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List of abbreviations

GHG	Greenhouse gas
GWP	Global Warning Potential
KP	Kyoto Protocol
PA	Paris Agreement
COP	Conference of Parties
ET	Emission Trading
CDM	Clean Development Mechanism
JI	Join Implementation
EU	European Union
NDC	Nationally Determined Contribution
SDG	Sustainable Development Goal
CER	Certified Emission Reduction
VER	Voluntary Emission Reduction
PDD	Project Design Document
LDV	Light Duty Vehicle
IEA	International Energy Agency
TEN-T	Trans European Transport Network
EV	Electric Vehicle
BEV	Battery Electric Vehicle
PHEV	Plug-in and Hybrid Electric Vehicle
Q.c.s.	Quick charging system
F.c.s	Superfast charging system

L1	Level 1 charger
L2	Level 2 charger
DCFC	Direct Current Fast Charger
BE	Baseline Emissions
EF	Emission Factor
MPG	Miles per gallon
PE	Project Emissions
EEA	Environmental European Agency
ER	Emission Reductions
BoCaM	Bologna Carbon Market

1. Introduction

The aim of this thesis is to evaluate the possibility and the quantity of emission reduction carbon credits through the development of sustainable mobility projects in the city of Genoa. Projects' ideas are based on the aim to develop VER (Voluntary emission reduction) credits from the installation of charging systems for electric vehicles in the urban area. The project will produce economic, social, and environmental benefits, generating credits in two different ways:

- by the installation of the charging systems;
- by the induced inhabitants' change of mentality.

To generate credits is necessary to follow two different methodologies. A methodology represents the study of a method in an emission reductions evaluation for a climate change mitigation project.

The methodology followed in the installation of new electric vehicle charging systems is the VM0038[1]. It is created by VERRA[2], that sets the standards for climate actions and sustainable developments with the construction of programs and activities that are collected inside a register. The second methodology is contained inside another register that is called eco2care[3] and it is based on a sustainable mobility project, Bologna Carbon Market (BoCaM)[4], where the municipality of Bologna wants to increase the city movement made by bicycle. The second methodology has been readapted, so the flux of bicycles is being replaced by the new electric vehicles that are induced by the installation of charging systems during the years, and this make possible to understand if people change their mentality.

Therefore, with an increase in the offer of electric vehicle charging systems, it is interesting to see if there will be a relevant substitution in circulant vehicles from fossil fuel to electric.

[1] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018
[2] https://verra.org/
[3] https://www.eco2care.org/
[4] Eco2care, "Bologna Carbon Market (BoCaM)", 2015.

The transport sector nowadays is one of the most impacting sectors, with a contribution in GHGs emissions in recent years of about 20%[5]. The different typologies of transport mode obviously have a different impact, that depends on:

- number of trips made in a year;
- amount of passengers or freights moved during the year;
- type of utilized fuel.

Due to the increase in transport demand of the future years, both private and public, it is necessary to reduce emissions through different climate change mitigation projects, like the one proposed in this thesis.

Inside cities around the world the intense urban traffic produces a high level of GHGs emissions, so trying to reduce the number of vehicles fuelled by fossil fuels with electric vehicles can produce advantages on the annual goals.

This is a project of climate change mitigation, and it has the aim to reduce GHG emissions, with the installation of more electric vehicle charging systems that will produce a change in people's mentality.

The final aim of the thesis is to create a calculation tool, for the evaluation of generable carbon credits from a sustainable mobility project. Therefore, if the final results are considered good surely this tool can be used for future sustainable mobility projects, which will create economic, environmental, and social benefits.

[5] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.

2. Climate change and international agreements for climate change limitation

2.1 Climate change and GHG effect

Climate change today is one of the main problems that humanity has to face, and it is referred to the changes that can be detected in a long period of monitoring, within a space scale. The phenomenon has global importance because climate change has an irreversible trend with consequent changes to the different ecosystems present in the affected areas.

The changes are due both to natural effects and to human activities that emit into the atmosphere greenhouse gases (GHGs). The climate defines which areas are habitable and exploitable for man and which are not.

Some of the effects of climate change are:

- Changing in weather patterns;

- Reduction in food production;

- Drought and flooding events that become more frequent and heavy;

- Rise in temperatures;

- Rise in sea levels and sea temperature.

Today, two methods of action against climate change have been defined: mitigation, in which the community tries to decrease the level of GHGs in the atmosphere through different actions, and adaptation, in which the community remains in the same conditions and will try to adapt through plans to what will be the effects of climate change. In Earth's system, the natural cycle of GHGs is self-balanced while the anthropogenic part of the emission is considered as an extra that is going to add to the system. GHGs are essential for the development of life on Earth, since they allow to retain some of the heat, that comes from the Sun, inside the atmosphere. But due to their continuous increase of concentration in the atmosphere less and less energy leaves the Earth. This reduction in energy leaving causes a consequent increase in global temperature, and in figure (1) it is possible to see how the global surface temperature change from 1880 up to 2017[6].

[6] https://climate.nasa.gov/news/2671/long-term-warming-trend-continued-in-2017-nasa-noaa/.

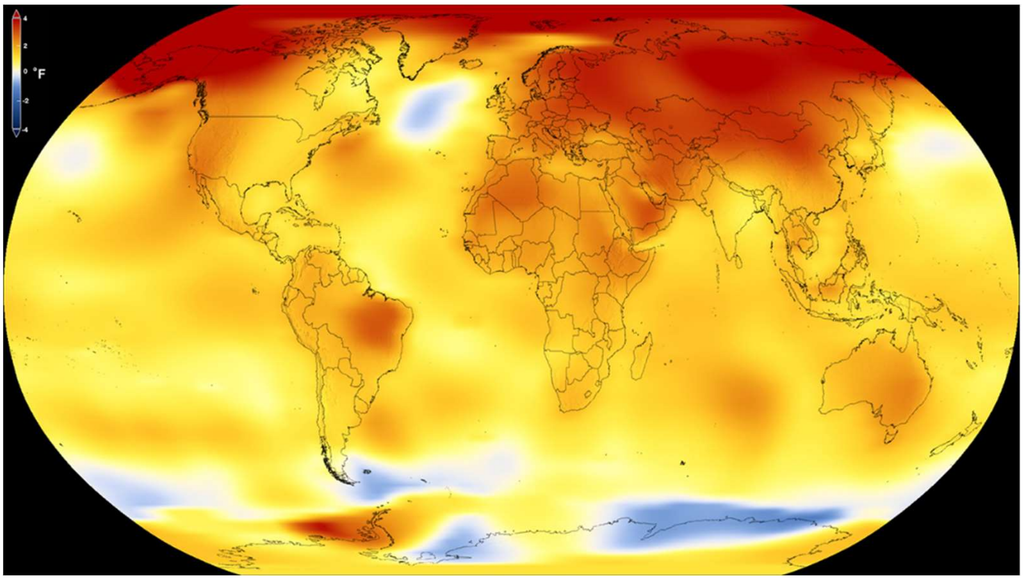

Figure 1- Global surface temperature variation

The tendency of the atmosphere to retain heat is known as the greenhouse effect. Although it is not a singular event, it does bring together all other local, global, short-term, and long-term processes that alter the atmospheric concentrations of CO_2, methane, and water vapour. A higher concentration of water vapour in atmosphere makes it more humid, while higher concentrations of CO_2 or methane retain more heat, so the atmosphere becomes warmer than an atmosphere with lower concentrations of these gases. Therefore, there is a correlation between the increase in atmospheric concentration CO_2 and the increase in temperature, in figure (2)[7].

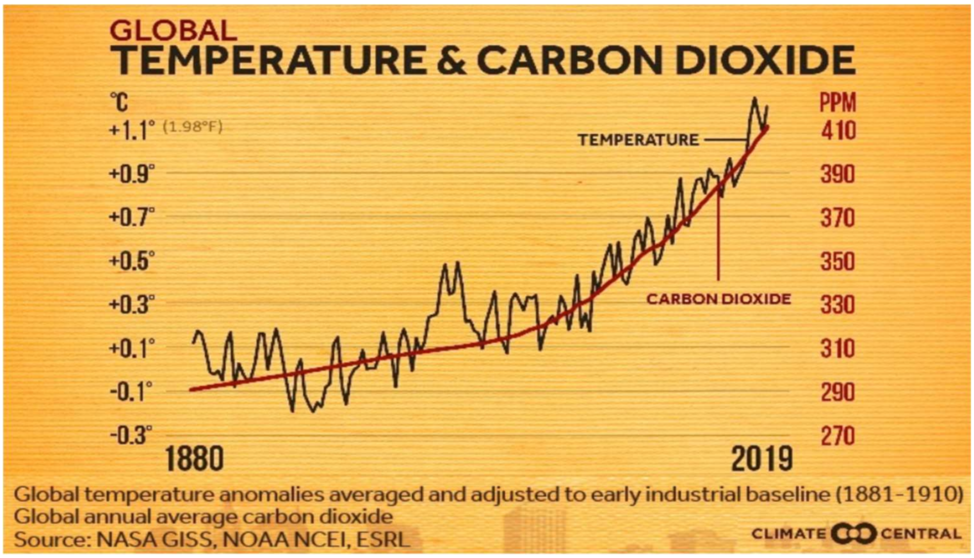

Figure 2- global average temperature increase correlated to increase in atmospheric CO_2 concentration

[7] https://climatesan.org/climate-warming-trend-impacts-building-support-for-action/.

The Earth's surface is heated by sunrays at 33% due to direct absorption, and 67% due to the retain of energy inside the atmosphere due to GHGs[8]. The clouds and aerosols in the atmosphere immediately absorb and reflect a portion of the energy from the Sun, a 55% of total energy, while the remaining portion, 45%, reaches the Earth's surface and is absorbed by: oceans, rocks, soils, and vegetation. A portion of the absorbed energy is sent back into space by the Earth as infrared radiation, and 35% of it escapes from the atmosphere by radiating into space, while the remaining portion is trapped and retained by the atmosphere, which causes the increase in the atmosphere temperature especially in the layers closest to the Earth's surface[9]. Therefore, the atmosphere that can retain a higher amount of heat has an increase in temperature, but it is also true the vice versa. The sketch in figure (3) [10] represents the Earth's energy balance, in which from a total solar incoming radiation a part is adsorbed by Earth, a part is reflected, and another part is reinjected to the space. But, with an increase in GHGs inside the atmosphere more energy is trapped inside it, so the temperature will increase.

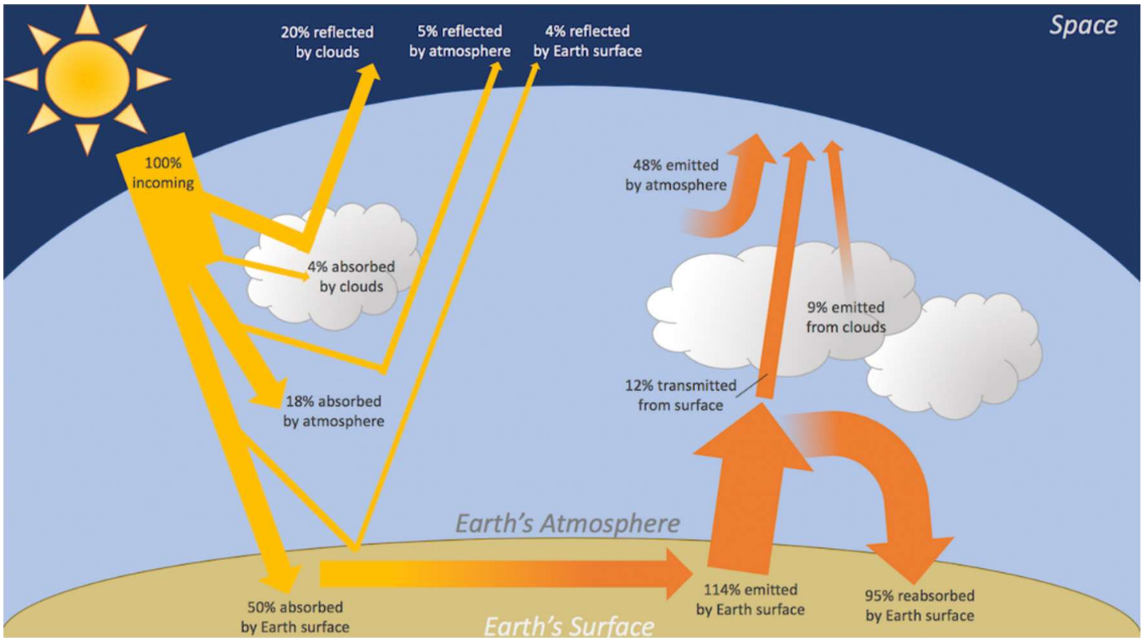

Figure 3- Earth's energy balance

[8] M. Gallo, A. Del Borghi, "Mitigation and adaptation to climate change slides", Unige, 2022.

[9] M. Gallo, A. Del Borghi, "Mitigation and adaptation to climate change slides", Unige, 2022.

[10] https://bio.libretexts.org/Courses/University_of_California_Davis/BIS_2B%3A_Introduction_to_Biology_-_Ecology_and_Evolution/03%3A_Climate_Change/3.01%3A_Earth%27s_Energy_Budget.

The GHGs are:

1) Water vapour (H_2O);
2) Carbon Dioxide (CO_2);
3) Methane (CH_4);
4) Nitrous oxide (N_2O);
5) Chlorofluorocarbons (CFC);
6) Sulphur hexafluoride (SF_6).

H_2O in vapour state represents the most present GHG with the 70% of the total. Due to water cycle it has a very fast elimination from the atmosphere, so its importance is for daily and seasonal cycle. Its effect is on the increase or decrease in air humidity inside the atmosphere. An atmosphere with a high level of humidity can retain more heat, while an atmosphere with a low level of air humidity can retain less heat.

CO_2 and CH_4 together represent 25% of the total GHG effect. These gases have a crucial role in controlling seasonal and ten-year cycles because in the atmosphere they are more stable than water vapour. These gases can keep the Earth's surface warm by reflecting specific wavelengths of light, and like water vapour, they are constantly exchanged between the atmosphere, land, and seas with different natural processes like volcanic eruption. This creates variations in the atmosphere's content of CO_2 and CH_4 on a daily and seasonal basis. CO_2 is the most widely considered GHG in our analysis because is the most impacting and stable in the atmosphere. The other GHGs considered in the list represent the last 5% of the GHG effect[11].

The continuous increase of emissions of GHG in the atmosphere is mainly related to anthropogenic causes due to the combustion of fossil fuels, this knowledge makes people grow an awareness of a problem that must be solved as soon as possible[12].

About 74% of all greenhouse gas emissions worldwide in 2018 were attributable to CO_2 that derive from fossil fuel consumption and land use. Compared to an average yearly growth of 1.3% over the previous ten years, CH_4 emissions increased by 1.7% in 2018. In contrast to a 1% yearly growth over the previous ten years, N_2O emissions, which are

[11] M. Gallo, A. Del Borghi, "Mitigation and adaptation to climate change slides", Unige, 2022.
[12] M. Gallo, A. Del Borghi, "Mitigation and adaptation to climate change slides", Unige, 2022.

mostly impacted by agricultural and industrial activities, increased by 0,8% in 2018. However, a notable rise in fluorinated gases was seen in 2018 (6.1%, compared to an average yearly rise of 4.6% over the previous ten years)[13].

From 1970 to 2010 the total amount of GHG emissions continuously increased due to the more impacting human activity that has reached the maximum historical amount of CO_2 concentration in the atmosphere[14]. For this reason, it has become necessary to establish agreements at global level to achieve increasingly sustainable economic growth with lower GHG emissions.

Thanks to the United Nations Framework Convention on Climate Change (UNFCCC) it was possible to create a United Nations body that gave rise to the Conferences of Parties (COP) which are annual climate summits. The first was held in Rio De Janeiro in 1992, where participating members meet to take decisions and make proposals for the increasingly sustainable development of the planet.

Over the years, several UN congresses have been held where the main theme is climate change. Some of the most important COPs were the third in 1995 for the stipulation of the Kyoto Protocol and in 2015 COP 21 for the Paris Agreement.

[13] Christensen John M., Olhoff A., “Emissions gap report 2019”. United Nations Environment Programme (UNEP), 2019.
[14] M. Gallo, A. Del Borghi, “Mitigation and adaptation to climate change slides”, Unige, 2022.

2.2 Kyoto protocol (1995)

It was the first UN legal instrument against climate change, and it contains commitments from different industrialized countries to reduce their emissions of various GHGs[15]. The protocol defines different objectives that bind countries to reduce GHG. The Kyoto Protocol, figure (4), divides the different countries into:

- Annex I → countries with economies in transition;

- Non annex I → developing countries;

- Annex B →most industrialized countries which must go to reduce GHG emissions more severely.

The real goal of the protocol is to equalize the emission right per capita and to achieve its objectives has created three flexible mechanisms[16]:

1. Emission Trading (ET) → system that allows the exchange of emission credits between various industrialized countries and with an economy in transition. The credits that are in excess may be sold to states that have not been able to meet the defined cap limit. For this type of mechanism EU introduce the ETS which is a cap & trade system of total emissions through the allocation of allowances;
2. Joint Implementation (JI) →using this mechanism, industrialized and economy-in-transition countries can develop projects that generate GHG emission reductions in countries of the same level by obtaining derived credits (ERUs);
3. Clean Development Mechanism (CDM) →with this mechanism industrialized and economies in transition countries can develop projects with consequent reduction of GHG emissions in countries with developing economies. States that carry out these projects receive CER credits equal to the tons of equivalent CO_2 that are eliminated with the project.

These three mechanisms encourage the reduction of GHG in different countries through green projects, thus promoting the sustainable development of countries following the main goals of the United Nations.

[15] https://unfccc.int/kyoto_protocol.
[16] https://www.isprambiente.gov.it/it/servizi/registro-italiano-emission-trading/aspetti-generali/protocollo-di-kyoto.

Figure 4- COP 3 symbol

2.3 Paris agreement and SDG (2015)

Then in 2015, at the climate conference held in Paris, COP21, an agreement was signed inside which there is no longer a distinction on the country's economy but that commits everyone to reduce GHG emissions.

Through the Paris Agreement[17], figure (5), different aspects have been defined that must be legally binding, in order to be respected, for a progressive reduction of GHG emissions at global level. Within this agreement there are different objectives including:

1. Maintain the global average temperature rise below 2 ºC respect the pre-industrial level, hoping for a maximum increase of 1.5 ºC;
2. Increasing private and national funding for sustainable development projects linked to lower GHG emissions;
3. Countries are required to present and comment every five years a national emission reduction target, Nationally Determined Contribution (NDC);
4. Countries must set clear and achievable emission reduction targets, with ever-increasing and ambitious targets;
5. With the Paris Agreement, all countries must develop plans and measures to adapt to climate change, which must be regularly updated;

A very important change that the agreement had produced, and that is described in Article 6[18] is the elimination of the CDM and of the JI introduced by the Kyoto Protocol[19]. Due to the elimination of distinction in the country's economy the Parties choose to follow voluntary projects in order to contribute to reach the designated mitigation and adaptation actions. Moving from an international to national mitigation contribution helps to obtain transparency and determined contribution on different mitigation projects. The quality of the results is evaluated by a supervisor body, that is designated by the COP and that has the aim to:

- Promote GHG emissions mitigation projects;

[17] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.
[18] https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf.
[19] https://unfccc.int/kyoto_protocol.

- Incentivize the participation of public and private entities in GHG emissions mitigation projects.

It is voluntary and approved by participating Parties to apply internationally transferred mitigation outcomes to meet nationally specified contributions under this Agreement. In this way, there is a change in the mechanism of credit production, from a mandatory one to a voluntary one.

Figure 5- COP21 symbol

In parallel with the Paris Agreement, the 2030 Agenda has been drawn up, which includes the Sustainable Development Goals (SDGs) [20]. In figure (6) is possible to see which are the seventeen goals that the countries must follow to achieve sustainable development, that is, a development that meets the economic, environmental, and social needs of the present generation without compromising the needs of future generations.

Figure 6 -Sustainable Development Goals

[20] https://www.istat.it/it/benessere-e-sostenibilit%C3%A0/obiettivi-di-sviluppo-sostenibile/quali-sono-i-17-goals

2.4 Carbon markets and carbon credits

Thanks to the Kyoto Protocol[21], carbon dioxide has now become a good with its market, the carbon market, where there is the possibility to buy, sell or exchange credits.

The market, both mandatory and voluntary, is based on carbon credits where each of them is equal to one tonne of CO_2 or equivalent GHG. The final aim of the introduction of this market is to guide the various plants and companies to a sustainable low-emission development. To encourage this, the climate change mitigation projects will produce emission reduction credits that can be sold to third parties.

In any case to obtain carbon credits there are some requirements that the project must be satisfy:

1) With the project there must be a reduction in the emissions, each carbon compensation that accompanies the outcome of the completed project must result in a decrease in emissions;
2) The project must be additional, so the economic income from the sale of the carbon credits is important but the most important thing is the environmental advantage;
3) Emission reductions are subject to rigorous scientific calculation, monitoring, and verification. Methodologies for calculation and monitoring that are suitable for the environment and the relevant technology must be accessible for this purpose;
4) The emission reductions that derive from the project are permanent, so they must not be returned after in another period;
5) A carbon credit corresponds to only one tonne of equivalent CO_2 (tCO_2eq).

The projects that produce and sell carbon credits are previously certified by a verifying entity, but still nowadays very huge amount of industries instead to buy the credits prefers to communicate the CO_2 compensation differently from the carbon credit mechanism.

[21] https://unfccc.int/kyoto_protocol.

2.4.1 Certified Emission Reduction (CER)

Certified Emission Reduction (CER) is an emission reduction credit, one CER is equal to one tonne of equivalent CO_2 removal, which derives from the Clean Development Mechanism (CDM). These credits are obtained when an industrialized country or a country with an economy in transition will develop a climate change mitigation project in a country with a developing economy. Currently, CDM Registry records the majority of granted CERs.

For the afforestation, reforestation, and revegetation projects there are two special CER:

- Temporary CER (tCER) → CER granted for a project activity involving afforestation or reforestation under the CDM and that expires at the end of the commitment period that comes after the one in which it was issued;
- Long CER (lCER) → CERs that are issued for reforestation or afforestation project activities and expire their crediting period.

The project owner can use or sell, to another Annex I country, these CERs in order to stay inside the emission reduction program of the Kyoto Protocol. The costs of CERs for CDM projects are not always the same as the overall project cost. By-products of CERs are produced by numerous CDM projects. For example, energy efficiency initiatives reduce electricity consumption, renewable resource-based projects provide electricity, and reforestation and afforestation projects produce forest products. For the multi-output CDM projects, total project costs are higher than CER costs, and it is possible that they cannot be distinguished from by-product costs. The cost of CERs is equal to the total project cost only for the projects that only generate CERs.

Nowadays the majority of the CDM projects are in the sector of:

- Construction;
- Transport;
- Agriculture;
- Forestry.

The CDM projects affect the way to reach the aim of the Kyoto Protocol, nowadays the energy projects make up more than 84% of the CDM portfolio, whereas afforestation and reforestation, industrial and landfill gas reduction, and methane avoidance initiatives make up only 12% of all projects but have higher CER costs[22].

The cost of CER is function of different factors, such as:

- Length of the crediting period;
- Project type;
- Project location.

It is important to note that investors also take into account the risks and costs involved with transactions at various stages of the production and selling processes, therefore the unit cost of CER does not always accurately reflect the full cost or value of the projects to investors.

When there is the idea to produce a CDM project there is the necessity to produce a Project Design Document (PDD)[23] inside which are included:

- A detailed description of the baseline scenario and emissions;
- An evaluation of the project additionality, and description of the monitoring plan;
- An environmental impact analysis due to the project installation;
- A description of environmental benefits that the project will produce with its installation.

2.4.2 Voluntary market and Voluntary Emission Reduction (VER)

The voluntary market creates the possibility to produce mitigation projects on voluntary basis where the obtained credits must be verified by a verification entity. This entity has to review if the project precisely follows some standards and methodologies. From this project there is the production of Voluntary Emission Reduction (VER), which is equivalent to one tonne of CO_2 emissions. The VERs can be bought from the plants in order to compensate their emissions. Permit individuals to voluntary reduce their emissions. The same guidelines that apply to CER creation also apply to this kind of carbon credit generation, but VERs are unrelated to the Kyoto Protocol commitments made by governments.

[22] Shaikh M.Rahman, Grant A. Kirkman, "Costs of Certified emissions reductions under the Clean Development Mechanism of the Kyoto protocol", 2019,Energy Economics.

[23] https://www.mite.gov.it/pagina/il-ciclo-dei-progetti-cdm

This type of credit has not a public countability, so there is the necessity to have a register that is useful to:

- Ensure credit traceability;
- Prevent selling the same batch of credits more than once;
- Project duplication across many VER programs;
- Make available all project paperwork, including details about the verification entity[24].

To generate VER the market follows these steps:

- National regulation input;
- Emission balance;
- Verification study by a third entity;
- Registration inside a registry;
- Buyers of the credit, in order to compensate the emissions of the installations[25].

The difference from the CER is that this type of credit cannot be used to achieve the Kyoto Protocol aims. In any case, it is important to underline that the VERs have substituted the CERs for the mitigation projects.

[24]https://reterus.it/public/files/GdL/Cambiamenti_climatici/seminario_10_marzo_2022/022_03_10_M.Gallo_WebinarRUS_GdLCC.pdf
[25] https://eco2care.it/Doc/poster_ecomondo08.pdf

3. Transport sector

3.1 Emissions in the transport sector

The transport sector has a great weight on the total emissions, such as to be one of the sectors with more emissions. During the period from 2010 to 2019, it had the fastest growing in combustion (fossil fuel-burning) sector globally. Transport was responsible for 30% of global final energy demand and for 23% of global direct CO_2 emissions from the energy sector in 2019. For what concern the 2020 COVID-19 pandemic reduced the global energy demand by a projected 4%, and the total global CO_2 emissions of an estimated 5.4%[26].

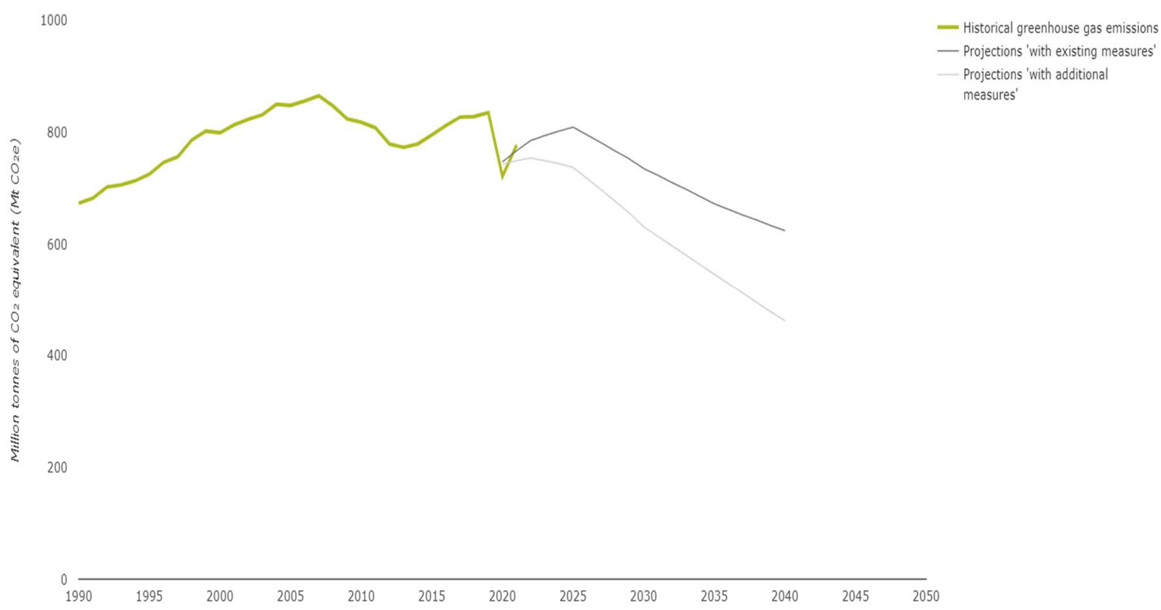

Figure 7- Trend EU's GHG emissions produced by transport sector

Figure (7) shows the trend of the GHG emissions in the EU produced by the transport sector with two different projections for the future, one with only the existing measures and one with additional measures. In the first projection there will be an increase of emissions up to 2025, and after this maximum it is expected to have a general decrease, in order to try to reach the aim of the emission reductions. While, in the second case with other measures there will be a trend that has not increased, so the 2030 goals will be achieved more easily[27].

[26] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.
[27] https://www.eea.europa.eu/ims/greenhouse-gas-emissions-from-transport

The majority of global transportation is by road, including both passenger and freight traffic, and its expansion is directly correlated with patterns in new car sales. In figure (8) it is visible the historical and projected global light-duty vehicles (LDV) sales, and also the percentage of sales year by year. It is possible to see that in 2020 due to the COVID-19 pandemic situation there was a decrease in sales of 12.8 million[28].

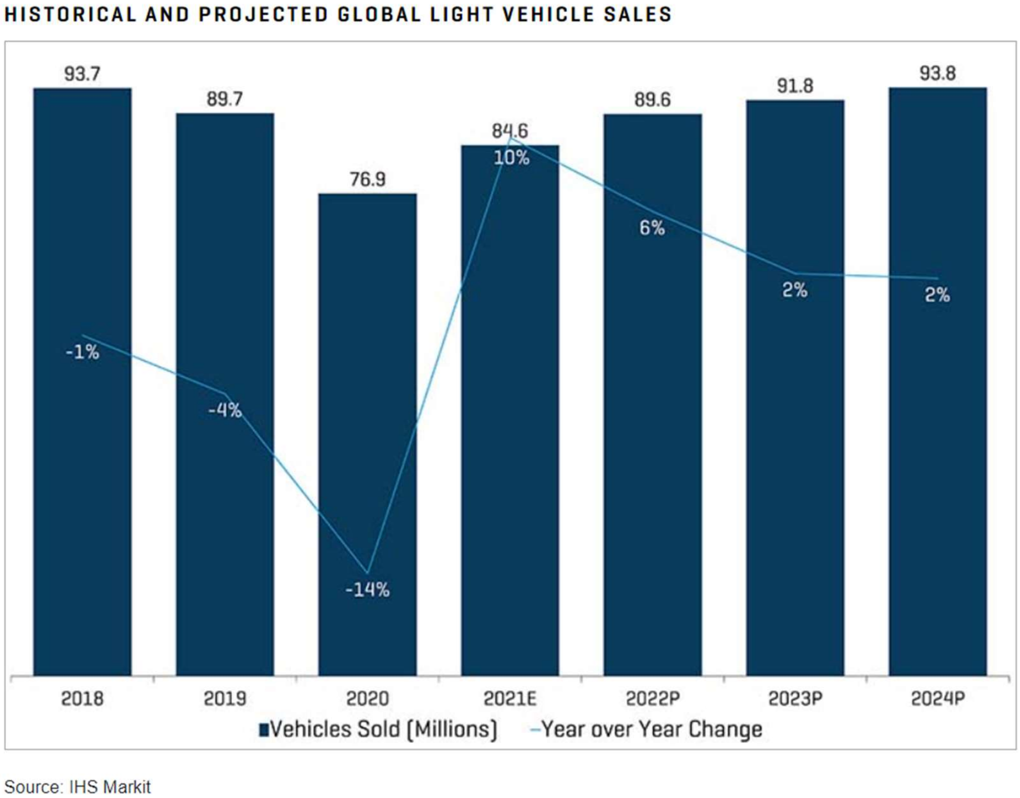

Figure 8- historical and projected sales of LDV

The number of passengers and commercial cars on the planet is predicted to more than double by 2050[29], and many of the older, more polluting vehicles, unfortunately, are anticipated to continue operating in Africa, Central Asia, and Latin America. The transport sector is used both for passenger and freight demand. For passenger transport 55 trillion passenger kilometers were traveled by people around the world in 2017, with 78% of those being traveled by road[30]. Despite having the lowest CO_2 emissions per passenger of any form of transportation, rail carried less than 8% of all passengers in that year.

[28] https://www.stout.com/en/insights/industry-update/automotive-industry-update-q3-2021

[29] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.

[30] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.

The highest expansion in passenger transport activity between 2015 and 2017 was driven by motorized two- and three-wheelers and airplanes, which had an increase of almost 25% overall[31]. Two and three-wheelers have the fastest-growing form of motorized transportation in many emerging nations. While for what concerns freight transport this sector is very hard to decarbonize due to a lack of policies and mature technologies. 14% of all worldwide greenhouse gas emissions in 2018 were related to transportation, figure (9)[32].

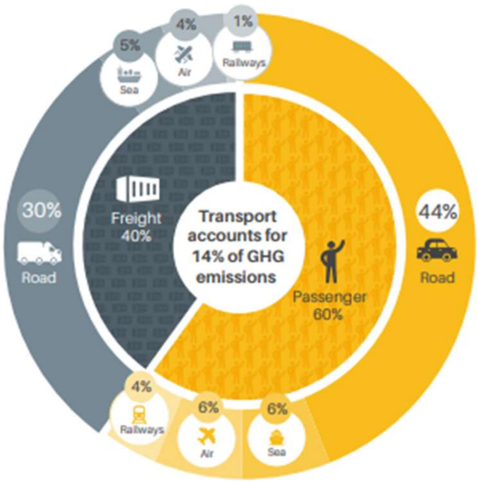

Figure 9- Worldwide GHG emissions by transport mode in 2018

In that year, road transport (including passenger and freight) contributed roughly 74% of all transport-related greenhouse gas emissions, compared to rail's 5% share. Aviation that is always under discussion for climate change is responsible only for 10% of the GHG emissions, while shipping for 11%[33].

For a focus on the urban region, they account for about 36% of transportation-related CO_2 emissions, of which 31.6% come from passenger travel and 4.7% from freight[34].

[31] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.
[32] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.
[33] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.
[34] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021

The transport demand is expected to grow in the future due to an increase in the global population. The international Energy Agency (IEA)[35] will expect that the global transport demand became double, where the car owners increase up to a 60% respect to the actual number. This is after reflected to an increase in transport vehicles and emissions. Only innovations, like electrification and shared mobility can help to satisfy the future transport demand and to not increase the emissions for the sector.

An IEA's report defines the optimistic scenario in which in 2070 the transport sector reaches net zero CO_2 emissions from global energy, in which the electrification and hydrogen technologies are the fundaments for this path. Unlike road urban transport, shipping and aviation transport are more difficult to decarbonize. In figure (10) the IEA's report[36] of 2020 describe the scenario for the net emissions in the transport sector, where 2/3 of the reductions come from the increase in technology that arrives in the future. The dotted lines present in figure (10) represents the forecast for which the different transport mode stop to be a direct contributor of CO_2 emissions from fossil fuel combustion[37].

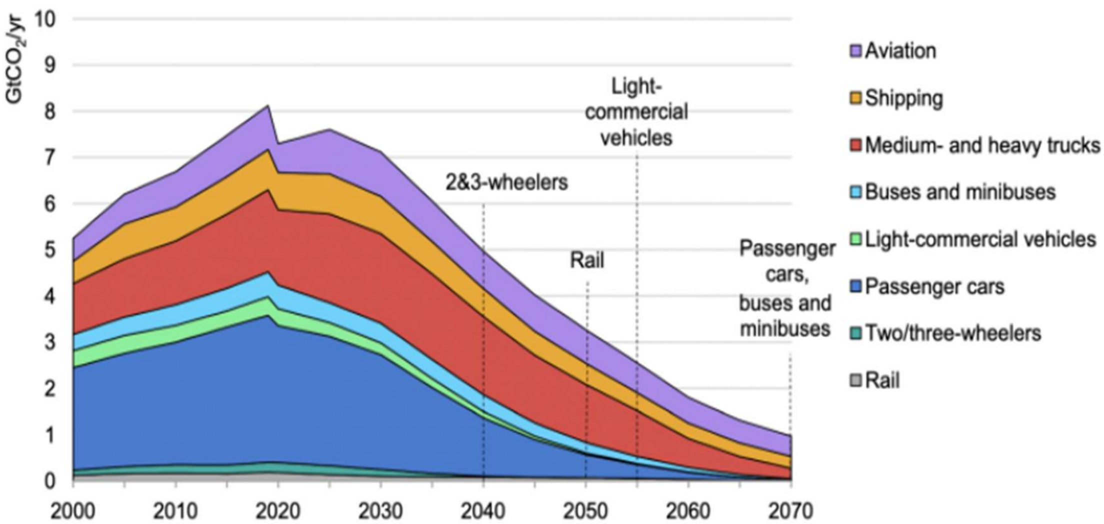

Figure 10- IEA's report of net emissions in transport sector

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[35] https://www.iea.org/.
[36] https://www.iea.org/reports/energy-technology-perspectives-2020.
[37] https://ourworldindata.org/co2-emissions-from-transport

3.2 Urban transport

The traffic congestion is nowadays a growing problem that afflicts most of the urban areas in the world, and it is responsible for about 8% of global CO2 emissions[38].

Other problems that affect the quality of urban life produced by transport are:

- Congestion;
- Air pollution;
- Noise;
- Safety;

With the creation of a low-carbon urban design of the city, the well-being of the population will increase. In order to reduce emissions without exclusively relying on technology, urban planning and design of cities are essential. However, the preferred means of transportation will have an impact on the potential to break the dependence on automobile use. One of the possible vehicle emission reductions will be shared or pooled mobility that can also have a great efficiency in suburbs and for long and commuting trips.

Urban transportation-related income and car ownership are the two main factors that influence GHG emissions, although even in places with comparable income and car ownership levels have significant heterogeneity.

The real key strategy for the decarbonization way of urban transport is defined by the substitution of the circulant vehicles fuelled by fossil fuels with electric vehicles. This substitution linked with a decrease in number of vehicles, and an increase in pooling and shared mobility define the correct way to follow. Planning cities around walkable subcentres, where numerous destinations, such as shops, employment opportunities, leisure activities, and others, can be accessed within a ten-minute walk or bicycle ride, is another way to find a solution[39].

[38] IPCC, “Climate Change 2022: Impacts, Adaptation and Vulnerability Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change”, 2022, Chapter 10
[39] IPCC, “Climate Change 2022: Impacts, Adaptation and Vulnerability Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change”, 2022, Chapter 10

3.3 Sustainable mobility policies

Sustainable transport defines the possibility that our transport systems meet the actual needs in economic, social, and environmental fields. To reach sustainability in the transport system, different transport policies are defined, and they are collected in the White Paper on Transport[40]. It is a paper in which are contained all the policies related to the transport sector up to 2050. Europe for example with its policies wants to have a GHG emission reduction of the 60%, following ten targets:

1. By 2030, the use of "conventionally fuelled" cars in urban transportation will be cut in half, and by 2050, they will be completely phased out;
2. By 2030, 30% of road freight should be transported by rail or water, and more than 50% by 2050;
3. By 2050, 40% of aviation fuels will be low-carbon sustainable fuels, and 40% (or 50%, if possible) of EU CO_2 emissions from marine bunker fuels will be as well;
4. Complete the high-speed rail system in Europe by 2050. By 2030, the current high-speed rail network should be triple its current length, and every Member State's railway system should remain dense;
5. By 2050, all key network airports should be connected to the rail network, ideally at high speeds. In the same way, all core seaports should be adequately connected to the rail freight network and, if possible, the inland canal system;
6. By 2030, the EU will have a fully operational multimodal TEN-T (Trans European Transport Network) "core network," and by 2050, a high-quality, high-capacity network will be in place with a commensurate set of information services;
7. Deployment of the modernized air traffic management infrastructure in Europe by 2020 and completion of the European common aviation area;
8. Create the foundation for a European information, management, and payment system for multimodal transport by the year 2020;
9. To almost zero road traffic fatalities by 2050. By 2020, the EU hopes to have cut down of traffic fatalities by half;
10. In order to remove distortions, especially detrimental subsidies, create income, and assure financing for future transportation expenditures, it is possible to work

[40] https://transport.ec.europa.eu/system/files/2016-09/swd%25282016%2529226.pdf.

toward the full application of the "user pays" and "polluter pays" principles and private sector engagement[41].

Goal nine focuses on transportation safety, another crucial component of sustainable mobility. Goals seven and eight encourage technology investments, while goal ten aims to increase equity by enforcing higher taxes for the use of infrastructure and the creation of pollution, as well as by raising funds to support improvements in the transportation industry.

The Action Plan for Low-Emission Mobility[42] is another document inside which there is the definition of the low-emission mobility that is a key component of future transportation.

The key objectives stated in the White Paper also specify the action plan's supporting pillars and emphasizes the significance of sustainable mobility in the European transport strategy:

- Increasing the use of low-emission alternative energy sources (low-emission alternative energy for transport, standardization, and interoperability for electro-mobility);
- Improving the efficiency of the transportation system;
- Optimizing the transport system;
- Pricing;
- Multi-Modality;
- Moving toward zero-emission vehicles;
- Horizontal enablers to support low-emission mobility.

The goal of European transportation policy is to promote environmentally friendly mobility while also cutting emissions. The use of conventional fuels for passenger and freight transportation is also strongly trending toward elimination or drastic reduction, favoring electric mobility for land transportation, such as rail transportation in metropolitan and suburban areas and electric or zero-emission vehicles in urban areas.

[41] European Commission, "Roadmap to a Single European Transport Area—Towards a Competitive and Resource Efficient Transport System, 2011, COM (2011) 144.
[42] https://ec.europa.eu/commission/presscorner/detail/nl/MEMO_16_2497.

The automotive industry is anticipated to be directed by this trend to spend more and more in alternative fuel cars, with a focus on electric vehicles, in addition to having a significant impact on future mobility habits[43]. The policies for sustainable mobility can be divided into three different topics:

- Environmental;
- Socio-economic;
- Technological.

Another important aspect that is useful to introduce is the application of the Avoid-Shift-Improve (A-S-I) measures that use all the possible methods in order to achieve the full benefits of sustainable mobility[44]. With this type of strategy, the transport emission reductions can be of around 40-60%[45]. The A-S-I strategy uses appropriate and context-sensitive steps in an implicit hierarchy. Avoidance measures are those that are supposed to be put into action first, then Shift measures, and ultimately Improve measures. This prioritization can aid in reducing negative environmental effects, enhancing socioeconomic opportunity access, improving logistics efficiency, reducing traffic, enhancing air quality, and enhancing road safety. In this framework, there is the necessity to:

1) Avoid the motorized trips that are unnecessary;
2) Shift to a low-carbon transport method;
3) Improve the efficiency of the vehicles.

[43] M.Gallo and M.Marinelli, "Sustainable mobility: a review of possible actions and policies", MDPI, 2020.
[44] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.
[45] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.

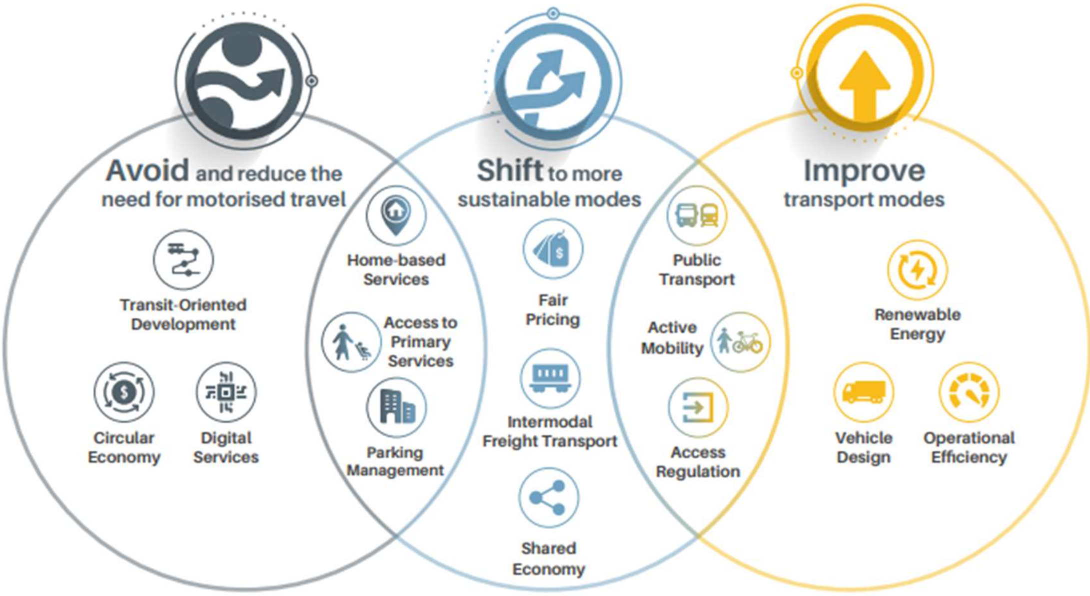

Figure 11- A-S-I framework

In figure (11) is possible to see a picture that represents an example of different aims and objectives that will improve in order to follow the A-S-I strategy[46].

[46] SLOCAT, "Global Transport and climate change", Transport and Climate Change Global Status Report 2nd edition, 2021.

4. Methodologies and additionality

For the evaluation of the emission reductions from a mitigation project, and so of the generated carbon credits it is fundamental to follow a verified methodology. It describes the problems and presents a way in which it is possible to calculate how many credits are possible to obtain with the proposed project. Several nations are looking for ways to objectively evaluate climate mitigation efforts made by subnational actors, improve transparency on mitigation outcomes, and foster confidence and trust with local stakeholders. In order to allow for replication in the design and execution of particular mitigation projects and actions, as well as to correctly be added to the national mitigation targets, mitigation results must be clear in their estimation and comparable among local governments. Nowadays for mitigation projects there are two principles registers of methodologies, that are UNFCCC[47], and VERRA[48]. All the projects that are produced from the Paris Agreement work[49] for the generation of voluntary credits are being sold in a voluntary carbon market. For the resolution of a methodology sometimes it is necessary also to follow some tools.

The methodology generally has a predefined structure composed by:

- Description of the methodology;
- Applicability conditions;
- Project boundaries;
- Baseline scenario;
- Additionality;
- Quantification of GHG emissions (baseline, project, leakage, and emission reductions);
- Monitoring plan.

Particular attention is dedicated to additionality because is what defines if the selected project can be developed or not. When a mitigation project is proposed it needs to satisfy different requests that are different in any methodology case. It has to produce GHG

[47] https://cdm.unfccc.int/methodologies/index.html.
[48] https://verra.org/.
[49] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

emission reductions without following the economic field, but only the environmental benefits. Sometimes it is necessary for the additionality definition the use of some tools or activity methods. When there is a project it is necessary to define the additional impact by defining different scenarios starting from the business-as-usual one (scenario without the project). Then when a project is concluded it is possible to sell the generated credits on a carbon market, in order to have an economic benefit.

5. EV charging system project

5.1 Project idea

The proposed project has the aim to reduce emissions and to produce voluntary emission reduction credits (VERs) that after will be sold in the carbon market. The project is a mitigation one that does not produce only an economical benefit, but also at community and environmental levels. The benefit for the community is represented by the possibility of more people to charge their EVs, while the environmental one is represented by the increase in EV number that is going to substitute in time the circulant vehicles fuelled by fossil fuels inside the city of Genoa.

The project has the aim to increase the number of charging points respect to the actual number of 314[50]. The project has a duration of ten years starting from 2024 to 2033 and it takes into consideration both BEV and PHEV.

Through this project, there is the aim to generate voluntary emission reduction credits that will be sold inside the carbon market. Nowadays there are on the national territory different types of charging systems, and the two selected for the sustainable mobility project are: quick charging systems (Q.c.s.) and superfast charging systems (F.c.s.). The number of new charging systems that are going to be installed in Genoa are eighteen for the quick type and two for the superfast type.

With time there is the hope that the number of EVs is going to increase, with a decrease of fossil fuel vehicles, due to an increase of the offer of the net of charging systems but also with the presence of new incentives for the substitution of the circulant vehicles. In this way, another desire is to eliminate the doubts about Ev's reliability due to the presence of more charging systems.

Following step by step the VM0038[51] methodology the baseline and project emissions have been evaluated, that are useful for the emission reductions calculation. In this way a structure that can be used, in future, for the generation of carbon credits has been created.

[50] Motus E, "Le infrastrutture di ricarica pubbliche in Italia", 2021

[51] https://verra.org/wp-content/uploads/imported/methodologies/VM0038-Methodology-for-Electric-Vehicle-Charging-Systems-v1.0-18-SEP-2018.pdf

5.2Used methodology VM0038 (methodology for EV charging systems)

To solve the project the VM0038[52] methodology from Verra register, has been used. Initially, it was born for American and Canadian projects but, it can also be used for projects that are in other regions of the world like in this case study, Italy. The methodology is applied to projects that consider inside their project boundaries both BEV and PHEV.

The methodology has to be applied to the electric vehicle (EV) charging systems, including their infrastructure. The GHG emission reductions are achieved through the displacement of fossil fuel vehicles with EVs.

The applicability conditions of the methodology are:

1) The EVs that can apply the methodology are limited to: LDV (light-duty vehicle) BEVs, HDV (high-duty vehicle) BEVs, and PHEV (plug-in hybrid electric vehicles).
   The chargers for LDV are L1 (charger which provides 120V at alternating current) and L2(charger which provides 240V at alternating current), and for BEVs are DCFCs (Direct current fast charger, typically at 200-1,000 V);
2) Project proponents must demonstrate that the EV models comprising the considered EVs of the project are comparable to their conventional fossil fuel baseline vehicles in category and passenger/load capacity;
3) To demonstrate that the double-counting emission reduction will not occur, the project proponent must maintain an inventory of EV charges inside the project, also including the infrastructure. The double counting relative to any issued GHG credits, from projects that introduce EV fleets, is defined using the emission reduction discount adjustment. In the project documentation for each EV charger there must be a classification of the performance voltage (L1, L2, and DCFC 50/100/150/320/500 kW), and the codes to identify the EV charger;
4) The methodology is applied to EV charging systems utilizing an associated infrastructure to provide electricity to EVs. There is also the necessity to have a

[52] https://verra.org/wp-content/uploads/imported/methodologies/VM0038-Methodology-for-Electric-Vehicle-Charging-Systems-v1.0-18-SEP-2018.pdf

metering system that must measure and trace all the electricity deliveries and receipts. This includes the electricity sourced from/returned to the grid, dedicated renewable energy on-site, on-site storage batteries, and/or the EV's on-board battery;

5) Projects with estimated annual emission reductions over 60,000 tCO_2eq are considered large-scale projects and they are permitted only if the project proponents can demonstrate that the project is located in a country with credible national data sources for GHG emission calculations, and they are listed in an activity method used for the determination of additionality of this methodology (VMD0049[53]);
6) The project proponent must demonstrate proof of ownership of emission reduction that can be achieved through a contractual agreement with the charging system owner, and with EV drivers through disclosure of credit ownership.

In VM0038[54] methodology the baseline scenario follows the business-as-usual principle. The baseline emissions are calculated by converting the electricity used to charge the project fleet vehicles at the EV chargers into the distance traveled by the EV. Multiplying this for the emission factor for fossil fuel used by vehicles to travel the same distance. In this evaluation there is to take also into account different default values.

The project emissions include the electricity consumption associated with the operation of the applicable fleet. In the project emission is important the estimation of the "time-of-day" that provide a new equation for the estimation of the project emissions.

The leakage in this methodology is not considered.

For the evaluation of the net GHG emission reductions and removals there is also to consider a discount factor (D_y), which consider if there are or no other project like the considered one inside the region, in order to adjust the credits that have been issued inside the project region:

$$ER_y = \left(BE_y - PE_y - LE_y\right) * D_y$$

[53] https://verra.org/wp-content/uploads/imported/methodologies/VMD0049-Activity-Method-for-Determining-Additionality-of-EV-Charging-Systems-v1.0-18SEP2018.pdf
[54] https://verra.org/wp-content/uploads/imported/methodologies/VM0038-Methodology-for-Electric-Vehicle-Charging-Systems-v1.0-18-SEP-2018.pdf

Where:

- ER_y[tCO_2eq] are the net GHG emission reductions in the year y;
- BE_y [tCO_2eq] are the baseline emissions in the year y;
- PE_y [tCO_2eq] are the project emissions in the year y;
- LE_y [tCO_2eq] are the leakage emissions in the year y. In this methodology the leakage are not considered, so they are set at zero;
- D_y [%] is a discount factor that is going to be applied for the year y. D_y is a factor that depends on the presence of other projects of this typology in the region that is taken into consideration. In fact, more projects are present less is the amount of credits that the project creates. In the proposed case there are not other projects of this type, so D_y is equal to 1.

The project proponent must have a monitoring plan in order to obtain, record, compile, and analyze data and parameters useful to evaluate GHG emissions. The data must be archived at least for two years after the end of the last crediting period. The report of the monitoring plan is different:

1) For activities monitored during project validation:
   a) Inventory and geographic location for the EV charging system;
   b) Where EV charging system associated infrastructure is utilized to provide electricity to EVs in order to store and dispatch the electricity at local and regional scale;
   c) Verify that there is no overlap of ownership with charger included in the project description;
   d) Review of any previously issued EV fleet credits to confirm the value of the discount factor.
2) For activities monitored each year during the crediting period:
   a) There is the necessity to have data on electricity consumption for each EV charger, that is a consistent manner with supporting data. If the project includes both LDV and HDV applicable fleets, the electricity consumption must be monitored separately;
   b) Supporting documentation is used to determine the parameters used in the evaluation of baseline emissions if it is not used a default factor.

5.3 Additionality verification

It is necessary to verify the additionality of the methodology in order to understand if the project is feasible or not. To do this the VM0038[55] methodology describes the steps that are needed to follow:

- Step 1 → Regulatory surplus, it is necessary to follow the indication of the VCS Standard[56];
- Step 2 → Positive list. The projects that follow the applicability conditions that are described in the VDM0049[57] are additional;
- Step 3 → this last step is used only when the other two steps are not verified, so it becomes necessary to define if the project is of small or of large scale. In the first case the project proponent has to demonstrate that without this methodology the project will not realize due to the presence of one or more barriers. While with a large-scale project it is necessary to use a demonstrative tool that is present inside VERRA register.

To demonstrate its additionality VM0038 methodology uses the positive list furnished by the activity method of the VMD0049 methodology.

VMD0049[58] is applied in projects that want to install inside a region new EV charging systems with the aim to offer a bigger service for the charging of EVs. With this installation the other aim is to try to develop an increase in the EVs number inside the region that are going to substitute the circulant vehicles fuelled by fossil fuels.

The additionality condition is defined by the market penetration of the EVs inside the region in which the project will be developed. To obtain it the market penetration has to be less than 5%. In VMD0049 are presents some tables in which are reported the countries in which the market penetration is less than the requested. Italy is a country in

[56] VERRA, “VCS Standard”, 2022
[57] https://verra.org/wp-content/uploads/imported/methodologies/VMD0049-Activity-Method-for-Determining-Additionality-of-EV-Charging-Systems-v1.0-18SEP2018.pdf
[58] https://verra.org/wp-content/uploads/imported/methodologies/VMD0049-Activity-Method-for-Determining-Additionality-of-EV-Charging-Systems-v1.0-18SEP2018.pdf

which the project will be developed because it is listed in the table of states with a penetration market that is less than 5%, so the proposed project is additional[59].

[59] VERRA, "VMD0049: Activity method for determining additionality of electric vehicle charging systems", 2018

5.4 Baseline emissions evaluation

VM0038 methodology describes that the baseline emissions are useful to evaluate the emissions of a fleet of vehicles fuelled by fossil fuels[60], baseline comparable fleet, equal in number to a fleet of EVs, applicable fleet.

When using EV chargers, electricity used to charge project-applicable fleets is converted into the distance traveled. This distance is then multiplied by the emission factor for fossil fuels used by baseline comparable fleet vehicles to travel the same distance to determine baseline emissions[61]. Considering a project period of ten years, the methodology offers a formula for the calculation of the annual baseline emissions:

$$BE_y = \Sigma_{i,f}\, ED_{iy} * EF_{ify} * 100 * IR_i^{y-1} / \, (AFEC_{iy} * MPG_{iy})$$

Where:

- BE_y is the baseline emissions for the year y [tCO_2eq];
- $ED_{i,y}$ is the electricity that is delivered by the project charging systems that serve the fleet i, during the year y [kWh];
- $EF_{i,f,y}$ is the correspondent emission factor of the fossil fuel f used by a fleet j during the year y [tCO_2eq/l];
- IR_i is the technology improvement factor of the fleet i, that is considered equal to 1 because the fleet considered by the project is only constituted by light-duty vehicles (LDV) [-];
- $AFEC_{i,y}$ is the weighted average electricity consumption per 100 km considering the EVs fleet i during the year y [kWh/100km];
- $MPG_{i,y}$ weighted average kilometers per liter for fossil fuel vehicles comparable to the EV fleet i during the year y [km/l].

In the American and Canadian calculus, the MPG parameter is measured in [miles/gallon], but due to the fact that this project will be realized in Italy, it was preferred to use as unity of measurements the [km/l]. An important aspect that is useful to underline is that this

[60] https://www.eea.europa.eu/help/glossary/eea-glossary/baseline-scenario
[61] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018.

change does not have a significant effect on the final results. Also, the AFEC parameter has a change in unity of measurements from [kWh/100 miles] to [kWh/100 km] and also in this case the results have not changed. The emission factor (EF) is the first evaluated parameter. In order to evaluate it four different types of fuelled vehicles (petrol, petrol hybrid, diesel, and diesel hybrid) have been considered inside the urban area of Genoa. From ISPRA the urban area data of CO_2, CH_4, and N_2O [62] related to the four considered fossil fuel vehicles have been downloaded. Then to obtain the EF it is necessary to multiply the data obtained from ISPRA and the average consumption[63] [64] of each fossil fuel vehicle. Inside table (1) it is possible to see all the obtained results:

Table 1- EF of only CO_2

Fuel	CO_2 [g/km]	Average consumption [km/l]	EF [tCO_2/l]
Petrol	251.53	13	0.00327
Petrol hybrid	197.58	31.3	0.00618
Diesel	236.37	16	0.00378
Diesel hybrid	141.05	40	0.00564

For what concern the other two GHG, CH_4 and N_2O, they need to be converted into equivalent CO_2 in order to calculate the EF referred in CO_2. Through IPCC table of the 2021, it is possible to download their conversion factor related to 100 years of Global Warming Potential (GWP 100). Then, multiplying the emissions at urban level and their related conversion factor there is the passage from these GHGs to equivalent CO_2. Considering that the conversion factor of CH_4 is 29.8 and of N_2O is 273[65], in the last column of the table (2) it is possible to read the final values of EF related to each fossil fuel:

[62] https://fetransp.isprambiente.it/#/

[63]https://www.autoscout24.it/informare/consigli/prima-dell-acquisto/auto-che-consumano-meno-classifica/#:~:text=Ma%20quanto%20consuma%20un'auto,16%20chilometri%20con%20un%20litro.

[64] https://motori.virgilio.it/auto/video/auto-ibride-plug-in-reali-consumi-triplo-quanto-dichiarato/177797/#:~:text=Il%20reale%20consumo%20di%20carburante,6%20e%208%2C4%20litri.

[65] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Table 2- EF of other GHG

Fuel	CH_4 [g/km]	N_2O [g/km]	Average consumption [km/l]	$CH_4 \rightarrow CO_2eq$ [gCO_2eq/km]	$N_2O \rightarrow CO_2eq$ [gCO_2eq/km]	EF [tCO_2eq/l]
Petrol	0.082	0.006	13	2.444	1.638	0.0033
Petrol hybrid	0.05	0.005	31.3	1.490	1.365	0.0063
Diesel	0.001	0.02	16	0.030	5.460	0.0039
Diesel hybrid	0.00008	0.009	40	0.002	2.457	0.0057

The EF that is useful for the calculus of baseline emissions is a weighted average of the four obtained in the table (2). To obtain this average it is necessary to take from the ACI national site the values of the number of circulant vehicles in the city of Genoa fuelled with the four selected fossil fuels for the year 2021[66], table (3).

Table 3- number of vehicles for different fossil fuel vehicles

Type of vehicle	N° of vehicles
Petrol vehicles	149,890
Petrol hybrid vehicles	10,076
Diesel vehicles	96,382
Diesel hybrid vehicles	649

From this weighted average, the resultant EF is equal to 0.0036 [tCO_2eq/l].

The parameter ED represents the amount of total electric energy that the charging systems have to distribute in a year to the vehicle fleets at which the project is applied. To evaluate the parameter two hypotheses are necessary:

1. The charging system does not work all the day because it is unrealistic, but it is considered that they work for 16 hours per day from 8 am to 12 pm;
2. The charging system in the 16 hours of work is not used without a stop, but from one charge to another one pass an average time of 30 minutes.

[66] https://opv.aci.it/WEBDMCircolante/

In Italy, in 2021 the number of EV charging systems is 26,024. Approximately 57% of the infrastructures are distributed in northern part of Italy, about 23% in Central, while only 20% in the South and in the Islands. 34% in the capitals of provinces and the rest in other municipalities. Lombardy is the region with the highest number of EV charging systems, and alone possesses 17% of all points. Follow in the order Lazio and Piemonte with 10% , after Veneto and Emilia-Romagna with 9% and Tuscany with 8%[67].

These six regions together cover 65% of the total points that are present in Italy and continue to grow with a constant trend[68]. In the following table[69] (4) there are presents the first ten Italian cities for EV charging points:

Table 4- EV charging points distribution in ten Italian cities

City	Residents	EV charging points
Roma	2,770,226	1,673
Milano	1,374,582	717
Firenze	368,419	522
Torino	858,205	387
Genova	566,410	314
Bologna	391,686	284
Napoli	922,094	211
Catania	300,356	147
Bari	317,205	70
Palermo	637,885	52

Always from ACI[70] this time there is the necessity to take the number of EVs, BEV+ PHEV, while from the Smart Mobility Report[71] of 2020 the collected data is the number of EVs that are forecasted to have in 2030. Making the hypothesis that the percentage of the EVs distribution does not change in time, it is possible to obtain how many vehicles will be in Genoa in 2030, table (5).

[67] Motus E, "Le infrastrutture di ricarica pubbliche in Italia", 2021.

[68] Motus E, "Le infrastrutture di ricarica pubbliche in Italia", 2021.

[69] Motus E, "Le infrastrutture di ricarica pubbliche in Italia", 2021.

[70] https://opv.aci.it/WEBDMCircolante/

[71] Smart mobility report, "La sostenibilità nei trasporti: opportunità e sfide per la filiera e gli end user", Politecnico di Milano, 2020.

Table 5- number of EVs from Italy to Genoa

Zone	Percentage of total EVs (%)	N° of EVs in 2021	N° of EVs in 2030
Italy	100	1,149,528	5,500,000
Liguria	2.5	28.433	137,500
Genoa	0.99	11,340	54,450

The number of charging systems that are going to be installed in Genoa depends on the percentage of EVs that are in the city. Therefore, the 0.99% of the new charging systems will be installed in Genoa, where eighteen will be quick charging systems type and two will be superfast charging systems type, for a total number of twenty.

The properties of the two different types of charging system are synthetized inside the table (6):

Table 6- properties for the two different charging systems

Power of Q.c.s.	22 kW
Type of dispensed current	Alternating current
N° of output	From 2 to 4
Charging time of Q.c.s. (from 0 to 100%)	2 hours
Power of F.c.s.	150 kW
Type of dispended current	Direct current
N° of output	2
Charging time of F.c.s. (from 0 to 100%)	20 minutes

From these properties the number of vehicles that a single output will charge during a classic day of work has been evaluated. Therefore, considering that it works in a day for sixteen hours, from 8 am to 12 pm, and with an interval from a charge to another of thirty minutes the obtained results are:

- Quick charging system output → 6.4 [cars/day];
- Superfast charging system output → 19.3 [cars/day].

Due to the three possibilities of outputs number of the quick charging systems also the ED evaluation is divided into three cases, one for each possibility. The installation of the two superfast type is hypothesized one in 2025 and the second in 2030. The two typologies of charging systems in the calculus are divided because, in function of the total outputs number, have a different weight on the final amount of ED. From the number of outputs is possible to calculate the applicable fleet, so the amount of vehicles that are charged during the project year y. This is evaluated by multiplying the number of charged vehicles per day for the 365 days of the year and for the number of outputs present during the project year y.

$$Applicable\ fleet = cars\ per\ day * 365 * n°\ outputs$$

Multiplying the applicable fleet for the number of hours that the output employs for the charge and for the installed power, it is possible to evaluate ED:

$$ED = Applicable\ fleet * output\ work\ hours * power$$

1. Quick charging systems with two outputs and superfast charging systems with two outputs, table (7):

Table 7- ED in two outputs case

years	N°outputs Q.c.s.	ED Q.c.s. [kWh]	N°outputs F.c.s.	ED F.c.s. [kWh]	ED tot [kWh]
2024	2	205,568	0	0	205,568
2025	4	411,136	2	696,578	1,107,714
2026	8	822,272	2	696,578	1,518,850
2027	12	1,233,408	2	696,578	1,929,986
2028	16	1,644,544	2	696,578	2,341,122
2029	22	2,261,248	2	696,578	2,957,826
2030	24	2,466,816	4	1,393,157	3,859,973
2031	28	2,877,952	4	1,393,157	4,271,109
2032	32	3,289,088	4	1,393,157	4,682,245
2033	36	3,700,224	4	1,393,157	5,093,381

2. Quick charging systems with three outputs and superfast charging systems with two outputs, table (8):

Table 8- ED in three outputs case

years	N°outputs Q.c.s.	ED Q.c.s. [kWh]	N°outputs F.c.s.	ED F.c.s. [kWh]	ED tot [kWh]
2024	3	308,352	0	0	308,352
2025	6	616,704	2	696,578	1,313,282
2026	12	1,233,408	2	696,578	1,929,986
2027	18	1,850,112	2	696,578	2,546,690
2028	24	2,466,816	2	696,578	3,163,394
2029	33	3,391,872	2	696,578	4,088,450
2030	36	3,700,224	4	1,393,157	5,093,381
2031	42	4,316,928	4	1,393,157	5,710,085
2032	48	4,933,632	4	1,393,157	6,326,789
2033	54	5,550,336	4	1,393,157	6,943,493

3. Quick charging systems with four outputs and superfast charging systems with two outputs, table (9):

Table 9- ED in four outputs case

years	N°outputs Q.c.s.	ED Q.c.s. [kWh]	N°outputs F.c.s.	ED F.c.s. [kWh]	ED tot [kWh]
2024	4	462,528	0	0	462,528
2025	8	925,056	2	696,578	1,621,634
2026	16	1,850,112	2	696,578	2,546,690
2027	24	2,775,168	2	696,578	3,471,746
2028	32	3,700,224	2	696,578	4,396,802
2029	44	5,087,808	2	696,578	5,784,386
2030	48	5,550,336	4	1,393,157	6,943,493
2031	56	6,475,392	4	1,393,157	7,868,549
2032	64	7,400,448	4	1,393,157	8,793,605
2033	72	8,325,504	4	1,393,157	9,718,661

Another parameter that is necessary to evaluate is the AFEC, that is related to the electric consumption for 100 km that is used by the fleet of EVs during the considered project year. Itcan be evaluated with the following formula:

$$AFEC_{iy} = \Sigma_a (EV_{aiy} * EVR_{aiy}) / \Sigma_a EVR_{aiy}$$

EV_{aiy} identifies the electric consumption for 100 km respect to the EVs fleet during the considered project year, while EVR_{aiy} represents the total number of EVs of the fleet during that year.

For this factor the hypothesis for which in the future the vehicles consumption will not change is necessary, so they are equal to the values that are reported in table (10):

Table 10- electric consumption per 100 km

BEVs	13.5[72]	kWh/100km
PHEVs	27[73]	kWh/100km

In addition to the EVs consumption, it is necessary to have data on the forecast of the number of vehicles that will be in the future. For the prediction on the EVs the percentages have been taken from the Smart Mobility Report 2020[74]:

- In 2025 there will be 62.5% of BEV, and 37.5% of PHEV;
- In 2030 there will be 74.5% of BEV, and 25.5% of PHEV.

These percentages are related to the total number of EVs that are forecasted in Italy and that will represent around 20% of the total circulant vehicles in 2030, that is 5,500,000[75].

Then through a linear interpolation the forecast of the scenario in the city of Genoa has been evaluated. Inside table (11) are reported the number of EVs that are prospected to have in the city up to 2033, while figure (12) represents all these data with a histogram in order to have a visual comparison on the growth trend, divided in: total number, number of BEV, and number of PHEV.

[72] https://pulsee.it/news-media/risparmio/consumo-auto-elettrica-quanto-corrisponde#:~:text=Il%20consumo%20medio%20di%20un,percorrere%20100%20Km%20di%20strada
[73] https://www.vaielettrico.it/quanto-poco-consumo-con-la-mia-ibrida-plug-in/
[74] Smart mobility report, "La sostenibilità nei trasporti: opportunità e sfide per la filiera e gli end user", Politecnico di Milano, 2020.
[75] Smart mobility report, "La sostenibilità nei trasporti: opportunità e sfide per la filiera e gli end user", Politecnico di Milano, 2020.

Table 11- projection of number of electric vehicles in Genoa up to 2033

years	Total n° of EVs	% BEVs	Total n° of BEVs	% PHEVs	Total n° of PHEVs
2024	25,710	48.2	12,400	51.8	13,310
2025	30,500	62.5	19,063	37.5	11,438
2026	35,290	64.9	22,903	35.1	12,387
2027	40,080	67.3	26,974	32.7	13,106
2028	44,870	69.7	31,724	30.3	13,596
2029	49,660	72.1	35,805	27.9	13,855
2030	54,450	74.5	40,565	25.5	13,885
2031	59,240	76.9	45,556	23.1	13,684
2032	64,030	79.3	50,776	20.7	13,254
2033	68,820	81.7	56,226	18.3	12,594

It is possible to see that in the future projection of the circulant vehicles, differently to the actual common think the PHEVs are not going to have great success, meanwhile the BEVs will have a bigger appreciation.

In figure (12) is possible to see the future distribution of the EVs that is forecasted for the project years.

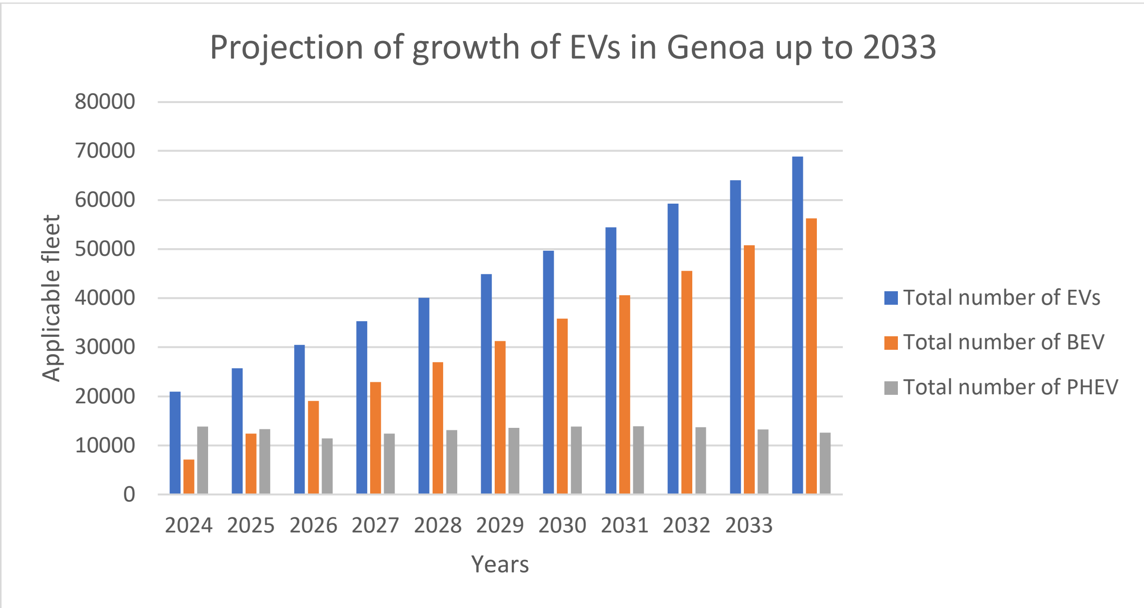

Figure 12- projection of growth of EVs in Genoa up to 2033

While, in figure (13) it is possible to see how the percentages of the presence in the circulant vehicles have to change, and it is understandable that there will be an inversion of the actual trend with the passing of the years.

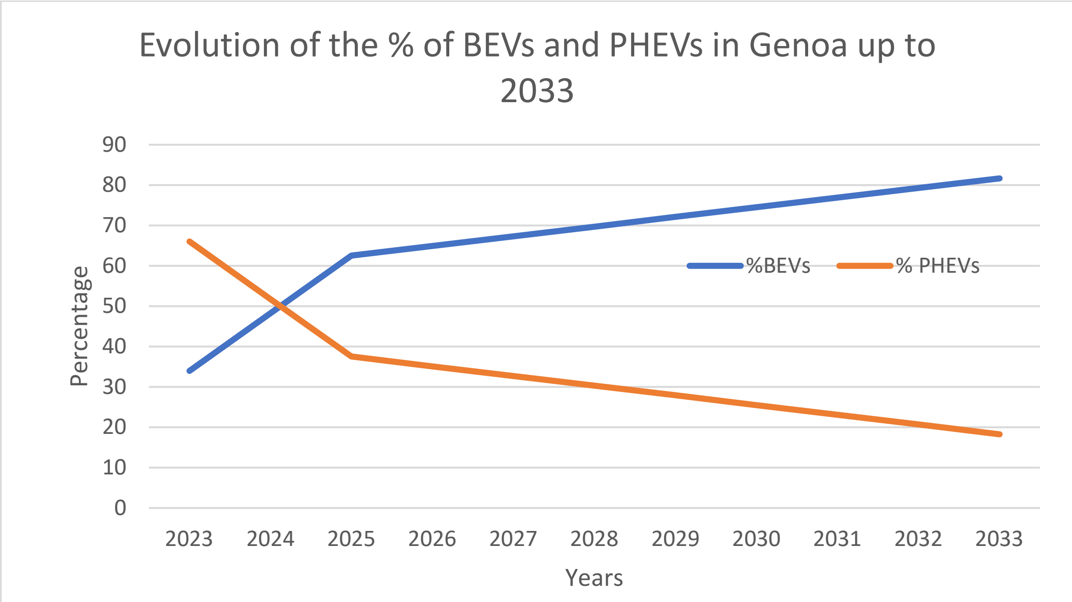

Figure 13- Evolution of the % of EVs in Genoa up to 2033

The $AFEC_{iy}$ factor results for the different project years are synthesized in table (12):

Table 12- AFEC values from 2024 to 2033

Years	AFEC [kWh/100km]
2024	20.49
2025	18.56
2026	18.24
2027	17.91
2028	17.59
2029	17.27
2030	16.94
2031	16.62
2032	16.29
2033	15.97

The last factor that is necessary to evaluate is the miles per gallon, MPG, that is evaluable following the formula:

$$MPG_{iy} = \Sigma_a(MPG_{aiy} * EVR_{aiy})/\Sigma_a EVR_{aiy}$$

MPG_{aiy} identifies the average consumption in km/l for the baseline comparable fleet i during the project year y, while EVR_{aiy} identifies the applicable fleet always during the project year. It is important to obtain an average MPG value between the four different types of considered fossil fuel vehicles. To do this is necessary to use the average consumption used before in the evaluation of EF. Therefore, from the calculation, the resulting average MPG is equal to 14.91 [km/l].

Then once all the necessary parameters are being calculated, the baseline emissions for the ten project years can be evaluated. Now it is necessary to divide the calculus for the three different cases of the possible output number of the quick charging systems.

Inside the table (13), (14), and (15) are synthesized the values for the different conditions, in which for each case are present three different baseline emissions: the first describes the emissions for the eighteen quick charging systems, the second defines the emissions for the two superfast charging systems, and the third represents the total one.

1. Quick charging system with two outputs and superfast charging system with two outputs, table (13):

Table 13- total baseline emissions in two outputs case

Years	Baseline emissions for Q.c.s. [tCO_2eq]	Baseline emissions for F.c.s. [tCO_2eq]	Total baseline emissions [tCO_2eq]
2024	246	0	246
2025	542	919	1,461
2026	1,104	935	2,038
2027	1,685	952	2,637
2028	2,288	969	3,258
2029	3,206	987	4,193
2030	3,564	2,013	5,577
2031	4,239	2,052	6,291
2032	4,941	2,093	7,034
2033	5,671	2,135	7,807

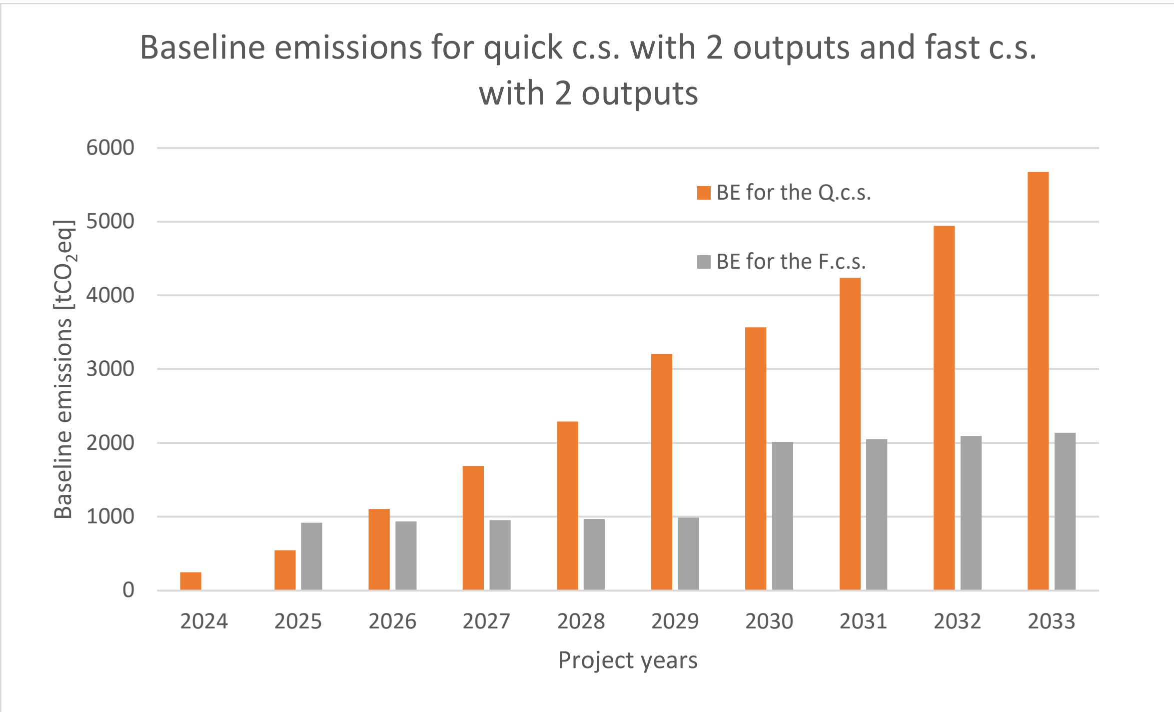

Figure 14- baseline emissions in two outputs case

2. Quick charging system with three outputs and superfast charging system with two outputs, table (14):

Table 14- total baseline emissions in three outputs case

Years	Baseline emissions for Q.c.s. [tCO_2eq]	Baseline emissions for F.c.s. [tCO_2eq]	Total baseline emissions [tCO_2eq]
2024	368	0	368
2025	813	919	1,732
2026	1,655	935	2,590
2027	2,528	952	3,480
2028	3,433	969	4,402
2029	4,808	987	5,796
2030	5,346	2,013	7,359
2031	6,358	2,052	8,410
2032	7,411	2,093	9,504
2033	8,507	2,135	10,642

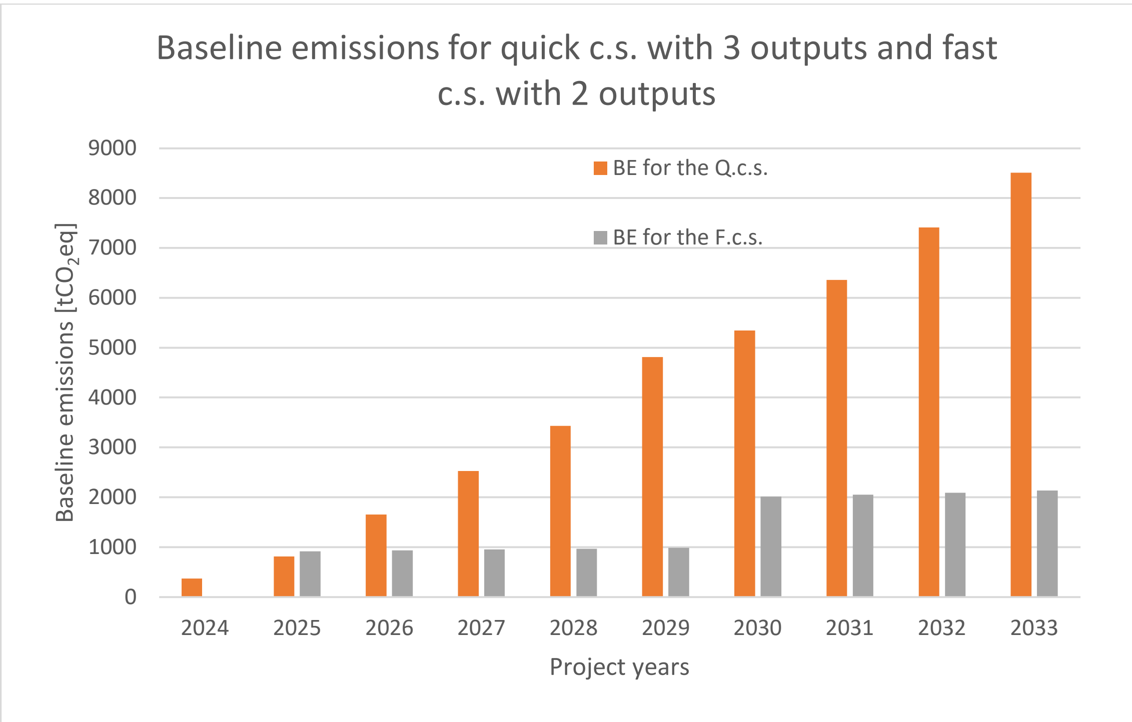

Figure 15- baseline emissions in three outputs case

3. Quick charging system with four outputs and superfast charging system with two outputs, table (15):

Table 15- total baseline emissions in four outputs case

Years	Baseline emissions for Q.c.s. [tCO_2eq]	Baseline emissions for F.c.s. [tCO_2eq]	Total baseline emissions [tCO_2eq]
2024	553	0	553
2025	1,220	919	2,138
2026	2,483	935	3,418
2027	3,792	952	4,744
2028	5,149	969	6,118
2029	7,213	987	8,200
2030	8,019	2,013	10,032
2031	9,358	2,052	11.590
2032	11,117	2,093	13,210
2033	12,760	2,135	14,896

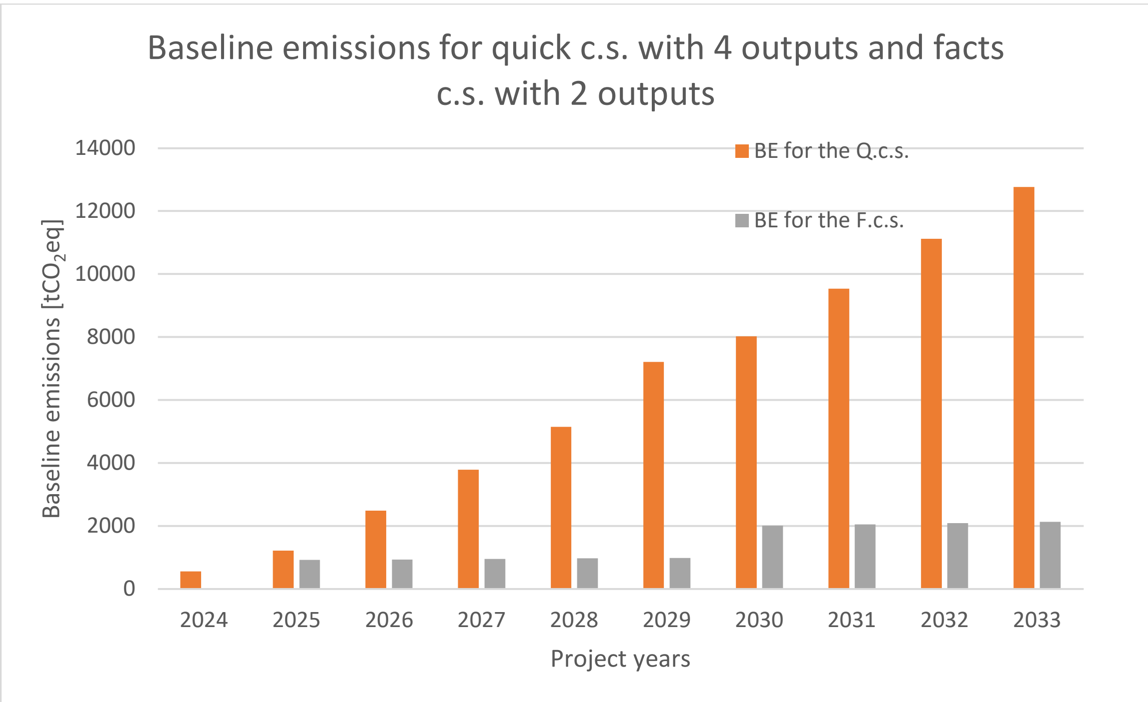

Figure 16- baseline emissions in four outputs case

In figures (14), (15), and (16) it is possible to see a comparison of the baseline emissions for different baseline emissions scenarios, in which it is easy to understand that with an increase in the charging system number there will also be an increase in the baseline emissions.

5.5 Project emissions evaluation

Passing to define the project emissions now the fleet is totally fuelled with electric energy, and not anymore with fossil fuels.

For their evaluation the VM0038[76] methodology furnished the formula to calculate the project emissions for each project year:

$$PE_y = \Sigma_{ij} EC_{ijy} * EFkW_{ijy}$$

The first parameter is EC_{ijy} [kWh/year] and it identifies the electric consumption of the project charging systems furnished by the region j that serve the fleet i during the project year y. Its value is equal to the one of ED, of the baseline emissions, and also in this case three different results have been obtained: total value, value for the quick charging systems, and value for the superfast charging systems.The second parameter is $EFkW_{ijy}$[tCO_2eq/kWh] that identifies the average EF variation for the electric consumption for the region j, and that serves to charge the fleet i through the EV charging systems during the project year y.

To evaluate the EF of the electric consumption (EFkW) two different plots are very useful, because they furnish data for the creation of an order of magnitude. The first is from the ISPRA[77], that is represented in figure (17) and plot the EF due to Italian electric consumption during the years. Taking the data from 2019 to 2021 a first base for a linear interpolation has been obtained.

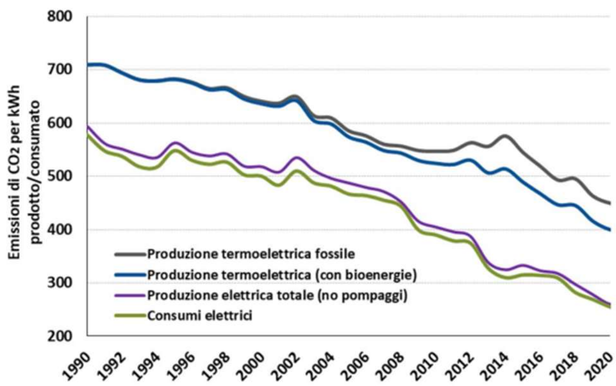

Figure 17- EF of Italian electric consumption

[76] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018.

[77] ISPRA, "Indicatori di efficienza e decarbonizzazione del Sistema energetico nazionale e del settore energetico", 2021.

In order to have a correct forecast for the trend of this EF it was useful to have a prevision at 2030, that is obtained from the EEA[78](Environmental European Agency), which offers an European trend with two different future scenarios of decrease of GHG emissions, figure (18). Using an engineering approach, the selected scenario in the analysis is the worst, but there is always to take into consideration that is a forecast at European level, so the result will be approximate.

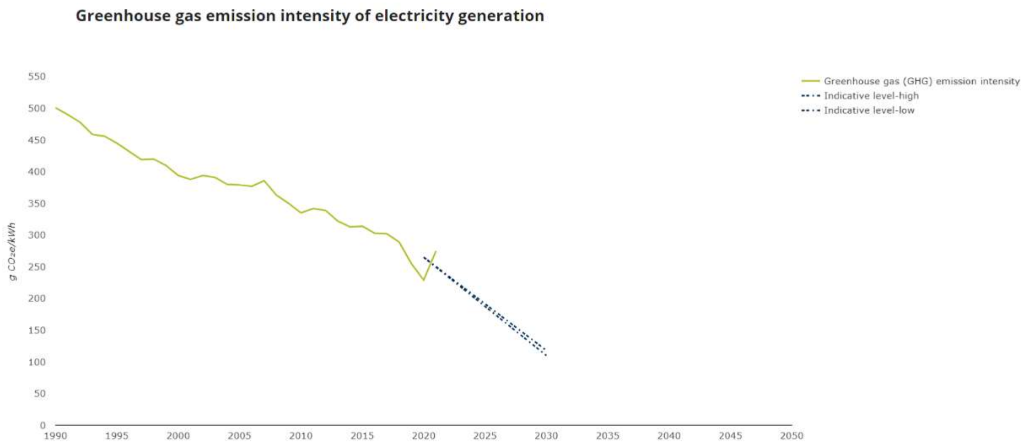

Figure 18- EF of European electric consumption and future projection of EEA

Figure (18) shows that the EF of electric consumption from 1990 has a decreasing trend. This is due to the fact that the electricity mix is always less impacting in order to achieve the European aim of the Net Zero Emissions inside the Green Deal[79] up to 2050.

The forecast according to EEA projection considers that at 2030 the EF of electrical consumption will be 95 [gCO_2/kWh][80].

[78] https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1
[79] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it-
[80] https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1

Performing a linear interpolation, the EFkW of all the project years have been obtained, table (16):

Table 16- EFkW

years	EFkW [tCO_2eq/kWh]
2019	0.000269
2020	0.000255
2021	0.000245
2022	0.000223
2023	0.000207
2024	0.000191
2025	0.000175
2026	0.000159
2027	0.000143
2028	0.000127
2029	0.000111
2030	0.000095
2031	0.000079
2032	0.000063
2033	0.000047

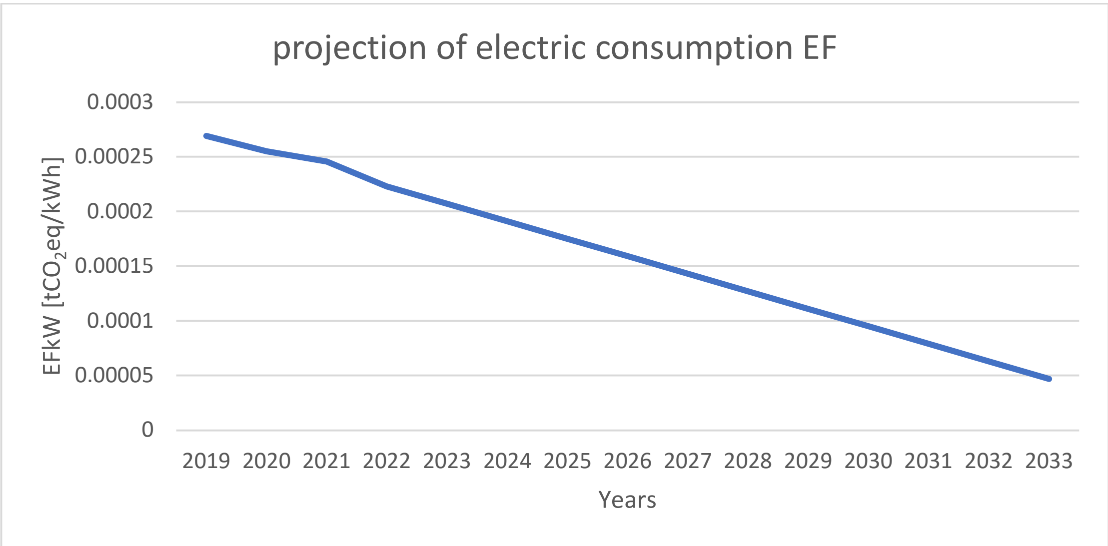

Figure 19- projection of Italian electric consumption EF

In figure (19) it is possible to see the plot of the trend that is expected in the future up to 2033, starting from data obtained from ISPRA. The trend is visibly decreasing reaching 95 [gCO_2/kWh] in 2030, data from EEA, and then continue to decrease up to 45 [gCO_2/kWh].

With a relation all the available data are being used in order to calculate the project emissions.

Therefore, also for the project emissions three different results have been obtained, one for each number outputs solutions of the quick charging systems. In fact, in table (17), (18), and (19) the obtained values are synthesized, while in figures (20), (21), and (22) the values are plotted in order to have a comparison.

1. Quick charging system with two outputs and superfast charging system with two outputs, table (17):

Table 17- project emissions in two outputs case

years	PE for Q.c.s. [tCO_2eq]	PE for F.c.s. [tCO_2eq]	Total PE [tCO_2eq]
2024	39	0	39
2025	72	122	194
2026	131	111	241
2027	176	100	276
2028	209	88	297
2029	251	77	328
2030	234	132	367
2031	227	110	337
2032	207	88	295
2033	174	65	239

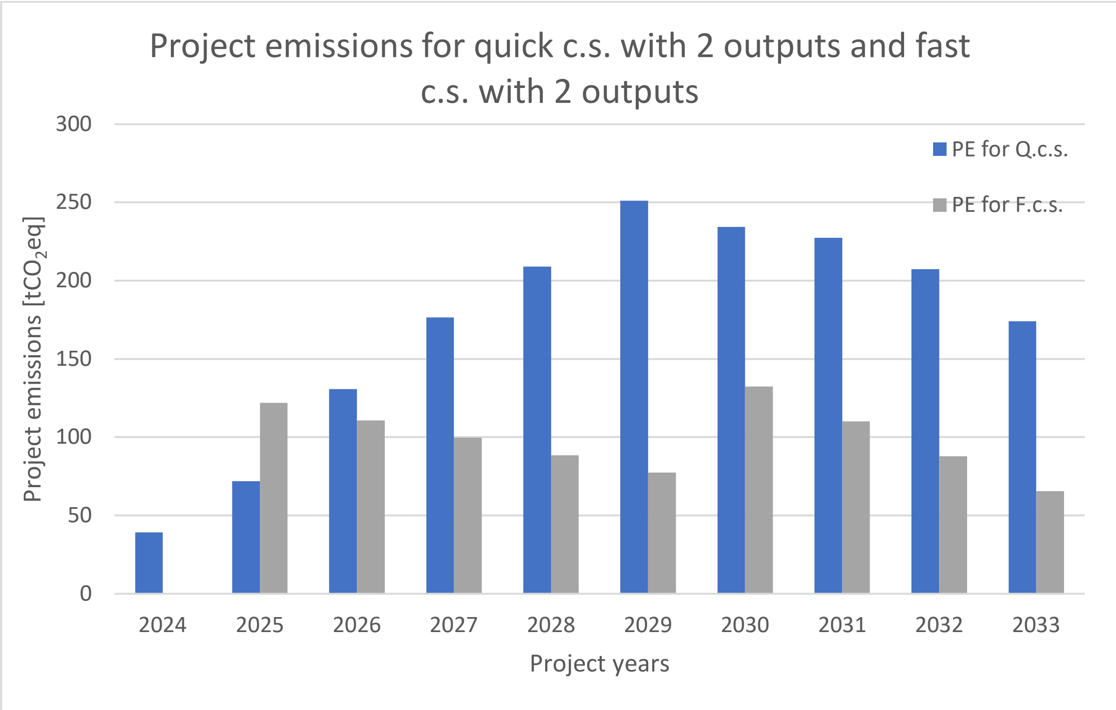

Figure 20- project emissions in two outputs case

2. Quick charging system with three outputs and superfast charging system with two outputs, table (18):

Table 18- project emissions in three outputs case

years	PE for Q.c.s. [tCO_2eq]	PE for F.c.s. [tCO_2eq]	Total PE [tCO_2eq]
2024	59	0	59
2025	108	122	230
2026	196	111	307
2027	265	100	364
2028	313	88	402
2029	376	77	454
2030	352	132	484
2031	341	110	451
2032	311	88	399
2033	261	65	326

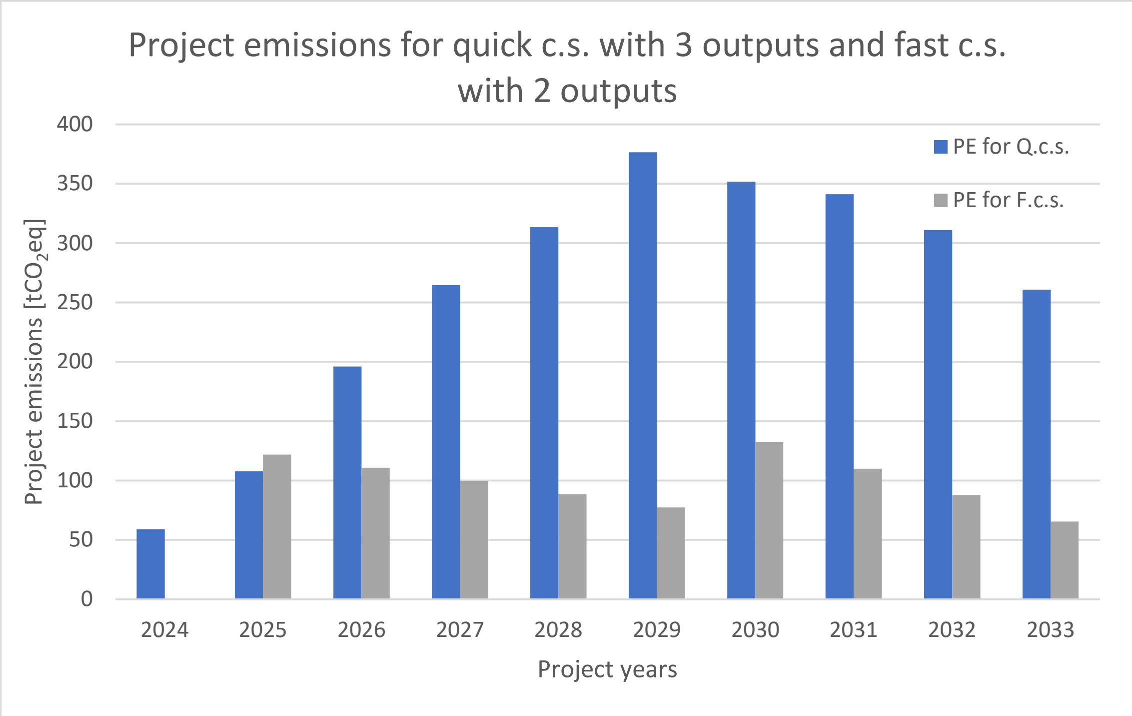

Figure 21- project emissions in three outputs case

3. Quick charging system with four outputs and superfast charging system with two outputs, table (19):

Table 19- project emissions in four outputs case

years	PE for Q.c.s. [tCO_2eq]	PE for F.c.s. [tCO_2eq]	Total PE [tCO_2eq]
2024	88	0	88
2025	162	122	284
2026	294	111	405
2027	397	100	496
2028	470	88	558
2029	565	77	642
2030	527	132	660
2031	512	110	622
2032	466	88	554
2033	391	65	457

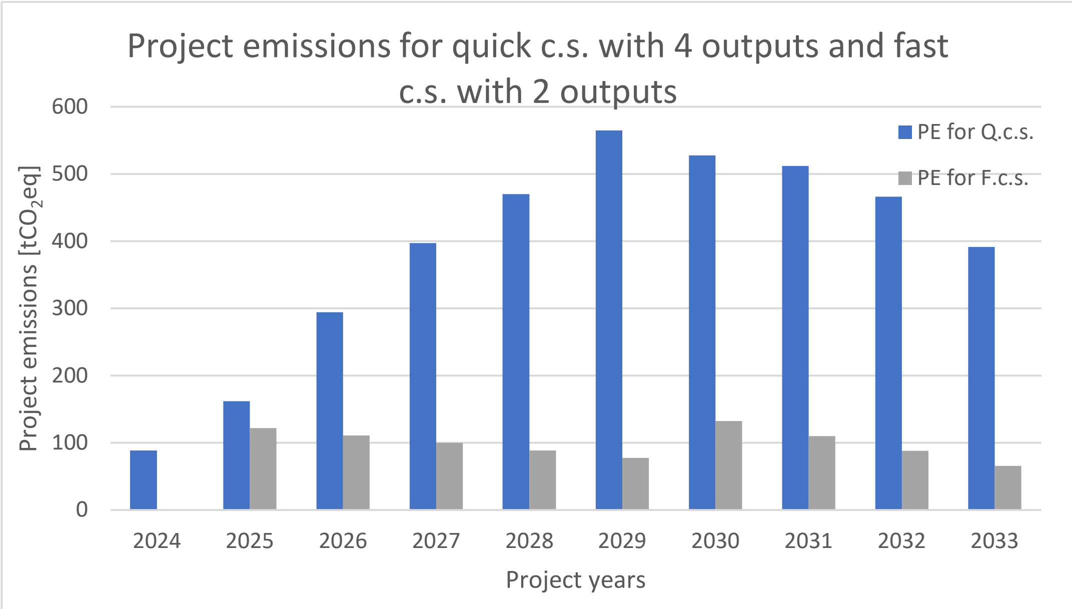

Figure 22- project emissions in four outputs case

In conclusion, the total project emissions results for the three different cases of possibility of output numbers have been plotted. In figure (23) an increase in the fleet corresponds to an increase in project emissions, reaching a maximum in 2028. There will be a little decrease in 2029, and in 2030 there is again an increase in the project emissions due to the installation of the second superfast charging system. Finally, up to 2033, there will be a decrease in the project emissions due to a great decrease in EFkW. This is a good information because a decrease in the project emissions means an increase in the credits generation.

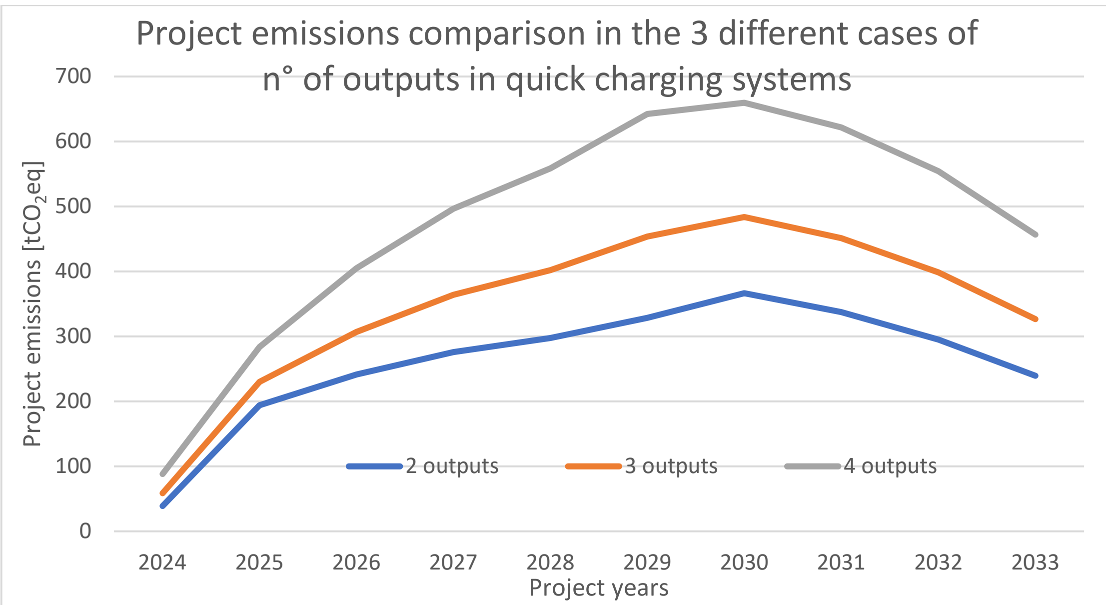

Figure 23- project emissions comparison for the three cases

5.6 Emission reductions evaluation and results

To conclude the methodology it is necessary to link the baseline and project emissions together, in order to evaluate the emission reductions produced by the proposed project. The result that is obtained represents the number of credits that are produced for any project year, that after are summed to evaluate the amount of generated credits by all the project. The formula to evaluate the emission reductions is:

$$ER_y = (BE_y - PE_y - LE_y) * D_y$$

Where:

- ER_y[tCO_2eq] are the net GHG emission reductions in the year y;
- BE_y [tCO_2eq] are the baseline emissions in the year y;
- PE_y [tCO_2eq] are the project emissions in the year y;
- LE_y [tCO_2eq] are the leakage emissions in the year y. In this methodology, the leakage emissions are not considered, so they are set at zero;
- D_y [%] is a discount factor that is going to be applied for the year y. D_y is a factor that depends on the presence of other projects of this typology in the region take into consideration, in fact more projects are present less is the amount of credits that the project creates. In the considered case there are not other projects of this type, so D_y is equal to 1.

For this evaluation two scenarios have been proposed:

1) Scenario according to projections;
2) Scenario with the electricity mix that totally comes from renewable energy.

5.6.1 Emission reductions in a scenario according to projections

In ER evaluation there is again a distinction between the three different cases of outputs number. For each of these cases there are three different results: one for the total credit number of the project, one of the produced credits by the quick charging systems, and the last of the obtained credits by superfast charging systems. Each of these results after is divided for the number of charging systems in order to obtain the generated credits for the charging system and then for the number of outputs to obtain the same results, but for output.

1. In the first case the quick charging system has two outputs, so the total number of quick outputs is thirty-six, also the superfast charging system has two outputs for a total of four outputs. The results are in table (20), while in figure (24) it is possible to see the growth of the total emission reductions.

Table 20- emissions reduction in two outputs case

year	Baseline emissions [tCO_2eq]	Project emissions [tCO_2eq]	Emission reductions [tCO_2eq]
2024	246	39	206
2025	1,461	194	1,267
2026	2,038	241	1,797
2027	2,637	276	2,361
2028	3,258	297	2,960
2029	4,193	328	3,865
2030	5,577	367	5,210
2031	6,291	337	5,954
2032	7,034	295	6,739
2033	7,807	239	7,567

Summing all the emission reductions the total amount of generated credits is 37,926 during the ten years of the project.

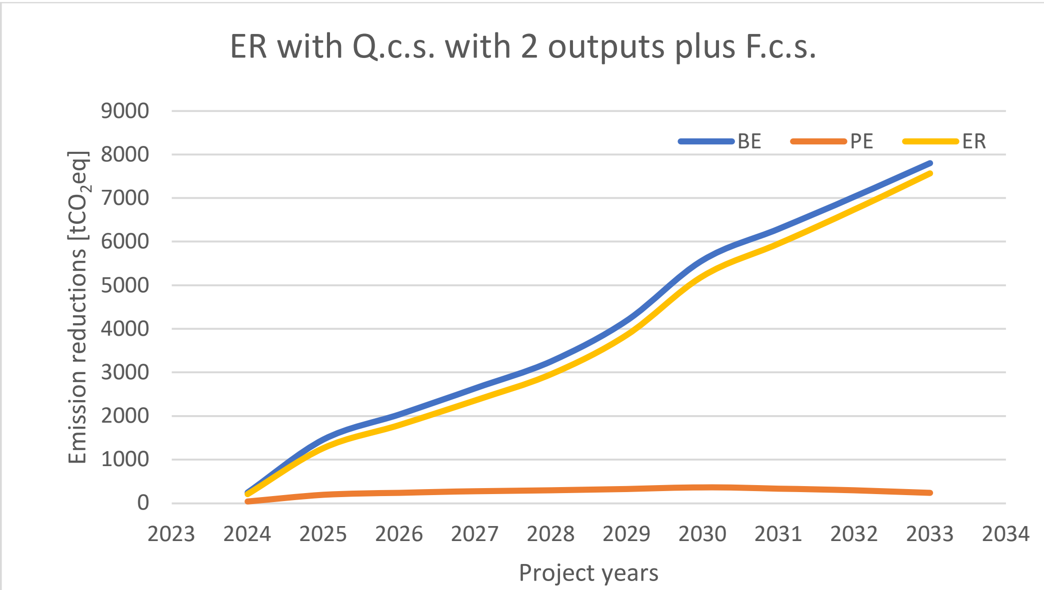

Figure 24- BE, PE, and ER in two outputs case

After the evaluation of the total amount of emission reductions for the case of quick charging systems with two outputs in table (21) are reported the values of the emission reductions for the two different types of charging systems and in figure (25) are reported the same values but it is possible to see the evolution in the project period.

Table 21- ER from two outputs Q.c.s. and from F.c.s.

years	Emission reductions Q.c.s. [tCO_2eq]	Emission reductions F.c.s. [tCO_2eq]
2024	206	0
2025	470	797
2026	973	824
2027	1,509	852
2028	2,080	881
2029	2,955	910
2030	3,330	1,880
2031	4,012	1,942
2032	4,734	2,005
2033	5,497	2,070

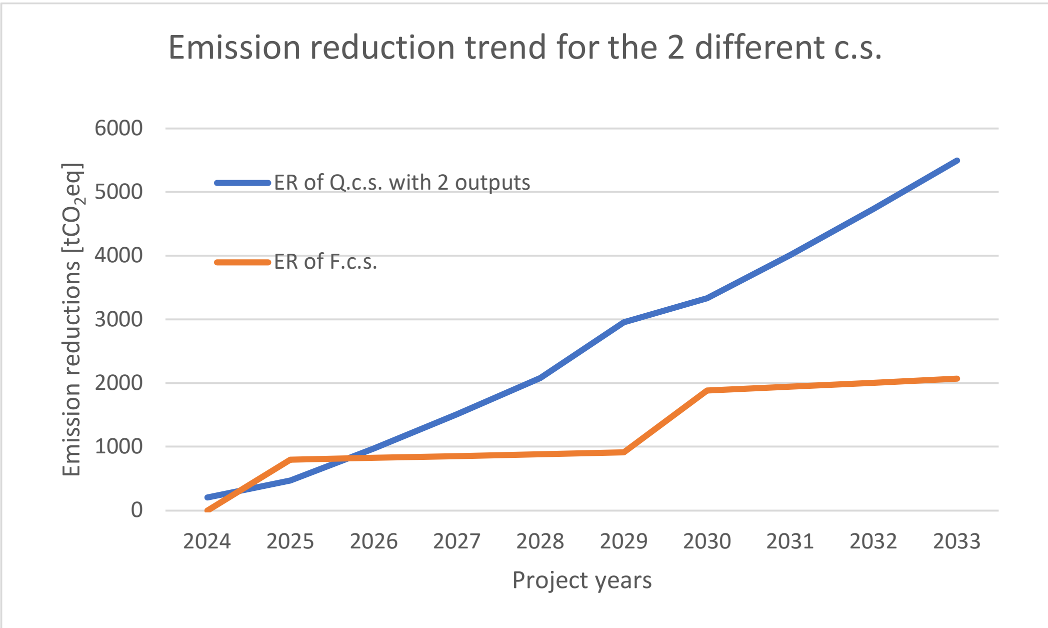

Figure 25- ER trend for the two different types of charging systems

It is useful to see in figure (25), that the ER produced by superfast charging systems is bigger than the ER of quick charging systems in 2025, but the final value of the quick charging systems is bigger than the amount of credits produced by the superfast charging systems. In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for charging system and for output, table (22):

Table 22- obtained credits in two outputs case

Total amount of credits	37,926
Total amount of credits from Q.c.s.	25,765
Credits for single Q.c.s.	1,431
Credits for single output of Q.c.s.	716
Total amount of credits from F.c.s.	12,161
Credits for single F.c.s.	6,081
Credits for single output of F.c.s.	3,040

2. In the second case the quick charging system has three outputs, so the total number of quick outputs is fifty-four, while the superfast charging system has two outputs for a total of four outputs. The results are in table (23), while in figure (26) it is possible to see the growth of the total emission reductions.

Table 23- emissions reduction in three outputs case

year	Baseline emissions [tCO_2eq]	Project emissions [tCO_2eq]	Emission reductions [tCO_2eq]
2024	368	59	309
2025	1,732	230	1,502
2026	2,590	307	2,283
2027	3,480	364	3,116
2028	4,402	402	4,000
2029	5,796	454	5,342
2030	7,359	484	6,875
2031	8,410	451	7,959
2032	9,504	399	9,106
2033	10,642	326	10,316

Summing all the emission reductions the total amount of generated credits is 50,808 during the ten years of the project.

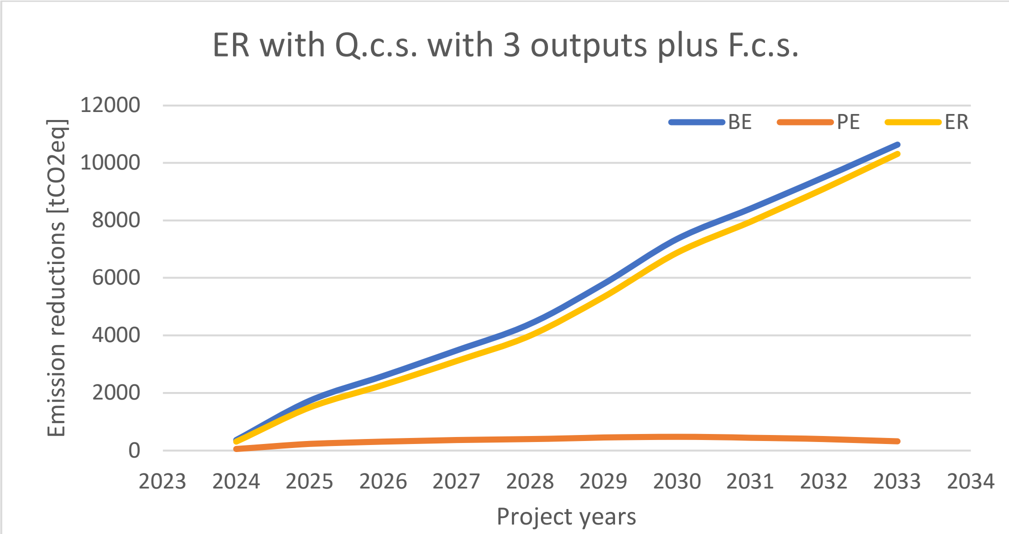

Figure 26- BE, PE, and ER in three outputs case

After the evaluation of the total amount of emission reductions for the case of quick charging system with three outputs in table (24) are reported the values of the emission reductions for the two different types of charging systems and in figure (27) are reported the same values but it is possible to see the evolution in the project period.

Table 24- ER from three outputs Q.c.s. and from F.c.s.

years	Emission reductions Q.c.s. [tCO_2eq]	Emission reductions F.c.s. [tCO_2eq]
2024	309	0
2025	705	797
2026	1,459	824
2027	2,263	852
2028	3,119	881
2029	4,432	910
2030	4,994	1,880
2031	6,017	1,942
2032	7,101	2,005
2033	8,246	2,070

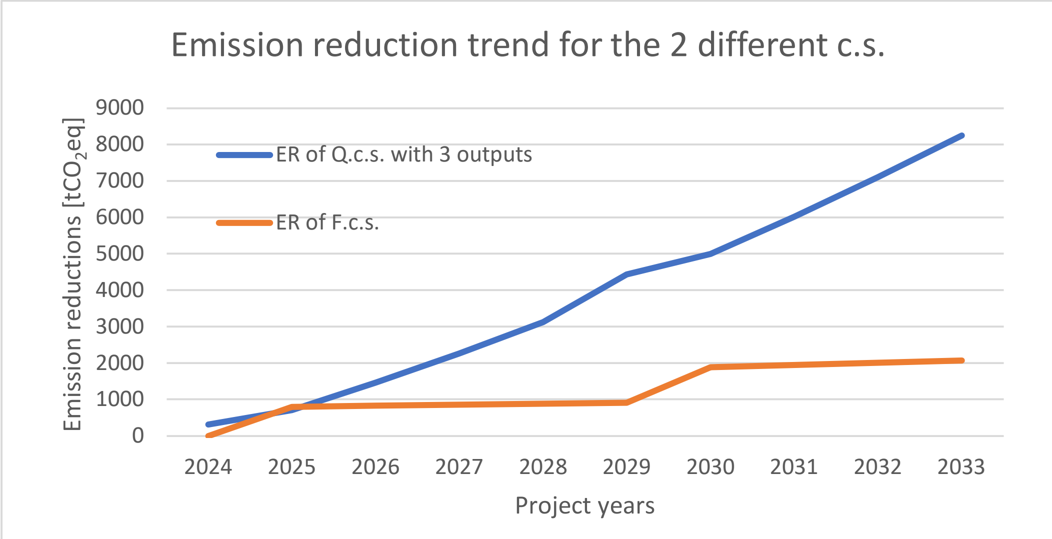

Figure 27- ER trend for the two different types of charging systems

It is useful to see in figure (27), that the ER produced by superfast charging systems is similar to the ER of quick charging systems in 2025. Respect to the case of two outputs in quick charging systems, in 2025 the three outputs case creates a similar amount of credits.

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for charging system and for output, table (25):

Table 25- obtained credits in three outputs case

Total amount of credits	50,808
Total amount of credits from Q.c.s.	38,647
Credits for single Q.c.s.	2,147
Credits for single output of Q.c.s.	716
Total amount of credits from F.c.s.	12,161
Credits for single F.c.s.	6,081
Credits for single output of F.c.s.	3,040

3. In the third case the quick charging system has four outputs, so the total number of quick outputs is seventy-two, while the superfast charging system has two outputs for a total of four outputs. The results are in table (26), while in figure (28) it is possible to see the growth of the total emission reductions.

Table 26- emissions reduction in four outputs case

year	Baseline emissions [tCO_2eq]	Project emissions [tCO_2eq]	Emission reductions [tCO_2eq]
2024	553	88	464
2025	2,138	284	1,855
2026	3,418	405	3,013
2027	4,744	496	4,247
2028	6,118	558	5,560
2029	8,200	642	7,558
2030	10,032	660	9,372
2031	11,590	622	10,968
2032	13,210	554	12,656
2033	14,896	457	14,439

Summing all the emission reductions the total amount of generated credits is 70,132 during the ten years of the project.

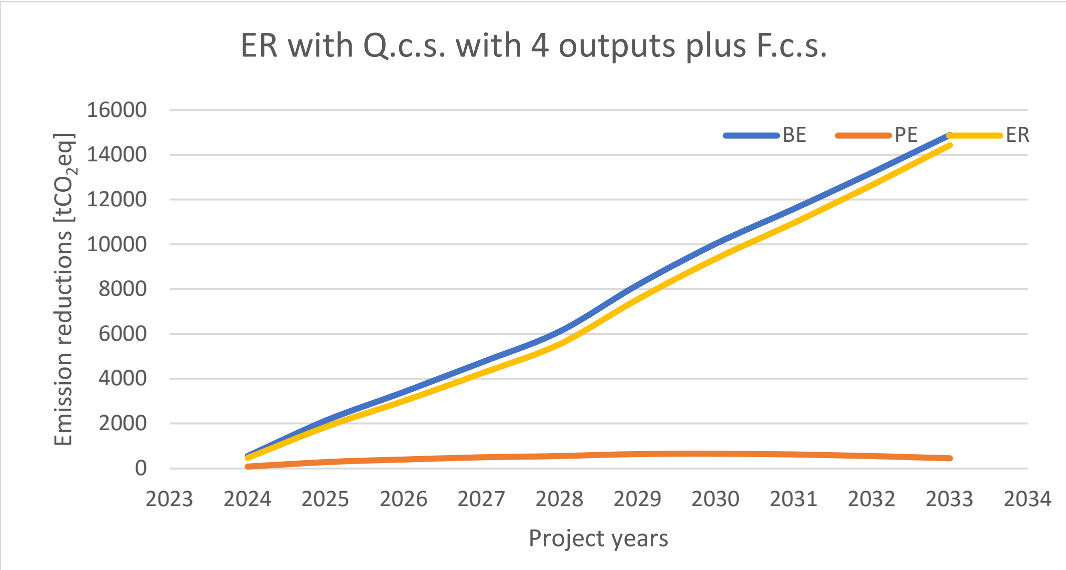

Figure 28- BE, PE, and ER in four outputs case

After the evaluation of the total amount of emission reductions for the case of quick charging systems with four outputs, in table (27) are reported the values of the emission reductions for the two different types of charging systems and in figure (29) are reported the same values but it is possible to see the evolution in the project period.

Table 27- ER from four outputs Q.c.s. and from F.c.s.

years	Emission reductions Q.c.s. [tCO_2eq]	Emission reductions F.c.s. [tCO_2eq]
2024	464	0
2025	1,058	797
2026	2,189	824
2027	3,395	852
2028	4,679	881
2029	6,648	910
2030	7,492	1,880
2031	9,026	1,942
2032	10,651	2,005
2033	12,369	2,070

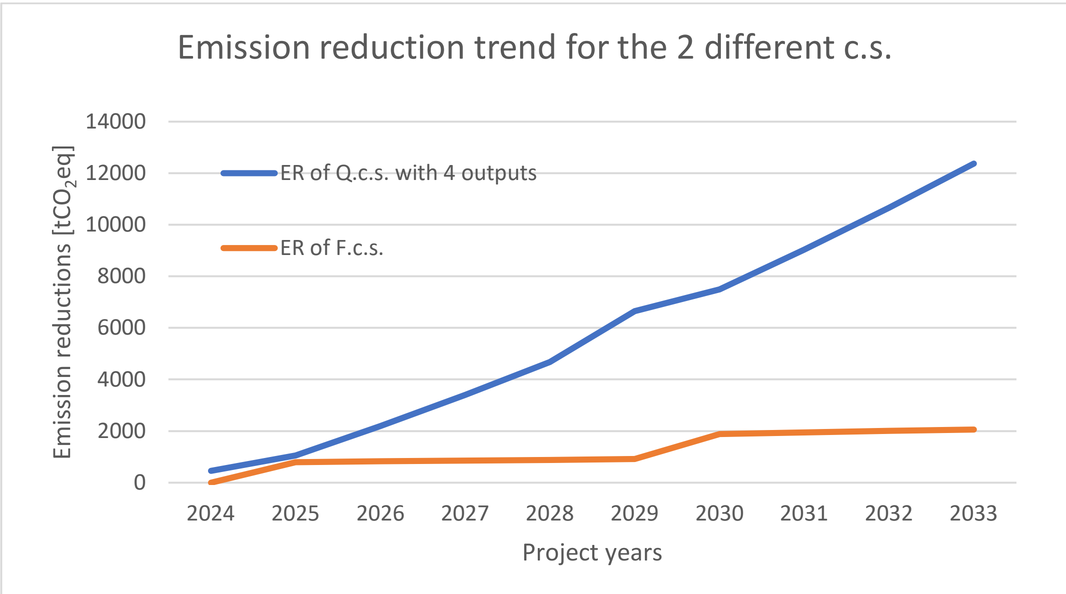

Figure 29- ER trend for the two different types of charging systems

In the case of four outputs also in 2025, the quick charging system produces more credits than to superfast charging system unlikely to the other two cases.

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for charging system and for output, table (28):

Table 28- obtained credits in four outputs case

Total amount of credits	70,132
Total amount of credits from Q.c.s.	57,971
Credits for single Q.c.s.	3,221
Credits for single output of Q.c.s.	805
Total amount of credits from F.c.s.	12,161
Credits for single F.c.s.	6,081
Credits for single output of F.c.s.	3,040

Then after the evaluation of all the generated credits from the three different cases a plot has been created to compare the results. Figure (26) shows the amount of credits that the three projects can create, and as it can expectable a bigger amount of outputs correspond to a bigger amount of generated credits.

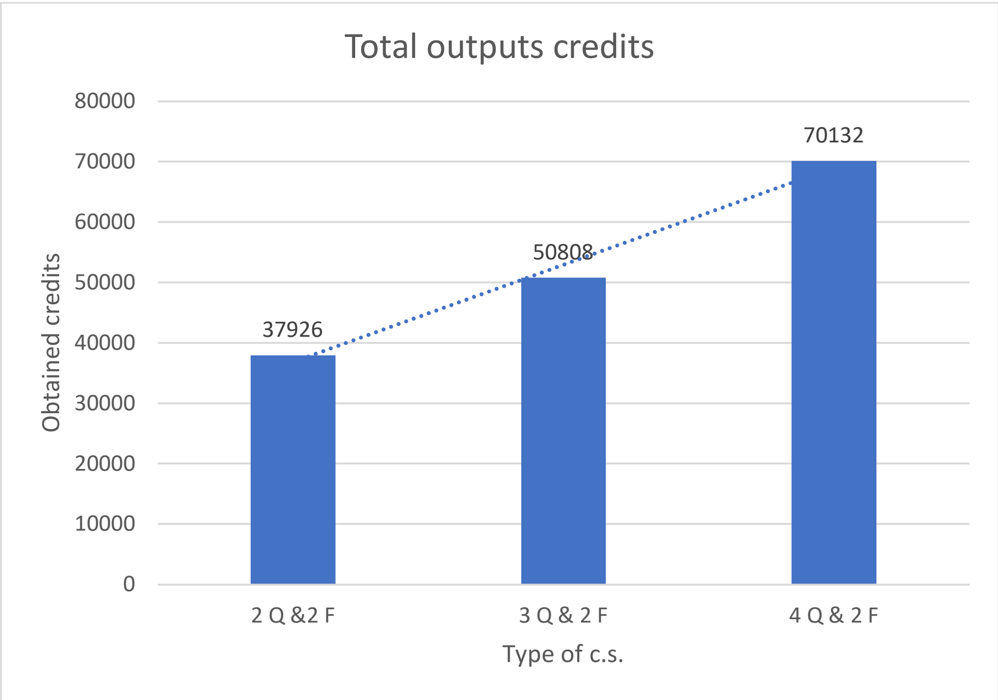

Figure 30- comparison of amount of obtained credits from the three cases

Therefore, in conclusion, due to the stability of the condition on the number of superfast charging systems outputs their ER does not change in the three cases, what change is the amount of ER generated by the three cases of quick charging system number of outputs. In figure (30) there is a histogram that describes the trend of increase in the number of generated credits in function of the three different cases. It is possible to understand that an increase in the number of outputs corresponds to an increase in the generated credits with an increase that has a linear trend.

5.6.2 Emission reductions with an electricity mix that completely derived from renewable energy

In ER evaluation there is always the distinction between the three different cases of outputs number. For each of these cases there are three different results: one for the total credit number of the project, one of the produced credits by the quick charging systems, and the last of the obtained credits by superfast charging systems. Each of these results after is divided for the number of charging systems in order to obtain the generated credits for charging system and then for the number of outputs to obtain the same results, but for output. The difference from the previous chapter stays in the electricity mix used and then in the emission factor for the electrical consumption. Due to the fact that in this case the electricity mix comes totally from renewable energy the emission factor is null, so also the project emissions are equal to zero. To reach the totality of the electricity from renewable energy probably the installation of photovoltaic panels on the charging systems is not enough. A real possibility comes from the verified acquisition of renewable energy from some societies.

1. In the first case the quick charging system has two outputs, so the total number of quick outputs is thirty-six, also the superfast charging system has two outputs for a total of four outputs. The results are in table (29), while in figure (31) it is possible to see the growth of the total emission reductions.

Table 29- emissions reduction in two outputs case

year	Baseline emissions [tCO_2eq]	Project emissions [tCO_2eq]	Emission reductions [tCO_2eq]
2024	246	0	246
2025	1,461	0	1,461
2026	2,038	0	2,038
2027	2,637	0	2,637
2028	3,258	0	3,258
2029	4,193	0	4,193
2030	5,577	0	5,577
2031	6,291	0	6,291
2032	7,034	0	7,034
2033	7,807	0	7,807

Summing all the emission reductions the total amount of generated credits is 43,484 during the ten years of the project.

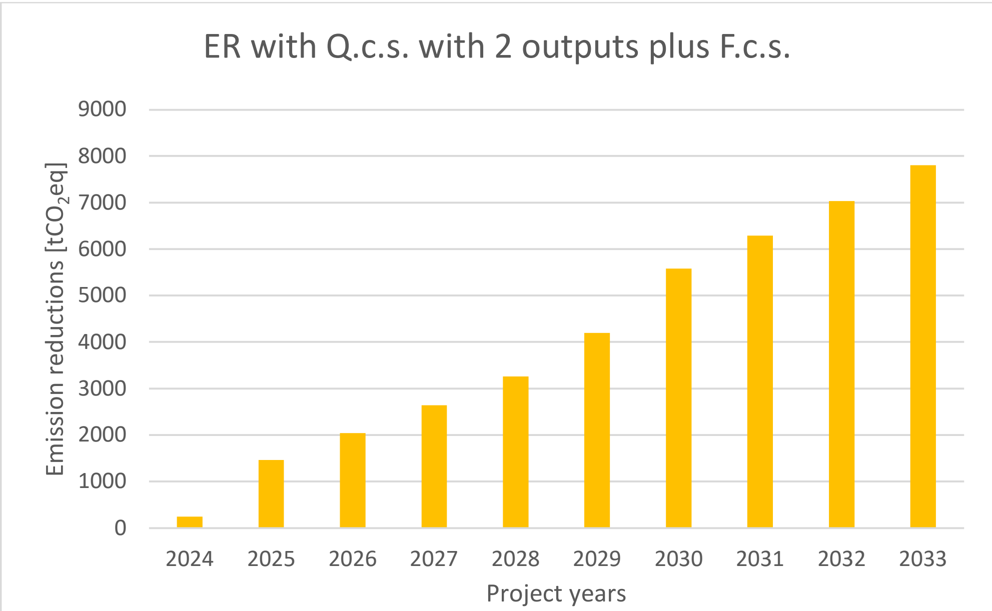

Figure 31- ER in two outputs case

After the evaluation of the total amount of emission reductions for the case of quick charging systems with two outputs, in table (30) are reported the values of the emission reductions for the two different types of charging systems and in figure (32) are reported the same values but it is possible to see the evolution in the project period.

Table 30- ER from two outputs Q.c.s. and from F.c.s.

years	Emission reductions Q.c.s. [tCO_2eq]	Emission reductions F.c.s. [tCO_2eq]
2024	242	0
2025	542	919
2026	1,104	935
2027	1,685	952
2028	2,288	969
2029	3,206	987
2030	3,564	2,013
2031	4,239	2,052
2032	4,941	2,093
2033	5,671	2,135

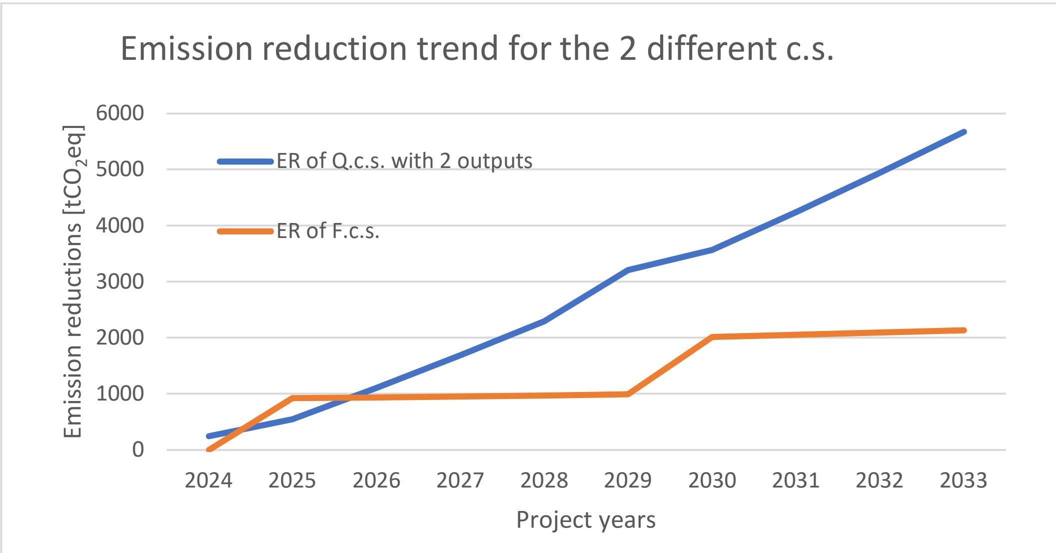

Figure 32- ER trend for the two different types of charging systems

It is useful to see in figure (32), that the ER produced by superfast charging systems is bigger than the ER of quick charging systems in 2025, but the final value of the quick charging systems is bigger than the amount of credits produced by the superfast charging systems.

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for charging system and for output, table (31):

Table 31- obtained credits in two outputs case

Total amount of credits	40,541
Total amount of credits from Q.c.s.	27,486
Credits for single Q.c.s.	1,527
Credits for single output of Q.c.s.	763
Total amount of credits from F.c.s.	13,055
Credits for single F.c.s.	6,527
Credits for single output of F.c.s.	3,264

2. In the second case the quick charging system has three outputs, so the total number of quick outputs is fifty-four, while the superfast charging system has two outputs for a total of four outputs. The results are in table (32), while in figure (33) it is possible to see the growth of the total emission reductions.

Table 32- emissions reduction in three outputs case

year	Baseline emissions [tCO_2eq]	Project emissions [tCO_2eq]	Emission reductions [tCO_2eq]
2024	368	0	368
2025	1,732	0	1,732
2026	2,590	0	2,590
2027	3,480	0	3,480
2028	4,402	0	4,402
2029	5,796	0	5,796
2030	7,359	0	7,359
2031	8,410	0	8,410

2032	9,504	0	9,504
2033	10,642	0	10,642

Summing all the emission reductions the total amount of generated credits is 54,283 during the ten years of the project.

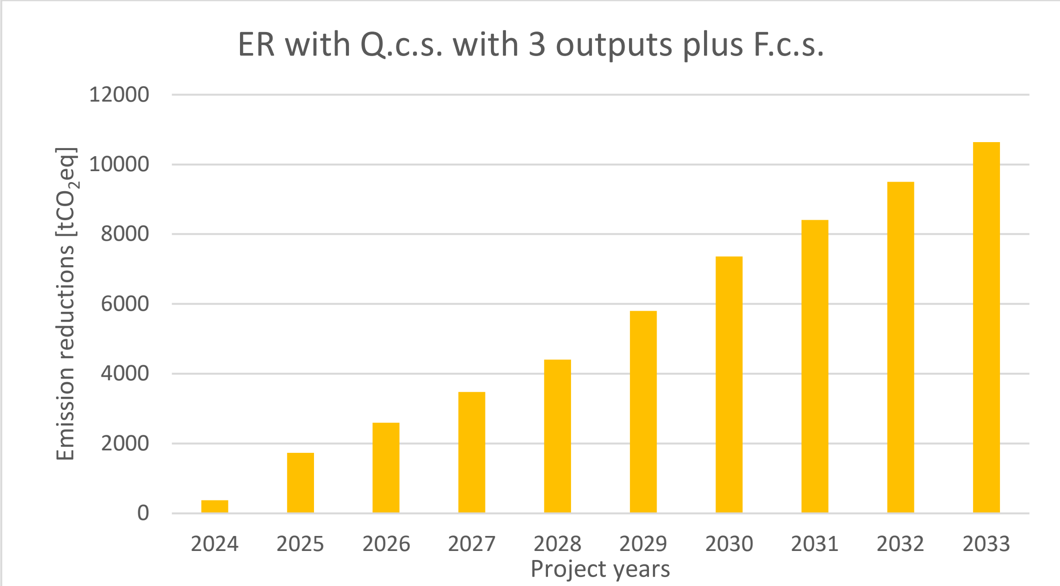

Figure 33- ER in three outputs case

After the evaluation of the total amount of emission reductions for the case of quick charging systems with three outputs, in table (33) are reported the values of the emission reductions for the two different types of charging systems and in figure (34) are reported the same values but it is possible to see the evolution in the project period.

Table 33- ER from three outputs Q.c.s. and from F.c.s.

years	Emission reductions Q.c.s. [tCO_2eq]	Emission reductions F.c.s. [tCO_2eq]
2024	368	0
2025	813	919
2026	1,655	935
2027	2,528	952
2028	3,433	969
2029	4,808	987
2030	5,346	2,013

2031	6,358	2,052
2032	7,411	2,093
2033	8,507	2,135

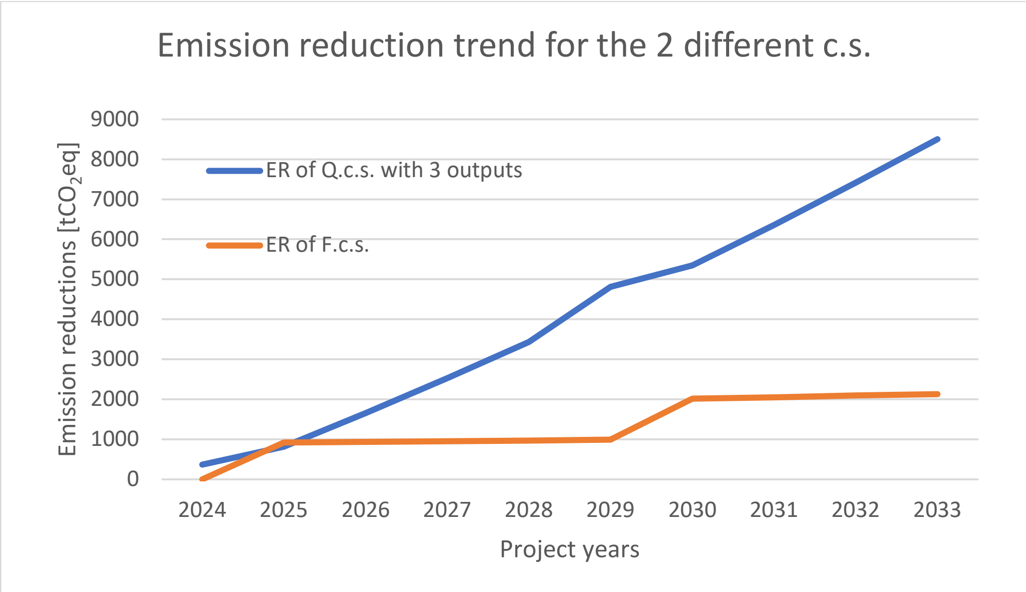

Figure 34- ER trend for the two different types of charging systems

It is useful to see in figure (34), that the ER produced by superfast charging systems is similar to the ER of quick charging systems in 2025. Respect to the case of two outputs in quick charging systems, in 2025 the three outputs case creates a similar amount of credits.

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for charging system and for output, table (34):

Table 34- obtained credits in three outputs case

Total amount of credits	54,283
Total amount of credits from Q.c.s.	41,229
Credits for single Q.c.s.	2,290
Credits for single output of Q.c.s.	763
Total amount of credits from F.c.s.	13,055
Credits for single F.c.s.	6,527
Credits for single output of F.c.s.	3,264

3. In the third case the quick charging system has four outputs, so the total number of quick outputs is seventy-two, while the superfast charging system has two outputs for a total of four outputs. The results are in table (35), while in figure (35) it is possible to see the growth of the total emission reductions.

Table 35- emissions reduction in four outputs case

year	Baseline emissions [tCO_2eq]	Project emissions [tCO_2eq]	Emission reductions [tCO_2eq]
2024	553	0	553
2025	2,138	0	2,138
2026	3,418	0	3,418
2027	4,744	0	4,744
2028	6,118	0	6,118
2029	8,200	0	8,200
2030	10,032	0	10,032
2031	11,590	0	11,590
2032	13,210	0	13,210
2033	14,896	0	14,896

Summing all the emission reductions the total amount of generated credits is 74,898 during the ten years of the project.

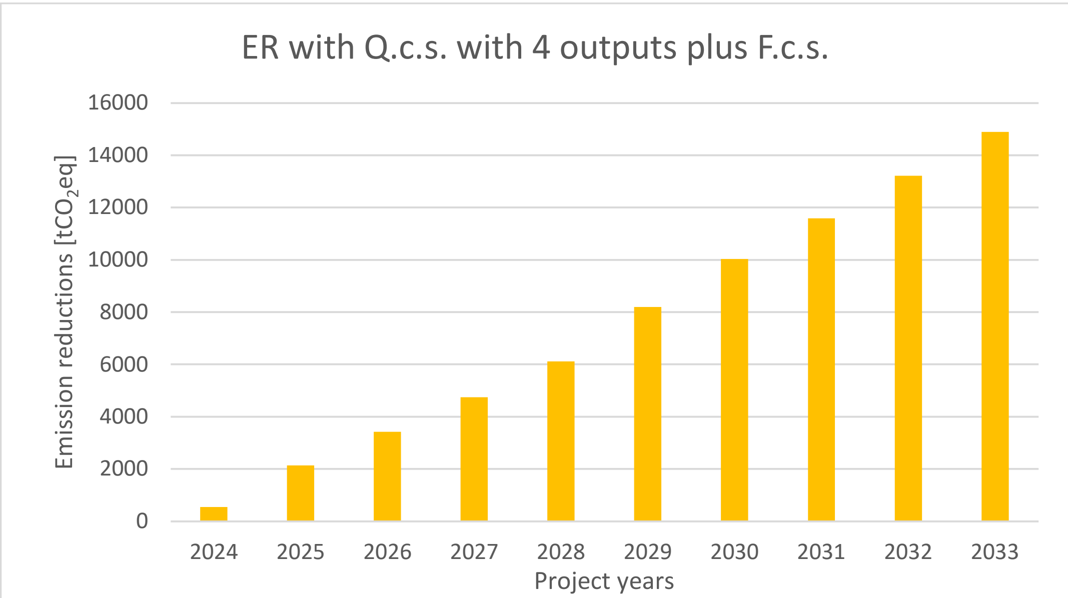

Figure 35- ER in four outputs case

After the evaluation of the total amount of emission reductions for the case of quick charging systems with four outputs, in table (36) are reported the values of the emission reductions for the two different types of charging systems and in figure (36) are reported the same values but it is possible to see the evolution in the project period.

Table 36- ER from four outputs Q.c.s. and from F.c.s.

years	Emission reductions Q.c.s. [tCO_2eq]	Emission reductions F.c.s. [tCO_2eq]
2024	553	0
2025	1,220	919
2026	2,483	935
2027	3,792	952
2028	5,149	969
2029	7,213	987
2030	8,019	2,013
2031	9,538	2,052
2032	11,117	2,093
2033	12,760	2,135

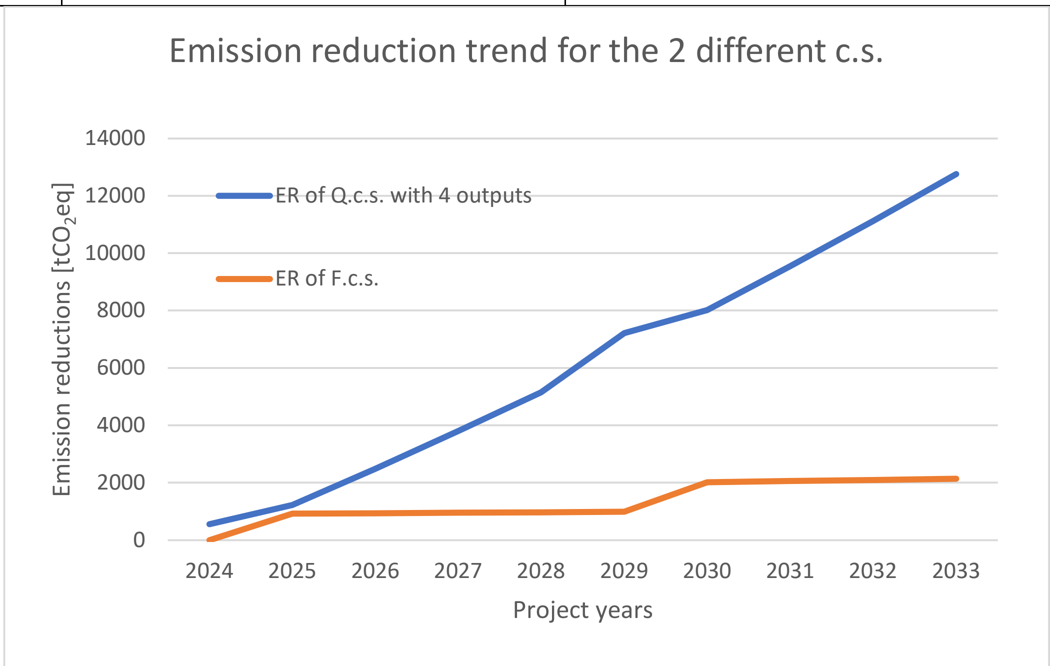

Figure 36- ER trend for the two different types of charging systems

In the case of four outputs also in 2025 the quick charging systems produce more credits than the superfast charging systems unlikely to the other two cases. In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for charging system and for output, table (37):

Table 37- obtained credits in four outputs case

Total amount of credits	74,898
Total amount of credits from Q.c.s.	61,843
Credits for single Q.c.s.	3,436
Credits for single output of Q.c.s.	859
Total amount of credits from F.c.s.	13,055
Credits for single F.c.s.	6,527
Credits for single output of F.c.s.	3,264

Then after the evaluation of all the generated credits from the three different cases a plot has been created to compare the results. Figure (37) shows the amount of credits that the three projects can create, and as it is expectable a bigger amount of outputs correspond to a bigger amount of generated credits.

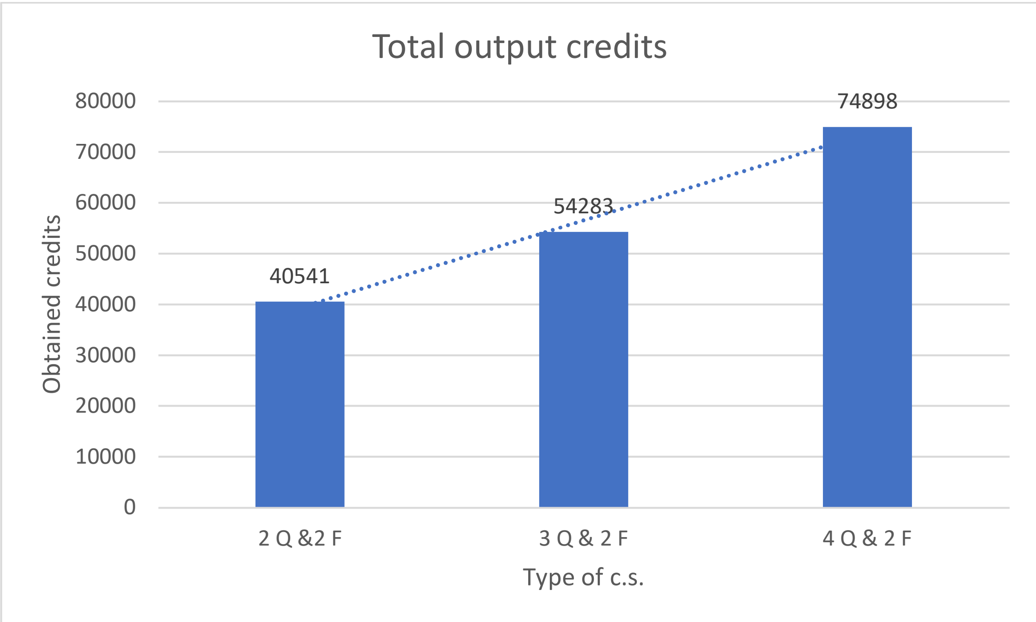

Figure 37- comparison of amount of obtained credits from the three cases

The number of generated credits is higher respect to the previous case due to the absence of the project emissions, but also in this case the increase in the obtained credits has a linear trend.

5.6.3 Emission reduction result comparison

The last paragraph of chapter 5 presents a summary of the final results based on the number of outputs that are obtained in the three cases of the quick charging system.

For what concern the emission reductions in the scenario that represent the actual projection the obtained results are represented in table (38):

Table 38- ER generation for the three cases in projected scenario

N° of outputs in Q.c.s.	2	3	4
Total ER credits for Q.c.s.	25,765	38,647	57,971
ER credits for Q.c.s.	1,431	2,147	3,221
ER credits for output of Q.c.s	716	716	805
Total ER credits for F.c.s.	12,161	12,161	12,161
ER credits for F.c.s.	6,081	6,081	6,081
ER credits for output of F.c.s	3,040	3,040	3,040
Total ER credits	37,926	50,808	70,132

From the results reported in table (38) it is possible to see that the total amount of credits, increases with the number of outputs, as it is expectable. Another interesting thing that is good to underline is the fact that the amount of emission reductions per output, in the quick charging systems, is equal in the case of two and three outputs while it increases in the case of four outputs. Probably it is due to the fact that in the quick charging system the baseline emissions respect to the project emissions increases a lot in the last case. Therefore, what changes from the generated credits in quick charging system with two or three outputs is the credits per charging system, because one is multiplied for the two outputs and the second for three outputs. With two plots is possible to see the difference in the results, where figure (38) is for the credits linked to charging system, while figure (39) is for the credits for output.

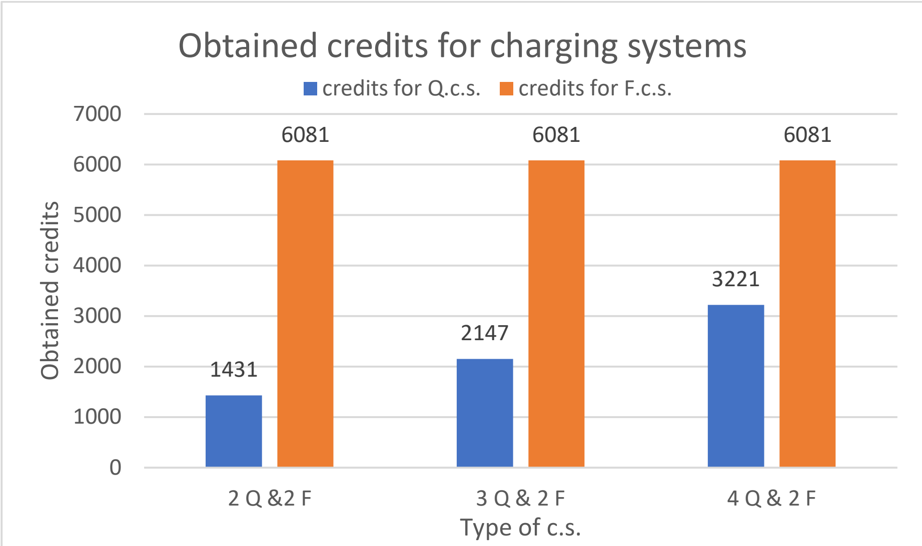

Figure 38- obtained credits for charging system type and case

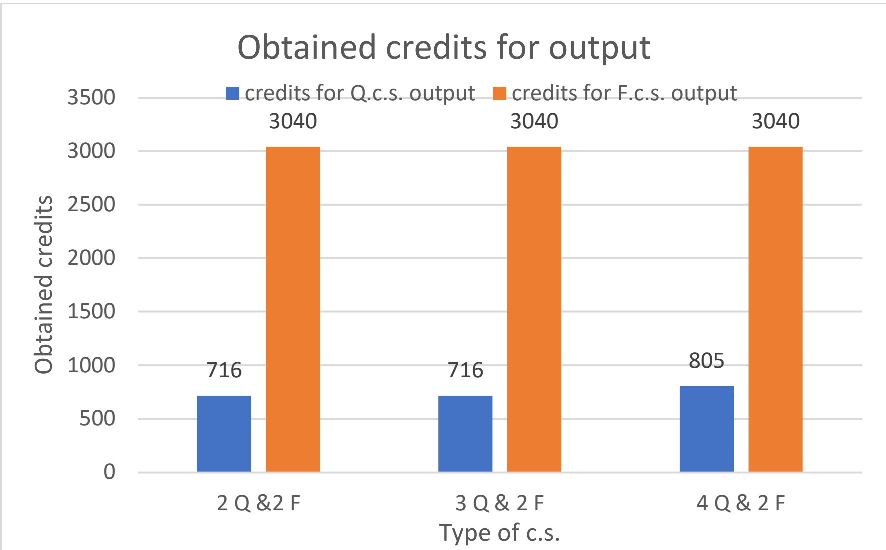

Figure 39- obtained credits per output for charging system type and case

In the second scenario, the one in which all the used electricity comes from renewable energy, the project emissions are null. Therefore, now the generated credits are more respect the previous case, but the number of extra credits is not so relevant as it is possible to imagine. In table (39) are presents the results obtained in terms of:

- Total credits;
- Credits for charging system;
- Credits for output.

Table 39- ER generation for the three cases in total renewable scenario

N° of outputs in Q.c.s.	2	3	4
Total ER credits for Q.c.s.	27,486	41,229	61,843
ER credits for Q.c.s.	1,527	2,290	3,436
ER credits for output of Q.c.s	763	763	859
Total ER credits for F.c.s.	13,055	13,055	13,055
ER credits for F.c.s.	6,527	6,527	6,527
ER credits for output of F.c.s	3,264	3,264	3,264
Total ER credits	40,541	54,283	74,898

From the results reported in table (39) it is possible to see that again the total amount of credits, and the amount for charging system increase with the number of outputs. Another interesting thing that happens again is the fact that the amount of emission reductions per output, in the quick charging systems, is equal in the case of two and three outputs while it increases in the case of four outputs. With two plots is possible to see the difference in the results, where figure (40) is for the credits linked to charging system, while figure (41) is for the credits of output.

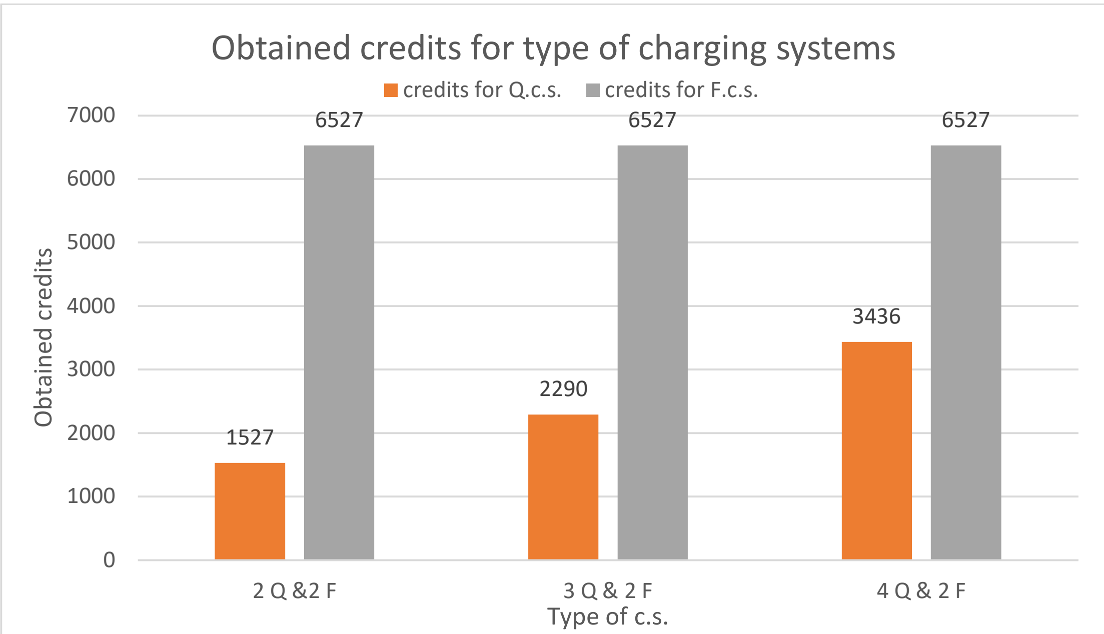

Figure 40- obtained credits for charging system type and case

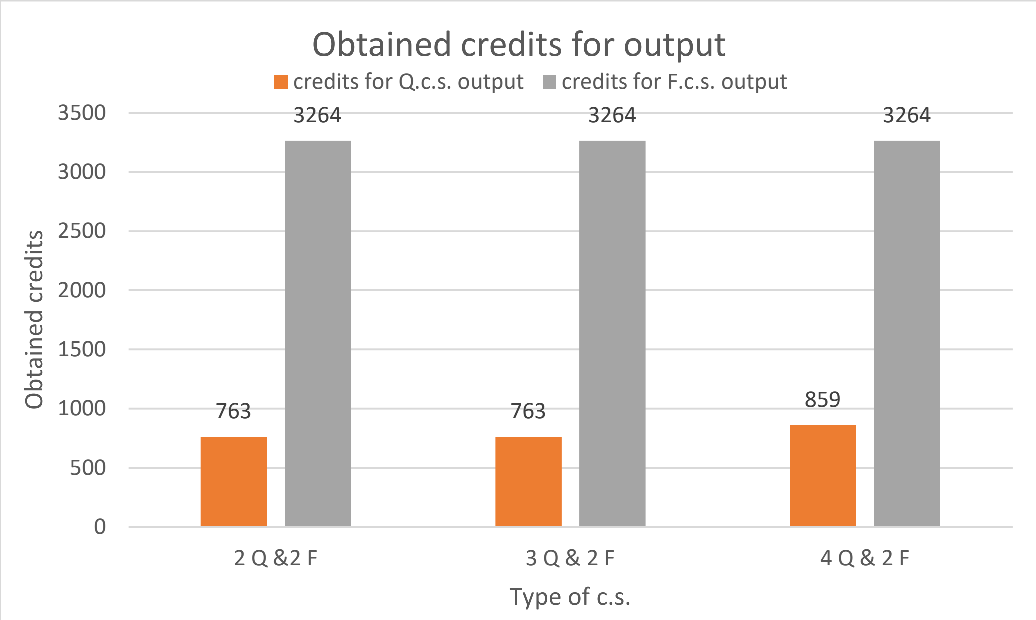

Figure 41- obtained credits per output for charging system type and case

A result that can be interesting is the difference in percentage between the amount of credits that are obtained in the two proposed scenarios. This type of result is reported in table (40):

Table 40- percentage increase from first scenario and total renewable scenario

N° of outputs in Q.c.s.	2	3	4
ER credits for Q.c.s.	+6.7%	+6.7%	+6.7%
ER credits for output of Q.c.s	+6.7%	+6.7%	+6.7%
ER credits for F.c.s.	+7.3%	+7.3%	+7.3%
ER credits for output of F.c.s	+7.3%	+7.3%	+7.3%
Total ER credits	+6.9%	+6.8%	+6.8%

Talking again of percentage inside the table (41) are present the increase in percentage from the case of two outputs up to the case of four, for the two scenarios.

Table 41- increase in generated credits percentage with an increase in number of outputs

Scenario	Credit increases 2 → 3 [%]	Credit increases 3 → 4 [%]	Credit increases 2 → 4 [%]
Projected scenario	+34%	+38%	+84.9%
Total renewable scenario	+33.9%	+38%	+84.7%

Figure (42) shows a comparison of the generated credits of the two proposed scenarios, and for the three different cases of outputs number of quick charging systems. The renewable scenario creates more credits respected the projected one.

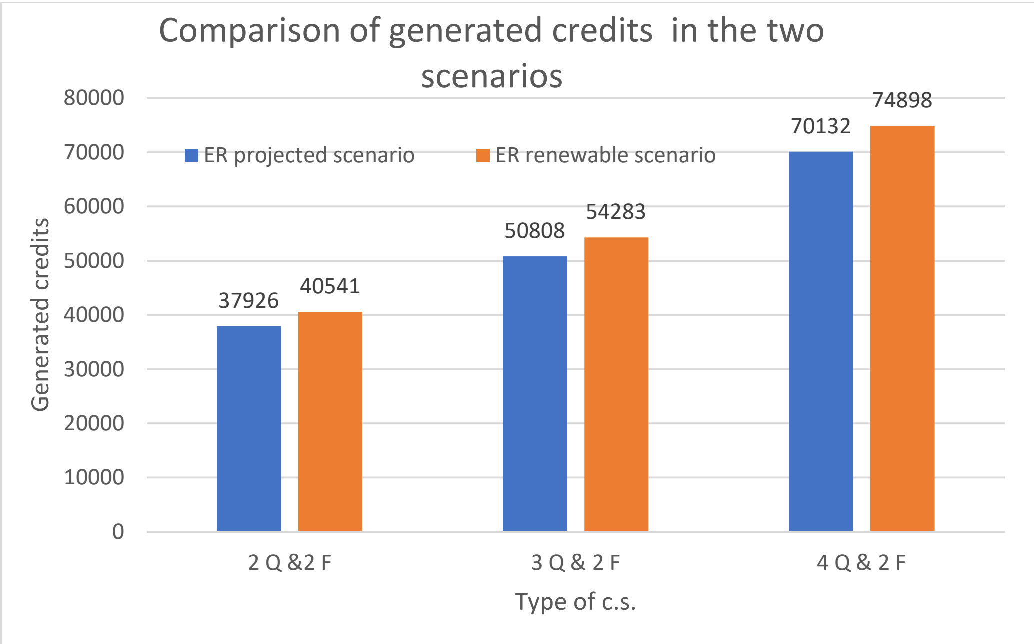

Figure 42- comparison of generated credits in the two scenarios for the three cases

6. Change of mind project

6.1 Project idea and methodology at the base

With this second part of the project there is the will to define if an increase in the offer of EV charging systems can induce in the citizens of Genoa a mentality change.

This change is related to the substitution of fossil fuel vehicles to EVs. As said before in Genoa there is the aim to install twenty new charging systems, divided in:

- Eighteen quick charging systems;
- Two superfast charging systems.

This increase in the number of offers in charging points is reflected to an increase in the number of vehicles that can be charged. Three different cases of number of outputs in quick charging systems have been defined in the methodology, VM0038[81], evaluated in chapter 5. These three cases define a different number of outputs at the end of the project with also a change in the total number of induced EVs.

To define if the people's mentality change, due to new charging systems installation, can produce emission reduction credits is necessary to use a new methodology. For this aim, there is not a specific methodology that performs an analysis on vehicle substitution. Due to this absence a methodology on increase in bicycle use, Bologna Carbon Market (BoCaM)[82] have been taken as starting point. With BoCaM project the municipality of Bologna has the aim to improve the mobility in the city with the bicycle in order to reduce the GHG emissions and to reduce traffic. To improve the number of bicycles is important to create a continuous, and safe cycling network that is connected with other forms of mobility.

Instead to use the bicycle flux during the project years, the used data is the induced number of EVs that comes from the project outputs in the different project years.

Therefore, to define the possible emission reductions it is necessary to evaluate the number of EVs that each output induce. To do it the numbers of EVs and the numbers of outputs have been taken in 2019 and 2021. The number of induced EVs for output is a

[81] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018.
[82] Eco2care, "Bologna Carbon Market (BoCaM)", 2015.

media of the ratio of the number of vehicles for the number of outputs in the two considered years. In table (42) is possible to see the values of the two years:

Table 42- ratio EVs for outputs

year	N° of outputs	N° of EVs[83]	EV/output
2019	200[84]	172	0.86
2021	314[85]	615	1.96

The media obtained from the two ratios is 1.41 [EV/output]. This value is the starting point for the evaluation of the baseline and of the project emissions that are used in the emission reduction evaluation. The induced vehicles represent the number of new autos that the installation of new project outputs implies during a project year in function to the average value of 1.41 [EV/output].

[83] https://opv.aci.it/WEBDMCircolante/.

[84] https://smart.comune.genova.it/articoli/genova-fa-il-pieno-di-energia-e-inaugura-100-colonnine-elettriche.

[85] Motus E, “Le infrastrutture di ricarica pubbliche in Italia”, 2021.

6.2 Baseline emissions

The baseline emissions are evaluated considering the vehicles induced by the outputs fuelled by fossil fuels, like in VM0038[86]. The formula that is considered the best one to calculate the baseline emissions is:

$$BE_y = induced\ auto_y * EF * km_y$$

Where:

- BE_y is the baseline emissions for the year y [tCO_2eq/year];
- $induced\ auto_y$ is the number of EVs that are induced during year y from the number of installed outputs;
- EF is the average value of the emission factor of the considered fossil fuels per km [tCO_2eq/km];
- km_y is the average number of kilometers that a person travels by car in a year [km/year].

The parameter km_y is considered as a constant and equal to 10,500[87] [km/year], from a regional media in which the Liguria is one of the regions with the less amount of traveled km per year.

Four different fossil fuel vehicles have been considered in the evaluation of the EF: petrol, petrol hybrid, diesel, and diesel hybrid. From ISPRA the urban area data of CO_2, CH_4, and N_2O[88] related to the four considered fossil fuel vehicles have been downloaded. For what concern the CH_4 and N_2O, they need to be converted into equivalent CO_2 in order to calculate the EF referred in CO_2. Through IPCC table of the 2021 it is possible to download their conversion factor related to 100 years of Global Warming Potential (GWP 100). Then, multiplying the emissions at urban level and their related conversion factor there is the passage from these GHGs to equivalent CO_2. Considering that the conversion factor of CH_4 is 29.8 and of N_2O is 273[89], in conclusion, in table (43) is reported the sum of the three EFs for the different fossil fuels vehicles.

[86] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018.
[87]https://www.dalcarnoleggio.it/kmannui/#:~:text=I%20risultati%20si%20differenziano%20leggermente,notevolmente%20da%20regione%20a%20regione.
[88] https://fetransp.isprambiente.it/#/
[89] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

Table 43- number of present outputs in the city of Genoa during the years

Fossil fuels type of vehicles	CO_2 [g/km]	CH_4 [g/km]	N_2O [g/km]	$CH_4 \rightarrow CO_2eq$ [gCO_2eq/km]	$N_2O \rightarrow CO_2eq$ [gCO_2eq/km]	EF [tCO_2eq/km]
Petrol	251.53	0.082	0.006	2.444	1.638	0.000256
Petrol Hybrid	197.58	0.05	0.005	1.490	1.365	0.000200
Diesel	236.37	0.001	0.02	0.030	5.460	0.000242
Diesel Hybrid	141.05	0.00008	0.009	0.002	2.457	0.000144

The EF that is used for the baseline emissions is a weighted average of the four obtained in table (43) with the number of vehicles that are present in Genoa[90]. In table (44) are presents the number of vehicles that are circulated in Genova in 2021 differentiated by the fossil fuels with which are fuelled.

Table 44- number of vehicles for different fossil fuels

Fossil fuels type of vehicles	Number of vehicles
Petrol	149,890
Petrol Hybrid	10,076
Diesel	96,382
Diesel Hybrid	649

Now with the number of vehicles and with the different values of EF is possible to make a weighted average of the EF. The result is 0.000248 [tCO_2eq/km].

[90] https://opv.aci.it/WEBDMCircolante/.

The quick charging systems have three possibilities in the outputs number, from two to four, defining in this way three different calculations of baseline emissions. Due to the different cases also the induced auto per output change, because the number of outputs per project year change. To evaluate this number it is necessary to multiply the number of outputs, that there are in that project year, with the medium value of induced EVs per output calculated before and equal to 1.41 [EV/output].

In conclusion, with the presented formula it is possible to evaluate the baseline emissions for the three different discussed cases of the number of outputs in the quick charging systems. In each case it is also important to define the amount of baseline emissions that derives from the quick and superfast outputs, in order to define the weight that the two types of charging system have on the project.

1. Two outputs for the quick charging systems and two outputs for superfast charging systems. In table (45) are collected the total values of induced EVs in the project.

Table 45- induced auto for the total new outputs

year	Outputs number	Induced auto per new output
2024	2	3
2025	6	9
2026	10	15
2027	15	21
2028	19	27
2029	23	33
2030	27	39
2031	32	44
2032	36	50
2033	40	56

While, in table (46) are collected the values of induced EVs for the two different types of charging systems.

Table 46- induced auto for outputs in the two-charging systems type

year	Outputs number Q.c.s.	Induced auto per new Q.c.s. output	Outputs number F.c.s.	Induced auto per new F.c.s. output
2024	2	3	0	0
2025	4	6	2	3
2026	8	11	2	3
2027	12	17	2	3
2028	16	23	2	3
2029	22	31	2	3
2030	24	34	4	6
2031	28	39	4	6
2032	32	45	4	6
2033	36	51	4	6

From the evaluation of all the parameters is possible to calculate the baseline emissions for the different numbers of induced EVs. In table (47) are collected these results, while figure (43) represents the same values of the two charging systems, but in a histogram.

Table 47- Baseline emissions

year	BE Q.c.s. [tCO_2eq/year]	BE F.c.s. [tCO_2eq/year]	BE tot [tCO_2eq/year]
2024	7	0	7
2025	15	7	23
2026	29	7	38
2027	44	7	54
2028	59	7	69
2029	81	7	85
2030	88	15	100
2031	103	15	116
2032	117	15	131
2033	132	15	147

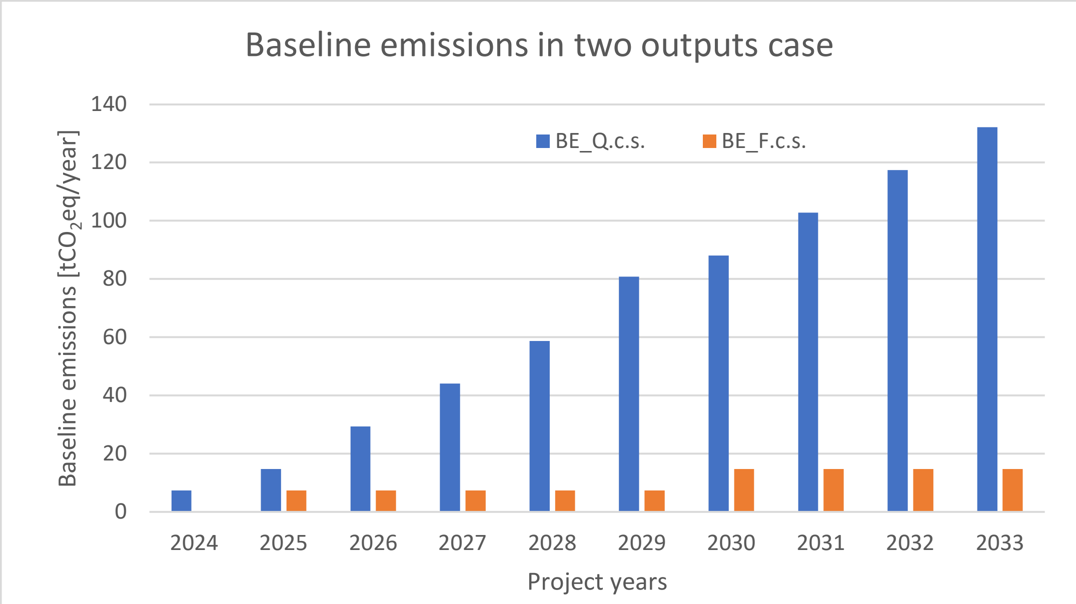

Figure 43- baseline emissions in two outputs case

2. Three outputs for the quick charging systems and two outputs for superfast charging systems. In table (48) are collected the total values of induced EVs in the project.

Table 48- induced auto for the total new outputs

year	Outputs number	Induce auto per new output
2024	3	4
2025	9	13
2026	15	21
2027	21	30
2028	27	39
2029	34	47
2030	40	56
2031	46	65
2032	52	73
2033	58	82

While, in table (49) are collected the values of induced EVs for the two different types of charging systems.

Table 49- induced auto for outputs in the two-charging systems type

year	Outputs number Q.c.s.	Induced auto per new Q.c.s. output	Outputs number F.c.s.	Induced auto per new F.c.s. output
2024	3	4	0	0
2025	6	8	2	3
2026	12	17	2	3
2027	18	25	2	3
2028	24	34	2	3
2029	33	47	2	3
2030	36	51	4	6
2031	42	59	4	6
2032	48	68	4	6
2033	54	76	4	6

From the evaluation of all the parameters is possible to calculate the baseline emissions for the different numbers of induced EVs. In table (50) are collected these results, while figure (44) represents the same values of the two charging systems, but in a histogram.

Table 50- baseline emissions

year	BE Q.c.s. [tCO_2eq/year]	BE F.c.s. [tCO_2eq/year]	BE tot [tCO_2eq/year]
2024	11	0	11
2025	22	7	33
2026	44	7	56
2027	66	7	78
2028	88	7	101
2029	121	7	123
2030	132	15	146
2031	154	15	168
2032	176	15	190
2033	198	15	213

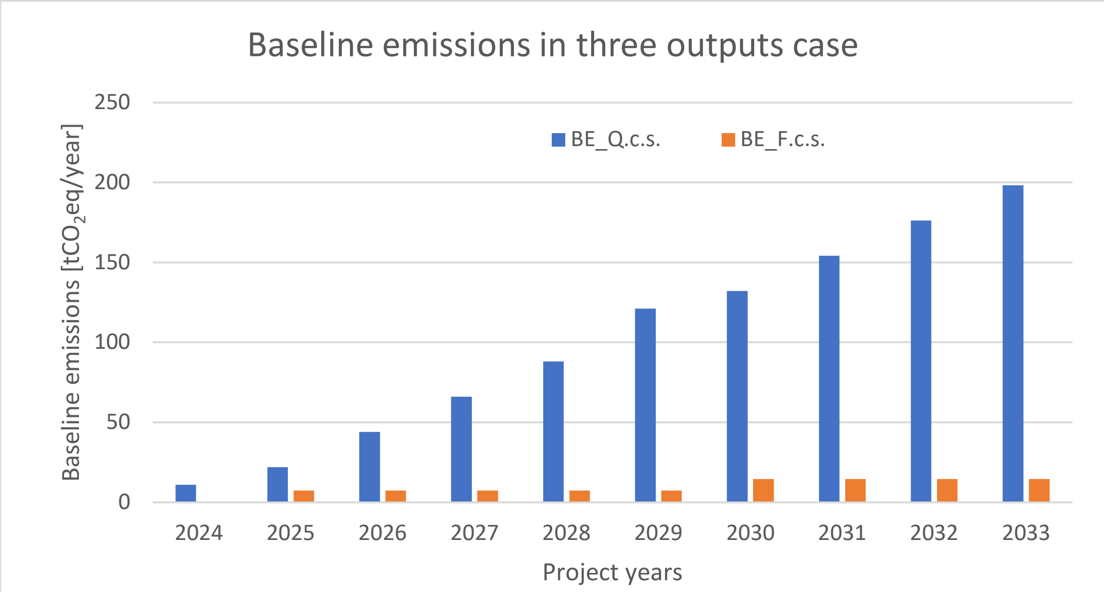

Figure 44- baseline emissions in three outputs case

3. Three outputs for the quick charging systems and two outputs for superfast charging systems. In table (51) are collected the total values of induced EVs in the project.

Table 51- induced auto for the total new outputs

year	Outputs number	Induce auto per new output
2024	4	6
2025	12	17
2026	20	28
2027	28	39
2028	36	51
2029	44	62
2030	52	73
2031	60	85
2032	68	96
2033	76	107

While, in table (52) are collected the values of induced EVs for the two different types of charging systems.

Table 52- induced auto for outputs in the two-charging systems type

year	Outputs number Q.c.s.	Induced auto per new Q.c.s. output	Outputs number F.c.s.	Induced auto per new F.c.s. output
2024	4	6	0	0
2025	8	11	2	3
2026	16	23	2	3
2027	24	34	2	3
2028	32	45	2	3
2029	44	62	2	3
2030	48	68	4	6
2031	56	79	4	6
2032	64	90	4	6
2033	72	101	4	6

From the evaluation of all the parameters is possible to calculate the baseline emissions for the different numbers of induced EVs. In table (53) are collected these results, while figure (45) represents the same values of the two charging systems, but in a histogram.

Table 53- baseline emissions

year	BE Q.c.s. [tCO_2eq/year]	BE F.c.s. [tCO_2eq/year]	BE tot [tCO_2eq/year]
2024	15	0	15
2025	29	7	44
2026	59	7	73
2027	88	7	103
2028	117	7	132
2029	161	7	161
2030	176	15	191
2031	206	15	220
2032	235	15	250
2033	264	15	279

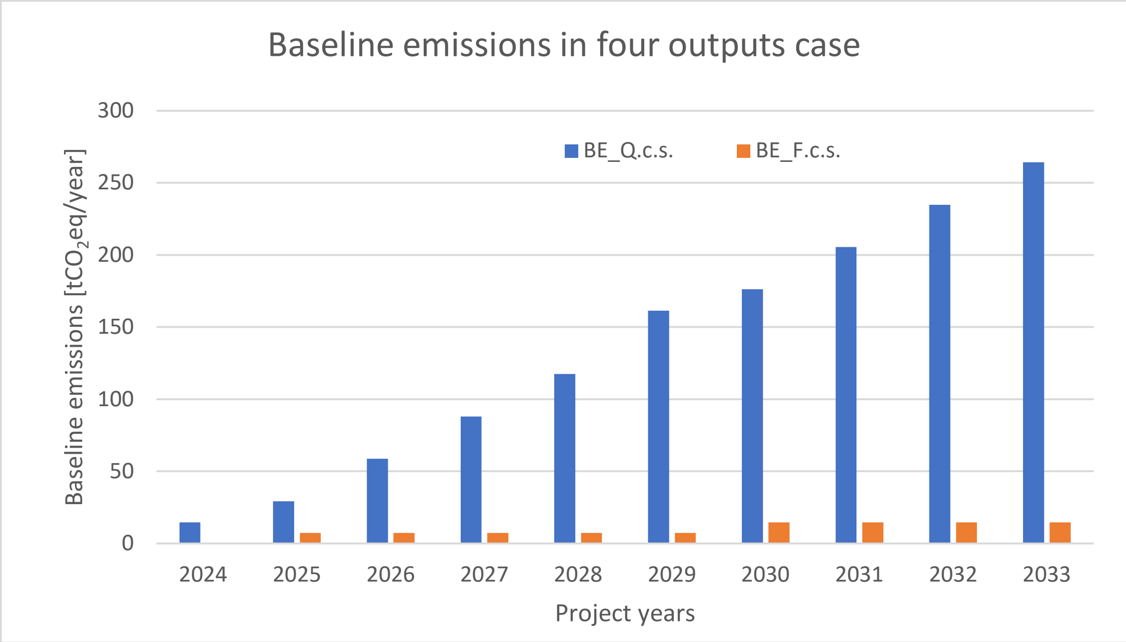

Figure 45- baseline emissions in four outputs case

6.3 Project emissions

The project emissions are evaluated starting from the same number of induced EVs of the baseline emissions, but now the EVs are fuelled by electricity and not anymore by fossil fuels. The formula that comes out for the project emissions is:

$$PE_y = induced\ auto_y * EFkW_y * \frac{AFEC_y}{100} * km_y$$

Where:

- PE_y identify the project emissions of the project year y [tCO_2eq/year];
- $induced\ auto_y$ is the number of EVs that are induced during year y from the number of installed outputs;
- $EFkW_y$ that identifies the EF variation for the electric consumption that serves to charge the induced EVs through the EV charging systems during the project year y [tCO_2eq/kWh];
- $AFEC_y$ is the weighted average electricity consumption per 100 km considering the induced EVs during the year y [kWh/100km];
- km_y is the average number of kilometers that a person travels by car in a year [km/year].

The parameter km_y is considered as a constant and equal to 10,500[91] [km/year], from a regional media in which the Liguria is one of the regions with the less amount of travelled km per year.

To evaluate the EF of the electric consumption (EFkW) two different plots are very useful, because they furnish data for the creation of an order of magnitude. The first is from the ISPRA[92], that is represented in figure (46) and plots the EF due to Italian electric consumption during the years. Taking the data from 2019 to 2021 a first base for a linear interpolation has been obtained.

[91] https://www.dalcarnoleggio.it/kmannui/#:~:text=I%20risultati%20si%20differenziano%20leggermente,notevolmente%20da%20regione%20a%20regione.

[92] ISPRA, "Indicatori di efficienza e decarbonizzazione del Sistema energetico nazionale e del settore energetico", 2021.

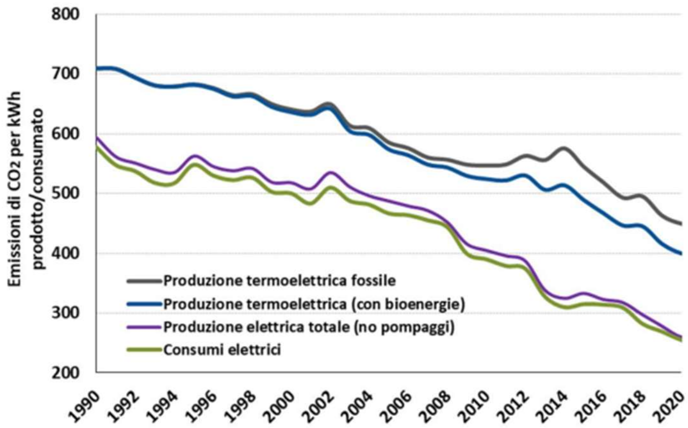

Figure 46- EF of Italian electric consumption

In order to have a correct forecast for the trend of this EF it was useful to have a prevision at 2030, that is obtained from the EEA[93](Environmental European Agency), which offers an European trend with two different future scenarios of decrease of GHG emissions, figure (47). Using an engineering approach, the selected scenario in the analysis is the worst, but there is always to take into consideration that is a forecast at European level, so the result will be approximate.

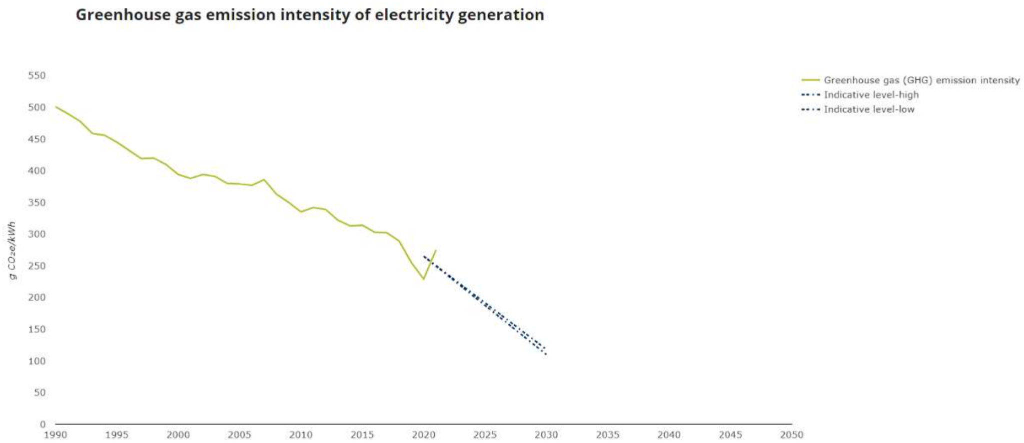

Figure 47- EF of European electric consumption and future projection of EEA

Figure (47) shows that the EF of electric consumption from 1990 has a decreasing trend. This is due to the fact that the electricity mix is always less impacting in order to achieve the European aim of the Net Zero Emissions inside the Green Deal[94] up to 2050.

[93] https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1

[94] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_it-

The forecast according to EEA projection considers that at 2030 the EF of electrical consumption will be 95 [gCO_2/kWh][95]. Performing a linear interpolation, the EFkW of all the project years have been obtained, table (54):

Table 54- EFkW

years	EFkW [tCO_2eq/kWh]
2019	0.000269
2020	0.000255
2021	0.000245
2022	0.000223
2023	0.000207
2024	0.000191
2025	0.000175
2026	0.000159
2027	0.000143
2028	0.000127
2029	0.000111
2030	0.000095
2031	0.000079
2032	0.000063
2033	0.000047

[95] https://www.eea.europa.eu/ims/greenhouse-gas-emission-intensity-of-1

The AFEC parameter, table (55), that is used for the evaluation of these project emissions has been just evaluated in paragraph 5.4. The obtained results are based on 100 km, so to obtain a value on km the result of the different project year y is divided for 100 in the project emissions evaluation.

Table 55- AFEC

Years	AFEC [kWh/100km]
2024	20.49
2025	18.56
2026	18.24
2027	17.91
2028	17.59
2029	17.27
2030	16.94
2031	16.62
2032	16.29
2033	15.97

Also, the induced number of EVs for new outputs during the years has just been evaluated in the baseline emissions, and they are divided for the three-possibility number of outputs of the quick charging systems.

1. Two outputs for the quick charging systems and two outputs for superfast charging systems. In table (56) are collected the total values of induced EVs in the project.

Table 56- induced auto for the total new outputs

year	Outputs number	Induced auto per new output
2024	2	3
2025	6	9
2026	10	15
2027	15	21
2028	19	27
2029	23	33
2030	27	39
2031	32	44
2032	36	50
2033	40	56

While, in table (57) are collected the values of induced EVs for the two different types of charging systems.

Table 57- induced auto for outputs in the two-charging systems type

year	Outputs number Q.c.s.	Induced auto per new Q.c.s. output	Outputs number F.c.s.	Induced auto per new F.c.s. output
2024	2	3	0	0
2025	4	6	2	3
2026	8	11	2	3
2027	12	17	2	3
2028	16	23	2	3
2029	22	31	2	3
2030	24	34	4	6
2031	28	39	4	6
2032	32	45	4	6
2033	36	51	4	6

2. Three outputs for the quick charging systems and two outputs for superfast charging systems. In table (58) are collected the total values of induced EVs in the project.

Table 58- induced auto for the total new outputs

year	Outputs number	Induce auto per new output
2024	3	4
2025	9	13
2026	15	21
2027	21	30
2028	27	39
2029	34	47
2030	40	56
2031	46	65
2032	52	73
2033	58	82

While, in table (59) are collected the values of induced EVs for the two different types of charging systems.

Table 59- induced auto for outputs in the two-charging systems type

year	Outputs number Q.c.s.	Induced auto per new Q.c.s. output	Outputs number F.c.s.	Induced auto per new F.c.s. output
2024	3	4	0	0
2025	6	8	2	3
2026	12	17	2	3
2027	18	25	2	3
2028	24	34	2	3
2029	33	47	2	3
2030	36	51	4	6
2031	42	59	4	6
2032	48	68	4	6
2033	54	76	4	6

3. Four outputs for the quick charging systems and two outputs for superfast charging systems. In table (60) are collected the total values of induced EVs in the project.

Table 60- induced auto for the total new outputs

year	Outputs number	Induce auto per new output
2024	4	6
2025	12	17
2026	20	28
2027	28	39
2028	36	51
2029	44	62
2030	52	73
2031	60	85
2032	68	96
2033	76	107

While, in table (61) are collected the values of induced EVs for the two different types of charging systems.

Table 61- induced auto for outputs in the two-charging systems type

year	Outputs number Q.c.s.	Induced auto per new Q.c.s. output	Outputs number F.c.s.	Induced auto per new F.c.s. output
2024	4	6	0	0
2025	8	11	2	3
2026	16	23	2	3
2027	24	34	2	3
2028	32	45	2	3
2029	44	62	2	3
2030	48	68	4	6
2031	56	79	4	6
2032	64	90	4	6
2033	72	101	4	6

After the evaluation of all the necessary parameters, the project emissions for the three different cases of outputs number of quick charging systems have been calculated.

1. Two outputs in quick charging systems and two outputs in superfast charging systems:

Table 62- project emissions

year	PE Q.c.s. [tCO_2eq/year]	PE F.c.s. [tCO_2eq/year]	PE tot [tCO_2eq/year]
2024	1	0	1
2025	2	1	3
2026	3	1	4
2027	5	1	6
2028	5	1	6
2029	6	1	7
2030	6	1	7
2031	5	1	6
2032	5	1	5
2033	4	0	4

Table (62) reports all the values of project emissions for the case taken into consideration, and figure (48) reports the values of the two types of charging systems inside a histogram.

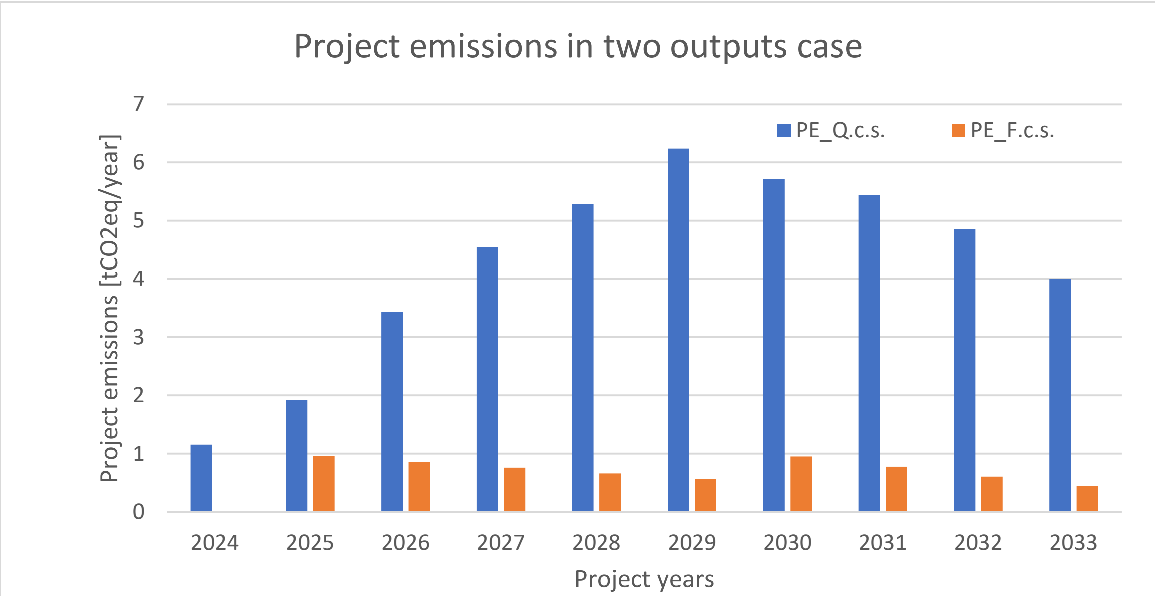

Figure 48- project emissions in two outputs case

2. Three outputs in quick charging systems and two outputs in superfast charging systems:

Table 63- project emissions

year	PE Q.c.s. [$tCO_2eq/year$]	PE F.c.s. [$tCO_2eq/year$]	PE tot [$tCO_2eq/year$]
2024	2	0	2
2025	3	1	4
2026	5	1	7
2027	7	1	8
2028	8	1	9
2029	9	1	10
2030	9	1	9
2031	8	1	9
2032	7	1	8
2033	6	0	6

Table (62) reports all the values of project emissions for the case taken into consideration, and figure (49) reports the values of the two types of charging systems inside a histogram.

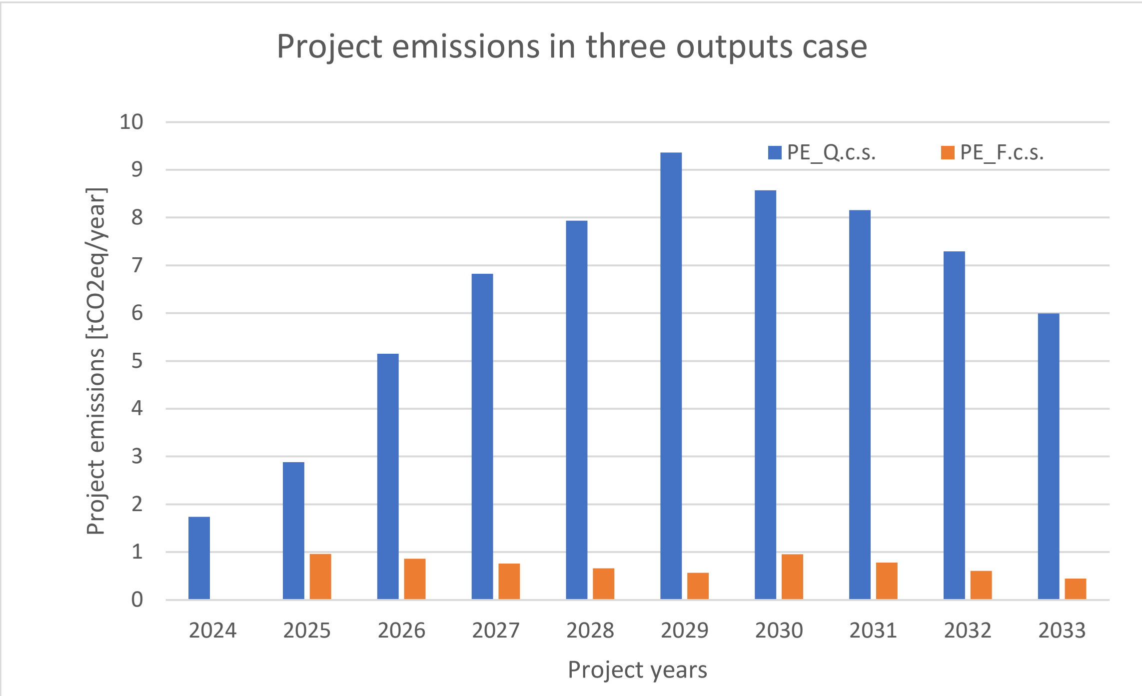

Figure 49- project emissions in three outputs case

3. Four outputs in quick charging systems and two outputs in superfast charging systems:

Table 64- project emissions

year	PE Q.c.s. [tCO_2eq/year]	PE F.c.s. [tCO_2eq/year]	PE tot [tCO_2eq/year]
2024	2	0	2
2025	4	1	6
2026	7	1	9
2027	9	1	11
2028	11	1	12
2029	12	1	12
2030	11	1	12
2031	11	1	12
2032	10	1	10
2033	8	0	8

Table (64) reports all the values of project emissions for the case taken into consideration, and figure (50) reports the values of the two types of charging systems inside a histogram.

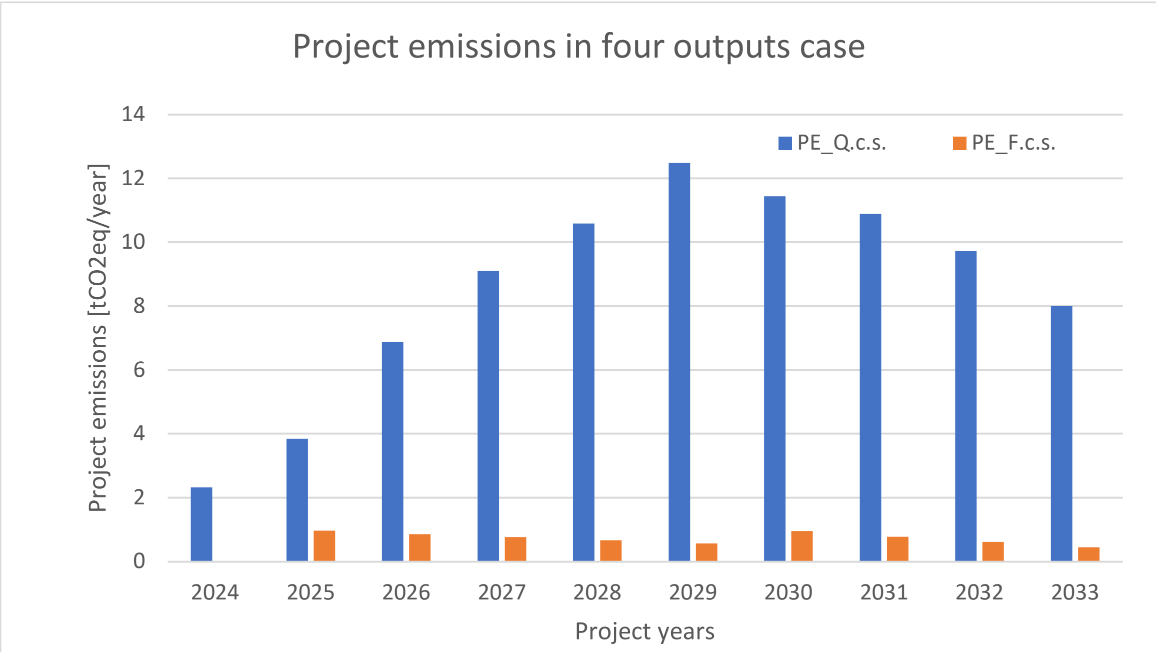

Figure 50- project emissions in four outputs case

6.4 Emission reductions

To conclude the methodology it is necessary to link the baseline and project emissions together, in order to evaluate the emission reductions produced by the proposed project. The result that is obtained represents the number of credits that are produced for any project year, that after are summed to evaluate the amount of generated credits by all the project. The formula to evaluate the emission reductions is:

$$ER_y = BE_y - PE_y$$

Where:

- ER_y[$tCO_2eq/year$] are the net GHG emission reductions in the year y;
- BE_y [$tCO_2eq/year$] are the baseline emissions in the year y;
- PE_y [$tCO_2eq/year$] are the project emissions in the year y.

For this evaluation two scenarios have been proposed:

1) Scenario according to projections;
2) Scenario with the electricity mix that totally comes from renewable energy.

6.4.1 Emission reductions in a scenario according to projections

In ER evaluation there is again a distinction between the three different cases of outputs number. For each of these cases there are three different results: one for the total credit number of the project, one of the produced credits by the quick charging systems, and the last of the obtained credits by superfast charging systems.

1. Two outputs in quick charging systems and two outputs in superfast charging systems. In table (65) are reported the three emission reductions that are obtained, which also are plotted in figure (51).

Table 65- emission reduction in quick charging system with two outputs case

year	ER Q.c.s. [$tCO_2eq/year$]	ER F.c.s. [$tCO_2eq/year$]	ER tot [$tCO_2eq/year$]
2024	6	0	6
2025	13	6	20
2026	26	6	34
2027	39	7	48
2028	53	7	63
2029	74	7	78
2030	82	14	94
2031	97	14	110
2032	113	14	126
2033	128	14	142

Summing all the generated credits in this case during the project years, the total amount of obtained credits for the project is 721 [tCO_2eq].

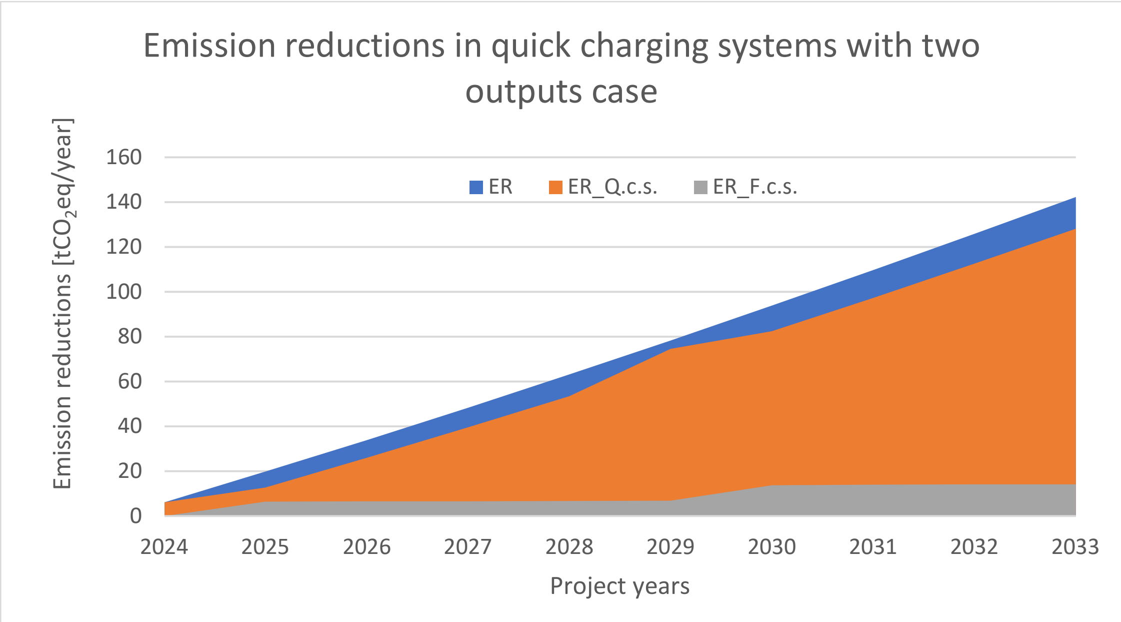

Figure 51- emission reductions in quick charging systems with two outputs case

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for output, table (66):

Table 66- obtained credits

Total amount of credits	721
Total amount of credits from Q.c.s.	633
Credits for single output of Q.c.s.	18
Total amount of credits from F.c.s.	89
Credits for single output of F.c.s.	22

2. Three outputs in quick charging systems and two outputs in superfast charging systems. In table (67) are reported the three emission reductions that are obtained, that are plotted in figure (52).

Table 67- emission reduction in quick charging system with three outputs case

year	ER Q.c.s. [$tCO_2eq/year$]	ER F.c.s. [$tCO_2eq/year$]	ER tot [$tCO_2eq/year$]
2024	9	0	9
2025	19	6	29
2026	39	6	49
2027	59	7	70
2028	80	7	92
2029	112	7	114
2030	124	14	136
2031	146	14	159
2032	169	14	183
2033	192	14	206

Summing all the generated credits in this case during the project years, the total amount of obtained credits for the project is 1,047 [tCO_2eq].

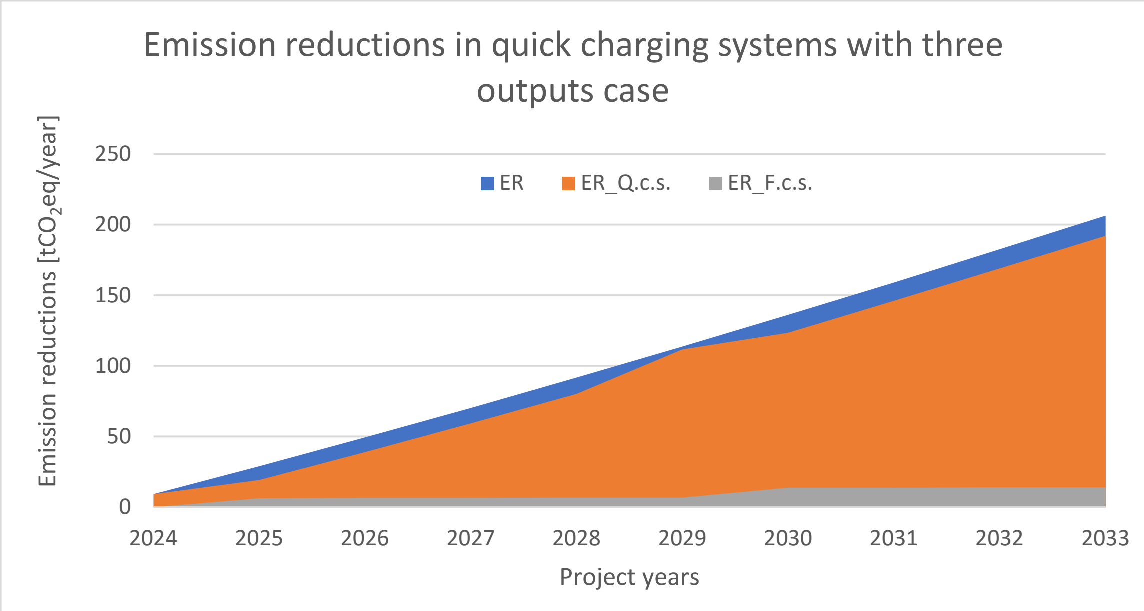

Figure 52- emission reductions in quick charging systems with three outputs case

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for output, table (68):

Table 68- obtained credits

Total amount of credits	1,047
Total amount of credits from Q.c.s.	949
Credits for single output of Q.c.s.	18
Total amount of credits from F.c.s.	89
Credits for single output of F.c.s.	22

3. Four outputs in quick charging systems and two outputs in superfast charging systems. In table (69) are reported the three emission reductions that are obtained, that are plotted in figure (53).

Table 69- emission reduction in quick charging system with four outputs case

year	ER Q.c.s. [tCO_2eq/year]	ER F.c.s. [tCO_2eq/year]	ER tot [tCO_2eq/year]
2024	12	0	12
2025	26	6	38
2026	52	6	65
2027	79	7	92
2028	107	7	120
2029	149	7	149
2030	165	14	178
2031	195	14	209
2032	225	14	239
2033	256	14	270

Summing all the generated credits in this case during the project years, the total amount of obtained credits for the project is 1,373 [tCO_2eq].

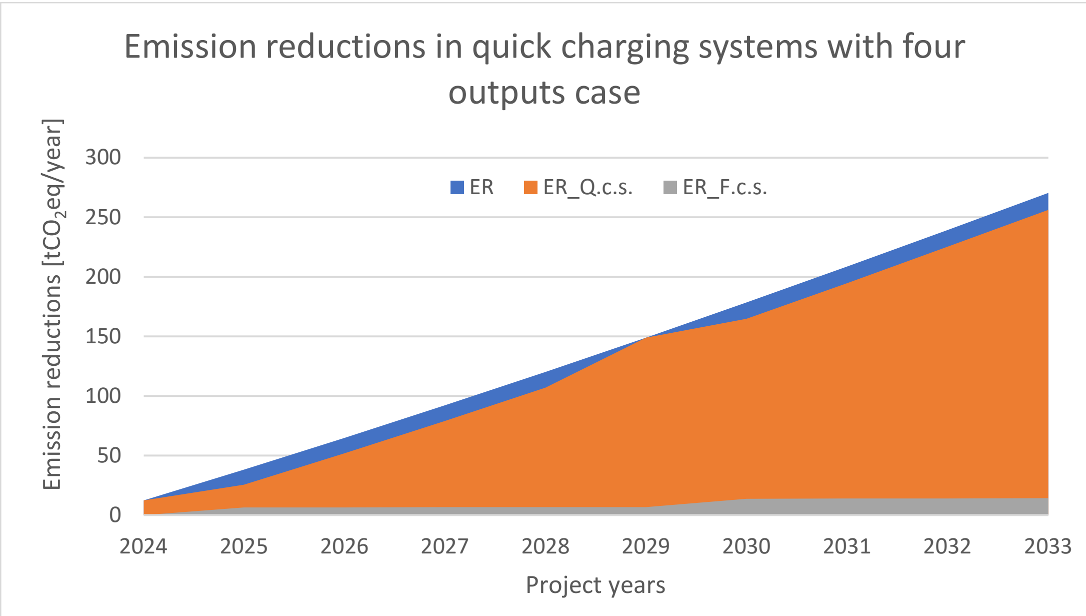

Figure 53- emission reductions in quick charging systems with four outputs case

In conclusion knowing the total amount of credits it is possible to evaluate the generated credit for output, table (70):

Table 70- obtained credits

Total amount of credits	1,373
Total amount of credits from Q.c.s.	1,265
Credits for single output of Q.c.s.	18
Total amount of credits from F.c.s.	89
Credits for single output of F.c.s.	22

Taking in relation the table (66), (68), and (70) the number of credits for output is the same both in quick and superfast charging systems. What changes is the number of outputs that are going to be installed in the project years with a bigger amount for the quick charging systems.

After the evaluation of all the generated credits is possible to see in figure (54) the linear trend of the obtained credits in function to the increase in the number of outputs of the quick charging systems.

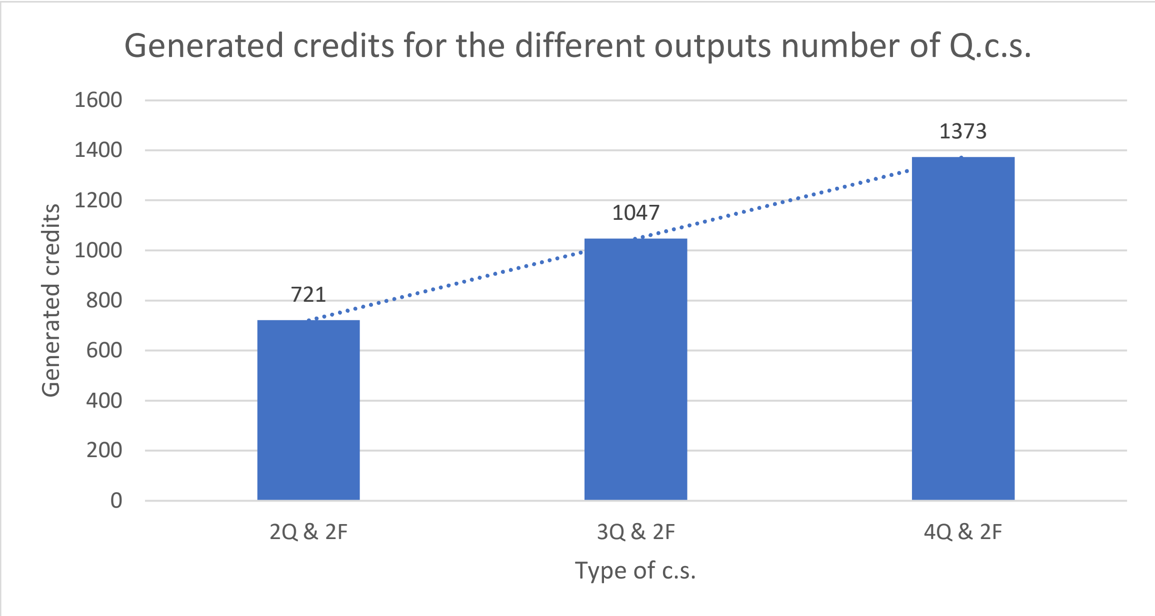

Figure 54- generated credits for the different outputs number of quick charging systems

6.4.2 Emission reductions with an electricity mix that completely derived from renewable energy

In ER evaluation there is always the distinction between the three different cases of outputs number. For each of these cases there are three different results: one for the total credit number of the project, one of the produced credits by the quick charging systems, and the last of the obtained credits by superfast charging systems

The difference from the previous chapter stays in the electricity mix used and then in the emission factor for the electrical consumption. Due to the fact that in this case the electricity mix comes totally from renewable energy the emission factor is null, so also the project emissions are equal to zero. To reach the totality of the electricity from renewable energy probably the installation of photovoltaic panels on the charging systems is not enough. A real possibility comes from the verified acquisition of renewable energy from some societies.

1. Two outputs in quick charging systems and two outputs in superfast charging systems. In table (71) are reported the three emission reductions that are obtained, that are plotted in figure (55).

Table 71- emission reduction in quick charging system with two outputs case

year	ER Q.c.s. [tCO_2eq/year]	ER F.c.s. [tCO_2eq/year]	ER tot [tCO_2eq/year]
2024	7	0	7
2025	15	7	23
2026	29	7	38
2027	44	7	54
2028	59	7	69
2029	81	7	85
2030	88	15	100
2031	103	15	116
2032	117	15	131
2033	132	15	147

Summing all the generated credits in this case during the project years, the total amount of obtained credits for the project is 771 [tCO_2eq].

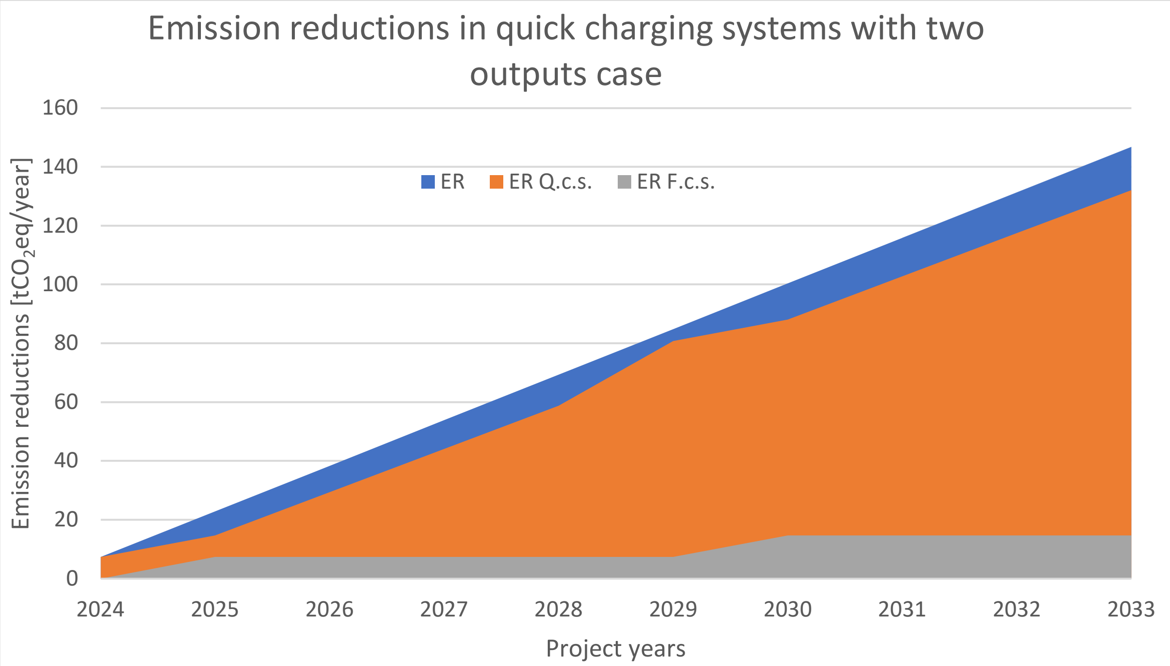

Figure 55- emission reductions in quick charging systems with two outputs case

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for output, table (72):

Table 72- obtained credits

Total amount of credits	771
Total amount of credits from Q.c.s.	675
Credits for single output of Q.c.s.	19
Total amount of credits from F.c.s.	95
Credits for single output of F.c.s.	24

2. Three outputs in quick charging systems and two outputs in superfast charging systems. In table (73) are reported the three emission reductions that are obtained, that are plotted in figure (56).

Table 73- emission reduction in quick charging system with three outputs case

year	ER Q.c.s. [tCO_2eq/year]	ER F.c.s. [tCO_2eq/year]	ER tot [tCO_2eq/year]
2024	11	0	11
2025	22	7	33
2026	44	7	56
2027	66	7	78
2028	88	7	101
2029	121	7	123
2030	132	15	146
2031	154	15	168
2032	176	15	190
2033	198	15	213

Summing all the generated credits in this case during the project years, the total amount of obtained credits for the project is 1,119 [tCO_2eq].

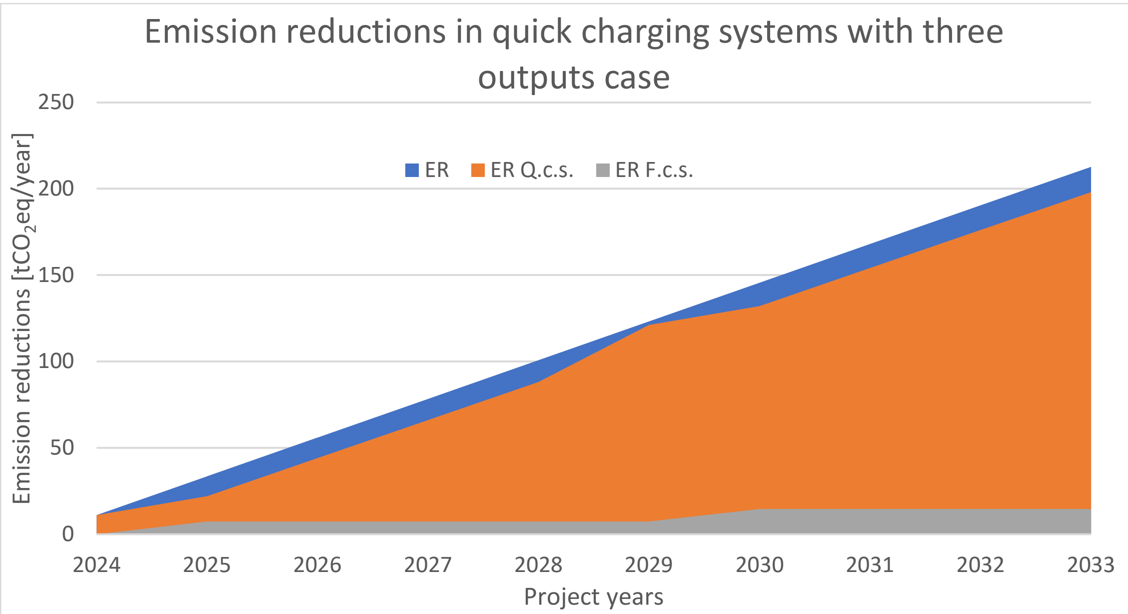

Figure 56- emission reductions in quick charging systems with three outputs case

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for output, table (74):

Table 74- obtained credits

Total amount of credits	1,119
Total amount of credits from Q.c.s.	1,013
Credits for single output of Q.c.s.	19
Total amount of credits from F.c.s.	95
Credits for single output of F.c.s.	24

3. Four outputs in quick charging systems and two outputs in superfast charging systems. In table (75) are reported the three emission reductions that are obtained, that are plotted in figure (57).

Table 75- emission reduction in quick charging system with four outputs case

year	ER Q.c.s. [tCO_2eq/year]	ER F.c.s. [tCO_2eq/year]	ER tot [tCO_2eq/year]
2024	15	0	15
2025	29	7	44
2026	59	7	73
2027	88	7	103
2028	117	7	132
2029	161	7	161
2030	176	15	191
2031	206	15	220
2032	235	15	250
2033	264	15	279

Summing all the generated credits in this case during the project years, the total amount of obtained credits for the project is 1,468 [tCO_2eq].

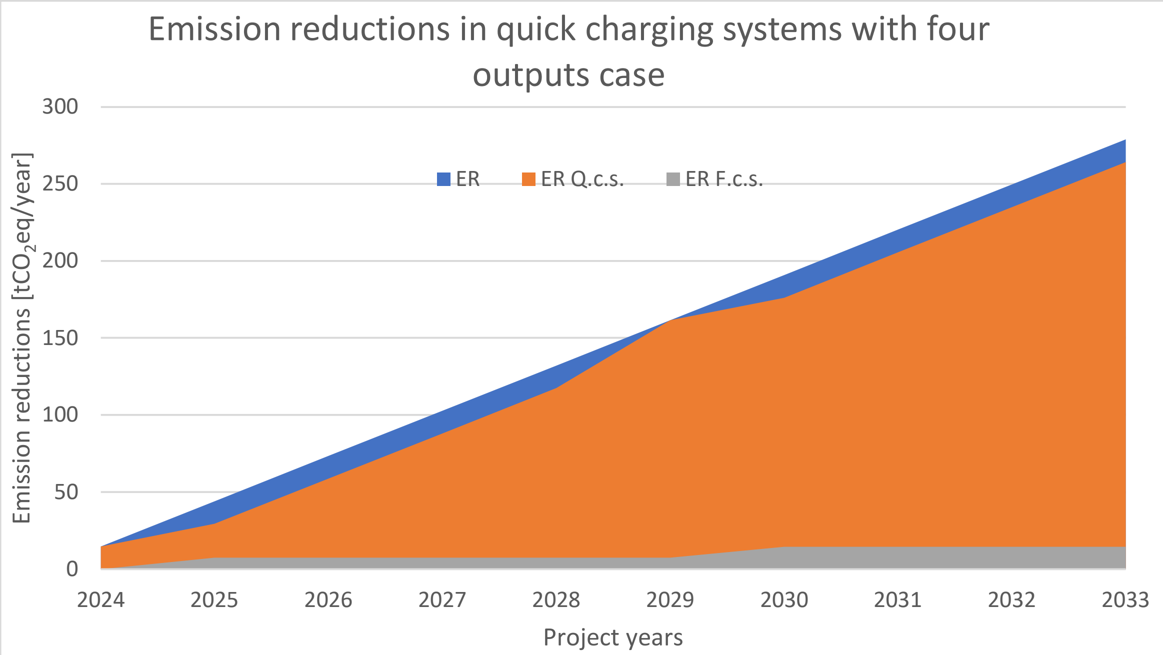

Figure 57- emission reductions in quick charging systems with four outputs case

In conclusion knowing the total amount of credits it is possible to evaluate the generated credits for output, table (76):

Table 76- obtained credits

Total amount of credits	1,468
Total amount of credits from Q.c.s.	1,351
Credits for single output of Q.c.s.	19
Total amount of credits from F.c.s.	95
Credits for single output of F.c.s.	24

Taking in relation the table (72), (74), and (76) the number of credits for output is the same both in quick and superfast charging systems. What changes is the number of outputs that are going to be installed in the project years with a bigger amount in the quick charging systems.

After the evaluation of all the generated credits is possible to see in figure (58) the linear trend of the obtained credits in function to the increase in the number of outputs of the quick charging systems.

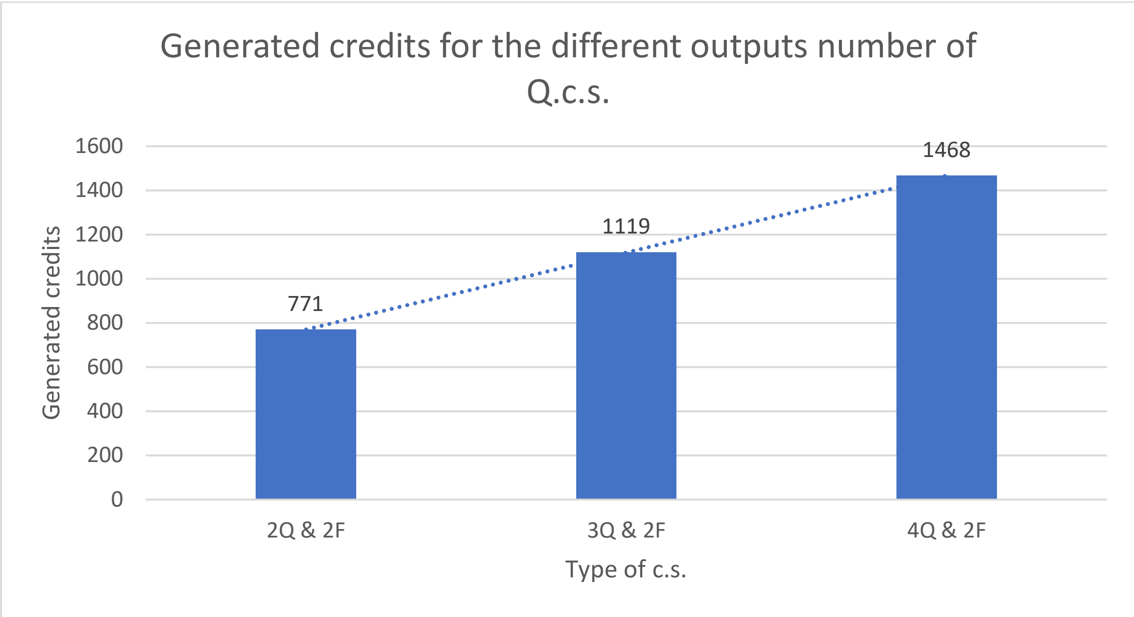

Figure 58- generated credits for the different outputs number of quick charging systems

6.4.3 Emission reductions comparison

In this chapter, the generated credits from the projected and renewable scenarios are compared in order to see how the null project emissions in the renewable scenario impact on the final result.

Starting from the projected scenario in table (77) is possible to see the total amount of credits that increase with the increase in the output's number, as it is expectable.

Another interesting thing that is good to underline is the fact that the amount of emission reduction per output, in the quick charging systems, is equal for all the cases differently from chapter 5. What changes is the final amount of generated credits in quick charging systems, due to the different possibilities of number of outputs for charging system.

Table 77- difference in credits generation based on the number of outputs of the quick charging systems in projected scenario

N° of outputs in Q.c.s.	2	3	4
Total ER credits for Q.c.s.	633	949	1,265
ER credits for output of Q.c.s	18	18	18
Total ER credits for F.c.s.	89	89	89
ER credits for output of F.c.s	22	22	22
Total ER credits	721	1,047	1,373

Figure (59) shows the amount of credits that derives from the quick charging system output, in the three different cases, compared to the credits obtained from superfast charging system output.

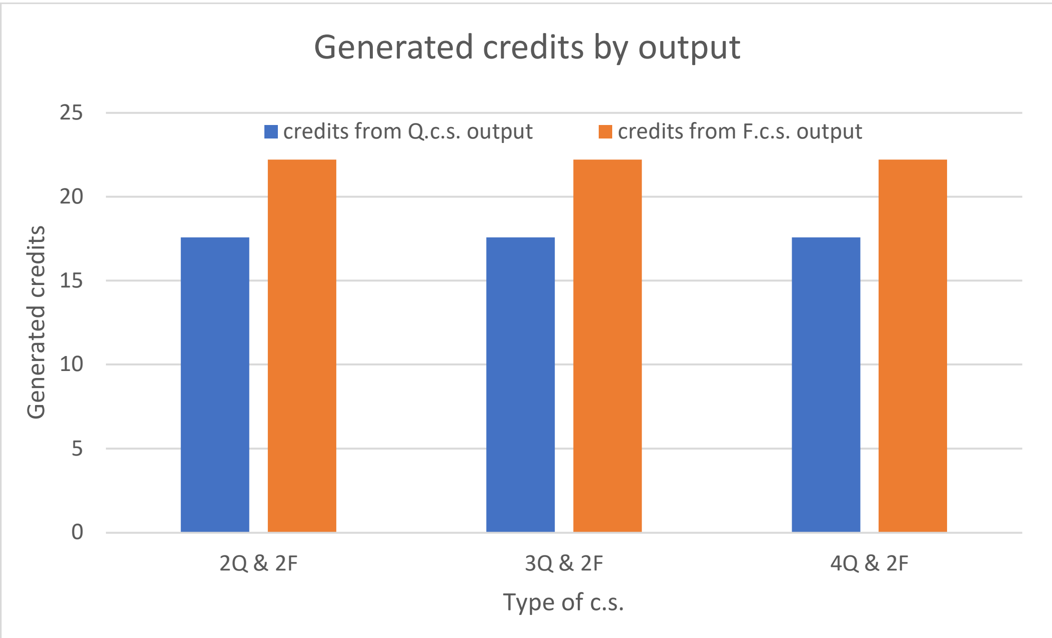

Figure 59- generated credits by output

In the second scenario, the one in which all the used electricity comes from renewable energy, the project emissions are null. Therefore, now the generated credits are more respect the previous case, but the number of extra credits is not so relevant as it is possible to imagine. In table (78) are presents the results obtained in terms of:

- Total credits;
- Credits for charging system;
- Credits for output.

Table 78- ER generation for the three cases in total renewable scenario

N° of outputs in Q.c.s.	2	3	4
Total ER credits for Q.c.s.	675	1,013	1,351
ER credits for output of Q.c.s	19	19	19
Total ER credits for F.c.s.	95	95	95
ER credits for output of F.c.s	24	24	24
Total ER credits	771	1,119	1,468

In table (78) also in this case the amount of credits obtained by output in both the charging system type remain equal.

Figure (60) shows the amount of credits that derives from the quick charging system output, in the three different cases, compared to the credits obtained from superfast charging system output.

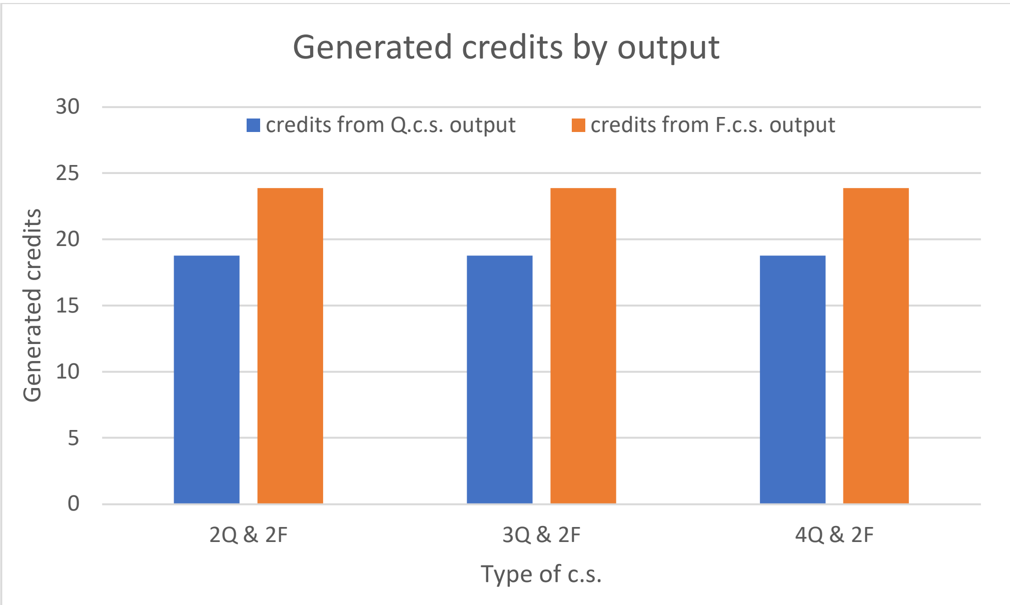

Figure 60-generated credits by output

A result that can be interesting is the difference in percentage between the amount of credits that are obtained in the two proposed scenarios. This type of result is reported in table (79):

Table 79- percentage increase from first scenario and total renewable scenario

N° of outputs in Q.c.s.	2	3	4
ER credits for output of Q.c.s	+6.9%	+6.9%	+6.9%
ER credits for output of F.c.s	+7.4%	+7.4%	+7.4%
Total ER credits	+6.9%	+6.9%	+6.9%

Talking again of percentage inside the table (80) are present the increase in percentage from the case of two outputs up to the case of four, for the two scenarios.

Table 80- increase in generated credits percentage with an increase in number of outputs

Scenario	Credit increases 2 → 3 [%]	Credit increases 3 → 4 [%]	Credit increases 2 → 4 [%]
Projected scenario	+45.2%	+31.1%	+90.5%
Total renewable scenario	+45.2%	+31.1%	+90.5%

Figure (61) shows a comparison of the generated credits of the two proposed scenarios, and for the three different cases of outputs number of quick charging systems. The renewable scenario as is expectable creates more credits than the projected one.

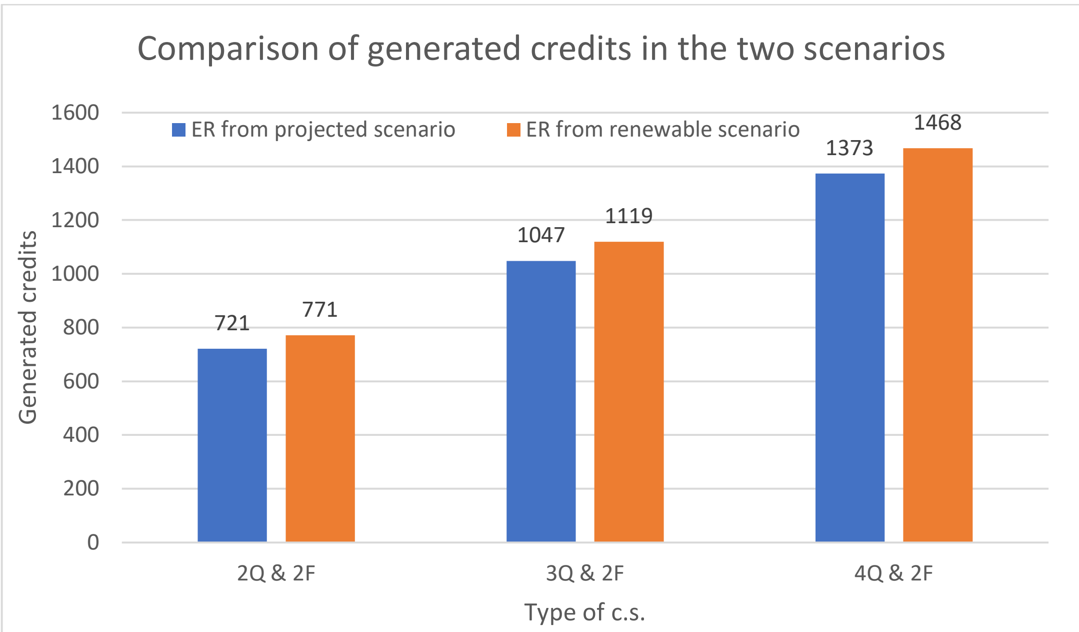

Figure 61- comparison of generated credits in the two scenarios for the three cases

7. Conclusions

The need to take an action against climate change is clear, and to provide it is necessary to push, on emission reductions, with the increase in climate change mitigation projects. These types of projects are one of the most important ways that people have to reduce emissions.

The transport sector is nowadays one of the most impacting sectors with a lot of GHG emissions every year. Some ideas to reduce the emissions from this sector are:

- the substitution of the actual modes of transport with an electric one;
- the propagation of the inter-modality;
- the increase of the sharing and pooling of electric vehicles.

From this type of projects, the emission reduction credits are generated and after they can be sold in a voluntary market. This market permits to some industries to buy the VER (voluntary emission reduction) credits in order to compensate their annual emissions.

This thesis has the aim to generate a calculation tool for emission reduction calculation due to the installation of new electric vehicle charging systems. The project from which the tool has been generated comes from a sustainable mobility project for the city of Genoa. From this thesis the generated credits, that derives from two different methodologies, are obtained considering a total number of twenty new charging systems that are going to be installed in the urban area of the city, divided in eighteen quick and two superfast.

An element with high relevance was the number of outputs of the quick charging systems because it can vary from two to four. While the superfast has only two outputs the quick one creates three possible solution cases that have been studied. The evaluation of the credits has been done using two methodologies: VM0038[96], from VERRA[97], that it has been followed step by step, and BoCaM[98], from eco2care[99], that has been used as starting point for the creation of a new mentality change methodology.

[96] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018.
[97] https://verra.org/.
[98] Eco2care, "Bologna Carbon Market (BoCaM)", 2015.
[99] https://www.eco2care.org/.

After the evaluation of the baseline and project emissions, the credits are being evaluated considering two possible scenarios:

- Projected;
- Totally renewable.

The credits that the two projects create are related to the number of outputs considered, in fact with their increase in number also the number of credits is higher. The total amount of generated credits are resumed in table (81), and in figure (62) these values are plotted.

Table 81- final amount of generated credits in the two scenarios

Type of charging system	Credits from the projected scenario	Credits from renewable scenario
2 Q.c.s. & 2 F.c.s.	38,647	41,311
3 Q.c.s. & 2 F.c.s.	51,856	55,403
4 Q.c.s. & 2 F.c.s.	71,505	76,366

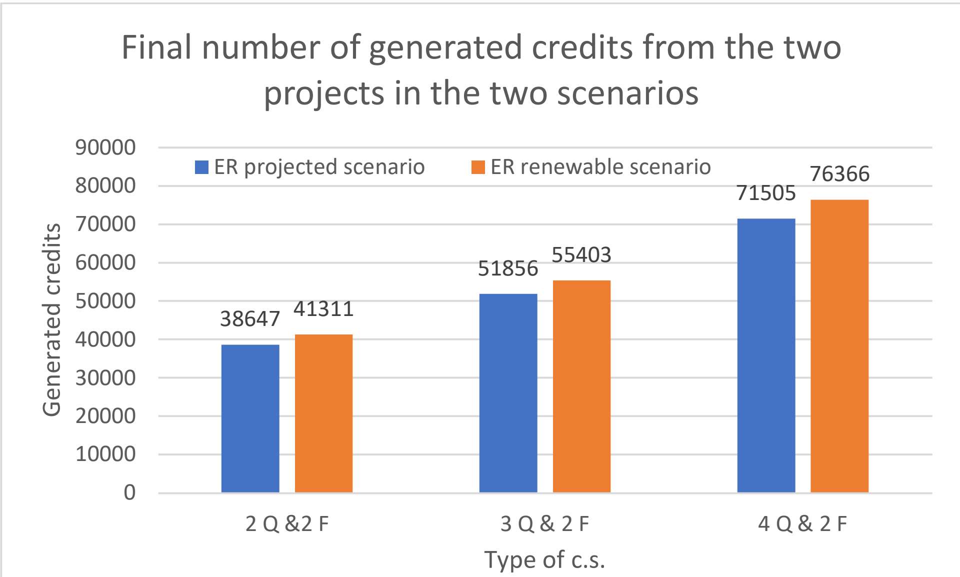

Figure 62- final amount of generated credits in the two scenarios

Therefore, summing the credits obtained from the two projects the generable credits can vary from a minimum of 38,647 to a maximum of 76,366. The case in which the minimum amount of credits is achieved is when the projected scenario is applied with the quick charging systems that have two outputs. While the maximum is reached when the project is performed in a total renewable scenario and with the quick charging systems that are installed with four outputs. With a difference of 37,719 the project in any case creates benefits in environmental, economic, and social fields that are exploitable by different figures, from societies to the common citizen.

Due to the absence of some data the linear interpolation and the formulation of some hypotheses are fundamental for the credit evaluation. This necessity surely affects the results that have been obtained with the creation of a linear trend for the different studied cases.

As is expectable the obtained results with the renewable scenario are higher due to the absence of the project emissions, because the emission factor of the electric consumption is null. Therefore, with the use of renewable energy the benefits are higher under environmental and economical fields. So, the project proponent, can decide to use renewable energy to charge the electric vehicles in order to obtain a higher amount of credits. This does not mean that the generated credits in the projected scenario are few, because the project emissions are also low due to the forecast of the emission factor of the electric consumption that is going to reduce in time coming close to zero.

An important point to consider is the creation of an efficient monitoring plan, that during the project years, uses different instruments and technologies in order to see if the proposed project is being followed in the correct way. This thesis does not consider this aspect but in the VM0038[100] there are some suggestions on its preparations, and it is predictable that the number of charging in the new charging systems will be a fundamental point for the monitoring.

Therefore, without a big amount of data some hypotheses and linear interpolations were necessary for the correct development of the project but creates a final result that is affected by them. This implies that with more and specific data the results probably will follow a real trend that is not linear.

[100] VERRA, "VM0038: Methodology for electric vehicle charging systems", 2018.

In conclusion, the proposed project wants to reduce, with the installation of new electric vehicles charging systems, the GHG emissions inside the city of Genoa due to the urban transport. Obviously with only twenty new charging systems the problem is not resolved, in fact more and more of this type of projects will be designed in the future from other entities.

To reach the Net Zero Emissions of the urban transport it is also fundamental to increase the carpooling and car sharing services and to reduce the number of circulant vehicles in the cities.

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