential rates, those for home charging, are cheaper. Moreover, with increased deployment of distributed generation such as solar and photovoltaics, it can become even cheaper. Instead, public charging stations tend to be more expensive, as operators have to budget for capital expenditure on equipment and land acquisition or leasing, as well as higher fixed grid connection costs due to high power ratings. In Europe and the United States, prices for public fast charging are two to four times higher than residential rates. On the other hand, in China they are only twice as high. The reason for this is economies of scale in the production of charging stations (Bibra et al., 2022, IEA)

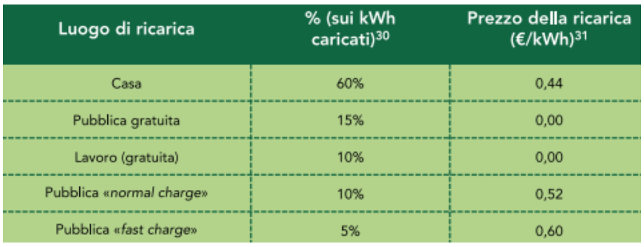
In particular, in Italy, public charging service has to be developed in competition, so there are countless players, such as charging station operators, mobility service providers, and commercial establishments that provide charging services under very different economic conditions. Indeed, charging can be billed based on energy consumption, parking occupancy time, or subscription composed of a fixed monthly cost and a variable cost per kWh recharged (ARERA, 2021a). To date, three-quarters of public charging is done on a per-energy basis. Particularly, ARERA from 2012 until 2023 has defined a tariff structure for low-voltage charging points dedicated exclusively to electric vehicle charging stations in publicly accessible locations, called BTVE (Bassa Tensione Veicoli Elettrici - Low Voltage Electric Vehicles). Alongside this tariff, there is another one for transport and general system charges applicable to non-domestic consumers connected at low voltage, called BTA, which is composed of annual fixed fee, fee proportional to power, and fee proportional to energy consumed. Of the two, the BTVE tariff is much cheaper in the common usage of about 100 hours per year (Chiesa et al., 2021, ES). A summary table below explains the difference between the two tariffs in more detail:



	BTA*	**BTVE**
Quota fissa annuale [€/anno]	**173**	**Non presente**
Quota proporzionale alla potenza impiegata [€/kW]	**59**	**Non presente**
Quota proporzionale all'energia consumata (accisa incluse) [c€/kWh]	**17**	**30**

Table 4: Comparing recharge rates in Italy (Chiesa et al., 2021, ES, p. 276)

Obviously, the price of recharging differs according to the place where it is done. Below are the prices of recharging in Italy, based on location and power:



Luogo di ricarica	**% (sui kWh caricati)[30]**	**Prezzo della ricarica (€/kWh)[31]**
Casa	60%	0,44
Pubblica gratuita	15%	0,00
Lavoro (gratuita)	10%	0,00
Pubblica «*normal charge*»	10%	0,52
Pubblica «*fast charge*»	5%	0,60

Table 5: Recharging prices in Italy, based on location and power (Boisrond et al., 2022, ES, p. 273)

Regarding price sensitivity, according to a survey by Energy & Strategy, 55% of electric car owners would be willing to pay more for charging if it could be done faster. Specifically:

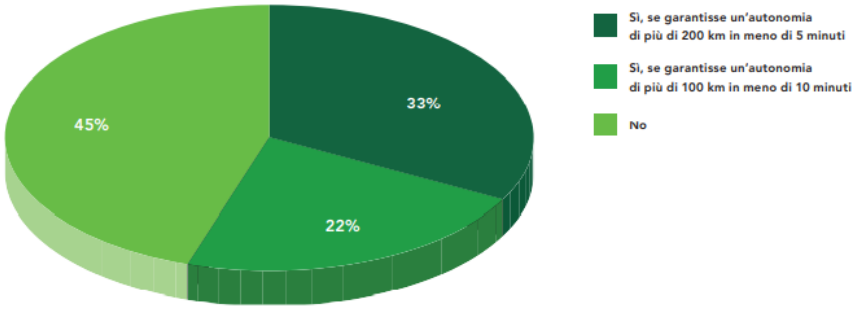


Figure 82: Sensitivity to EV owners' charging price compared to speed (Chiesa et al., 2021, ES, p. 344)

Instead, for private charging, costs depend on (ARERA, 2021a):

- The ability to use an already active point of delivery or the need to have to activate a new one;
- The ability to smartly manage the simultaneity of loads;
- The ability to meet part of the energy requirements for charging through self-generation;
- The ability to aggregate condominium boxes of different owners into a single consumption unit;
- The cost of the "energy matter" component provided by the different commercial offers available on the market.

In the case of private domestic recharging, the domestic tariff is applied in Italy, through the electric utility already active for domestic use. The typical committed power in the domestic setting is 3 kW, but if the electricity counter needs to be increased, the user must incur additional fixed costs and a fee for each kW of additional power required (Chiesa et al., 2021, ES).

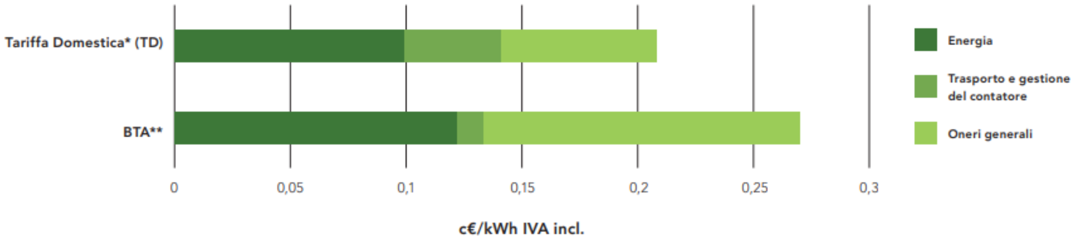


Figure 83: Proportional share of energy consumed in Italy (Chiesa et al., 2021, ES, p. 279)

5.5.2. Cost of Purchasing and Installing Charging Infrastructure

Effectively analyzing the purchase prices of charging devices is quite complex, as there is a wide variety of products with as many different business approaches. It is also particularly difficult to analyze economies of scale, which strongly impact purchase costs. An example is the difference of price between quick and fast charging devices, which are used solely by charging point operators to build entire infrastructures, and slow charging devices, which are characterized instead by single B2C sales. However, to really understand the purchase price, it is important to analyze the length of the distribution chain. For the same maximum charging power, the final price is largely related to the components needed to manage user interactions, such as displays, RFID/NFC chips, and control capabilities via mobile applications. However, the price also varies greatly depending on the power output. For example, in Italy (ARERA, 2021b):

- Slow charging devices: average expense for purchase and home installation of a wallbox capable of delivering no more than 7.4 kW can be estimated at €1,200 including VAT. This cost is composed of the wallbox itself and its installation. The cost of the wallbox can change depending on the power (3.7 or 7.4 kW), whether the system is single-phase or three-phase, the possibility of integrating web connectivity and remote control services, the presence of an automatic local load management system, and the possibility of having RFID;
- Quick charging devices: the basic products in this segment, i.e., single-socket, with 11 kW power and without any authentication mechanism, nor internet connection, can have prices slightly higher than those in the previous segment, i.e., between €700 and €1,300 + VAT. Instead, for a charging coloumn with 2 charging stations, each with 22 kW, typical prices can range from 2,000 to 4,000 € + VAT. The highest price range, between 3,000 and 4,000 € + VAT, corresponds to full-featured devices, such as RFID and Internet connections via LAN, via Wifi or with SIM on board the device;
- Fast charging devices: in this market segment, as explained in Chapter 2, direct current (DC) products, alternating current (AC) products, and bivalent (DC+AC) products coexist, and price analysis cannot ignore this distinction. In AC products, 44 kW single-socket charging stations can be found with prices ranging from €7,000 to €9,000 + VAT. Instead, for DC products, a 50 kW charging station ranges between 22,000 and 29,000 € + VAT;
- Ultra-Fast Charging Devices: the market segment is characterized by a very wide range of charging powers delivered in DC, but a price distinction can be made between two ranges, for charging stations with powers below or above 150 kW. For charging stations with power ratings below 150 kW, list prices range between €26,000 and €40,000 + VAT, increasing with the power delivered, while for charging stations with power ratings above 150 kW, prices range between €54,000 and €80,000 + VAT.

Therefore, it can be concluded that DC devices are generally about twice the price of AC devices.

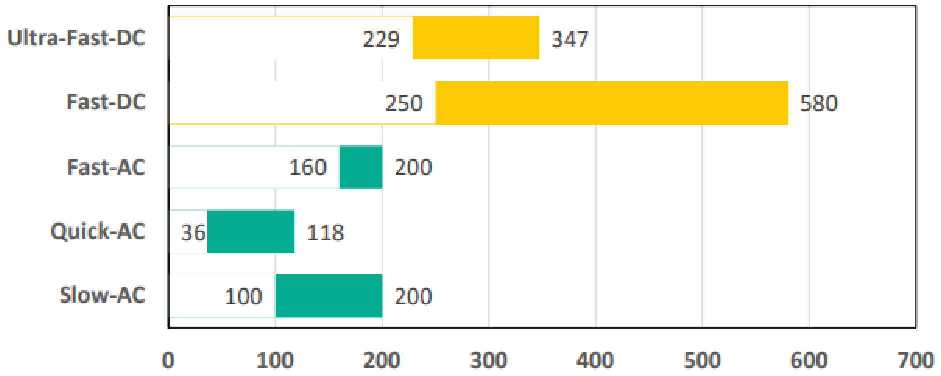


Figure 84: Unit prices [€/kW] for the purchase of charging devices based on power and charging type (ARERA, 2021b, p. 27)

5.6. Location

The capillarity of charging stations needs to be put in place by charging companies and encouraged by governments. However, the growth of fast-charging infrastructure implies the need for more spaces to actually charge EVs. In an effort to meet demand, remove the perceived inconvenience for those still hesitant to switch to EVs, and help meet CO2 emission reduction targets, charging stations are being built everywhere from homes to workplaces, from retail outlets to fleet depots, and on-the-go charging sites (Heldmann et al., 2021, McKinsey & Co.). The EV per charger ratio can help assess the suitability of the charging network. Indeed, the appropriate number of chargers per EV depends on a number of factors, including (Bibra et al., 2022, IEA):

- The power of the charger, as fast chargers can serve more EVs than slow chargers;
- The housing stock;
- The average distance traveled by a user;
- The population density;
- The percentage of PHEVs and BEVs, since PHEVs normally need less public charging.

In most countries, it has been observed that as the share of BEVs increases, the ratio of charging stations to BEVs decreases. Similarly, countries with a relatively low share of EVs tend to have a low ratio of EVs to charging stations, as initial infrastructure development may precede EV sales (Bibra et al., 2022, IEA).

Hosseini & Sarder (2019) identified which locations are best for charging stations, following the goal of maximizing the sustainability of the installation. To do so, they analyzed four main criteria, economic, environmental, social, and technical:

- Environmental criterion, within which there are three additional subcriteria:

  - Air quality: reducing air pollution is one of the most important motivations for the use of electric vehicles in polluted cities. Therefore, priority of charging infrastructure locations is given to cities and neighborhoods with the highest pollution levels;
  - Waste discharge: during the construction of infrastructure, the amount of waste water discharged should also be measured, as this could cause environmental damage in the location under consideration. In addition, the disposal of batteries that will be needed during the life cycle of the infrastructure should also be taken into account;
  - Degree of destruction of water resources: land development for infrastructure construction often involves the deterioration of groundwater resources.
- Economic criterion, which in turn consists of:
  - Cost of land: it must be economically evaluated whether it is worthwhile to rent or buy the land on which the infrastructure will be developed;
  - Cost of building the infrastructure;
  - Maintenance costs, which can be divided into preventive and corrective costs for repair and replacement of parts of the charging stations.
- Social criterion, which is broken down into:
  - Traffic convenience, determined by the number of intersections within a 5 km radius of the site location. It was found that the desirable location of the site in terms of traffic convenience should cover at least 5 intersections within a 5 km radius. However, this distance may vary depending on factors such as the density of the city, the ratio of electric vehicles entering the charging station, and the number of electric vehicles passing through the charging station;
  - Level of service, in terms of the number of electric vehicles that can be served by the charging station;
  - Population density: priority for the construction of charging stations is given to the highest density neighborhoods. Indeed, the demand for charging is higher in these locations;
  - Location security: construction priority should be given to locations that are safe 24 hours a day for public access without major threats. These areas must also be well lighted for planned nighttime charging.
- Technical criterion, mainly composed of the time of power failure for example due to a breakdown. The technical criterion therefore refers to the reliability of the power supply in the vicinity of the site. Power supply reliability is defined in terms of time to failure or time between power outages. It is obvious that sites with a longer time to power outages are more reliable.

Furthermore, regarding the optimal location of vehicles, Bhattacharya et al. (2021) found that the location of infrastructure does not have to be on main roads. Indeed, the goal is to place infrastructure in locations where the investment costs for the land are not high and the energy loss of the distribution network is minimal. Rather, the optimal location would be in secondary roads, not remote from the main one.

Regarding the specific case of Italy, Motus-E (2021) conducted a study to identify which are the best places to install quick, fast and ultra-fast charging stations:

- Quick charging stations are to be preferred in urban and/or medium-long stay contexts and currently represent 73.6 percent of the total in Italy. In particular, it is optimal to place them:
    - On the side of roads, near parking areas, so as to recharge the vehicle during overnight parking;
    - In the interchange parking lots of large certain urban areas, to recharge the vehicle during the day. In this way, users can manage the home-work trip with an electric vehicle even in cases where company parking lots do not have private charging facilities;
    - At points of interest, to recharge the vehicle while parked at attractive hubs characterized by a large influx of people, such as stadiums, cultural or tourist points of interest.
- Fast and ultra-fast charging stations are essential to provide charging service in the shortest possible time, with a goal of stopping for the specific purpose of recharging, often on highways and in suburban areas, and constitutes 6.1% of the total today. Specifically, the ideal location would be in:
    - Service areas of highways or freeways for rapid recharging when travel exceeds the vehicle's maximum range;
    - Rail stations, airports, and local and suburban public transport nodes for rapid vehicle recharging;
    - Loading and unloading freight areas and logistics nodes, in order to rapidly recharge vehicles through networks designed to deliver goods in urban areas with parking stalls comparable with light commercial vehicles.

On the other hand, Energy & Strategy (2021) identified the current location of public and private public access charging stations in Italy. The research showed that there is a clear predominance of urban installations, about 55-60%, on-street or in public parking lots, but points of interest also cover an important role with 30-35% of the total charging stations, with the rest being suburban charging stations. It should be highlighted that a charging station at a point of interest is a strong incentive for the owner of an electric vehicle to go to that point of interest.

6 Conclusion

The mobility market present numerous alternatives to the current fuel-based ones. Fuel retailers have realized that the fuel distribution market, although always one of the most resilient within the oil and gas industry, cannot remain the sole driver of mobility for much longer. For this reason, fuel retailers are increasingly looking to diversify their businesses with service, alternative fuels and non-fuel retail. In this context, Smart Mobility enters the picture, which seeks to embrace current transportation trends such as electrification, alternative fuels, x-sharing, vehicle-grid integration, and autonomous driving.

The most important technological alternatives to traditional ICEVs are BEVs, HEVs, PHEVs, FCEVs, vehicles powered by LNG, biofuels, and synthetic fuels. In a current situation of climate and energy emergency, a considered choice must be made of the solution that is deemed most efficient for the energy transition. Indeed, it does not make sense to spread investments over several solutions, as it involves a major economic, technological and infrastructural effort.

It emerges from this discussion that as far as ICE cars are concerned, the fastest implementable decarbonizing solution is electric cars. Indeed, BEVs have high propulsion efficiency, lower lifecycle emissions, and can be integrated with smart electric grids. However, there are barriers regarding the mass adoption of electric cars. These limitations include the purchase price, at least 30% more than an equivalent ICEV, the perceived inadequacy of the charging infrastructure, and, more for governments, the lack of consumption taxation. On the other hand, these limitations can be easily offset by various measures, such as purchase incentives, new taxation policies, and the development of an extensive charging infrastructure. Instead, as far as transportation over long distances is concerned, especially for trucks, ships and planes, electrification is not possible. Consequently, transportation dercarbonization in these cases can take place through other energy carriers, such as LNG and advanced biofuels.

Finally, the analysis of charging infrastructure showed that Italy is above the European average in terms of the number of charging stations for EVs. However, 70% of EV owners have a home charging station and 46% use it as their exclusive charging system. These figures indicate a marked improvement and increased confidence for the charging infrastructure. However, there remains a need for more development of the charging infrastructure at highways, with particular emphasis on ultra-fast charging stations, which are considered key to stimulating EV mobility as they enable the ability to make long trips. In general, the transition to electric mobility seems to be succeeding, as 90% of EV owners do not consider going back to using an ICEV.

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A Appendix: IEA's Scenarios

IEA's World Energy Outlook develops scenarios to examine future energy trends. Each scenario is based on different assumptions about how the energy system might evolve. This approach makes it possible to compare different possible versions of the future, with the goal of developing different solutions. In 2021, four scenarios were developed (IEA, 2021a):

- Net Zero Emission Scenario: this is a normative scenario, designed to achieve specific goals. Specifically, a pathway is defined to bring the net CO2 emissions of the global power sector to zero by 2050;
- Scenario Announced Pledges: this scenario is exploratory, as it defines baseline conditions and, based on modeling representations, assumes how they will evolve in the future. The scenario assumes that all climate commitments adopted by governments will be met on time;
- Stated Policies Scenario: this is also an exploratory scenario and reflects current policy positions versus those announced;
- Sustainable Development Scenario: like the net zero emission scenario, it is normative. It identifies a pathway to ensure universal access to affordable, reliable and sustainable energy services by 2030 to reduce pollution and fight climate change.

B Appendix: Effort Sharing Regulation

In 2018, the Effort Sharing Regulation was adopted, which sets national targets for the reduction of emissions from:

- Road transport;
- Heating of buildings;
- Agriculture;
- Industrial plants;
- Waste management.

Prior to this regulation, the sectors previously listed were not included in the EU ETS, but they generate 60% of the EU's GHG emissions. The Effort Sharing Regulation is set up in such a way that all member states contribute equally, distributing efforts according to GDP per capita. Countries with higher GDP per capita have higher emission reduction targets. Each member state has annual emission targets, which are reduced each year with a view to 2030. Obviously, there are ranges of flexibility to allow member states to meet the targets in a cost-efficient manner (European Commission, 2021b).

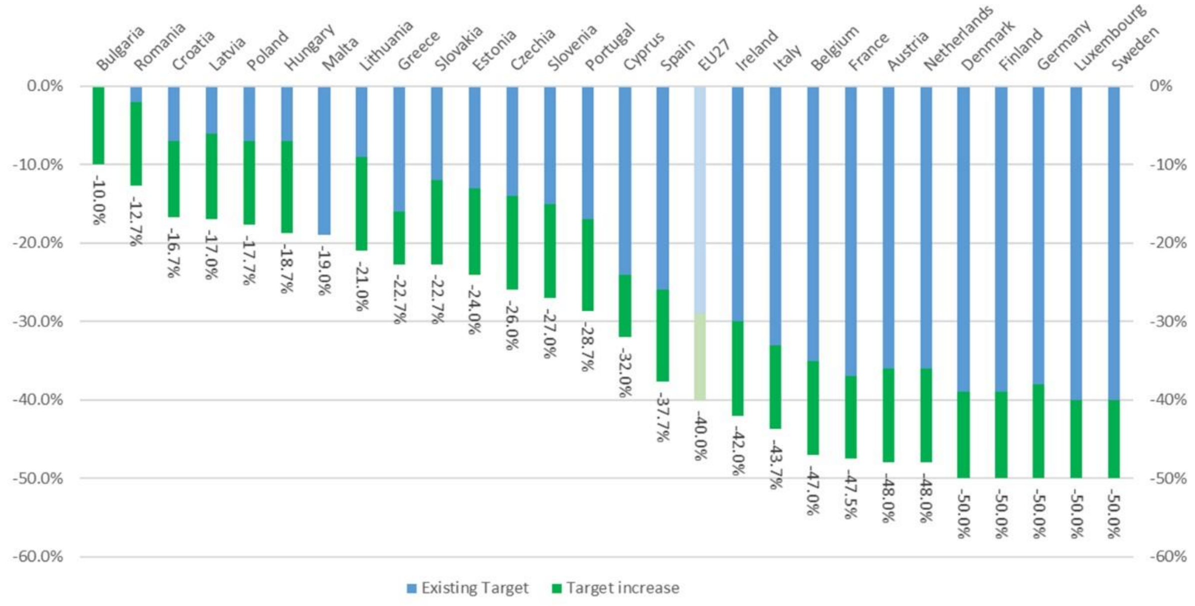
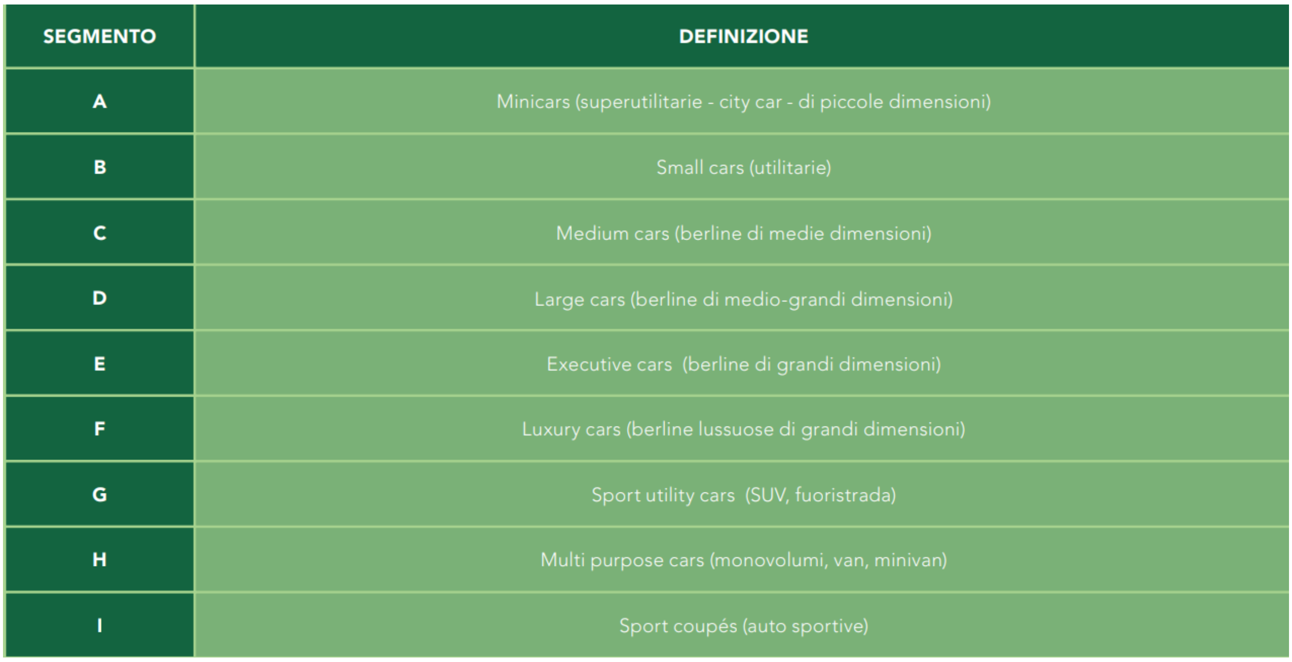


Figure 85: Effort Sharing Regulation Mechanism, with the comparison between the existing targets and the target increases for each EU Member State (European Commission, 2021b)

C Appendix: Car Segments

The convention of segments has been adopted to distinguish different models of passenger cars. Segments make it possible to identify to which category a car belongs on the basis of its size. In the European market, these segments are denoted by the letters of the alphabet, A through D enclosing the main ones, but the segments go up to I (Automobile.it, 2021):

- Segment A: In Europe, this refers to citycars, i.e. hatchback cars with compact measurements, suitable for city traffic. Some example models are the Citroen C1, Fiat 500, Fiat Panda, Toyota Aygo and Hyundai i10;
- Segment B: This includes small cars that are about 4 meters long. It is one of the most competitive segments, some models that belong to it are Lancia Ypsilon, Ford Fiesta, Renault Clio, Opel Corsa, Peugeot 208;
- Segment C: indicates cars longer than 4 meters. It is by far the most contested segment in the European market. The reference model is Volksawagen Golf;
- Segment D: refers to cars between 4.5 and 5 meters in length. In this case, we talk mostly about three-box sedans and SUVs. The most popular models are BMW 3 Series, Audi A4, Mercedes C-Class, Alfa Romeo Stelvio, Volkswagen Tiguan.



SEGMENTO	DEFINIZIONE
A	Minicars (superutilitarie - city car - di piccole dimensioni)
B	Small cars (utilitarie)
C	Medium cars (berline di medie dimensioni)
D	Large cars (berline di medio-grandi dimensioni)
E	Executive cars (berline di grandi dimensioni)
F	Luxury cars (berline lussuose di grandi dimensioni)
G	Sport utility cars (SUV, fuoristrada)
H	Multi purpose cars (monovolumi, van, minivan)
I	Sport coupés (auto sportive)

Table 6: Definitions of the different auto segments, according to the European classification (Chiesa et al., 2021, ES, p. 186)

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