STARDUST

D4.6 Report on the electric vehicle models to address both intra-urban and extra-urban needs

WP 4, T 4.4, Subtask 4.4.2

Authors: Alyona Zubaryeva, Andrea Grotto, Giuseppe Rotondo (EURAC), Alex Tomasi (TRENTO), Marco Cattani (Trentino Mobilita´), Sonia Gantioler (EURAC)

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1 Technical references

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	Date	Beneficiary	Author
V1	19/10/2023	EURAC, TRENTO	Alyona Zubaryeva, Andrea Grotto, Alex Tomasi, Marco Cattani, Sonja Gantioler
	Date	**Beneficiary**	**Reviewed by**
V2	**30/11/2023**	**TRENTO**	**Alex Tomasi**
	Date	**Beneficiary**	**Approved by**
	05/11/2023	CENER	Florencio Manteca

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2 Public administration transition towards zero-emission fleets

1. Introduction

2.1 CO2 emission trends in corporate fleets

The CO2 emissions in corporate fleets are a topic of increasing global relevance due to the growing environmental concerns and increasingly stringent regulations on greenhouse gas emissions[1] [2] [3]. Here is some information about the trends in CO2 emissions in corporate fleets that many companies are following:

1. Corporate sustainability policies: these involve the development of sustainability policies that establish objectives for reducing CO2 emissions within their fleets as part of their corporate social responsibility. Business strategies should seamlessly integrate efficient Supply Chain methods, such as the "lean" approach focused on efficiency, with sustainable one commonly referred to as "green" approach [4].
   Sustainable policies involve, on one hand, the adoption of specific mobility technologies, such as the use of electric vehicles or cycling [5], and, on the other hand, “passive practices” like carpooling [5] or green fleet management [6,7] focused on CO2 reduction [8].Results from this Global Survey [9] show that:
   - almost 35% of the respondents from travel, transport, logistic companies say that sustainability programs had generated value in the last five years.
   - almost 50% of the respondents from travel, transport, logistic companies say they expect the sustainability programs to generate value in the next five years.
2. Environmental awareness: this term refers to the understanding and concern for environmental issues, especially CO2 emissions, by companies and organizations that manage vehicle fleets. A new IBM Institute for Business Value (IBV) study [10] revealed that sustainability is rising higher on corporate agendas, and CEOs recognize sustainability as a business imperative:

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- 48% of CEOs say "increasing sustainability is one of their highest priorities for their organization in the next two to three years – up from roughly a third in 2021";
- Nearly 70% of surveyed CEOs say they are directly involved in defining their organization's sustainability strategy.
- Over 80% of CEOs believe that their company's sustainability investments will produce improved business results in the next five years and nearly half of CEOs (45%) think that sustainability will accelerate business growth.

3. Sustainability reports: including information on CO2 fleet emissions and reduction measures in their sustainability reports to communicate progress to their stakeholders. According to a sustainability survey conducted by KPMG [11], the reporting rates among a sample of 5,800 companies have consistently increased with each global survey. A decade ago, 64% of these companies reported their sustainability efforts, whereas in 2022, this number rose to 79%. Furthermore, the same study reveals that today, almost all of the world's top 250 companies publish sustainability reports. In 2022, the reporting rate among the G250 remained at 96%, the same as in 2020. For an illustrative example, please refer to this report "An illustrative case can be found in this report" [12] .
4. Data collaborative and partnerships: collaborating with vehicle and mobility service providers to develop more sustainable solutions and reduce CO2 emissions. Raghunath Banerjee, VP of Data Solutions & Innovation at Bridgestone Mobility, during the Webfleet Conference 2022 says that open data platforms will allow people to run experiments on several aspects such as vehicle data and CO2 emissions, eventually offering solutions for safer, sustainable and efficient mobility.[13] Frost & Sullivan research projects steady growth in the EV fleet management market in North America and Europe from $24.6 million in 2022 to $594.6 million in 2028. From 2017 to 2019, the percentage of companies forming data-related partnerships rose from 21% to 40%.[14] A growing share of business competitors are also deciding to connect their data rising from 7% to 17%.[14]
5. Incentive measures: companies are increasingly inclined towards the adoption of electric vehicles due to a combination of fiscal and financial incentives on one hand and a focus on Total Cost of Ownership (TCO) on the other. In Europe, the corporate channel has overtaken the private channel [15]. In 2010, the private and corporate

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market segments for car registrations in Western Europe were nearly equal, with 7.3 million private registrations and 7.2 million corporate registrations. However, over the years, there has been a significant shift in the market dynamics towards more corporate car registrations. By 2016, there was a noticeable change in the distribution, with 6.3 million private registrations accounting for 42% of the total registrations, and 8.7 million corporate registrations making up the remaining 58%.[15]. In 2019 57% of the registered cars were private while 43% were commercial. [16] This increase can be explained with the economic recovery but also current to low interest rates permit attractive financial incentives. The share of electric vehicles in the company car segment was almost 4% in 2019, higher than the private segment (2.7% in 2019)[16]. The higher adoption of electric vehicles (EVs) by companies can be explained by the fact that corporate purchase decisions are influenced by the Total Cost of Ownership (TCO), rather than the purchase price alone.

2.2 Electric vehicle for passenger transport trends in EU and Italy

European Union saw a strong growth of electric passenger vehicles over the last decade. Passing from slightly over 21,000 cars in 2011 to nearly 2.2 million cars in 2021[1]. This is backed by a series of initiatives and declarations such as the intergovernmental Electric Vehicles Initiative (EVI30)[2], which sets a global target of at least 30 percent new electric vehicle sales by 2030; or the EV100 initiative grouping companies, which commit to 100% electric fleets by 2030[3]. In addition, in the public transportation domain, electrified bus sector saw a fast development, in fact the number of buses on European roads increased from only 286 battery electric buses in 2011 to over 7,350 in 2021[1].

There is a number of charging stations of different types that have been installed in the last decade in European Union, that range from few kW to 475 kW[17]. Several incentives for the installation of charging infrastructure both public and private for electric vehicles have

[1] European Alternative Fuels Observatory, https://alternative-fuels-observatory.ec.europa.eu/transport-mode/road/european-union-eu27 (accessed on 16/06/2022)

[2] IEA, 2022, https://www.iea.org/areas-of-work/programmes-and-partnerships/electric-vehicles-initiative (assessed on 21/06/2022)

[3] The Climate Group EV100, https://www.theclimategroup.org/ev100 (accessed on 16/06/2022)

been introduced and are being assessed at to their effectiveness [18]. In EU, countries such as the Netherlands, France, Germany, and Italy show the highest numbers (as shown in Figure 1) and there is a continuous and rapid growth in the last years.

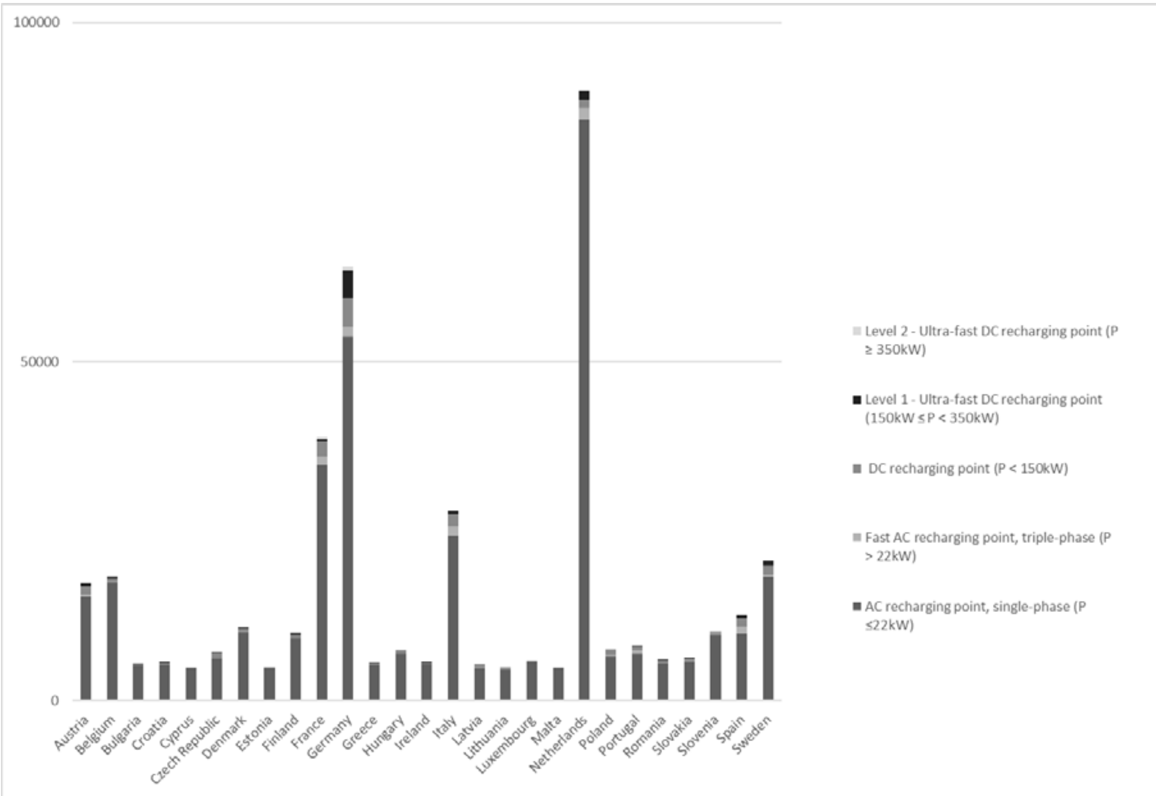

Figure 1: Charging infrastructure in EU27 for electric vehicles. Source: EAFO, 2022[4][17].

This is supported by the forthcoming revision of the Alternative Fuels Infrastructure Directive [19] that aims at introducing binding targets for electric vehicle charging points in EU27, with current regulation recommending that there should be at least 1 recharging point per 10 cars [20]. Despite the growing need for charging stations corresponding to the growing electric vehicle numbers, access to public charging stations is limited compared to the conventional fuelling stations. Another current trend is the uneven geographical distribution of charging stations for EVs. In Italy, 57% of those are located in the North, while 23% in the Central and only 20% in the South and Islands. 34% are placed in the regional capitals [21].

1. [4] EAFO, 2022: https://alternative-fuels-observatory.ec.europa.eu/ (accessed on 03/05/2022).

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Technologically the trends for the new types of charging stations are an increase in the power transmitted and vehicle-to-grid (V2G) enabling to be able to provide axillary services and to improve the power quality for the distribution system operators, [22]. Mobile charging stations is another technological possibility that is being introduced to equip areas with weaker grid connections or in the absence of whereof [23].

Further main trends that can be identified are:

- Gradual reduction of GHG emissions targets for the new passenger, light and heavy-duty vehicles: emission regulations in Europe are driving automakers to accelerate the development and adoption of electric vehicles. This includes emissions targets and incentives for low and zero-emission vehicles [24]
- Government Incentives: Some European countries provide various incentives, including tax benefits, financial subsidies, and reimbursement programs, to encourage the adoption of electric vehicles (EVs). These incentives are designed to make EVs more financially attractive and affordable for consumers [25]
- Integration of renewable energy [26]: many European countries are integrating renewable energy sources, such as wind and solar, into the electric grid. This makes charging EVs even more environmentally friendly.
- Increase of innovative Urban Mobility Solutions: European cities are increasingly adopting electric buses, trams, and shared electric mobility services to improve urban air quality and reduce noise pollution [27].

3 Electrification of private and public corporate fleets, trends and opportunities

Company fleets will make the biggest and fastest contribution to decarbonizing road transport. With 63 million vehicles, the fleet represents 20% of the total European vehicle fleet, covers more than 40% of total vehicle kilometres and contributes to half of total road transport emissions. Fleet electrification is being driven by stringent CO2 emission standards, as well as numerous low- and zero-emission zones to keep polluting vehicles out of cities. As a result, corporate fleet vehicles could play an important role in the transition to clean road transportation, and it is possible that their electrification will occur in an accelerated timeframe. With many vehicles registered to corporate fleets, companies are in a unique position to start the electric transportation revolution from scratch. This is largely due to their high vehicle purchase rate (company vehicles account for a significant proportion of newly registered passenger cars - 64% in Germany and 57% in the UK) and their more intensive use of vehicles compared to private vehicles.

3.1 Challenges

Adoption of electric vehicles in corporate fleets is still low. Studies have shown that lack of information influences fleet managers' attitudes toward investing in electric vehicles. Specifically, lack of information and awareness among fleet managers about the technical characteristics of EVs, lack of trust, the role of information and knowledge, and the perception of the ease of use of EVs. In addition, the limited availability of electric vehicles tailored to the needs of businesses can be another limiting factor, especially when it comes to the adoption of electric vehicles for freight transportation. Decisions based on imperfect information are risky because they increase the likelihood of strategic missteps. Indeed, in dynamic industries, fleet managers need to make the right strategic decisions while carrying out their core business and keeping an eye on the future of the market in which they operate.

3.2 Opportunities

Important motivators for the introduction of electromobility in corporate fleets are environmental aspects such as the positive impact of electromobility on reducing CO2 emissions, its low noise level compared to conventional vehicles with combustion engines, and its positive impact on reducing air pollution.

From an economic point of view, lower fuel costs and higher efficiency, and thus lower total cost of ownership, are the main reasons for the introduction of electromobility in corporate fleets. While ICE vehicles currently benefit from lower acquisition costs, they suffer from fluctuating fuel prices, higher maintenance costs and usually also higher insurance premiums. For EVs, servicing and maintenance are cheaper.

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In the regulatory domain, incentives that reduce the tax levy on EVs (or increase them for conventional vehicles) can further increase the acceptance of electric mobility in fleets and consequently serve as a source of motivation.

In addition, incorporating electric vehicles into the corporate fleet can promote a positive corporate image due to their high level of general acceptance by the public (Figure 2).

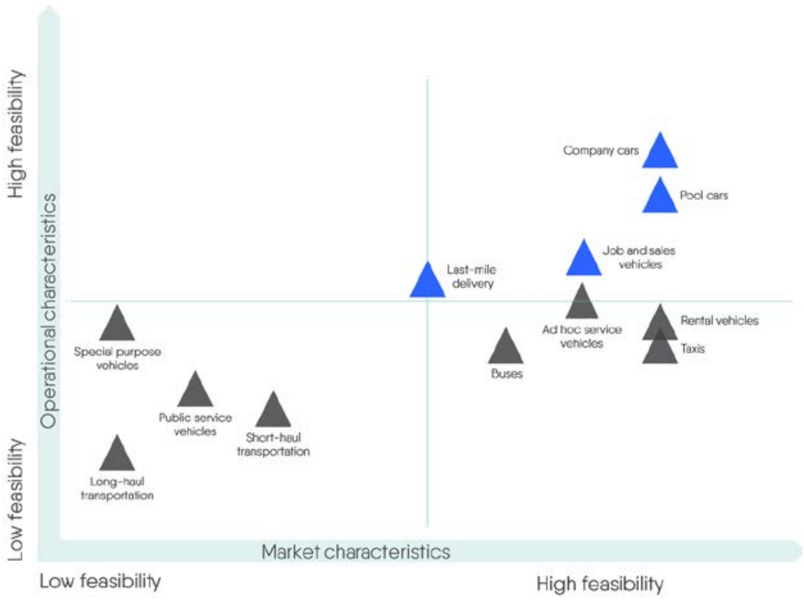

Figure 2 Individual operational characteristics to assess suitability for electrification.[5]

3.3 Outlook

Several global and European companies have made the commitments for the total fleet electrification by 2030. EDF made the biggest corporate fleet addition in 2021 – putting 1,950 EVs on the road, bringing its total to 6,331. With almost 750 new vehicles purchased, AstraZeneca increased its operational EV fleet by 4%, with nearly 1 in 10 vehicles across its operations now electric. Novartis added almost 1,000 EVs to its commercial fleet right across the world, including in the US, Germany, Netherlands, and Sweden[6].

[5] Ernst&Young, Accelerating fleet electrification in Europe When does reinventing the wheel make perfect sense,
[6] EV100: Progress and Insights Report, March 2022.

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In order to strengthen the knowledge base for the companies and promote common efforts for the electrification a peer network for the companies to gain knowledge and common efforts for the electrification has been promoted by ClimateGroup - EV100 - global initiative bringing together companies committed to switching their owned and contracted fleets up to 7.5t to electric vehicles and installing charging infrastructure for employees and customers by 2030.

4 Role of public administrations and its fleets in urban transport greening

4.1 Mobility Management and mobility manager good practices

Mobility management is a set of practices used to plan, coordinate, and optimize the movement of people and goods within a specific area, such as a city, a province or region.[28] It involves planning and optimizing transportation, improve efficiency, reduce congestion, and promote sustainable transportation [29]. The policies of mobility management apply both to internal travels (during working hours) and external travels (to and from home). In Italy, the Ronchi Decree of 1998 [30] introduced the Mobility Manager role, requiring companies and public administrations with more than 100 employees in certain areas to adopt yearly commuting plans to reduce private car use. The ministerial decree of May 12, 2021 [31] regulates his tasks and functions. In the context of public administration, examples of best practices that the Mobility Manager can adopt are:

1. Public Transport incentives: encourage employees to use public transportation by providing discounts, incentives, or company-sponsored transit passes.
2. Awareness and training: conduct awareness and training programs to educate employees about available sustainable commuting options.
3. Vehicle usage monitoring: implement vehicle monitoring systems to track the use of company vehicles and encourage the efficient use of sustainable transportation options.
4. Telecommuting and flexible work hours: support telecommuting and flexible work hours to reduce the need for daily commuting.

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5. Incentives and Recognition: offer financial incentives or recognition to employees who adopt sustainable transportation methods.
6. Cycling Incentives: promote bicycle usage as a means of commuting by providing incentives for bike purchases and repair services.
7. Carpooling Initiatives: Facilitate carpooling among employees by offering dedicated parking spaces for carpoolers.

The Municipality of Trento has appointed its Mobility Manager in the person of the head of the director of the Department of Mobility and Urban Regeneration. In the last five years some strategies implemented have been:

- Acquisition of a fleet of 10 electrics vehicles that replaced 10 Euro 0, Euro 1 and Euro 2 cars. These cars are subject to continuous monitoring;
- Training courses have been conducted for staff of the Municipality of Trento to instruct them on the technical specifications and usage of electric vehicles. Incentives for bike acquisition: in 2020, more than 700 requests for the Bike Bonus (600 euros for e-bikes and 100 euros for bikes);
- 30% discount for the public transportation annual subscription for the public administration employees;
- From 2020 introduction of the remote working (at maximum 2 days per week) for many Municipality employees;
- Ongoing activities on the elaboration of the “Plan movements home-work" with the submission of questionnaires for the preliminary analysis.

4.2 Green fleet management good practices

Municipality of Trento approved in 2014 the Action Plan for the sustainable energy and climate (Paesc[7], Figure 3).

[7] https://www.comune.trento.it/content/download/1453109/13838536/file/PAESC.pdf

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Figure 3 Pictogram of the PAESC of Trento city[8]

In 2014 the Municipality of Trento subscribes the Covenant of Mayors in which each city has to reduce the emissions and mitigate the climate changing effects with a first objective 20% reduction of CO2 emissions Trento has passed this first objective in 2019 with 22% reduction CO2 reduction with respect to 2006.

In December 2020, the Municipality signed a renewal of the agreement that integrates the mitigations of CO2 emissions and adjustment to climate changing in the political, strategic and plans. New objective will be a reduction to 40% till 2030 and the carbon neutrality for 2050. In the document it has been identified 26 mitigation actions and 12 of adaptation.

In order to monitor the mitigation actions and the adaptation, Municipality of Trento decided to implement dedicated dashboard for monitoring:

- Electric and gas consumption of each building owned by the Municipality
- Fuel consumption of the fleet of the Municipality
- Consumption of the e-vehicles fleet
- Monitoring of the waste recycling.

[8] https://www.comune.trento.it/Aree-tematiche/Ambiente-e-territorio/Energia-sostenibile/Patto-dei-sindaci-per-il-clima-e-l-energia/Paesc2

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This dashboard is available in the Smart Control Room implemented for the Task 4.6. Figure 4 portrays the example of the data visualization of the dashboard.

Figure 4 Example of the dashboard windows showing waste management, type of waste and fuel consumption of municipality´s fleet.

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4.2.1 Procurement rules for green transport for public administrations

The Italian Legislative Decree No. 257/2016 that implements the European directive 2014/94/UE have defined the steps and some mandatory actions for the public administration related to the acquisition of vehicle for the public fleet.

Specifically, in Article 18 “Actions for the diffusion of CNG, LNG and electricity in the road transport” requires that at any substitution of vehicle in the public fleet at least the 25% of vehicle must have CNG, LNG or electric supply, or hybrid. This regulation is also valid for the public transport companies.

In addiction the city administration decided to follow as much as possible the principle of substitute the old cars (Euro 0, Euro 1 and Euro 2) with new ones that has a lower CO2 emission in order to achieve the target of the PAESC and also to save fuel and indirectly money.

These principles are valid for passenger vehicles and light-duty ones. For trucks and working machines this can be very difficult to apply due to the limited amount of vehicle models currently on the market and the overall usability and quality of the vehicles. The graphs in the Figure 5, shows the trend of leaving the most pollutant vehicles and the introduction of new vehicles also with different supply.

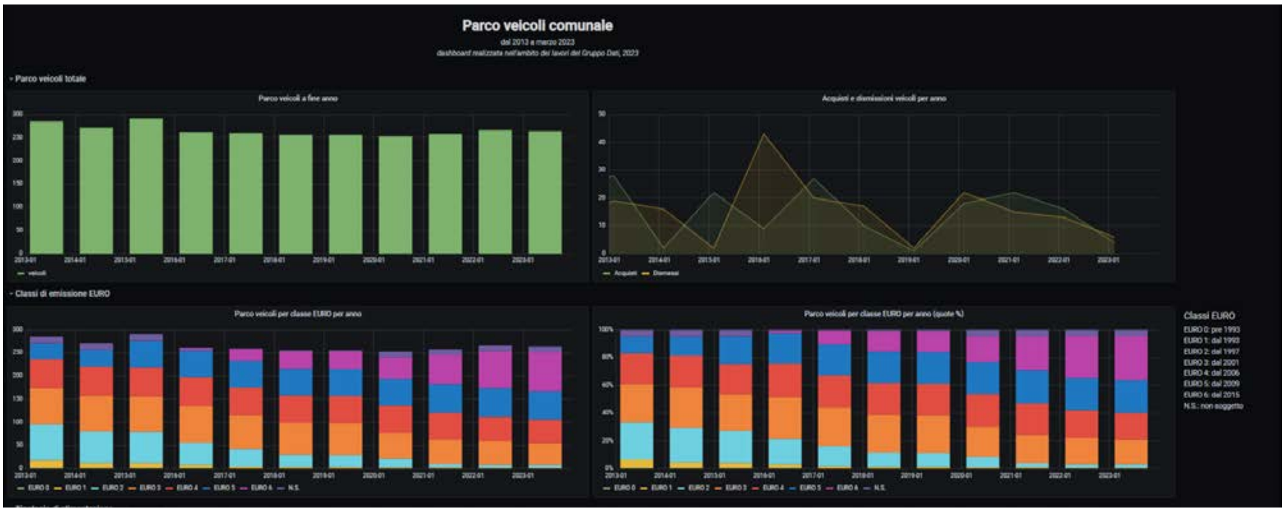

Figure 5 Statistics on the fleet for the Municipality of Trento

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5 Electric vehicles for public administration

5.1 Market overview of the EV models

In recent years, the electric vehicle (EV) market has experienced a notable transformation, reflecting a global shift towards eco-friendly and sustainable transportation. Despite facing challenges such as supply chain disruptions, macroeconomic and geopolitical uncertainties, and escalating commodity and energy prices, 2022 proved to be another groundbreaking year for EV sales.

This substantial surge in electric vehicle sales occurred within the context of a worldwide automotive market that contracted, witnessing a 3% decline in total car sales in 2022 compared to the previous year. Globally, EV sales reached a remarkable milestone, exceeding 10 million units in 2022. To put this into perspective, these sales numbers outpaced the total number of cars sold across the entire European Union, totalling approximately 9.5 million vehicles. Furthermore, EV sales accounted for nearly half of China's total car sales for the same year [32].

This growth signifies a five-fold increase in EV sales over a span of five years, from 2017 to 2022. In contrast, it took five years, from 2012 to 2017, to transition from 100,000 to 1 million EV sales, highlighting the exponential nature of the EV market's expansion. Additionally, the market share of electric cars exhibited a notable increase, rising from 9% in 2021 to 14% in 2022, underscoring a more than tenfold rise in their market presence since 2017 [33].

As governments and consumers increasingly prioritize the reduction of carbon emissions and the adoption of cleaner alternatives, the automotive industry has responded with a diverse range of EV models. These electric vehicles offer a wide spectrum of choices, ranging from compact urban cars to high-performance luxury vehicles, providing innovative and sustainable mobility solutions. This trend has also sparked a growing interest in the integration of electric vehicles into corporate and public fleets, holding significant potential to enhance the sustainability of government operations and contribute to the reduction of environmental impact.

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Furthermore, to provide insights into the Italian market, Table 1 lists the top 10 best-selling compact car models in Italy in 2022[34].

Table 1 Top 10 best-selling compact car models in Italy in 2022

Model	Manufacturer	Type	Sales	Share
500	Fiat	Compact car	6285	12,7
Fortwo	Smart	Compact car	4545	9.2
Model Y	Tesla	Compact crossover	4276	8.6
Spring	Dacia	Compact crossover	2825	5.7
Twingo	Renault	Compact car	2742	5.5
208	Peugeot	Compact car	2122	4.3
Mini	Mini	Compact car	1561	3.2
ID.3	Volkswagen	Compact car	1561	3.1
Zoe	Renault	Compact car	1553	2.9
2008	Peugeot	Compact car	1442	2.9

5.2 Municipality of Trento electric vehicles

Within Stardust project, Municipality of Trento has decided to acquire 10 electric vehicles to start the transformation of its fleet towards the zero-emission one. The acquisition of these vehicles was split in 2 parts: 4 cars for the 1st attempt and then the other 6 for the second attempt.

This modality has been decided for 3 main reasons:

- Substitute vehicles that more pollutant in order to save CO2 emission and fuel;
- Internal evaluation of the kilometres done by each car in order to increase the ratio between kilometres and fuel;
- Evaluation related to the chance of install the charging station and the energy capability of the place in which they are installed.

For these reasons the first 4 cars have been putted in the innovation and local police pole since it has easier to install the infrastructure. The other 6 EVs have been bought later since the work for the installation took more time than expected.

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Figure 6: EV Fleet of the Municipality

5.3 Management of current municipality EV fleet

The service of EV fleet is managed by the Department of Road management and Park of the Municipality, specifically by the car park office. The 10 e-cars are located in the Department parking slot in which has been also installed the charging station. The location has been decided using 2 criteria: first one is environmental criteria that is the historical analysis of the usage of the previous cars to save as much as possible CO2 emissions and, secondly, a technical criterion that is the possibility of installing the charging station in the parking slots of the departments Table 1.

Table 2 List of services that use EV in the municipality of Trento.

DEPARTMENT	VEHICLE ID	PLATES	LOCATION
Local Police	4	GA 591 ZY	Via Maccani, 148
	10	GC 138 CP	Via Maccani, 148
Mayor and public relations	9	GC 134 CP	Via Belenzani, 19
Social activities	5	GA 595 ZY	Via Bronzetti, 1
	8	GC 135 CP	Via del Brennero, 312

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Building heritage management and local requalification	7	GC 137 CP	Via del Brennero, 312
Education	6	GC 136 CP	Via Alfieri, 6
Innovation and digital transition	1	GA 534 ZY	Via Maccani, 148
	2	GA 578 ZY	Via Maccani, 148
	3	GC 139 CP	Via Maccani, 148

Due to the statistics of usage made in collaboration with Innovation and Digital Transition, the locations have been changed in the last years at least a couple of times, mostly due to a not frequent usage of e-cars. The motivation of non-usage is due to a non-familiarity with e-cars and the type of the automation. At the beginning these problems were stronger than now as usage and word of mouth increased (easy to use, drive, assurance).

Monitoring of use of the vehicles and respective data collection is performed in two different ways:

- **Manually**: due to internal regulations, the employees that have to use the car, must use a dedicated web application in which he/she has to fill a page where indicate address of starting point and the destination, date and time and the motivation. In addition in any car there's a register book in which the user has to insert again date and time, destination, motivation, kilometres at the beginning and at the end of trip and (for e-cars only) the percentage of the battery at the beginning and at the end of the trip. These manual books are used also for backup in case the automatically data collection fails. Only for e-cars, these books are digitalised in a Google Spreadsheet and the data are shared with Eurac for further analysis in combination with the automatic data collection.
- **Automatically**: Data collection occurs through the use of an electronic device installed in the vehicle, which gathers information when the vehicle is operational via the CAN bus. This device transmits the data to an AWS server via an internet

connection, and in case the connection is temporarily unavailable, the data is stored within a memory and subsequently sent when the connection is reestablished.

Figure 7: Device installation on the EV car

5.3.1 Preliminary monitoring results

An initial analysis was conducted on a fleet of 10 electric vehicles to evaluate their performance and operational data. This preliminary study aims to provide an overview of the initial results and observed trends, as described above, using data collected through dedicated electronic devices.

These devices collected energy consumption, battery status (SOC, State of Charge), charging time, the number of recharges. They are collected during the night and stored in a central DBC database, enabling continuous monitoring.

The data visualization dashboard, created using Grafana, is composed of several key sections, each of which provides specific information (Figure 6):

1. Last SoC: the dashboard records and displays the State of Charge (SOC) for each vehicle during overnight periods. This operational information allows the manager to understand in the morning whether the vehicle is discharged or charged.
2. Timeline for SoC: the dashboard maintains a historical log of SOC data, including the last recorded SOC for each vehicle. These logs enable

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retrospective analysis and help in understanding trends in the context of vehicle shutdowns.

3. Monthly rechargers: A visual representation of the number of recharging events occurring each month.
4. Monthly consumption: A graphical representation illustrating the energy consumption that occurs for each month (kWh).
5. Data Monitored Since the Beginning of Monitoring: Energy consumption, Energy consumption for rechargers and recharge events.

Figure 8 Grafana Dashboard for Electric Vehicle Fleet Monitoring (Vehicle 6)

Each vehicle of the fleet is identified by a number and can be selected from the dashboard.

Since the beginning of the monitoring, the following monthly results have been obtained:

1. a maximum monthly consumption per vehicle of 189 kWh (vehicle 3)
2. an average consumption per vehicle around 40 kWh.
3. maximum number of recharges equal to 14 (vehicle 1)
4. an average number of recharges per vehicle equal to 5.

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6 Last-mile urban logistics with electric vehicles

6.1 Introduction

In recent years, the rapid development of urban logistics has made people's lives more convenient; however, many negative impacts (i.e. traffic congestion and greenhouse gases) have also affected the cities. According to the European Commission, freight transport should become CO2-free in major urban centres by 2030. Moreover, Clean Vehicles Directive (Directive (EU) 2019/1161) set minimum procurement targets for the Member States for the clean light duty and clean heavy-duty vehicles, setting as well low CO2 emission thresholds to be met by 2025 for clean light-duty vehicles. At the same time logistic sector has undergone a radical transformation. The increasingly fast development of information and communication technology (ICT) has had important consequences on logistics chain. It has innovated service in all phases, ranging from transport organization, warehouse management, to deliveries in the city. Urban logistics is now considered one of the most important issues and cities are calling the attention of administrator to careful planning this sector [35].

The strong interaction of goods' transport with other urban activities involves risks in terms of traffic congestion and road safety, noise pollution and conflicts in use of urban space. Last mile delivery is therefore a difficult sector to manage as it involves problems linked to several fronts.

In addition to heterogeneity of goods transported and vehicles used, urban logistics involves a multitude of interested parties, each with divergent interests and objectives. Often these parties do not have a shared and global view on system status and on priorities for action, so actions taken may not be the most appropriate for the context. While local authorities are interested in opportunities to reduce congestion, pollution and noise, transport companies and retailers are primarily concerned with keeping costs under control and maintaining or increasing service levels. This complexity can often lead to partial, suboptimal or in some

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cases even counterproductive decisions and solutions [36]. For better coordination of different interests brought by actors involved, further research is needed to study relationships between parties by adopting a holistic perspective in order to obtain efficient solutions. Adoption of effective projects and methods can offer promising opportunities. It can lead urban logistics operations to become more efficient and more environmentally sustainable. However, detailed feasibility studies that evaluate prerequisites, implications, and benefits of initiatives applicable in this area have not been yet carried out. For this reasons replicability of actions undertaken is still strongly limited in different contexts form those in which they are developed [37].

6.1.1 Last-mile (city) logistics

Freight transport and logistics form an important backbone of economic development within urban agglomerations and cities. Historically, this especially connects to the **supply of goods** for economic production. More recently, urban socio-economic transformations have resulted in an increased emphasis on the provision of goods to a city's service economy and on the satisfaction of defined customers' needs with regard to e-commerce business-to-consumer (B2C). According to the OECD/ITF [38], in the EU-27 overall freight volumes by road did not change significantly between 2011 and 2014, for example amounting to approximately 20,000 million tonne-kilometres in Italy in 2014. However, in light of on-going urbanisation trends and the before-mentioned structural transformations of economic systems, the authors underline the substantial and increasing contribution of urban freight transport and logistics to the production of freight volumes. Already in 2015, **urban road freight activity** represented roughly 50% of road tonne-kilometres of freight transported in all OECD countries [38].

In this regard, urban road freight activity significantly contributes to the **environmental impact** of the freight transport sector. This especially regards greenhouse gas emissions such as carbon dioxide (CO_2), and pollutants such as particulate matters (PM) and nitrogen dioxide (NO_2), caused by internal combustion engines (ICEs) using fossil fuels. Based on analysis of CO_2 emissions from transport using PRIMES-TREMOVE modelling [9], the European Commission estimated that urban transport accounts for 23% of transport CO_2

[9] https://ec.europa.eu/clima/policies/strategies/analysis/models_en

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emissions, and of which a quarter can be attributed to urban freight. According to the International Transport Forum Outlook [38], the increased use of road transport especially for short distances is assumed to be a potentially major driver of CO_2 emissions from global freight. The strong interaction of urban road freight transport with other urban activities also bears risks with regard to traffic congestion and road safety, noise emissions or urban space conflicts (e.g. parking lots). Furthermore, in an urban context especially the 'last mile' represents a challenging task for transport operators from a **financial perspective**. It relates to issues such as meeting customer satisfaction as well as ensuring cost efficiency, for example in light of risks such as high delivery failure and empty trips.

Logistic efficiency denotes one area of action to address those challenges, especially regarding **last-mile logistics (LML)**. According to a review by [39], most definitions agree that LML represents the last stretch of a delivery process. More specifically, the authors conclude that '*it takes place from the order penetration point (i.e., fulfilment centre) to the final consignee's preferred destination point (e.g., home or cluster/collection point), for reception of goods'* [39]. As such, if interpreted in a more narrow sense, LML (network) design aims at logistic efficiency by optimising loading and routing between those two points, addressing both the tonnes transported and the kilometres travelled. It can also refer to both the development of distribution structures (e.g. push-centric systems) and the identification of design variables (e.g. merchandise-oriented) [39]. According to a more recent literature review of different domains of urban logistics research [40], LML describes '*the final leg of transport in which the goods reach their consumption point, or to the first leg of transport in which the goods are shipped from their origin in the city towards a location where they are bundled with other goods outside the city*'. The latter part of the definition more closely relates LML to the urban environment. [40] also conclude that related research especially focuses on operational solutions with regard to the development of micro-consolidation platforms; ex-ante evaluations of vehicle types, collaboration and delivery methods; and routing problems to reduce distances and costs of transport [40].

However, not necessarily LML definitions are limited to the urban context, which might also explain the coining of the term last-mile city logistics. It more closely links to interpretations of **city logistics**, although similar to other terms no commonly agreed definition of the latter exists. [41] for example described it as "*the process for totally optimising the logistics and transport activities by private companies in urban areas while considering the traffic*

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environment, the traffic congestion and energy consumption within the framework of a market economy”. Following [40], city logistics looks at the ‘*interdependencies of citizen welfare, logistics systems and public administration of urban logistics policy*’, and pays particular attention to the ‘*decision-making process setting up measures*’. Related research seems mostly focusing on two components 1) the modelling of complex city transport systems, not only taking into consideration urban freight movements but also the different agents involved in its design, and 2) the public decision context, including for example the establishment of low-emission zones (LEZ) [40]. The authors overall conclude that city logistics aspires at managing the interactions and relationships linked to the movement of goods within the city and its inhabitants, aiming at improving the quality of life of the urban population.

Table 3: Dimensions and characteristics of urban logistics research [40]

Characteristics	Last mile delivery and collection	Urban goods distribution	City Logistics
Research methodologies	• Mathematical modelling • Operations research • Routing Simulation	• Transport Simulation • Mathematical modelling • Agent based simulation	• Survey • Agent based simulation • Multi criteria analysis
Network typology	• Deliveries • Multi node networks • Loading and unloading spaces	• Freight transport system • Terminals and consolidation • Multi-modal transport	• Full ecosystem of urban logistics • Information flows focused
Type of variables	• Towards quantitative	• Neutral	• Towards qualitative
Performance measurement	• Distance • Time • Load factor • Operational costs	• Traffic congestion reduction • Emissions • Financial performance • Number of vehicles	• Quality of life • Competitively • Outcomes from regulation
Research subjects	• Routing • Distance reduction • Optimisation • Alternative vehicles	• Data collection process • Urban distribution centres • Freight transport infrastructure • Public policies performance • Emissions	• Stakeholders relationships • Sustainability • Systemic approach to challenges • Collaboration • Decision making process • Land use

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Planning Horizon	• Towards operational decisions	• Neutral	• Towards long-term decisions
Target audience	• Firm and supply chains	• Set of firms, their supply chains, • and resource and infrastructure • managers	• Stakeholders and policy makers
Innovations	• Optimisation algorithms • Drones	• Decision Support Systems • Communication systems	• Urban access restrictions schemes

In this regard, an important trait of city logistics is its systemic nature, reflected in a range of key characteristics described in Table 1, such as an ecosystem network typology, application of agent-based modelling in research and consideration given to qualitative variables and multitude of stakeholders. Connecting it to LML and its characteristics puts an increased focus on additional aspects such as the development of micro-consolidation hubs in a multi-node complex network and quantitative performance measurements such as distance, time and load factor.

One area so far not addressed and inherently a key aspect of the urban logistic dimension of urban goods distribution refers to the **type of vehicles and the technologies** applied to counter some of the environmental and financial challenges urban logistics is facing. This especially refers to replacement of ICEs with electric vehicles (EVs) to reduce the economic and environmental impact of fossil fuel use, and the according transformation of the transport and energy infrastructure of a city. Related research either strongly focuses on the total costs of ownership and market share of EVs (e.g. [42]), their market uptake (e.g. Figenbaum et al 2015, Kihm and Trommer 2014), the deployment of charging infrastructure (e.g. Philipsen et al 2016), the related impact on the electricity grid especially regarding vehicle-grid-integration, challenges linked to the life-cycle costs of batteries production and charging (e.g. , [43] and energy density and storage (e.g. [44]).

Increasingly attention is also paid to the interaction of e-vehicle technologies with other dimensions of urban logistics. This especially refers to LML solutions and city logistics more broadly, the latter particularly in relation to a range of research and innovation projects supported by the EU's research programme (e.g. FRevue - Validating Freight Electric

Vehicles in Urban Europe or BESTFACT – Best Practice Factory for Freight Transport). This especially links to an increased awareness of the design of city logistics requiring an **integrated approach**, which combines logistic network design, technological solutions, and policy interventions, in order to address the complexity of persisting problems. All these components will also form part of the analysis of this report, following the assumption that last-mile e-logistics goes beyond the "*optimisation of delivery*".

6.1.2 Challenges and drivers linked to last-mile e-logistics

Building on the previously discussed characterisations, the following definition is applied to **last mile e-logistics** in the framework of this work: '*The process of organising the final leg of urban goods distribution, by shipping them to a location where they are bundled to reach their final consumption point, using electric vehicles and ICT for optimal routing and decreased environmental impact and taking into due consideration interdependencies of citizen welfare, logistics systems and the public administration of urban logistics policy*'.

Following this definition, last mile e-logistics is assumed to address the following important areas of action:

1) **Policy interventions:** This for example refers to regulative instruments such as the development of low emission zones to the application of financial instruments such as subsidies for the purchase of e-vehicles.
2) **Network and infrastructure design**: It includes activities such as the design of LML distribution structures as well as the development of the recharging infrastructure for e-vehicles.
3) **Vehicle and ICT technology**: The area refers to the selection of vehicle types, ranging from light duty e-vehicles to 2-wheelers such as e-cargo bikes, and the development of ICT technology for an optimised allocation of tasks and routes, including e-charging considerations.
4) **Organisational structure and business models**: The area addresses all organisational activities that are adopted to conduct business in the framework of last-mile e-logistics.

Technical characteristics and cost-based aspects are often described as one of the main entry barriers regarding the larger adoption of electric vehicles. This relates to aspects such

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as driving range; distrust in the technology; availability, speed, and use of charging infrastructure; as well as initial upfront purchasing costs, vehicle depreciation and fuel price variation [42]. With regard to logistics, especially factors such as the potential reduction of load capacity linked to the space required by batteries, range limitations (depending on operations), narrowing time ranges, lack of schemes for sufficient manufacturer back-up support have been brought forward as main issues. On the other hand, besides environmental considerations and addressing related liabilities, also economic aspects can be important facilitating factors, especially linked to reduced fuel and maintenance costs.

In addition, especially policy interventions can play an important role in driving the uptake of e-vehicles. According to [45], different instruments have been key in increasing the attractiveness of EVs to private and business customers in countries and regions leading on the EV adoption, such as China, Europe, or the United States. It links to the instruments' perceived impact in reducing risks and providing incentives in scaling up production. These can include **regulatory interventions**, which set important frameworks at the national, international, and local level. For example, can this refer to vehicle emission and technological standards, setting restrictions on vehicle access and circulation depending on vehicle emission performance (where, when and which type of freight) or also regulating the development of charging infrastructure (e.g. EU Directive 2014/94 on the deployment of alternative fuels infrastructure).

It also involves so called **market-based instruments** such as subsidies (e.g. financial support e-vehicle purchase) and tax reliefs (e.g. vehicle registration tax exemptions), which can help overcome some of the perceived entry barriers related to cost-related aspects. In addition, the application of land use **planning instruments** can also have an important impact on the use of e-vehicles, including measures such as dedicated e-vehicle parking space for logistics or access to high-occupancy preference lanes. **Public procurement initiatives** can also play an important role, especially in relation to the development of charging infrastructure and the promotion of an increased visibility of e-vehicles. Visibility can be an important lever to promote an increased use, especially if taking into account social influences and their contribution to the adoption of new technologies linked to e-vehicles [46].

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With regard to network and infrastructure design, the development of the **recharging infrastructure** for e-vehicles is considered one of the most important aspects to consider with regard to the uptake of e-vehicles. Large part of the existing academic literature focuses on its importance for light-duty passenger vehicles, looking into aspects such as charging point location, charging point access and payment, costs of charging or the required number of charging stations [17]. Little literature is available which specifically looks into how related issues impact the use of e-vehicles for urban freight transport. According to [17], charging opportunities at home and at work are considered one of the most important aspects for an increased use of passenger e-vehicles. It can be assumed that charging location also plays a key role regarding commercial vehicles, though the role of public charging stations might be smaller, taking into consideration the economic need for ready-to-use charging stations due to further limited time windows. In an analysis of green logistics in last mile delivery for B2C E-Commerce [47], the author studies the importance of fast-charging stations, by considering potentially occurring financial costs. He concluded that fast-charging stations might allow up to 2 freight distribution shifts of roughly 95 km each, allowing economies of scale and leading to smaller financial costs compared to the use of diesel vehicles. However, the difference regarding financial costs was smaller than expected, as the increased number of charging cycles is assumed to decrease the lifetime of batteries, thus requiring the acquisition of 7 rather than only 4 batteries over an ownership time of eight years [47].

The further scale-up of e-vehicle use will have a significant impact on the electricity grid linked to an increased electricity demand and shifting demand peaks (e.g. over-night recharging). This is also increasingly linked to efforts to integrate transport and energy systems, including notions such as **vehicle-to-grid** (V2G), which refers to the "*bidirectional flow of electricity between the PEV and electrical grid, adding the ability of idle PEVs to store electricity from the grid and to give or sell it back*" [48].

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6.2 E-vehicle market for freight transport

6.2.1 Overview and trends

According to the global outlook on electric vehicles (EVs) by the International Energy Agency [45]), close to 250,000 **electric light commercial vehicles** (LCVs) were considered on the road in 2017. Of those, nearly 70% occurred in China, including also “special vehicles” such as for street cleaning or garbage trucks. The second largest fleet is provided by France (13%), followed by Germany with a significantly smaller share (4%). The outlook also emphasises that especially companies and governmental institutions employ electric LCVs, of which 99% consist of battery-electric vehicles (BEVs) rather than plug-in hybrids (PHEVs) or even less commonly fuel cell electric vehicles (FCEVs). They add to the 3.1 million electric passenger cars on the road in 2017, and an overall rate of sales growth of electric cars amounting to 54%, particularly driven by the Chinese market. In the EU’s 28 member states more specifically, around 31 million LCVs and 6 million medium and heavy commercial vehicles were in use in 2015, an increase of 1.8 and 1.7 respectively compared to 2014, following a report by the European Automobile Manufacturers Association (ACEA 2017). LCVs consisted to 0.2% of electric vehicles (including plug-in), with Belgium (1.3%), France (0.4%) and Austria (0.3%) offering the highest shares and the segment only amounting to 0.1% in Italy in 2015. Fuel cell electric vehicles (FCEV), and hybrids combining battery driven vehicles and those applying fuel cells for the transformation of hydrogen into electricity as range extenders, amounted to 7,200 units in 2017, with roughly 50% being in use in the United States, followed by Japan (32%) and Europe (16%), especially Germany and France [45].

The use of **electric medium- and heavy-duty vehicles** often occurs in an urban environment, being part of large fleets of commercial or service vans. At EU level, the overall share of electric medium- to heavy-duty vehicles was slightly smaller compared to LCVs, amounting to 0.1% in 2015, with Belgium (1.6%) and Lithuania (0.4%) leading the way regarding overall share [49]. Medium-sized electric duty vehicles are most frequently applied in municipal services (e.g. street cleaning or waste collection). This for example refers to the adoption of electric vehicles recovering electricity from regenerative braking, linked to their stop-and-go use pattern [45], although bearing challenges regarding the available load capacity. Electric trucks are mostly part of demonstration projects initiated by logistics

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companies and usually represent retrofits of conventional, internal combustion engine (ICE) vehicles. Although still of limited volume, fuel cell technology has become of increased interest especially for the development of heavy-duty, long-distance vehicles, given the opportunity they offer in extending transport ranges. In this regard, increasingly demonstration and pilot projects are under way, such as the testing of the hydrogen driven Toyata Alpha truck at Toyota Logistics Services in the Port of Los Angeles starting in 2018 [50].

More difficult to grasp is the contribution of **electric two- and three-wheelers** in transporting freight especially with regard to last-mile e-logistics (e.g. delivery). Besides representing broad and not well-defined categories (e.g. including scooters, hoverboards and segways or tricycles) only sales data for a given year are usually available and it is difficult to assess the current stock. According to IEA [45], most recent numbers suggest that 900 million two-wheelers circulated in ASEAN (Association of Southeast Asia Nations) countries, China and India in 2017, commonly powered by ICE and fuelled by gasoline. However, it was estimated that in China alone, in 2017 electric two-wheelers amounted to 250 million units, with annual sales adding up to 30 million. The country also likely had 50 million electric three-wheelers operating in the same year. In the EU, around 18,000 electric motorbikes and 21,000 low-speed electric vehicles were registered in 2017. With regard to **bicycles and electric-power-assisted-cycles** (EPACs), almost 20 million were sold across Europe in 2020, out of which 13 million were also produced in the EU [51]. The same year, EPAC sales amounted to 1.7 million and production to 1.2 million in the EU-28, the former increasing by 22 % and the latter by 13 % compared to 2019.

6.2.2 Light commercial e-vehicles

6.2.2.1 Brands and market shares

Table 3 summarizes the status of the BEV market and models for LDV in EU27, showing that larger share is covered by Renault, Peugeot and Nissan.

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Table 4: Light-commercial vehicles: BEVs ranking and shares EU-27 (EAFO, 2022)

Ranking	Brand	Model	YTD 2018	Share PEV market	YTD 2017	2017 Total	Share PEV market	2016 Total	2015 Total	2014 Total	2013 Total	2012 Total	2011 Total
1	Renault	Kangoo ZE	2590	38.4%	1287	4100	25.8%	3688	4114	4186	5895	5602	994
2	Street Scooter	Work	1240	18.4%	994	4092	25.8%	1800	200	0	0	0	0
3	Peugeot	Partner EV	807	12.0%	530	1373	8.7%	830	427	498	191	37	80
4	Nissan	e-NV200	568	8.4%	1378	3270	20.6%	3739	2448	1712	0	0	0
5	Citroen	Berlingo EV	436	6.5%	359	981	6.2%	473	268	307	22	52	149
6	Goupil	G4	315	4.7%	179	537	3.4%	10	0	0	0	0	0
7	Renault	Zoe Van	305	4.5%	211	747	4.7%	442	215	221	47	0	0
8	LDV	Maxus EV80	216	3.2%	0	8	0.1%	0	0	0	0	0	0
9	Ligier	Pulse 4	82	1.2%	83	167	1.1%	755	216	0	0	0	0
10	Goupil	G5	58	0.9%	46	113	0.7%	109	50	0	0	0	0
Others	/	/	121	1.8%	218	475	3.0%	1026	1551	1419	984	867	715

Note: YTD = year to date. PEV = Plug-in electric vehicles

While PHEV market looks rather different in respect to BEV ones, lead by Audi and BMW (Table 4).

Table 5: Light-commercial vehicles: PHEVs ranking and shares, EU-28 (EAFO n.d.)

Ranking	Brand	Model	YTD 2018	Share PEV market	YTD 2017	2017 Total	Share PEV market	2016 Total	2015 Total	2014 Total	2013 Total	2012 Total	2011 Total
1	Audi	Q7 e-Tron Van	N/A	N/A	1	2	0.0%	0	0	0	0	0	0
2	BMW	i3 Rex Van	N/A	N/A	2	2	0.0%	0	0	1	0	0	0
3	BMW	225xe Active Tourer Van	N/A	N/A	1	1	0.0%	1	0	0	0	0	0

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4	Mit-subishi	Outlander PHEV Van	N/A	N/A	0	1	0.0%	7	0	0	0	0	0	

Note: YTD = year to date. PEV = Plug-in electric vehicles

6.2.2.2 Technical and financial parameters

The following table provides an overview of key technical parameters applying to selected light duty vehicles with a load volume around 3 to 4 m^3. It includes those with the highest market share in the EU (e.g. Renault Kangoo Maxi ZE to Nissan e-NV200) and specific, more local brands, which offer tailored features for commercial uses (e.g. Alkè in Italy).

Table 6: Light duty vehicles technical parameters

Brand *Model*	**Renault** *Kangoo Maxi ZE*	**Street Scooter** *Work Box*	**Peugeot** *Partner EV*	**Nissan** *e-NV200*	**Citroen** *Berlingo EV*	**Piaggio** *Porter Electric*	**Alkè** *ATX 320E*
							
Power	44kW	30kW	49 kW	80kW	49kW	11 kW	14 kW
Range							
NEDC	270 km	118 km	170 km	280 km	170 km	110 km	75 km
Electricity per 100km	15.2 kWh	n.d.	17.7 kWh	16.5 kWh	17.7 kWh	n.d.	n.d
Speed, max.	130 km/h	85 km/h	110 km/h	123 km/h	110 km/h	55 km/h	44km/h
Battery capacity	33 kW	20 kW	22.5 kW	24 kW	22.5 kW	17 kW	10 kW
Recharging time							
Normal	~ 6 h	~ 7 h	~ 8 h	~ 6 h	~ 8-15 h	~ 8 h	~ 8
Fast	n.a	n.a.	~ 0.5 h	~ 0.5 h	~0.5 h	n.a.	n.a.
Gross vehicle weight	2,190 kg	2,180 kg	2,180 kg	2,250 kg	2,180 kg	1,800 kg	1,510 kg

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Battery weight	260 kg	n.d.	327 kg	n.d.	317 kg	n.d.	
Kerb weight	1,585 kg	1,460 kg	1,789 kg	1,555 kg	1,789 kg	1,330 kg	900 kg
Max. payload	605 kg	720 kg	477 kg	695 kg	552 kg	470 kg	610 kg
Load volume	4 m^3	4.3 m^3	4.1 m^3	4.2 m^3	3.3 m^3	3 m^3	n.d.

Notes: n.a. = not applicable, n.d.= not included in technical specifications,

Purchasing costs are difficult to assess, given the information is not always immediately retrievable and prices can strongly vary depending on features and modes of financing. Most brands offer the opportunity to lease the battery, to advance lower upfront purchasing prices, to take into consideration amortisation costs linked to the battery's fast technological development and to cover some of the forgone income from engine maintenance. For example, Nissan lists a base price of € 25,700 (without VAT) if the battery is bought, and € 20,800 (without VAT) if the battery is leased. Battery leasing prices depend on contract duration and vehicle kilometres travelled, for example amounting to € 86 per month (without VAT) based on a 24-month contract and up to 15,000 km travelled per year (Nissan 2016). Citroen provides a base price of € 15,700 (without VAT) for the Berlingo Electric, with additional battery purchase costs of € 5,300 or a monthly battery leasing rate amounting to € 87 (Citroen 2016). Renault provides a base price of € 23,000 (without VAT) for its Kangoo Z.E., without battery included and not publicly available leasing prices for example for Italy.

6.2.3 Last-mile delivery potential interventions at city level

To improve last mile delivery in cities, various solutions can be applied. In several cities many initiatives have already demonstrated the possibility of achieving benefits, but the main complexity lies in selecting the most suitable solution for the context, taking into account local factors and the contribution of the initiative to the established strategic objectives [36]. Observing the multitude of solutions found at a global level, four macro-categories can be defined into which these initiatives fall:

- **Landuse regulation:** These measures allow authorities to impose certain rules and restrictions on the use of urban infrastructure for logistics within the city. Some typical examples are: limited access to certain areas, based on a set of vehicle criteria; the provision of time slots for access to certain streets; the determination of areas in

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which only one or a limited number of transporters can make deliveries. These measures are generally applied in combination as they can influence the behavior of transporters leading to a reduction in the impact of last mile delivery in such areas. Access restrictions and time slots are common enforcement tools in many cities, however these initiatives pose several critical issues if not structured and managed efficiently. A first aspect to evaluate concerns the capital cost that these initiatives may entail for transporters, consequently this aspect must be considered in the service design phase to make costs for transporters reasonably low. The extent of these compliance costs can in fact favor large transport operators over smaller ones, with the possibility of distorting competition in the sector. A second critical aspect of these tools is the guarantee of sanctions in case of violation of the restrictions. The authorities must be able to guarantee the effectiveness of these tools through systematic control, which often involves considerable costs for the management and administration of the system. Finally, a further critical issue concerns the definition of restrictions on vehicles; in this context it is necessary to determine a system that is able to incentivize less polluting vehicles and which present a minimum load factor in order to rationalize the sector [36].

- **Preparation of infrastructure:** these measures involve the creation of alternative transport and logistics infrastructures or the re-adaptation of existing infrastructures, to better meet the needs of urban freight transport. One of the biggest challenges at the moment is the optimization of loads and routes taken in the delivery service through coordination between couriers belonging to different operators within the city. In this direction, urban distribution centers (CDUs) offer great opportunities for synergies between different actors in the supply chain, with the possibility of achieving an environmentally friendly and efficient flow of goods to cities [37]. A CDU converges downtown-bound shipments at a warehouse on the edge of the city, where goods are collected from multiple sources before being shipped into the city for last-mile delivery. The objective is to increase the average load factor of the vehicles used to optimize the total distance travelled, to the benefit of the level of traffic congestion in the city and air quality. The impact of a UDC depends mainly on the extent to which it can increase the average load factor, which is influenced by the nature of the goods, the transporters involved and the local density. A further level of consolidation can be achieved through collection points for orders deriving from e-commerce, by setting

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up automated lockers that allow transporters to deliver packages to individual locations, thus concentrating shipments.

Another possibility allows the arrival of goods directly near the historic city center using alternative means of mass transport such as trains or buses, after which other means of transport can carry out last mile deliveries having to cover shorter distances. This measure is not convenient for transporters at this time due to the increase in additional cost of transportation, but it can enable urban delivery of goods in areas where vehicle access to the historic urban center is severely limited. Cities can also reserve dedicated logistics spaces in the city center or allow vehicles to use bus lanes at certain times of the day. This measure is already widely adopted in various realities and recent implementations use the possibility of dynamic access to parking lots or access to bus lanes allowed using real-time information [36].

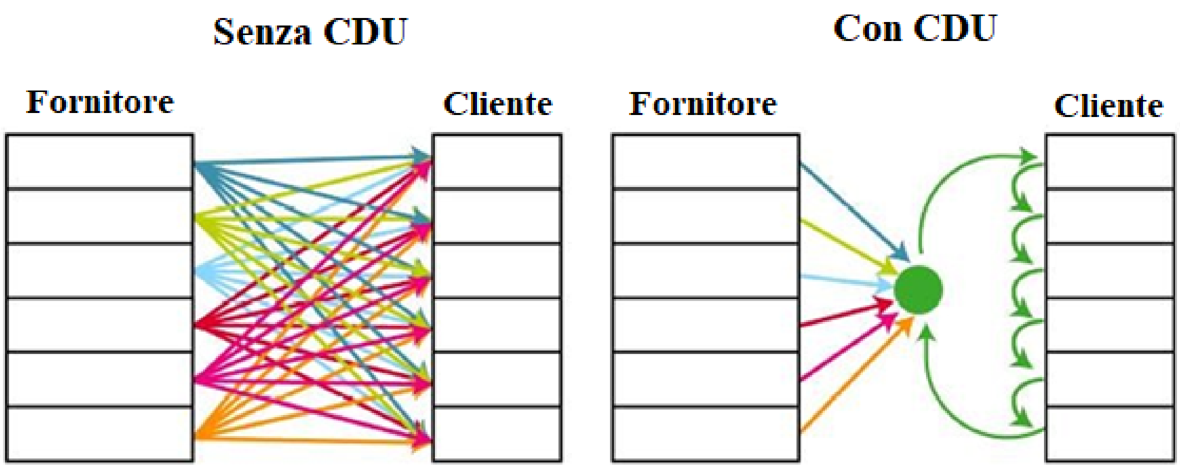

Figure 9 Lastmile delivery impacts with the introduction of CDUs

- **Financial measures:** public authorities can offer financial incentives to urban transport service providers to guide their decisions and reduce negative externalities linked to the service. However, these measures are often defined at a local or regional level and only local operators can benefit from them.

Other systems may involve the use of toll rates in certain urban areas through automatic systems based on license plate recognition or by installing a signalling device in the vehicle. The implementation of this measure requires large investments and can be politically

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sensitive. Rates can be “smart” by varying based on different factors, such as the vehicle's emissions level, load factor or time of day, and can optimize the tolling system, via a higher mark-up only on those vehicles that contribute more to emissions and traffic congestion. Pricing mechanisms can also be demand-driven, with a system of setting the tariff in relation to the volume of traffic present. This tool allows what is defined as the internalisation of the external costs of transport, i.e., it evaluates the external costs associated with the use of a vehicle, thus allowing the effects of vehicular transport on the community to be considered in as objective a way as possible, transferring, albeit with some inevitable approximations, the external costs on the real generators of such costs [36].

- **Equipment and technology:** the impact created by last mile deliveries can be reduced with eco-friendly vehicles. In addition to the replacement of fossil fuel vehicles with electric vehicles, in recent years the new types of alternative transport available have multiplied, including cargo bikes, electric scooters and drones. These means of transport are often combined with other tools that can be adopted in the field of last mile delivery such as CDUs (Gantioler 2019). Another important piece for the management of urban logistics is represented by the preparation of equipment that allows the analysis of a large amount of data through ICT solutions that allow the optimization of individual deliveries. Such an infrastructure can enable the efficiency of both the route taken based on real-time traffic information and the load factor. Most logistics service providers use these types of systems for route optimization, but the first initiatives for an integrated system for freight transportation are still in an experimental phase [36].

The management and implementation of new services and projects should provide modern and well-structured proposals, with active involvement of various stakeholders, such as governments, couriers, retailers and citizens. Initiatives falling into these macro categories have been undertaken by many European cities, including some small and medium-sized cities, which in recent years are also starting to take an interest in the management of freight transport. However, the effect of such initiatives would be more far-reaching if they were part of a general and integrated mobility strategy. Especially in the case of smaller cities, regional approaches and partnerships with local associations and stakeholders are extremely important, but to avoid being isolated and seize the opportunities related to large-scale ICT deployment they are not the only ones subjects to relate to. Currently, the

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initiatives that can be undertaken are therefore varied and the effectiveness of the different combinations does not find direct confirmation as the evaluations, when present, struggle to detach themselves from the reference context [35]. This need for collaboration and sharing has also been grasped by the European Union, which with the Horizon 2020 and Horizon Europe programs has undertaken a path of innovation that involves various sectors including that of urban logistics, with the aim of encouraging the search for smart solutions and establish guidelines towards a sustainable future [52]. Through similar initiatives, the European Union is trying to bring cities a further step forward in the smart field by sharing projects developed at a local level with the aim of achieving global and integrated strategies that expand the boundaries of the initiatives undertaken and lead to greater benefits than those obtainable in a local context [36].

6.2.4 In-depth case analysis

The determination of a sustainable last mile logistics business model for the city of Trento was conducted through the comparison between four cases of real application. On the basis of the reported cases, we proceeded to determine as many scenarios suitable for the context of the city of Trento. To carry out this operation, three meetings were organized with the organizers of the service in Trento, or with representatives of the Municipality of Trento and Trentino Mobility Spa, through which the hypotheses for the model were determined. Below is an overview of the main characteristics of the different service settings analyzed:

- **Vicenza:** since 2004 the Municipality of Vicenza has approved an ordinance which prohibits the transport of goods with own vehicles in the historic center of the city (within the restricted traffic zone). At the same time, the Vicenza Eco-Logistics Center was launched (Figure 8), which is characterized by an operational headquarters that acts as a central hub for deliveries within the ZTL. The Center therefore functions as a collection point for all goods entering the city, which are subsequently loaded onto electric vehicles responsible for distribution to the individual businesses located in the historic center (www.velocelogistic.com). On the basis of this case, a scenario has been outlined for the city of Trento which envisages the presence of a single central hub that manages deliveries to the historic center, however in this case it was assumed that the service is not mandatory and therefore the ZTL is not closed to deliveries made by third parties as in the case of Vicenza.

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Figure 10 Trento city representatives visiting Vicenza hub

- **La Rochelle:** In 2001, the urban community of La Rochelle established a zero-emission goods distribution system in the urban center through the European ELCIDIS project. The implemented solution involved the setting up of a mini-hub from which direct deliveries were made to the historic center via electric vehicles, thus alleviating traffic congestion and reorganizing delivery management. From an analysis of the results conducted in 2005, this experiment presented a satisfactory

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situation, although there were several constraints relating to organisation, size and delivery areas that limited the possible extension and duration of the system (Figure 9[53]. On the basis of this case, a scenario was therefore defined in which direct deliveries towards the historic center are divided between three mini-hubs, in order to prevent the dimensional limits of this application case.

Figure 11 Trento city representatives visiting La Rochelle hub

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- **London:** Given the size of its population, which is close to nine million, the problem of logistics is particularly acute in the city of London. Over the years, numerous initiatives have therefore been undertaken in this sector, including the setting up of latest generation mini-hubs that are completely autonomous in managing the goods inside them. This management system therefore does not require the presence of warehouse workers to move the goods, and the couriers interface directly with the system software to obtain the goods to be delivered (Court 2019). Based on this case, a scenario was defined for the city of Trento in which direct deliveries to the historic center are managed via three fully automated mini-hubs. This solution requires a high level of automation of the hubs implemented in order to allow autonomous and safe management of goods.
- **Padua:** in this case the goods destined for the historic center are delivered to a hub located within the Padua Interport area. The zero-emission vehicles leave from here for final distribution towards the centre. This system, operational since 2004 and based on voluntary participation by couriers, allows you to take advantage of the logistical support offered by the interport (Figure 9). The success of this service approach is mainly given by the high involvement of stakeholders in the definition of the characteristics of the service and in the use of a "neutral" platform guaranteed by the choice of the interport as the single hub (www.interportopd.it). On the basis of this scenario, the use of a hub at the Trento interport was defined for the city of Trento, combined with the help of two mini-hubs near the historic center which act as logistical support, one of which is completely automated.

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Figure 12 Trento city representatives visiting Padua hub

The motivation for the choice of the cases described lies in the fact that in the cities of Vicenza, La Rochelle and Padua the service was implemented in the early 2000s and has continued until today, demonstrating the quality of the models implemented in these realities. For the case of London, however, the motivation lies in the extreme innovation of the proposed case, which reflects the developments and new trends in the sector. It was therefore considered that together these examples of real application could reflect a wide range of possibilities for evaluating the best alternative for the context of Trento.

Complete analysis of the business models that have been assessed for the Trento city logistics hub with electric vehicles can be found in [54]

6.3 Operation of TRENTOYOU service.

Based on the detailed analysis of the case studies, potential business models and sustainability indicated presented in the deliverables of WP7 as well as an innovative work

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with the university of Trento regarding the branding of the last-mile logistics service of Trento, logistics hub TRENTOYOU was established in 2021 (Figure 9).

Figure 13 E-van of TRENTOYOU service operating in the historical center of the city.

Service

After its beginning in October 2021, the service operated regularly, with a store operator / driver coordinated by the service manager, who has been mainly looking for customers.

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The service named TRENtoYOU is available by couriers and also private retailers for the goods delivery to the LTZ of Trento (and from it), starting from the hub located in the logistic zone north to the city.

The two vehicles Trentino Mobilità has chosen to perform the new service are e-vans, e.g. Citroën eJumpy.

In the purchased version, they have a load capacity of about 5.8 m3 and 900 kg, and more than 300 km of autonomy, given by a 75 kWh battery.

They have proven absolutely fit to the required tasks, consisting in city centre deliveries of small/medium size parcels, also with suburban pick-ups at local distributors / suppliers / producers.

The first semester results were largely lower than expected: customers and deliveries have steadily grown but reaching only very small volumes. In June 2022, the average daily deliveries were 2, for a global income in the January-June period of only 1500 euro. In the same period, total costs, consisting of services, store rental, personnel and goods depreciation (mainly the two e-vans), reached 80000 euro.

LTZ rules modifications, decided by the Municipality, could not help TRENto YOU: besides 24 h access authorization granted to the vehicles belonging to the new service, these measures consisted in time slot reduction for the vehicles used for postal service (that could be used also for goods delivery): starting from March 21st 2022, these vehicles are allowed to enter the LTZ only between 9.00 and 12.00 and between 14.00 and 16.00.

What has been observed is:

- Transport operators (couriers) still prefer to rely on its own organization, even though the Municipality actions seem to have pushed a fleets' evolution, where new vehicles such as e-vans and cargobikes are now used;
- LTZ retailers don't have more access limitations than they had before, so they are not encouraged to check out the new service.
- TRENtoYOU customers are producers or distributors with factories or stores located around Trento, supplying shops in the LTZ. Basically, TRENto YOU has in charge the

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entire transport, not only the "last mile", replacing other couriers or the self-delivery. In this way, the intermediate reloading is avoided.

- Other such customers (not couriers) would be keen to use the service, only if it could cover other destinations in the region (outside the town and its surroundings)
- The Thursday weekly market in a significant part of the city centre, together with the closing day of many shops on Mondays, reduce heavily the service potential demand two days a week. This affects TRENto YOU more than it does to other couriers, that can serve different destinations in these days.

The managers work led in any case to an income growth, reaching the 1,000 euro per month threshold at the end of the year (2022). These results were considered as insufficient by the company (Trentino Mobilità) and the Municipality.

This led to the decision, taken by the Municipality in December 2022, of downsizing the service, to reduce its costs until the completion of the test period, as required in the Stardust project (2 years, expiring in October 2023).

Table 7 Main monitoring data for the TRENTOYOU service for 2022

mese	n. viaggi	n. colli	peso effettivo (kg)	corrispettivo (IVA esclusa)
gennaio	2	11	80,0	€ 18,70
febbraio	15	113	649,4	€ 156,00
marzo	29	152	1088,2	€ 275,30
aprile	34	189	1334,3	€ 295,00
maggio	38	203	1387,2	€ 321,50
giugno	61	274	1755,1	€ 507,00
luglio	52	208	1053,6	€ 401,30
agosto	60	339	1817,2	€ 538,20
settembre	58	320	2401,4	€ 547,30
ottobre	69	320	2271,3	€ 597,30
novembre	90	547	3724,8	€ 939,71
dicembre	131	1041	6581,3	€ 1.381,00

Therefore, starting from January 2023, TRENto YOU is offered only in strict "last mile mode": the whole transport from the customer factory or store is no longer provided, but only the delivery from the hub to the city centre.

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This led to the decision, by all previous customers, not to rely on it anymore. Basically, from the beginning of 2023, the service has no longer operated, having no income.

7 Bus Charging Infrastructure Planning

7.1 Introduction

This section presents the process in which, through a simulation tool developed internally in EURAC Research, It was possible to define the transition scenario of the bus fleet for local public transport from endothermic motor vehicles to fully electric vehicles, for the province of Trentino and with a focus on the city of Trento. This tool, starting from real data on the roads of the territory, the routes currently made by buses and analysis of vehicles currently on the market, allows to derive the necessary fleet of buses and the number and geographical position of the necessary charging points, considering different charging strategies.

7.2 Material and Methods

The tool is structured with different consequential steps, each with its own necessary input data and its own intermediate outputs, up to obtain as final output the characteristics of the necessary charging infrastructure. The main steps are given in this section, while a more detailed presentation of the methodology can be found in the literature, having the South Tyrol area as a case study [55]. The steps are reported below:

- Vehicle study: This step defines the type of electric vehicle chosen from the simulation (or an “average” vehicle) starting from the real vehicles on the market
- Road Network: This step includes an analysis of the roads in the territory considered, starting from the data of the 2D roads the altitude information is added and then the special cases (e.g. tunnels and bridges) are "arranged"
- Vehicle Modelling: In this step the energy required to cover the various routes covered by the buses is calculated and dually the real consumption of the vehicles during the operation is evaluated.
- Locate Charging Stations: In this step the number of electric buses needed to cover all the routes considered is identified, as well as the number and location of charging

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points, showing of the latter also the amount of electricity supplied during the day simulated and the number of daily recharges.

7.2.1 Vehicle Study

The choice of vehicle to be used within the simulation tool starts with an analysis of the buses currently on the market. The models on the market vary in terms of their characteristics depending on their use (urban or extra-urban), and from this are derived the main technical characteristics such as weight, dimensions and battery capacity, from which derive other characteristics such as consumption and autonomy.

An ideal 'average' bus was considered in the following study, with technical characteristics derived from an average of the vehicles on the market. Even though in reality the most optimal choice would be to use different types of bus depending on the route to be travelled (e.g. "smaller" buses with lower autonomy but also lower consumption for urban routes and buses with greater dimensions and autonomy for extra-urban routes), since only one type of bus had to be used for all the routes studied, it was considered more appropriate to take a bus with "average" characteristics, even if they do not correspond with any "real" model on the market.

7.2.2 Road Network

The simulation tool used in this study is based on an initial analysis of the territory under consideration; in more detail, this analysis consists of the following steps:

The provincial street map provided by the Openstreet map portal contains the 2D version of the roads in the territory and is then merged with the open DTM file provided by Copernicus, so as to make the roads three-dimensional by adding the altitude information.

The 3D roads obtained in this way are then "cleaned up" by using a python code to "fix" all the special cases in which the slope of the roads presents irregularities, such as in the case of tunnels (where the altitude value of the mountain may have been taken instead of the road passing through the tunnel) or vice versa in the case of bridges.

The roads thus obtained are finally "filtered", taking into account only those in which local public transport vehicles pass during the routes travelled over a day (starting from the GTFS data of public transport lines). This step is inserted to reduce the amount of data that need to be processed by the simulation tool thus reducing computational time.

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7.2.3 Vehicle Modelling

Once the analysis of the roads covered in the various lines has been completed, it is therefore possible to obtain the energy required by the vehicles on the various sections. The equations used to calculate these values represent a "simplified" version and do not for example include aspects such as air friction (which would depend on the shape of the vehicle) or ground friction. However, the inclusion of aspects such as regenerative braking (fundamental for the type of vehicle considered) or the increase in energy required for vehicle air conditioning, make the approach used valid and robust. For the definition of the ideal consumption $cons_{ideal}$ (i.e. the consumptions that the vehicles would have with perfectly flat ground and in absence of friction) the effect of air conditioning was included and not through an ad hoc coefficient.

The total energy required for each line E_{tot} is defined as:

$$E_{tot} = E_{dist} + E_{disl_{up}} - E_{disl_{up}}$$

With:

$$E_{dist} = cons_{ideal}\ [\text{kWh/km}] * \text{distance}$$

$$\mathrm{E_{disl_{up}}} = 9.81 * \frac{\left(\mathrm{m_{bus}} + m_{\mathrm{passengers}} * \%_{\mathrm{affluence}}\right) * \Delta\mathrm{disl_{up}}}{\eta_{\mathrm{up}}}$$

$$\mathrm{E_{disl_{down}}} = 9.81 * \left(\mathrm{m_{bus}} + m_{\mathrm{passengers}} * \%_{\mathrm{affluence}}\right) * \Delta\mathrm{disl_{down}} * \eta_{\mathrm{down}}$$

η_{up} = 0.85 Motor to wheel efficiency (up) [1]

η_{down} = 0.75 Motor to wheel efficiency (down) [2]

$\%_{affluence}$ = 0.7 bus occupancy percentage

7.2.4 Locate charging stations

The last step of the simulation tool, once the energy required to cover each route has been calculated, consists in defining the amount of buses required to cover all the routes that during the day belong to this line. Starting from the GTFS file, the various routes are analysed chronologically, “creating” and “allocating a new bus, when a bus lines starts for the first time of the day, then each time a route of the same line should start, the tool "studies” if the buses already "created" are able to travel this route (because they are located near the starting point and have the battery enough to fully run the route to the terminus),

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otherwise a new bus is "created and assigned to the line". This analysis is made for all the routes of all the lines of a working day, thus going to individuate the total amount of buses required.

In parallel with this analysis, the amount and location of charging points required for each line is also identified. For each line, the first charging point is located at the starting point of the line itself and then if this is not enough to recharge the vehicles created so far, a new charging point is created in the terminus, from the third charging point onwards the chosen location corresponds to one of the intermediate stops of the line that is being studied at that time.

This process is then repeated for all the lines and is represented schematically within the Figure 14.

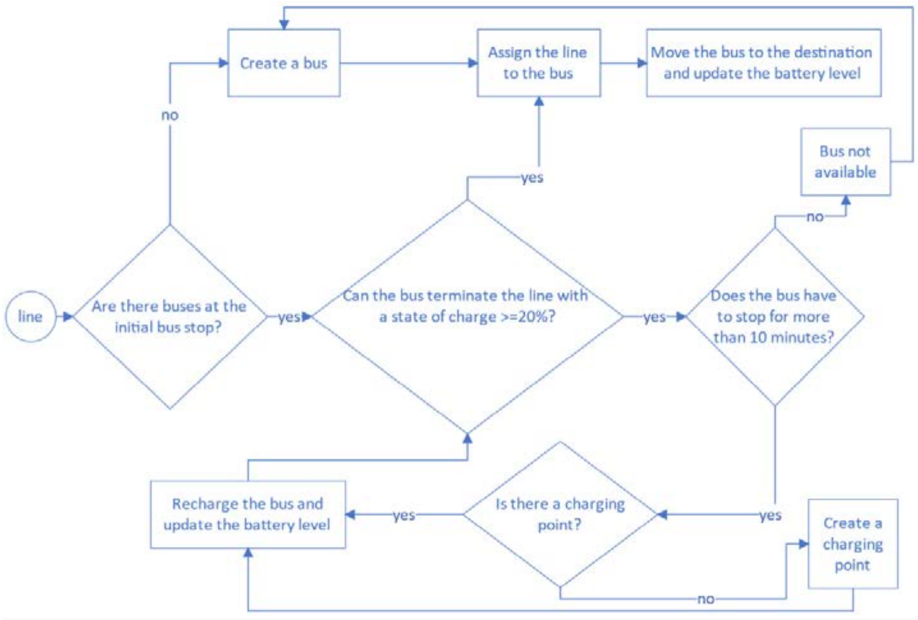

Figure 14 – Diagram of the process of creating and allocating the buses and charging stations during the day

The simulation tool used also allows to define different scenarios, going to define in addition to "standard" reference scenarios, also possible scenarios in which the potential benefits deriving from different charging strategies used are studied. More specifically, the scenarios considered in the study are:

- DIESEL: reference scenario in which diesel vehicles are included, in this scenario no charging points are installed but it is crucial for having a reference value of the size of the bus fleet

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- DAYTIME: scenario where vehicles are recharged during the day and whenever possible
- DAYTIME <40% SOC: scenario where vehicles are recharged during the day but only if their current battery percentage is less than 40%

7.3 Results

In this section are reported the results obtained by the simulation tool for all the steps that characterize it, starting from the analysis of the roads and the territory of the case study, up to the definition of the bus number and of the infrastructure of recharge demanded for the transition of the fleet of local public transport towards vehicles to zero emission.

7.3.1 Vehicle Study

The main electric buses on the market were taken into consideration, mainly analyzing the "ideal" consumption values (from which the energy needed to travel the various lines is calculated) and the battery capacity (on which depends the amount of buses needed to meet the various lines). the "average" consumption, shown in Figure 15, and the "average" capacity of the battery, as shown in Figure 16.

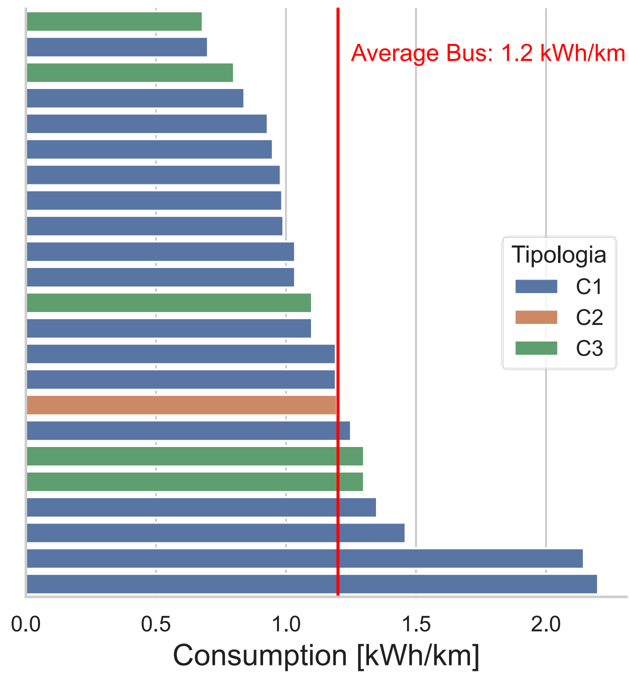

Figure 15 – Ideal consumption analysis for the major vehicles on the market, highlighting the average value used for this study.

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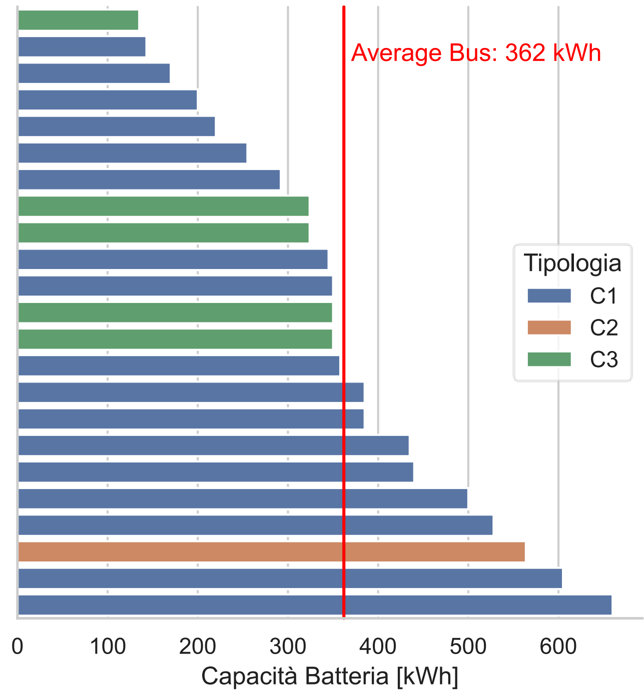

Figure 16 – Battery capacity analysis for the major vehicles on the market, highlighting the average value used for this study.

7.3.2 Road Network

The first output provided by the simulation tool concerns the analysis of the roads of the territory of Trentino. More specifically in Figure 17 is reported the analysis of the difference in height and altitude of the roads considered, before they are "cleaned" and "filtered" in the next steps of the code. It should be stressed that high altitude values imply a strong increase in the energy required by vehicles to travel the routes, compared to the "ideal" values with flat ground and no friction. Conversely, roads with significant negative gradients will allow the bus to take advantage of regenerative braking and "recharge" partially its battery.

A further output provided by the analysis of the roads in the territory of Trentino concerns the slope of the roads, as shown in Figure 18. Being a mountainous territory, it can be noticed that almost all the roads have a slope greater than 15%.

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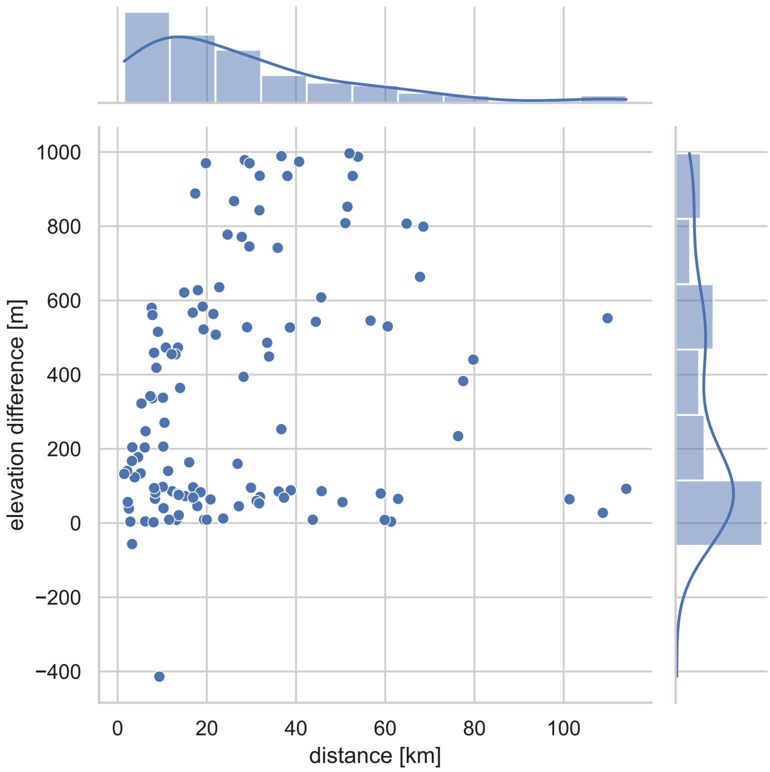

Figure 17 –Elevation and distance of the roads analyzed in the Trentino Province

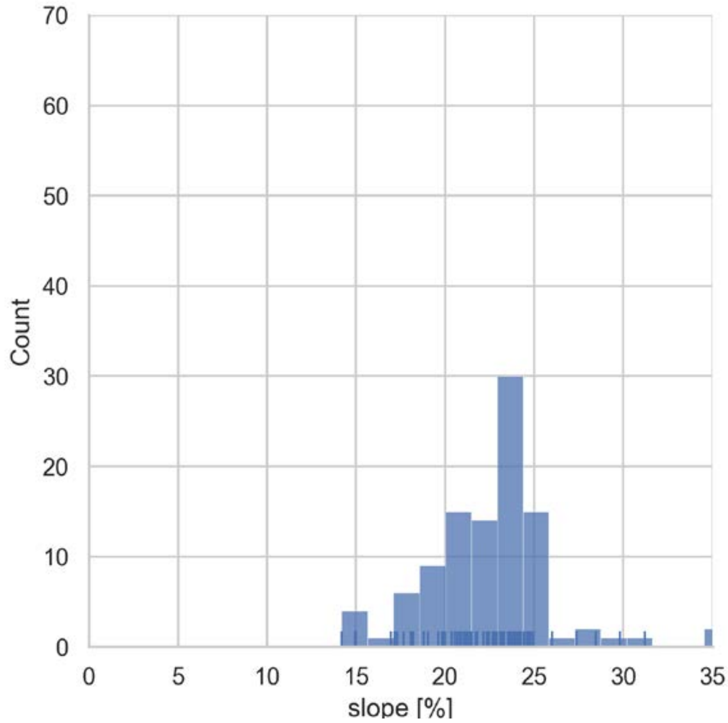

Figure 18 – Number of roads within each range of slope for the roads of the Trentino Province

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7.3.3 Modelling Buses Driving the Single Trips and Assumptions

Once the analysis of the roads of the territory has been completed, it is possible to evaluate the energy required to travel the various routes. In Figure 19 the distribution in percentage is reported, subdividing the routes in 5 categories. The sections with negative value derive from having to cover roads where the descents are prevalent and it is therefore possible to take advantage of the energy recovered by regenerative braking (having assumed positive energy if consumed by the vehicle and then exiting the battery and instead negative energy if entering the battery).

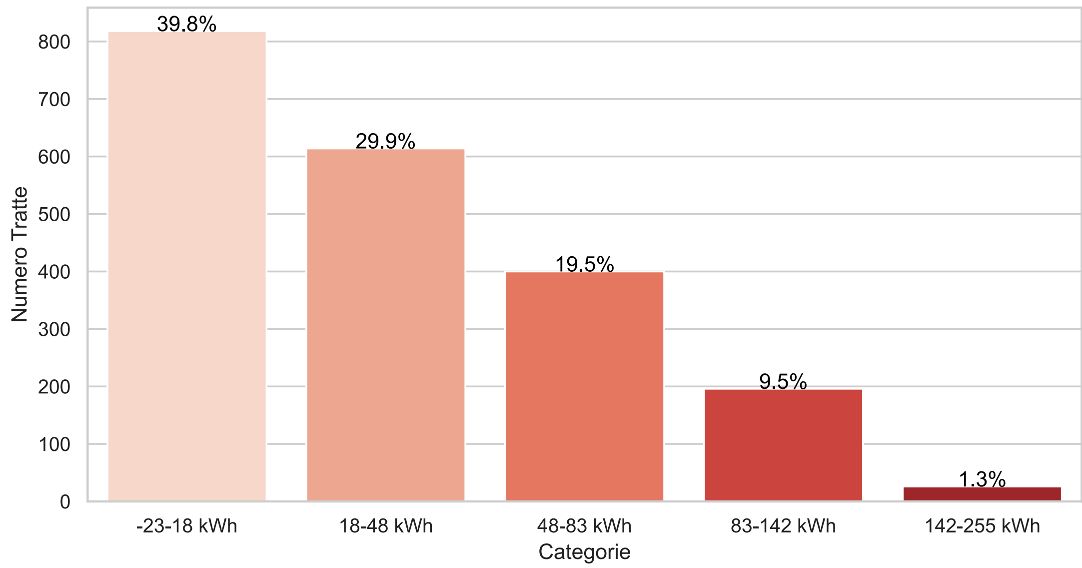

Figure 19 – Distribution of the energy required to travel through the routes covered in the Trentino Province

Starting from the energy required for each route, it is possible to calculate the "real" consumption of the vehicles, which in fact depend on the differences in levels and the gradients that the buses have to make during the day. The highest, lowest and mean values are shown in Table 8, considering all the lines simulated. As a result of the altitude values previously shown in the figure, the average value of consumption is greater than the "ideal" starting value, equal to 1.2 kWh/km.

Table 8 – Minimum, Mean and Maximum "real" consumption obtained during the simulation of the operation of the vehicles during a working day

REAL VEHICLE CONSUMPTION [kWh/km]	
MIN	-2,73

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STARDUST

MEAN	1,88
MAX	8.56

7.3.4 Bus Fleet & Charging Points

The latest results obtained through the simulation tool concern the required fleet and the recharging points needed to recharge this fleet of vehicles, following the methodology presented in Paragraph 7.2.4. The results depend on the scenario considered and therefore on the charging strategy adopted, as shown in Table 9, and in general the transition from buses with endothermic engines to electric buses does not lead to a drastic increase in the number of vehicles needed. Another interesting aspect is that the transition from a charge "whenever possible" during the day to a charge only with SOC less than 40% implies a reduction in the amount of charging columns required, thus reducing the initial investment cost for charging infrastructure. This also implies a slight increase in the amount of vehicles required, although overall the cost advantage of the transition to zero emission vehicles is considerable.

Table 9 – Number of vehicles required and charging points needed for each of the scenario considered withing the simulation tool

	DIESEL bus	ELECTRIC bus	
CHARGING STRATEGY		Daytime	Daytime <40% SOC
BUS NUMBER	594	595	604
CHARGING POINT NUMBER	-	336	85

As for the charging infrastructure in more detail, below is shown the position of the charging points in the “Daytime” (Figure 20) and “Daytime <40% SOC” (Figure 21) scenario. Both the bus routes and the infrastructure required within the territory of the province of Trentino are included, therefore considering both urban and suburban routes.

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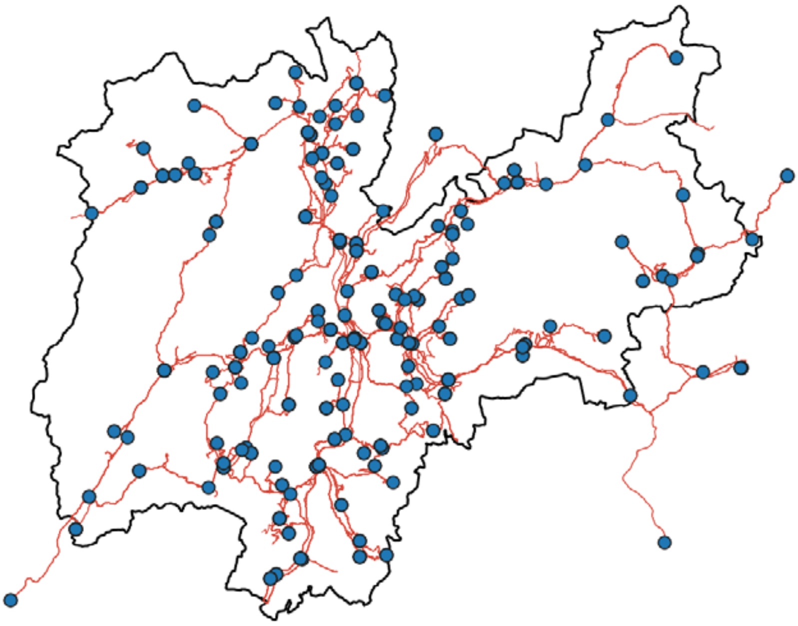

Figure 20 - Position of the charging points in the "Daytime" scenario

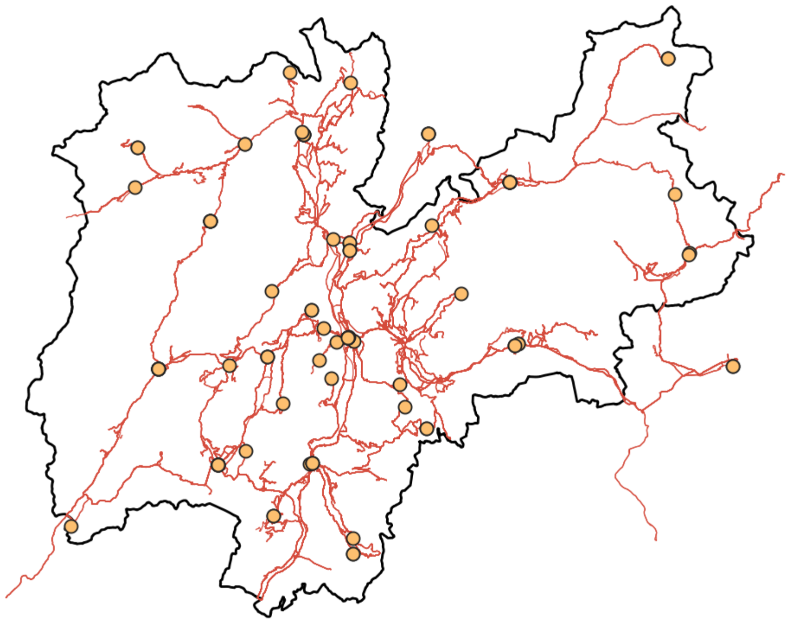

Figure 21 - Position of the charging points in the "Daytime <40% SOC" scenario

A more specific analysis was also carried out, considering only the territory of the city of Trento. Figure 22 shows the position, power and energy required by the various charging points for the "Daytime <40%SOC" scenario. This scenario shows that to achieve a complete transition of the local public transport fleet to zero-emission vehicles, it would be

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sufficient to install 6 charging points, which can also be further reduced to 4 charging points, aggregating those that are geographically close.

Figure 22 – Bus roats and charging points (each with 1 plug) for the city of Trento in the "Daytime <40% SOC" scenario

7.4 Discussion and Conclusions

This chapter showed the steps in which using the simulation tool developed in eurac it was possible to calculate the number and location of charging points needed to support the transition of the local public bus fleet to full electric vehicles. This analysis, carried out both for the province of Trentino and with a focus on the city of Trento, shows how such a transition is possible without a major disruption of both the routes that are currently served in the territory considered and the number of vehicles needed. It is also shown that the installation of only 6 charging points is necessary in the territory of the city of Trento, which can be further reduced to 4.

The results obtained, although the result only of a simulation model, represent a valid starting point for the analysis and definition of development plans for the transition towards a zero-emission public transport fleet for the Trentino Province and the Trento City.

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