D9.3. Cost benefit analysis from administration point of view

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TECHNICAL REFERENCES

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[1] PU = Public

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Table 1. Document history

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ACRONYMS

Acronym	Definition
AC	Alternative Current
ACEA	European Automobile Manufacturers' Association
ADVENIR	Frent support program for EVs and CS
ASR	Age-standardised rate
BCR	Benefit-Cost Ratio
BEV	Battery Electric Vehicle
BEV	Battery Electric Vehicle
BMP	Purchase tax (Vehicles) in the Netherlands
Bollo	Ownership tax (Netherlands)
CBA	Cost Benefit Analysis
CPs	Charging Points equivalent to EVSE
CS	Charging Station (private plus public)
DALY	Disability-adjusted life-year
dB	Decibels
DC	Direct Current
DSO	Distribution System Operator
EC	European Commission
ENTSO	European Network of Transmission System Operators for Electricity
ETSC	European Transport Safety Council
EU	European Union
EV	Electric Vehicle
EVs	Electric Vehicles (BEV and PHEV)
EVSE	Electric Vehicle Supply Equipment
FDR	Financial Discount Rate
GBD	Global Burden Disease
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GWh	Gigawatt hours
HDI	Human Development Index
HEV	Hybrid Electric Vehicle
HFCV	Hydrogen Fuel Cell Vehicle
HV	High Voltage
HVAC	High Voltage Alternative Current
HVDC	High Voltage Direct Current
ICE	Internal Combustion Engine (cars)
INH	Inhabitants
IVTM	Circulation tax (Spain)

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Acronym	Definition
KV	Kilovolts
kW	Kilowatts
kWh	Kilowatt hour
LAQ	Local Air Quality
LDV	Light Duty Vehicle
LV	Low Voltage
MOVES	Spanish support program for EVs and CS
MRB	Motor Vehicle Tax (Netherlands)
MV	Medium Voltage
NPV	Net Present Value
NPV	Net Present Value
NSUS	National Security Vetting Solution (UK)
OEM	Original Equipment Manufacturer
OGL	UK Department of Transport
PESTEL	Political, Environmental, Social, Technical, Economic and Legal Study
PHEV	Plug-in Hybrid Electric Vehicle
PHEV	Plug in hybrid Electric Vehicle
PM2.5	Particular Matter 2.5 Micrometres
PPA	Power Purchase Agreement
PrCS	Private Station
PuCS	Public Charging Station
REs	Renewable Energies
SPuCS	Semi Public Charging Station
SUMI	Sustainable Urban Mobility Indicators
SUMPs	Sustainable Urban Mobility Plans
SWOV	Dutch Institute for Road Safety Research
TSO	Transmission System Operator
VAT	Value-Added Tax
WLTP	Worldwide Harmonised Light Vehicles Test
YLDs	Years lived with Disability
YLLs	Years of life lost

Table 2. Acronym table

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1. EXECUTIVE SUMMARY

This deliverable D9.3 discusses the principles of Cost-Benefit Analysis (CBA) and its application in evaluating public investment projects, particularly in the context of electromobility in urban areas. CBA aims to determine the best alternative, the financial requirements, the project impacts, and the associated risks. The typical CBA structure encompasses feasibility analysis, financial analysis, economic analysis, and risk assessment.

The primary objective is to provide decision-makers with quantitative evidence of the value offered by electric vehicle (EV) charging infrastructure, as proposed by the INCIT-EV project. The specific objectives include:

- Evaluating and monetizing externalities resulting from public investment and EV adoption in five use case cities.
- Conducting a sensitivity analysis to identify optimal investment points by comparing "best case" and "worst case" scenarios.
- Developing a practical tool for replicating results in other EU cities.

The study's boundaries encompass several key considerations:

- Cost Calculations: Costs incurred by administrations to accelerate electromobility are classified into five categories. These costs are calculated from 2021 to 2035, at constant 2021 prices. Assumptions are made based on policy actions promoting electromobility in each city. The study considers costs and incomes directly borne by public administrations to promote electromobility, including grants, tax reductions, support for e-infrastructure, grid modifications, and investments in renewables. Assumptions are based on PESTEL analysis and deployment scenarios identified in D9.2.
- Externalities: The study evaluates externalities resulting from the EV penetration and Charging Points deployment, including positive externalities improving air and noise conditions (e.g., PM2.5 and CO2 emissions, noise pollution) in parallel to some public initiatives reducing overall vehicle stock and the negative externalities, such as increased casualties, parking land costs, traffic congestion, and charging time losses, are also considered. The main externalities are assessed including environmental and health effects, safety consequences, and social effects.

The document presents deployment scenarios for EVs and charging points and includes projections for private chargers. In summary, this text outlines the principles and objectives of a CBA applied to electromobility in urban environments, defining the scope of the analysis and providing insights into the study's methodology and assumptions.

Public Investments

In this chapter, an estimation of public investment and potential incomes for administrations in the use-case cities (Paris Centre, Utrecht, Zaragoza, Turin, and Tallinn) was introduced. The cost concepts considered encompass various aspects outlined in point 2.5 of the document:

1. **Direct Support to EV Upfront Costs**: Public administrations are expected to provide financial support to reduce the initial costs of Electric Vehicles (EVs) for consumers.
2. **Tax Policy Support**: Tax policy measures to encourage EV purchase or use will be considered as part of the cost calculations.
3. **Support for E-infrastructure**: This category includes upfront costs and fiscal measures related to supporting public, private, or semi-private EV charging infrastructure in the use-case cities.
4. **Grid Modifications**: Any modifications to the electrical grid necessitated by the deployment of EV chargers will be factored in, particularly if these modifications are

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funded by the administrations. Typically, larger-scale grid optimizations at the transmission level are the responsibility of administrations.

5. **Renewable Energy Investments**: The administrations may contribute to investments in renewable energy sources (REs) to supply electricity to new EV charging infrastructure, typically in the form of grants. While deploying REs in city centers can be challenging, an estimation of total energy requirements will be calculated.

Notable insights include:

- Utrecht, as a leading city, exhibits significantly higher per capita investment, with €3,769 per capita allocated between 2021 and 2035, in stark contrast to Tallinn's €288 per capita.
- Lagging cities are advised to progressively increase investments to reach a minimum support level, whereas leading cities like Utrecht might considerably reduce investments, given the substantial efforts made to date.
- Supporting policies vary significantly among countries, with grid adaptation emerging as a major investment requirement. These disparities reflect the diverse strategies adopted by cities and countries to promote electromobility.

In summary, this chapter provides a comprehensive overview of the estimated public investments and potential incomes associated with promoting electromobility across the use-case cities, shedding light on the varying levels of support and policy approaches across regions.

Positive Externalities

This chapter discusses the process of monetizing environmental impacts, particularly focusing on three aspects: the monetization of air pollutants (PM2.5), greenhouse gas emissions (CO2 eq.), and noise hindrance (>55 dB). Monetization of environmental impacts involves assigning monetary values to environmental damages caused by products or processes. This approach allows for economic quantification of the harm caused, providing a basis for monetary incentives to mitigate these impacts.

1. For **air pollutants** (PM2.5), the text describes how air pollution leads to health issues and outlines a methodology (SUMI 3) for quantifying its effects. It considers factors like vehicle types, emissions, and population exposure. The monetary valuation is based on factors like disability-adjusted life years (DALY) and is expressed as €/kg PM2.5 eq. The results show positive externalities, indicating economic benefits from improved air quality due to the introduction of electric vehicles (EVs).
2. **Regarding greenhouse gas emissions (CO2 eq.)**, the text discusses carbon pricing as a means to internalize the external costs of emissions. It presents a methodology (SUMI 7) for estimating CO2 emissions reductions due to EV adoption. The valuation is based on the cost of restoring CO2 levels in line with climate targets, expressed as €/ton of CO2 eq. The results indicate economic benefits from reducing emissions through EV adoption.
3. Lastly, the text covers **noise hindrance (>55 dB)** and its effects on health and well-being. It introduces a methodology (SUMI 4) for calculating noise levels and population exposure. The reduction in noise due to the introduction of electric vehicles is considered. Monetary valuation is based on factors like disturbance levels and DALY costs, expressed in €. The results show positive externalities from reduced noise pollution.

In summary, the chapter highlights the economic quantification of environmental impacts, demonstrating that the adoption of electromobility, particularly electric vehicles, leads to positive externalities in terms of improved air quality, reduced greenhouse gas emissions, and decreased noise hindrance over time. These positive externalities result in economic benefits for society. Main results in the base case scenario are deployed below:

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Negative Externalities. The chapter discusses the quantification of negative externalities associated with the adoption of electric vehicles (EVs) and the transition to electromobility in urban areas. These negative externalities are evaluated in monetary terms and are the following:

4. **Road Deaths and Serious Injuries** (SUMI 5, Ext. 4): The impact of road deaths and serious injuries resulting from car accidents is calculated based on the number of deaths. A fixed ratio of 35 injured people per death is used, following a recent report by the European Transport Safety Council (ETSC). The costs associated with road crashes in the Netherlands in 2021, taken as a base, are estimated at €27 billion (3% of GDP), with the majority being human costs. The cost per road death is approximately €6.5 million, and for serious road injuries, €0.7 million.
5. **Monetization of Congestion and Delays** (Ext. 5): The text discusses the challenges in quantifying the economic impact of congestion and delays due to the introduction of EVs. It considers factors like increased mileage due to EV adoption and how congestion affects traffic. The analysis estimates additional time spent in congestion due to EVs, which results in social costs and potentially more accidents. This extra time in congestion is monetized based on average salaries and car occupancy.
6. **Monetization of Public Charging Space Usage** (Ext. 6): This section evaluates the economic impact of public space used for charging infrastructure. It calculates the cost of land for charging points, considering land prices, inflation, and the space occupied by each charger. The costs associated with public charging space are projected for various years.
7. **Extra Time Losses in the Charging Process** (Ext. 7): The text explores the additional time required by professional drivers of electric vehicles, such as electric taxis and vans, for recharging. It is estimated that, in 2021, professionals extend their working day by 0.5 hours to accommodate charging needs. This extra time is attributed to factors like weather conditions, charger availability, and technology limitations. Over time, it is expected that these time losses will decrease as charging infrastructure improves.

The monetary values associated with these externalities are calculated based on various assumptions and are subject to changes over time as technology and infrastructure evolve. These externalities are considered negative because they represent additional costs or inconveniences associated with the transition to electric mobility. The calculations are extrapolated to future years to assess the overall impact and compare it with the investments made in EV adoption.

In the base case scenario, the results have been as follows in absolute values (million €, NPV 2021) and per capita.

CBA Abs (Million €)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	A+B	A+B+C
Paris	-1,926.6	633.2	-1,512.0	-1,293.5	-2,805.5
Utrecht	-1,363.6	184.1	-483.5	-1,179.4	-1,662.9
Turin	-1,729.9	5,526.3	-1,658.6	3,796.4	2,137.8
Zaragoza	-434.2	1,864.7	-557.2	1,430.5	873.3
Tallinn	-130.3	1,013.1	-680.5	882.8	202.3

CBA Results in absolute terms (million €). Results considering only Positive Externalities and last column All Externalities.

CBA Per capita (€)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	A+B	A+B+C
Paris	-889.9	292.5	-698.4	-597.4	-1,295.8
Utrecht	-3,769.4	509.0	-1,336.6	-3,260.4	-4,597.1
Turin	-768.0	2,453.5	-736.4	1,685.5	949.1
Zaragoza	-634.1	2,723.4	-813.7	2,089.2	1,275.5
Tallinn	-287.9	2,239.1	-1,503.9	1,951.1	447.2

CBA Results per capita (in €). Results considering only Positive Externalities and last column All Externalities.

Main recommendations for city planners based on their current situations and efforts towards electromobility are the following:

1. **Paris:** Paris is considered a follower city with high mobility restrictions in the city center and a low need for EVs due to limited mileage. The recommendation is to limit investments in public charging infrastructure and focus on private charging points and charging hubs in and outside the city. Continue upfront support for EVs but consider reducing it slightly to maintain a balanced approach.
2. **Utrecht:** Utrecht has a clear clean mobility policy and a significant deployment of electric vehicles. However, the average mileage is low, leading to fewer environmental benefits. As past public support was high, the recommendation is to reduce supporting measures to align

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with other cities. Focus on supporting private infrastructure and charging hubs for professionals. Equip garages, offices, and public parkings with charging stations.

3. **Turin:** Turin has been steadily growing its clean mobility policy and has a high traffic density and mileage. It has a positive environmental record. Public investments are average, and the recommendation is to continue reinforcing support for electromobility. Consider traffic control measures to prevent congestion that could mitigate the environmental benefits.
4. **Zaragoza:** Zaragoza is similar to Turin, with a flourishing electromobility policy and excellent results in cost-benefit analysis. The recommendation is to maintain at least a base level of support to ensure affordability for future EV users. Support both public and private charging points to accommodate cars parked on the streets.
5. **Tallinn:** Tallinn has relatively less public support for electromobility, but the natural penetration of EVs is occurring due to OEM efforts. Recommendations for Tallinn include providing basic aids to vehicles and chargers to meet sales forecasts. Implement measures for clean mobility alternatives within the city to reduce traffic density and congestion costs.

These recommendations consider the current state of electromobility in each city and aim to balance support for EV adoption with environmental benefits while considering budget constraints and existing policies.

Sensibility Analysis. The sensitivity analysis conclusions for each city provide insights into how different factors, such as public investments, mileage, and externalities, impact the cost-benefit analysis (CBA) of electromobility adoption. Here are the key findings for each city:

1. **Paris** (Follower City with Low Mileage): Paris has very low mileage per inhabitant due to mobility restrictions and alternative options. A small traffic increase leads to substantial negative externalities, mainly due to additional congestion and casualties. The CBA is negative in all scenarios, considering only positive or all externalities.
2. Utrecht (Leader City with Low Mileage): Utrecht has low mileage and high EV penetration. Despite substantial public investments, the CBA is very negative, mainly due to terrain costs for public chargers and increased negative externalities, such as congestion and casualties. Even a slight increase in public investments worsens the CBA.
3. **Turin** (Follower City with High Mileage): Turin has high mileage and a growing electromobility policy. The positive externalities are high and offset public investments. Negative externalities are lower due to the city's size. The CBA is positive in all scenarios, but it can turn negative if investments exceed a certain threshold, leading to raise negative externalities.
4. **Zaragoza** (Follower City with High Mileage and Low Costs): Zaragoza has high mileage, a strong promotional policy, and low costs. Positive externalities are high, and negative externalities are lower than Turin. The CBA is positive in all scenarios and more resilient to variations in investments compared to Turin.
5. **Tallinn** (Lagging City with High Mileage and Very Low Costs): Tallinn has high mileage, low EV penetration, and a soft promotional policy. Despite low public investments, the CBA is slightly positive due to inertia-driven EV adoption. In the best scenario, the CBA becomes negative as the number of EVs, and negative externalities increase.

These findings emphasize the importance of considering the unique circumstances of each city when planning electromobility policies. High mileage cities with substantial public investments need to be cautious not to exceed a threshold where negative externalities outweigh the positive ones. Lagging cities can benefit from incremental support to stimulate EV adoption without incurring significant negative externalities.

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2. INTRODUCTION

According to the EC, a Cost-benefit analysis[1] is a prescriptive technique. It has an explicit normative basis and is performed for the purpose of informing policy makers about what they ought to do. It is based on welfare economics and requires all policy impacts to be stated in monetary terms. Cost-benefit analysis seeks to identify the cheapest way of improving citizens welfare. While one can think of arguments for choosing expensive solutions, one should never forget the fact that once resources have been committed to an expensive solution to a problem, they are no longer available for alternative, and possibly more beneficial, uses.

Therefore, a Cost-Benefit Analysis (CBA) is not just about money, it's about social welfare. The value of this economic tool is to help in the selection of the best projects and policies for the benefit of society[2].

The CBA applied on INCIT-EV address mainly the local administrations at city level and identify the best supporting options to promote electromobility and reduce barriers for an accelerate penetration of Electric Vehicles into cities. It balances the investments in supporting measures for e-infrastructure and e-mobility with the by produced externalities improving the citizens welfare. Both plates of the balance are monetized following the methodology described in the EU "*Guide to Cost-Benefit Analysis of Investment Projects Economic appraisal tool for Cohesion Policy 2014-2020*" updated by the Regulation 2021/1060[3] "Common provisions on the European Regional Development Fund, the European Social Fund Plus, the Cohesion Fund, the Just Transition Fund and the European Maritime, Fisheries and Aquaculture Fund and financial rules for those and for the Asylum, Migration and Integration Fund, the Internal Security Fund and the Instrument for Financial Support for Border Management and Visa Policy" that provides some rules for the calculations in the period 2021-2027 with some slight differences with the previous guide. It has been also included some adaptations by the authors as some externalities had been calculated in a different way due to inexistence of references.

2.1. Background

A Cost Benefit Analysis provides a consistent methodology for evaluating decisions in terms of their consequences. In practices it is used to assess public investment projects. A coherent CBA tries to identify:

1. The best feasible alternative
2. The financial resources needed to execute the project.
3. The project impacts on the area where it will be implemented. In this case the use case cities.
4. Project risks and their financial and economic implications.

In most cases, the structure of a CBA is organised as follows:

1. Feasibility analysis and different applicable options. Which among these alternatives is the best?

[1] https://road-safety.transport.ec.europa.eu/statistics-and-analysis/statistics-and-analysis-archive/cost-benefit-analysis-measures/use-cost-benefit-analysis_en

[2] Introduction to cost-benefit analysis: looking for reasonable shortcuts. De Rus, G. Edward Elgar Publishing. 2021.

[3] https://www.eumonitor.eu/9353000/1/j4nvk6yhcbpeywk_j9vvik7m1c3gyxp/vllqc884y3zl

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2. Financial analysis. How much financial resources are necessary to execute the option selected? We can add here the need for EU co-financing and determine the rate.
3. Economic analysis. What will be the economic impact in the area. The monetization of the externalities will be key at this point.
4. Risk assessment. How can we make forecasts over the project horizon? It is possible to make the project more financial robust and economically desirable=

2.2. Objectives

To increase social welfare, public bodies may want to "take shortcuts", meaning policies and support actions to help the economy and society thrive. In the case of electromobility, administrations are trying to accelerate the adoption of EVs. INCIT-EV proposes several charging solutions and use cases that, in theory, contribute to that objective; but decision-makers require quantitative evidence that the benefits outweigh the costs.

The objective of this deliverable is to report the analysis done in T9.2 "*Cost/benefit analysis from the public bodies' perspective in each use case*" and, by doing this, provide decision-makers with evidence of the value that the EV charging infrastructures developed in the project provide to society in different scenarios and use cases.

The specific objectives of this deliverable are:

1. **Assess and monetize externalities** in the five use case cities for a given level of public investment and penetration of electric vehicles and public chargers identified in deliverable D9.2 "Demand Scenarios."

2. Carry out a **sensitivity study** with two trajectories also marked in the D9.2 deliverable, one called "best case" that represents a greater investment effort and a more positive impact of externalities (not in all cases as we will see) and a "worst case" scenario with less investment and lower impact. The objective will be to find out where the gradient between positive externalities and investment is optimized, or, in other words, where the investment is more profitable.

3. **Prepare the extrapolation of results** and develop a practical tool to facilitate the replication in other EU cities whatever type they were. This point will be widely treated in T9.5 "Replication Potential and replication Strategy".

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2.3. Scope

The present study must be framed in certain boundary conditions. The approach must be necessarily approximative considering some assumptions:

1. Cost's calculations

- Costs are those made by the Administrations in a given use-case city to accelerate the penetration of the electromobility. Those costs are classified in five categories; incentives to cheapen the acquisition of EVs (upfront costs), tax policy to support electromobility, direct support to e-infrastructures (private and/or public charging points), investments in the transformation of the grid (mainly the transmission grid as the distribution usually relays in the beneficiaries of the auctions), and incentives to support the Renewable energies associated to the e-charging).
- The costs will be calculated from 2021 to 2035 and at constant prices 2021 reaching a net present value by city.
- The PESTEL information by city will be used to establish the conditions in 2021. Then, an extrapolation has been done till 2035 where the incentives will be progressively retired as soon as the market gets maturity. This will be considered the base case. Then, two additional scenarios are added, the best and the worst cases, modifying the supporting actions. These scenarios were described in D9.2 and the penetration of the electromobility depicted in the curves as in the examples below.

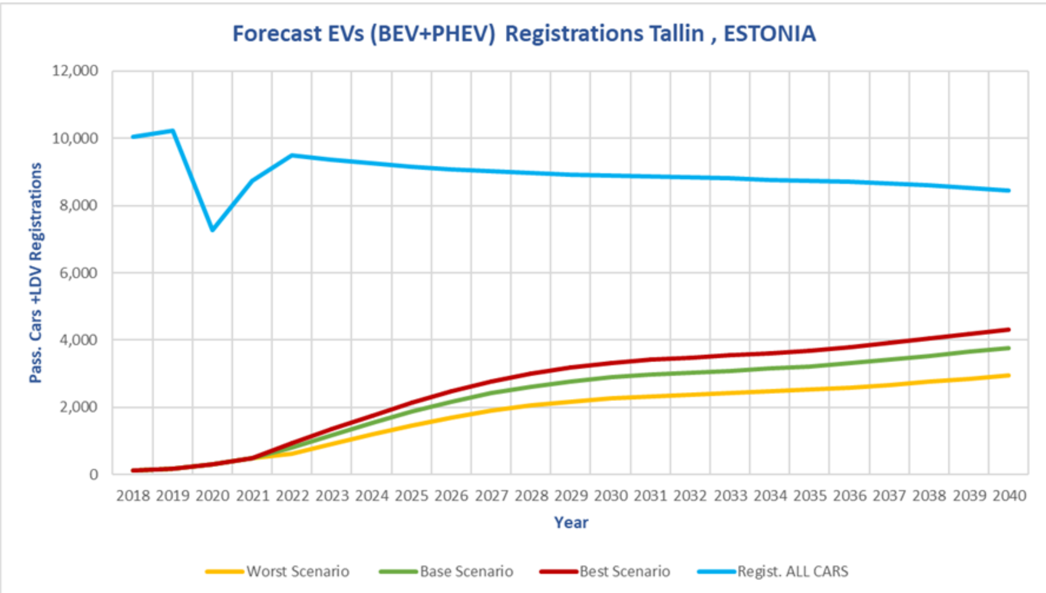

Figure 1. Example of EVs penetration curves in Tallin and reduction of all vehicles stock (blue line)

- Some assumptions will be adopted by each city according to policies taken to promote electromobility.

2. Externalities

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The externalities are derived from the Electric Vehicles penetration in the cities that modifies the air and noise conditions but also thanks to other factors that reduce the vehicles' stock (all types) inside the city, also improving the environmental conditions.

- Some additional externalities (negative in this case) are also considered as the cost of extra casualties, the cost of the parking areas, the additional traffic congestions, or some time losses in the charging process.
- These externalities will offtake the investments done by the administrations.
- The externalities will be generally calculated according to the SUMI standards as explained later in this study, but not in all the cases or not exactly as the standard specify, as some further adaptations were needed.
- An **economic value per city** compared with the current situation with the ICE cars in the streets is the main output of this task, after balancing public investments with the monetised externalities (applied as benefits or losses).

2.4. Externalities identification

According to the aim of the task, it is largely accepted that the balance is in favour of EVs, even if cons exist when adopting electromobility in a city boosted by the public investments to accelerate the penetration of the technology including those measures to promote the electric infrastructure. However, as it will be explained later, not in all cases the promoting measures have the same effect. The externalities that the study will contemplate, measured at city level, will be the following,

1. Environmental and health effects (mainly due to PM2.5 and CO2 equivalent emissions and noise hindrance).
2. Safety consequences due to the adoption of EVs (sometimes negative for pedestrian)
3. Some other social effects (extra congestions, time losses in charging process or charging space costs)

2.5. Cost and Incomes considered.

The cost and incomes incurred are those directly afforded by the public administration in the use case cities to promote electromobility. Could be money from the local administrations or from the regional or national ones. The penetration of the EVs in the use case cities have been widely evaluated in D9.2 Deployment scenarios (new registrations and stock). As mentioned previously, the investments can be classified in four main groups:

1. Direct support of administrations by granting programs to contribute to reduce or mitigate the upfront costs in new EVs.
2. Direct support of administrations in tax reductions for EVs.
3. Direct support to e-infrastructure by upfront costs payment (partially or totally) and taxes advantages. We include here the public incentives to public, private or semi-private chargers.
4. Investments to modify the grid due to the e-chargers deployment process only if they are paid by the administrations. Usually, the distribution grid modifications are paid by the auction's winner, but the transmission large optimizations are paid by the administrations.

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5. Contribution of administrations to the Investment in renewables to provide electricity to the new e-infrastructure, usually in the form of grants.

To make all these calculations, it was required to establish some assumptions representing the average efforts done by the administrations from the information gathered in the PESTEL analysis, especially in sections "Political" and "Economic". The deployment scenarios identified in D9.2 were used to check the number of ICE cars retired from the streets considering as well, the progressive reduction of new registrations widely explained in that report.

In the next pages, the summary table prepared in D9.2 "Demand Scenarios" is provided with the calculated deployment scenarios. The number of Charging Points is also included. Finally, there is also a projection of the private chargers and the total.

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PENETRATION CURVES (LINKS)	PARIS CENTRAL			UTRECHT			TURIN			ZARAGOZA			TALLINN		
	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST
Nº EVS															
2021	36,720	36,720	36,720	21,991	21,991	21,991	46,551	46,551	46,551	2,107	2,107	2,107	3,157	3,157	3,157
2025	90,832	97,215	110,176	51,185	55,122	60,914	98,757	112,597	143,992	7,934	13,107	16,701	7,346	8,512	9,302
2030	152,093	166,097	196,966	99,299	109,370	125,374	202,614	244,348	339,024	38,233	42,875	50,864	17,170	21,126	23,808
2035	164,009	182,125	221,342	114,640	126,929	156,023	276,003	339,196	482,556	70,184	79,083	94,397	28,657	35,964	40,918
Nº Public Charging St.															
2021	1,600	1,600	1,600	586	586	586	789	789	789	77	77	77	50	50	50
2025	3,966	4,237	4,771	1,409	1,468	1,656	1,694	1,907	2,475	397	437	507	128	132	148
2030	6,191	6,743	7,929	2,572	2,713	3,190	3,168	3,748	5,289	1,293	1,450	1,721	372	392	459
2035	6,680	7,393	8,900	2,976	3,149	3,977	4,207	5,061	7,329	2,374	2,675	3,193	756	801	947
Level 1 (2.4-7 kW)															
2021	1,302	1,302	1,302	476	476	476	642	642	642	62	62	62	40	40	40
2025	3,227	3,447	3,881	1,146	1,194	1,347	1,378	1,552	2,014	323	356	413	104	108	121
2030	5,037	5,486	6,451	2,093	2,207	2,595	2,578	3,050	4,303	1,052	1,180	1,400	302	319	373
2035	5,435	6,015	7,241	2,422	2,562	3,236	3,423	4,118	5,963	1,932	2,177	2,598	615	652	770
Level 2 (7-22 kW)															
2021	207	207	207	76	76	76	102	102	102	10	10	10	6	6	6
2025	513	548	617	182	190	214	219	247	320	51	57	66	17	17	19
2030	801	873	1,026	333	351	413	410	485	685	167	188	223	48	51	59
2035	865	957	1,152	385	408	515	545	655	949	307	346	413	98	104	123
Level 3 (22-120 kW)															
2021	73	73	73	27	27	27	36	36	36	3	3	3	2	2	2
2025	181	193	217	64	67	75	77	87	113	18	20	23	6	6	7
2030	282	307	361	117	124	145	144	171	241	59	66	78	17	18	21
2035	304	337	406	136	143	181	192	231	334	108	122	145	34	36	43
Level 4,5 (>120 kW)															
2021	18	18	18	7	7	7	9	9	9	1	1	1	1	1	1
2025	45	48	54	16	17	19	19	22	28	5	5	6	1	2	2
2030	71	77	90	29	31	36	36	43	60	15	17	20	4	4	5
2035	76	84	101	34	36	45	48	58	83	27	30	36	9	9	11

Table 3. Summary table with EVs and EVSEs penetration in the use-case cities by type (years 2021, 2030, 2035) in base, best and worst scenarios (source D9.2)

PENETRATION CURVES (LINKS)	PARIS CENTRAL			UTRECHT			TURIN			ZARAGOZA			TALLINN		
	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST
Nº EVS															
2021	36,720	36,720	36,720	21,991	21,991	21,991	46,551	46,551	46,551	2,107	2,107	2,107	3,157	3,157	3,157
2025	90,832	97,215	110,176	51,185	55,122	60,914	98,757	112,597	143,992	7,934	13,107	16,701	7,346	8,512	9,302
2030	152,093	166,097	196,966	99,299	109,370	125,374	202,614	244,348	339,024	38,233	42,875	50,864	17,170	21,126	23,808
2035	164,009	182,125	221,342	114,640	126,929	156,023	276,003	339,196	482,556	70,184	79,083	94,397	28,657	35,964	40,918
Total CPs															
2021	24,730	24,730	24,730	14,810	14,810	14,810	31,351	31,351	31,351	1,419	1,419	1,419	2,126	2,126	2,126
2025	73,616	78,628	88,521	42,782	44,583	50,285	80,865	91,069	118,180	9,616	10,601	12,296	6,630	6,885	7,704
2030	96,133	104,704	123,105	65,354	68,945	81,061	130,199	154,032	217,356	24,101	27,027	32,064	12,618	13,317	15,572
2035	98,736	109,275	131,550	71,987	76,158	96,188	169,189	203,518	294,727	42,111	47,450	56,638	20,360	21,578	25,503
Nº Private CPs															
2021	23,130	23,130	23,130	14,224	14,224	14,224	30,562	30,562	30,562	1,342	1,342	1,342	2,076	2,076	2,076
2025	69,650	74,392	83,752	41,373	43,115	48,629	79,172	89,162	115,705	9,220	10,164	11,789	6,503	6,752	7,556
2030	89,942	97,961	115,177	62,782	66,231	77,871	127,031	150,284	212,067	22,808	25,577	30,343	12,246	12,925	15,113
2035	92,056	101,882	122,650	69,010	73,009	92,211	164,982	198,457	287,399	39,736	44,775	53,445	19,605	20,777	24,556
Nº Public CPs															
2021	1,600	1,600	1,600	586	586	586	789	789	789	77	77	77	50	50	50
2025	3,966	4,236	4,769	1,409	1,468	1,656	1,694	1,907	2,475	397	437	507	128	132	148
2030	6,191	6,743	7,928	2,572	2,713	3,190	3,168	3,748	5,289	1,293	1,450	1,721	372	392	459
2035	6,680	7,393	8,900	2,976	3,149	3,977	4,207	5,061	7,329	2,374	2,675	3,193	756	801	947

Table 4. Total number of EVs, total number of CPs, total number of public CPs, total number of Private CPs in the use case cities

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3. METHODOLOGY

3.1. Introduction

A Cost-Benefit Analysis from the point of view of an administration, is a methodology that compares the costs and the benefits for the citizens (measured through the by-produced externalities) arising from a given project to decide whether to proceed with it or not. There are usually several options, and the best balanced positive final figure provides the winning option. So, it can be considered a decision support tool for the authorities. The project's costs and benefits are measured in monetary terms after adjusting for the time value of money, thus providing a true picture of the costs and benefits.

Net Present Value and Benefit-Cost Ratio are the two most common methods of doing a cost-benefit analysis. The NPV model chooses the project with the highest NPV. The benefit-cost ratio model chooses the project with the highest benefit-cost ratio.

This economical balance technique involves adding up the benefits of a course of action, and then comparing those with the costs associated, assuming that a monetary value can be placed on all the costs and benefits of a program, including tangible and intangible returns to other people and organizations in addition to those immediately impacted. As such, a major advantage of cost-benefit analysis lies in forcing people to explicitly and systematically consider the various factors which should influence strategic choice.[4]

There is not a single universally accepted method of performing a cost-benefit analysis. However, every process usually presents some variation of the following six steps.

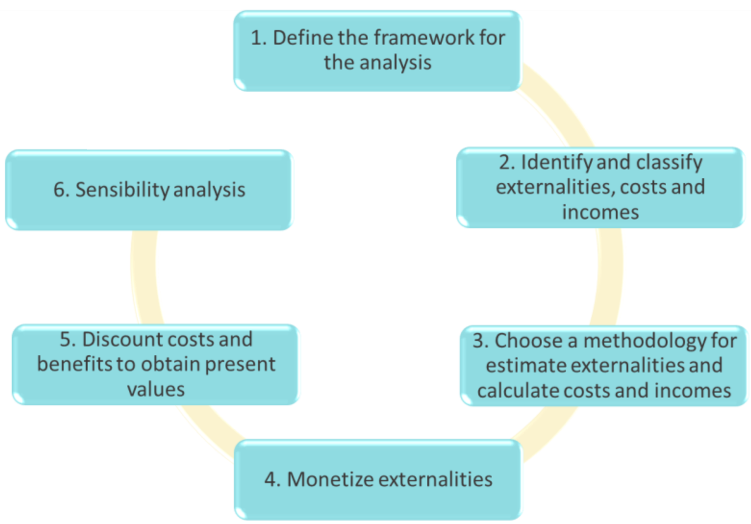

Figure 2. Traditional steps in a Cost-Benefit analysis

A brief description of each step is explained here:

1. **Define the framework for the analysis.**

[4] https://www.wallstreetmojo.com/cost-benefit-analysis/

In our case, this framework is represented by the use-case cities in the same way they were represented in deliverable D9.2. Every city in Europe has specific features that may them different from any other. The city topology, the mobility habits, the economic situation, the incentives provided by the administrations, etc, forces a unique profile that impacts in the EVs penetration. In IncitEV, we will classify cities by similar patterns to allow a further replication of the penetration conditions, but it must be clear that none of them will be identical to any other and a specific analysis should be done in case we would like to reach a more detailed result.

2. **Identify and classify externalities, costs, and incomes.**

   Once the project is clearly defined, the benefits and the costs (for society and the public administration) derived from its implementation must be identified. In general, mobility projects have direct effects on the sector (e.g., public mobility solutions, existing petrol stations, etc.) but also significant effects on secondary markets (e.g., health, environment, etc.). The externalities, cost and incomes selected are those that impacts widely in the EVs and e-infrastructure penetration.

3. **Choose a methodology to estimate externalities and calculate costs and incomes.**

   For the externalities, it has been chosen the Sustainable Urban Mobility Indicators (SUMI)[5]. The European Sustainable Urban Mobility Indicators Project (SUMI) developed a tool that assists cities with performing a standardized evaluation of the sustainability of their transport system. The tool consists of 20 spreadsheets, each of them covering one specific urban mobility indicator. Example indicators are about the Affordability of public transport, Transport fatalities, Greenhouse gas emissions from the transport sector, Accessibility for mobility-impaired groups, Noise hindrance, Quality of public spaces and others. The indicator set was designed to be applicable to a broad range of urban contexts, just like its predecessor, an indicator set of the World Business Council for Sustainable Development. SUMI developed this indicator with a specific view on practicability and data availability. In IncitEV only 5 SUMI indicators (one adapted) plus two additional developed specifically for our project were selected. The chosen Externalities have been:

   - Air Pollutants (NOx, PM2.5). SUMI 3
   - Green House Emissions (CO_2, NO_2, CH_4, O_3). SUMI 7
   - Noise Hindrance (population affected). SUMI 4
   - Road casualties and serious injured (% of population per year). SUMI 5 (adapted)
   - Delays due to extra congestion (% delays in peak hours because of traffic increase when driving electric). SUMI 8
   - Mobility space usage (public space occupied by charging points). Own calculation
   - Time losses due to charging processes (extra time dedicated by professionals, LDV drivers). Own calculation

   The SUMI tool helps authorities to quantitatively capture the impacts of various mobility measures or policies and to track the sustainability of its mobility system over time.

   SUMI aims to foster a longer-term commitment to monitoring and improving the sustainability of transport systems.

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[5] https://changing-transport.org/sustainable-urban-mobility-indicators-project/

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In relation to the costs, the methodology described in the Guide to Cost-Benefit Analysis of Investment Projects[6] launched by the EC in December 2014, Economic appraisal tool for Cohesion Policy 2014-2020, was applied.

Within the methodology, two situations must be compared: 1) city impacts with the assumptions done (penetration of EVs forecast) and 2) impacts without them (as it is in 2021). The latter is called the *counterfactual*.

Our counterfactual is represented by the evolution of the market and the cities' impact with the percentage of EVs existing in 2021, that are latterly compared with the penetration forecast of the EVs in three scenarios base, best and worst.

4. **Monetise Externalities**

   Monetise externalities is defined by the SUMI methodology and requires a very precise information. In some cases, however, the working team has developed a particular methodology as it was not contemplated under any of the available spreadsheets.

5. **Discount costs and benefits to obtain present values.**

   The Net Present Value has been applied considering an inflation rate of 2% (although nowadays is higher but supposedly will be controlled soon) and a financial discount rate (FDR) of 4 % as recommended by recent EU data[7] (although nowadays in higher due to the high inflation). The period considered was set between 2021 to 2035 (15 years).

   To clarify the discount rates, when investors, either private or public, commit capital to a project, they have an implicit cost deriving from sacrificing a return to another project. In other terms, the resources employed have an opportunity cost. Thus, to induce the investment, the expected return should be at least as high as the opportunity cost of funding. This is why inflows and outflows of a project are discounted by means of a financial discount rate (FDR). The FDR is the opportunity cost of capital and is valued as the loss of income from an alternative investment with a similar risk profile. It considers the time value of money, for example the idea that money available now is worth more than the same amount of money in the future because it could be earning interest (in a non-risk deposit), and the risk of the anticipated future cash flow being less than expected.

6. **Sensibility analysis**

   In all this process, a sensibility analysis will be implemented, following the approach described in the D9.2 report, with the result of three scenarios to compare against the counterfactual, base, best and worst.

3.2. Scenarios description

[6] https://wayback.archive-it.org/12090/20221203224508/https://ec.europa.eu/inea/sites/default/files/cba_guide_cohesion_policy.pdf

[7] https://competition-policy.ec.europa.eu/system/files/2023-04/reference_rates_base_rates2023_05_croatia_eurozone.pdf

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Base scenario. The incentives to accelerate the EVs penetration in the referenced cities will be progressively soften as soon as the market will get maturity (till 2035). One assumption was that in 2035 , an EV model will likely cost the same (upfront costs) than the equivalent ICE model nowadays. The most recent comparisons among the Total cost of Ownership (TCO) [8] that includes upfront costs, depreciation, taxes, insurance, maintenance, tyres, fuel or electricity, provides a small difference between electric and non-electric (between 1% and 3%) although this comparison considers 10 years of lifetime.

However, if we compare upfront costs between equivalent electric and non-electric cars, the electrics are from 30%- 35% more expensive excluding the aids. For instance, the basic e-Nissan left costs around 32,100 € and the basic ICE Juke around 23,700 €. The Renault Zoe (basic version) costs reaches 32,200 € that compared with the Renault ICE Megane 24,800 € shows the same difference in upfront costs. According to CarEdge[9], an American consultancy company, In January 2020, the average electric car price was $54,668, or 42% higher than the overall market average. In 2023, the average cost of a new EV is $58,940, or about 20% higher than the overall new car market.

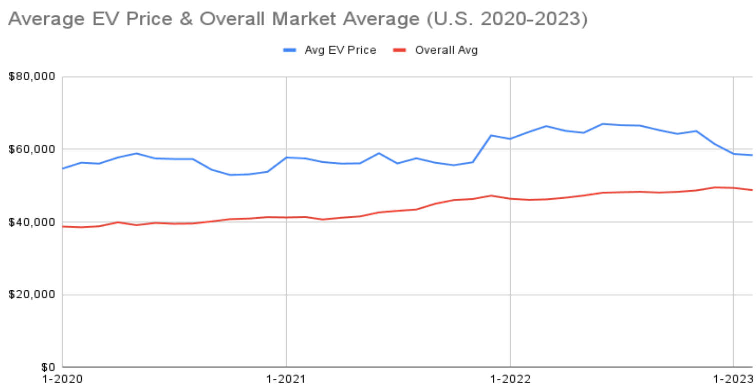

Figure 3. Evolution of EV upfront price compared with the average

Notwithstanding that the EVs upfront prices and costs have not yet goes down, they will do in the future if the batteries highly reduce their cost. A recent report from the International Council from Green Transportation (ICCT) [10] depicted the most likely evolution of the EVs cars by power category till 2035.

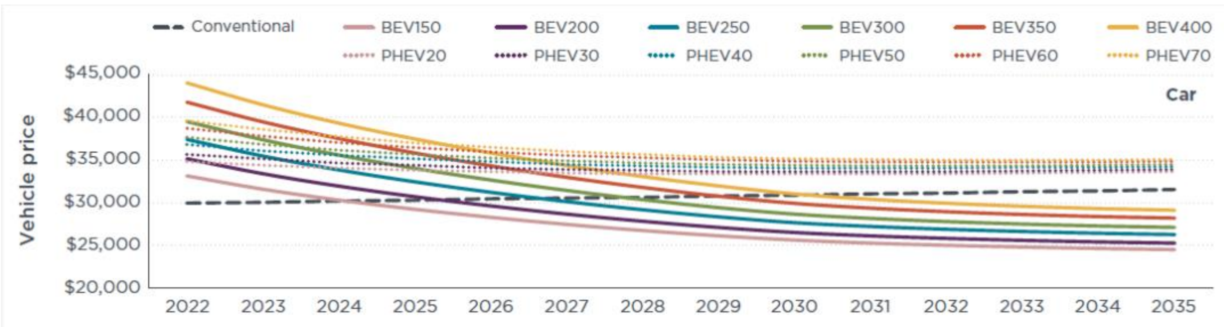

Figure 4. Conventional, battery electric, and plug-in hybrid electric vehicle prices of cars.

[8] Lease plan. Total cost of ownership: How electric vehicles and ICE vehicles compare Joel Wetterhahn, February 2022

[9] https://caredge.com/guides/average-price-of-an-electric-car

[10] https://theicct.org/publication/ev-cost-benefits-2035-oct22/

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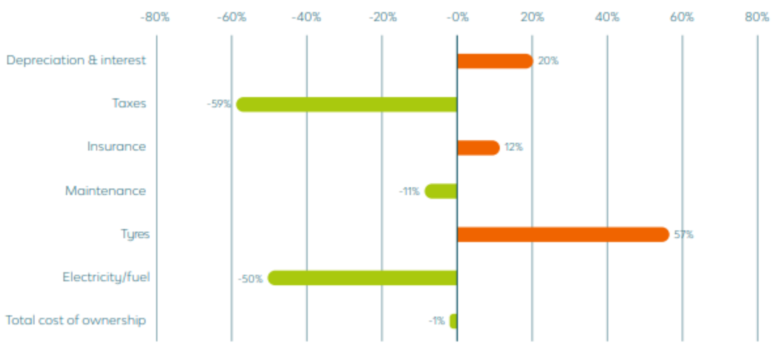
The figure indicates that conventional cars will increase prices, plug-in will reduce them slightly and pure BEV will goes done to the current price of conventional cars or even lower.

In summary, the base scenario will reflect this situation reducing the 2021 incentives progressively till the convergence to the current conventional car's upfront prices. At that moment, the TCO of EVs will be much lower than the actual ICE cars.

In the next figure, we clarify what costs concepts in the EVs will reduce or increase the cost compared to conventional.



Cost element	EV vs ICE	Explanation
Depreciation & interest	−	EVs have a higher catalogue price due to the added cost of the batteries and thus a higher monthly depreciation and interest cost
Maintenance	+	EVs have fewer moving parts compared to ICE vehicles so less maintenance is required
Tyres	−	EVs have, on average, higher torque and weight which results in higher wear and tear on tyres
Insurance	−	Insurance is often related to the catalogue price and the weight of the vehicle and is therefore slightly higher for EVs
Taxes	+	EVs are supported by government incentives in many countries
Electricity/fuel	+	The average cost per km for electricity is less than for fossil fuels (petrol/diesel)
Total cost of ownership (TCO)	+	**Taking into account all the cost elements, the TCO of an EV is similar to that of an ICE vehicle**

Figure 5. Clarification on the differences between ICE and EVs cost concepts making TCO equivalent. Source Lease Plan

<u>Best Scenario</u>. This scenario was defined as mentioned by deliverable D9.2. The maximum increase in EVs penetration over the base scenario may reach 25% up, but it is limited by the trends in 25 factors (please check D9.2) that reduces this maximum increase on a case by case basis.

<u>Worst Scenario</u>. This scenario was also defined by deliverable D9.2. The maximum decrease compared to the base case scenario may reach 25% down, but it is limited by the trends in 25 factors (please check D9.2) that reduces this maximum decrease on a case by case basis.

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4. COST ANALYSIS FROM ADMINISTRATIONS' VIEWPOINT

4.1. Introduction

In this chapter, a calculation to estimate how much public investment will be released by the administrations in the use-case cities (Paris Centre, Utrecht, Zaragoza, Turin, and Tallinn) was introduced. However, there might be also some incomes for the Administrations that will be also estimated. The cost concepts considered are those mentioned in point 2.5. Specifically:

1. Direct support to EVs upfront costs by the administrations
2. Direct support in taxes policy for the EVs purchase or use.
3. Direct support to e-infrastructure by upfront costs payment (partially or totally) and also some fiscal measures. The public incentives to public, private, or semi-private chargers in the use-case cities will be estimated in this dot.
4. Modifications in the grid due to the e-chargers deployment process, only if they are paid by the administrations, will be also considered. Commonly, the distribution grid modifications are paid by the auction's winners, but the transmission grid large optimizations are usually paid by the administrations. This last will be the one considered.
5. Contribution of administrations to the investments in Renewables to provide electricity to the new e-infrastructure, usually in the form of grants. In the city centers, it is difficult to deploy REs, but a calculation will be done to estimate the total energy requirements.

4.2. Support measures for EVs

4.2.1. Direct Support to EVs upfront costs by the Administrations

Assumptions. Most countries and cities in Europe provide certain aids to reduce the upfront costs for EV, that reach an average overcost, compared with conventional ICE cars, rounding 35%. There are also tax reductions or the elimination of some fees or taxes. These measures are kept every year, but the trend is to progressively reduce them as soon as the upfront costs for EVs drops over time. Thus, the promotional efforts are shared between the private OEMs and the administrations.

The assumption made in this report, is to start from the amount of money allocated in 2021 for EVs aids (including upfront aids, taxes, and other measures), for a given number of new registrations in each specific city, and progressively reduced those aids to "O" in 2035, when the upfront cost for an EV will be theoretically equal to the current upfront cost of an ICE car. The Net Present value (NPV) will be calculated for the total investments disbursed given a specified financial discount index (FDI) of (4%) and an inflation rate (IR) of (2%).

One additional aspect considered is that the upfront costs on average differ from one country to another.

Based on a comparison of 11 EVs found out in an automotive magazine[11], substantial differences in costs were identified with a simple rule, as higher country purchase power, the less upfront costs. The results are summarised in the aside figure.

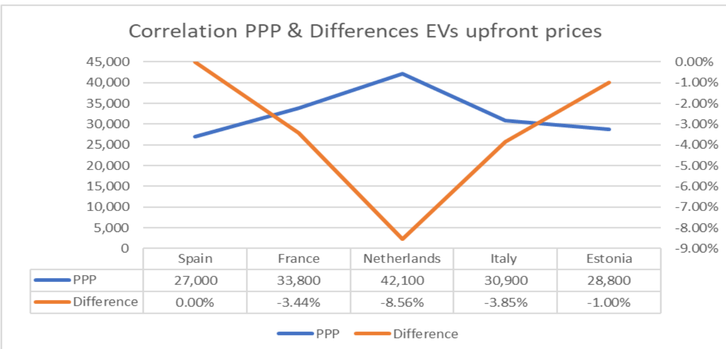

Figure 6. Correlation Purchase Power Parity and EVs upfront prices

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Considering this fact, an average upfront retail price in 2021 for the EVs in Spain (36,796 €) was estimated with the lower purchase power parity and consequently, this retail price is lower in the other use case countries according to the percentages estimated in figure 7. The second assumption was expecting that in 2035, those vehicles shall cost 27% less, being more or less, equal to the current upfront costs of the equivalent ICE cars. In the incentive/EV column in table 5, the current average support for EVs in a given use case city was included, assuming that will drop to zero in 2035. If we multiply the number of new registrations by the incentive, we will have the total public support. However, we have considered that not all EVs accedes to the subsidies. In some countries for instance, the total budget allocated cannot reach all interested customers and some vehicles, for instance those over 45,000 € retail price are not allowed to receive subsidies(this figure slightly differs from country to country). To simplify the calculation, we have considered that incentives cover 70% of demanding customers as we cannot estimate how much budget each country will allocate in the future (based on the observation of Spanish EVs market). The complete table for Paris city in the base scenario is provided herein.

PARIS (Base)	New Reg EVs	EV Stock	Incentive/EV	Total Public Incentives	Average EV Retail Price	%Support	%Red Cost	%Red aid
2018	3,204	9,613						
2019	3,766	13,380						
2020	8,052	21,431						
2021	15,289	36,720	4,968	53,171,300	35,530	13.98%		
2022	15,304	51,960	4,637	49,676,173	34,890	13.29%	-1.80%	-6.67%
2023	15,350	67,230	4,306	46,266,259	34,251	12.57%	-3.60%	-13.33%
2024	15,757	82,827	3,975	43,840,038	33,611	11.83%	-5.40%	-20.00%
2025	16,034	98,540	3,643	40,891,379	32,972	11.05%	-7.20%	-26.67%
2026	16,126	114,025	3,312	37,387,984	32,332	10.24%	-9.00%	-33.33%
2027	16,127	129,191	2,981	33,651,897	31,693	9.41%	-10.80%	-40.00%
2028	16,107	142,094	2,650	29,876,080	31,053	8.53%	-12.60%	-46.67%
2029	16,116	155,006	2,319	26,155,248	30,414	7.62%	-14.40%	-53.33%
2030	16,184	167,423	1,987	22,513,229	29,774	6.67%	-16.20%	-60.00%
2031	16,327	175,698	1,656	18,926,826	29,135	5.68%	-18.00%	-66.67%
2032	16,548	176,957	1,325	15,346,198	28,495	4.65%	-19.80%	-73.33%
2033	16,838	178,491	994	11,711,743	27,855	3.57%	-21.60%	-80.00%
2034	17,182	180,323	662	7,967,502	27,216	2.43%	-23.40%	-86.67%
2035	17,559	182,125	0	0	25,937	0.00%	-27.00%	-100.00%
				437,381,856				

Table 5. Calculation of public support in subsidies to purchase an EVs in Paris Central

The second and third columns represent the penetration of new registrations and the EVs in use in the city of Utrecht according to the D9.2 deliverable penetration curves. Column four depicts the average incentive per vehicle in that city and the progressive reduction till 2035. Column six represents the total investment done by the administration for the given number of new registrations limited to the 70%. Column seven represents the upfront retail prices reduction for the EVs till they reach in 2035 equal prices of the equivalent ICE car in 2021. Columns eight, nine and ten are percentage of reduction of these factors.

[11] https://evfleets.electricautonomy.ca/topics/analyzing-total-ev-lifecycle-cost/

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Below, the Net Present Value of the total upfront investments in EVs incentives done by each city till 2035 was calculated, considering an inflation rate of 2% and the Financial Discount Index of 4%.

EVs UPFRONT (NPV) BASE	PARIS NPV (M€)	UTRECHT NPV (M€)	TURIN NPV (M€)	ZARAGOZA NPV (M€)	TALLIN NPV (M€)	TOTAL USE CASES
Year	M €	M €	M €	M €	M €	M €
2021	53.17	16.69	5.62	3.24	0.60	79.32
2022	48.72	23.00	10.31	4.89	0.90	87.82
2023	44.50	24.85	13.04	6.59	1.19	90.17
2024	41.36	25.37	14.79	7.86	1.41	90.79
2025	37.84	24.70	15.55	8.62	1.55	88.26
2026	33.93	23.12	15.42	8.87	1.60	82.94
2027	29.95	20.90	14.59	8.67	1.58	75.70
2028	26.08	18.33	13.26	8.12	1.49	67.29
2029	22.39	15.64	11.64	7.32	1.35	58.35
2030	18.90	13.00	9.90	6.36	1.18	49.35
2031	15.59	10.52	8.15	5.31	1.00	40.56
2032	12.39	8.23	6.45	4.24	0.80	32.11
2033	9.28	6.11	4.83	3.17	0.60	23.98
2034	6.19	4.08	3.25	2.12	0.40	16.04
2035	0.00	0.00	0.00	0.00	0.00	0.00
	400.29	234.54	146.82	85.37	15.65	882.68
					Inflation Rate	2%
					FDR	4%

Table 6. Present Value of the total subsidies (absolute values) to support the EVs upfront costs, BASE.

The tables for the remaining use case cities are included in the annex 1 of the present document.

It is worthy to mention, that Estonia is not providing any aids for the EVs upfront retail prices nowadays. However, we have considered an aid of 1,744 € (weighted amount), considering the 74% of BEV (2,000 €/EV) and 26% of PHEV (1,000 €/EV). This is aligned with the countries with less purchase power. If no aid is given, probably the penetration of EVs will not be achieved as expected.

4.2.2. Direct support by taxes policy in vehicles

4.2.2.1. Paris Central

Tax reduction in registration fee of EVs

There is no national tax reduction applied for private car owners[12] (other than tax reductions on charging points). However, locally, the cost of initial vehicle registration (delivery of "Carte Grise" which is the vehicle ID papers) can sometimes be exempted or reduced for an EV. This is the case for Paris central, there is a full exemption of the registration tax (carte gris) for EVs. On average this "Carte Grise" may cost around 250 €. If we consider the number of EVs (passenger cars and commercial) according to the penetration curves developed in D9.2, a total of **53 million €** (present value) will be invested by the municipality to grant this concept from 2021 to 2035 (see table 9). We don't consider a phase out of this measure before 2035.

[12] https://blog.wallbox.com/france-ev-incentives/

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Tax reduction in VAT for commercial EVs

For Businesses, VAT exemption is only applicable to LDV but not on regular EV cars. The common VAT for motor vehicles in France is 20%. If we consider a 15% of LDV from the total number of new EVs registrations, an average retail price of 25,000 €, and we consider a reduction of 50% in the exemption from 2028 onward, the total invested by the Paris municipality from year 2021 to year 2035 may reach **€134 million** (present value).

Tax applied to pollutant ICE cars.

Finally, France has imposed taxes for the ICE cars. This is a punitive measure when selling a high-emitting CO_2 vehicles (above 123 g CO_2/km) must pay a tax (ecological malus[13]) that increases with the emission level, from €50 up to €50,000 for vehicles emitting 225 g CO_2/km[14]. A pollution tax is payable on the purchase of a new vehicle registered where the CO_2 emissions or power output exceeds a minimum threshold. Since 1st Jan 2021 the tax has not been payable on the registration of a second-hand car. The ecotax (or malus) payable on the purchase of a new vehicle depends on the level of CO_2 emissions. It does not apply to utility vehicles, only to passenger cars.

Since 1st March 2020, a new formula based on the 'Worldwide Harmonised Light Vehicles Test Procedures' (WLTP) was applied for new registrations. This considers both consumption and emissions. The French malus tax is much restrictive than the Spanish tax for ICE cars. If we apply the same classification in percentage of sales than those in Spain as confirmed by some sources[15], we may distribute 2021 registrations in Paris among the CO_2 categories as explained below,

Category All cars 2021, Paris	Nº	%	CO_2 aprox (g/km)	Malus tax/Veh(€)	Tot. Malus (M€)
Urban/Compact	16,164	39.14%	<123	0	0.00
Sedan type/Luxury	1,426	3.45%	170	5,715	8.15
Sport	74	0.18%	200	21,966	1.63
Monovolume	710	1.72%	150	1,504	1.07
SUV/All terrain	22,926	55.51%	160	3,119	71.51
TOTAL	41,301	100.00%	100.00%		82.35

Table 7. Calculation Malus incomes for Paris in 2021 according to vehicles type

Considering the reduction in the number of cars for all types mentioned in D9.2, we can simulate the Malus incomes per year till 2035, applying a 0,5% incomes reduction per year also because the whole fleet will become greener. Table 9 reflect the results.

CO_2	Amount
Under 123 CO_2	€ 0
128 CO_2	€ 170
130 CO_2	€ 210
134 CO_2	€ 280
135 CO_2	€ 310
140 CO_2	€ 540
150 CO_2	€ 1,504
160 CO_2	€ 3,119
170 CO_2	€ 5,715
180 CO_2	€ 9,550
190 CO_2	€ 14,881
200 CO_2	€ 21,966
210 CO_2	€ 31,063
220 CO_2	€ 42,231
225+ CO_2	€ 50,000

Table 8. Malus' penalties according to car emissions (very punitive for most pollutant)

In table 9, all the measures with economic impact in the local administration from 2021 to 2035 are summarised.

1. The "carte gris" applied to all EVs (tax exemption in Paris) supposes and investment of **€53.02 million** from 2021 to 2035.
2. The VAT exemption applied to LDV EVs supposes €133.9 million in the 15 years considering that in 2028 the exemption will be limited to 50% (assumption by the document 'authors).

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[13] https://www.service-public.fr/particuliers/vosdroits/F35947

[14] https://www.eea.europa.eu/data-and-maps/daviz/data-visualization-27#tab-chart_1 CO2 emissions

[15] https://www.fiches-auto.fr/articles-auto/chiffres-de-ventes/s-2272-evolution-des-ventes-de-suv-en-france.php

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3. The MALUS tax that applies to All ICE cars represents incomes of €753.9 million in the 15 years, but there will be a progressive reduction if we consider the 2021 figure as a base due to two effects; on one side the total number of registrations will fall and secondly, the new vehicles will become cleaner and consequently will reduce the punitive tax. The losses described in the table below, will reach in total -€481.4 million in 15 years (NPV). Figures in column c (Lost MALUS) are built detracting one year over the previous one; example.

   58.42 (Million in 2022) – 82.35 (Million in 21) equal to -23.93 (Million) representing the reduction of taxes for the municipality due to the new car registration reduction and the percentage of them that are converted in clean vehicles.

In summary, the total investment from 2021 to 2035 for the Paris authorities will reach around €668.3 million (net present value), applying an inflation rate of 2% and a FDR of 4%.

PARIS (Base)	BASE SCENARIO			ECONOMIC IMPACT MEASURES				TOTAL
	New. Registrations ALL CARS	New Registrations All EVs	New Registrations LDV EVs	(a) Carte Gris NPV (M€)	(b) LDV VAT NPV (M€)	Inc. MALUS NPV (M€)	(c) Lost MALUS NPV (M€)	Total Invest NPV
			15%	250 €	20%	ICE vehicles		(a)+(b)+(c)
				All Veh.	25,000 €			
	Units	Units	Units	(M€)	50% (2028) (M€)	(M€)	(M€)	(M€)
2021	41,301	15,289	2,293	-3.82	-11.47	82.35	0.00	-15.29
2022	31,446	15,304	2,296	-3.75	-11.26	58.42	-23.93	-38.94
2023	30,793	15,350	2,303	-3.69	-11.07	56.11	-26.24	-41.01
2024	30,243	15,757	2,364	-3.72	-11.15	54.05	-28.30	-43.17
2025	29,786	16,034	2,405	-3.71	-11.13	52.20	-30.14	-44.98
2026	29,411	16,126	2,419	-3.66	-10.98	50.56	-31.79	-46.43
2027	29,108	16,127	2,419	-3.59	-10.77	49.07	-33.28	-47.63
2028	28,865	16,107	2,416	-3.52	-10.55	47.73	-34.62	-48.68
2029	28,672	16,116	2,417	-3.45	-10.35	46.50	-35.85	-49.65
2030	28,518	16,184	2,428	-3.40	-5.95	45.36	-36.99	-46.34
2031	28,393	16,327	2,449	-3.36	-5.89	44.29	-38.06	-47.31
2032	28,285	16,548	2,482	-3.34	-5.85	43.27	-39.08	-48.27
2033	28,185	16,838	2,526	-3.33	-5.84	42.29	-40.06	-49.24
2034	28,081	17,182	2,577	-3.34	-5.85	41.32	-41.02	-50.21
2035	27,963	17,559	2,634	-3.34	-5.86	40.36	-41.99	-51.19
TOTAL	449,049	242,848	36,427	-53.02	-133.95	753.87	-481.37	-668.34

Table 9. Projection Economic investments in supportive measures to promote electromobility (2021-2035), Paris.

4.2.2.2. Utrecht taxes

In relation to the tax exemptions or extra recovery for electromobility, the Netherlands is one of the most advance countries in Europe. The fiscal actions can be distinguished as follows:

Private car owners & business

a) Purchase tax (Belasting van personenauto's en motorrijwielen; BPM):

   BPM is the tax you pay when buying a passenger car or a motorcycle. The amount of BMP you need to pay depends on; the CO_2 emissions of cars, the net list price, and the accessories. EV owners receive the following BPM tax benefits:

   BEV. Battery electric vehicles:

   i. Until 2024: fully exempt from purchase tax.
   ii. 2025: you'll pay a purchase tax fee of €360 per car.
   iii. After 2025: purchase tax fee will increase with inflation every year.

   PHEVs (Plug-in Hybrids)

   i. BPM rates are based on the World Harmonized Light Vehicle Testing Procedure (WLTP) CO2 testing method;

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b) Motor Vehicle Tax (MRB) (ownership tax):

MRB is an annual tax you pay on the possession of a car, motorcycle, or truck. EV owners receive the following MRB tax benefits:

BEV:

i. Until 2024: fully exempt from motor vehicle tax.
ii. 2025: 75% discount on MRB
iii. 2026 onwards: full MRB applies.

PHEVs:

i. Until 2024: 50% discount on motor vehicle tax
ii. 2025: 25% discount on MRB
iii. 2026 onwards: full MRB applies.

Business only

a) VAT exemption: companies who promote electric driving don't have to pay the 21% VAT, however the 2.7% VAT private correction applies.

b) Environmental Investment Allowance (MIA): Using the MIA, companies can receive an investment deduction of up to 36% of the amount invested into the EV. EVs on the Environmental List 2020 are eligible for this.

c) Bijtelling: this is a type of tax that applies if you use the company car privately. Basically, depending on the emissions of your vehicle, a percentage of its list price is added to your taxable income base. EV owners receive the following Bijtelling benefits:

i. 2021. discounted rate of 12% (instead of 22%)

ii. 2022-25: discounted rate of 16% (instead of 22%)

iii. 2026 onward, full rate of 22% applies.

Taxes for ICE Cars

Punitive measures: high-emitting CO_2 vehicles that are more than 12 years old have to pay another 15% on top of existing ownership tax as of 2019.

CALCULATION:

BMP or ownership tax. Paid once. It is paid in any transference of a car, even if this car is a second-hand one. The BMP is calculated following the indications for document in this link[16].

- For a passenger car over the CO_2 emissions based on WLTP values
- For delivery vans over the net list price

The following table reflects the cost limits for each segment applied in 2021.

[16] https://download.belastingdienst.nl/belastingdienst/docs/bpm_forms_bpm651z11fdeng.pdf

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UTRECHT	BMP Costs for passenger cars, 2021			
Passenger cars	Min	Max	Average	Equivalent EV
From 0 to 82 g/km	0 €	400 €	200 €	
From 86 gr/km to 106 g	400 €	564 €	482 €	50%
From 106 gr/km to 148	564 €	2,196 €	1,380 €	Small EV
From 148 gr/km to 165	2,196 €	8,454 €	5,325 €	Compact EV
From 165 gr/km to - GF	8,454 €	12,602 €	10,528 €	50%

Table 10. Cost limits and average per CO_2 segment, BMP, Utrecht, 2021

To simplify the calculation, the new EVs registrations was grouped in two of the five groups for ICE; the electric utilitarian vehicles (smaller one for city trips) are compared with cars releasing from 106 to 148 gr/km. The compact EVs (bigger one as the Tesla) are compared with cars realising from 148 gr/km to 165 gr/km. There will be 50% of each type. The equivalent BMP rates are depicted in the table. An average figure has been selected for each group.

The conditions applied to BEV and PHEV are reflected aside. In relation to the PHEV, a 32% of PHEV/EVs was assumed that is progressively reduced to 0 in 2035. From 2026 onward, the PHEV pays the BMP as the conventional ICE.

BEV	till 2024	Exempt
	2025	360 €
	2026 onw.	360 €+IR
PHEV	till 2025	Based WLTP
	2026 onw.	Full BMP

Table 11. Utrecht. Conditions for BEV and PHEV per year

The estimation for the next fifteen years was done, with an increased number of new registrations per year as stated in deliverable D9.2. The results are depicted in the next table.

UTRECHT	Reg. New	Invest BMP	NPV Invest BMP
Year	All EVs	M €	M €
2021	5,454.58	-18.29	-18.29
2022	8,211.93	-27.53	-27.00
2023	9,744.77	-32.67	-31.42
2024	10,986.65	-36.83	-34.75
2025	11,901.13	-35.61	-32.95
2026	12,492.12	-25.36	-23.01
2027	12,795.71	-27.06	-24.09
2028	12,872.00	-29.19	-25.48
2029	12,796.93	-31.27	-26.77
2030	12,654.10	-32.78	-27.52
2031	12,526.60	-33.46	-27.55
2032	12,488.87	-33.38	-26.96
2033	12,598.45	-32.79	-25.98
2034	12,887.91	-31.86	-24.75
2035	13,356.59	-30.49	-23.23
	173,768.33	**-458.58**	**-399.77**

Inflation Rate	2%
FDR	4%

Table 12. BMP Investment Calculation for Utrecht (NPV)

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Motor Vehicle Tax (MRB) (ownership and road tax):

This tax is paid by all cars' owners every three months. For the sake of calculation, an average amount will be calculated per year per type of vehicle. The amount of tax you must pay depends on the type of vehicle, its weight, the type of fuel and its environmental impact.

To simplify. the electric vehicles are classified in two groups of weight; utilitarian for the use inside cities and the compact or medium size, the first with a weight around 1,700 kg (as the Nissan Leaf) and the second with a weight of 2,250 kg (as the Tesla Model S). These vehicles might replace others ICE cars of same weight. The Dutch government provides a simple tool to calculate the MRB with two options gasoline or diesel. This tax collects the following for the assigned weights:

MRB		Gasoline	Diesel	Average
Pass. Cars		66%	33%	
1,700 kg	50%	1,112 €	2,270 €	1,780 €
2,250 kg	50%	1,596 €	3,102 €	
LDV		5%	95%	
1,700 kg	25%	704 €	1,832 €	2,240 €
2,250 kg	75%	1,008 €	2,468 €	

Table 13. Average MRB taxes per type of vehicle, weight, and fuel

PASS. CARS	till 2024	Exempt
	2025	Exempt 75%
	2026	Full MRB
LDV	till 2024	Exempt
	2025	Exempt 25%
	2026	Full MRB

Table 14. Conditions MRB tax

A total of €303.3 million in net present value will be the investment required to promote electromobility in the city of Utrecht during the five years of support accounting the MRB exemptions.

UTRECHT	BASE							
Year	Total Stock ALL	Stock EV	Stock EV Pas.Cars	Stock EV LDV	MRB EV PC	MRB EV LDV	MRB TOTAL	MRB TOTAL PV
				15%				
2021	446,545	21,991	18,692	3,299	-39.1	-7.4	-46.5	-46.5
2022	444,734	28,660	24,490	4,170	-51.0	-9.3	-60.4	-59.2
2023	443,430	36,605	31,439	5,166	-65.2	-11.6	-76.7	-73.8
2024	442,571	45,535	39,301	6,234	-81.1	-14.0	-95.0	-89.6
2025	442,086	55,122	47,803	7,320	-24.5	-12.3	-36.8	-34.1
2026	441,900	67,358	58,681	8,676				
2027	441,936	79,870	69,891	9,979				
2028	442,114	90,172	79,243	10,929				
2029	442,354	100,479	88,666	11,812				
2030	442,576	109,370	96,898	12,472				
2031	442,700	116,442	103,562	12,880				
2032	442,649	120,719	107,766	12,953				
2033	442,342	123,573	110,712	12,861				
2034	441,699	125,474	112,807	12,667				
2035	440,637	126,929	114,500	12,430				
					-260.9	**-54.6**	**-315.5**	**-303.3**

Inflation Rate	2%
FDR	4%

Table 15. Required investments from Utrecht municipality to promote electromobility with the MRB exemptions.

VAT exemption for companies and the use of the company car privately.

This VAT exemption will not be calculated as there are no data to estimate how many companies will promote electromobility and to what extent. The same applies to companies' EVs managed by employees.

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Taxes for ICE Cars

Punitive measures: high-emitting CO_2 vehicles that are more than 12 years old have to pay another 15% on top of existing ownership tax as of 2019. The ACEA report vehicles in use Europe-2023 provides a figure of 4,487,494 passengers cars with more than 10 years from the total 10.3 million vehicles. There are 398,222 LDV with more than 10 years. We don't know how many of them will have more than 12 years, but probably a short percentage. For the forecast, we estimated a 25% of such figure. The assumptions to make this calculation have been:

- The average MRB for passengers' cars is 1,780 € and 2,240 € for LDV, in 2021
- From the total fleet in use, the passengers' cars with more than 12 years we consider to be the 12.40% and from the LDV the 8,31%
- The extra incomes for the municipality due to the ICE tax for vehicles older than 12 years sum up €151.2 million at net present value considering inflation rate of 2% and Financial Discount rate of 4%.

Netherlands	All cars and vans	All Pass. cars	All LDV
All	10,248,317	9,049,959	1,198,358
More than12 y	1,221,429	1,121,874	99,556
%	11.92%	12.40%	8.31%

UTRECHT	BASE				
Year	Stock all cars (1)	Stock Pass. cars	Stock LDV	12% MRB ICE	NPV 12% MRB ICE
				12%	2% infl, 4% FDR
2021	53,221	48,883	4,338	11.6	11.6
2022	53,005	48,685	4,320	11.6	11.3
2023	52,849	48,542	4,308	11.5	11.1
2024	52,747	48,448	4,299	11.5	10.9
2025	52,689	48,395	4,295	11.5	10.6
2026	52,667	48,374	4,293	11.5	10.4
2027	52,671	48,378	4,293	11.5	10.2
2028	52,693	48,398	4,295	11.5	10.0
2029	52,721	48,424	4,297	11.5	9.8
2030	52,748	48,448	4,299	11.5	9.7
2031	52,763	48,462	4,301	11.5	9.5
2032	52,756	48,456	4,300	11.5	9.3
2033	52,720	48,423	4,297	11.5	9.1
2034	52,643	48,352	4,291	11.5	8.9
2035	52,517	48,236	4,280	11.5	8.7
(1) Over 12 years				172.6	151.2

Inflation Rate	2%
FDR	4%

Table 16. Calculation of extra incomes for the Utrecht city due to the tax of ICE cars older than 12 years. (1). Stock of all cars in Utrecht with more than 12 years

Summary table for Utrecht

As explained above Utrecht city following national rules, has committed three main actions to promote electromobility from the point of view of the taxes applied to the vehicles:

- The BMP tax of over new vehicles registrations with one unique payment. The exemptions allocated to this tax represent an investment for the municipality of €400 million in net present value.

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- The MRB tax for all the fleet paid yearly representing an investment of €303.2 million in present value.
- The ICE tax for ICE cars older than 12 years paid also yearly. Represents an income for the municipality of €151.2 million in present value for 15 years.

In the next table, all the results are shown in a summary for Utrecht.

UTRECHT	NPV BMP Total	NPV MRB TOTAL	NPV 12% MRB ICE	TOTAL TAXES Invest
BASE	M €	M €	M €	M €
2021	-18.29	-46.53	11.61	-53.21
2022	-27.00	-59.20	11.34	-74.86
2023	-31.42	-73.81	11.09	-94.15
2024	-34.75	-89.64	10.85	-113.54
2025	-32.95	-34.08	10.63	-56.40
2026	-23.01		10.42	-12.59
2027	-24.09		10.22	-13.86
2028	-25.48		10.03	-15.45
2029	-26.77		9.84	-16.93
2030	-27.52		9.66	-17.86
2031	-27.55		9.48	-18.08
2032	-26.96		9.29	-17.67
2033	-25.98		9.11	-16.87
2034	-24.75		8.92	-15.83
2035	-23.23		8.73	-14.50
	-399.77	**-303.25**	**151.23**	**-551.79**

Table 17. Summary of fiscal measures’ impact in Utrecht

4.2.2.3. Turin

Tax Benefits

Ownership tax (yearly tax called “bollo”[17]):

In Italy, a car tax must be paid on every car regardless of whether it is being used or not. The amount charged is a calculation based on EU emission grades, type of fuel and the power of the car. In most Italian regions, both fully electric vehicles and plug-in hybrids are exempt from paying annual **ownership tax** for five years from the date of registration. After this five-year period, they benefit from a 75% reduction of the equivalent tax rate for most petrol vehicles. In the calculation, we consider that the EVs may substitute recent Euro 7 cars so, the due amount considered has been €600 by car and year. We have considered that this measure will be kept active for 10 years as after that the measure could be very expensive.

[17] http://www.italycarimport.com/pay-annual-registration-road-tax-bollo-auto.html

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TURIN	New Regist. EVs	TOTAL	TOTAL PV
BASE	Nº units	Million €	Million €
	75%		
2021	5,352	-3.21	-3.21
2022	10,726	-9.65	-9.46
2023	14,893	-18.58	-17.88
2024	18,668	-29.78	-28.10
2025	21,831	-37.28	-34.50
2026	24,281	-44.50	-40.38
2027	26,022	-51.22	-45.59
2028	27,135	-57.46	-50.16
2029	27,759	-65.42	-56.01
2030	28,072	-73.01	-61.31
2031	28,267	-80.28	-66.11
2032	28,533		
2033	29,031		
2034	29,875		
2035	31,111		
TOTAL	351,557	-470.40	-412.70

10 years is the average lifetime we consider for EVs with one battery switched in year 5. Based on these assumptions, the total public investment derived from the tax exemption might reach €470.4 million. If the present value is applied for an inflation rate of 2% and a financial discount rate of 4%, the figure reaches €413.7 million.

Table 18. Tax exemption (bollo) for EVs in Turin from 2021 to 2031

4.2.2.4. Zaragoza

In some municipalities, depending on the specs of the engine, the type of fuel and the environmental impact, the tax on mechanical traction vehicles (levied on the ownership of vehicles suitable for driving in public roads) is reduced. In the city of Zaragoza[18], vehicles with an electric motor and/or zero emissions enjoy a discount of 75% of the IVTM[19]. The cost of this tax is paid yearly ranging from €20.30 to €201.63. For the sake of the calculation, it has been considered €150 on average. The exemption will impact on the 75% of this figure.

ZARAGOZA	New Regist. EVs	TOTAL IVTM	TOTAL IVTM (NPV)
BEST	Nº units	Million €	Million €
	75%		
2021	983	-0.04	-0.04
2022	1,620	-0.10	-0.10
2023	2,396	-0.19	-0.18
2024	3,158	-0.31	-0.29
2025	3,852	-0.45	-0.42
2026	4,446	-0.62	-0.56
2027	4,927	-0.80	-0.71
2028	5,293	-1.00	-0.87
2029	5,557	-1.21	-1.03
2030	5,739	-1.42	-1.20
2031	5,867	-1.61	-1.32
2032	5,968	-1.77	-1.43
2033	6,071	-1.91	-1.51
2034	6,202	-2.02	-1.57
2035	6,379	-2.12	-1.61
	68,457	-15.55	-12.84

The IVTM tax is exempted by all new registered EV during the vehicle whole life (10 years). Every year includes the cumulative IVTM taxes from previous years plus the new registrations. The amount left to be entered by the regional or local government might reach €15.6 million from 2021 to 2035. If the present value is applied for an inflation rate of 2% and a financial discount rate of 4%, the figure reaches €12.8 million.

Table 19. IVTM tax exemption for EVs in Zaragoza from 2021 to 2035

[18] https://www.elperiodicodearagon.com/zaragoza/2023/02/14/zaragoza-rebaja-10-impuesto-circulacion-82948724.html

[19] https://movilidadelectricazaragoza.es/bonificaciones-fiscales-y-otras-ventajas-para-la-movilidad-electrica/

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Taxes for the ICE cars. Tax on specific mobility modes to encourage shift to other modes.

From 2021, the tax on ICE will be increased in Spain. The "Special tax on certain means of transport" will be calculated depending on the CO_2 emissions attributed to each automobile model. When this indicator is below 120 grams/km, the tax is exempt (0%). From 120 to 160 grams a rate of 4.75% is applied, while from 160 to 200 a 9.75% is charged and from 200 onwards a tax of 14.75% is set. This tax is applied in substitution to the previous registration tax, either to new vehicles or the second-hand vehicles imported and registered in Spain. According to ANFAC (Spanish vehicles association), summary report for 2021[20], the collection for automotive fees and taxes in 2021, summed up €34,1 billion for a fleet in use of 29.2 million vehicles (all types) where only 0.47 million were electric. New registrations for 2021 reached 1 million new vehicles with 67,000 BEV or PHEV.

Below, it is listed all the fees and taxes recovered by the public administrations related to the automotive sector in Spain, for 2021. In brown colour, the total amount collected under the registration tax concept (for the new registrations and the second-hand imported vehicles) already with the new procedure to charge a bigger percentage to the more contaminant vehicles.

COLLECTION FOR AUTOMOBILE FEES AND TAXES (In K€)	
1 For the acquisition of new vehicles	4,257,417
1.1 VAT (1)	3,839,202
1.2 Registration Tax (2)	418,215
2 By fuel consumption (3)	20,467,250
2.1. VAT	7,287,635
2.2. Special Tax	13,179,615
3 By road tax	2,961,831
4 For transfers of used vehicles	520,643
4.1 Property Transfer Tax	312,385
4.2 VAT	158,539
4.3 Registration Tax (4)	49,719
5 For maintenance, vehicle repair and trade in spare parts and spare parts (VAT)	4,494,949
6 By enrollment fee	114,974
7 By circulation permit	80,784
8 By ownership change rate	187,556
9 for insurance	1,062,934
	34,148,338

It is complex to define how this tax will be reduced overtime, as it will rely on the technical evolution of the OEMs and also in the penetration of the electromobility, but for sure it will reduce its amount a percentage per year. This process will be likely slow but continues. For the calculation, it has been considered a 5% reduction per year.

Table 20. Collection for automotive fees and taxes, Spain, 2021. Source. ANFAC

According to the ANFAC report, there were 859,476 passenger cars registered in Spain in 2021 and 224,758 commercial and pick up.

New Regist. 2021	Aragon	Spain
Passenger cars	17,886	859,476
Commercial cars	4,138	224,758
% Aragon /Spain	22,024	1,084,234
2.03%		

Table 21, Registered cars Spain and Aragon, 2021

For the calculation of the ICE tax impact in the municipality accounts, it was considered:

- Aragon represents the 2.03% of total new registrations and Zaragoza covers the 60%.
- Every year a 5% of the incomes are lost as fleet becomes greener.
- Present Value is calculated with 2% inflation and 4% of financial discount rate.
- Total impact reaches €28.3 million in 15 years.

Category Pass.Cars	Number	%
Urban/Compact	336,387	39.14%
Sedan type/Luxury	29,678	3.45%
Sport	1,540	0.18%
Monovolume	14,781	1.72%
SUV/All terrain	477,090	55.51%
TOTAL	859,476	100.00%

Table 22. Classification by car category, 2021, Spain

[20] ANFAC, Annual report 2021,

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ZARAGOZA	New Reg.	TAX Recovered	Lost TAX (greener)	NPV Lost TAX
BASE	Nº All Veh	Million €	Million €	Million €
2021	15,554	5.70	0.00	0.00
2022	15,555	5.42	-0.29	-0.28
2023	15,415	5.10	-0.60	-0.58
2024	15,284	4.76	-0.94	-0.89
2025	15,160	4.41	-1.29	-1.20
2026	15,043	4.05	-1.65	-1.50
2027	14,932	3.69	-2.01	-1.79
2028	14,826	3.34	-2.36	-2.06
2029	14,725	3.01	-2.69	-2.31
2030	14,627	2.69	-3.02	-2.53
2031	14,533	2.39	-3.32	-2.73
2032	14,440	2.10	-3.60	-2.91
2033	14,350	1.84	-3.86	-3.06
2034	14,260	1.61	-4.10	-3.18
2035	14,170	1.39	-4.31	-3.29
TOTAL		51.51	-34.04	-28.30

The total investment for the municipality of Zaragoza in 15 years will account for €28.3 million in Net Present Value (2021)

Table 23. Impact of ICE tax on municipality accounts

4.2.2.5. Tallinn taxes

Estonia is the only EU country without a car tax and fuel consumptions tax on cars. There were more than 470,000 registered passengers and LDV vehicles in 2021 but no plans to introduce a car tax anytime soon.

By registering your vehicle in Estonia, you only need to pay a state fee of approx. 150 € once. Estonia does not have CO_2 taxation based on the registration fee, as majority of the EU members have or are planning to do.

In summary, there won't be any extra effort based on taxation in Tallinn to promote the electromobility as there are no taxation on cars or fuel consumption and no registration fee discriminated by emissions.

4.2.2.6. Summary results for vehicles taxation in the five use case cities

In the next table, it is summarised all the economic impacts derived from the EVs exemptions and ICE extra taxation in the five use case cities for the next 15 years. The figures are approximative with the available information and based on average figures, starting in 2021.

IMPACT TAXES EVs	PARIS				UTRECHT				TURIN	ZARAGOZA		
	Carte Gris NPV	LDV VAT NPV	Lost MALUS NPV	PARIS TOT	BMP NPV	MRB NPV	MRB ICE NPV	UTRECHT TOT	TURIN TOT	IVTM NPV	ICE Tax NPV	ZARAG. TOT
BASE	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €
2021	3.82	11.47	0.00	15.29	18.29	46.53	-11.61	53.21	3.21	0.00	0.00	0.00
2022	3.75	11.26	23.93	38.94	27.00	59.20	-11.34	74.86	9.46	0.10	0.28	0.38
2023	3.69	11.07	26.24	41.01	31.42	73.81	-11.09	94.15	17.88	0.18	0.58	0.76
2024	3.72	11.15	28.30	43.17	34.75	89.64	-10.85	113.54	28.10	0.29	0.89	1.18
2025	3.71	11.13	30.14	44.98	32.95	34.08	-10.63	56.40	34.50	0.42	1.20	1.61
2026	3.66	10.98	31.79	46.43	23.01		-10.42	12.59	40.38	0.56	1.50	2.06
2027	3.59	10.77	33.28	47.63	24.09		-10.22	13.86	45.59	0.71	1.79	2.50
2028	3.52	10.55	34.62	48.68	25.48		-10.03	15.45	50.16	0.87	2.06	2.93
2029	3.45	10.35	35.85	49.65	26.77		-9.84	16.93	56.01	1.03	2.31	3.34
2030	3.40	5.95	36.99	46.34	27.52		-9.66	17.86	61.31	1.20	2.53	3.73
2031	3.36	5.89	38.06	47.31	27.55		-9.48	18.08	66.11	1.32	2.73	4.06
2032	3.34	5.85	39.08	48.27	26.96		-9.29	17.67		1.43	2.91	4.34
2033	3.33	5.84	40.06	49.24	25.98		-9.11	16.87		1.51	3.06	4.57
2034	3.34	5.85	41.02	50.21	24.75		-8.92	15.83		1.57	3.18	4.75
2035	3.34	5.86	41.99	51.19	23.23		-8.73	14.50		1.61	3.29	4.90
	53.02	133.95	481.37	668.34	399.77	303.25	-151.23	551.79	412.70	12.81	28.30	41.10

Table 24. Summary of taxes' policies to incentive electromobility in the use-case territories (Base Scenario)

Note. Tallinn has not been included as there is not a specific policy to incentive electromobility in its territory different to the general policies to support the automotive sector (for instance no VAT)

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4.2.3. Support measures for EVs' chargers

4.2.3.1. Initial assumptions

European countries apply different strategies to support the EVs' chargers. Some of them support exclusively the public or semi-public ones, whilst some other put the major effort on the private. There are also fiscal aids, in the same way than the electric vehicles, but the approaches vary from country to country.

The calculations implemented hereinafter must be considered a rough approach based on the available data per country and the projections done in D9.2 for the penetration curves of chargers in the base, best and worst scenarios. The intention of this calculation is to later compare the administration' investments with the approximate impact derived from the transition to electric in the different use case cities, monetising the externalities, as was largely explained before. In advance to enter into the details, we include herein some assumptions to better understand the figures to be provided.

Cost of chargers

There is not a very extensive literature of the real CAPEX costs for the EVs chargers. INCIT-EV will do its own analysis in task 9.3 (D9.4 LCCA and D9.5 Pricing and revenue models), however, for this current deliverable, some average costs will be considered based on literature. There are many technologies involved and it is not easy to extract the real CAPEX grouping equipment which are not exactly equivalent. The following definitions have been adopted in this report.

- PuCS: Public Charging Station; these are the Charging Stations installed in the public domain for the use of any client. We include here those installed in the streets, in charging hubs, those at the Gas Stations, in Commercial molls, etc. Public does not mean necessary public ownership. In many cases these stations are managed privately.
- SPuCS: Semi-public Charging Station; these are the Charging Stations installed in the public domain for the use of some authorized clients (for instance, taxi drivers or car sharing companies, etc). Both PuCS and SPuCS will be called together as PCS.
- PrCS: Private Charging Station; these are the CS installed privately at home or at the workplace. They can be solely used by one or several authorised persons.

Generally speaking, all of them are called with the acronym CS. Each CS contains one or many electric vehicles supply equipment units (EVSEs) or Charging Points (CPs) that are able to serve a vehicle. One EVSE may have one or many connectors installed. Typical AC chargers have only a single Type 2 or Schuko connector installed, whereas DC chargers often have a CCS and a CHAdeMO connector installed. If multiple connectors are installed, only one of them can be used at any moment in time. So, graphically, we can see the following:

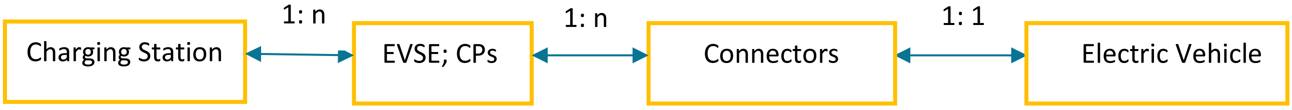

Figure 7. Relationships among the components of a Charging Station

In summary:

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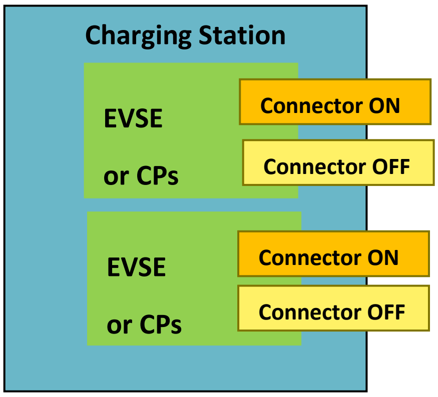
- A charging station (CS) can contain several service stations (EVSE) or charging points (CPs).
- A charge point (EVSE) can contain several connectors / outlets; but per charge point (EVSE), not more than one connector can be active at a time.



To simplify our calculation, the UK NSVS (National Security Vetting Solution) classification of chargers was used as reference but distinguishing only 4 categories as described below (Level 1; from 2.4 kW to 7 kW, Level 2; from 7 kW to 22 kW, Level 3; from 22 kW to 120 kW, Level 4 (>120 kW).

Figure 8. Representation of a Charging Station

Although, it is difficult to estimate, it has been considered that Level 1 CS (lower power) contains on average one single CP, level 2 (2 CPs), level 3 (3 CPs) and level 4 (4 CPs).

	Power	Range added per hour	Charging time	Typical application
Level 1 - single phase (domestic)	2.4-3.7kW	10-20km range / hour	5-16 hours	Home
Level 2 slow - single phase (domestic or public)	7 kW	30-45km range / hour	2-5 hours	Home,work, shopping centres, car parks
Level 2 fast - three-phase (public)	11-22kW	50-130km range / hour	30mins - 2 hours	Urban roadside
Level 3 - fast charge (public)	50kW	250-300km range / hour	20-60 mins	Regional near highways, motorways and key routes
Level 4 - super-fast charge (public)	120kW	400-500km range / hour	20-40 mins	Regional near highways, motorways and key routes
Ultra-fast charge (public)	350kW	1000+ km range / hour	10-15 mins	Highways and motorways

Figure 10. Most common standards for chargers

The standards for Electric vehicles plugs are included above being the Tesla one, only adapted for their own cars.

Figure 9. Basic classification of chargers' type by power, charging time and typical application

Some authors like Alberer[21] or Hecht[22] recently performed an extensive literature review and estimated some metrics for the average costs of the chargers. Unfortunately, the authors did not provide an indication of how many EVSEs there were per CS. It is, however, clear that the price assumptions vary widely across literature.

[21] Alberer, L. (2020). Kostensenkungspotentiale bei Schnell-Ladeinfrastruktur bis 2025. Diplom, Universität für Bodenkultur

[22] C. Hecht, J.Figgener, D.Uwe (2022), Analysis of electric vehicle charging station usage and profitability in Germany based on empirical data. iScience

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Costs are heavily influenced by land acquisition, hardware suppliers, project management, and many other factors (like product capabilities as smart charging, V2G, etc).

The uncertainty is even greater for AC-CS with a power rating from 11 or 22 kW. Literature provides investment estimations per CS with large uncertainty from 2,000[23] to 15,000[24] €. Large influencing factors for these variations are hardware or installation costs, which vary a lot. Wallboxes with a rated power of 3.7 kW are seen as cheaper with investment costs of 2,700[25] €. Depending on the location, however, installation costs can become a significant factor for this category as well. Given these findings, we make the following assumptions for the CPs.

Category	Minimum Cost (€)	Maximum Cost (€)	Average Cost (€)	Av. Weight. Power (kW)
Level 1 (2.4-7 kW)	2,000 €	6,000 €	**4,000 €**	4.7
Level 2 (7-22 kW)	4,000 €	15,000 €	**9,500 €**	22.0
Level 3 (22-120 kW)	9,500 €	120,000 €	**64,750 €**	100.0
Level 4,5 (>120 kW)	120,000 €	250,000 €	**185,000 €**	200.0

Table 25. Average costs and power per category of Charging Point

Chargers' projections.

To finalise the introduction, the projections over time of the number of chargers per type in all the use case cities are provided. Deliverable D9.2 generated a data base with the intermediate figures for years 2021, 2025, 2030 and 2035. The figures were related to the Charging Points (or EVSE). A regression curve is consequently created for each type of CP (public classified by power, private, etc) and compared with the number of expected EVs deployed . These figures are used later to estimate the investments done by the local administrations in public or private chargers depending on the specific support measures, including direct support measures for the upfront costs of chargers and the additional fiscal supporting measures.

4.2.4. Direct Support to chargers' upfront costs and taxes by the Administrations

Hereinafter, the incentives scenarios that differs significantly among the use-case cities[26] are described.

4.2.4.1. Paris

The situation in France in relation to the charging stations is as follows:

ADVENIR[27], is the French EV Infrastructure Charging Program, that was launched in 2016 to help finance private charging infrastructure for company fleets and in apartment buildings.

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[23] Emobilitaet.business Redaktion (2020).Öffentliche Ladestationen: alle Infos aufeinen Blick

[24] Plank-Wiedenbeck, U., Harder, R., and Kohl, P. (2021). Fortschreibung der Ladeinfrastrukturstrategie des Freistaates

Thüringen bis 2030. Schlussbericht (Weimar).

[25] Langer, A. (2018). Ladeinfrastruktur als Geschäftsfeld (E-Mobility). Germany

[26] https://alternative-fuels-observatory.ec.europa.eu/interactive-map

[27] https://blog.evbox.com/ev-charging-infrastructure-incentives-eu#France

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As part of its renewal for the period 2020 - 2023, the ADVENIR program has a budget of €100 million with the objective of financing more than 45,000 new charging points by the end of 2023.

The ADVENIR program grants charging stations to three main beneficiaries; collective buildings, enterprises, and public roads.

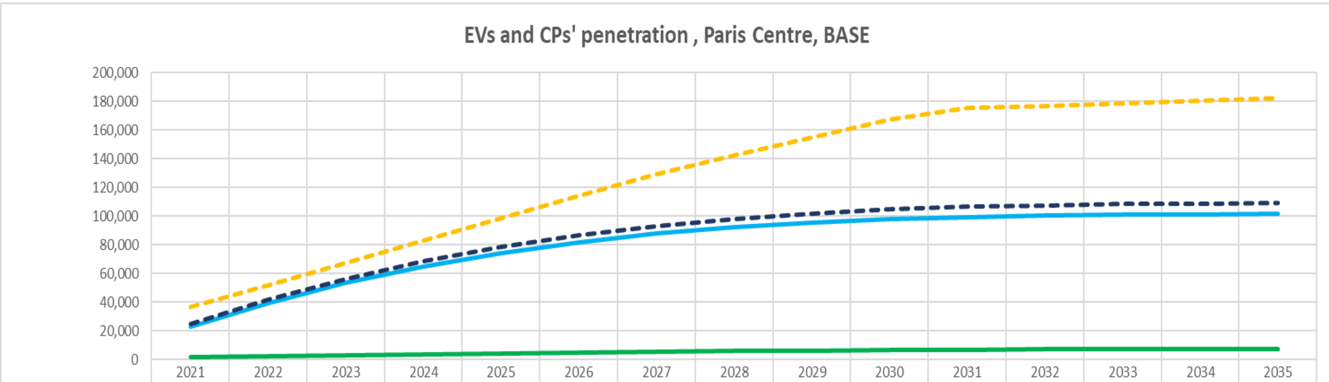
In collective buildings, 50% of total costs are granted with a maximum of 960 € if you are an individual, 1,660 € for share charging points and 8,000 € for all the parking spaces (till 100). Thus, for shared private charging, the law gives users a "right to the charge" that avoid blocking by building management or collective decision.

Enterprises has three main options as well; trucks, private parkings open to the public and employees' fleets. For the trucks, the aid is the 50% and the maximum amount depends on the technology and power of trucks (till 43 kW AC, 2,200 €, till 40 kW DC, 3,300 €, till 140 kW, DC 7,500 € and over 140 kW DC, 15,000 €). For the private parkings with public access, the level of support reaches 30% with a ceiling of 1,000 € in AC CPs s and 2,700 € for DC CPs. Finally, CPs to feed the employees fleets are supported with a 20% of installation costs and a ceiling of 600 €. No VAT is paid.

Private companies investing in the public roads can receive a support of 30% of installation costs with a top from 1,000 € to 9,000 €.

To make the calculation, we will consider the following assumptions:

- It has been considered that France spent all the resources allocated in the ADVENIR program during years 2020 to 2023, distributing the budget proportional to the number of new CPs (private and public). It was assumed that the following years an equivalent amount will be allocated to continue financing new CPs till 2035.
- However, the level of support will be reduced over time in certain percentages, as the number of CPs grows. In 2035, a 35% reduction in the stimulus will be considered.
- The lifetime of chargers has been considered 10 years. Thus, the new yearly installed CPs are calculated by the difference between the stock of year i+1 minus year i, minus the calculated CPs withdrawn (please check table 28).



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Total Pu.CPs	1,600	2,278	2,949	3,604	4,236	4,835	5,394	5,904	6,356	6,743	7,055	7,285	7,423	7,462	7,393
Total Pr.CPs	23,130	39,515	53,375	64,928	74,392	81,980	87,915	92,411	95,687	97,961	99,445	100,363	100,930	101,362	101,882
TOTAL CPs	24,730	41,793	56,324	68,532	78,628	86,816	93,309	98,315	102,043	104,704	106,501	107,648	108,353	108,824	109,275
TOTAL EVs	36,720	51,960	67,230	82,827	98,540	114,025	129,191	142,094	155,006	167,423	175,698	176,957	178,491	180,323	182,125

Total Pu.CPs — Total Pr.CPs — TOTAL CPs — TOTAL EVs

Figure 11. EVS and main categories of CPs (public and private) penetration in Paris Centre (stock, BASE)

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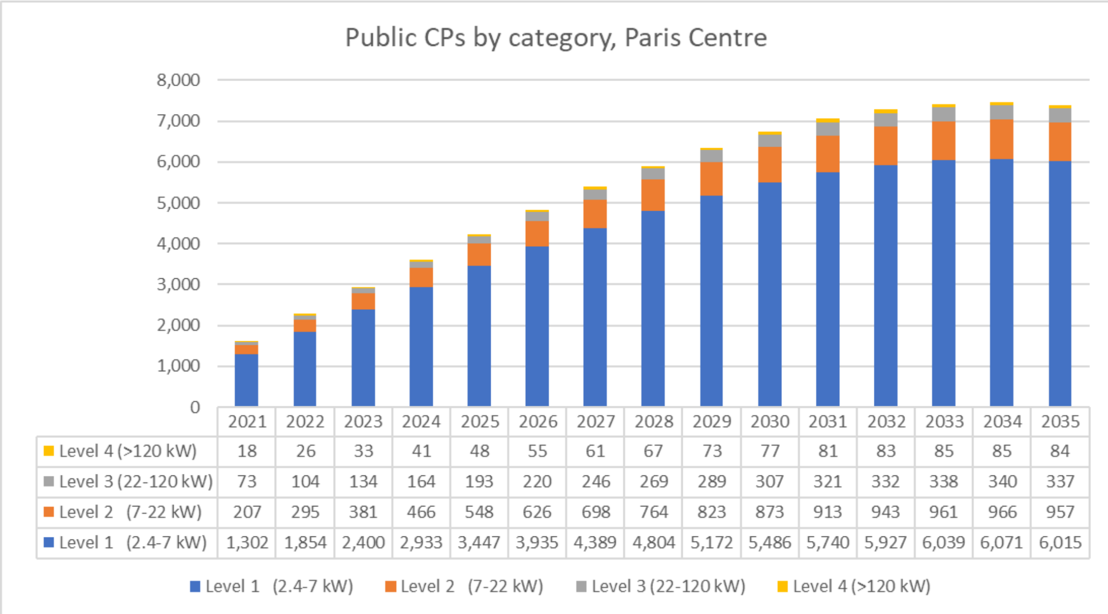
Herein, the public CPs distributed by the three main categories; level 1, 2, 3 and 4.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 4 (>120 kW)	18	26	33	41	48	55	61	67	73	77	81	83	85	85	84
Level 3 (22-120 kW)	73	104	134	164	193	220	246	269	289	307	321	332	338	340	337
Level 2 (7-22 kW)	207	295	381	466	548	626	698	764	823	873	913	943	961	966	957
Level 1 (2.4-7 kW)	1,302	1,854	2,400	2,933	3,447	3,935	4,389	4,804	5,172	5,486	5,740	5,927	6,039	6,071	6,015

Figure 12. Public CPs forecast classified by category in Paris Centre (stock, BASE)

The calculation of the total investment in all concepts (upfront costs and fiscal advantages) will consider the new units per year which are reduced over time. The same proportion of investment (€100 million from 2020 to 2023) will be kept for the next years till 2035 according to the number of new CPs.

PARIS BASE	Total Pu.CPs	Total Pr.CPs	Stock CPs (units)	CPs Withdrawals	New CPs (units)	Advenir Paris (M€)	Advenir Paris NPV (M€)
2020			17,063	85	5,511		
2021	1,600	23,130	24,730	247	7,914	1.43	1.43
2022	2,278	39,515	41,793	418	17,481	3.17	3.11
2023	2,949	53,375	56,324	1,690	16,221	2.94	2.83
2024	3,604	64,928	68,532	3,427	15,635	2.89	2.73
2025	4,236	74,392	78,628	5,504	15,599	2.88	2.67
2026	4,835	81,980	86,816	8,682	16,870	3.12	2.83
2027	5,394	87,915	93,309	11,197	17,690	3.27	2.91
2028	5,904	92,411	98,315	17,063	22,070	3.40	2.97
2029	6,356	95,687	102,043	24,730	28,458	4.38	3.75
2030	6,743	97,961	104,704	41,793	44,454	6.85	5.75
2031	7,055	99,445	106,501	56,324	58,120	8.95	7.37
2032	7,285	100,363	107,648	68,532	69,679	9.30	7.51
2033	7,423	100,930	108,353	78,628	79,332	10.59	8.39
2034	7,462	101,362	108,824	86,816	87,287	11.65	9.05
2035	7,393	101,882	109,275	93,309	93,760	12.51	9.53
					590,569	87.3	72.82
						IR	2%
						FDR	4%

Table 27. NPV forecast expected expenses ADVENIR in CPs in Paris, BASE

Stock 2021	PuCPs	PrCPs	Total CPs
France	37,240	252,183	289,423
Paris	3,182	21,548	24,730
	% Paris/France		8.54%

Table 26. Weight of Paris over total in CPs stock

% incentives	Period (years)	Tot CPs Paris (units)	Advenir France Mill €	Advenir Paris Mill €
	2020	5,511	11.7	
100%	21-23	41,615	88.3	7.55
90%	24-27	65,794	142.3	12.16
75%	28-31	153,101	275.9	23.58
65%	32-35	330,059	515.5	44.05
	21-35	590,569	1,022	87.33

Table 28. ADVENIR program contribution to Paris

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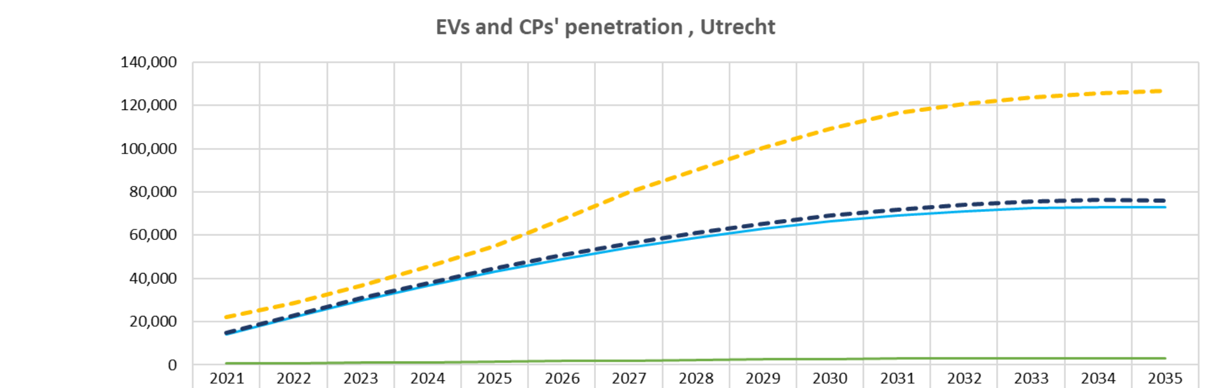
Paris Centre represents the **8.54%** of the total stock of CPs in France. A total of €1,022 million (real value) can be estimated as the amount disbursed by the ADVENIR program and the following ones, for the whole France from 2021 to 2035, and €87.3 million the amount allocated to Paris according to the weight of Paris over the total. The Net Present Value of this last figure supposes an investment of **€77.8 million.**

4.2.4.2. Utrecht

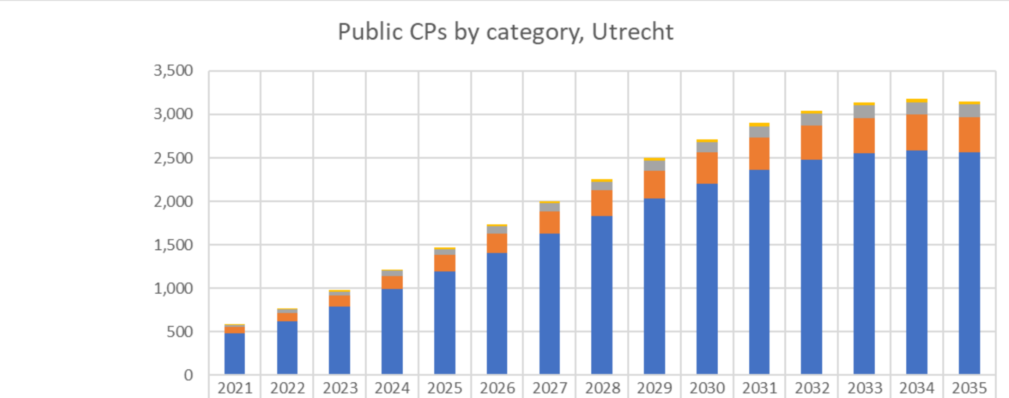
Incentives in the Netherlands are mainly focused on public Charging Points. Free public CPs can be requested by residents in most municipalities including Utrecht. There is a free access to public charging stations for EVs drivers using a charging card, meaning you only pay for the energy used to charge your card. At the moment, the Netherlands doesn't offer any national or local incentives for the purchase and installation of private charging points. Instead, the government offers some charger incentives for companies and focuses on the development of public charging stations. Below, the stock projection curves for EVs and CPs for Utrecht,



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TOTAL Pu.CPs	586	764	975	1,213	1,468	1,732	1,997	2,254	2,496	2,713	2,898	3,043	3,138	3,176	3,149
TOTAL Pr. CPs	14,224	22,249	29,749	36,710	43,115	48,948	54,192	58,832	62,850	66,231	68,959	71,016	72,388	73,057	73,008
TOTAL CPs	14,810	23,012	30,725	37,923	44,583	50,680	56,189	61,086	65,346	68,944	71,857	74,059	75,526	76,234	76,157
TOTAL EVs	21,991	28,660	36,605	45,535	55,122	67,358	79,870	90,172	100,479	109,370	116,442	120,719	123,573	125,474	126,929

Figure 13. EVS and main categories of CPs (public and private) penetration in Utrecht (stock, BASE)

Herein, the public CPs distributed by the three main categories; level 1, 2, 3 and 4 in Utrecht.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 4 (>120 kW)	7	9	11	14	17	20	23	26	28	31	33	35	36	36	36
Level 3 (22-120 kW)	27	35	44	55	67	79	91	103	114	124	132	139	143	145	143
Level 2 (7-22 kW)	76	99	126	157	190	224	258	292	323	351	375	394	406	411	408
Level 1 (2.4-7 kW)	476	621	794	987	1,194	1,409	1,625	1,834	2,031	2,207	2,358	2,475	2,553	2,584	2,562

Figure 14. Public CPs forecast classified by category in Utrecht (stock, BASE)

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The assumptions considered for the calculation of the administration’ investments in Utrecht, have been the following:

- All the new public chargers will be paid by the city central administration.
- The new capacity is valued at the economic rates indicated in table 28 for year 2021. Then, a cost reduction is expected in a yearly 0.03 percent over the previous year, reaching a 35% cost reduction in 2035.

Considering all the assumptions, the following investments will be necessary in Utrecht .

UTRECHT		Level 1 (2.4-7 kW)			Level 2 (7-22 kW)			Level 3 (22-150 kW)			Level 4 (>120 kW)			TOTALS		
Price Evol.	BASE	Stock (PuCPs)	New Capacity	M€	Stock (PuCPs)	New Capacity	M€	Stock (PuCPs)	New Capacity	M€	Stock (PuCPs)	New Capacity	M€	TOT.New	M€	NPV M€
1.00	**2021**	476	119	0.48	76	19	0.18	27	7	0.43	7	2	0.31	146	1.40	**1.40**
0.97	**2022**	621	145	0.56	99	23	0.21	35	8	0.51	9	2	0.36	178	1.65	**1.62**
0.94	**2023**	794	172	0.65	126	27	0.25	44	10	0.59	11	2	0.42	212	1.90	**1.90**
0.91	**2024**	987	193	0.71	157	31	0.27	55	11	0.64	14	3	0.46	238	2.07	**1.84**
0.89	**2025**	1,194	207	0.73	190	33	0.28	67	12	0.67	17	3	0.48	255	2.15	**1.84**
0.86	**2026**	1,409	215	0.74	224	34	0.28	79	12	0.67	20	3	0.48	264	2.16	**1.78**
0.83	**2027**	1,625	215	0.72	258	34	0.27	91	12	0.65	23	3	0.47	265	2.11	**1.66**
0.81	**2028**	1,834	209	0.68	292	33	0.26	103	12	0.61	26	3	0.44	257	1.98	**1.51**
0.78	**2029**	2,031	197	0.62	323	31	0.23	114	11	0.56	28	3	0.40	242	1.81	**1.32**
0.76	**2030**	2,207	368	1.12	351	66	0.48	124	23	1.14	31	6	0.82	463	3.56	**2.50**
0.74	**2031**	2,358	462	1.36	375	74	0.52	132	26	1.24	33	6	0.88	568	4.00	**2.70**
0.72	**2032**	2,475	409	1.17	394	65	0.44	139	23	1.06	35	6	0.76	503	3.43	**2.23**
0.69	**2033**	2,553	271	0.75	406	43	0.28	143	15	0.68	36	4	0.49	333	2.21	**1.38**
0.67	**2034**	2,584	238	0.64	411	38	0.24	145	13	0.58	36	3	0.42	293	1.89	**1.13**
0.65	**2035**	2,562	193	0.50	408	31	0.19	143	11	0.46	36	3	0.33	237	1.48	**0.85**
TOTALS			3,614	11.42		583	4.37		205	10.48		51	7.51	4,453	33.79	**25.66**

Figure 15. Public investments on new public CPs from 2021 to 2035, Utrecht

Clarifications:

- The figures in the new capacity columns, correspond to cumulative number of chargers for the year assigned (this figure comes from the regressive curve created in D9.2 data)
- 10 years have considered the lifetime of the chargers.
- From installed chargers in 2021, it was assumed that a 25% was new.
- Yellow columns correspond to the new capacity installed per year. After 10 years some of the 2021 chargers will be substituted (40%, 35% and 25% in successive years.). After year 2031, the chargers installed 10 years ago should also be substituted and so on.
- The NPV was calculated considering an inflation rate of 2% and a FDR of 4%.

A total of €25.7 million (NPV) is the expected investment in 15 years to install a total of 4,453 new charging points. This infrastructure will service 127,000 EVs fleet in 2035.

4.2.4.3. Turin

Italy launched an initiative to finance till 80% of private CPs and condominium CPs in October 2021, for two years but it didn’t enter in execution after a final extension in years 2023 and 2024. There will be 40 million per year to apply this new regulation[28].

To recap:

- Incentives only applies to the private sector.

[28] https://www.gazzettaufficiale.it/eli/id/2022/10/04/22A05633/sg

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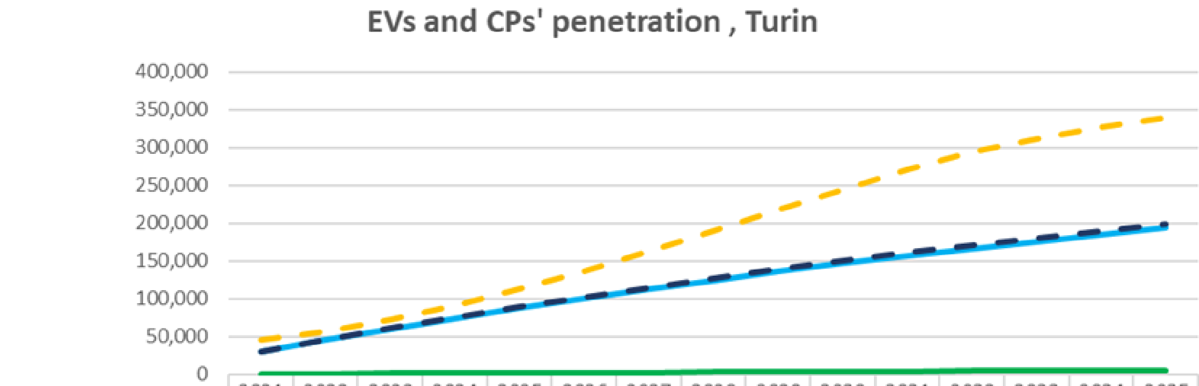
- There is an 80% discount, up to a maximum of 1,500 euros per person, on the purchase of home charging infrastructure;
- There is 80% discount, up to a maximum of 8,000 euros per condominium, on the purchase of condominium charging infrastructure.
- The discount may only apply to standard electrical infrastructure purchases (less 22 kW)

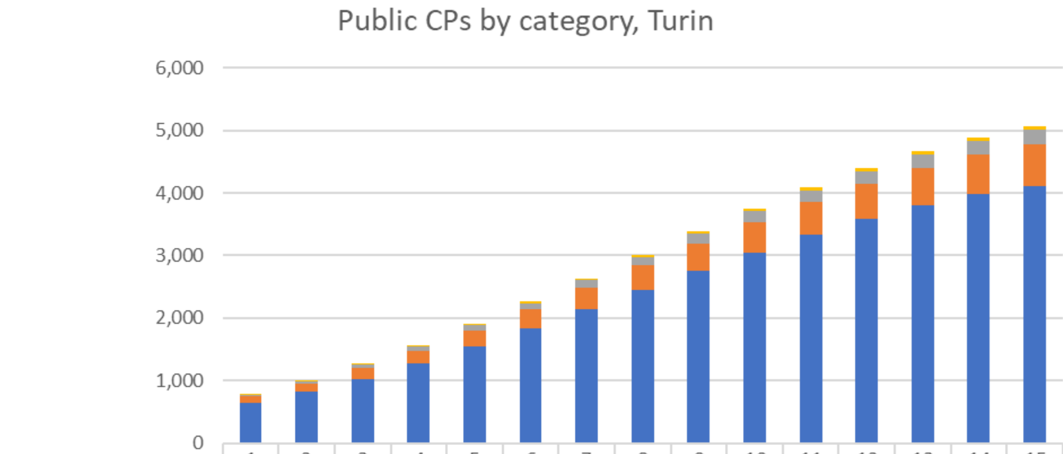
Below, the stock projection curves for EVs and CPs for Turin



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TOTAL Pu.CPs	789	1,004	1,268	1,572	1,907	2,265	2,637	3,014	3,387	3,748	4,088	4,398	4,669	4,893	5,061
TOTAL Pr. CPs	29,782	45,046	59,708	73,781	87,278	100,21	112,59	124,44	135,76	146,58	156,89	166,73	176,09	184,99	193,46
TOTAL CPs	30,571	46,050	60,976	75,353	89,185	102,47	115,23	127,45	139,15	150,33	160,98	171,13	180,76	189,89	198,52
TOTAL EVs	46,551	57,270	72,154	90,804	112,59	136,80	162,71	189,56	216,94	244,34	270,28	293,46	311,77	326,75	339,19

Figure 16. EVS and main categories of CPs (public and private) penetration in Turin (stock, BASE)

Herein, the public CPs distributed by the three main categories; level 1, 2, 3 and 4 in Turin.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Level 4 (>120 kW)	9	11	14	18	22	26	30	34	39	43	47	50	53	56	58
Level 3 (22-120 kW)	36	46	58	72	87	103	120	137	154	171	186	200	213	223	231
Level 2 (7-22 kW)	102	130	164	203	247	293	341	390	438	485	529	569	604	633	655
Level 1 (2.4-7 kW)	642	817	1,032	1,279	1,552	1,843	2,145	2,452	2,756	3,049	3,326	3,578	3,799	3,981	4,117

Figure 17. Public CPs forecast classified by category in Turin (stock, BASE)

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Some assumptions for Turin:

- The amount approved will be €40 million for 2023 and €40 million for 2024. We consider that this figure will be fully disbursed in the period. After this plan, additional incentives plans will be approved adapted to the number of new CPs to be installed.
- Turin represents the 4,74% of the total CPs of the Italian territory.
- The incentives will be progressively reduced in percentage as stated in the first column while the number of CPs grows.
- NPV has been calculated with an inflation rate of 2% and a FDR of 4%.

% incentives	TURIN BASE	Total Pr.CPs	PrCPs Withdrawals	New PrCPs (units)	Inc. Plan Italy (M€)	Inc. Plan Turin (M€)	Inc. Plan NPV Turin (M€)	Inc. Plan Turin (M€)	Inc. Plan NPV Turin (M€)
	2021	29,782	298	10,092					
	2022	46,039	921	16,257					
100%	2023	60,961	1,829	14,923	80.0	3.79	3.61	1.71	1.65
	2024	75,334	3,767	18,140				2.08	1.96
95%	2025	89,162	6,241	20,069	100.2	4.75	4.35	2.19	2.02
	2026	102,450	10,245	23,533				2.56	2.33
90%	2027	115,201	13,512	26,263	120.3	5.70	5.02	2.57	2.29
	2028	127,421	19,690	31,910				3.13	2.73
80%	2029	139,114	29,782	41,475	163.3	7.74	6.55	3.25	2.78
	2030	150,284	46,039	57,208				4.49	3.77
75%	2031	160,937	60,961	71,615	195.0	9.24	7.53	4.21	3.47
	2032	171,077	75,334	85,474				5.03	4.06
70%	2033	180,707	89,162	98,792	182.8	8.66	6.79	4.07	3.22
	2034	189,832	102,450	111,576				4.59	3.57
65%	2035	198,457	115,201	123,826	28.9	1.37	1.04	1.37	1.04
				751,151	870.5	41.2	34.9	41.2	34.88

Table 29. Forecast NPV Incentive Plan contribution for charging Stations in Turin (BASE)

The incentive plan for the private Charging points installation will suppose a net present value investment of €34.9 million between 2023 (date when the incentive program starts) and 2035.

4.2.4.4. Zaragoza

The Spanish government regulates mobility aid through successive programs called MOVES. Three programs have been launched to date; Moves I, II and III. The Moves II Plan opened on June 17, 2020, and closed on March 3, 2021. It was initially endowed with €100 million, of which €2,8 million corresponded to Aragon, although there was a later increase with another €2.5 million for this region. 50% of this amount was earmarked for aid to charging infrastructures. The Move III Plan opened on April 17, 2021, and will close on December 31, 2023. It was initially endowed with €400 million, but in successive extensions its budget has doubled to €865 million. Of this amount, approximately €34.1 million correspond to Aragon with a maximum of 50% for the charging infrastructure.

This program finances individuals with 70% of the amount of the charger installation and 80% if it is in a municipality with less than 5,000 inhabitants. For companies that install chargers of more than 50 kW, an amount of 35%, 45% or 55% is established if they are large, medium, or small companies respectively. These amounts rise to 40%, 50% and 60% in municipalities with less than 5,000 inhabitants. Those companies that install chargers with powers of less than 50 kW will receive 30% and 40% in municipalities with fewer than 5,000 inhabitants.

Assumptions.

- The exact amounts for the execution of the program are not known, but it will be assumed that 50% goes to electric chargers and that the programs are fully executed.
- The amounts will be distributed proportionally to the forecast of chargers per annuity. It will be considered that the Moves II program allocates a quarter of its budget to the first quarter of 2021. The aids go to public and private chargers indifferently.

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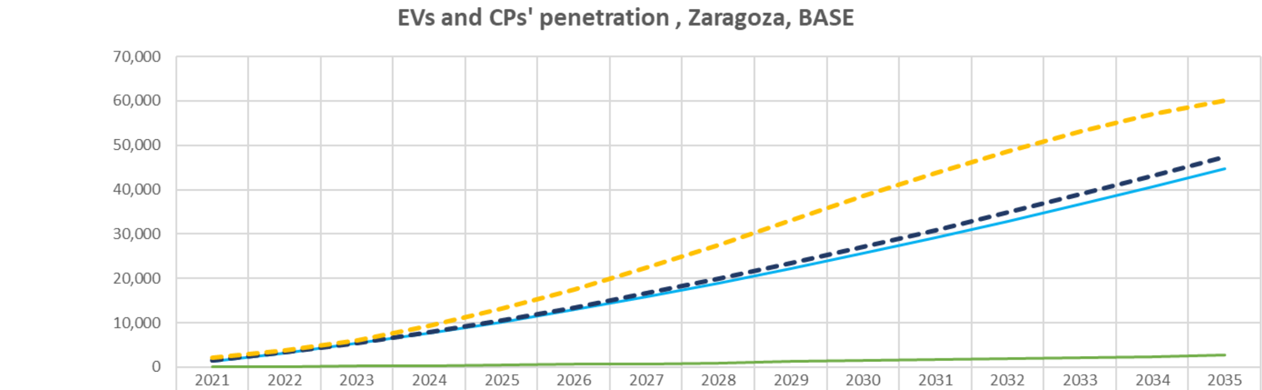
- Besides, it will be assumed that in successive years, the programs grow proportionally to the number of chargers but with a reduction in aid of up to 35% in the year 2035, as inferred from previous analyses.
- Zaragoza represents the 50% of total installations in Aragón.

The forecast for the EVs and the CP penetration in Zaragoza is depicted below:

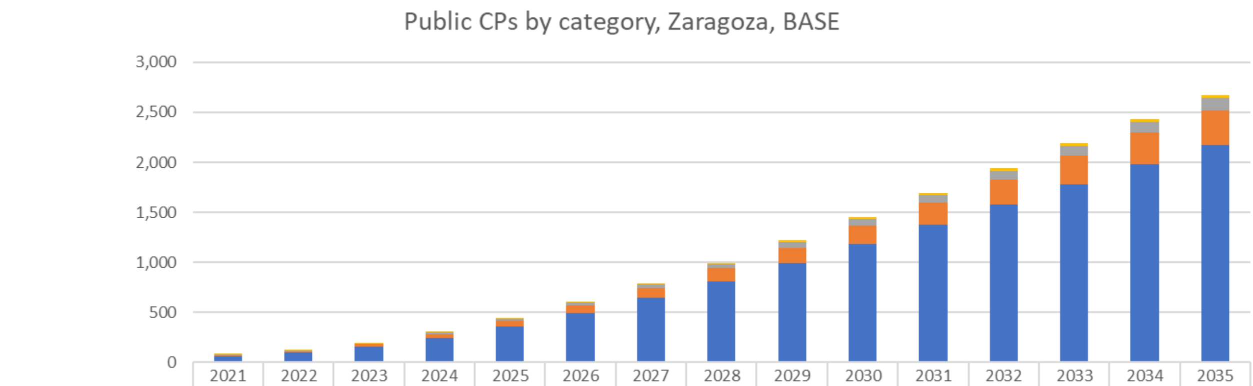


	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
TOTAL Pu.CPs	77	115	190	299	437	602	789	995	1,217	1,450	1,693	1,940	2,188	2,435	2,675
TOTAL Pr. CPs	1,342	3,218	5,320	7,638	10,164	12,888	15,800	18,892	22,154	25,577	29,151	32,867	36,716	40,688	44,775
TOTAL CPs	1,419	3,333	5,510	7,937	10,601	13,489	16,589	19,887	23,371	27,028	30,843	34,807	38,904	43,123	47,450
TOTAL EVs	2,107	3,724	6,117	9,268	13,107	17,527	22,414	27,609	33,035	38,539	43,708	48,693	53,144	56,949	60,171

TOTAL Pu.CPs TOTAL Pr. CPs TOTAL CPs TOTAL EVs

Figure 18. EVS and main categories of CPs (public and private) penetration in Zaragoza (stock, BASE)

Below, the forecast for the distribution of public chargers in Zaragoza



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 4 (>120 kW)	1	1	2	3	5	7	9	11	14	17	19	22	25	28	31
Level 3 (22-120 kW)	3	5	9	14	20	27	36	45	55	66	77	88	100	111	122
Level 2 (7-22 kW)	10	15	25	39	57	78	102	129	158	188	219	251	283	315	346
Level 1 (2.4-7 kW)	62	94	155	243	356	489	642	809	990	1,180	1,377	1,578	1,780	1,981	2,177

Level 1 (2.4-7 kW) Level 2 (7-22 kW) Level 3 (22-120 kW) Level 4 (>120 kW)

Figure 19. Public CPs forecast classified by category in Zaragoza (stock, BASE)

Plan	Aragón 2020-21	Aragón 2021	Zaragoza 2021	Aragón 2022	Aragón 2023	Zaragoza 2022	Zaragoza 2023
Moves II	5.3	1.3	0.7				
	2021-23						
Moves III	34.1	5.0	2.5	13.3	15.8	6.7	7.9
TOTAL	39.4	6.3	3.1	13.3	15.8	6.7	7.9

Table 30. Distribution CPs aids in Zaragoza years 2021 to 2023

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Table 30 distributes Plan Moves II and III for CPs aids between years 2021 and 2023 for Zaragoza city.

Table 31 shows that the Spanish Plan MOVES will allocate around €106.8 million to Zaragoza in financing public and private CPs in the base scenario, from 2021 to 2035, equivalent to €91.3 million in net present value considering an inflation rate of 2% and a financial discount rate of 4%.

% incentives	ZARAGOZA BASE	Total CPs	CPs Withdrawals	NewCPs (units)	Moves Zaragoza (M€)	Moves Zaragoza NPV (M€)
	2021	1,419	28	738	3.1	3.15
	2022	3,333	67	1,981	6.7	6.54
100%	2023	5,510	165	2,342	7.9	7.59
96.5%	2024	7,937	397	2,824	9.2	8.66
93.1%	2025	10,601	636	3,300	10.0	9.24
89.8%	2026	13,489	850	3,738	10.2	9.21
86.6%	2027	16,589	1,078	4,178	9.8	8.75
83.6%	2028	19,887	1,273	4,571	9.0	7.85
80.6%	2029	23,371	1,402	4,886	7.7	6.63
77.8%	2030	27,028	1,419	5,076	6.3	5.26
75.0%	2031	30,843	3,333	7,149	6.6	5.45
72.4%	2032	34,807	5,510	9,473	6.3	5.13
69.8%	2033	38,904	7,937	12,034	5.6	4.46
67.4%	2034	43,123	10,601	14,819	4.7	3.63
65.0%	2035	47,450	13,489	17,817	3.7	2.78
				94,926	106.8	94.32

Table 31. Total foreseen investments in CPs aids for Zaragoza city between 2021 and 2035, BASE

4.2.4.5. Tallinn

Estonia is not providing any aids to charging stations. The only available supporting program is address to EVs acquisitions with a very limited budget.

4.2.5. Summary of supporting actions for CPs (public or private) in the use case cities.

Bellow, a summary of the projections for the supporting actions for the electric charging infrastructure deployment (public or private) in the use case-cities.

Aids CPs BASE	PARIS NPV (M€)	UTRECHT NPV (M€)	TURIN NPV (M€)	ZARAGOZA NPV (M€)	TALLIN NPV (M€)	TOTAL USE CASE
Year	M €	M €	M €	M €	M €	M €
2021	1.43	1.40	0.00	3.15	0.00	5.98
2022	3.11	1.62	0.00	6.54	0.00	11.27
2023	2.83	1.90	1.65	7.59	0.00	13.97
2024	2.73	1.84	1.96	8.66	0.00	15.19
2025	2.67	1.84	2.02	9.24	0.00	15.77
2026	2.83	1.78	2.33	9.21	0.00	16.15
2027	2.91	1.66	2.29	8.75	0.00	15.61
2028	2.97	1.51	2.73	7.85	0.00	15.05
2029	3.75	1.32	2.78	6.63	0.00	14.49
2030	5.75	2.50	3.77	5.26	0.00	17.27
2031	7.37	2.70	3.47	5.45	0.00	18.99
2032	7.51	2.23	4.06	5.13	0.00	18.93
2033	8.39	1.38	3.22	4.46	0.00	17.45
2034	9.05	1.13	3.57	3.63	0.00	17.38
2035	9.53	0.85	1.04	2.78	0.00	14.21
	72.82	25.66	34.88	94.32	0.00	227.69

Table 32. Supporting foreseen public investments for the CPs deployment in the use case cities (2021-2035, BASE)

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4.3. Summary public investments in upfront and taxes' exemptions/reduction for EVs and CPs in the use case cities.

AIDS, CPs & EVs, BASE	PARIS NPV (M€)				UTRECHT NPV (M€)				TURIN NPV (M€)				ZARAGOZA NPV (M€)				TALLINN NPV (M€)				TOTAL NPV
	Upfront EVs	Tax EVs	CPs	SubTotal	Upfront EVs	Tax EVs	CPs	SubTotal	Upfront EVs	Tax EVs	CPs	SubTotal	Upfront EVs	Tax EVs	CPs	SubTotal	Upfront Evs	Tax EVs	CPs	SubTotal	SubTotal
Year	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	M €	
2021	**53.17**	**15.29**	**1.43**	**69.90**	**16.69**	**53.21**	**1.40**	**71.30**	**5.62**	**3.21**	**0.00**	**8.83**	**3.24**	**0.00**	**3.15**	**6.39**	**0.60**	**0.00**	**0.00**	**0.60**	**157.01**
2022	48.72	38.94	3.11	90.77	23.00	74.86	1.62	99.47	10.31	9.46	0.00	19.77	4.89	0.38	6.54	11.81	0.90	0.00	0.00	0.90	222.72
2023	44.50	41.01	2.83	88.34	24.85	94.15	1.90	120.90	13.04	17.88	1.65	32.56	6.59	0.76	7.59	14.94	1.19	0.00	0.00	1.19	257.93
2024	41.36	43.17	2.73	87.25	25.37	113.54	1.84	140.74	14.79	28.10	1.96	44.85	7.86	1.18	8.66	17.69	1.41	0.00	0.00	1.41	291.96
2025	**37.84**	**44.98**	**2.67**	**85.48**	**24.70**	**56.40**	**1.84**	**82.94**	**15.55**	**34.50**	**2.02**	**52.07**	**8.62**	**1.61**	**9.24**	**19.47**	**1.55**	**0.00**	**0.00**	**1.55**	**241.51**
2026	33.93	46.43	2.83	83.18	23.12	12.59	1.78	37.49	15.42	40.38	2.33	58.13	8.87	2.06	9.21	20.14	1.60	0.00	0.00	1.60	200.55
2027	29.95	47.63	2.91	80.49	20.90	13.86	1.66	36.43	14.59	45.59	2.29	62.47	8.67	2.50	8.75	19.93	1.58	0.00	0.00	1.58	200.89
2028	26.08	48.68	2.97	77.73	18.33	15.45	1.51	35.29	13.26	50.16	2.73	66.15	8.12	2.93	7.85	18.90	1.49	0.00	0.00	1.49	199.56
2029	22.39	49.65	3.75	75.79	15.64	16.93	1.32	33.89	11.64	56.01	2.78	70.44	7.32	3.34	6.63	17.29	1.35	0.00	0.00	1.35	198.77
2030	**18.90**	**46.34**	**5.75**	**70.99**	**13.00**	**17.86**	**2.50**	**33.37**	**9.90**	**61.31**	**3.77**	**74.97**	**6.36**	**3.73**	**5.26**	**15.34**	**1.18**	**0.00**	**0.00**	**1.18**	**195.85**
2031	15.59	47.31	7.37	70.27	10.52	18.08	2.70	31.30	8.15	66.11	3.47	77.73	5.31	4.06	5.45	14.81	1.00	0.00	0.00	1.00	195.10
2032	12.39	48.27	7.51	68.18	8.23	17.67	2.23	28.13	6.45	0.00	4.06	10.51	4.24	4.34	5.13	13.70	0.80	0.00	0.00	0.80	121.31
2033	9.28	49.24	8.39	66.90	6.11	16.87	1.38	24.35	4.83	0.00	3.22	8.05	3.17	4.57	4.46	12.20	0.60	0.00	0.00	0.60	112.10
2034	6.19	50.21	9.05	65.45	4.08	15.83	1.13	21.05	3.25	0.00	3.57	6.82	2.12	4.75	3.63	10.50	0.40	0.00	0.00	0.40	104.21
2035	**0.00**	**51.19**	**9.53**	**60.73**	**0.00**	**14.50**	**0.85**	**15.36**	**0.00**	**0.00**	**1.04**	**1.04**	**0.00**	**4.90**	**2.78**	**7.68**	**0.00**	**0.00**	**0.00**	**0.00**	**84.81**
TOTAL (M€)	400.29	668.34	72.82	1,141.46	234.54	551.79	25.66	812.00	146.82	412.70	34.88	594.40	85.37	41.10	94.32	220.80	15.65	0.00	0.00	15.65	2,784.30
PER CAPITA (€)	184.89 €	308.70 €	33.64 €	527.23 €	648.37 €	1,525.38 €	70.94 €	2,244.69 €	65.18 €	183.23 €	15.49 €	263.90 €	124.69 €	60.03 €	137.76 €	322.48 €	34.59 €	0.00 €	0.00 €	34.59 €	470.62 €

Table 33. Projections public investment for the support of electromobility (EVs and CPs) in absolute terms and per capita, in the use case cities, BASE SCENARIO.

The city with a larger investment in mobility incentives, in absolute terms, is Paris, followed by Utrecht, then Turin, Zaragoza and Tallinn. Per capita, the larger investment by far is Utrecht, then Paris, Zaragoza and finally Turin and Tallinn.

4.4. Electricity demand growth caused by the EVs deployment.

4.4.1. Introduction

This chapter will address the electrical impact at city level derived from the deployment of electric vehicles. This research aims to assess the approximate economic impact of deployment on each of these cities. The calculations will start from some premises based on approximate data that return an order of magnitude for the comparison between cities. The main assumptions that have been made were the following:

- The consumption of 9 commonly used EVs has been evaluated, establishing three categories; large, medium, and small for which the average consumption has been indicated.
- It must be pointed out that this consumption can vary from one city to another depending on geography (for example, if a city is very hilly, consumption may be much higher than estimated, and therefore the impact on energy networks underestimated). However, we have considered these average consumptions to simplify the calculation.
- Percentages of use of each of the mentioned sizes have been established based on an UK recent report and analysis[29] written after the monitoring of a large fleet of EVs; with the result of 21% for large, 44% for medium and 35% for small.
- The average efficiency of the batteries has been estimated at 90%[30] Battery charging efficiency can vary, but it is often 84% to 93%, so 90% can be considered an average.
- Based on the average area of the target cities, an annual mileage of approximately three times the maximum diameter of the target cities has been established. Although it is clear that the configuration of all of them is very different (for instance the pedestrian areas, the mobility habits, etc), it was considered that the purchase of an electric vehicle is motivated mostly to go inside the cities and park there with the usual advantages (free parking, etc). Whoever buys an electric vehicle in a pedestrian city does so to move from the suburbs more easily and go to the city center of such towns.
- The total energy demand by those cars were estimated using the average consumption figures for the proposed mileage and then comparing it with the total city energy demand, calculating the percentage represented by the electromobility over time (no trucks or micromobility was included). The average MWh/inhabitant was taken from the report "European Electricity Review 2023"[31] that provides country figures. Then the city population was compared with the country population provided the city energy by the rule of three.

[29] Wai Ming Cheung, 8 June 2022, A scenario-based approach to predict energy demand and carbon emissions of electric vehicles on the electric grid.

[30] Richardson DB (2013) Electric vehicles and the electric grid: a review of modeling approaches, impacts, and renewable energy integration.Renew Sustain Energy Rev 19:247–254. https:// doi. org/ 10. 1016/j. rser. 2012. 11. 042

[31] EMBER, David Jones, 1 January 2023, European Electricity Review 2023

- The total energy requirement was then converted in equivalent renewable energy considering an average load factor of 28.5[32]. This exercise intends to evaluate how much money should be invested if all the new electricity for the electromobility should come from Renewables although this won't be necessarily the case.
- Latterly, this amount of energy was monetized with an average PPA (Power Purchase Agreement) for renewable taken from the last available report of Pexapark entity, being this figure 62 €/MWh[33] on average for Europe, but it was broken down by country, as there are substantial differences. The April 2023 figures were taken as an average as they are in between the expensive figures generated by the Ukraine war and the cheapest of 2021 and before. The figures till 2035 were not modified as these numbers are very volatile and complex to forecast.
- Then, as the electricity demand is cumulative and there is an existing share of renewable per country[34],[35], it was supposed that the current REs share is already installed and therefore this amount was deducted from the Administrations' future investments and then the remaining quantity monetized.
- The European Council has agreed to reduce energy consumption at EU level by 2030, by 36% for final energy consumption and 39% for primary energy consumption. The key target of a 36% reduction in final energy consumption at EU level would be binding. The targets use a new baseline and correspond to a 9%[36] reduction target from 2020. As the EC has as target this reduction between 2020 and 2030, it was considered a progressive reduction of 0.1% per year to reach 13% in 2035.
- Finally, the economic investment required was distributed proportionally to the new registrations and then, the NPV was calculated with a 2% of inflation rate and a 4% of FDR.

4.4.2. Preliminary calculations

As mentioned, a representation of the existing EVs were recovered from the M.W Cheung report as reported below,

OEM	EV name	Battery Capacity (kWh)	Av.distance (km)	Consumption (kWh/100 km)	Type
Tesla	Model S	85.0	424.0	20.0	L
Audi	E-Tron	71.0	240.0	29.6	L
Kia	Soul	27.0	211.2	12.8	M
Nissan	Leaf	24.0	198.4	12.1	M
Ford	Focus-e	23.0	121.6	18.9	M
BMW	i3	22.0	128.0	17.2	M
Renault	Zoe	22.0	238.4	9.2	M
Volkswagen	E-Up	18.7	148.8	12.6	S
Mitsubitshi	Outlander-e	12.0	51.2	23.4	S

Table 34. Some EVs features in relation to battery capacity, distance, and consumption.

[32] National Statistics publication Digest of UK Energy Statistics (DUKES) produced by the Department for Business, Energy and Industrial Strategy (BEIS), 28Jul22. https://assets.publishing.service.gov.uk.

[33] Pexapark 10-year PPA trends, edition April 2023

[34] European Environment Agency 2023, https://www.eea.europa.eu/ims/share-of-energy-consumption-from

[35] Enerdata, 2023, https://yearbook.enerdata.net/renewables/renewable-in-electricity-production-share.html

[36] https://www.consilium.europa.eu/es/press/press-releases/2022/06/27/fit-for-55-council-agrees-on-higher-targets-for-renewables-and-energy-efficiency/ 27 June 2022

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These vehicles were anonymized and classified in three major groups as described below,

EVs Clasification	Battery Capacity (kWh)	Av.distance (km)	Consumption (kWh/100 km)	% EVs fleet
Large EVs	78	332	24.8	21%
Medium EVs	24	180	15.2	44%
Small EVs	15	100	12.6	35%

Table 35. Anonymized group of EV vehicles classified by features.

Country	PPA REs (€/MWh)
France	60.2
Netherlands	56.7
Italy	75.6
Spain	40.9
Estonia	62.0
	RES Aver.Load factor
	28.5%

Table 36. Average PPA Res, and average load factor for REs

The average PPA for REs was taken from the Pexapark reports and reflects an average foreseen figure for the next 15 years, although subjected to suffer modifications, as this is a very volatile figure.

The selected load factor is the average from all renewables and include, onshore and offshore wind, marine energy, solar PV, small and large scale hydro, and bioenergy excluding cofiring and non-biodegradable wastes.

City Data	Population 2021	Total Energy 2021 (GWh)	MWh/inh 2021
Paris	2,200,000	16,500	7.5
Utrecht	361,700	2,387	6.6
Turin	886,800	4,815	5.4
Zaragoza	693,200	3,868	5.6
Tallinn	400,100	2,797	7.0

Table 37. Calculation of total energy consumed by the use case cities based on population and per capita country consumption in 2021.

Country Data	Share REs 2021
France	23%
Netherlands	33%
Italy	41%
Spain	47%
Estonia	27%

Table 38. Share of REs by country in 2021

Use case city	Area (km^2)	Ave. Diameter	Km/day	Km/año
Paris Department	105	11.6	34.7	**12,661**
Turin	130	12.9	38.6	**14,088**
Zaragoza	200	16.0	47.9	**17,474**
Utrecht	100	11.3	33.9	**12,356**
Tallin	159	14.2	42.7	**15,580**

Table 39. Calculation of EV average mileage per year and use case city.

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4.4.3. Main Results

4.4.3.1. Paris

PARIS						Yearly km	12,661						
BASE	TOTAL EVs Stock (units)	New regist. EV (units)	New Reg large EVs (units)	New Reg,Med, EVs (units)	New Reg. Small EVs (units)	Energy New Reg. EVs (GWh)	Cum Total Energy EVs (GWh)	Cum. Total Energy city (GWh)	% Cum Reg. EV/City Energy	Energy New RES for EVs (GWh)	Invest REs (M€)	Invest REs NTV (M€)
2021	36,720	15,289	3,211	6,727	5,351	31.6	75.9	16,500.0	0.5%	110.8	6.67	6.67
2022	51,960	15,304	3,214	6,734	5,356	31.6	107.3	16,335.0	0.7%	110.9	6.68	6.42
2023	67,230	15,350	3,224	6,754	5,373	31.7	138.9	16,171.7	0.9%	111.3	6.70	6.19
2024	82,827	15,757	3,309	6,933	5,515	32.6	171.1	16,009.9	1.1%	114.2	6.88	6.11
2025	98,540	16,034	3,367	7,055	5,612	33.1	203.6	15,849.8	1.3%	116.2	7.00	5.98
2026	114,025	16,126	3,386	7,095	5,644	33.3	235.6	15,691.3	1.5%	116.9	7.04	5.78
2027	129,191	16,127	3,387	7,096	5,645	33.3	266.9	15,534.4	1.7%	116.9	7.04	5.56
2028	142,094	16,107	3,383	7,087	5,638	33.3	293.6	15,379.1	1.9%	116.8	7.03	5.34
2029	155,006	16,116	3,384	7,091	5,641	33.3	320.2	15,225.3	2.1%	116.8	7.03	5.14
2030	167,423	16,184	3,399	7,121	5,664	33.4	345.9	15,073.0	2.3%	117.3	7.06	4.96
2031	175,698	16,327	3,429	7,184	5,714	33.7	363.0	14,922.3	2.4%	118.4	7.12	4.81
2032	176,957	16,548	3,475	7,281	5,792	34.2	365.6	14,773.1	2.5%	120.0	7.22	4.69
2033	178,491	16,838	3,536	7,409	5,893	34.8	368.8	14,625.4	2.5%	122.1	7.35	4.59
2034	180,323	17,182	3,608	7,560	6,014	35.5	372.5	14,479.1	2.6%	124.6	7.50	4.50
2035	182,125	17,559	3,687	7,726	6,146	36.3	376.3	14,334.3	2.6%	127.3	7.66	4.42
		242,848	50,998	106,853	84,997	501.7	RES Av.Load factor	28.5%	1.8%	1,760.4	106.0	81.2
											IR	2.00%
											FDR	4.00%

Table 40. Calculation of required investment to cover the electricity of the new EVs in the city of Paris.

In Paris, the EVs energy requirements represent the 0.9 % in 2021 and will reach the 2.6% in 2035 with an average of 1.8%. There will be a total of 502 GWh requirements during the 15 years that converted in Renewables supposes 1,760 GWh. Considering the average cost for the PPA in France of 60.2 €/MWh, a total of €81 million NPV will be required in the 15 years (from 2021 to 2035) in the base case scenario. The inflation rate was a 2% and the Financial Discount Rate, a 4%.

4.4.3.2. Utrecht

UTRECHT			Yearly km	12,356								
BASE	TOTAL EVs Stock (units)	New EV reg (units)	New Reg large EVs (units)	New Reg,Med, EVs (units)	New Reg. Small EVs (units)	Energy New Reg. EVs (GWh)	Cum Total Energy EVs (GWh)	Cum. Total Energy city (GWh)	% Cum Reg. EV/City Energy	Energy New REs for EVs (GWh)	Invest REs (M€)	Invest REs NTV (M€)
2021	21,991	5,455	1,145	2,400	1,909	11.0	44.3	2,387.2	1.9%	38.6	2.2	2.2
2022	28,660	8,212	1,725	3,613	2,874	16.6	57.8	2,363.3	2.4%	58.1	3.3	3.2
2023	36,605	9,745	2,046	4,288	3,411	19.6	73.8	2,339.7	3.2%	68.9	3.9	3.6
2024	45,535	10,987	2,307	4,834	3,845	22.2	91.8	2,316.3	4.0%	77.7	4.4	3.9
2025	55,122	11,901	2,499	5,236	4,165	24.0	111.1	2,293.2	4.8%	84.2	4.8	4.1
2026	67,358	12,492	2,623	5,497	4,372	25.2	135.8	2,270.2	6.0%	88.4	5.0	4.1
2027	79,870	12,796	2,687	5,630	4,478	25.8	161.0	2,247.5	7.2%	90.5	5.1	4.1
2028	90,172	12,872	2,703	5,664	4,505	26.0	181.8	2,225.0	8.2%	91.1	5.2	3.9
2029	100,479	12,797	2,687	5,631	4,479	25.8	202.6	2,202.8	9.2%	90.5	5.1	3.8
2030	109,370	12,654	2,657	5,568	4,429	25.5	220.5	2,180.8	10.1%	89.5	5.1	3.6
2031	116,442	12,527	2,631	5,512	4,384	25.3	234.8	2,159.0	10.9%	88.6	5.0	3.4
2032	120,719	12,489	2,623	5,495	4,371	25.2	243.4	2,137.4	11.4%	88.4	5.0	3.3
2033	123,573	12,598	2,646	5,543	4,409	25.4	249.1	2,116.0	11.8%	89.1	5.1	3.2
2034	125,474	12,888	2,706	5,671	4,511	26.0	253.0	2,094.8	12.1%	91.2	5.2	3.1
2035	126,929	13,357	2,805	5,877	4,675	26.9	255.9	2,073.9	12.3%	94.5	5.4	3.1
		173,768	36,491	76,458	60,819	350.3	RES Av.Load factor	28.5%	7.7%	1,229.3	69.7	52.4
											IR	2.00%
											FDR	4.00%

Table 41. Calculation of required investment to cover the electricity of the new EVs in the city of Utrecht.

In Utrecht, the EVs energy requirements represent the 1.9 % in 2021 and will reach the 12.3% in 2035 with an average of 7.7%. There will be a total of 350 GWh requirements during the 15 years that converted in Renewables supposes 1,229 GWh. Considering the average cost for the PPA in the Netherlands of 56.7 €/MWh, a total of €52.4 million NPV will be required in the 15 years (from

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2021 to 2035) in the base case scenario. The inflation rate was a 2% and the Financial Discount Rate, a 4%.

4.4.3.3. Turin

TURIN			Yearly km	14,088								
BASE	TOTAL EVs Stock (units)	New EV reg (units)	New Reg large EVs (units)	New Reg,Med, EVs (units)	New Reg. Small EVs (units)	Energy New Reg. EVs (GWh)	Cum Total Energy EVs (GWh)	Cum. Total Energy city (GWh)	% Cum Reg. EV/City Energy	Energy New REs for EVs (GWh)	Invest REs (M€)	Invest REs NTV (M€)
2021	46,551	5,352	1,124	2,355	1,873	12.3	107.0	4,815.3	2.2%	43.2	3.3	3.3
2022	57,270	10,726	2,253	4,720	3,754	21.6	131.7	4,767.2	2.8%	75.9	5.7	5.5
2023	72,154	14,893	3,128	6,553	5,213	30.0	165.9	4,719.5	3.5%	105.4	8.0	7.4
2024	90,804	18,668	3,920	8,214	6,534	37.6	208.7	4,672.3	4.5%	132.1	10.0	8.9
2025	112,597	21,831	4,584	9,606	7,641	44.0	258.8	4,625.6	5.6%	154.4	11.7	10.0
2026	136,802	24,281	5,099	10,684	8,499	49.0	314.5	4,579.3	6.9%	171.8	13.0	10.7
2027	162,711	26,022	5,465	11,450	9,108	52.5	374.0	4,533.5	8.3%	184.1	13.9	11.0
2028	189,562	27,135	5,698	11,939	9,497	54.7	435.8	4,488.2	9.7%	192.0	14.5	11.0
2029	216,943	27,759	5,829	12,214	9,716	56.0	498.7	4,443.3	11.2%	196.4	14.8	10.8
2030	244,348	28,072	5,895	12,352	9,825	56.6	561.7	4,398.9	12.8%	198.6	15.0	10.5
2031	270,287	28,267	5,936	12,438	9,894	57.0	621.3	4,354.9	14.3%	200.0	15.1	10.2
2032	293,468	28,533	5,992	12,554	9,987	57.5	674.6	4,311.3	15.6%	201.9	15.3	9.9
2033	311,772	29,031	6,096	12,774	10,161	58.5	716.7	4,268.2	16.8%	205.4	15.5	9.7
2034	326,754	29,875	6,274	13,145	10,456	60.2	751.1	4,225.5	17.8%	211.3	16.0	9.6
2035	339,196	31,111	6,533	13,689	10,889	62.7	779.7	4,183.3	18.6%	220.1	16.6	9.6
		351,557	73,827	154,685	123,045	710.3	RES Av.Load factor	28.5%	10.0%	2,492.3	188.4	138.1
											IR	2.00%
											FDR	4.00%

Table 42. Calculation of required investment to cover the electricity of the new EVs in the city of Turin.

In Turin, the EVs energy requirements represent the 2.2 % in 2021 and will reach the 18.6% in 2035, with an average of 10%. There will be a total of 710 GWh requirements during the 15 years that converted in Renewables supposes 2,492 GWh. Considering the average cost for the PPA in Italy of 75.6 €/MWh, a total of €138 million NPV will be required in the 15 years (from 2021 to 2035) in the base case scenario. The inflation rate was a 2% and the Financial Discount Rate, a 4%.

4.4.3.4. Zaragoza

ZARAGOZA			Yearly km	17,474								
BASE	TOTAL EVs Stock (units)	New EV reg (units)	New Reg large EVs (units)	New Reg,Med, EVs (units)	New Reg. Small EVs (units)	Energy New Reg. EVs (GWh)	Cum Total Energy EVs (GWh)	Cum. Total Energy city (GWh)	% Cum Reg. EV/City Energy	Energy New REs for EVs (GWh)	Invest REs (M€)	Invest REs NTV (M€)
2021	2,107	983	206	433	344	2.8	6.0	3,868.1	0.2%	9.8	0.4	0.4
2022	3,724	1,620	340	713	567	4.6	10.6	3,829.4	0.3%	16.2	0.7	0.6
2023	6,117	2,396	503	1,054	839	6.8	17.4	3,791.1	0.5%	24.0	1.0	0.9
2024	9,268	3,158	663	1,389	1,105	9.0	26.4	3,753.2	0.7%	31.6	1.3	1.1
2025	13,107	3,852	809	1,695	1,348	11.0	37.4	3,715.6	1.0%	38.5	1.6	1.3
2026	17,527	4,446	934	1,956	1,556	12.7	50.0	3,678.5	1.4%	44.5	1.8	1.5
2027	22,414	4,927	1,035	2,168	1,724	14.0	63.9	3,641.7	1.8%	49.3	2.0	1.6
2028	27,609	5,293	1,111	2,329	1,852	15.1	78.7	3,605.3	2.2%	53.0	2.2	1.6
2029	33,035	5,557	1,167	2,445	1,945	15.8	94.2	3,569.2	2.6%	55.6	2.3	1.7
2030	38,539	5,739	1,205	2,525	2,009	16.4	109.9	3,533.5	3.1%	57.4	2.3	1.7
2031	43,708	5,867	1,232	2,581	2,053	16.7	124.6	3,498.2	3.6%	58.7	2.4	1.6
2032	48,693	5,968	1,253	2,626	2,089	17.0	138.8	3,463.2	4.0%	59.7	2.4	1.6
2033	53,144	6,071	1,275	2,671	2,125	17.3	151.5	3,428.6	4.4%	60.7	2.5	1.6
2034	56,949	6,202	1,302	2,729	2,171	17.7	162.4	3,394.3	4.8%	62.0	2.5	1.5
2035	60,171	6,379	1,340	2,807	2,233	18.2	171.6	3,360.4	5.1%	63.8	2.6	1.5
		68,457	14,376	30,121	23,960	195.2	RES Av.Load factor	28.5%	2.4%	684.9	28.0	20.3
											IR	2.00%
											FDR	4.00%

Table 43. Calculation of required investment to cover the electricity of the new EVs in the city of Zaragoza.

In Zaragoza, the EVs energy requirements represent the 0.2 % in 2021 and will reach the 5.1% in 2035 with an average of 2.4 %. There will be a total of 195 GWh requirements during the 15 years that converted in Renewables supposes 685 GWh. Considering the average cost for the PPA in

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Spain of 40.9 €/MWh, a total of €20.3 million NPV will be required in the 15 years (from 2021 to 2035) in the Base case scenario. The inflation rate was a 2% and the Financial Discount Rate, a 4%.

4.4.3.5. Tallinn

TALLIN			Yearly km	15,580								
BASE	TOTAL EVs Stock (units)	New EV reg (units)	New Reg large EVs (units)	New Reg,Med, EVs (units)	New Reg. Small EVs (units)	Energy New Reg. EVs (GWh)	Cum Total Energy EVs (GWh)	Cum. Total Energy city (GWh)	% Cum Reg. EV/City Energy	Energy New REs for EVs (GWh)	Invest REs (M€)	Invest REs NTV (M€)
2021	3,157	488	103	215	171	1.2	8.0	2,796.7	0.3%	4.4	0.3	0.3
2022	3,963	807	169	355	282	2.1	10.1	2,768.7	0.4%	7.2	0.4	0.4
2023	5,122	1,170	246	515	409	3.0	13.0	2,741.0	0.5%	10.4	0.6	0.6
2024	6,654	1,533	322	674	536	3.9	16.9	2,713.6	0.6%	13.7	0.8	0.8
2025	8,512	1,871	393	823	655	4.8	21.6	2,686.5	0.8%	16.7	1.0	1.0
2026	10,656	2,170	456	955	760	5.5	27.1	2,659.6	1.0%	19.4	1.2	1.2
2027	13,037	2,421	508	1,065	847	6.2	33.1	2,633.0	1.3%	21.6	1.3	1.3
2028	15,606	2,622	551	1,154	918	6.7	39.7	2,606.7	1.5%	23.4	1.4	1.4
2029	18,315	2,776	583	1,221	971	7.1	46.6	2,580.6	1.8%	24.8	1.5	1.5
2030	21,126	2,889	607	1,271	1,011	7.3	53.7	2,554.8	2.1%	25.8	1.6	1.5
2031	24,006	2,973	624	1,308	1,040	7.6	61.0	2,529.3	2.4%	26.5	1.6	1.6
2032	26,937	3,036	638	1,336	1,063	7.7	68.5	2,504.0	2.7%	27.1	1.7	1.6
2033	29,910	3,092	649	1,360	1,082	7.9	76.0	2,479.0	3.1%	27.6	1.7	1.6
2034	32,928	3,150	662	1,386	1,103	8.0	83.7	2,454.2	3.4%	28.1	1.7	1.7
2035	35,964	3,219	676	1,417	1,127	8.2	91.4	2,429.6	3.8%	28.7	1.8	1.7
		34,218	7,186	15,056	11,976	87.0	RES Av.Load factor	28.5%	1.7%	305.2	18.9	18.2
											IR	2.00%
											FDR	4.00%

Table 44. Calculation of required investment to cover the electricity of the new EVs in the city of Tallinn.

In Tallinn, the EVs energy requirements represent the 0.3 % in 2021 and will reach the 3.8 % in 2035, with an average of 1.7%. There will be a total of 87 GWh requirements during the 15 years that converted in Renewables supposes 305 GWh. Considering the average cost for the PPA in Estonia of 62 €/MWh, a total of €18.2 million NPV will be required in the 15 years (from 2021 to 2035) in the base case scenario. The inflation rate was a 2% and the Financial Discount Rate, a 4%.

4.4.4. Summary of Results

Bellow, the summary of the required investment in net present value to cover the electricity demand generated by the EVs deployment (BEV and PHEV) from 2021 to 2035 in the INCITEV use case cities.

BASE	PARIS Invest REs NTV (M€)	UTRECHT Invest REs NTV (M€)	TURIN Invest REs NTV (M€)	ZARAGOZA Inv. REs NTV (M€)	TALLIN Invest REs NTV (M€)
2021	6.67	2.19	3.26	0.40	0.27
2022	6.42	3.17	5.52	0.64	0.43
2023	6.19	3.61	7.36	0.91	0.62
2024	6.11	3.92	8.88	1.15	0.82
2025	5.98	4.08	9.98	1.35	1.00
2026	5.78	4.12	10.67	1.50	1.15
2027	5.56	4.06	11.00	1.59	1.29
2028	5.34	3.92	11.03	1.65	1.39
2029	5.14	3.75	10.85	1.66	1.48
2030	4.96	3.57	10.55	1.65	1.54
2031	4.81	3.39	10.21	1.62	1.58
2032	4.69	3.25	9.91	1.59	1.61
2033	4.59	3.16	9.70	1.55	1.64
2034	4.50	3.10	9.60	1.52	1.68
2035	4.42	3.09	9.61	1.51	1.71
	81.19	52.39	138.12	20.28	18.21

Table 45. Investments on REs to cover the EVs electric demand in the use case cities.

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4.5. Grid adaptation investments.

4.5.1. Introduction

Grid adaptation costs remains as one of the most difficult factors to evaluate as the grid conditions are very different from one place to other. It's important to note that the specific ownership structure of TSOs and DSOs can vary significantly between countries and regions, and there may be cases where a combination of public and private ownership exists. The energy market regulations and policies of each country dictate the ownership and operational models for TSOs and DSOs. Specifically, in the use case countries, the situation is as follows:

- In France, TSOs (Transmission System Operators) and DSOs (Distribution System Operators) can be both public and private entities, depending on the specific organization. The main TSO in France is RTE (Réseau de Transport d'Électricité), which is responsible for the high-voltage electricity transmission system. In the country, there are numerous DSOs responsible for the distribution of electricity. These DSOs can be both public and private entities, depending on the geographic region.
- In the Netherlands, TSOs (Transmission System Operators) and DSOs (Distribution System Operators) are primarily regulated as public entities. The Dutch electricity and gas transmission networks are managed by TenneT, which is a public TSO. TenneT is responsible for the transmission of electricity and gas at high voltages across the country. On the other hand, DSOs are responsible for the distribution of electricity and gas at lower voltages to end consumers. In the Netherlands, the DSOs are organized as regional entities and are predominantly publicly owned. Each region typically has its own DSO, which is responsible for maintaining and operating the local distribution networks.
- In Italy, both Transmission System Operators (TSOs) and Distribution System Operators (DSOs) can be either public or private entities. The energy sector in Italy has undergone several reforms in recent years, aiming to promote competition and improve efficiency. The main TSO in Italy is Terna S.p.A., which is a publicly listed company but with the majority of shares owned by Cassa Depositi e Prestiti, an Italian state-owned financial institution. In Italy, there are multiple DSOs operating in different regions or areas. Some of these DSOs are publicly owned, while others are privately owned or operated by local municipalities or consortiums.
- In Spain, both Transmission System Operators (TSOs) and Distribution System Operators (DSOs) can be either public or private entities. The energy sector in Spain has undergone various reforms over the years, and the ownership structure of TSOs and DSOs has evolved as a result. Historically, the TSO in Spain, known as Red Eléctrica de España (REE), was a publicly owned company. However, in recent years, the Spanish government has taken steps to privatize REE. Some DSOs in Spain are publicly owned, operated by municipal or regional governments, while others are privately owned.
- In Estonia, both Transmission System Operators (TSOs) and Distribution System Operators (DSOs) are predominantly public entities. The primary TSO in Estonia is Elering, which is a state-owned company. On the other hand, DSOs in Estonia are regional companies responsible for the distribution of electricity to end consumers. The majority of DSOs in Estonia are also publicly owned, although some private companies may operate in specific regions.

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In this report, the grid adaptation cost will be added to the public investments balance plate although as we have seen, the ownership is not necessarily public. The increased generation costs (through renewables) and the transmission and distribution investments will impact and increase necessarily the retail rates for the charging electricity.

4.5.2. Initial considerations

According to the latest ChargeUP[37] report, at a European level, 80% of chargers are installed in homes, 10% in the workplace, 8% are public AC chargers and 2%, public DC chargers with higher power. Therefore, the charging of electric vehicles is not homogeneous as depends mainly on the charging point location derived from the user preferences and conditions, as can be seen in the normalized charging profile figure[38] below. The weekend profile also clearly differs from the working one.

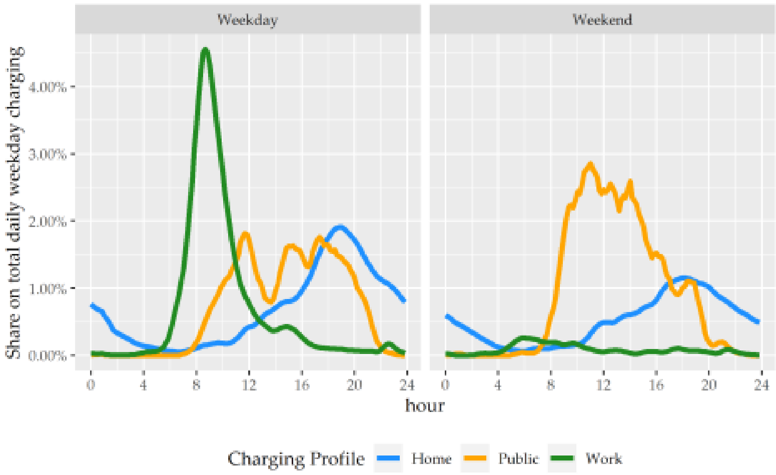

Figure 20. Daily profiles by type of charging and day type

The existence of these peaks of maximum demand is what causes that if the number of users is sufficiently increased, without flexible management systems, the capacity of the network can be compromised and generate congestion problems. Congestion at grid level results in loss of power quality and even outages. This can lead to a damage of household appliances, data loss or automatic resets.

The potential grid problems will depend on numerous factors difficult to standardize in a generic type document such as the one raised in this deliverable since they can be caused by an excessive density of electric vehicles at a point in the grid, the existence of fast or superfast charging chargers that increase the overall power, the unpredictable behaviour of users, the deficiencies of the network itself at the time when more electric vehicles are incorporated into the area or the lack of intelligent management systems, among others.

Unidirectional smart charging, also known as V1G, get advantage of the extra time that majority of EV owners has in the charging process when charging at home or at the workplace. Most EV users charge their vehicles at home in the early evening (7 pm) and do not need to leave for work again until early morning (7 am), this leaves plenty of room to schedule charging in a smart way. Simply delaying the moment of charging towards the night ensures that the charging peak does

[37] ChargeUP Europe, R. Samuels, F. Timmermans, 2023 State of the Industry Report

[38] ResearchGate, F. Nerotti, M. Noussan, Cross-Country Comparison of Hourly Mixes for EV Charging Profile

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not coincide with the household peak (cooking, washing, heating, …). In addition, the potential of smart charging is not limited to its use at home. When parked during the day, smart charging can be aligned with renewable energy production.

In these circumstances, the loading process can be temporarily interrupted when there is a risk of imbalance between supply and demand and restarted later automatically when the congestion situation has subsided. To proceed in this way, a centralized management of the car's data is needed, but this can generate some social impact[39] if the user cannot intervene in this process, for example in cases of charging urgency (deriving in range anxiety). In addition, the control strategy may be designed in a way that could harm the user economically. In general, there are three criteria that are not necessarily convergent; it is possible to design the load control looking for the minimum cost for the user, especially if the rate varies hourly, it is possible to design it to save emissions and in this, the expansion of the network increases these emissions affecting the electricity tariffs, and finally it can be designed to optimise the battery deterioration that progressively loses efficiency if there are excessive charging and discharging cycles. These three strategies are not necessarily convergent as mentioned and in favour of the EV owner.

Bidirectional V2G is the most advance smart charging when the vehicle is able to allow bidirectional exchange with the grid. This opens an entire new range of opportunities; bidirectional charging is a particularly promising way to store energy on the grid[40]. The technology would be a timely solution because the need for grid storage is expected to rise during the transition to renewable energy. As mentioned, to be implemented, bidirectional charging would require grid operators to partner with EV owners, and that would create new business models to compensate them for depleting their batteries. Moreover, the EV can function as a power backup for buildings, contribute to local congestion management, optimize consumption on building or neighbourhood level and maximize the use of renewable energy sources. However, implementing V2G technology requires more complex hardware infrastructure than V1G: the communication and energy flow need to be bidirectional to enable the advanced services. All electric vehicles have an AC/DC adapter to charge the battery. This adapter is sufficient in V1G mode (from EVSE to vehicle). Whether it is fast or super-fast charging, these adapters are usually included within the EVSE. However, in the V2G configuration, a second DC/AC adapter is required to inject electricity into the network. Most of the current vehicles do not include this second adapter so the V2G option is not currently viable for most existing EVs. This entire process must be controlled by appropriate software that must interact with an external control to determine the ideal loading and unloading times. This system requires real-time data, forecasts and interacting with the user to determine their preferences, which is not easy.

The advance of these two technologies, together with those inherent to the electric vehicle itself, batteries, charging systems, etc., directly impacts the investment needs in the grid and therefore, it is difficult to evaluate the necessary investments if a model is not developed with very specific assumptions that, without any doubt, can be modified in the real world, at the moment in which some of the technologies indicated evolve. Therefore, at this point we will try to evaluate the grid extra costs for administrations for the use cases' cities in an approximate and macro way without a more detailed analysis on the specific city conditions.

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[39] EC. EU Smart Cities Information System. Electric Vehicles & the grid. Solution boioklet. October 2022

[40] Mc Kinsey, J. Colzada, F. Naguele, S. Ramanathan, P. Schaufuss. Europe's EV opportunity and the charging infrastructure needed to meet it. October 2022.

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4.5.3. Technical and cost considerations

The cost of adapting the electric vehicle (EV) charging infrastructure can vary depending on several factors, including the scale of the adaptation, location, existing infrastructure, and the specific requirements of the charging system. Adapting the grid to support EV charging often requires upgrades to the electrical infrastructure, such as transformers, distribution lines, and substations. The cost of these upgrades can vary widely based on the existing infrastructure and the capacity needed to support the charging demand. Costs for electrical infrastructure upgrades can range from thousands to millions of euros. It is worthy to mention that building a networked charging system with communication capabilities requires additional infrastructure, including data connections, software systems, and monitoring equipment. These costs can also vary based on the desired level of connectivity and functionality. They typically involve an upfront investment for hardware and software, as well as ongoing maintenance and subscription fees for network services. Finally, as the number of EVs increases, grid management and load balancing become critical to ensure the smooth operation of the charging infrastructure. Implementing smart charging solutions and demand response programs may be necessary to optimize charging patterns and avoid overloading the grid during peak periods. The costs associated with grid management and load balancing can involve investments in software systems, data analytics, and grid monitoring technologies. Here are some of the equipment upgrades that may be necessary and their associated costs:

1. Substations: EV charging stations require a significant amount of power, which may require upgrading local substations. The cost of upgrading a substation can vary widely depending on the existing infrastructure and the extent of the upgrades needed. Distribution substations are usually smaller and range in capacity from €500,000 to €5 million. Transmission substations can range from €5 million to several tens of millions of euros.

2. Transformers: Transformers step up or step down the voltage of electricity as it moves through the grid. Upgrading transformers to handle the additional load from EV charging stations can cost several thousand euro per unit. On average, for transformers in the 5 MVA to 100 MVA range, the prices can range from approximately €100,000 to €5 million or more.

3. Distribution Lines (typically from 4 kV to 35 kV) : The existing distribution lines may need to be reinforced or expanded to accommodate the increased electricity demand. This can involve upgrading wires, poles, and related equipment. The cost depends on the length of the lines, the required capacity, and the complexity of the installation. For overhead distribution lines, the cost typically ranges from €6,000 to €30,000 per km. Underground distribution lines can range from €60,000 to €300,000 per km.

4. Transmission Lines (typically from 69 kV-230 kV): Electric vehicle charging infrastructure may require new power lines and cables to be installed to connect charging stations to the grid. The cost depends on the distance, voltage requirements, and any necessary digging or construction work. Some references; Overhead Transmission Lines; High Voltage (HV) lines (138 kV to 230 kV): €0.3 million to €1.25 million per km. Medium Voltage (MV) lines (69 kV to 115 kV): €0.15 million to €0.6 million per km. Underground Transmission Cables; High Voltage Direct Current (HVDC) cables: €3 million to €9 million per km. High Voltage Alternating Current (HVAC) cables: €1.8 million to €6.2 million per km.

5. Switchgear and Protection Devices: Upgrades to switchgear and protection devices may be necessary to ensure the safe and reliable operation of the grid with the increased load

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from EV charging stations. The costs will depend on the specific requirements and complexity of the system but can range from thousands to tens of thousands of euros.

6. Monitoring and Control Systems: Implementing advanced monitoring and control systems can help manage the increased demand from EVs efficiently. This includes smart grid technologies, load management systems, and communication infrastructure. Costs can vary significantly based on the scale of the system and the desired functionalities.

Although, it is complex to give a single solution, some common elements can be identified to provide an overview of the potential grid issues related to different use cases. The following table[41] provided by ENTSO, summarises some of the most interesting use cases considered in terms of power and energy issues, grid reinforcement needs and potential flexibility services.

Use cases	Connection characteristics	Grid Impact analysis	
› Public, Slow Charging Street parking, Social/recreational areas, Park & Ride › Home/private Charging Single houses, apartments, hotels, offices › Company Fleets Pool vehicles (utilities, public services, private companies)	› Slow, AC charging › Connection to low voltage lines › Medium/long connection time	Power issues:	In the event of multiple installations, significant impacts can be expected in Secondary Substations (MV/LV transformers) and MV and LV lines where power flows sum up. Peak shaving solutions could significantly limit this problem. Voltage issues can be expected in rural areas.
		Energy issues:	no significant issues in terms of energy supply.
		Grid reinforcement:	It could be necessary to replace MV/LV transformers and/or MV and LV feeders.
		Potential for flexibility:	High potential due to long connection times. Best case: company fleets with predictable use patterns.
› High Power Chargers – "Fuel Station" Model Fast chargers (50–150 kW) in existing fuel stations › Urban Hyper Hubs Hyper fast chargers (150–350 kW) in new dedicated areas. Designed for cars in urban areas.	› Fast or ultrafast, DC charging › Connection to medium voltage lines, through shared (fuel station) or dedicated (hyper hub) POD. › Short connection time	Power issues:	Also, single installations may require a significant increase of power absorption. Loads generated by EV charging add up to other LV and MV loads. The impacts could be significant, also on MV lines.
		Energy issues:	energy withdrawal from the network could be significant but no issues are expected
		Grid reinforcement:	it could be necessary to install a dedicated MV substation with additional cost and time. MV lines (and in some cases, MV/LV transformers) could need to be replaced.
		Potential for flexibility:	minimum potential due to time constraints. Energy storage systems could be installed to limit peak power and to allow the participation to flexibility services
› Bus Depots High number (tens/hundreds) of buses performing night charging	› High power (50–100 kW/bus) charging, both AC and DC. › Connection to medium voltage lines. Possibility to share connection with other LPT loads (e. g. subway). › Long connection time, but coherent with required charging time (high battery capacity)	Power issues:	A single deposit could require 5–10 MW, often in urban areas. There is a strong need for coordination between grid operators and local public transport operators.
		Energy issues:	Moderate additional energy demand.
		Grid reinforcement:	In the event of the high number of buses, new primary substations could be required. Interventions could be required for MV lines.
		Potential for flexibility:	Good control of vehicle consumption and of the charging process due to predictable usage. Only a partial opportunity for flexibility services, due to time/power constraints.
› Highway Hyper Hubs Hyper fast chargers (150–350 kW) in new dedicated areas on highways both for cars and for heavy duty vehicles.	› Multiple ultrafast, DC charging › Connection to High Voltage Lines, through dedicated POD. › Short connection time and high contemporaneity factor	Power issues:	A single hub could require more than 10 MW, often in rural areas. There is a strong need for coordination with grid operators in order to locate hubs close to existing HV lines.
		Energy issues:	Energy withdrawal from the network could be significant but no issues are expected.
		Grid reinforcement:	A new Primary Substation would be required. A well-planned location would minimise the need for new HV lines.
		Potential for flexibility:	Minimum potential due to time constraints. Energy storage systems could be installed to limit peak power and to allow the participation to flexibility services

Figure 21. Potential grid issues related to different use cases.

[41] ENTSO-E Position Paper. Electric Vehicle Integration into Power Grids. 31 March 2'21

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Three main conclusions can be derived from these use cases;

- Diffused slow charging could generate excessive power demand due to contemporaneity effects. This will occur mostly when many other loads are connected to LV lines (typically during evening-peak hours) and could create overloads on Secondary Substations or on LV lines themselves. As mentioned, smart charging can dramatically reduce this problem.
- Secondly, when high power connections are punctually required, new, dedicated substations (and connection lines) must be installed. This generates additional costs and time.
- Finally, when charging infrastructure is aimed at buses and trucks, tens of MW could be additionally required. In this case, new lines or even new primary substations could be necessary. A strong coordination among charging operators and grid operators is highly recommended to identify the best location and the best technical options.

4.5.4. Base for calculation

The calculation of distribution and transmission costs has been prepared based on an impact model carried out by the consulting firm BCG[42] in 2019 but updating the calculations for 2023 and modifying some assumptions. They defined a "representative" utility, a utility with an initial system capacity of 12 GW (gigawatts), baseline electricity sales of about 40 million megawatt-hours (MWh), and wholesale prices that range from roughly $23 per MWh during off-peak times to $34 per MWh during peak periods. They assumed that, on average, an EV in the light-duty fleet within the utility's territory will consume about 2,960 kilowatt-hours (kWh) per year from 2019 to 2030.

Their base case scenario assumed that EV penetration will gradually increase from about 1% in 2019 to roughly 15% in 2030, with a moderately optimized charging pattern. This pattern considers that 33% of EVs makes off-peak charging; 33% shoulder, mid or partial-peak charging; and 33% peak charging. Some charging occurs in areas with capacity constraints.

Under that scenario they projected transmission and distribution costs, and energy consumption as follows:

- **Transmission and Distribution Costs.** Given 1.1 million EVs in service by 2030, their model estimates that the representative utility will need to make cumulative transmission and distribution investments of $2.8 billion through 2030, for an estimated grid capacity upgrade cost of $2,600 per EV. That's a meaningful sum given that a US utility of this size tends to spend about $1 billion annually on transmission and distribution capital expenditures. As noted earlier, most of these costs are from investments in distribution assets; transmission assets account for only $110 per EV in costs, or less than 5% of the total investment costs.

There were two scenarios; one of them optimised and the second non-optimized. The results can be seen in the following summary picture:

[42] BCG, December 2019.A.Sahoo, K.Mistry, T.Baker. The Costs of Revving Up the Grid for Electric Vehicles

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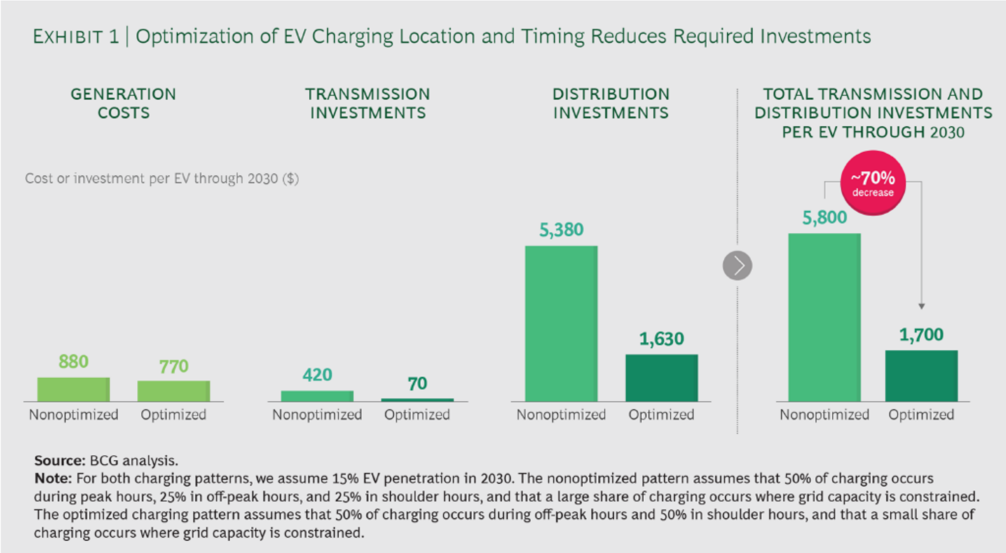

Figure 22. Generation, transmission, and distribution cost per vehicle (model BCG)

Said that, the main differences with our model are the following issues:

- The cost figures in our calculation will be much approximative to provide an order of magnitude.
- On IncitEV, just one scenario will be considered; making an average from the optimised and non-optimised one from the BCG study. Then, we will apply our best and worst scenario.
- The average consumption in IncitEV will be close to 2,065 kWh as we have classified vehicles in three sizes with three different consumptions, whilst BCG considers 2,960 kWh on average (check table 35).
- The current average PPAs for the evaluation of the electricity costs is not 23$/MWh to 34$/MWh as the figure nowadays has ramped up from 40 €/MWh to 75€/MWh, as indicated in table 36.
- In our IncitEV scenario, generation costs round 550 €/EV whilst BCG considers between 770$ (675 €) to 880$ (771 €) /EV (1 € was equal to 1.14$ in 2020). This difference is due to the less energy required on IncitEV by EV (2,065 kWh against 2,960 kWh) although the IncitEV PPA is higher (20% higher on IncitEV than BCG).
- Anyway, these generation costs do not modify the transmission and distribution costs that we will be kept equivalent to those calculated by BCG in their model as the learning curve that reduces costs, should likely be absorbed by the rocketing inflation rates from last year. For the years onward, the inflation rate was set in 2%.

4.5.5. Main Results

Said that, the results are the following:

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4.5.5.1. Paris

PARIS BASE	New EV reg (units)	Invest REs NTV (M€)	Transmission Costs M€	Distribution Costs M€	TOTAL M€ (Trans+Distr)	TOTAL M€ NPV Trans+Distrib
2021	15,289	6.67	3.75	47.01	50.8	50.8
2022	15,304	6.42	3.75	47.05	50.8	49.8
2023	15,350	6.19	3.76	47.20	51.0	49.0
2024	15,757	6.11	3.86	48.45	52.3	49.3
2025	16,034	5.98	3.93	49.30	53.2	49.2
2026	16,126	5.78	3.95	49.58	53.5	48.6
2027	16,127	5.56	3.95	49.58	53.5	47.6
2028	16,107	5.34	3.95	49.52	53.5	46.7
2029	16,116	5.14	3.95	49.55	53.5	45.8
2030	16,184	4.96	3.97	49.76	53.7	45.1
2031	16,327	4.81	4.00	50.20	54.2	44.6
2032	16,548	4.69	4.05	50.88	54.9	44.4
2033	16,838	4.59	4.13	51.77	55.9	44.3
2034	17,182	4.50	4.21	52.83	57.0	44.3
2035	17,559	4.42	4.30	53.99	58.3	44.4
	242,848	81.19	59.50	746.65	806.1	704.0
					IR	2.00%
					FDR	4.00%

Transmission and distribution costs accounts for €704 million (NPV) in 15 years in Paris

Table 46. Transmission and distribution Costs in Paris (base scenario)

4.5.5.2. Utrecht

UTRECHT BASE	New EV reg (units)	Invest REs NTV (M€)	Transmission Costs M€	Distribution Costs M€	TOTAL M€ (Trans+Distr)	TOTAL M€ NPV Trans+Distrib
2021	5,455	2.19	1.3	16.8	18.1	18.1
2022	8,212	3.17	2.0	25.2	27.3	26.7
2023	9,745	3.61	2.4	30.0	32.3	31.1
2024	10,987	3.92	2.7	33.8	36.5	34.4
2025	11,901	4.08	2.9	36.6	39.5	36.6
2026	12,492	4.12	3.1	38.4	41.5	37.6
2027	12,796	4.06	3.1	39.3	42.5	37.8
2028	12,872	3.92	3.2	39.6	42.7	37.3
2029	12,797	3.75	3.1	39.3	42.5	36.4
2030	12,654	3.57	3.1	38.9	42.0	35.3
2031	12,527	3.39	3.1	38.5	41.6	34.2
2032	12,489	3.25	3.1	38.4	41.5	33.5
2033	12,598	3.16	3.1	38.7	41.8	33.1
2034	12,888	3.10	3.2	39.6	42.8	33.2
2035	13,357	3.09	3.3	41.1	44.3	33.8
	173,768	52.4	42.6	534.3	576.8	499.2
					IR	2.00%
					FDR	4.00%

Transmission and distribution costs accounts for €499 million (NPV) in 15 years in Utrecht

Table 47. Transmission and distribution Costs in Utrecht (base scenario)

4.5.5.3. Turin

TURIN BASE	New EV reg (units)	Invest REs NTV (M€)	Transmission Costs M€	Distribution Costs M€	TOTAL M€ (Trans+Distr)	TOTAL M€ NPV Trans+Distrib
2021	5,352	3.3	1.3	16.5	17.8	17.8
2022	10,726	5.5	2.6	33.0	35.6	34.9
2023	14,893	7.4	3.6	45.8	49.4	47.6
2024	18,668	8.9	4.6	57.4	62.0	58.5
2025	21,831	10.0	5.3	67.1	72.5	67.1
2026	24,281	10.7	5.9	74.7	80.6	73.1
2027	26,022	11.0	6.4	80.0	86.4	76.9
2028	27,135	11.0	6.6	83.4	90.1	78.6
2029	27,759	10.8	6.8	85.3	92.1	78.9
2030	28,072	10.5	6.9	86.3	93.2	78.2
2031	28,267	10.2	6.9	86.9	93.8	77.3
2032	28,533	9.9	7.0	87.7	94.7	76.5
2033	29,031	9.7	7.1	89.3	96.4	76.3
2034	29,875	9.6	7.3	91.9	99.2	77.0
2035	31,111	9.6	7.6	95.7	103.3	78.7
	351,557	138.1	86.1	1,080.9	1,167.0	997.4
					IR	2.00%
					FDR	4.00%

Transmission and distribution costs accounts for €997 million (in NPV) in 15 years in Turin

Table 48. Transmission and distribution Costs in Turin (base scenario)

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4.5.5.4. Zaragoza

ZARAGOZA BASE	New EV reg (units)	Invest REs NTV (M€)	Transmission Costs M€	Distribution Costs M€	TOTAL M€ (Trans+Distr)	TOTAL M€ NPV Trans+Distrib
2021	983	0.4	0.2	3.0	3.3	3.3
2022	1,620	0.6	0.4	5.0	5.4	5.3
2023	2,396	0.9	0.6	7.4	8.0	7.7
2024	3,158	1.1	0.8	9.7	10.5	9.9
2025	3,852	1.3	0.9	11.8	12.8	11.8
2026	4,446	1.5	1.1	13.7	14.8	13.4
2027	4,927	1.6	1.2	15.1	16.4	14.6
2028	5,293	1.6	1.3	16.3	17.6	15.3
2029	5,557	1.7	1.4	17.1	18.4	15.8
2030	5,739	1.7	1.4	17.6	19.1	16.0
2031	5,867	1.6	1.4	18.0	19.5	16.0
2032	5,968	1.6	1.5	18.3	19.8	16.0
2033	6,071	1.6	1.5	18.7	20.2	16.0
2034	6,202	1.5	1.5	19.1	20.6	16.0
2035	6,379	1.5	1.6	19.6	21.2	16.1
	68,457	20.3	16.8	210.5	227.2	193.1

Transmission and distribution costs accounts for €193 million (in NPV) in 15 years in Zaragoza

Table 49. Transmission and distribution Costs in Zaragoza (base scenario)

4.5.5.5. Tallinn

TALLINN BASE	New EV reg (units)	Invest REs NTV (M€)	Transmission Costs M€	Distribution Costs M€	TOTAL M€ (Trans+Distr)	TOTAL M€ NPV Trans+Distrib
2021	488	0.3	0.1	1.5	1.6	1.6
2022	807	0.4	0.2	2.5	2.7	2.6
2023	1,170	0.6	0.3	3.6	3.9	3.7
2024	1,533	0.8	0.4	4.7	5.1	4.8
2025	1,871	1.0	0.5	5.8	6.2	5.7
2026	2,170	1.2	0.5	6.7	7.2	6.5
2027	2,421	1.3	0.6	7.4	8.0	7.2
2028	2,622	1.4	0.6	8.1	8.7	7.6
2029	2,776	1.5	0.7	8.5	9.2	7.9
2030	2,889	1.5	0.7	8.9	9.6	8.1
2031	2,973	1.6	0.7	9.1	9.9	8.1
2032	3,036	1.6	0.7	9.3	10.1	8.1
2033	3,092	1.6	0.8	9.5	10.3	8.1
2034	3,150	1.7	0.8	9.7	10.5	8.1
2035	3,219	1.7	0.8	9.9	10.7	8.1
	34,218	18.2	8.4	105.2	113.6	96.4
					IR	2.00%
					FDR	4.00%

Transmission and distribution costs accounts for €95 million (in NPV) in 15 years in Tallin

Table 50. Transmission and distribution Costs in Tallin (base scenario)

4.5.6. Summary Transmission and Distribution Costs

ASE	PARIS TOTAL M€ NPV Trans+Distrib	UTRECHT TOTAL M€ NPV Trans+Distrib	TURIN TOTAL M€ NPV Trans+Distrib	ZARAGOZA TOTAL M€ NPV Trans+Distrib	TALLIN TOTAL M€ NPV Trans+Distrib	TOTAL TOTAL M€ NPV Trans+Distrib
2021	50.75	18.11	17.77	3.26	1.62	91.51
2022	49.83	26.74	34.92	5.27	2.63	119.39
2023	49.01	31.12	47.56	7.65	3.74	139.07
2024	49.35	34.41	58.46	9.89	4.80	156.91
2025	49.25	36.55	67.05	11.83	5.75	170.43
2026	48.58	37.63	73.15	13.39	6.54	179.29
2027	47.65	37.80	76.88	14.56	7.15	184.04
2028	46.67	37.30	78.63	15.34	7.60	185.53
2029	45.80	36.37	78.89	15.79	7.89	184.74
2030	45.11	35.27	78.24	16.00	8.05	182.67
2031	44.63	34.24	77.27	16.04	8.13	180.31
2032	44.37	33.48	76.50	16.00	8.14	178.49
2033	44.28	33.13	76.34	15.96	8.13	177.84
2034	44.31	33.24	77.05	15.99	8.12	178.72
2035	44.41	33.78	78.69	16.14	8.14	181.17
	704.00	499.17	997.40	193.12	96.43	2,490.11
						2.00%
						4.00%

Table 51. Summary of transmission and distribution Costs in the five use case cities (base scenario)

Transmission and distribution costs represent a meaningful expenses' items compared with some other concepts in a municipality. The adaptation of the grid is a big requirement when a municipality intends to make the transition toward electromobility. In some cases, distribution costs, the most important expense item compared to transmission, are partially absorbed by the beneficiary of the public auctions to install public chargers or by the private collective buildings, but in most cases, those expenses are latterly reflected in the electricity charging rates.

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4.6. Summary of Administrations' investments

INVEST	PARIS NPV (M€)							UTRECHT NPV (M€)							TURIN NPV (M€)						
BASE	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	Total	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	Total	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	Total
Year	Units	M €	M €	M €	M €	M €	M €	Units	M €	M €	M €	M €	M €	M €	Units	M €	M €	M €	M €	M €	M €
2021	**36,720**	**53.17**	**15.29**	**1.43**	**6.67**	**50.75**	**127.32**	**21,991**	**16.69**	**53.21**	**1.40**	**2.19**	**18.11**	**91.59**	**46,551**	**5.62**	**3.21**	**0.00**	**3.26**	**17.77**	**29.86**
2022	51,960	48.72	38.94	3.11	6.42	49.83	147.02	28,660	23.00	74.86	1.62	3.17	26.74	129.37	57,270	10.31	9.46	0.00	5.52	34.92	60.21
2023	67,230	44.50	41.01	2.83	6.19	49.01	143.55	36,605	24.85	94.15	1.90	3.61	31.12	155.63	72,154	13.04	17.88	1.65	7.36	47.56	87.48
2024	82,827	41.36	43.17	2.73	6.11	49.35	142.71	45,535	25.37	113.54	1.84	3.92	34.41	179.07	90,804	14.79	28.10	1.96	8.88	58.46	112.19
2025	**98,540**	**37.84**	**44.98**	**2.67**	**5.98**	**49.25**	**140.71**	**55,122**	**24.70**	**56.40**	**1.84**	**4.08**	**36.55**	**123.58**	**112,597**	**15.55**	**34.50**	**2.02**	**9.98**	**67.05**	**129.10**
2026	114,025	33.93	46.43	2.83	5.78	48.58	137.55	67,358	23.12	12.59	1.78	4.12	37.63	79.24	136,802	15.42	40.38	2.33	10.67	73.15	141.95
2027	129,191	29.95	47.63	2.91	5.56	47.65	133.70	79,870	20.90	13.86	1.66	4.06	37.80	78.29	162,711	14.59	45.59	2.29	11.00	76.88	150.35
2028	142,094	26.08	48.68	2.97	5.34	46.67	129.74	90,172	18.33	15.45	1.51	3.92	37.30	76.52	189,562	13.26	50.16	2.73	11.03	78.63	155.81
2029	155,006	22.39	49.65	3.75	5.14	45.80	126.73	100,479	15.64	16.93	1.32	3.75	36.37	74.01	216,943	11.64	56.01	2.78	10.85	78.89	160.18
2030	**167,423**	**18.90**	**46.34**	**5.75**	**4.96**	**45.11**	**121.06**	**109,370**	**13.00**	**17.86**	**2.50**	**3.57**	**35.27**	**72.20**	**244,348**	**9.90**	**61.31**	**3.77**	**10.55**	**78.24**	**163.76**
2031	175,698	15.59	47.31	7.37	4.81	44.63	119.71	116,442	10.52	18.08	2.70	3.39	34.24	68.94	270,287	8.15	66.11	3.47	10.21	77.27	165.21
2032	176,957	12.39	48.27	7.51	4.69	44.37	117.23	120,719	8.23	17.67	2.23	3.25	33.48	64.87	293,468	6.45	0.00	4.06	9.91	76.50	96.92
2033	178,491	9.28	49.24	8.39	4.59	44.28	115.77	123,573	6.11	16.87	1.38	3.16	33.13	60.64	311,772	4.83	0.00	3.22	9.70	76.34	94.09
2034	180,323	6.19	50.21	9.05	4.50	44.31	114.27	125,474	4.08	15.83	1.13	3.10	33.24	57.39	326,754	3.25	0.00	3.57	9.60	77.05	93.46
2035	**182,125**	**0.00**	**51.19**	**9.53**	**4.42**	**44.41**	**109.57**	**126,929**	**0.00**	**14.50**	**0.85**	**3.09**	**33.78**	**52.23**	**339,196**	**0.00**	**0.00**	**1.04**	**9.61**	**78.69**	**89.34**
	TOTAL (M€)	400.3	668.3	72.8	81.2	704.0	1,926.6	TOTAL (M€)	234.5	551.8	25.7	52.4	499.2	1,363.6	TOTAL (M€)	146.8	412.7	34.9	138.1	997.4	1,729.9
	PER CAPITA (	184.9	308.7	33.6	37.5	325.2	889.9	PER CAPITA (	648.4	1,525.4	70.9	144.8	1,379.9	3,769.4	PER CAPITA (	65.2	183.2	15.5	61.3	442.8	768.0

Table 55. Forecast Total investments compromised by Paris, Utrecht, and Turin cities to promote electromobility from 2021 to 2035.

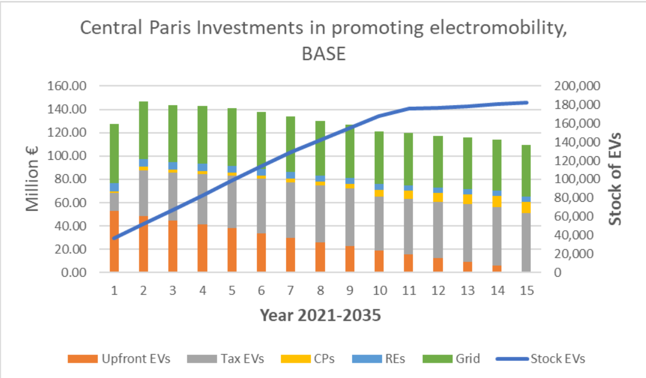

Table 55. Forecast Central Paris investments in CPs and EVs

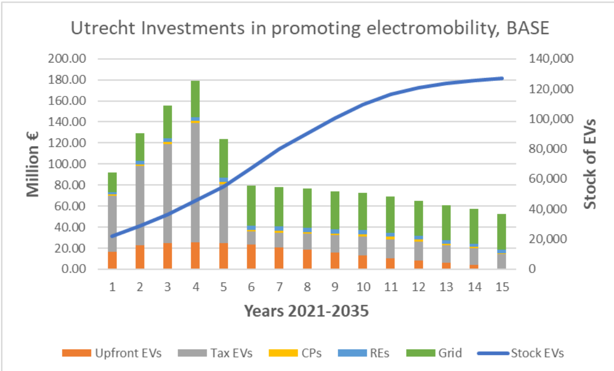

Table 55. Forecast Utrecht investments in CPs and EVs

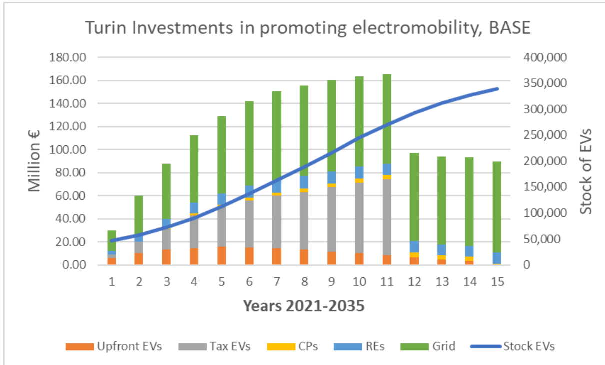

Table 55. Forecast Utrecht investments in CPs and EVs

INVEST BASE	ZARAGOZA NPV (M€)							TALLINN NPV (M€)							TOTAL USE CASEs
	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	Total	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	Total	
Year	Units	M €	M €	M €	M €	M €	M €	Units	M €	M €	M €	M €	M €	M €	M €
2021	2,107	3.24	0.00	3.15	0.40	3.26	10.05	3,157	0.60	0.00	0.00	0.27	1.62	2.49	261.31
2022	3,724	4.89	0.38	6.54	0.64	5.27	17.72	3,963	0.90	0.00	0.00	0.43	2.63	3.96	358.28
2023	6,117	6.59	0.76	7.59	0.91	7.65	23.49	5,122	1.19	0.00	0.00	0.62	3.74	5.55	415.70
2024	9,268	7.86	1.18	8.66	1.15	9.89	28.73	6,654	1.41	0.00	0.00	0.82	4.80	7.03	469.73
2025	13,107	8.62	1.61	9.24	1.35	11.83	32.65	8,512	1.55	0.00	0.00	1.00	5.75	8.29	434.33
2026	17,527	8.87	2.06	9.21	1.50	13.39	35.03	10,656	1.60	0.00	0.00	1.15	6.54	9.29	403.06
2027	22,414	8.67	2.50	8.75	1.59	14.56	36.07	13,037	1.58	0.00	0.00	1.29	7.15	10.02	408.43
2028	27,609	8.12	2.93	7.85	1.65	15.34	35.88	15,606	1.49	0.00	0.00	1.39	7.60	10.48	408.43
2029	33,035	7.32	3.34	6.63	1.66	15.79	34.75	18,315	1.35	0.00	0.00	1.48	7.89	10.72	406.38
2030	38,539	6.36	3.73	5.26	1.65	16.00	32.99	21,126	1.18	0.00	0.00	1.54	8.05	10.78	400.79
2031	43,708	5.31	4.06	5.45	1.62	16.04	32.47	24,006	1.00	0.00	0.00	1.58	8.13	10.70	397.04
2032	48,693	4.24	4.34	5.13	1.59	16.00	31.29	26,937	0.80	0.00	0.00	1.61	8.14	10.55	320.86
2033	53,144	3.17	4.57	4.46	1.55	15.96	29.72	29,910	0.60	0.00	0.00	1.64	8.13	10.37	310.58
2034	56,949	2.12	4.75	3.63	1.52	15.99	28.02	32,928	0.40	0.00	0.00	1.68	8.12	10.20	303.34
2035	60,171	0.00	4.90	2.78	1.51	16.14	25.32	35,964	0.00	0.00	0.00	1.71	8.14	9.86	286.32
	TOTAL (M€)	85.4	41.1	94.3	20.3	193.1	434.2	TOTAL (M€)	15.6	0.0	0.0	18.2	96.4	130.3	5,584.6
	PER CAPITA	124.7	60.0	137.8	29.6	282.1	634.1	PER CAPITA	34.6	0.0	0.0	40.2	213.1	287.9	943.9

Table 56. Forecast Total investments compromised by Zaragoza and Tallinn cities to promote electromobility and total from 5 use-case cities, from 2021 to 2035.

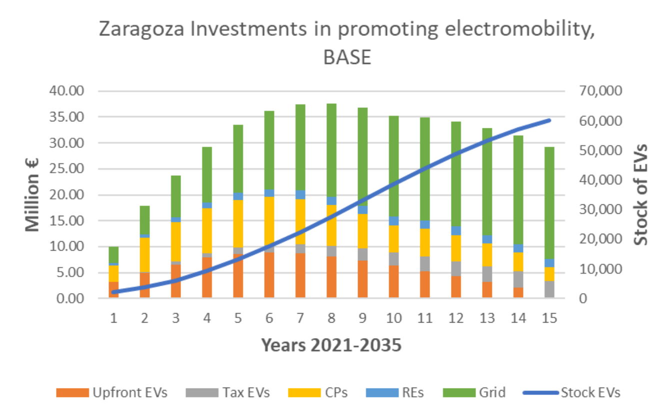

Table 57. Forecast Zaragoza investments in CPs and EVs

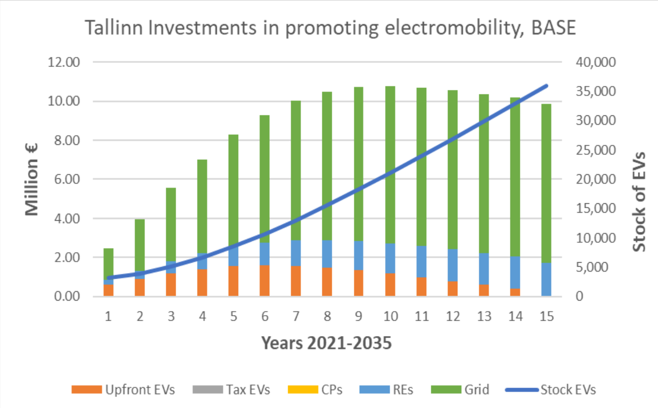

Table 58. Forecast Tallin investments in CPs and EVs

Notes

- **Upfront EVs.** Summary of city aids to contribute to the upfront costs of EVS (BEV or PHEV).
- **Tax EVs.** Summary of taxes exempt or reduced when acquiring an EV minus municipality incomes taxes applied to ICE cars (passenger cars and LDV)
- **CPs.** Summary of upfront aids and tax exemptions or reduction when installing a charging point in the indicated city
- **REs.** Investments in Renewables to supply all the required electricity to support the electromobility in a given city.
- **Grid.** Investments to upgrade and enhance the transmission and distribution grid to support the electromobility in a given city.

Some Insights

- Per capita Utrecht as leading city surplus by far the remaining cities with 3,769 €/per capita of investment between 2021 and 2035, compared to the 288 € from Tallinn.
- Lagging cities should increase investments over time to reach a minimum supporting level while leaders as Utrecht might reduce substantially the investments as major efforts has been already done to date.
- Supporting policies varies a lot among countries with grid adaptation as the major investment requirement.

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5. EXTERNALITIES CALCULATION

5.1. Background

This chapter is devoted to analysing the externalities linked to the penetration of the electromobility in the use case cities with the diffusion rates described in table 3 of this report. In addition, the installation of charging points, especially the high power charging hubs will also have some impact in the externalities.

As previously explained, the Cost-Benefit Analysis (CBA) provides the present value of the benefits (also called monetized externalities) associated to a project against the sum of the present value of the administration investments associated (already calculated in the previous chapter 4).

The selected externalities were roughly identified in section 2.4 and can be classified in those affecting the environment with impact in the health of citizens, those related to the modification of the safety conditions of traffic and finally, some gathered under the group "social" also with economic impact. Specifically,

Air pollutant emissions (NO_x, PM 2.5)	Environment & Health
Greenhouse gas emissions (CO_2, NO_2, CH_4, O_3)	
Noise hindrance (% population affected)	
Road deaths (% per population per year)	Safety
Congestion & delays (% delay during peak hours)	
Mobility space usage (all transport space, per population)	Social
Time losses (hours of working time)	

Table 59. Externalities considered in the IncitEV CBA.

The European Commission has developed a comprehensive set of practical and reliable indicators that support cities to perform a standardised evaluation of their mobility systems and to measure improvements that result from new mobility practices or policies.

Therefore, the *EU Sustainable Urban Mobility Indicators* (SUMI) methodology was chosen to complete the required information for some indicators. This is a useful tool for cities and urban areas that identify the strengths and weaknesses of the mobility systems and enhance areas of improvement[43].

[43] https://transport.ec.europa.eu/transprt-themes/clean-transport-urban-transport/sumi_en

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As cities and urban areas continue to develop *Sustainable Urban Mobility Plans* (SUMPs) and work towards EU policy goals, it is important to ensure that such information is used and that IncitEV results are aligned with those Plans.

A full set of indicators were identified by the SUMI methodology, divided into different categories according to European Commission's consideration on strategic importance:

CORE INDICATORS	NON-CORE INDICATORS
Indicator 1: Affordability of public transport for the poorest group	*Indicator 14*: Quality of public spaces
Indicator 2: Accessibility of public transport for mobility-impaired groups	*Indicator 15*: Urban functional diversity
Indicator 3: Air Pollutants emissions	*Indicator 16:* Commuting travel time
Indicator 4: Noise hindrance	*Indicator 17*: Mobility space usage
Indicator 5: Road deaths	*Indicator 18:* Security
Indicator 6: Access to mobility services	
Indicator 7: Greenhouse gas emissions	
Indicator 8: Congestion and delays	
Indicator 9: Energy efficiency	
Indicator 10: Opportunity for Active Mobility	
Indicator 11: Multimodal integration	
Indicator 12: Satisfaction with public transport	
Indicator 13: Traffic safety active modes	

Table 60. SUMI Core and non-core indicators

In a SUMI project developed between years 2017-2020, a group of almost 50 pilot cities, voluntarily filled in and submitted a total of 473 indicator spreadsheets. These formed the initial database that provided the minimum, maximum, average, and median score for each indicator. Some further general guidelines for calculating those indicators can be found in the "Harmonisation Guidelines"[44] document. Table 61 shows all the selected externalities and the related SUMI methodology applied.

[44] https://transport.ec.europa.eu/system/files/2020-09/sumi_wp1_harmonisation_guidelines.pdf

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	MEASUREMENT UNIT	METHODOLOGY
Air pollutant emissions	Emission harm equivalent index (kg PM2.5 eq./cap per year)	Sustainable Urban Mobility Indicators (SUMI) Nº 3
Greenhouse gas emissions	Greenhouse gas emission (tonnes CO_2(eq.) /cap. Per year)	Sustainable Urban Mobility Indicators (SUMI) Nº 7
Noise	Noise hindrance index (Δ EV/ICE) (% of population)	Sustainable Urban Mobility Indicators (SUMI) Nº 4
Road deaths	Fatality rate (Δ EV/ICE) (per 100,000 urban area cap. per year)	Sustainable Urban Mobility Indicators (SUMI) Nº 5
Congestion & delays	Congestion and delay index (Δ EV/ICE) (% of delay during peak hours)	Sustainable Urban Mobility Indicators (SUMI) Nº 8
Mobility space usage	Proportion of land use, including direct and indirect uses, by all city transport modes (Δ EV/ICE) (ha/ cap.)	Sustainable Urban Mobility Indicators (SUMI) Nº 17
Time losses	Hours of working time lost by EV charging and infrastructure construction (Δ EV/ICE) (hours/year)	Estimation for each charging type

Table 61. Methodologies, units, and indicators by externality

It is worth mentioning that each externality, except the "time losses", has its own procedure integrated in the SUMI's methodology although not all can be applied as they are described in our specific case. ANNEX 3 – SUMI's USER GUIDES" provides the specific functions that define each indicator. The "time losses" externality has its own methodology that will be explained in the corresponding point and some other externalities have suffered modifications in relation to this standard.

5.2. Some clarifications for the Externalities

5.2.1. Global Warming Potential. Externality 1 and Externality 2.

The Global Warming Potentials to be used at IncitEV, are regulated in the Annex to the Commission delegated supplementing Regulation (EU) 2018/1999 of the European Parliament and the Council, where the values for the global warming potentials are explained. The inventory guidelines are explained in the Commission delegated regulation (EU) No 666/2014.

To measure the contribution of the IncitEV project to the global climate change, two indicators were selected, the **Air Pollutant Emissions** and the **Greenhouse Gas Emissions**, calculated in "kilogram of PM 2.5 equivalent" and "tonnes of CO_2 equivalent" respectively, as output of the SUMI' Indicators #3 and #7.

The fine particulate matter (PM2.5) is the air pollutant that poses the greatest risk to health globally, affecting more people than any other pollutant. Chronic exposure to this matter increases considerably the risk of respiratory and cardiovascular diseases.

In the other hand, Greenhouse gases refer to the sum of seven gases that have direct effects on climate change, mainly carbon dioxide (CO_2), but also methane (CH_4) and nitrous oxide (N_2O). Other air emissions include those from sulphur oxides (SOx) and nitrogen oxides (NOx), provided as quantities of SO_2 and NO_2, emissions of carbon monoxide (CO), and emissions of volatile organic compounds (VOC). All those greenhouse gases are indirectly calculated and expressed in CO_2 equivalent, referring all, to the gross direct emissions from human activities.

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5.2.2. Global Burden of Disease. Externality 3 and Externality 4.

The Global Burden of Disease (GBD) provides a comprehensive picture of mortality and disability across countries, time, age, and sex. It quantifies health loss from hundreds of diseases, injuries, and risk factors, so that health systems can be improved, and disparities eliminated. Global Burden of Disease research incorporates both the prevalence of a given disease or risk factor and the relative harm it causes. GBD is based out of the Institute for Health Metrics and Evaluation (IHME) at the University of Washington funded by the Bill and Melinda Gates Foundation.

Two of the parameters to evaluate the global burden of disease referred to the electromobility, are the **Noise Hindrance** and **Road Deaths** that are quantified using the *Disability-Adjusted Life Year* (DALY). One DALY represents the loss of the equivalent of one year of full health. DALYs for a disease or health condition are the sum of the years of life lost to due to premature mortality (YLLs) and the years lived with a disability (YLDs) due to prevalent cases of the disease or health condition in a population. It was introduced in the *1993* by the World Health Organization and the World Bank collaborators.[45]

A conceptual framework for the DALY uses the term "disability" to refer to any acute or chronic illness that reduces physical or mental health status in the short-term or the long-term. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability.[46]

The basic equation for the DALY is the sum of a population's years of the life lost (YLL) to premature death and the years lived with disability (YLD). A graphic scheme in figure 23 might help understanding this model[47].

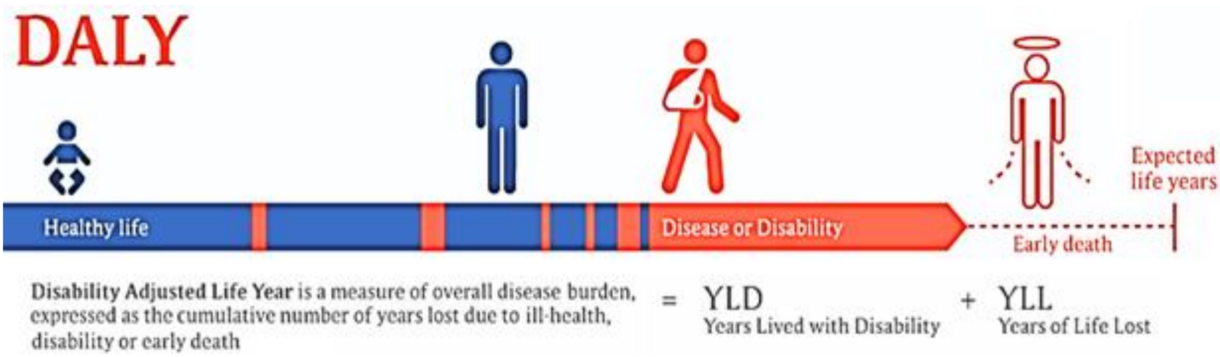

Figure 23. Concept and calculation of DALY

[45] https://www.alnap.org/system/files/content/resource/files/main/%5Bchen-et-al-2015%5D-the-evolution-of-the-daly.pdf

[46] http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

[47] https://en.wikipedia.org/wiki/Disability-adjusted_life_year#/media/File:DALY_disability_affected_life_year_infographic.svg

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Regarding **Noise Hindrance**, it can be assumed that traffic noise affecting the European cities represents on average **860 DALY per million citizens and year**, in accordance with *Hänninen & Knol 2011 Report*[48].

In addition, the cost of a human life in road accidents was taken from two sources, on one side from a SWOV report (Dutch Institute from Road Safety Research)[49] where it was calculated the social cost of a road death and seriously injured. The costs amount to about € 6.5 million per road death and € 0.7 million per serious road injury. The percentage of seriously injured over the number of deaths was set in 35.7 injured per casualty[50]. The relationship between electric vehicles (EVs) and traffic accidents is a complex topic, and it is difficult to make a general statement that applies universally. However, it is expected a slight increase in car accidents by three main reasons; low noise affecting pedestrian, faster acceleration leaving to easier collisions and higher weight, compromising braking and generating more serious accidents. The issue will be explained extensively in the corresponding point (references in chapter 5.7.4).

5.3. Congestions and delays. Externality 5.

The impact on the **Congestions & Delays externality** has been calculated on IncitEV using the public and private corridors examples detailed in some of the city questionnaires mentioned in section 5.1, and also evaluating each daily driving pattern. Figures 24 and 25 shows the average traffic density per hour in an average week, in the 5 cities considered in INCIT-EV Project. Colour scale from white to dark red determine rush hours for each of them. In parallel to the penetration of the electric vehicles, there will be a reduction of the conventional cars as it was demonstrated in D9.2 "Demand Scenarios" because of a set of factors (please check that report). The consequence will be a reduction of the rush hours to a certain extent and consequently the reduction in time loses that can be monetized. However electric cars are used more due to OPEX cost reduction, so there will be a combination of positive and negative effects.

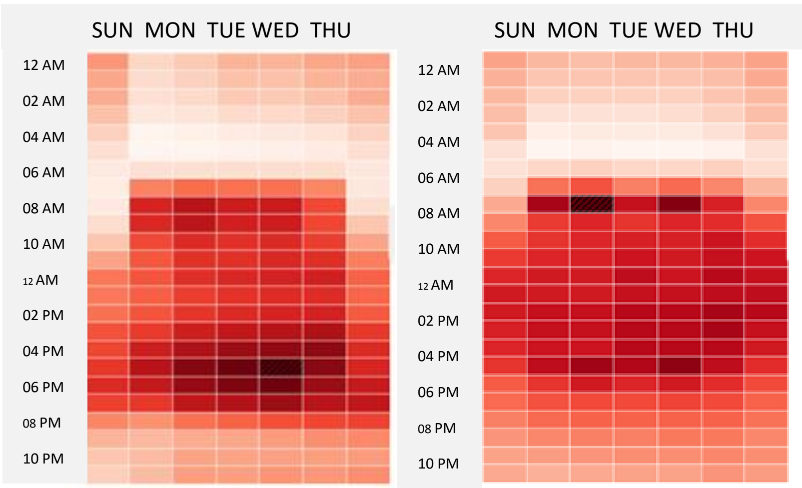

Figure 24. Rush hours in Paris Central (left) and Utrecht (right)

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[48] European Perspectives on Environmental Burden of Disease. O. Hänninen & A.Knol. THL Finland Report. 2011.

[49] SWOV (Dutch Institute for Road Safety Research), 2022.

[50] WHO (2016). Global health estimates 2015: deaths by cause, age, sex, by country and by region, 2000-2015. Geneva: WHO. Available at: http://www.who.int/healthinfo/global_burden_disease/estimates/en/index1.html

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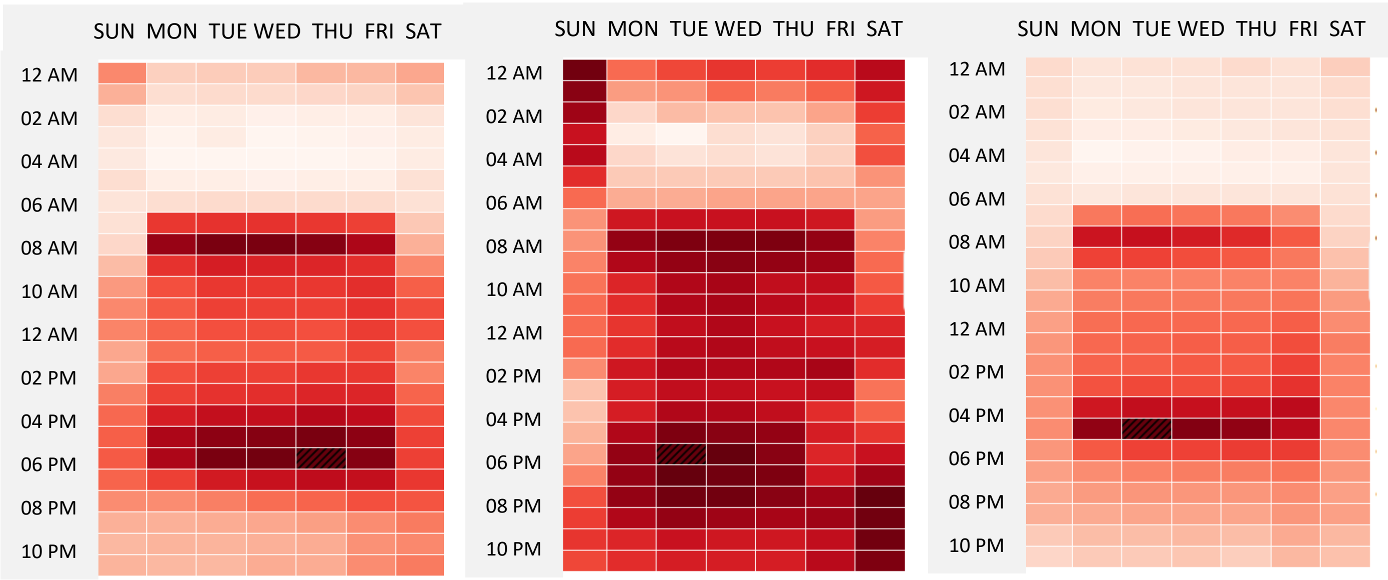

Figure 25. Rush hours in Turin, Zaragoza, and Tallinn (left to right respectively)

Observing the patterns, and considering only weekdays, it can be extracted an estimation of peak hours to complement the SUMI methodology and estimate the future impacts in congestions and delays because of the EVs' penetration.

Rush hours	Paris	Utrecht	Torino	Zaragoza	Tallinn
Peak hours	17-19:30	8-9 + 17-18	8-9 + 17-19	7-10 + 17-21	8-9 + 16-18
Peak hours/day	2,5	2,0	3,0	7,0	3,0

Table 62. Estimation of workdays peak hours

5.4. Mobility Space usage. Externality 6.

The **Space Usage** due to the installation of charging stations has been also included as an externality. This is a negative externality as reduces the available public space in the cities. Only the public chargers have been considered in the calculation. According to the mentioned questionnaire in section 5.1, the average parking area for a single car, measures **18 m^2** per EV charger. For a conventional isolated charging hub will be estimate around **300 m^2**, with capacity to charge 12 vehicles at same time.

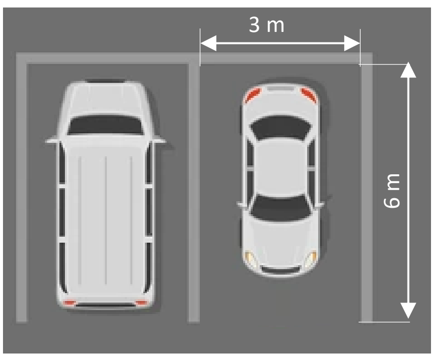

Figure 27. Parking area dimensions for EV charging Point

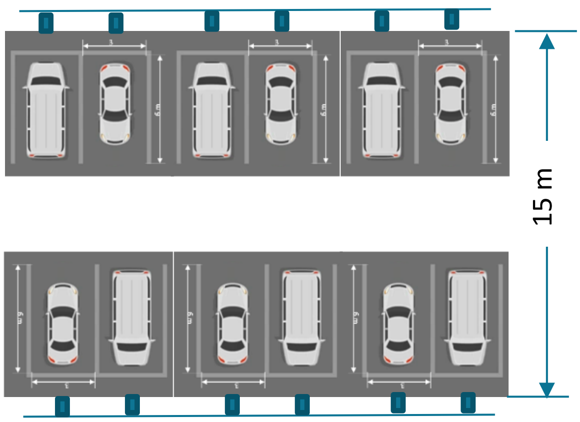

Figure 26. Public Charging hub

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5.5. Time losses. Externality 7.

The last Externality considered in the CBA is referred as the "**time losses**", defined as the time that professionals (only light duty vehicles will considered here) lost in the charging process when they prompt to charge their electric vehicles in public charging stations at working hours. This externality is not included in the SUMI methodology, so it has been calculated from an estimation of time under different scenarios of vehicles and chargers. Charging time during a travel stop for lunching or shopping at a mall, is not considered.

The recharging time depends on a host of variables that make impossible to provide a precise number. Ignoring some less relevant factors like battery age, weather conditions, state of charge, etc., the charging time of an EV relays basically on two major factors, **the charger power** and the **car battery capacity**.

Figure 28. EV charging time major affecting factors

In the next table, we present an overview based on a former paper[51] that considers four average battery sizes and a few different charging power outputs. Then, an accurate approximation of how long it takes on average to charge an EV (three sizes) categorized by the chargers' power output, can be estimated.

CHARGER POWER				CHARGING TIME (ChT, in hours)			Units	WEIGHTED ChT
Charging speed	Type	%/ Group	Power Output kW	Small EV 35% 15	Medium EV 44% 24	Large EV 21% 78	% /fleet KWh	Weighted Charging time (h)
Slow (< 7,5 kW)	Level 1	100%	2.3	6.52	10.43	33.91	h	14.00
Semi-Fast (7,5 - 22 kW)	Level 2	40%	7.4	2.03	3.24	10.54	h	3.20
		40%	11	1.36	2.18	7.09		
		20%	22	0.68	1.09	3.55		
Fast (22 - 120 kW)	Level 3	80%	50	0.30	0.48	1.56	h	0.57
		20%	120	0.13	0.20	0.65		
Super-Fast (120 - 175 kW)	Level 4	90%	150	0.10	0.16	0.52	h	0.21
Ultra-Fast (> 175 kW)	Level 5	10%	240	0.06	0.10	0.33		

Table 63. Weighted Charging time by level of charger (in hours). Source. Own elaboration

The calculation of the times loses due to the charging process is not standardised with a specific SUMI. Indeed, it is very difficult to calculate this figure as it depends on the specific conditions of the professional fleets (sometimes they prepare their own fast charging hub to lose as less time as possible), it also depends on the distribution of the charging spaces along the city and the power of the chargers. Some technical articles reflect from time to time the complaints of certain professional groups as the taxi drivers, because they must extent their workday some extra hours

[51] https://evbox.com/en/ev-charging-guide

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to charge their vehicle. If we review table 63, we can see that in the most usual cases, level 3 an hour is required for a full charge and 3.20 h for level 2. To make the estimation we have considered that every professional group member (mainly taxi drivers, parcel and delivery services, service vans, etc.) requires at least loses approximately half an hour/day on unplanned load. This is applied only to LDV that represents on average the 15% of the EV fleet.

There are of course, differences among countries and years, but we will keep this figure as constant. The lost hourly salary per country will be the average working salary in 2021 growing a 2% per year as we can see in the aside table.

	2,021	
COUNTRY	Av. Yearly Salary	Av. Hourly Salary
France	49,313 €	29.35 €
Netherlands	60,923 €	36.26 €
Italy	40,767 €	24.27 €
Spain	39,202 €	23.33 €
Estonia	33,188 €	19.75 €

Table 64. Average salary per use-case country, 2021

5.6. Cities' characterization

One of the main objectives of INCIT-EV is to easily replicate the Cost-Benefit Analysis in different European cities with diverse boundary conditions.

Based on an article developed in 2012 by some German Research Centers[52] a town can be classified in nine typical Urban Structures or blocks defined as archetypes for most common in European cities. The following building blocks showed in figure 29 will be considered in futures calculations:

Figure 29. Urban Structure Types based on subsets of orthophoto images.

[52] Urban structure type characterization using hyperspectral remote sensing and height information. German Aerospace Center. Zentrum. U. Heiden, W. Heldens, S.Roessner. April 2012 https://www.researchgate.net/publication/225023024_Urban_structure_type_characterization_using_hyperspectral_remote_sensing_and_height_information.

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For the characterization of the use case cities and the influence in air pollutant dispersion, each of them was evaluated from the environmental and social view point, inferring how aerial contaminants dissipate along the territory.

The physical parameters with the greater influence in the pollutant dissipation are orography (ground and urban), temperature, pluviometry, wind speed, green spaces, and population density. All these parameters were included in the analysis for each use case city.

Methodology. The air pollutant dispersion was identified according to the mentioned parameters. Every parameter has three possible options (low, regular, or high), corresponding to 1 point, 2 or 3. The urban orography and the population density are represented by the percentage of each type. Then, there a weight representing the relative importance of each parameter in the air dispersion. The final score will be a number between 1 to 3 which is the weight average in every city of the air dispersion; from 1 to 1.66 indicates very low dispersion, 1.66 to 2.33 medium dispersion and 2.33 to 3, great dispersion. An abrupt and complex orography (mountain) favours the development of local thermal circulations (breezes), high building by the contrary, reduce the air circulation as the high population.

INCIT-EV	Scores per category				Score by city				
	1	2	3		Paris	Utrecht	Turin	Zaragoza	Tallinn
Air pollutant dispersion	Low (L)	Regular (R)	High (H)	Weight	Value (L, R, H)	Value (L, R, H)	Value (L, R, H)	Value (L, R, H)	Value (L, R, H)
Ground orography	Valley	Plain	Mountain	20%	L, R, H	L, R, H	L, R, H	L, R, H	L, R, H
Urban block orography (buildings height)	[X] High (13 floors or above)	[Y] Mid (5 to 12 floors)	[Z] Low (4 floors or under)	20%	X% Y% Z%	X% Y% Z%	X% Y% Z%	X% Y% Z%	X% Y% Z%
Population density (inhab./km²)	> 5.000 inh./km² [X]	1.500 - 5.000 inh./km² [Y]	< 1.500 inh./km² [Z]	10%	X% Y% Z%	X% Y% Z%	X% Y% Z%	X% Y% Z%	X% Y% Z%
Average annual temperature (°C)	> 14 °C	6 - 14 °C	< 6 °C	10%	L, R, H	L, R, H	L, R, H	L, R, H	L, R, H
Average annual pluviometry (mm)	< 800 mm	800 - 1.600 mm	> 1.600 mm	10%	L, R, H	L, R, H	L, R, H	L, R, H	L, R, H
Mean wind speed (m/s) (https://globalwindatlas.info/)	< 3 m/s	3 - 6 m/s	> 6 m/s	20%	L, R, H	L, R, H	L, R, H	L, R, H	L, R, H
Green space coverage within city (%)	< 15 %	15 - 30 %	> 30 %	10%	L, R, H	L, R, H	L, R, H	L, R, H	L, R, H

Table 65. Questionnaire for air pollutant dispersion

The same exercise will be applied to any city in Europe on T9.6 for the replication, classifying the cities among those where air is easily dispersed, and thus, the pollution impact is lower and those where the air is not easily dispersed, where population is highly impacted and consequently inferring a higher morbidity and mortality. In annex 4, the results of the five cities evaluation is provided, resulting in an air pollutant dispersion medium in all the cases, so no corrective figures were applied to the SUMI figures using an average DALY in all cases.

CONCENTRATION AIR INDEX	Weighted Ratio by city (index, 1-3)				
	Paris	Utrecht	Turin	Zaragoza	Tallinn
Air pollutant dispersion	1.94	2.39	1.80	2.20	2.20

Table 66. Concentration Air Index

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5.7. Monetization of externalities

Monetisation of environmental impacts describes the effort of expressing emissions into the environment in monetary values with the goal of an economic quantification of environmental damage caused through a product or process, which then can be the basis for a monetary incentive void said impacts[53]. It can also be expressed in the opposite way; the monetization of positive externalities can justify investments in clean technologies (as the electromobility represents).

5.7.1. Ext. 1. Monetization of Air Pollutants (PM2.5, Sumi 3)

Air pollution is responsible of many deaths and serious illness. Impacts caused by emissions to air other than climate change, namely ozone layer depletion, acidification, photochemical oxidant formation, particulate matter formation, nitrogen deposition from emissions to air, terrestrial and aquatic ecotoxicity and human toxicity from toxic emissions to air, are defined in the LCA methodologies. PM stands for particulate matter and the 2.5 refers to size. To help understanding it refers to matter that has a diameter of 2.5 micrometers or smaller. People who are sensitive to air pollution might experience symptoms when PM2.5 levels are high. This includes people with heart or lung conditions. Common sources of PM2.5 particles include car and truck exhausts.

The SUMI 3 methodology starts from the identification of the total number of vehicles km in a city and then classify those vehicles by type of engine and year of construction (using the Euro car classification). This information was recovered from all the participant cities in IncitEV. For instance, the distribution in Paris in year 2021 was as follows:

PARIS 2021												
VKM	(Mill. vkm/year)	Gasoline	Diesel	CNG	LPG	Ethanol	Bio-Etha.	Bio -Diesel	Hydrogen	Electric.	Gas. hybrid	Diesel hybrid
car (M1)	2,000.3	**1,091.1**	**762.9**	1.0	1.0	1.0	1.0	1.0	1.0	103.9	18.0	18.4
bus (M2)	505.0	0.0	449.5	6.7	6.7	6.7	6.7	6.7	6.7	13.3	0.9	1.0
PTW/Motorcycle	282.5	282.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LGV (<1305kg)	164.3	13.1	142.9	0.3	0.3	0.3	0.3	0.3	0.3	0.0	3.3	3.3
LGV (1305-1760kg)	109.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LGV (>1760kg)	54.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HGV	130.1	0.0	117.1	2.2	2.2	2.2	2.2	2.2	2.2	0.0	0.0	0.0

Table 67. Distribution of the million vehicles.km per type of motorization in Paris 2021

Then, the cars (gasoline and diesel) were classified as follows by year (Euro classification)

YEAR (EURO)	PM2.5 gr/km	Mill. VKM CAR (M1 Gas)
Euro 0	2.64	65.5
Euro 1	0.52	0.0
Euro 2	0.28	68.7
Euro 3	0.11	109.1
Euro 4	0.07	170.2
Euro 5	0.07	259.7
Euro 6	0.07	417.9
TOTAL		**1,091.1**

Table 69. Classification of million vkm of gasoline cars in Paris 2021, by year of production

YEAR (EURO)	PM2.5 gr/km	Mill. VKM CAR (M1 Dies.)
Euro 0	0.75	9.9
Euro 1	0.80	0.0
Euro 2	0.83	16.0
Euro 3	0.90	76.3
Euro 4	0.67	184.9
Euro 5	0.70	475.8
Euro 6	0.24	0.0
TOTAL		**762.9**

Table 68. Classification of million vkm of diesel cars in Paris 2021 by year of production

Every Euro category represents an average PM 2.5 eq emission, different for gasoline or diesel vehicles.

[53] Möglichkeiten und Grenzen der Monetarisierung von Natur und Umwelt. Beckenbach, Hampicke, Schulz. Berlin. 1998.

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The evolution of the vkm overtime, the weight of each type of motorization and the percentages of Euro categories, were calculated by the T9.2 team based on the trends from 2019 to 2022 and according to the projections already fixed in deliverable D9.1 for the electric vehicles and all cars (classified in cars and vans). To that end, also the ACEA progress reports[54] were used as reference.

With these figures identified by all types of vehicles, the evolution over time for years 2025, 2030 and 2035 was projected. We have considered that only cars and vans evolve over time, to isolate the possible effects of other type of vehicles in the air pollution, that were considered stable, and this way, evaluate appropriately the electrification effect for cars and vans, in terms of PM2.5 emissions. Thus, the air quality in the IncitEV cities in the future, will be probably better than the one represented in our figures because also buses, trucks, etc., will use cleaner technology, but this effect, as mentioned, was not quantified.

A compensation cost expresses the social cost of pollution and indicates the occurring loss of economic welfare when pollutants are emitted to the environment, looking at human health damage (morbidity, i.e., sickness and disease, and premature mortality). The endpoint valuation of human health is based on valuation of a DALY (Disability Adjusted Life Year) as mentioned. Recipe 2016 endpoint characterisation factors for PM formation are utilised to derive the monetisation factors (Huijbregts et al., 2016[55]). The value that has been considered for the project is 65.10 EUR/kg PM2.5 eq. NOx[56] is also converted in PM2.5 equivalent as explained in the table below:

The SUMI 3 methodology provides then a total kg PM2.5 /per capita that must be multiplied by the expected number of citizens in the referenced years. Below, the obtained results:

Emission Harm Effect in PM2.5 equivalents	
NO_x	0.067
PM2.5	1

Table 71. Relation NOx, PM2.5 equivalent

BASE PM2.5	Paris	Utrecht	Turin	Zaragoza	Tallinn
2,021	0.178	0.131	3.764	3.030	1.673
2,025	0.164	0.104	3.627	2.765	1.419
2,030	0.154	0.089	3.610	2.650	1.292
2,035	0.150	0.085	3.571	2.612	1.244

Table 70. kg PM2.5 eq /per capita per use case city in years 2021, 2025, 2030 and 2035, BASE Scenario

The economic impact was calculated in constant euros, considering the Daly values mentioned before, with inflation rate of 2%, then discounted at FDR of 4% and finally discounted euros establishing 2021 as the base (all values at zero in 2021 and the remaining years comparing their figures with this 2021 as reference year). These figures are positive representing savings in human health. Results are showed below:

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[54] ACEA Progress Report 2022. https://www.acea.auto/files/ACEA-2022-Progress-Report-Making-the-transition-to-zero-emission-mobility.pdf

[55] Huijbregts, M. A., Steinmann, Z. J., Elshout, P. M., Stam, G., Verones, F., Vieira, M. D. M., ... & van Zelm, R. (2016). ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and endpoint level. report I: characterization; RIVM Report 2016-0104. National Institute for Human Health and the Environment, Bilthoven.

[56] Source: TSAP report 15, IIASA http://ec.europa.eu/environment/air/pdf/TSAP-15.pdf

(Clean Air Programme/ National Emissions Ceilings Directive)

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Constant € kg PM 2.5 eq. (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	25.13	3.09	551.98	135.06	49.29
2025	25.68	2.73	579.56	135.46	45.59
2030	27.47	2.69	641.11	145.62	46.04
2035	30.34	2.91	715.45	160.51	48.96

Table 72. Social economic costs (in constant euros) in the use case cities due to PM2.5 eq. pollution

Discounted € kg PM 2.5 eq. (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	25.13	3.09	551.98	135.06	49.29
2025	21.95	2.34	495.41	115.79	38.97
2030	19.30	1.89	450.43	102.31	32.34
2035	17.52	1.68	413.15	92.69	28.27

Table 73. Social Economic costs (in discounted euros, 4%) in the use case cities due to PM2.5 eq. pollution

Discounted € (base 2021) kg PM 2.5 eq. (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	3.18	0.75	56.57	19.27	10.32
2030	5.84	1.20	101.55	32.75	16.95
2035	7.61	1.41	138.83	42.37	21.02

Table 74. Social Economic costs (in discounted euros with base 2021) in the use case cities due to PM2.5 eq. pollution

In order to monetise the values considered for the PM2.5 (€/kg eq.) an inflation rate of 2% was considered, throwing the following data;

EQUIVALENCES	Unit	2021	2025	2030	2035
PM 2.5 (€/ kg eq)	**€/kg PM2.5**	65.1	71.9	81.3	92.0

Table 75. Projections of the compensation costs for the PM 2.5 during years 2021, 20256, 2030 and 2035 with 2% inflation rate growth.

These impacts will be then extrapolated to the intermedium years to obtain the overall impact and compare with the investments done. Please check conclusion chapter with final curves. PM2.5 is a positive externality as the air quality is improved over time.

5.7.2. Ext. 2. Green House emissions (CO_2 eq., Sumi 7)

Carbon pricing is an instrument that captures the external costs of greenhouse gases (GHG) emissions; the costs of emissions that the public pays for, such as damage to crops, health care costs from heat waves and droughts, and loss of property from flooding and sea level rise, and ties them to their sources through a price, usually in the form of a price on the carbon dioxide (CO_2) equivalent emitted. A price on carbon helps shift the burden for the damage from GHG emissions back to those who are responsible for it and who can avoid it.[57]

[57] https://carbonpricingdashboard.worldbank.org/

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Placing an adequate price on CO_2 emissions is critical to internalize the external cost of climate change in the broadest possible range of economic decision making and in setting economic incentives for clean development.

Contribution to climate change from emissions of greenhouse gases are those from carbon dioxide, methane, nitrous oxide, among others. Emissions of greenhouse gases increase their atmospheric concentration (ppb), which rise the radiative forcing capacity and consequently increases the global mean temperature. Ultimately, extreme weather patterns, reduced agricultural yields and increased frequency of natural disasters can result in damage to the economy, human health, e.g., increased risk of diseases, natural disasters, and ecosystems (Huijbregts et al. 2016).

It is awaited to align costs of carbon with Paris Climate Agreement 2015 temperature targets. That is why the European Investment Bank Group[58] set a forecast with the estimated median values for 2020, 2030 and 2050, with linear interpolation for years in between. Aligned with this approach, the True Price Foundation[59] established a restoration cost for kg of CO_2 emitted in 2021, equivalent to 0.157 €/kg CO_2 eq. A restoration cost expresses the abatement cost for achieving the policy targets of reducing greenhouse gas emissions to meet the 2-degree target as set in the Paris Agreement, based on a meta-study of 62 marginal abatement cost estimates (Kuik, Brander and Tol, 2009)[60].

In the calculations of the economic benefits in terms of CHG. emissions reduction due to electrification of the private and public fleets, it was considered the reference value for 2021 indicated in the mentioned report from the True Price foundation, 157 € /ton of CO_2 eq. However, the growth of this number overtime, was increased 0.5 points over the inflation rate. The reason was the perception of the need to stimulate the rule that who pollutes pays as this trend is being consolidated in all the actions of the European Commission. Consequently, the monetization was established through the following figures:

EQUIVALENCES	Unit	2021	2025	2030	2035
CO_2 (€/ tCO2e)	**€/ton CO2eq**	157.0	173.3	196.1	221.8

Table 76. Compensation costs for the CO_2 eq. emissions

The procedure to calculate the emissions, following the SUMI 7 for this chapter, is very similar to the one used for the PM2.5. The SUMI 7 methodology also starts from the identification of the total number of vehicles km in a given city and then classify those vehicles by type of motorization (11 groups) and year of construction (using the Euro car classification, 6 groups). This information was recovered, as indicated in the previous chapter, from all the participant cities in IncitEV.

The SUMI 7 methodology provides then a total tons CO_2 eq. /per capita that must be multiplied by the expected number of citizens in the referenced years. Below, the obtained results for the base case.

[58] Climate Bank Roadmap 2021-2025. European Investment Bank Group. 2020.

[59] True Cost Foundation, V2.03 (2021). Monetization factors for true pricing

[60] Kuik, O., Brander, L., & Tol, R. S. (2009). Marginal abatement costs of greenhouse gas emissions: A meta-analysis. Energy policy, 37(4), 1395-1403. https://doi.org/10.1016/j.enpol.2008.11.040

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BASE SUMI 7 (TCO2/per cap)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2,021	0.526	0.751	6.051	6.877	5.235
2,025	0.489	0.669	5.992	6.745	5.162
2,030	0.458	0.570	5.906	6.615	5.039
2,035	0.448	0.514	5.768	6.463	4.880

Table 77. tons of CO2 eq. emitted by the overall vehicles fleet in the use-case cities. The reduction is due to the electrification process.

Below, the monetization of the CO_2 emissions in constant euros in the use-case cities, due to the existing fleet of vehicles (including, cars, vans, trucks, motorcycles, and buses) for the base scenario. Then, the same values discounted with FDR of 4% and finally, the same figures but considering 2021 as the base year.

Constant € CO_2 eq (Million €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	178.88	42.67	2,139.86	739.20	371.85
2025	184.75	42.38	2,308.90	796.76	399.85
2030	197.32	41.26	2,529.36	876.43	433.00
2035	218.56	42.30	2,786.95	957.89	463.20

Table 78. Social economic costs (in constant euros) in the use case cities due to CO_2 eq. pollution

Discounted € CO_2 eq (Million €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	178.88	42.67	2,139.86	739.20	371.85
2025	157.93	36.23	1,973.66	681.07	341.79
2030	138.63	28.99	1,777.09	615.77	304.22
2035	126.21	24.43	1,609.39	553.15	267.49

Table 79. Social economic costs (in discounted euros, 4%) in the use case cities due to CO2 eq. pollution

Discounted € (base 2021) CO_2 eq (Million €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	20.95	6.44	166.21	58.13	30.06
2030	40.25	13.68	362.77	123.43	67.63
2035	52.67	18.24	530.47	186.05	104.37

Table 80. Social Economic costs (in discounted euros with base 2021) in the use case cities due to CO_2 eq. pollution

These impacts will be then extrapolated to the intermedium years to obtain the overall impact and compare with the investments done. Please check conclusion chapter with final curves. CO_2 eq. is a positive externality as the air quality is improved over time, so the figures represent savings due to reduction of emissions thanks to the substitution of conventional vehicles buy the electric ones. Low figures in Paris and Utrecht indicates that the improvement margin is lower as pioneering countries than in the other cities where margin is higher.

5.7.3. Ext. 3. Monetization of Noise Hindrance (>55 db., Sumi 4).

Noise from road, rail, and air traffic affects a great number of people. Exposure to transport noise may cause sleep disturbance as well as annoyance, potentially leading to high blood pressure and

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increased incidence of myocardial infarction (WHO, 2000 b[61]; Miedema & Vos 2007[62]; Babisch 2006[63], 2008). Transport noise exposure as a part of total environmental noise has also been linked to effects on cognition. However, effects on cognition were excluded, as these are difficult to quantify.

The methodology established by SUMI 4 to calculate the noise hindrance is based on defining what percentage of population is affected by an annoyance level of noise. This is fixed for noises over 55 db till 75 db. Thus, the population is classified by noise bands. The main noise sources are traffic, major railways, and close airports. In our estimations noise from railway and airports are considered fix whilst the traffic is affected by the introduction of the electric cars, less noisy. Furthermore, every band is assigned to a Lden values. These Lden values is a percentage of a given band of population that is affected by disturbance noise. For low level bands, this percentage is lower than from high level bands. The calculation is adjusted to a given curve:

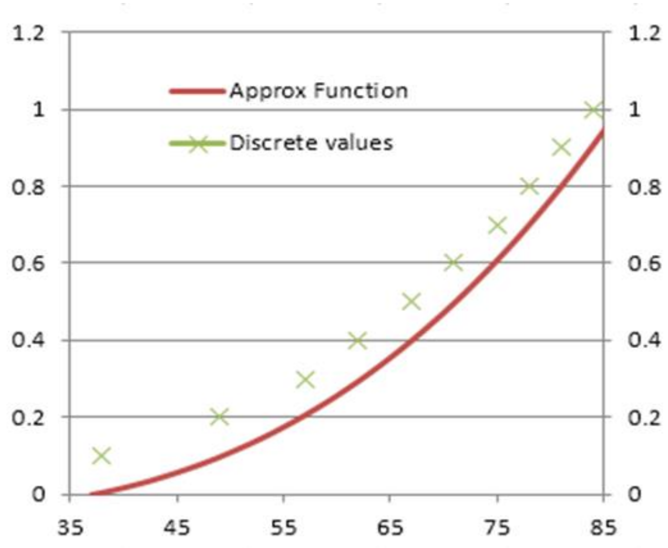

Figure 30. Relation between noise level and Lden value (in this case from 0 to 1)

There are two complex questions here:

a. In one side, how to calculate in a given city the number of people exposed to the level of noise, by the effect of traffic, railways, and planes.
b. On the other side, how to evaluate the modification of those coefficients of impact over time, due to the introduction of the electric vehicles.

The first problem was solved taking the information from a report signed by the European Environmental Agency[64] with data from 2017. It provides noise data by EU major cities and

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[61] WHO, 2000b. Transport-related Health Effects with a Particular Focus on Children. Topic report: noise. CONTRIBUTION

TO THE UNECE - WHO TRANSPORT, HEALTH AND ENVIRONMENT PAN-EUROPEAN PROGRAMME - THE

PEP. Available at: http://www.euro.who.int/Document/trt/PEPNoise.pdf

[62] Miedema HME & Vos H, 2007. Associations between self-reported sleep disturbance and transport noise based on reanalyses of pooled data from 24 studies. - Behavioural Sleep Medicine 5(1): 1-20.

[63] Babisch W, 2006. Transportation noise and cardiovascular risk: Review and synthesis of epidemiological studies, exposure-response curve and risk estimation. WaBoLu-Hefte; 01/06, Umweltbundesamt, Berlin

[64] European Environmental Agency. European noise in Europe 2020. No 22/2019, ISSN 1977-8449

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classified by source. Those data were then updated to year 2021 and later to 2025, 2030 and 2035. Although this information was asked to the IncitEV use case cities, the information provided was not coherent with the data of this report that was considered as more official and reliable.

The second issue is the key aspect of the calculation. The utopia of whisper-quiet cities and low-noise road traffic is not easy to achieve. First of all, the minimum requirement of a noise level of 57 dB is comparatively low and corresponds to normal conversation volume. In respect of electric cars, since July 2019, all electric and hybrid vehicles placed on the market in the EU, including Ireland, are required under Commission Delegated Regulation (EU) 2017/1576 to have an acoustic vehicle alerting system (AVAS) fitted, that will automatically emit a noise when travelling at speeds below 20 km/h and when reversing to alert pedestrians of oncoming vehicles. The device is obligatory in all new EVs since 1 July 2021. This sound can reach from 56 to 75 decibels. However, the greatest hope is offered by technology in the form of directed sound (only when required). In terms of e-cars, a combination of today's pedestrian and cyclist detection assistance systems, and a targeted warning sound is conceivable. In this way, electric cars would emit the driving noise or other acoustic signals directly to persons they recognise in the dangerous zones, while the vehicle would seem noiseless to other passers-by. However, for the moment, and considering that in traffic jams, vehicles drive at an average speed of 10 km/h (below 20 km/h) and that this speed increases on average to 30 km/h in non-rush hours, we have concluded that an electric vehicle might be a 60% less noisy than a conventional ICE car. Consequently, the penetration of electric vehicles reduces the sound bands proportionally to these numbers. In this sense, all vehicles in a given city in a reference year are converted in an equivalent number of vehicles considering that the electric fleet makes less noise.

Another important issue is related to associate the noise bands due to traffic to the flow of vehicles at that moment (in Vehicles/h). The following table was used to match these two concepts.

Type of Vehicle Noise level (db)/ Veh/h	ICE	EV
50	38.1	28.8
150	41.9	29.9
250	45.8	31.1
350	49.7	32.3
450	53.6	33.4
550	57.5	34.6
666	62.0	35.9
794	67.0	37.4
922	72.0	38.9
999	75.0	39.8

In table aside, we can see that 550 vehicles/hour in a given city generate 57.5 db. if all the cars are ICE and 34.6 db. if all of them were EVs. The same can be derived for the remaining noise bands. 57.5 db. is the average of a band between 55-59 db.

Table 81. Relation between vehicles flow and noise level (in db) for ICE and EV

In the tables below, the percentages of noise for the traffic in years 2021, 2025, 2030 and 2035 in the major use case country' cities are presented.

2021	France	Netherland	Italy	Spain	Estonia
55-59	18.20%	16.80%	14.00%	16.33%	14.00%
60-64	15.40%	13.07%	17.73%	17.27%	19.60%
65-69	10.73%	6.53%	14.93%	11.67%	14.00%
70-74	3.73%	0.93%	9.33%	5.60%	3.73%
>75	0.93%	0.47%	3.73%	1.87%	0.47%
TOTAL	49.0%	37.8%	59.7%	52.7%	51.8%
Inhabit	2,165,000	361,699	2,252,379	684,686	452,455
EVs	36,720	21,991	46,551	2,107	3,157
All Veh	707,200	446,545	1,598,221	472,671	344,483

Table 83. Percentage of population affected by noise traffic over 55 db. in major cities of the use-case countries in 2021 (Base scenario).

2025	France	Netherland	Italy	Spain	Estonia
57	17.08%	15.99%	13.49%	16.01%	13.74%
62	14.40%	12.40%	17.06%	16.91%	19.23%
67	10.00%	6.18%	14.34%	11.41%	13.73%
72	3.47%	0.88%	8.95%	5.47%	3.66%
>75	0.87%	0.44%	3.58%	1.82%	0.46%
TOTAL	45.8%	35.9%	57.4%	51.6%	50.8%
Inhabit	2,181,401	365,580	2,223,605	681,660	447,012
EVs	98,540	55,122	112,597	13,107	8,512
All Veh	695,548	442,086	1,573,672	468,746	340,858

Table 82. Percentage of population affected by noise traffic over 55 db. in major cities of the use-case countries in 2025 (Base scenario).

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2030	France	Netherland	Italy	Spain	Estonia
57	16.00%	14.96%	12.84%	15.43%	13.40%
62	13.43%	11.54%	16.19%	16.26%	18.72%
67	9.29%	5.72%	13.56%	10.96%	13.35%
72	3.21%	0.81%	8.44%	5.25%	3.55%
>75	0.80%	0.40%	3.37%	1.75%	0.44%
TOTAL	42.7%	33.4%	54.4%	49.6%	49.5%
Inhabit	2,195,050	369,219	2,184,130	675,767	438,249
EVs	167,423	109,370	244,348	38,539	21,126
All Veh	689,462	442,576	1,567,004	464,731	338,717

Table 84. Percentage of population affected by noise traffic over 55 db. in major cities of the use-case countries in 2030 (Base scenario).

2035	France	Netherland	Italy	Spain	Estonia
57	15.72%	14.55%	12.36%	14.93%	13.03%
62	13.18%	11.20%	15.53%	15.70%	18.18%
67	9.10%	5.54%	12.98%	10.56%	12.94%
72	3.14%	0.78%	8.06%	5.05%	3.44%
>75	0.78%	0.39%	3.21%	1.68%	0.43%
TOTAL	41.9%	32.5%	52.2%	47.9%	48.0%
(2035-2021)	-7.1%	-5.3%	-7.6%	-4.8%	-3.8%
Inhabit	2,200,689	371,057	2,178,063	668,069	427,864
EVs	182,125	126,929	339,196	60,171	35,964
All Veh	685,966	440,637	1,560,123	461,078	337,186

Table 85. Percentage of population affected by noise traffic over 55 db. in major cities of the use-case countries in 2035 (Base scenario).

According to the European Energy Agency [65], about 18 million people suffer long-term annoyance from transport noise in the European Union (EU). The European Commission's zero pollution action aims to reduce the number of people chronically disturbed by transport noise by 30% by 2030, compared to 2017 levels. However, in our estimations this figure will not be reduced too much between 2021 and 2030.

The results of the SUMI 4 for noise are included in the following table:

SUMI 4 (Noise % people affected, BASE)	2021	2025	2030	2035
Paris	31.21%	31.18%	31.13%	31.12%
Utrecht	29.19%	29.17%	29.13%	29.11%
Turin	36.69%	36.67%	36.62%	36.58%
Zaragoza	33.26%	33.25%	33.23%	33.21%
Tallinn	32.57%	32.56%	32.55%	32.53%

Table 86. Percentage of affected population of noise hindrance in the use-case cities by year

This coefficient is the result of considering all sources of noise (traffic, railway and plain) in the given cities and apply the Lden coefficients which are different by band of noise and the SUMI 4 methodology.

Finally, there are two additional concepts to introduce. According to the True Cost Foundation Report, there are 860 Dalys /over a million inhabitants suffering a high disturbance noise. The cost of these Dalys is 103,000 €/Daly increasing the cost according to the inflation rate in 2% per year.

EQUIVALENCES	Unit	2021	2025	2030	2035
Cost of (DALY)	**€/DALY**	103,000	**111,491**	**123,095**	135,906

Table 87. Cost of Daly. Source Tru Cost Foundation

Applying all these figures, the final results in million savings for the base scenario, are the following, using the same methodology than former externalities; constant values, discounted and discounted with base in 2021:

[65] https://www.eea.europa.eu/highlights/eu-unlikely-to-meet-noise#:~:text=The%20European%20Commission's%20zero%20pollution,2030%2C%20compared%20to%202017%20levels.

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Constant € Noise Hindrance (Mill. €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	59.86	9.35	73.20	20.17	13.05
2025	65.21	10.22	78.17	21.73	13.96
2030	72.34	11.38	84.67	23.77	15.10
2035	80.05	12.63	93.12	25.93	16.27

Table 88. Social economic costs (in constant euros) in the use case cities due to noise hindrance

Discounted € Noise Hindrance (Mill. €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	59.86	9.35	73.20	20.17	13.05
2025	55.74	8.74	66.82	18.58	11.93
2030	50.83	8.00	59.49	16.70	10.61
2035	46.23	7.29	53.78	14.97	9.40

Table 89. Social economic costs (in discounted euros, 4%) in the use case cities due to noise hindrance

Discounted € (base 2021) Noise Hindrance (Mill. €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	4.12	0.61	6.38	1.60	1.12
2030	9.04	1.35	13.71	3.47	2.44
2035	13.64	2.06	19.42	5.20	3.66

Table 90. Social Economic costs (in discounted euros with base 2021) in the use case cities due to noise hindrance

These impacts will be then extrapolated to the intermedium years to obtain the overall impact and compared with the investments done. Please check conclusion chapter with final curves. Noise hindrance is also a positive externality as the noise in the use case cities will be reduced over time with the progressive introduction of the electromobility.

5.7.4. Ext. 4. Road deaths and serious injury, (Sumi 5).

SUMI 5 calculates the impact of road deaths and serious injury people, based on the number of deaths. There is then a relation between the deaths and the serious injured people in car accidents. This is a fix number that we have set on 35 injured people by 1 death, according to a recent report of the European Transport Safety Council (ETSC)[66].

Another report from the Institute for Road Safety Reseach (SWOV)[67] provides the real costs of a traffic death in the Netherlands in 2021. The social costs of road crashes in the Netherlands in 2021 were estimated in € 27 billion (between € 15 and € 36 billion), equivalent to 3% (1.9-4.5%) of the gross domestic product (GDP). This is significantly higher than other traffic-related social costs such as traffic congestion or environmental damage. About three quarters of the total costs are human costs, while the damage to vehicles is the second highest cost item (14% of the total costs).

Other cost items are medical costs, loss of production, settlement costs and congestion costs. The costs amount to about € 6.5 million per road death and € 0.7 million per serious road injury.

[66] ETSC Panel. Ranking EU Progress on road safety. 17th Road Safety Performance Index Report, June 2023

[67] SVOW Raod Crash Costs. SWOV fact sheet, November 2022

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ROAD DEATHS	2021	2025	2030	2035
Cost of road death (Million €) NL	6.5	7.04	7.77	8.58
Cost od Serious road injury NL	0.7	0.76	0.84	0.92
Relaton Serious injury/Death	35			

Table 91. Cost of death and serious injured in the Netherlands (2021) by traffic accident

Then, these figures have been adapted to the life level of the other countries applying the UN human development index[68] that modifies the figures for the rest of the cities.

Externality	Unit	Paris	Utrecht	Turin	Zaragoza	Tallinn
Human Development Index (HDI)	Value	**0.903**	**0.941**	**0.895**	**0.905**	**0.890**

Table 92. Human Development Index in the use case countries

IncitEV use case cities has been asked to provide data (death and injured people) on Pedestrian, Bicycle (including e-bike, etc.), Moped, Motorcycles, Cars, LDV (<3.5 tons), Trucks (≥3.5 tons), Bus, Tram, Light rail and other mobility options. Electric vehicles can impact on cars but also in pedestrian, bicycles, or motorbikes if they are involved in the accidents.

The numbers provided by the cities (for all vehicles) where then compared with the average number of deaths by country according to the ESTC report (table 93 below). If deviation were not significant, they were accepted and only in case there were huge differences, the numbers from the ESTC report were selected as correct.

Then, these figures were projected according to the trends in number of deaths through a yearly percentage of reduction (in most cases). This trend was taken also from the said report. This was called the historical trend. It is worthy to mention that in the case of the Netherlands, there is a slight increase in deaths. The reason can be justified by the fast deployment of the electric fleet.

The reason of this increase when EVs penetrate can be found in recent studies that point out that electric vehicles can infer more accidents than conventional specially among pedestrians because of the lack of noise but also between cars because of the fast accelerations allowed by the electric engines. This trend seems to be real, and we have considered it in our calculations. Thus, in one hand there is a reduction in car accidents in all cities due to the improvements in car safety appliance and also thanks to the reduction in average mileage inside cities. In the other hand, it has been demonstrated that EVs infer some more accidents by the mentioned reasons (lack of noise, more weight or faster acceleration)[69], [70] as reported by an AXA study and other sources.

[68] United Nations. Development Programme. Human Development Reports. https://hdr.undp.org/data-center/human-development-index#/indicies/HDI

[69] https://www.cbsnews.com/news/electric-vehicle-safety-heavy-battery/

[70] https://www.reuters.com/article/us-autos-insurance-idUSKCN1VC1R4

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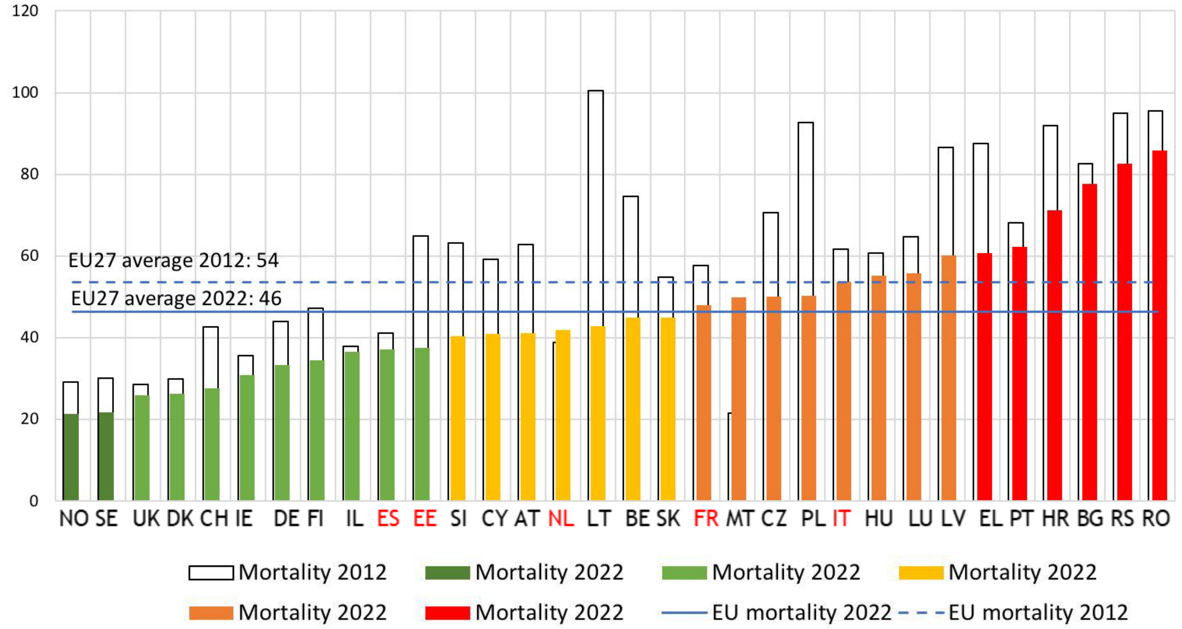

Table 93. Mortality (road deaths per million inhabitants) in 2022 (with mortality in 2012 for comparison). (1) National provisional estimates used for 2022, as final figures were not available at the time this report went to print. (2) CARE provisional data

Hence, the reasonable doubt is how to measure the impact of the electromobility on this trend. AXA Switzerland[71] statistics recently showed (august 2022) that, compared to drivers of traditional combustion vehicles, owners of electric cars are responsible for 50% more collisions causing damage to their own vehicle. The researchers noted that faster acceleration plays a critical role in these accidents as well as the noise. We do believe that although this issue requires additional research, we have placed a 25% increase in cars accidents due to electrification.

Therefore, from the trend in car accidents reduction, it has been set a 25% increase in accidents proportional to the electric weight in the overall fleet. This way, the subtraction between an ICE trend scenario and a scenario with an increase in accidents due to the electrification of part of the fleet, makes up a (negative) externality due to the adoption of electric vehicles.

In the table aside, we can see how the number of casualties is modified by the introduction of EVs.

The upper table quantifies the extra deaths due to the EVs penetration whilst the down table follows the historical trend (deaths / 100,000 inhabitants)

REAL DEATHS FORECAST	Deaths /100.000 Inh	Paris	Utrecht	Turin	Zaragoza	Tallinn
	2021	6.49	3.14	5.15	7.16	4.00
	2025	6.18	3.23	5.02	6.95	3.29
	2030	5.73	3.35	4.87	6.76	2.59
	2035	5.22	3.39	4.63	6.58	2.05

HISTORICAL DEATHS TREND	Deaths /100.000 Inh	Paris	Utrecht	Turin	Zaragoza	Tallinn
	2021	6.49	3.14	5.15	7.16	4.00
	2025	5.97	3.14	4.94	6.91	3.27
	2030	5.40	3.15	4.69	6.63	2.55
	2035	4.90	3.17	4.39	6.38	2.00

Table 94. Number of dead people by car accident, with (upper table) and without (down table) the EV effect in use case cities (by 100,000 inhabitants).

The same tables can be shown considering 2021 as the reference year with the following results.

[71] https://s3.observador.pt/wp-content/uploads/2022/09/07165231/axa-switzerland-takes-the-following-position-regarding-the-reactions-to-the-crash-tests-carried-out-on-august-25.pdf

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EXTRA DEATHS BY EV	Deaths /100.000 Inh	Paris	Utrecht	Turin	Zaragoza	Tallinn
	2021	0.00	0.00	0.00	0.00	0.00
	2025	0.21	0.10	0.09	0.05	0.02
	2030	0.33	0.19	0.18	0.14	0.04
	2035	0.33	0.23	0.24	0.21	0.05

EXTRA DEATHS & INJURED BY EV (COSTS)	Cost deaths & injured (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
	2021	0.00	0.00	0.00	0.00	0.00
	2025	-12.42	-5.87	-5.16	-2.84	-1.19
	2030	-21.25	-12.91	-11.80	-8.92	-2.56
	2035	-23.27	-16.69	-16.99	-14.91	-3.78

Table 95. Upper table. Extra deaths by the influence of EV penetration (Base year 2021, deaths by 100,000 inhabitants). Down table. Quantification of cost by the extra deaths and seriously injured (Million €. Constant price)

Subject to extra research, apparently, EVs cause additional accidents inside the cities by the lack or very reduced noise affecting pedestrian and the high acceleration. This was quantified in 25% additional deaths compared to the ICE technology, so this is a negative externality. Table 95 above, calculates the cost of these extra accidents considering that there are 35 serious injured people per each casualty.

If we make the discounted table with Financial Discount Rate of 4%, the table shows the following aspect:

Discounted € (base 2021) Road Deaths (Million €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	-10.62	-5.02	-4.41	-2.43	-1.02
2030	-14.93	-9.07	-8.29	-6.27	-1.80
2035	-13.44	-9.64	-9.81	-8.61	-2.18

Table 96. Discounted road deaths and injured costs due to extra accidents by the influence of EV penetration (Million €)

These impacts will be then extrapolated to the intermedium years to obtain the overall impact and compare with the investments done. Please check conclusion chapter with final curves. "Casualties and serious injured people externality" is a negative one as the casualties in the use case cities due to the electromobility are increased over time.

5.7.5. Ext. 5. Monetization of congestions and delays.

The calculation of the congestion and associated delays due to the introduction of the electric vehicles in the use case cities is the most difficult externality to measure. Indeed, the Sumi 8 to calculate these congestions was partially used and a new methodology was adopted here. The new methodology presumes the following assumptions:

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a. Several studies[72],[73] have identified that the use of electric vehicles inside cities increases the yearly mileage. This is due to the "rebound effect". The rebound effect is an induced demand of a good due to a change in the price of the good. It is a common effect in environmental economics and should be considered in economic appraisal of environmental policies. According the OGL report, although retail prices for EVs are higher, the daily operating costs are relatively cheaper compare with ICE, as we can see in the following charts. That move users to drive more than conventional ICE car owners.

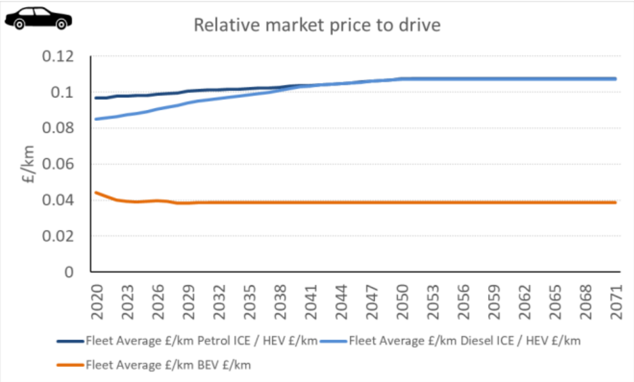

Figure 31. Comparison market prices to drive in cars.

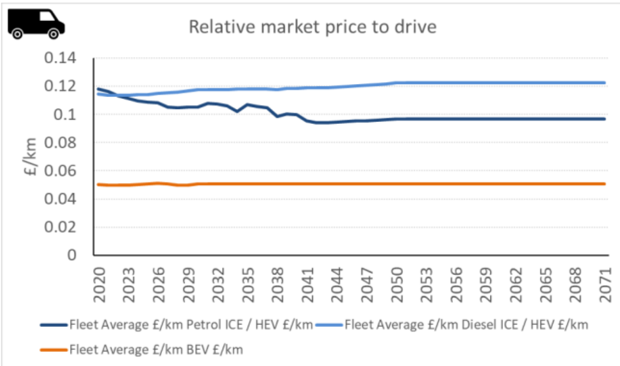

Figure 32. Comparison market price to drive in vans.

The report also identifies an average curve with the extra road traffic demand for electric cars and vans which is significative. The additional mileage (vkms) reflects the additional time spent in congestion due to electric cars and vans. This also represents a greater number of expected accidents as a result of more mileage, and therefore the social damage cost to other drivers as a result. This trend is the opposite if we look to the long distance trips where electric cars reduce the milage. The reason is the complexity to drive long distances with autonomy limitations.

In the section related to the car accidents, it was estimated a 25% additional number of deaths and serious injured caused by electric cars, due to three main reasons; extension of mileage, lack or reduce noise affecting mainly pedestrian run over and sudden accelerations. For the same reason, we have assessed the extension of daily mileage in a 20% for EVs compared to ICE cars. Of course, this figure cannot be clearly proven and require additional research, but the mentioned recent papers suggest that this figure may be appropriate and was consequently, taken as reference in our calculations.

b. SUMI 8 methodology was not fully adopted for the calculation, as this procedure estimate the congestion in a city for all cars but not the extra congestion generated by the EVs that is caused by the extra mileage as mentioned associated to the weight of EVs in the circulating fleet. Is this difference what interest us.

---

[72] UK Department for Transport. OGL, Zero Emissions Vehicle Mandate and non-ZEV Efficiency Requirements Consultation-stage Cost Benefit Analysis, March 2023. www.gov.uk/government/organisations/department-for-transport.

[73] A. Grigorev et all. How will electric vehicles affect traffic congestion and energy consumption: an integrated modelling approach. [eess.SY], October 2021

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However, cities are suffering many policies aimed at reinforcing public transport, micromobility or shared transport, zero-emission zones or pedestrianizing of the streets, etc., (please check deliverable D9.1) with the result of reducing new car registrations and to a minor extent, the stock of vehicles on public roads, although not necessarily the congestion in those places where circulation is allowed to conventional vehicles.

A recent study in the city of Madrid[74] has assessed that after the implementation of a zero emission zone in its center, traffic has been significantly reduced in said area, but not in the streets bordering it, where it was increased. Therefore, to assess the extra congestion in a city, when electric cars are being incorporated, we must consider the following:

- Not all the existing stock of vehicles in a city circulates daily. Normally, it is considered that between 30% to 70% for conventional cars and 90% for electric ones, circulate daily. In our analysis, we have considered that those cities with more measures to promote electromobility will be close to 30% and those with fewer measures will be around 70%. In deliverable D9.1, a ratio of public support measures was identified for each city that, conversely, it has helped us to decide this percentage by applying the inverse formula. See the calculations in the example.

	From D9.1 Change by scenario	Paris	Utrecht	Turin	Zaragoza	Tallinn
	Measures to boost E-Mobility	61.86%	64.92%	33.44%	16.50%	14.40%
2,021	Stock of EVs	36,720	21,991	46,551	2,107	3,157
	Stock all cars & Vans	707,200	446,545	1,598,221	472,671	344,483
2,025	Stock of EVs	98,540	55,122	112,597	13,107	8,512
	Stock all cars & Vans	695,548	442,086	1,573,672	468,746	340,858
2,030	Stock of EVs	167,423	109,370	244,348	38,539	21,126
	Stock all cars & Vans	689,462	442,576	1,567,004	464,731	338,717
2,035	Stock of EVs	182,125	126,929	339,196	60,171	35,964
	Stock all cars & Vans	685,966	440,637	1,560,123	461,078	337,186
					Max 70%	Max 70%
	Ratio to infer stock circulating	45.77%	42.10%	70.00%	70.00%	70.00%

Table 98. Stock of EVs and all cars and vans in years 2021, 2025, 2030 and 2035, and calculation of percentage of such stock circulating daily

2,021	%Cars and vans in use daily	45.8%	42.1%	70.0%	70.0%	70.0%
	Vehicles Entering daily	323,671	187,978	1,118,755	330,870	241,138
2,025	Cars in use daily	44.2%	40.5%	69.4%	69.4%	69.4%
	Vehicles Entering daily	307,306	178,899	1,092,758	325,497	236,692
2,030	Cars in use daily	41.8%	38.0%	68.6%	68.6%	68.6%
	Vehicles Entering daily	288,214	168,284	1,074,965	318,805	232,360
2,035	Cars in use daily	39.8%	36.0%	67.9%	67.9%	67.9%
	Vehicles Entering daily	273,153	158,575	1,059,324	313,072	228,949

Table 98. Stock of vehicles in use daily in the use case cities in years 2021, 2025, 2030 and 2035. Base Scenario.

[74] J. Moral-Carcedo. Dissuasive effect of low emission zones on traffic: the case of Madrid Central, July 2022. https://doi.org/10.1007/s11116-022-10318-4

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- In the table ahead, the percentages of daily traffic are applied to year 2021. Later, for years 2025, 2030 and 2035 those percentages are reduced a bit. This is due to the increasing measures to discourage citizens to use the cars inside the cities. Thus, we do believe that those percentages will be reduced slightly in parallel to the reduction of cars and vans stock. To calculate such reduction per year, we have used the formula.

$$Y = 0.0275.X + 0.02125$$

where X is the inverse of the electromobility promotion ratio in percentage (between 30% and 70%) and Y indicates the annual percentage reduction of vehicles in circulation over those existing in the year 2021. Y goes from 1.30% if measures to discourage ICE mobility are very strong (X=30%) to 0.2%, if measures are very light (Y=70%). Considering all these assumptions the initial table that showcases the number of electric vehicles in daily circulation and the rest of cars is as follows;

Daily vehicles circulating inside the cities (a percentage of the total stock)		Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	EVs	33,048	19,792	41,896	1,896	2,841
	Rest ICE	290,623	168,186	1,076,858	328,973	238,297
	All cars and vans 2021	**323,671**	**187,978**	**1,118,755**	**330,870**	**241,138**
2025	EVs	88,686	49,610	101,337	11,796	7,661
	Rest ICE	218,620	129,289	991,421	313,701	229,031
	All cars and vans 2025	**307,306**	**178,899**	**1,092,758**	**325,497**	**236,692**
2030	EVs	150,681	98,433	219,913	34,685	19,013
	Rest ICE	137,533	69,851	855,052	284,120	213,347
	All cars and vans 2030	**288,214**	**168,284**	**1,074,965**	**318,805**	**232,360**
2035	EVs	163,912	114,236	305,277	54,154	32,368
	Rest ICE	109,240	44,339	754,047	258,918	196,582
	All cars and vans 2035	**273,153**	**158,575**	**1,059,324**	**313,072**	**228,949**

Table 99. Daily vehicles circulating inside the use case cities classified by electric and the rest, for years 2021, 2025, 2030 and 2035.

- The next step is to calculate the number of hours of congestion (jam) in the different cities in the year 2021. To this end, the values were obtained from a Tom-tom[75] website, which provides the following information:

  a. The average time spent driving during the year inside the city and from that time how much time in a congestion. I.e., in the case of Utrecht, this was 83 h/year and 26h/ in congestion.

  b. In a route of 10 km, how much extra time was needed in the morning and in the afternoon traffic jam. I.e., in the case of Utrecht, 2 extra minutes in the morning and 4 extra minutes in the afternoon.

[75] https://www.tomtom.com/traffic-index/utrecht-traffic/

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c. How fast you can drive during rush hours in the city. In Utrecht, during the morning rush, it was 61 km/h and in the afternoon 51 km/h.

In order to treat the data, an average between morning and afternoon rush was done. The results per city are deployed below.

	CONGESTION CALCULATION	Paris	Utrecht	Turin	Zaragoza	Tallinn	
2021	V2: Average speed in rush hour (km/h)	18.5	56.0	20.5	38.0	27.5	Tomtom data
	V1: Average speed no rush hour (km/h)	34.4	77.8	32.8	46.9	45.1	10 km, calculated
	V3. Average Speed in highway			110.0	110.0	110.0	Time Rush-Extra time
	T2: time (rush hours) (h)	0.54	0.18	0.49	0.26	0.36	Tomton data
	T1: time no rush hours (h)	0.29	0.13	0.30	0.21	0.22	Calculated
	Extra time in rush hour (h)	0.25	0.05	0.18	0.05	0.14	Tomtom data
	Hours congestion/year & Veh (h)	107	18	26	26	63	Calculated with check
	Hours no congestion /year& Veh (h)	137	57	142	95	105	Sum up
	Hours no congestion extra province			89	148	259	From previous line
	Hours total/year&Veh (h)	**244**	**75**	**257**	**269**	**427**	
	km (rush hours)/Veh&year	1,974	1,019	527	988	1,733	
	km (no congestion)/Veh &year	4,715	4,433	14,472	20,743	33,198	
	km total /Veh&year	6,689	5,453	14,999	21,731	34,930	
	vkm (million km)	2,165	1,025	16,780	7,190	8,423	
	vkm Check	**2,165**	**1,025**	**16,780**	**7,190**	**8,423**	

Table 100. Calculations on congestion and non-congestion KPIs in the use-case cities

- Now, the next step distributes the total Vkm provided by the cities for cars and vans among ICE and EVs, considering that EVs makes a 20% more kms/day or year. This is due to the less operating costs as mentioned. The results are showed below:

	DISTRIBUTION OF MILEAGE	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	$km_{[2]}$ equv(ICE)/Veh&year	6,554	5,340	14,887	21,706	34,848
	km $equiv_{[1]}$ (EV)/Veh&year	7,864	6,408	17,865	26,048	41,818
	$VKm_{[2]}$ (ICE)/All&year (Mill. km)	1,905	898	16,032	7,141	8,304
	$Vkm_{[1]}$ (EV)/All&year (Mill. km)	260	127	748	49	119
	Check All Vkm	**2,165**	**1,025**	**16,780**	**7,190**	**8,423**
		Paris	Utrecht	Turin	Zaragoza	Tallinn
2025	$km_{[2]}$ equv(ICE)/Veh&year	6,666	5,454	14,970	21,851	35,096
	km $equiv_{[1]}$ (EV)/Veh&year	7,999	6,545	17,964	26,221	42,115
	$VKm_{[2]}$ (ICE)/All&year (Mill. km)	1,457	705	14,841	6,855	8,038
	$Vkm_{[1]}$ (EV)/All&year (Mill. km)	709	325	1,820	309	323
	Check All Vkm	**2,167**	**1,030**	**16,662**	**7,164**	**8,361**
		Paris	Utrecht	Turin	Zaragoza	Tallinn
2030	$km_{[2]}$ equv(ICE)/Veh&year	6,879	5,616	15,074	22,043	35,442
	km $equiv_{[1]}$ (EV)/Veh&year	8,255	6,739	18,089	26,451	42,530
	$VKm_{[2]}$ (ICE)/All&year (Mill. km)	946	392	12,889	6,263	7,561
	$Vkm_{[1]}$ (EV)/All&year (Mill. km)	1,244	663	3,978	917	809
	Check All Vkm	**2,190**	**1,056**	**16,867**	**7,180**	**8,370**
		Paris	Utrecht	Turin	Zaragoza	Tallinn
2035	$km_{[2]}$ equv(ICE)/Veh&year	7,153	5,839	15,168	22,200	35,702
	km $equiv_{[1]}$ (EV)/Veh&year	8,583	7,006	18,201	26,640	42,843
	$VKm_{[2]}$ (ICE)/All&year (Mill. km)	781	259	11,437	5,748	7,018
	$Vkm_{[1]}$ (EV)/All&year (Mill. km)	1,407	800	5,556	1,443	1,387
	Check All Vkm	**2,188**	**1,059**	**16,993**	**7,191**	**8,405**

Table 101. Distribution of vkm between electric and non-electric in the use case cities

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- Now, it is possible to calculate the rush hour spent in congestions comparing the rush hours in 2021 with the increase in traffic for the next years (vkm in 2025, 2030 and 2035). The results are shown below.

Hours Cong./Veh&y	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	106.68	18.20	25.72	26.00	63.00
2025	106.78	18.29	25.54	25.91	62.53
2030	107.93	18.75	25.85	25.96	62.60
2035	107.85	18.81	26.05	26.00	62.87

Table 102. Distribution of rush hours in the use-case cities per reference year

- The final calculation is the monetization of this extra time spent in rush hours. To that end, we have considered an average salary for the salaried staff per given country, with a 2% increase due to the inflation rate, and it was considered and an average car occupation by city[76]

Salaries /h	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	29.35	36.26	24.27	23.33	19.75
2025	31.77	39.25	26.27	25.26	21.38
2030	35.08	43.34	29.00	27.89	23.61
2035	38.73	47.85	32.02	30.79	26.07

Table 103. Average salary for the use case cities

Car Occupancy	Paris	Utrecht	Turin	Zaragoza	Tallinn
Total Person /car in rush	1.35	1.45	1.30	1.40	1.75

Table 104. Car occupancy by use-case city

Total cost Rush hours (Million €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	1,368.2	179.9	907.7	281.0	525.2
2025	1,407.5	186.3	952.9	298.2	553.9
2030	1,473.2	198.3	1,047.7	323.2	601.0
2035	1,540.3	207.0	1,148.5	350.9	656.5

Table 105. Total cost of rush hours in the use-case cities in years 2021, 2025, 2030 and 2035 derived from the EVs penetration. BASE

Total cost Rush hours (Million €, base 2021)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	39.31	6.32	45.22	17.14	28.68
2030	104.93	18.34	140.03	42.13	75.80
2035	172.08	27.05	240.78	69.85	131.36

Table 106. Total cost of rush hours in the use case cities with reference year 2021 derived from the EVs penetration.

[76] ChatGPT https://openai.com/chatgpt

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If we make the discount with a 4% FDR with base in 2021, the table shows the following:

Discounted € (base 2021)					
ıgestions (Million €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	-33.60	-5.40	-38.66	-14.65	-24.52
2030	-73.72	-12.89	-98.38	-29.60	-53.26
2035	-99.37	-15.62	-139.04	-40.34	-75.85

Table 107. Total cost of rush hours with reference in year 2021 discounted with an FDR of 4%.

These impacts will be then extrapolated to the intermedium years to obtain the overall impact and compared with the investments done. Please check conclusion chapter with final curves. Extra time in congestions derived from the electric vehicle's deployment is a negative externality as this time in the use case cities, is increased over time.

5.7.6. Ext. 6. Monetization of the public charging space usage.

In the same way as in the previous chapter, the assessment of the economic impact of public space for the use of chargers has not been calculated on the basis of SUMI 17, which assesses the use of public space that serves all mobility (electric or not). The calculation formula proposed is in this case, relatively simple, estimating the additions of new public chargers in the reference years (2021, 2025, 2030 and 2035), considering that each public charger occupies an 18 square-meter and valuing the public space at half the cost per square meter for dwelling in the reference cities, and considering an inflation rate of 2%. To value the cost of the land, price ranges have been established in the center and in the suburbs and the averages have been calculated. The data has been obtained from the Numbeo[77] website.

LAND PRICES IN USE CASE CITIES 2021 (€/m2)	Paris		Utrecht		Turin		Zaragoza		Tallinn	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Land Price in City Centre (€/m2)	10,000 €	15,000 €	5,620 €	9,500 €	2,700 €	4,000 €	2,260 €	5,000 €	2,800 €	4,800 €
Assigned Land Price in City Center for CPs (€/m2) (50%)	6,250 €		3,780 €		1,675 €		1,815 €		1,900 €	
Land Price in sorroundings (€/m2)	7,000 €	11,500 €	4,500 €	5,600 €	1,250 €	2,000 €	1,200 €	2,300 €	2,000 €	3,500 €
Assigned Land price in sorroundings for CPs (€/m2) (50%)	4,625 €		2,525 €		813 €		875 €		1,375 €	
Average assigned price for CPs space (€/m^2)	5,438 €		3,153 €		1,244 €		1,345 €		1,638 €	
Data Source	numbeo.com									

Table 108. Prices of public land assigned for CPs in the use case cities.

In the next table, the cost of new land for the Charging Points' space in the use case cities is provided, considering the land prices set in table 108 for 2021 and the projections for years 2025, 2030 and 2035 in the base case scenario with an inflation rate of 2%.

YEAR		2021	2025	2030	2035
CITY		PARIS			
Nº Pu Chargers (additions)	Units	832	886	1,186	2,349
Space /charger	m^2	18	18	18	18
Cost of land /m^2	€/m^2	5,438	5,886	6,498	7,175
TOTAL COST (Mill. €)	Mill. €	81.43	93.85	138.78	303.31

Table 110. Cost of public space additions in 2021, 2025, 2030 and 2035.

[77] https://www.numbeo.com/property-investment

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YEAR		2021	2025	2030	2035
CITY		UTRECHT			
Nº Pu Chargers (additions)	Units	305	343	510	839
Space /charger	m^2	18	18	18	18
Cost of land /m^2	€/m^2	3,153	3,412	3,768	4,160
TOTAL COST (Mill. €)	Mill. €	17.28	21.07	34.61	62.79
CITY		TURIN			
Nº Pu Chargers (additions)	Units	371	428	755	1,156
Space /charger	m^2	18	18	18	18
Cost of land /m^2	€/m^2	1,244	1,346	1,486	1,641
TOTAL COST (Mill. €)	Mill. €	8.30	10.38	20.21	34.15
CITY		ZARAGOZA			
Nº Pu Chargers (additions)	Units	36	160	272	516
Space /charger	m^2	18	18	18	18
Cost of land /m^2	€/m^2	1,345	1,456	1,607	1,775
TOTAL COST (Mill. €)	Mill. €	0.87	4.18	7.87	16.49
CITY		TALLIN			
Nº Pu Chargers (additions)	Units	23	38	90	169
Space /charger	m^2	18	18	18	18
Cost of land /m^2	€/m^2	1,638	1,772	1,957	2,161
TOTAL COST (Mill. €)	Mill. €	0.69	1.22	3.16	6.58
Inflation Rate	2%				

Table 111. Total Cost of Space occupied by public charging additions in the use case cities.

Below, the cost of the public charging space usage in constant €;

Constant €					
Charging Space Usage (Mil. €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	-81.43	-17.28	-8.30	-0.87	-0.69
2025	-93.85	-21.07	-10.38	-4.18	-1.22
2030	-138.78	-34.61	-20.21	-7.87	-3.16
2035	-303.31	-62.80	-34.15	-16.49	-6.58

Table 112. Cost of charging space usage in euro constant for the use case cities

The same cost applying a financial discount rate of 4%

Discounted €					
Charging Space Usage (Mil. €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	-81.43	-17.28	-8.30	-0.87	-0.69
2025	-80.22	-18.01	-8.88	-3.58	-1.04
2030	-97.51	-24.32	-14.20	-5.53	-2.22
2035	-175.16	-36.26	-19.72	-9.52	-3.80

Table 113. Cost of the charging space with an FDR of 4%.

Finally, the same costs but taken 2021 as referenced year.

Discounted € (base 2021)					
ging Space Usage (Mil. €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	1.21	-0.73	-0.58	-2.71	-0.35
2030	-16.07	-7.03	-5.90	-4.66	-1.53
2035	-93.72	-18.98	-11.42	-8.65	-3.11

Table 114. Cost of the charging space usage discounted at 4% and referenced to year 2021.

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These economic impacts will be then extrapolated to the intermedium years to obtain the overall impact and compare with the investments done. Please check conclusion chapter with final curves. Public chargers space derived from the electric vehicle's deployment is a negative externality as this space in the use case cities, reduces the number of conventional parking spaces, increases over time, and has a very high cost.

5.7.7. Ext. 7. Extra time losses in the charging process.

This is another little-researched chapter to date. There are only a few references from professional groups that are very intensive in the use of electric vehicles who have referred the need to spend extra time on top of their workday to recharge electric vehicles in opportunity chargers.

General speaking, professional electric drivers (taxi, delivery…) often need to spend an additional hour each day[78],[79] for charging compared to their counterparts who drive conventional gasoline or diesel-powered vehicles. This extra time is necessary because electric vehicles (EVs) generally have a limited range and require regular recharging to ensure they have enough power to operate throughout the day.

The charging time for an electric taxi can vary depending on several factors, including the vehicle's battery capacity, charging infrastructure availability, and the charging speed of the charging station being used. On average, it can take anywhere from 30 minutes to a few hours to charge an electric taxi fully.

To compensate for this additional charging time, professional electric taxi drivers may need to adjust their work schedule accordingly. They may choose to start their day earlier or finish later to accommodate the charging needs of their vehicles. Alternatively, they can plan their routes strategically to incorporate charging stops during periods of low passenger demand.

It's worth noting that the charging infrastructure for electric vehicles is continually improving, with the deployment of fast-charging stations and advancements in battery technology. As a result, the charging times for electric vehicles are expected to decrease in the future, which would reduce the additional time spent charging for electric taxi drivers and other professional.

For our calculations, we have considered that every professional (driver of an electric van) extend the working day around 0.5 h/day in 2021, due to the need to make an extra recharge in an opportunity charger. There are many reasons behind this assumption. Sometimes the weather is too cold or too hot reducing the battery autonomy till 30%[80], sometimes the chargers are busy or broken, sometimes the public chargers are not fast enough, or they are limited in number, finally sometimes the working day extends unpredictably forcing a fast opportunity load. This 0.5 h extension is then reduced overtime as soon as the infrastructure is deployed, and the technology improved according to the next table.

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[78] EVS30 Symposium. O.Olsson et all. Lessons learned from electric cars in daily taxi operation in Gothenburg. Oct 2017

[79] https://www.lbc.co.uk/news/london/electric-black-cabs-petrol-charging-points/

[80] https://www.cbc.ca/news/canada/sudbury/electric-vehicle-cold-range-1.6738892

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DAILY LOST TIME IN CHARGING (h/day)			
2021	2025	2030	2035
0.50	0.40	0.32	0.26

Table 115. Daily lost time in electric professional drivers

The stock of e-LDV vehicles was calculated in D9.1 being on average the 15% of all EVs in the city for the given year. From them, a percentage already calculated in the section of congestions is circulating daily. The stock of e-LDVs circulating was then calculated as follows:

Stock of e-LDVs	PARIS	UTRECHT	TURIN	ZARAGOZA	TALLINN
2,021	5,508	3,299	6,983	316	474
2,025	14,781	8,268	16,889	1,966	1,277
2,030	25,113	16,406	36,652	5,781	3,169
2,035	27,319	19,039	50,879	9,026	5,395
% Stock circulating from total	45.77%	42.10%	70.00%	70.00%	70.00%
2,021	2,521	1,389	4,888	221	331
2,025	6,765	3,481	11,823	1,376	894
2,030	11,494	6,906	25,656	4,047	2,218
2,035	12,503	8,015	35,616	6,318	3,776

Table 116. Stock of e-LDV in circulation in the use case cities during the referenced years.

Time losses at euro constant are reflected in the next chart:

Constant €					
Losses charging (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	**-13.50**	**-9.19**	**-21.65**	**-0.94**	**-1.20**
2025	**-31.38**	**-19.95**	**-45.34**	**-5.08**	**-2.79**
2030	**-47.09**	**-34.96**	**-86.90**	**-13.18**	**-6.12**
2035	**-45.25**	**-35.83**	**-106.56**	**-18.18**	**-9.20**

Table 117. Time losses in euro constant due the charging process in the use case cities and referenced years.

Applying a financial discount rate of 4%, these figures are transformed into the following:

Discounted €					
Losses charging (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	**-13.50**	**-9.19**	**-21.65**	**-0.94**	**-1.20**
2025	**-26.83**	**-17.05**	**-38.76**	**-4.34**	**-2.39**
2030	**-33.09**	**-24.56**	**-61.06**	**-9.26**	**-4.30**
2035	**-26.13**	**-20.69**	**-61.53**	**-10.50**	**-5.31**

Table 118. Time losses in real euro due the charging process applying an FDR of 4% in the use case cities and referenced years.

Finally, if we reference all costs to 2021, the previous table is converted in the following.

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Discounted € (base 2021)					
Losses charging (Mill €)	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	0.00	0.00	0.00	0.00	0.00
2025	-13.32	-7.86	-17.11	-3.40	-1.19
2030	-19.58	-15.37	-39.41	-8.32	-3.10
2035	-12.63	-11.50	-39.89	-9.55	-4.12

Table 119. Time losses in real euro due the charging process applying an FDR of 4% in the use case cities and using 2021 as reference year.

These economic impacts will be then extrapolated to the intermedium years to obtain the overall impact and be compared with the investments done. Please check the chapter with the final curves. Extra time used to recharge in opportunity chargers daily by professionals is a negative externality as these figures represent an extra cost in the transition to electrification.

5.8. Cumulative curves 2021-2035 for externalities.

The accumulated data of the monetized externalities for each of the target cities between the years 2021 and 2035 are presented below. It has been broken down into two chapters, on the one hand, the positive externalities derived from the environmental externalities (mainly PM2.5, GHG and noise hindrance) and, on the other, the set of externalities where it is observed that the economic impact is negative. These negative impacts will be explained later in the conclusions section. All the figures have been extrapolated to the intermediate years and discounted by a 4% FDR, considering an average inflation rate of 2%.

5.8.1. Positive Externalities

Below, an example of a projection of the Paris Central impact of positive externalities (PM2.5, CO2 eq. and Noise hindrance), compared with year 2021 in net present values and according to the electric vehicles forecast penetration.

	Paris
2021	**0.00**
2022	7.67
2023	14.93
2024	21.79
2025	**28.26**
2026	34.34
2027	40.06
2028	45.42
2029	50.43
2030	**55.12**
2031	59.47
2032	63.52
2033	67.26
2034	70.72
2035	**73.91**

Table 120. Positive Externalities Paris (years 2022-2035), base 2021

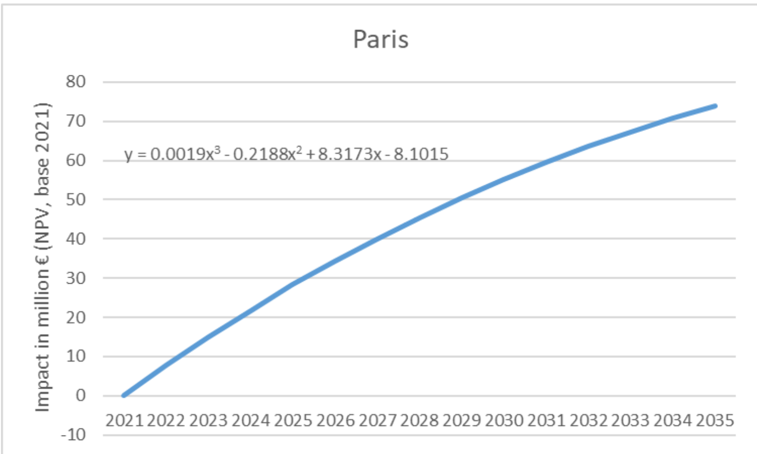

Figure 33. Projection, positive externalities in Paris Central (base years 2021, constant values)

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Below the same table, representing the positive externalities for the five use case cities,

Positive Externalities	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
2022	7.67	1.99	59.91	21.41	10.92
2023	14.93	3.96	118.05	41.64	21.46
2024	21.79	5.91	174.45	60.80	31.64
2025	**28.26**	**7.81**	**229.15**	**79.00**	**41.51**
2026	34.34	9.66	282.15	96.35	51.07
2027	40.06	11.44	333.51	112.97	60.36
2028	45.42	13.14	383.25	128.98	69.43
2029	50.43	14.76	431.40	144.50	78.30
2030	**55.12**	**16.24**	**478.03**	**159.66**	**87.02**
2031	59.47	17.65	523.05	174.48	95.54
2032	63.52	18.91	566.60	189.19	103.98
2033	67.26	20.03	608.69	203.85	112.34
2034	70.72	21.00	649.34	218.58	120.65
2035	**73.91**	**21.71**	**688.72**	**233.62**	**129.04**
TOTAL	632.89	184.21	5,526.30	1,865.02	1,013.27

Table 121. Impact of positive externalities in the use case cities according to the electric vehicle penetration (years 2022-2035) (2021 base year at constant values)

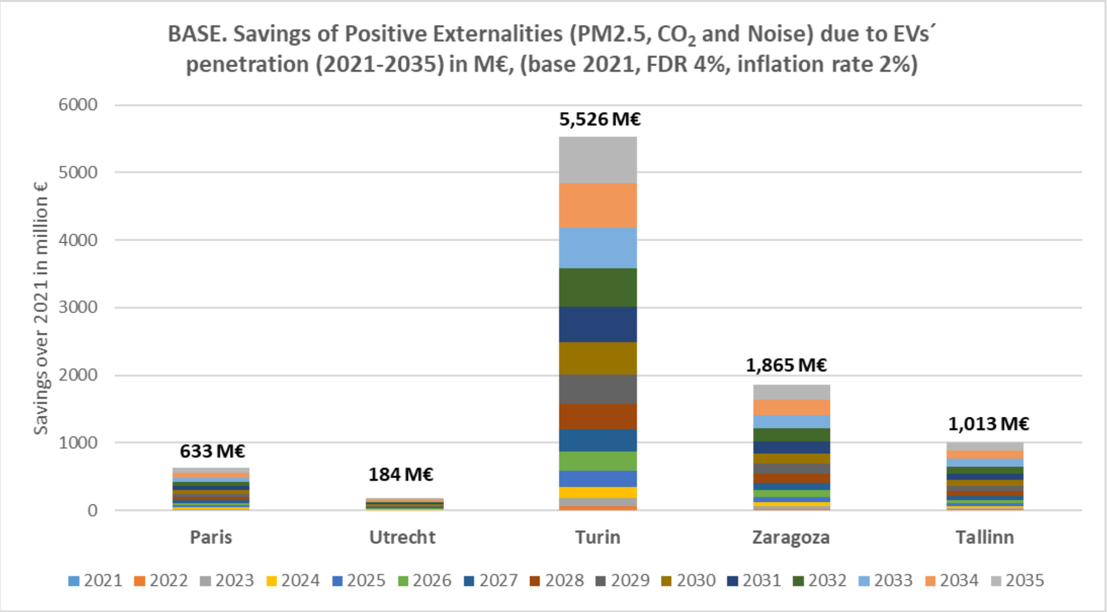

Figure 34. Graph of positive externalities in the use case cities according to the electric vehicle penetration (years 2022-2035) (2021 base year at constant cost)

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5.8.2. All Externalities

The same exercise can be done for all the externalities. In this case, the results for Paris and Utrecht are negative as it can be seen in the graph below.

rnalities	Paris
2021	**0.00**
2022	-7.58
2023	-14.63
2024	-21.38
2025	**-28.07**
2026	-34.96
2027	-42.28
2028	-50.27
2029	-59.17
2030	**-69.19**
2031	-80.70
2032	-93.80
2033	-108.80
2034	-125.92
2035	**-145.25**

Table 122. All Externalities Paris (years 2022-2035), base 2021

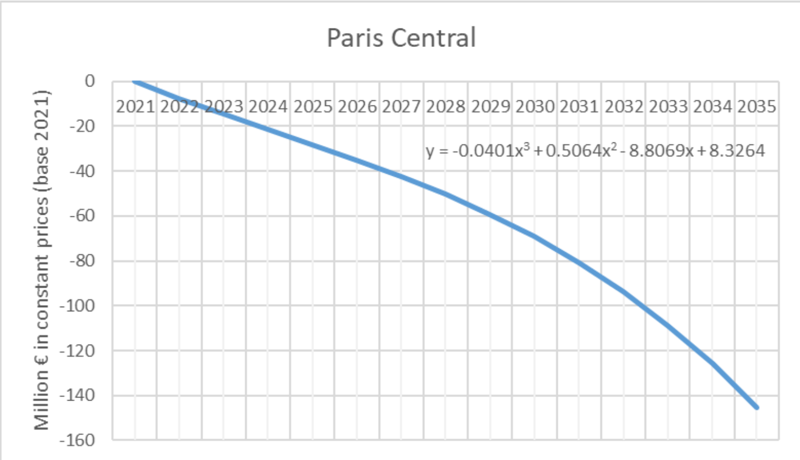

Figure 35. Projection, all externalities in Paris Central (base years 2021, constant values)

Bellow, all the externalities explored in the use case cities with positive and negative impact.

All Externalities	Paris	Utrecht	Turin	Zaragoza	Tallinn
2021	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
2022	-7.58	-2.12	47.80	15.53	4.27
2023	-14.63	-4.78	91.44	29.91	8.05
2024	-21.38	-7.85	131.45	43.29	11.42
2025	**-28.07**	**-11.21**	**168.39**	**55.82**	**14.43**
2026	-34.96	-14.75	202.80	67.64	17.22
2027	-42.28	-18.33	235.23	78.90	19.82
2028	-50.27	-21.85	266.21	89.75	22.33
2029	-59.17	-25.17	296.29	100.33	24.81
2030	**-69.19**	**-28.12**	**326.04**	**110.81**	**27.33**
2031	-80.70	-30.74	355.96	121.28	30.05
2032	-93.80	-32.74	386.63	131.94	32.96
2033	-108.80	-34.07	418.57	142.91	36.17
2034	-125.92	-34.59	452.35	154.35	39.76
2035	**-145.25**	**-34.04**	**488.55**	**166.47**	**43.77**
TOTAL	-882.00	-300.35	3,867.72	1,308.92	332.41

Table 123. Impact of all externalities (positive and negative) in the use case cities according to the electric vehicle penetration (years 2022-2035) (2021 base year at constant values)

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This information has been placed in the next chart.

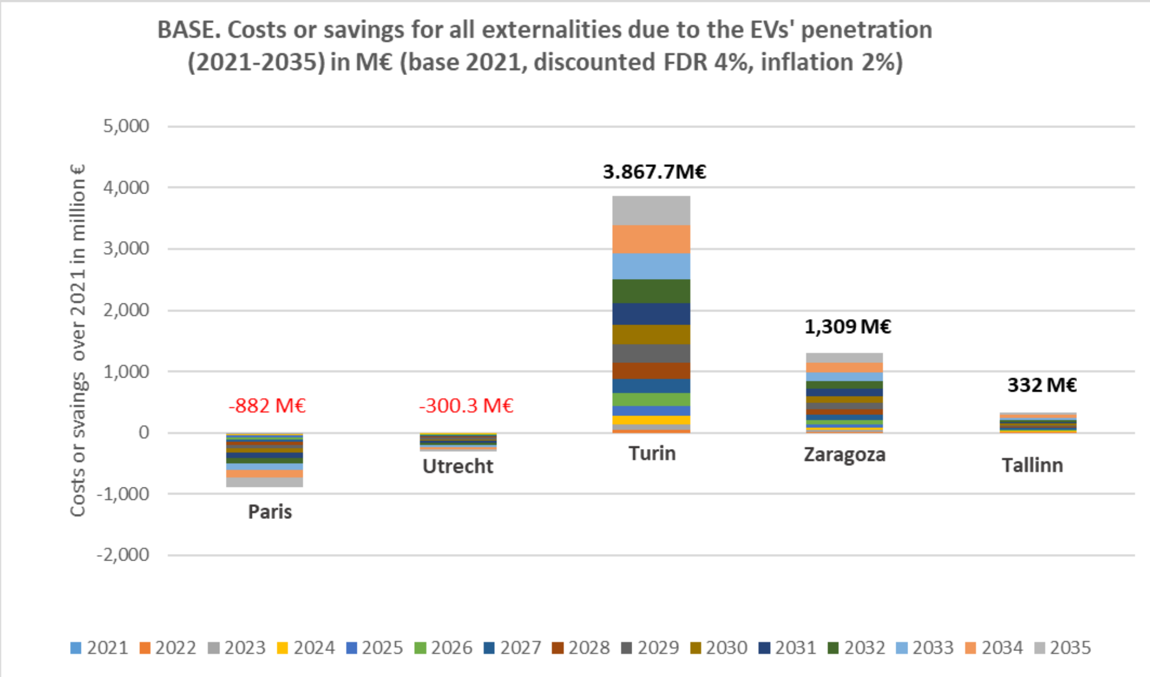

Figure 36. Graph of all externalities (positive and negative) in the use case cities according to the electric vehicle penetration (years 2022-2035) (2021 base year at constant cost)

In the next chapter we will perform the Cost Benefit Analysis combining the information of the first section (investments done by the administrations) and the second section (externalities obtained). One can be surprised that apparently those cities which are investing more are receiving less. The reason for that conclusion is that in the richest and leading cities as Paris or Utrecht, there was a substantial investment in the past (before 2021) in favour of electrification joined with measures to remove the ICE vehicles from inside the cities, expressed by a low vkm in such cities compared with the average inhabitants. Consequently, the future economic efforts will not impact proportionally in less pollution as can be seen in other current more polluted cities.

The follower and lagging cities have a much longer environmental path, even investing very little but taking advantage of the natural tendency to replace combustion vehicles with the electric ones, an effort mainly supported by the OEMs. In addition, the cost of terrain to install the public chargers is much lower in those cities than in the leading ones deriving in a global positive effect of all externalities. Let's see the reasons in detail in the CBA analysis in next chapter.

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6. COST BENEFIT ANALYSIS

In this chapter the city investments to promote electromobility and the externalities derived from it, will be compared for every given use case city.

6.1. Preliminary graphs

Before analysing the results, city by city, some graphs that explains the later results are provided herein. These graphs are; the total vehicles per inhabitant, the total electric vehicles per inhabitant, the total electric vehicles per total vehicles (penetration), the total stock of public chargers per electric vehicle and the total kms travelled by inhabitant.

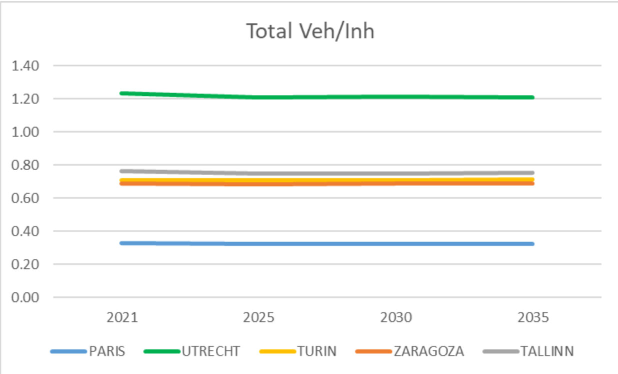

Figure 38. Total Vehicles per inhabitant

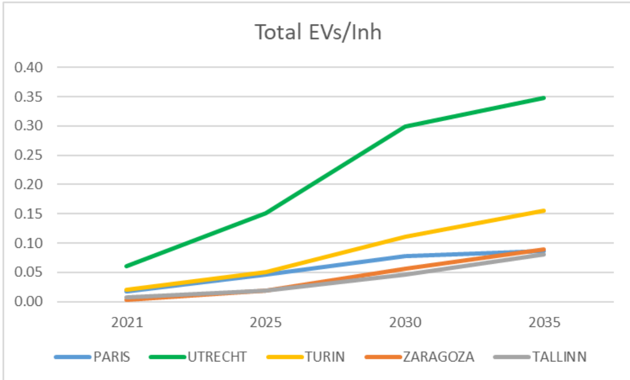

Figure 37. Total electric vehicles per inhabitant

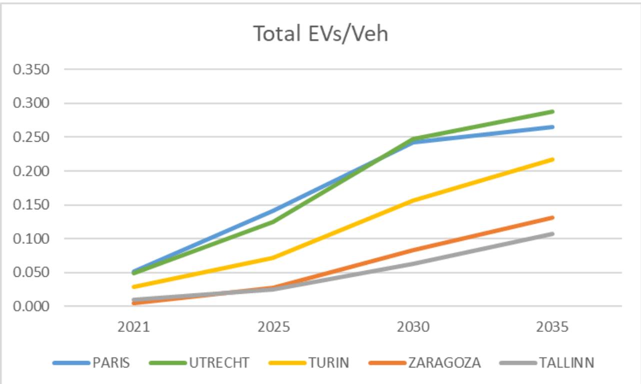

Figure 39. Total EVs per all vehicles

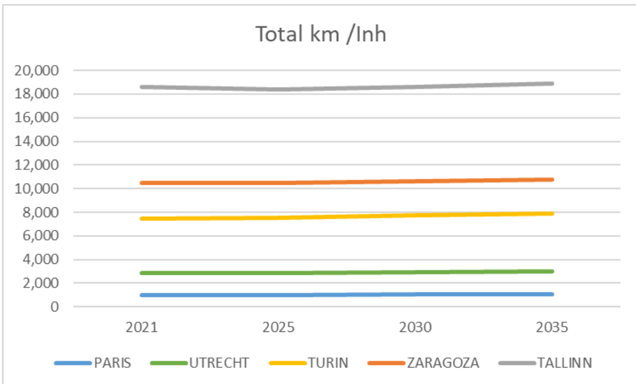

Figure 40. Total kms travelled by inhabitant.

KPIs	PARIS	UTRECHT	TURIN	ZARAGOZA	TALLINN
Total Veh/Inh	Low	High	Medium	Medium	Medium
Total EVs/Inh	Medium	High	Medium	Low	Low
Pu Ch Stock/EV	High	Medium	Low	High	Low
Total km/Inh	Low	Low	Medium	Medium	High
EVs/Veh	Medium	High	Medium	Low	Low

Table 124. Summary of indicators

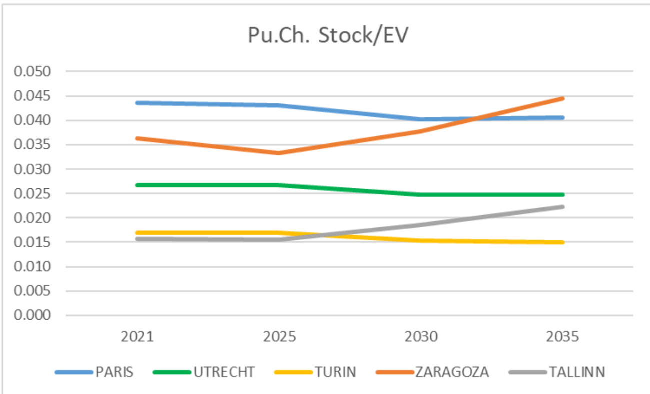

Figure 41. Public chargers Stock per EV

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The impact of these tables in the figures can be summarised as follows:

a. Total vehicles per inhabitants reflects in most cases how rich a country is.

b. Penetration of electric vehicle per all vehicles, reflects the environmental awareness of citizens joined with the positive measures to incentivise the transition to electric and sometimes the difficulties to enter in the city center with a conventional ICE vehicle. So, sometimes a high EVs penetration is the consequence of the policies against combustion engines.

c. Total electric vehicles per inhabitants reflects in one side the interest of citizens forced by the strict policies or by own decision to electrify but also reflect how clean the city is with less or more inhabitants driving an electric car. For instance, in Paris there are a low number of conventional vehicles and electric vehicles per inhabitant but the percentage of electric over total is high. So, Paris does not facilitate the use of conventional cars nor electric, but in case you have to use, you will drive electric.

d. Total kms travelled per year and inhabitants reflects how much the car is used daily. For instance, Dutch owns 1.20 cars per inhabitant (very high) but they do very low mileage. A high mileage inside the city with a high transition to electric provides lot of positive externalities. This is not the case for Utrecht or Paris as their yearly mileage is low.

e. The negative externalities are caused by a high use of electric cars inside the city (more accidents, more charging space, and more congestions, as electric drivers use to drive more. If electric LDV are highly used, there is also an extra time spent in the charging process for the same services.

Data must be analysed in absolute values but also in relative considering the number of inhabitants. The next table reflects this study considering the population in 2021 that varies very little over time in Europe for the five use case cities.

2021-2035 BASE	PUBLIC INVESTMENT					POSITIVE EXTERNALITIES			NEGATIVE EXTERNALITIES				Million €/€
PARIS	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
Expenditure Million €	-400.3	-668.3	-72.8	-81.2	-704.0	67.9	460.4	104.9	-169.4	-826.7	-307.4	-208.4	-2,805.5
			-1,141.5		-785.2			633.2				-1,512.0	
Expend./per cap. €	-184.9	-308.7	-33.6	-37.5	-325.2	31.3	212.7	48.5	-78.3	-381.8	-142.0	-96.3	-1,295.8 €
			-527.2		-362.7			292.5				-698.4	
UTRECHT	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
Expenditure Million €	-234.5	-551.8	-25.7	-52.4	-499.2	13.7	154.7	15.8	-100.5	-138.3	-89.5	-155.2	-1,662.9
			-812.0		-551.6			184.1				-483.5	
Expend./per cap. €	-648.4	-1,525.4	-70.9	-144.8	-1,379.9	37.8	427.6	43.6	-277.7	-382.4	-247.5	-429.1	-4,597.1 €
			-2,244.7		-1,524.7			509.0				-1,336.6	
TURIN	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
Expenditure Million €	-146.8	-412.7	-34.9	-138.1	-997.4	1,192.2	4,177.0	157.0	-92.5	-1,092.1	-64.9	-409.0	2,137.8
			-594.4		-1,135.5			5,526.3				-1,658.6	
Expend./per cap. €	-65.2	-183.2	-15.5	-61.3	-442.8	529.3	1,854.5	69.7	-41.1	-484.9	-28.8	-181.6	949.1 €
			-263.9		-504.1			2,453.5				-736.4	
ZARAGOZA	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
Expenditure Million €	-85.4	-41.1	-94.3	-20.3	-193.1	383.5	1,440.9	40.2	-69.0	-339.1	-60.8	-88.3	873.3
			-220.8		-213.4			1,864.7				-557.2	
Expend./per cap. €	-124.7	-60.0	-137.8	-29.6	-282.1	560.2	2,104.4	58.8	-100.8	-495.2	-88.7	-129.0	1,275.5 €
			-322.5		-311.7			2,723.4				-813.7	
TALLINN	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
Expenditure Million €	-15.6	0.0	0.0	-18.2	-96.4	197.8	786.9	28.4	-20.6	-608.7	-17.9	-33.3	202.3
			-15.6		-114.6			1,013.1				-680.5	
Expend./per cap. €	-34.6	0.0	0.0	-40.2	-213.1	437.2	1,739.2	62.7	-45.4	-1,345.4	-39.5	-73.6	447.2 €
			-34.6		-253.4			2,239.1				-1,503.9	

Table 125. CBA in the use case cities in absolute and relative values (per inhabitant) Global 2021-2035

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The same table but in a summarised format only for the absolute data is depicted below.

CBA Abs (Million €)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	A+B	A+B+C
Paris	-1,926.6	633.2	-1,512.0	-1,293.5	-2,805.5
Utrecht	-1,363.6	184.1	-483.5	-1,179.4	-1,662.9
Turin	-1,729.9	5,526.3	-1,658.6	3,796.4	2,137.8
Zaragoza	-434.2	1,864.7	-557.2	1,430.5	873.3
Tallinn	-130.3	1,013.1	-680.5	882.8	202.3

Table 126. CBA for the use case cities (summarized format, absolute figures in million €)

CBA Per capita (€)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	A+B	A+B+C
Paris	-889.9	292.5	-698.4	-597.4	-1,295.8
Utrecht	-3,769.4	509.0	-1,336.6	-3,260.4	-4,597.1
Turin	-768.0	2,453.5	-736.4	1,685.5	949.1
Zaragoza	-634.1	2,723.4	-813.7	2,089.2	1,275.5
Tallinn	-287.9	2,239.1	-1,503.9	1,951.1	447.2

Table 127. CBA for the use case cities (summarized format, per capita, in €)

6.2. Cost benefit analysis for Paris Central area

6.2.1. Analysis investments and externalities in Paris Central area

In the table below, a summary of the Paris Central projections for investments and externalities is provided. They have been grouped by public investments, and positive and negative externalities, distributed from 2021 to 2035. Columns 6 and 7 represents absolute values and 8 and 9 per capita. The overall result for Paris reflects €-2.805,5 million in costs if we consider all the externalities and €-1,293.5 million in costs if we only consider the positive externalities. Per capita, the balance considering all the externalities is also negative in -1,295.8 €/inhabitant and -597.5 n€/inh. if we consider solely the positive externalities.

Inhabitants	2,165,000							
PARIS	Units	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1)	Balance PE (2)	Balance (3)	Balance PE (4)
BASE	Stock EVs	Million €	Million €	Million €	Million €	Million €	All Ext. Per cap. €	P. Ext. Per Cap. €
2,021	36,720	-127.32	0.00	0.00	-127.3	-127.3	-59	-59
2,022	51,960	-147.02	7.67	-15.24	-154.6	-139.3	-71	-64
2,023	67,230	-143.55	14.93	-29.52	-158.1	-128.6	-73	-59
2,024	82,827	-142.71	21.79	-43.10	-164.0	-120.9	-76	-56
2,025	98,540	-140.71	28.26	-56.33	-168.8	-112.5	-78	-52
2,026	114,025	-137.55	34.35	-69.17	-172.4	-103.2	-80	-48
2,027	129,191	-133.70	40.07	-82.17	-175.8	-93.6	-81	-43
2,028	142,094	-129.74	45.43	-95.47	-179.8	-84.3	-83	-39
2,029	155,006	-126.73	50.45	-109.34	-185.6	-76.3	-86	-35
2,030	167,423	-121.06	55.12	-124.31	-190.3	-65.9	-88	-30
2,031	175,698	-119.71	59.51	-139.79	-200.0	-60.2	-92	-28
2,032	176,957	-117.23	63.56	-156.87	-210.5	-53.7	-97	-25
2,033	178,491	-115.77	67.32	-175.53	-224.0	-48.4	-103	-22
2,034	180,323	-114.27	70.79	-196.02	-239.5	-43.5	-111	-20
2,035	182,125	-109.57	73.91	-219.16	-254.8	-35.7	-118	-16
TOTAL	Abs (Million €)	-1,926.6	633.2	-1,512.0	-2,805.5	-1,293.5	-1,295.8	-597.4
	Per capita (€)	-889.91	292.46	-698.38	-1,295.83	-597.45		

(1) Balance Investments, positive externalities and negative externalities (absolute values in million €)
(2) Balance Investments and positive externalities (absolute, in million €)
(3) Balance Investments, positive externalities and negative externalities (per capita in €)
(4) Balance Investments and positive externalities (per capita in €)

Table 128. Summary of Investments and Externalities (Paris)

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6.2.2. Graph representation in absolute values (Paris Central)

Hereinafter, the investments, positive and negative externalities depicted in a single graph for the absolute figures.

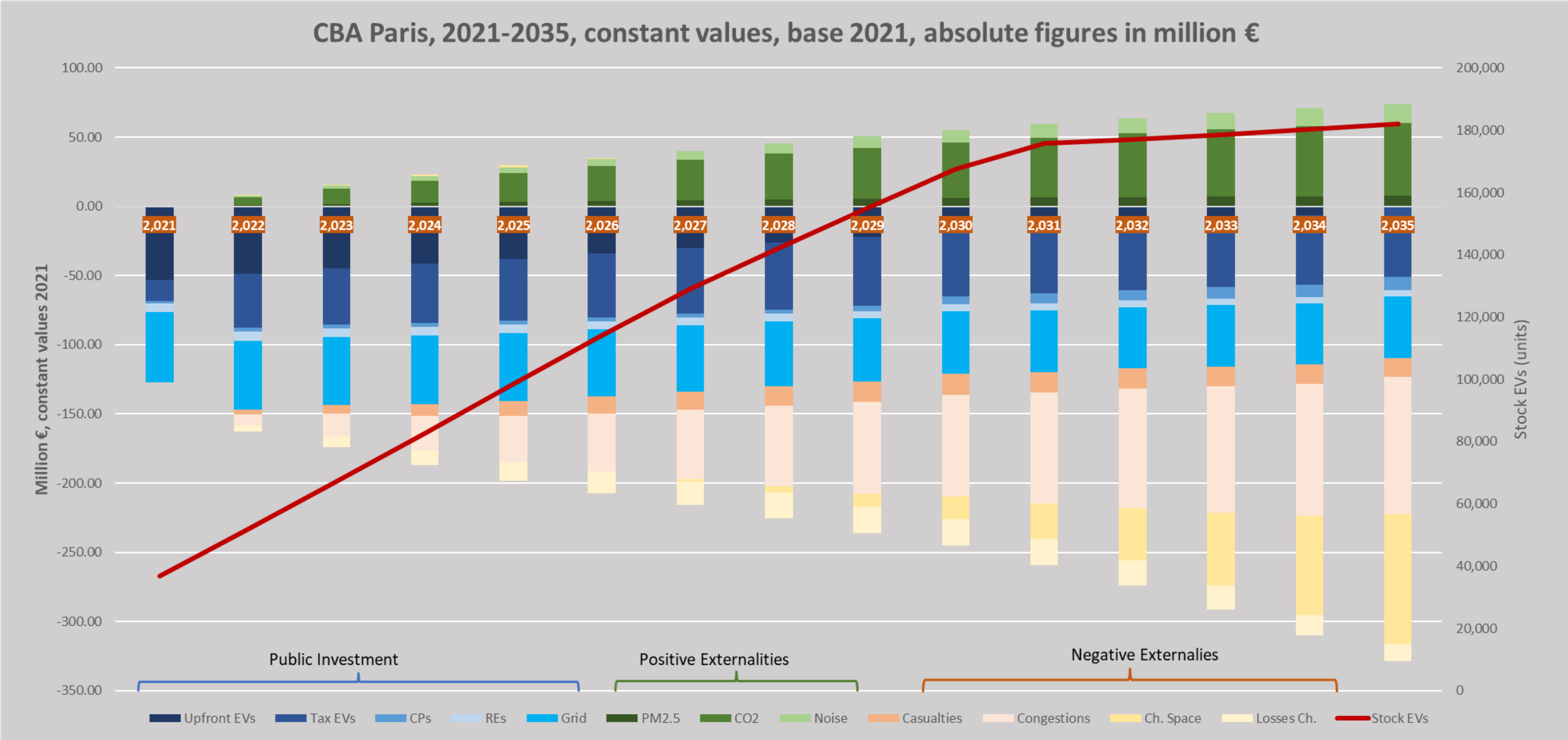

Figure 42. Detailed investments concepts and externalities (positive and negative) for Paris Central (Projections 2021 to 2035, Graph)

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Below, the table with all the figures calculated for Paris centre.

PARIS	Units	PUBLIC INVESTMENT					POSITIVE EXTERNALITIES			NEGATIVE EXTERNALITIES				Million €
BASE	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
2,021	36,720	-53.17	-15.29	-1.43	-6.67	-50.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-127.32
2,022	51,960	-48.72	-38.94	-3.11	-6.42	-49.83	0.91	5.72	1.04	-3.39	-8.08	0.20	-3.97	-154.58
2,023	67,230	-44.50	-41.01	-2.83	-6.19	-49.01	1.74	11.12	2.08	-6.27	-16.43	0.70	-7.52	-158.14
2,024	82,827	-41.36	-43.17	-2.73	-6.11	-49.35	2.50	16.19	3.10	-8.66	-24.94	1.14	-10.64	-164.02
2,025	98,540	-37.84	-44.98	-2.67	-5.98	-49.25	3.18	20.95	4.12	-10.62	-33.60	1.21	-13.32	-168.78
2,026	114,025	-33.93	-46.43	-2.83	-5.78	-48.58	3.83	25.40	5.12	-12.15	-42.03	0.55	-15.54	-172.37
2,027	129,191	-29.95	-47.63	-2.91	-5.56	-47.65	4.41	29.54	6.12	-13.31	-50.40	-1.16	-17.30	-175.80
2,028	142,094	-26.08	-48.68	-2.97	-5.34	-46.67	4.94	33.39	7.10	-14.13	-58.50	-4.28	-18.56	-179.78
2,029	155,006	-22.39	-49.65	-3.75	-5.14	-45.80	5.43	36.95	8.07	-14.65	-66.23	-9.13	-19.33	-185.62
2,030	167,423	-18.90	-46.34	-5.75	-4.96	-45.11	5.84	40.25	9.04	-14.93	-73.72	-16.07	-19.58	-190.25
2,031	175,698	-15.59	-47.31	-7.37	-4.81	-44.63	6.30	43.22	9.98	-14.90	-80.17	-25.40	-19.30	-199.99
2,032	176,957	-12.39	-48.27	-7.51	-4.69	-44.37	6.70	45.95	10.92	-14.72	-86.17	-37.50	-18.48	-210.54
2,033	178,491	-9.28	-49.24	-8.39	-4.59	-44.28	7.07	48.42	11.84	-14.37	-91.37	-52.68	-17.10	-223.97
2,034	180,323	-6.19	-50.21	-9.05	-4.50	-44.31	7.42	50.63	12.74	-13.89	-95.67	-71.30	-15.15	-239.49
2,035	182,125	0.00	-51.19	-9.53	-4.42	-44.41	7.61	52.67	13.64	-13.44	-99.37	-93.72	-12.63	-254.82
TOTAL	Abs (Million €)	-400.29	-668.34	-72.82	-81.19	-704.00	67.86	460.40	104.91	-169.42	-826.69	-307.45	-208.43	-2,805.47
TOTAL	Per capita (€)	-184.89	-308.70	-33.64	-37.50	-325.17	31.35	212.65	48.46	-78.26	-381.84	-142.01	-96.27	-1,295.83

Table 129. Detailed investments concepts and externalities (positive and negative) for Paris Central (Projections 2021 to 2035, Table).

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6.2.3. Per capita results (Paris Central)

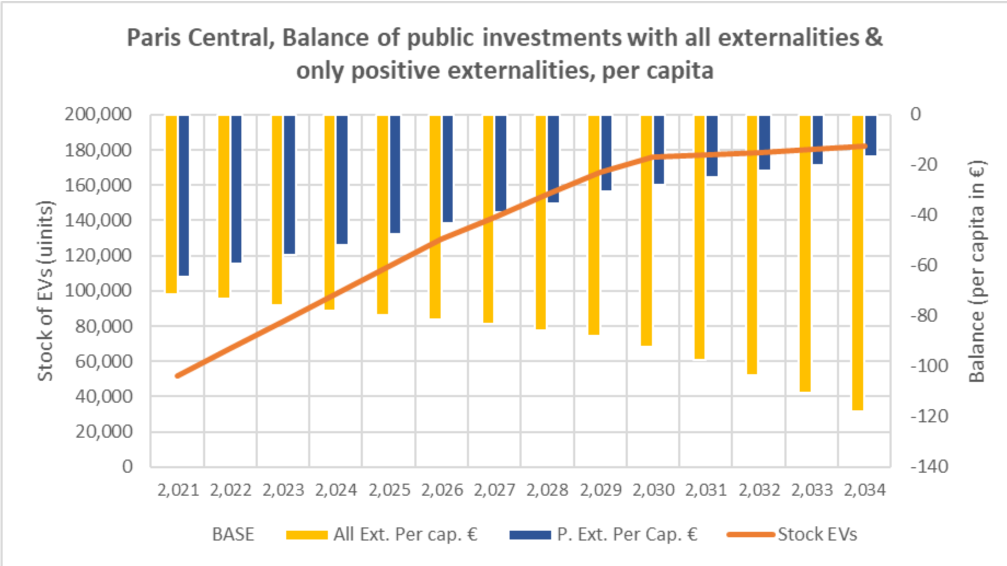

Figure 43. Balance per capita for Paris Central with all externalities and only positive one in the Base scenario

Results reflects a negative balance per capita and in absolute values although the situation is improved per capita over time, as soon as the stock of EVs is increased.

6.3. Cost benefit analysis for Utrecht

6.3.1. Analysis investments and externalities in Utrecht.

In the table below, a summary of the city projections for investments and externalities is provided. They have been grouped in public investments and positive and negative externalities, distributed from 2021 to 2035.

Inhabitants	361,742							
UTRECHT	Units	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1)	Balance PE (2)	Balance (3)	Balance PE (4)
BASE	Stock EVs	Million €	Million €	Million €	Million €	Million €	All Ext. Per cap. €	P. Ext. Per Cap. €
2,021	21,991	-91.59	0.00	0.00	-91.6	-91.6	-253.2	-253.2
2,022	28,660	-129.37	1.99	-4.11	-131.5	-127.4	-363.5	-352.1
2,023	36,605	-155.63	3.96	-8.73	-160.4	-151.7	-443.4	-419.3
2,024	45,535	-179.07	5.91	-13.75	-186.9	-173.2	-516.7	-478.7
2,025	55,122	-123.58	7.81	-19.01	-134.8	-115.8	-372.6	-320.0
2,026	67,358	-79.24	9.66	-24.38	-94.0	-69.6	-259.8	-192.3
2,027	79,870	-78.29	11.44	-29.74	-96.6	-66.9	-267.0	-184.8
2,028	90,172	-76.52	13.14	-34.94	-98.3	-63.4	-271.8	-175.2
2,029	100,479	-74.01	14.75	-39.85	-99.1	-59.3	-274.0	-163.8
2,030	109,370	-72.20	16.24	-44.36	-100.3	-56.0	-277.3	-154.7
2,031	116,442	-68.94	17.64	-48.25	-99.5	-51.3	-275.2	-141.8
2,032	120,719	-64.87	18.90	-51.48	-97.4	-46.0	-269.4	-127.1
2,033	123,573	-60.64	20.01	-53.87	-94.5	-40.6	-261.2	-112.3
2,034	125,474	-57.39	20.97	-55.30	-91.7	-36.4	-253.6	-100.7
2,035	126,929	-52.23	21.71	-55.75	-86.3	-30.5	-238.5	-84.4
TOTAL	Abs (Million €)	-1,363.6	184.1	-483.5	-1,662.9	-1,179.4	-4,597.1	-3,260.4
	Per capita (€)	-3,769.4	509.0	-1,336.6	-4,597.1	-3,260.4		

(1) Balance Investments, positive externalities and negative externalities (absolute values in million €)
(2) Balance Investments and positive externalities (absolute, in million €)
(3) Balance Investments, positive externalities and negative externalities (per capita in €)
(4) Balance Investments and positive externalities (per capita in €)

Table 130. Summary of Investments and Externalities, (Utrecht)

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The overall result for Utrecht reflects €-1,662.9 million in costs if we consider all the externalities and €-1,179.9 million in costs if we only consider the positive externalities. Per capita the situation is much negative with a cost of -4,597.1 € /inhabitant considering all externalities and -3,260.4 € /inhabitant if we just consider the positive externalities.

Therefore, the behaviour for Utrecht is similar to Paris, although if we check the figures per capita, this city is by far the one who is investing more, with Paris the second and some less for Turin. Utrecht invests per capita 4.2 times the second city and indicates the level of compromise of this municipality with the environment. Unfortunately, if we check the cost benefit analysis per capita, it is even more negative reaching €-4,597.1/per capita as positive externalities are less than half the negative.

6.3.2. Graph representation per capita (Utrecht)

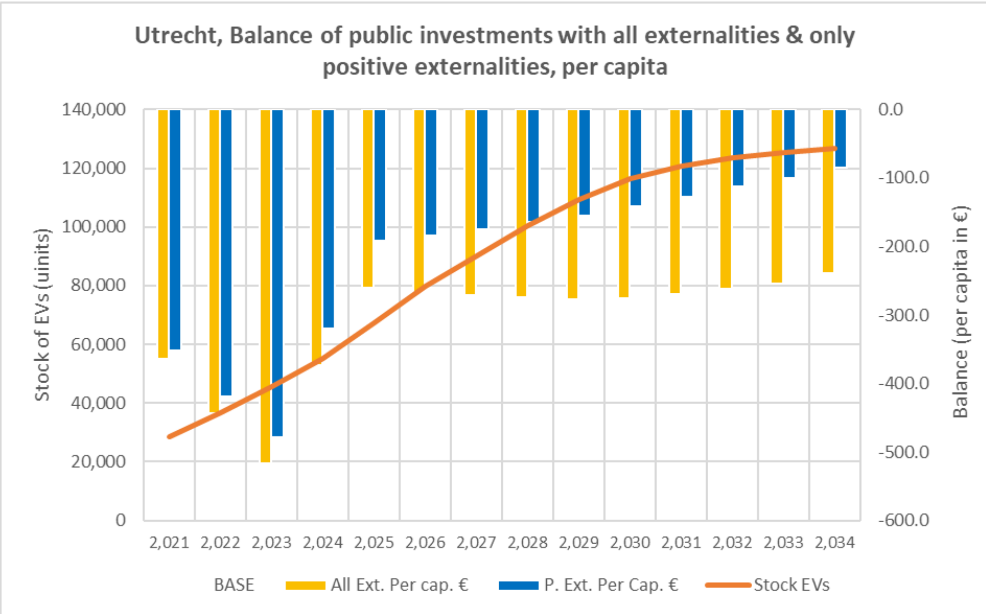

Figure 44. Balance Utrecht per capita considering all externalities and only positive (2021-2035)

In the next chart, Per capita de balance for Utrecht is always negative although the situation is getting better as soon as the investments are reduced.

6.3.3. Graph representation in absolute values (Utrecht)

In the next graph, it is reflected the balance between investments and externalities for Utrecht in the period 2021-2035 in absolute values. The balance is negative. An explanation will be provided in the conclusion chapter.

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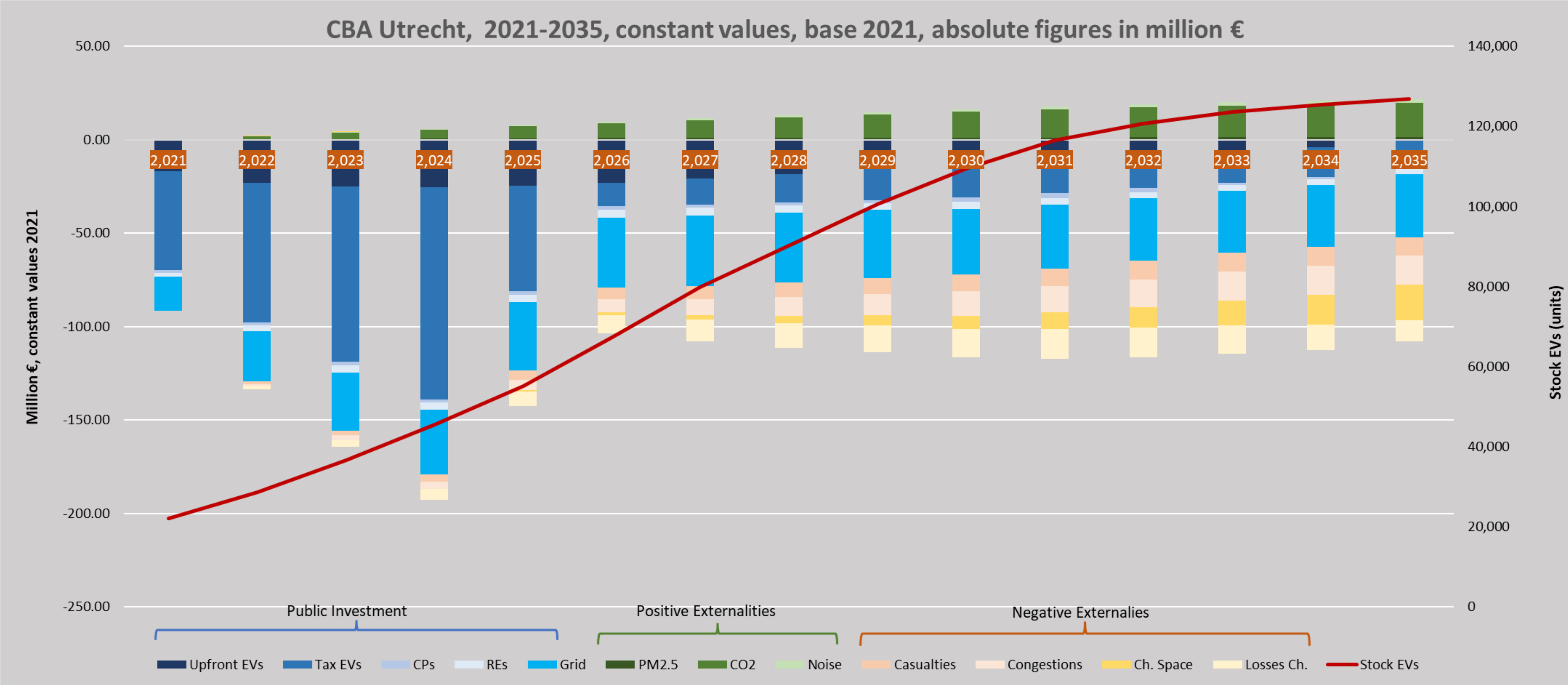

Figure 45. Detailed investments concepts and externalities (positive and negative) for Utrecht (Projections 2021 to 2035, in absolute values)

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Below, the table with all the figures calculated for Utrecht city.

UTRECHT	Units	PUBLIC INVESTMENT					POSITIVE EXTERNALITIES			NEGATIVE EXTERNALITIES				Million €
BASE	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
2,021	21,991	-16.69	-53.21	-1.40	-2.19	-18.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-91.59
2,022	28,660	-23.00	-74.86	-1.62	-3.17	-26.74	0.23	1.60	0.15	-1.37	-1.11	0.19	-1.82	-131.49
2,023	36,605	-24.85	-94.15	-1.90	-3.61	-31.12	0.43	3.22	0.31	-2.67	-2.41	0.13	-3.78	-160.40
2,024	45,535	-25.37	-113.54	-1.84	-3.92	-34.41	0.60	4.84	0.46	-3.89	-3.86	-0.18	-5.82	-186.91
2,025	55,122	-24.70	-56.40	-1.84	-4.08	-36.55	0.75	6.44	0.61	-5.02	-5.40	-0.73	-7.86	-134.78
2,026	67,358	-23.12	-12.59	-1.78	-4.12	-37.63	0.87	8.02	0.76	-6.07	-6.98	-1.52	-9.81	-93.96
2,027	79,870	-20.90	-13.86	-1.66	-4.06	-37.80	0.97	9.55	0.91	-7.00	-8.57	-2.55	-11.62	-96.59
2,028	90,172	-18.33	-15.45	-1.51	-3.92	-37.30	1.05	11.02	1.06	-7.83	-10.11	-3.81	-13.19	-98.31
2,029	100,479	-15.64	-16.93	-1.32	-3.75	-36.37	1.12	12.42	1.21	-8.53	-11.55	-5.30	-14.46	-99.10
2,030	109,370	-13.00	-17.86	-2.50	-3.57	-35.27	1.20	13.68	1.35	-9.07	-12.89	-7.03	-15.37	-100.33
2,031	116,442	-10.52	-18.08	-2.70	-3.39	-34.24	1.21	14.93	1.50	-9.55	-13.96	-8.97	-15.77	-99.54
2,032	120,719	-8.23	-17.67	-2.23	-3.25	-33.48	1.25	16.01	1.65	-9.85	-14.82	-11.14	-15.67	-97.44
2,033	123,573	-6.11	-16.87	-1.38	-3.16	-33.13	1.27	16.95	1.79	-9.99	-15.40	-13.52	-14.96	-94.50
2,034	125,474	-4.08	-15.83	-1.13	-3.10	-33.24	1.29	17.75	1.93	-9.97	-15.64	-16.13	-13.57	-91.72
2,035	126,929	0.00	-14.50	-0.85	-3.09	-33.78	1.41	18.24	2.06	-9.64	-15.62	-18.98	-11.50	-86.27
TOTAL	Abs (Million €)	-234.54	-551.79	-25.66	-52.39	-499.17	13.67	154.69	15.77	-100.45	-138.32	-89.53	-155.21	-1,662.95
TOTAL	Per capita (€)	-648.37	-1,525.38	-70.94	-144.82	-1,379.91	37.79	427.61	43.61	-277.68	-382.39	-247.51	-429.07	-4,597.05

Table 131. Detailed investments concepts and externalities (positive and negative) for Utrecht (Projections 2021 to 2035, Table)

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6.4. Cost benefit analysis for Turin

6.4.1. Analysis investments and externalities in Turin

In the table below, a summary of the city projections for investments and externalities is provided. They have been grouped in public investments and positive and negative externalities, distributed from 2021 to 2035. The overall result for Turin reflects a superavit of €-2137.8 million if we consider all the externalities and €3.796 million in superavit if we only consider the positive externalities.

Inhabitants	2,252,379							
TURIN	Units	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1)	Balance PE (2)	Balance (3)	Balance PE (4)
BASE	Stock EVs	Million €	Million €	Million €	Million €	Million €	All Ext. Per cap. €	P. Ext. Per Cap. €
2,021	46,551	-29.86	0.00	0.00	-29.9	-29.9	-13.3	-13.3
2,022	57,270	-60.21	59.91	-12.11	-12.4	-0.3	-5.5	-0.1
2,023	72,154	-87.48	118.05	-26.62	4.0	30.6	1.8	13.6
2,024	90,804	-112.19	174.45	-43.00	19.3	62.3	8.5	27.6
2,025	112,597	-129.10	229.15	-60.76	39.3	100.0	17.4	44.4
2,026	136,802	-141.95	282.15	-79.35	60.8	140.2	27.0	62.2
2,027	162,711	-150.35	333.51	-98.29	84.9	183.2	37.7	81.3
2,028	189,562	-155.81	383.25	-117.04	110.4	227.4	49.0	101.0
2,029	216,943	-160.18	431.40	-135.10	136.1	271.2	60.4	120.4
2,030	244,348	-163.76	478.03	-151.99	162.3	314.3	72.0	139.5
2,031	270,287	-165.21	523.04	-167.08	190.7	357.8	84.7	158.9
2,032	293,468	-96.92	566.60	-179.97	289.7	469.7	128.6	208.5
2,033	311,772	-94.09	608.69	-190.11	324.5	514.6	144.1	228.5
2,034	326,754	-93.46	649.33	-196.97	358.9	555.9	159.3	246.8
2,035	339,196	-89.34	688.72	-200.17	399.2	599.4	177.2	266.1
TOTAL	Abs (Million €)	-1,729.92	5,526.28	-1,658.55	2,137.8	3,796.4	949	1,685
	Per capita (€)	-768.0	2,453.5	-736.4	949.1	1,685.5		

Table 132. Summary of Investments and Externalities (Turin)

6.4.2. Graph representation per capita (Turin)

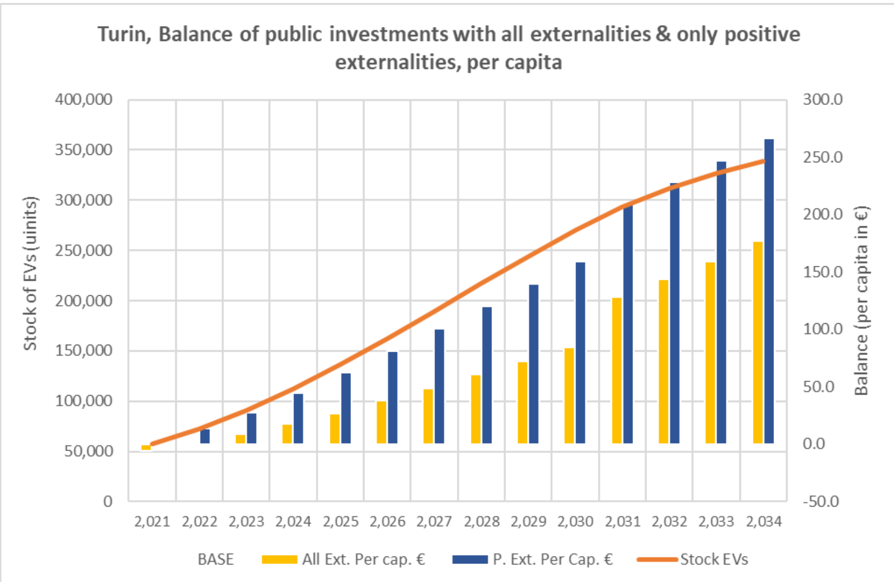

Figure 46. Balance investments/externalities per capita in Turin considering all and only positive externalities in the period (2021-2035)

Turin is a congested city with three times the traffic than Paris or Utrecht and few measures promoting electromobility to date. In that sense there is a long pathway for improvement even with a small investment effort.

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6.4.3. Graph representation in absolute values (Turin)

In the next chart, we can see the global situation for Turin city.

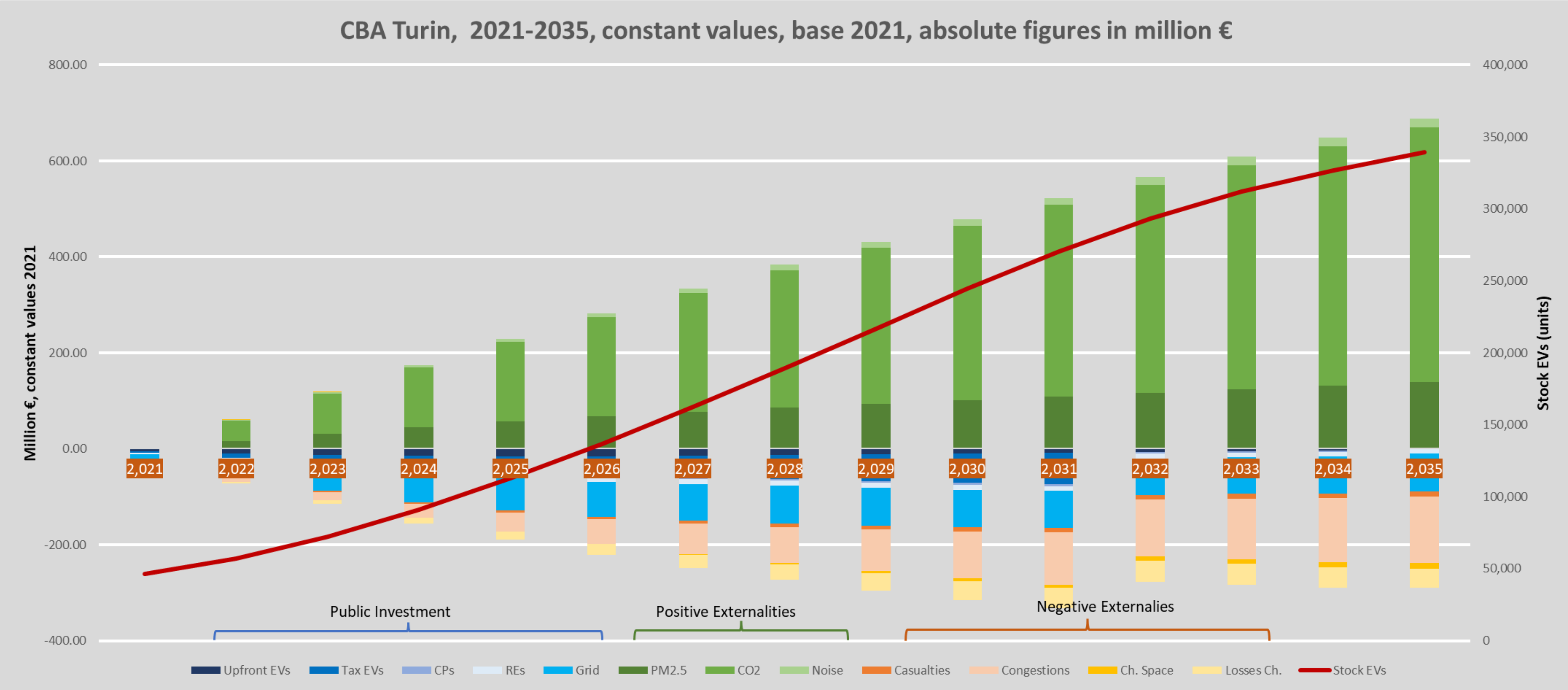

Figure 47. Detailed investments concepts and externalities (positive and negative) for Turin (Projections 2021 to 2035, absolute values)

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Below, the table with all the figures calculated for Turin city.

TURIN	Units	PUBLIC INVESTMENT					POSITIVE EXTERNALITIES			NEGATIVE EXTERNALITIES				Million €
BASE	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
2,021	46,551	-5.62	-3.21	0.00	-3.26	-17.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-29.86
2,022	57,270	-10.31	-9.46	0.00	-5.52	-34.92	16.57	41.73	1.60	-1.19	-7.81	0.33	-3.43	-12.41
2,023	72,154	-13.04	-17.88	-1.65	-7.36	-47.56	31.40	83.44	3.21	-2.33	-17.04	0.32	-7.56	3.96
2,024	90,804	-14.79	-28.10	-1.96	-8.88	-58.46	44.67	124.98	4.80	-3.40	-27.41	0.00	-12.19	19.26
2,025	112,597	-15.55	-34.50	-2.02	-9.98	-67.05	56.57	166.21	6.38	-4.41	-38.66	-0.58	-17.11	39.29
2,026	136,802	-15.42	-40.38	-2.33	-10.67	-73.15	67.24	206.98	7.93	-5.34	-50.49	-1.38	-22.15	60.85
2,027	162,711	-14.59	-45.59	-2.29	-11.00	-76.88	76.90	247.17	9.45	-6.19	-62.64	-2.35	-27.09	84.88
2,028	189,562	-13.26	-50.16	-2.73	-11.03	-78.63	85.71	286.62	10.93	-6.97	-74.85	-3.46	-31.76	110.40
2,029	216,943	-11.64	-56.01	-2.78	-10.85	-78.89	93.85	325.20	12.36	-7.65	-86.84	-4.67	-35.94	136.12
2,030	244,348	-9.90	-61.31	-3.77	-10.55	-78.24	101.55	362.77	13.71	-8.29	-98.38	-5.90	-39.41	162.28
2,031	270,287	-8.15	-66.11	-3.47	-10.21	-77.27	108.84	399.17	15.04	-8.74	-109.07	-7.18	-42.08	190.75
2,032	293,468	-6.45	0.00	-4.06	-9.91	-76.50	116.05	434.28	16.28	-9.14	-118.76	-8.41	-43.65	289.70
2,033	311,772	-4.83	0.00	-3.22	-9.70	-76.34	123.30	467.95	17.43	-9.43	-127.15	-9.57	-43.96	324.49
2,034	326,754	-3.25	0.00	-3.57	-9.60	-77.05	130.78	500.05	18.50	-9.61	-133.95	-10.61	-42.81	358.90
2,035	339,196	0.00	0.00	-1.04	-9.61	-78.69	138.83	530.47	19.42	-9.81	-139.04	-11.42	-39.89	399.21
TOTAL	Abs (Million €)	-146.82	-412.70	-34.88	-138.12	-997.40	1,192.25	4,177.01	157.03	-92.51	-1,092.11	-64.90	-409.03	2,137.81
TOTAL	Per capita (€)	-65.18	-183.23	-15.49	-61.32	-442.82	529.33	1,854.49	69.72	-41.07	-484.87	-28.82	-181.60	949.13

Table 133. Detailed investments concepts and externalities (positive and negative) for Turin (Projections 2021 to 2035, Table)

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6.5. Cost benefit analysis for Zaragoza

6.5.1. Analysis investments and externalities in Zaragoza

In the table below, a summary of the city projections for investments and externalities is provided. They have been grouped in public investments and positive and negative externalities, distributed from 2021 to 2035. The overall result for Zaragoza reflects €873.3 million in superavit if we consider all the externalities and € 1,430.5. million in superavit if we only consider the positive externalities.

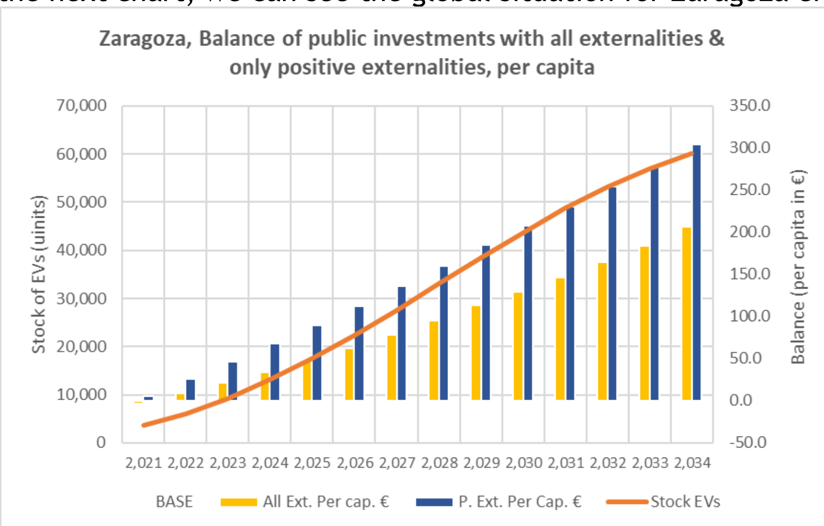
Inhabitants	684,686							
ZARAGOZA	Units	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1)	Balance PE (2)	Balance (3)	Balance PE (4)
BASE	Stock EVs	Million €	Million €	Million €	Million €	Million €	All Ext. Per cap. €	P. Ext. Per Cap. €
2,021	2,107	-10.05	0.00	0.00	-10.1	-10.1	-14.7	-14.7
2,022	3,724	-17.72	21.41	-5.89	-2.2	3.7	-3.2	5.4
2,023	6,117	-23.49	41.64	-11.74	6.4	18.1	9.4	26.5
2,024	9,268	-28.73	60.79	-17.51	14.5	32.1	21.2	46.8
2,025	13,107	-32.65	79.00	-23.18	23.2	46.3	33.8	67.7
2,026	17,527	-35.03	96.34	-28.73	32.6	61.3	47.6	89.5
2,027	22,414	-36.07	112.96	-34.11	42.8	76.9	62.5	112.3
2,028	27,609	-35.88	128.96	-39.29	53.8	93.1	78.6	135.9
2,029	33,035	-34.75	144.47	-44.24	65.5	109.7	95.6	160.3
2,030	38,539	-32.99	159.66	-48.85	77.8	126.7	113.7	185.0
2,031	43,708	-32.47	174.44	-53.35	88.6	142.0	129.4	207.3
2,032	48,693	-31.29	189.13	-57.43	100.4	157.8	146.6	230.5
2,033	53,144	-29.72	203.77	-61.17	112.9	174.1	164.9	254.2
2,034	56,949	-28.02	218.49	-64.52	126.0	190.5	184.0	278.2
2,035	60,171	-25.32	233.62	-67.15	141.1	208.3	206.1	304.2
TOTAL	Abs (Million €)	-434.19	1,864.67	-557.15	873.3	1,430.5	1,275.5	2,089.2
	Per capita (€)	-634.1	2,723.4	-813.7	1,275.5	2,089.2		

(1) Balance Investments, positive externalities and negative externalities (absolute values in million €)
(2) Balance Investments and positive externalities (absolute, in million €)
(3) Balance Investments, positive externalities and negative externalities (per capita in €)
(4) Balance Investments and positive externalities (per capita in €)

Table 134. Summary of Investments and Externalities (Zaragoza)

6.5.2. Graph representation per capita (Zaragoza)

In the next chart, we can see the global situation for Zaragoza city.



Zaragoza is a city with an old fleet of vehicles, a high use of ICE cars (Vkm) and very limited actions to date to promote electromobility and, consequently very good opportunities to improve the air quality and other externalities. Public investments have been also very moderated.

Figure 48. Balance investments/externalities per capita in Zaragoza considering all and only positive externalities in the period (2021-2035)

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6.5.3. Graph representation in absolute values (Turin)

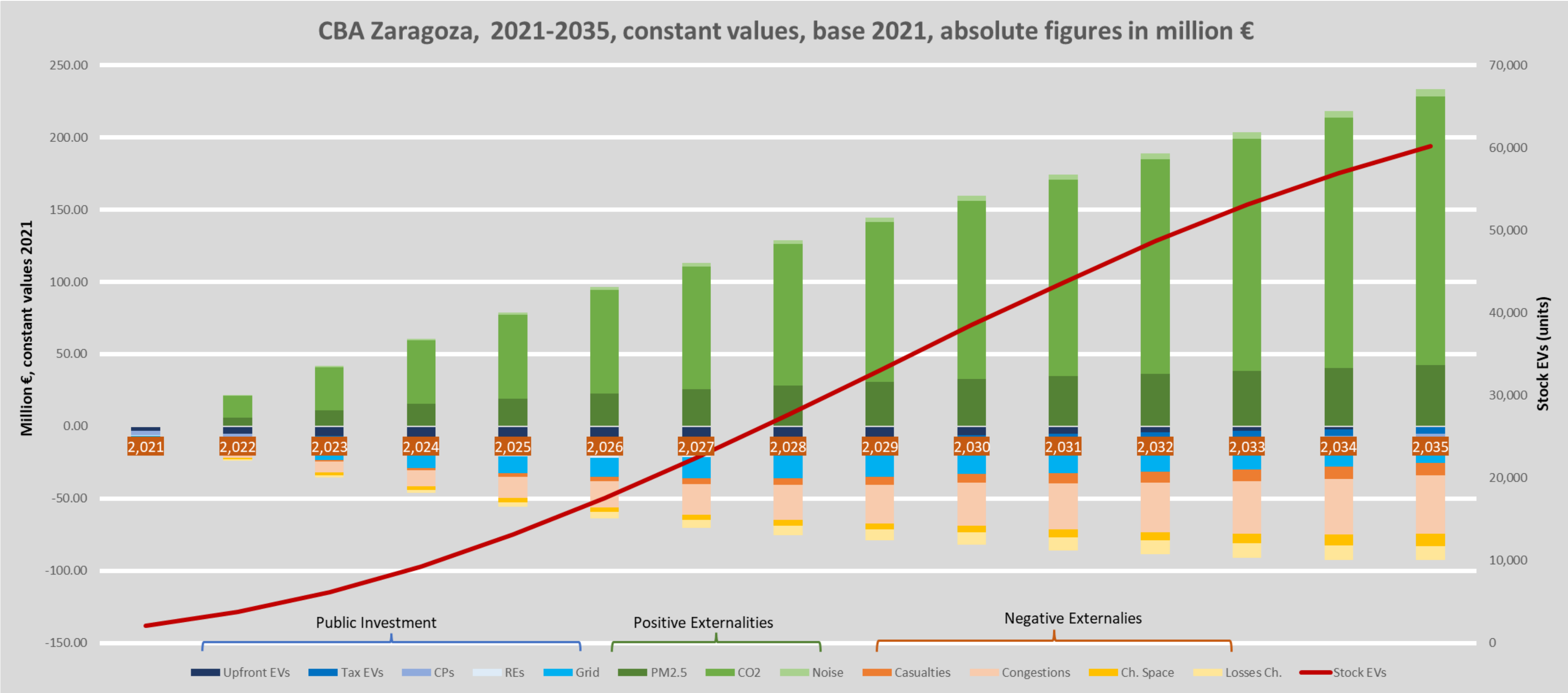

Figure 49. Detailed investments concepts and externalities (positive and negative) for Zaragoza (Projections 2021 to 2035, Graph)

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Below, the table with all the figures calculated for Zaragoza city.

ZARAGOZA	Units	PUBLIC INVESTMENT					POSITIVE EXTERNALITIES			NEGATIVE EXTERNALITIES				Million €
BASE	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
2,021	2,107	-3.24	0.00	-3.15	-0.40	-3.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-10.05
2,022	3,724	-4.89	-0.38	-6.54	-0.64	-5.27	5.80	15.21	0.41	-0.47	-3.87	-0.90	-0.65	-2.20
2,023	6,117	-6.59	-0.76	-7.59	-0.91	-7.65	10.89	29.94	0.81	-1.05	-7.60	-1.63	-1.46	6.41
2,024	9,268	-7.86	-1.18	-8.66	-1.15	-9.89	15.36	44.23	1.20	-1.71	-11.20	-2.22	-2.39	14.55
2,025	13,107	-8.62	-1.61	-9.24	-1.35	-11.83	19.27	58.13	1.60	-2.43	-14.65	-2.71	-3.40	23.17
2,026	17,527	-8.87	-2.06	-9.21	-1.50	-13.39	22.68	71.68	1.98	-3.19	-17.95	-3.13	-4.46	32.57
2,027	22,414	-8.67	-2.50	-8.75	-1.59	-14.56	25.66	84.94	2.36	-3.98	-21.11	-3.50	-5.52	42.77
2,028	27,609	-8.12	-2.93	-7.85	-1.65	-15.34	28.28	97.95	2.74	-4.78	-24.10	-3.87	-6.55	53.79
2,029	33,035	-7.32	-3.34	-6.63	-1.66	-15.79	30.61	110.75	3.11	-5.55	-26.94	-4.25	-7.51	65.48
2,030	38,539	-6.36	-3.73	-5.26	-1.65	-16.00	32.75	123.43	3.47	-6.27	-29.60	-4.66	-8.32	77.82
2,031	43,708	-5.31	-4.06	-5.45	-1.62	-16.04	34.67	135.94	3.83	-6.96	-32.11	-5.21	-9.07	88.62
2,032	48,693	-4.24	-4.34	-5.13	-1.59	-16.00	36.54	148.41	4.18	-7.56	-34.44	-5.84	-9.59	100.41
2,033	53,144	-3.17	-4.57	-4.46	-1.55	-15.96	38.38	160.87	4.52	-8.05	-36.60	-6.62	-9.90	112.89
2,034	56,949	-2.12	-4.75	-3.63	-1.52	-15.99	40.27	173.37	4.86	-8.43	-38.57	-7.58	-9.94	125.95
2,035	60,171	0.00	-4.90	-2.78	-1.51	-16.14	42.37	186.05	5.20	-8.61	-40.34	-8.65	-9.55	141.14
TOTAL	Abs (Million €)	-85.37	-41.10	-94.32	-20.28	-193.12	383.54	1,440.88	40.25	-69.03	-339.08	-60.75	-88.30	873.32
TOTAL	Per capita (€)	-124.69	-60.03	-137.76	-29.62	-282.05	560.16	2,104.45	58.78	-100.82	-495.23	-88.73	-128.96	1,275.51

Table 135. Detailed investments concepts and externalities (positive and negative) for Zaragoza (Projections 2021 to 2035, table)

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6.6. Cost benefit analysis for Tallinn

6.6.1. Analysis investments and externalities in Tallinn

In the table below, a summary of the city projections for investments and externalities is provided. They have been grouped in public investments and positive and negative externalities, distributed from 2021 to 2035. The overall result for Tallinn reflects €203.3 million in superavit if we consider all the externalities and € 882.8 million in superavit if we only consider the positive externalities. Tallinn is another city with good results in the CBA along with Zaragoza.

Inhabitants	452,455							
TALLINN	Units	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1)	Balance PE (2)	Balance (3)	Balance PE (4)
BASE	Stock EVs	Million €	Million €	Million €	Million €	Million €	All Ext. Per cap. €	P. Ext. Per Cap. €
2,021	3,157	-2.49	0.00	0.00	-2.5	-2.5	-5	-5
2,022	3,963	-3.96	10.92	-6.66	0.3	7.0	1	15
2,023	5,122	-5.55	21.46	-13.43	2.5	15.9	5	35
2,024	6,654	-7.03	31.64	-20.25	4.4	24.6	10	54
2,025	8,512	-8.29	41.51	-27.08	6.1	33.2	14	73
2,026	10,656	-9.29	51.06	-33.86	7.9	41.8	17	92
2,027	13,037	-10.02	60.36	-40.55	9.8	50.3	22	111
2,028	15,606	-10.48	69.42	-47.11	11.8	58.9	26	130
2,029	18,315	-10.72	78.28	-53.47	14.1	67.6	31	149
2,030	21,126	-10.78	87.02	-59.69	16.6	76.2	37	169
2,031	24,006	-10.70	95.52	-65.43	19.4	84.8	43	187
2,032	26,937	-10.55	103.95	-70.92	22.5	93.4	50	206
2,033	29,910	-10.37	112.30	-76.04	25.9	101.9	57	225
2,034	32,928	-10.20	120.60	-80.71	29.7	110.4	66	244
2,035	35,964	-9.86	129.04	-85.27	33.9	119.2	75	263
TOTAL	Abs (Million €)	-130.28	1,013.09	-680.45	202.3	882.8	447	1,951
	Per capita (€)	-287.9	2,239.1	-1,503.9	447.2	1,951.1		

(1) Balance Investments, positive externalities and negative externalities (absolute values in million €)
(2) Balance Investments and positive externalities (absolute, in million €)
(3) Balance Investments, positive externalities and negative externalities (per capita in €)
(4) Balance Investments and positive externalities (per capita in €)

Table 136. Summary of Investments and Externalities (Tallinn)

6.6.2. Graphs representation per capita (Tallinn)

In the next chart, we can see the global situation for Tallinn city.

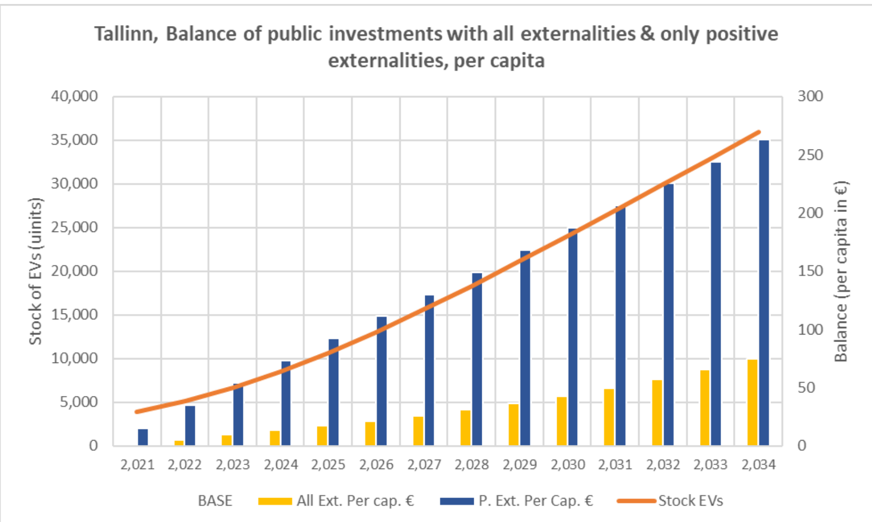

Figure 50. Balance investments/externalities per capita in Tallinn considering all and only positive externalities in the period (2021-2035)

Tallinn has barely invested in electromobility measures, however the market inertia and the adoption of electric vehicles by default infers a very beneficial effect on the urban environment, which is currently very compromised, resulting in a positive balance.

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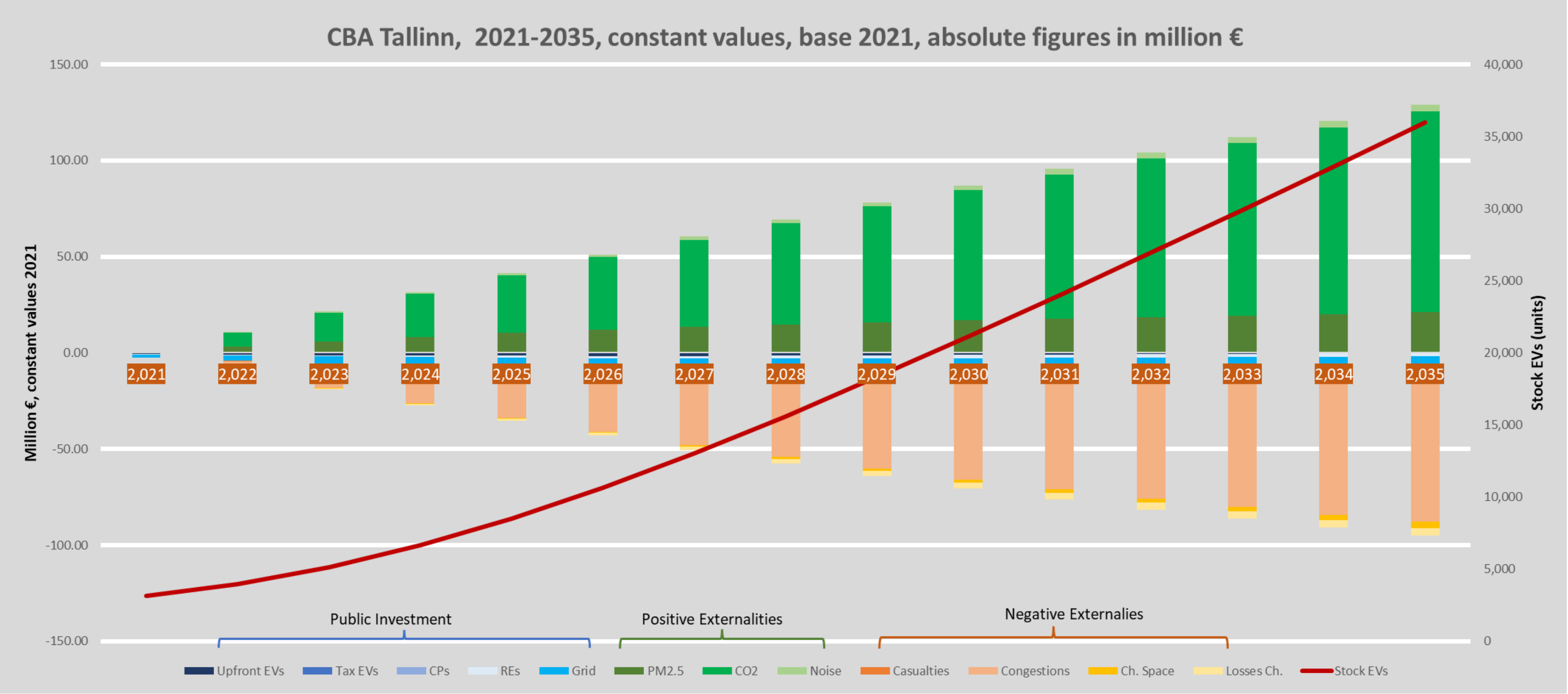

Figure 51. Detailed investments concepts and externalities (positive and negative) for Tallinn (Projections 2021 to 2035, Graph)

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Below, the table with all the figures calculated for Tallinn city.

TALLINN	Units	PUBLIC INVESTMENT					POSITIVE EXTERNALITIES			NEGATIVE EXTERNALITIES				Million €
BASE	Stock EVs	Upfront EVs	Tax EVs	CPs	REs	Grid	PM2.5	CO2	Noise	Casualties	Congestions	Ch. Space	Losses Ch.	Total
2,021	3,157	-0.60	0.00	0.00	-0.27	-1.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-2.49
2,022	3,963	-0.90	0.00	0.00	-0.43	-2.63	3.15	7.49	0.29	-0.30	-6.12	-0.03	-0.22	0.30
2,023	5,122	-1.19	0.00	0.00	-0.62	-3.74	5.90	15.00	0.57	-0.56	-12.26	-0.10	-0.50	2.49
2,024	6,654	-1.41	0.00	0.00	-0.82	-4.80	8.27	22.52	0.85	-0.81	-18.41	-0.21	-0.83	4.37
2,025	8,512	-1.55	0.00	0.00	-1.00	-5.75	10.32	30.06	1.12	-1.02	-24.52	-0.35	-1.19	6.14
2,026	10,656	-1.60	0.00	0.00	-1.15	-6.54	12.07	37.59	1.40	-1.22	-30.54	-0.53	-1.57	7.91
2,027	13,037	-1.58	0.00	0.00	-1.29	-7.15	13.57	45.12	1.66	-1.40	-36.46	-0.74	-1.96	9.79
2,028	15,606	-1.49	0.00	0.00	-1.39	-7.60	14.85	52.64	1.93	-1.55	-42.24	-0.98	-2.34	11.84
2,029	18,315	-1.35	0.00	0.00	-1.48	-7.89	15.95	60.14	2.19	-1.68	-47.83	-1.23	-2.72	14.10
2,030	21,126	-1.18	0.00	0.00	-1.54	-8.05	16.95	67.63	2.44	-1.80	-53.26	-1.53	-3.10	16.56
2,031	24,006	-1.00	0.00	0.00	-1.58	-8.13	17.77	75.05	2.70	-1.90	-58.35	-1.80	-3.37	19.38
2,032	26,937	-0.80	0.00	0.00	-1.61	-8.14	18.56	82.44	2.95	-1.98	-63.21	-2.10	-3.63	22.47
2,033	29,910	-0.60	0.00	0.00	-1.64	-8.13	19.32	89.79	3.19	-2.05	-67.74	-2.41	-3.83	25.89
2,034	32,928	-0.40	0.00	0.00	-1.68	-8.12	20.09	97.08	3.43	-2.11	-71.93	-2.73	-3.95	29.69
2,035	35,964	0.00	0.00	0.00	-1.71	-8.14	21.02	104.37	3.66	-2.18	-75.85	-3.11	-4.12	33.92
TOTAL	Abs (Million €	-15.65	0.00	0.00	-18.21	-96.43	197.80	786.92	28.37	-20.56	-608.72	-17.85	-33.32	202.35
TOTAL	Per capita (€)	-34.59	0.00	0.00	-40.24	-213.12	437.18	1,739.21	62.70	-45.45	-1,345.38	-39.46	-73.63	447.23

Table 137. Detailed investments concepts and externalities (positive and negative) for Tallinn (Projections 2021 to 2035, Table)

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6.7. Conclusions Cost-Benefit Analysis in the Base Case Scenario

6.7.1. Summary tables in absolute figures and per capita

The main results of the CBA in the base case scenario are provided below:

Abs. (M€)	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1) Abs
Paris	-1,926.6	633.2	-1,512.0	-2,805.5
Utrecht	-1,363.6	184.1	-483.5	-1,662.9
Turin	-1,729.9	5,526.3	-1,658.6	2,137.8
Zaragoza	-434.2	1,864.7	-557.2	873.3
Tallinn	-130.3	1,013.1	-680.5	202.3

Table 138. CBA in use case cities in absolute figures (BASE)

Per cap. (€)	Public Invest.	Posit.Ext	Negat. Ext.	Balance (1) Per cap
Paris	-889.9	292.5	-698.4	-1,295.8
Utrecht	-3,769.4	509.0	-1,336.6	-4,597.1
Turin	-768.0	2,453.5	-736.4	949.1
Zaragoza	-634.1	2,723.4	-813.7	1,275.5
Tallinn	-287.9	2,239.1	-1,503.9	447.2

Table 139. CBA in use case cities per capita (BASE)

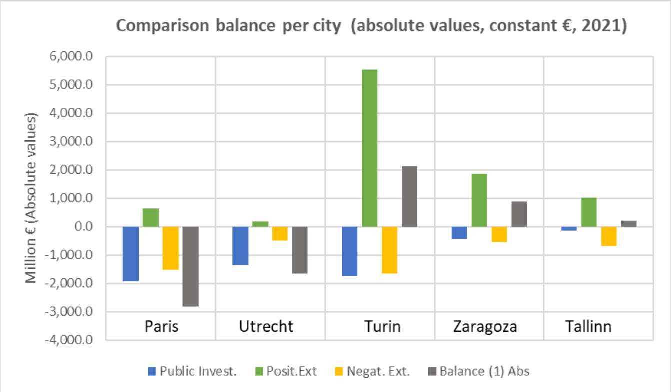

Figure 53. CBA in use case cities in absolute figures

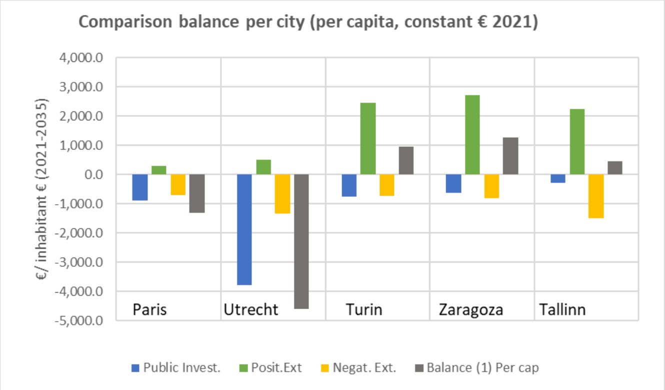

Figure 52. CBA in use case cities per capita

6.7.2. Cost-Benefit Analysis main conclusions

6.7.2.1. Public Investments

There are relevant differences in public support among use case cities; Utrecht is by far the city with a significant higher per capita investment reaching four times the next city. We can consider Utrecht as the leading city. Then, Paris, Turin and Zaragoza can be considered follower cities with investment per capita rounding 600 € to 900 €. Finally, Tallin can be attributed as lagging city with around 300 €/inhabitant. However, the support goes to different issues. Let's check by city:

PARIS

Parisians with high purchasing power buy electric cars and private chargers. The administration contributes to the financing through the ADVENIR program with a per capita cost for the whole 15 years, adding upfront costs for EV, tax reduction and aids to electric chargers, amounting around €1,927 million in absolute values and 890 €/inhabitant. This is the second highest per capita amount after Utrecht. Therefore, the level of expenditure is high and the penetration of the electric car over the conventional vehicle is also high.

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Investments in renewables and grid adaptation in Paris are intermediate as they depend on the consumption of electric vehicles among other parameters. Parisien do very few kms per year and consume less energy than expected (1,000 km/per capita) as the restrictions within the city are very high.

UTRECHT

Public investments in Utrecht differ from those in Paris in terms of higher tax advantages, which, however, will be reduced over time. In contrast to Paris, the traffic jams generated by the penetration of electric vehicles will be smaller, since the number of vehicles in circulation is lower. The costs of public parking spaces are also lower because the land is cheaper than in Paris. Network adaptation costs are higher because the penetration of electric vehicles is very high per capita and the mileage two times the mileage from Paris. Utrecht as leading and pioneering city will allocate €1,363 million, although per capita represents much more, €3,769 per inhabitant, the highest figure of the five cities, more than four times the next (Paris).

TURIN

Per capita, Turin is a city that will undertake some measures to promote electromobility being on the middle of the group with 768 €/inhabitant very similar to the Paris situation. However, if the planned measures are implemented, it is a candidate city to obtain a great environmental benefit and an improvement in air quality and noise pollution for its citizens. In relation to the preliminary graphs included in dot 4.1, Turin is in most cases in the middle of rest of cities, except in the public chargers' stock against Electric Vehicles which presents the worst position with less than 0.015 public charger per EV.

ZARAGOZA

Zaragoza is the second at the bottom (after Tallinn) in less measures to promote electromobility with 634 €/inhabitant but not far from Paris or Turin. Thus, if the planned measures are implemented, it is a candidate city to obtain a great environmental benefit and an improvement in air quality and noise pollution for its citizens. In relation to the preliminary graphs included in dot 4.1, Zaragoza has a very low number of EVs per capita (similar to Tallinn), however the number or public chargers per EVs is the second highest. In addition, with around 10,500 km/year is the second city with more km driven on average after Tallinn.

TALLINN

Tallinn is the city with less investment per capita to promote electromobility from the five analysed, with 288 €/inhabitant, less than half the invest of Zaragoza and one third of Paris or Turin. Utrecht investment is 13 times the invest of Tallin. Regardless this low investment is however a candidate city to obtain a great environmental benefit and an improvement in air quality and noise pollution for its citizens. In relation to the preliminary graphs included in dot 4.1, Tallin has the highest mileage per capita, very low number of EVs per capita, very low number of public chargers per EVs per capita and an average number of vehicles per inhabitant.

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6.7.2.2. Externalities (PM2.5, CO_2, Noise, casualties, congestions, space usage and time losses).

PARIS. It is worth noting that in terms of positive externalities, those countries that have done their homework earlier and had in 2021 a modern electric vehicle fleet, coupled with strong in-city mobility restrictions and a set of good non-vehicle alternatives, will show much less runaway environmental benefits than more polluted countries with older fleets at that time. This is why the environmental benefit for Paris and Utrecht in terms of P2.5 and CO_2 emissions are low. In both countries, the average annual mileage is also very low impacting in these two indicators. Noise by the contrary is high in Paris specially in those streets where traffic is admitted. In this indicator the potential improvement is higher.
In relation to the negative externalities, they are the lower if we consider them per capita (€698/inhabitant) although high in absolute terms. The reason must be found in the internal traffic restrictions in Paris Central that lead to less congestion, less accidents, and less time losses per capita).

In total, Paris does not recover the investment neither in absolute terms nor in relative. If we only consider the positive externalities, they also lose € 1,293 million € in absolute terms. The reason is, as explained, the low average milage, the very restrictive driving conditions inside the city, but at same time a high number of electric vehicles bought by the citizens and charging points supported by the authorities which are not amortised. The high cost of the charging places is also a drawback.

UTRECHT. In relation to the positive externalities, in Utrecht there are 1.2 vehicles per inhabitant, but they drive on average 2,833 km per year. In addition, the penetration of the electromobility is the higher reaching 30% of stock in 2035. If we combine all these aspects, we get some environmental improvement over a yet clean city in 2021. Compared to Paris the positive externalities are more than two times those from Paris.

However, the negative externalities erase the positive led by extra congestions as the penetration of electric vehicles is very high and drivers will tend to drive more due to the reduced OPEX costs. There will be more accidents and casualties and the parking space for chargers will be also expensive. Thus, the negative externalities surplus the positive.

TURIN. The positive externalities in Turin per capita (€2,453 million) are similar to Zaragoza and 8 times the worst city Paris. The reason is that in the Turin area, the stock of ICE vehicles (1.6 million) is twice the next city (Paris centre), the fleet is quite old, and the vehicles km are the highest by far (16.780 million km / year) compared to 7.190 million from Zaragoza and much more if we compare with Paris (2,165 million) or Utrecht (1,025 million). Thus, Turin has a big improvement pathway ahead if the ICE cars and vans are substituted by EVs. Their announcements in this regard are compelling, being the future policy one of the most aggressive compared with the rest of cities.

With regard the negative externalities in the case of Turin, the traffic inside the city is very dense. If we consider that the transition to electric will aggravate the traffic jams by the mentioned "rebound effect" described in chapter 6.5, we will see an increment in the number and profoundness of congestions with great time losses. However, the total balance will be kept positive with €949 million in superavit.

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ZARAGOZA. As explained before, the low number of EVs to date in Zaragoza and the high average yearly distance driven per capita, provides an opportunity to improve the air quality, the CO_2 emissions, and the noise in the city center once the EVs will progressively substitute the ICE cars. Although the city authorities are not highly promoting electromobility, the private OEMs offering with better vehicle features (more autonomy, fast charging, lower prices, etc) are moving citizens to purchase electric cars and the private chargers at home or in the offices, by the inertial deployment of the technology. In some way, the pioneering countries and cities investing as early adopters are blowing up the market generating a tracking effect that makes the follower countries adopt later the technology without investing so much. This is the main reason why Zaragoza presents the highest positive externalities without a large investment (2,723 €/ inhabitant).

The negative externalities per capita in Zaragoza are in the middle with 814 €/inhabitant against doble for Utrecht or Tallinn. Negative Externalities includes casualties, congestion time, charging space and charging losses for professionals. In Zaragoza, the time lost in congestion per capita represents the 60% of the total negative externalities. This is a low figure as in these two cities the traffic is not very dense, by strict limitations in Paris and by the low traffic in a large city as Zaragoza. Turin and Tallin have by the contrary a very dense traffic and consequently congestions will be higher once the EVs will substitute the ICE vehicles. In Paris the charging space is expensive but for a limited number of charging units.

TALLINN. The positive externalities (2,239.1 €/ inhabitant) are high but in the middle of the table compared with the other cities. The reason must be found in a large fleet of ICE cars and vans, with the highest mileage and a very low number of EVs to date, so the improvement pathway is high. However economic crisis and the almost null support of public administrations could jeopardise the introduction of the electromobility and the achievement of the expected sales forecast.

The negative externalities per capita in Tallinn are the highest from the five participant cities, mainly due to the potential high congestions inside the city once the electric vehicles will substitute the ICE car. Currently Tallin has a very dense traffic with very low mobility alternatives, hence, the rebound effect of electrics (extra driving due to the low OPEX cost) might increase this yet dense traffic, increasing the time losses. The other negative externalities are by the contrary, very limited.

6.7.2.3. Recommendations for city planners

PARIS will invest around 890 €/ inhabitants from 2021 to 2035 representing this figure a follower city (as Turin and to a minor extent, Zaragoza). Inside the city center of Paris, mobility restrictions are very high, the surface parking places are reduced over time and the public transportation and the micromobility are both strongly reinforced, so, probably the need for a very dense network of public charging points or the support for the purchase of electric vehicles would not be so necessary in relation to the city center as citizens are limited in the use inside and make very small mileage. This reduced mileage led to a very low positive externalities whilst the negative, are also in the middle of the table. The recommendation is to limit the investments and maybe concentrate them in the charging points specially the private ones, and some charging hubs in and outside for the professionals. Upfront support for EVs must be kept maintaining the sales forecast as it is but reducing a bit it, to keep the overall balance under control.

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UTRECHT is a pioneering city, reaching 2021 with a clear clean mobility policy and major deployment of electric vehicles than the rest. The average mileage is also low with 3,000 km on average, as in Paris, inferring less environmental benefits than other more conventional cities. The past public support was high, four times the next, so what we suggest is to reduce the supporting measures aligning them with other cities as the major effort has been already done. The citizens are environmentally aware, so we suggest again as in Paris to support the private infrastructure instead of the public one in the streets. Chargers in the streets must be addressed to the professionals and also for some people passing by, placing some charging hubs along the city. Garages, offices and public parkings must be equipped with the charging stations better than outside.

TURIN. The clean mobility policy has been growing steadily in Turin since 2021, but investments were not high in the past. This means that Turin, with a high traffic density and high mileage, has a very positive environmental record onward. Turin has a great opportunity to make the ecological transition toward electromobility and improve substantially the air quality with a positive balance even considering the negative externalities. Public investments are on the average (follower city) and consequently the recommendation is to continue reinforcing the support to electromobility and maybe controlling a bit the traffic inside the city by applying different measures preventing large congestions which could mitigate the very positive externalities achieved.

ZARAGOZA. The situation of Zaragoza is very similar to the Turin one. There is a young a flourishing electromobility policy that will infer substantial benefits for the city environment. Indeed, Zaragoza is the city with best results in the cost-benefit analysis, combining the city's traffic conditions with the support measures. The recommendation for cities as Zaragoza is to keep sustaining at least a base support because maybe the future EV users will not be able to afford the transition and the EVs sales forecast will not be able to be accomplished. This support in this case should be addressed to public but also private charging points, as many cars sleep in the streets and this feature will condition a lot the availability of charging points.

TALLINN is the use case city with less public support to electromobility. However, the country doesn't barely charge taxes to the cars, without substantial differences between ICE or EVs. This causes a certain lack of interest in the transition to electric vehicles. The reason maybe can be found in the limited public resources, entitling this kind of cities as "lagging" ones. However, the natural (or inertial) penetration of the electromobility due to the OEMs effort makes the citizens to adopt this technology to a certain extent with a very beneficial environmental effects without investing too much.

The recommendations for Tallinn, are to support the transition with some basic aids to vehicles and chargers, to let the sales forecast be accomplished. In addition, some measures providing clean mobility alternatives inside the city will reduce the traffic density and consequently minimising the congestion costs. Estonia has a great potential for improvement as many actions can be performed, taking advantage of the advances and best practices achieved in the leading countries.

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7. SENSIBILITY ANALYSIS

7.1. Introduction

The sensibility analysis consists of modifying the input data for the best and worst scenario, following the table below:

DATA	CITIES	2021	2025			2030			2035		
--	--	BASE	WORST	BASE	BEST	WORST	BASE	BEST	WORST	BASE	BEST
Stock Total (EVs+ICE)	PARIS	707,200	660,770	695,548	730,325	654,989	689,462	723,935	651,668	685,966	720,265
	UTRECHT	446,545	419,981	442,086	464,190	420,447	442,576	464,704	418,605	440,637	462,669
	TURIN	1,598,221	1,494,989	1,573,672	1,652,356	1,488,654	1,567,004	1,645,354	1,482,117	1,560,123	1,638,129
	ZARAGOZA	472,671	445,309	468,746	492,184	441,494	464,731	487,967	438,024	461,078	484,132
	TALLIN	344,483	323,815	340,858	357,901	321,781	338,717	355,653	320,327	337,186	354,045
Stock Total EVs (Passangers and LDV, BEV and PHEV)	PARIS	36,720	92,020	98,540	111,783	153,280	167,423	198,573	164,009	182,125	221,342
	UTRECHT	21,991	51,185	55,122	60,914	99,299	109,370	125,374	114,640	126,929	156,023
	TURIN	46,551	98,757	112,597	143,992	202,614	244,348	339,024	276,003	339,196	482,556
	ZARAGOZA	2,107	7,934	13,107	16,701	21,185	38,539	50,595	31,879	60,171	79,825
	TALLIN	3,157	7,346	8,512	9,302	17,170	21,126	23,808	28,657	35,964	40,918
Nº ICEs (or REST)	PARIS	670,480	568,751	597,007	618,542	501,708	522,039	525,362	487,659	503,842	498,923
	UTRECHT	424,555	368,797	386,963	403,276	321,148	333,206	339,330	303,965	313,707	306,646
	TURIN	1,551,670	1,396,231	1,461,076	1,508,364	1,286,039	1,322,656	1,306,330	1,206,114	1,220,927	1,155,573
	ZARAGOZA	470,564	437,375	455,639	475,483	420,309	426,191	437,372	406,145	400,907	404,306
	TALLIN	341,326	316,469	332,346	348,599	304,611	317,591	331,845	291,670	301,222	313,127
Nº Public Chargers (stock)	PARIS	1,600	3,966	4,236	4,769	6,191	6,743	7,928	6,680	7,393	8,900
	UTRECHT	586	1,409	1,468	1,656	2,572	2,713	3,190	2,976	3,149	3,977
	TURIN	789	1,694	1,907	2,475	3,168	3,748	5,289	4,207	5,061	7,329
	ZARAGOZA	77	397	437	507	1,293	1,450	1,721	2,374	2,675	3,193
	TALLIN	50	128	132	148	372	392	459	756	801	947

Table 140. Table with the input data for the best and worst scenarios

Results will be interpreter roughly from the overall tables and graphs, but it won't be possible to make a deep analysis due to space restrictions.

In the next table we summarise the best, base, and worst scenarios in absolute terms for the five cities.

BEST (2021-2035)

CBA Abs (Million €)	Increase Stock EVs	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	CBA PE	CBA ALL
Paris	184,622	-2,263.8	670.4	-2,551.4	-1,593.3	-4,144.7
Utrecht	134,032	-1,579.1	189.3	-929.7	-1,389.7	-2,319.4
Turin	436,005	-2,422.7	6,583.2	-6,087.8	4,160.5	-1,927.2
Zaragoza	77,718	-560.7	2,118.6	-933.8	1,557.9	624.1
Tallinn	37,761	-149.9	1,026.6	-1,271.6	876.7	-394.9

Table 141. Summary of CBA Results for the Best Scenario (major EVs stock in circulation and CPs and high public support in absolute values in million €)

BASE (2021-2035)

CBA Abs (Million €)	Increase Stock EVs	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	CBA PE	CBA ALL
Paris	145,405	-1,926.6	633.2	-1,512.0	-1,293.5	-2,805.5
Utrecht	104,939	-1,363.6	184.1	-483.5	-1,179.4	-1,662.9
Turin	292,645	-1,729.9	5,526.3	-1,658.6	3,796.4	2,137.8
Zaragoza	58,064	-434.2	1,864.7	-557.2	1,430.5	873.3
Tallinn	32,807	-130.3	1,013.1	-680.5	882.8	202.3

Table 142. Summary of CBA Results for the Base Scenario (average EVs stock in circulation and CPs and medium public support in absolute values in million €)

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WORST (2021-2035)

CBA Abs (Million €)	Increase Stock EVs	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	CBA PE	CBA ALL
Paris	127,289	-1,760.4	587.8	-661.4	-1,172.6	-1,834.0
Utrecht	92,649	-1,227.4	177.4	-378.9	-1,049.9	-1,428.8
Turin	229,451	-1,417.7	3,866.0	-1,615.7	2,448.3	832.7
Zaragoza	29,772	-278.0	1,403.0	-308.9	1,124.9	816.0
Tallinn	25,500	-99.1	832.3	-379.6	733.3	353.6

Table 143. Summary of CBA Results for the Worst Scenario (low EVs stock in circulation and CPs and timid public support in absolute values in million €)

Being the information included the following:

a. **Increase Stock EVs.** The difference in stock between years 2035 and 2021
b. **Public investments (A).** The sum up of all public efforts including EVs support (upfront costs and taxes), CPs support (upfront costs and taxes), Renewables to provide the extra electricity and infrastructure investments. It is always a negative figure.
c. **Positive Ext.** (B). These are the positive environmental externalities including CO2 equivalent avoided emissions, PM2.5 equivalent avoided particles in air and noise hindrance. All positive in favour of citizens.
d. **Negative Ext.**(C). Negative Externalities including extra congestions, extra casualties and injured people, public space occupied by parking slots and extra time in charging process during workday of professionals. These externalities are always negative.
e. **CBA PE.** This is the sum up of A+B (public investments and positive externalities)
f. **CBA All .** This is the sum up of A+B+C (public investments, positive externalities and negative one)

The same result has been analysed per capita, which more relevant than in absolute figures. The results are the following:

BEST (2021-2035)

CBA Per capita (€)	Incr. Stock Evs(%)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	CBA PE	CBA ALL
Paris	8.53%	-1,045.6	309.7	-1,178.5	-735.9	-1,914.4
Utrecht	37.05%	-4,365.2	523.4	-2,570.0	-3,841.8	-6,411.8
Turin	19.36%	-1,075.6	2,922.8	-2,702.8	1,847.2	-855.7
Zaragoza	11.35%	-818.9	3,094.2	-1,363.8	2,275.3	911.5
Tallinn	8.35%	-331.3	2,269.0	-2,810.5	1,937.7	-872.8

Table 144. Summary of CBA Results for the Best Scenario (major EVs stock in circulation and CPs and high public support per capita in €)

BASE (2021-2035)

CBA Per capita (€)	Incr. Stock Evs(%)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	CBA PE	CBA ALL
Paris	6.72%	-889.9	292.5	-698.4	-597.4	-1,295.8
Utrecht	29.01%	-3,769.4	509.0	-1,336.6	-3,260.4	-4,597.1
Turin	12.99%	-768.0	2,453.5	-736.4	1,685.5	949.1
Zaragoza	8.48%	-634.1	2,723.4	-813.7	2,089.2	1,275.5
Tallinn	7.25%	-287.9	2,239.1	-1,503.9	1,951.1	447.2

Table 145. Summary of CBA Results for the Base Scenario (average EVs stock in circulation and CPs and medium public support per capita in €)

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WORST (2021-2035)

CBA Per capita (€)	Incr. Stock Evs(%)	Public Invest.(A)	Positive Ext. (B)	Negative Ext.(C)	CBA PE	CBA ALL
Paris	5.88%	-813.1	271.5	-305.5	-541.6	-847.1
Utrecht	25.61%	-3,392.9	490.4	-1,047.3	-2,902.5	-3,949.8
Turin	10.19%	-629.4	1,716.4	-717.3	1,087.0	369.7
Zaragoza	4.35%	-406.1	2,049.0	-451.2	1,643.0	1,191.8
Tallinn	5.64%	-218.9	1,839.6	-839.1	1,620.6	781.5

Table 146. Summary of CBA Results for the Worst Scenario (low EVs stock in circulation and CPs and timid public support per capita in €)

In these last tables, the first column has been represented as a percentage (Increase in EVs stock (2035-2021)/inhabitant in %)

Finally, we add a table representing the variations between scenarios:

	Variation	Stock variation	PI Variation	Post. Ext. Var.	Neg. Ext. Var.
Paris	Best/Base	1.8%	17.5%	5.9%	68.7%
	Worst/base	-0.8%	-8.6%	-7.2%	-56.3%
Utrecht	Best/Base	8.0%	15.8%	2.8%	92.3%
	Worst/base	-3.4%	-10.0%	-3.6%	-21.6%
Turin	Best/Base	6.4%	40.0%	19.1%	267.1%
	Worst/base	-2.8%	-18.1%	-30.0%	-2.6%
Zaragoza	Best/Base	2.9%	29.1%	13.6%	67.6%
	Worst/base	-4.1%	-36.0%	-24.8%	-44.6%
Tallinn	Best/Base	1.1%	15.1%	1.3%	86.9%
	Worst/base	-1.6%	-24.0%	-17.8%	-44.2%

Table 147. Variation among best/base and worst/base scenarios (in %)
Note: Stock variation is a subtraction not a division like the other columns

7.2. Sensibility analysis conclusions

We will base our analysis through the "per capita" tables as they reflect better the real efforts done by the different administrations. In addition, we will distinguish between leading cities (Utrecht), followers (Paris, Turin, and Zaragoza) and lagging (Tallinn). Besides, we must also add other parameters for the analysis, the traffic density and kms/vehicle, which depends on the inside city driving restrictions and/or alternative mobility options and the shape of the city (larger cities increase the use of the vehicles). We this in mind, we can infer the following:

7.2.1. Paris sensibility analysis conclusions (follower city with low mileage)

Paris is a city with a very reduced mileage per inhabitant due to increasing driving restriction inside the Paris Central area. It is expensive to drive and park at the city center and the alternative mobility options are being promoted substantially. In Paris some roads have been pedestrianized, so the existing available roads suffer from traffic jams. Consequently, a small traffic increase will not impact a lot in the positive externalities as the mileage will continue being low, but reversely, the negative externalities will be increased substantially mainly because of the additional congestions, time losses, casualties, etc. Table 146 reflects that, for instance, an increase in public investments of 17.5% (comparing best/base) infers a 1.8% increase in the stock, moving up the benefits of the positive externalities in a 5.9% but the negative in a 68.7%. The CBA analysis is negative for PARIS in all scenarios, considering only the positive externalities or all the externalities. This happens when the mileage is very low, the cost of terrain is high, and the negative externalities very negative as explained.

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7.2.2. Utrecht sensibility analysis conclusions (leader city with low mileage)

The same analysis can be applied to Utrecht. Utrecht is a city with very low mileage and an strong investment to date and in the future toward electromobility promotion with the highest penetration of EVs from the five studied cities. This large penetration of EVs and CPs, with 4 times the public investments than the follower cities, led by upfront and taxes and the REs and grid adaptation costs, does not generate sufficient positive externalities to offset such investment from 2021 to 2035 but, by the contrary, also infers a substantial effect on the negative externalities, mainly by the terrain costs to place the public chargers and the congestions and casualties generated. The CBA is consequently very negative per capita in all scenarios (for base case, -4,597 €/inhabitant from 2021 to 2035). Besides, in Utrecht, an increase in the public investment of 15,8 % (comparing Best/Base) generated an 8% of additional EVs in the streets but generate only a 2.8% of positive externalities but a huge 92.3 % of negative externalities making the CBA worse in the best case compared with the base case. Rarely, the worst case is the one with the best cost benefit analysis.

7.2.3. Turin sensibility analysis conclusions (follower city with high mileage)

Turin has not yet implemented many electromobility promotional actions to date, however, it has launched an strong supportive policy from now onward. These actions will increase the EVs stocks in the base case scenario in a 13% comparing figures from 2035 to those in 2021. To that end, public investments will reach 768 €/inhabitant in that period. As the mileage is very high and dominated by ICE vehicles, the positive externalities will be very high (2,453 €/inhabitant) offsetting the public investments done. The negative externalities will not be so high because the city is large amounting for -736 €/inhabitant (less congestions and casualties) and consequently the CBA considering only the positive externalities or considering all, are both positive. If we analyse the worst and best scenarios, we can see that if we invest a 40% more (table 146), the stock of vehicles increases by 6.4%, increasing the positive externalities by a 19% but also the negative in a high 267 %. So, at certain moment when we increase the public investments and modify consequently the number EVs and CPs, the negative externalities become so large that makes the CBA negative. Therefore, follower cities that start introducing promotional measures must take care of not exceeding the effort or the CBA with reverse.

7.2.4. Zaragoza sensibility analysis conclusions (follower city with high mileage and low costs)

Zaragoza is a city with high mileage, a strong promotional policy from now onward and low prices for terrain, REs, etc. The analysis is similar to Turin, but the CBA becomes much positive in all scenarios because the positive externalities are higher whilst the negative are lower (check figure 52). When we analyse the best and worst scenarios, we see that there are more possibilities of a reduced public investment than an increase, compared to Turin (best/base 40%, worst/base -18%) compared to Zaragoza (best/base 29%, worst/base -36%) (table 146). That less reduction on the forecast investment in Zaragoza infers fewer negative externalities in the best case scenario but also improves the situation in the worst scenario as less EVs proportionally might be on the streets, resulting in a positive CBA when considering only the positive externalities but also with all of them. Therefore, Zaragoza remains in the best situation of all studied cities.

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7.2.5. Tallinn sensibility analysis conclusions (lagging city with high mileage and very low costs)

Tallinn has a large mileage per capita, with very reduced EVs penetration and very soft promotional electromobility policy. We can consider Tallinn as a lagging city. The size of the city is medium. Contrary to what it might seem, the CBA for Tallinn is slightly positive. The reason is that public investments are very low (-288 €/inhabitant), the positive externalities will be quite positive if we consider that a number of EVs will be bought in the city by the natural inertia derived from the high quality EVs offered by the OEMs. Those who buy (citizens with high purchasing power) will invest also in a private charging point and the administrations will necessarily do some grid adaptations and investments in REs. As the number of EVs is not high the negative externalities will be also low, resulting, as mentioned, in a slightly positive CBA.

If we check the best and worst scenario, we will see that the CBA considering only the positive externalities, growth as the number of EVs do, but in parallel the negative externalities also growth at major speed and, reversely to what we can expect, the best scenario makes the global CBA negative and the worst scenario makes it more positive.

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8. CONCLUSIONS

The cost-benefit analysis (CBA) pertaining to electromobility yields unforeseen outcomes, with the primary inference being that augmented investment does not invariably translate into commensurate economic benefits for urban areas. Nevertheless, it does contribute positively to environmental aspects, although this effect exhibits variability across different city typologies. Cities characterized by verticality, high population densities, and traffic volumes, which invest in electromobility while eschewing traffic restrictions or other eco-friendly mobility initiatives, will experience improved air quality but will likely incur substantial expenses due to the deployment of public charging infrastructure. This may result in heightened traffic congestion due to the rebound effect, additional time losses in opportunistic charging, and an increase in accident rates. To avert such consequences, it is imperative to curtail conventional traffic within the city, accompanying the proliferation of electric vehicles with measures aimed at reducing traffic, such as expanding pedestrian zones, promoting telecommuting, enhancing public transport, encouraging car-sharing, and fostering micromobility, among other strategies.

Cities that have already implemented such measures (e.g., Utrecht and, to a lesser extent, Paris) will observe minimal differences in air quality when investing in public charging infrastructure, but they will yield negative economic returns. Despite substantial previous investments, these cities may exhibit a negative cost-benefit analysis (CBA) due to the disproportionate growth of negative externalities compared to the relatively lower positive externalities, given that their air quality was initially clean.

Conversely, cities characterized by heavy traffic and low electric vehicle adoption, concurrently implementing a suite of aforementioned measures (e.g., Turin or Zaragoza), will witness a substantial enhancement in air quality (and noise reduction) with potentially modest to moderate investments. When coupled with traffic reduction strategies, these efforts are likely to yield unequivocally positive outcomes as they mitigate negative externalities and, subsequently, improve the CBA.

An intriguing paradox emerges in cities with limited public investment, high pollution levels, and heavy traffic (e.g., Tallinn). In such cases, these locales stand to benefit from automakers' efforts to electrify their vehicle fleets. The inertia of higher-income citizens purchasing electric vehicles and private chargers can inadvertently impact air quality in these cities, resulting in a positive albeit relatively modest CBA.

Another contentious aspect pertains to the necessity of public charging infrastructure. Public chargers add to their cost the occupation of public space, reducing conventional parking spaces, the requirement for increased renewable energy sources to ensure clean electricity supply, and grid infrastructure adaptation. The resolution of this dilemma is multifaceted. Notably, early adopters of electric vehicles typically possess greater purchasing power and access to private garages or workplace charging, rendering public chargers primarily utilized for opportunistic charging or by transient EV users, such as tourists and commercial enterprises in transit.

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However, as electric vehicle adoption becomes more widespread, particularly among individuals with limited purchasing power who lack private garages, the need for convenient and accessible daily charging solutions will become paramount. Some cities, like London and Berlin, are exploring innovative approaches, such as chargers integrated into streetlights. Yet, the challenge remains to ensure fair and equitable access to street chargers, thereby avoiding conflicts among lower-income residents, who may face longer commutes and charging hassles.

One potential solution involves facilitating the electrification of private parking spaces within cities, which already account for a significant portion of vehicles. New constructions must mandate pre-installed charging points at every electric-accessible parking space. Meanwhile, the remaining citizens should be provided with alternative mobility options to navigate the city efficiently. Those residing outside the city should access large proximity parking facilities, potentially offering low-cost or free parking, from where they can transition to cleaner transportation modes or public transit. Urban areas should feature ultra-fast charging hubs strategically located across the city for emergencies, complemented by slow charging systems in peripheral neighbourhoods, accessible through a reservation system via mobile applications for residents. Furthermore, all private and commercial parking facilities should be equipped with electrified parking spaces. All charging points should count with smart charging features to reduce the impact in the grid and reduce the charging costs. Beginning in 2035, the use of internal combustion engine (ICE) vehicles for city entry should be restricted or prohibited, while long-distance travel outside city limits should remain unrestricted. The progressive electrification of vehicles will naturally phase out older ICE vehicles over time.

In terms of policy recommendations to support urban mobility, the following categorizations are proposed:

a. Leading cities already characterized by clean mobility and high electric vehicle penetration: Prioritize the electrification of private parking spaces, mandating regulatory modifications to enforce charging point pre-installation in new constructions and retrofitting existing structures. Focus public investments on fast or ultra-fast charging hubs distributed throughout the city and encourage workplace and residential charging through legal mandates. Gradually reduce upfront investments as electric vehicle costs normalize. Massive implementation of Smart Charging and Dynamic Tariffs.

b. Follower cities with low electric vehicle adoption but ambitious future investment plans: Combine investments in electric mobility with traffic reduction measures. Concentrate public investments on fast or ultra-fast charging hubs, alongside incentives for workplace and residential charging infrastructure pre-installation. Incrementally diminish upfront investments as electric vehicle costs align with traditional vehicles.

c. Lagging cities with limited resources: Prioritize investments in private charging infrastructure and electric vehicle acquisition, deferring public charging investments until later stages. In all cases, emphasize investments in proximity parking facilities and integrated clean mobility solutions.

These recommendations aim to promote sustainable urban mobility while aligning with the unique characteristics and progression of cities along their respective electromobility journeys.

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ANNEX 1. CALCULATION OF UPFRONT SUBSIDIES FOR EVs in UTRECHT, TURIN, ZARAGOZA, and TALLINN (Paris Central depicted in chapter 3)

UTRECHT (Base)	New Reg EVs	EV Stock	Incentive/EV	Total Investment	Average Cost	% Support	% Red Cost	% Red aid
2018	2,571	10,284						
2019	2,490	12,773						
2020	3,763	16,536						
2021	5,455	21,991	4,370	16,686,701	33,645	12.99%		
2022	8,212	28,660	4,079	23,447,230	33,040	12.35%	-1.80%	-6.67%
2023	9,745	36,605	3,788	25,836,464	32,434	11.68%	-3.60%	-13.33%
2024	10,987	45,535	3,496	26,888,386	31,828	10.98%	-5.40%	-20.00%
2025	11,901	55,122	3,205	26,699,255	31,223	10.26%	-7.20%	-26.67%
2026	12,492	67,358	2,914	25,477,360	30,617	9.52%	-9.00%	-33.33%
2027	12,796	79,870	2,622	23,486,872	30,012	8.74%	-10.80%	-40.00%
2028	12,872	90,172	2,331	21,001,692	29,406	7.93%	-12.60%	-46.67%
2029	12,797	100,479	2,039	18,269,305	28,800	7.08%	-14.40%	-53.33%
2030	12,654	109,370	1,748	15,484,623	28,195	6.20%	-16.20%	-60.00%
2031	12,527	116,442	1,457	12,773,843	27,589	5.28%	-18.00%	-66.67%
2032	12,489	120,719	1,165	10,188,289	26,984	4.32%	-19.80%	-73.33%
2033	12,598	123,573	874	7,708,267	26,378	3.31%	-21.60%	-80.00%
2034	12,888	125,474	583	5,256,913	25,772	2.26%	-23.40%	-86.67%
2035	13,357	126,929	0	0	24,561	0.00%	-27.00%	-100.00%
				259,205,201				

Table 148. Calculation Upfront Costs to incentive the EVs purchase in Utrecht (Base scenario)

TURIN (Base)	New Reg EVs	EV Stock	Incentive/EV	Total Investment	Average Cost	% Support	% Red Cost	% Red aid
2018	378	4,319						
2019	667	12,852						
2020	2,328	25,452						
2021	5,352	46,551	1,500	5,619,922	35,378	4.24%		
2022	10,726	57,270	1,400	10,511,921	34,741	4.03%	-1.80%	-6.67%
2023	14,893	72,154	1,300	13,552,866	34,105	3.81%	-3.60%	-13.33%
2024	18,668	90,804	1,200	15,681,480	33,468	3.59%	-5.40%	-20.00%
2025	21,831	112,597	1,100	16,809,742	32,831	3.35%	-7.20%	-26.67%
2026	24,281	136,802	1,000	16,997,024	32,194	3.11%	-9.00%	-33.33%
2027	26,022	162,711	900	16,393,986	31,557	2.85%	-10.80%	-40.00%
2028	27,135	189,562	800	15,195,381	30,921	2.59%	-12.60%	-46.67%
2029	27,759	216,943	700	13,601,772	30,284	2.31%	-14.40%	-53.33%
2030	28,072	244,348	600	11,790,158	29,647	2.02%	-16.20%	-60.00%
2031	28,267	270,287	500	9,893,510	29,010	1.72%	-18.00%	-66.67%
2032	28,533	293,468	400	7,989,226	28,373	1.41%	-19.80%	-73.33%
2033	29,031	311,772	300	6,096,480	27,737	1.08%	-21.60%	-80.00%
2034	29,875	326,754	200	4,182,501	27,100	0.74%	-23.40%	-86.67%
2035	31,111	339,196	0	0	25,826	0.00%	-27.00%	-100.00%
				164,315,969				

Table 149. Calculation Upfront Costs to incentive the EVs purchase in Turin (Base scenario)

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ZARAGOZA (Base)	New Reg EVs	EV Stock	Incentive/EV	Total Investment	Average Cost	%Support	%Red Cost	%Red aid
2018	131	191						
2019	235	426						
2020	698	1,124						
2021	983	2,107	4,710	3,241,102	36,796	12.80%		
2022	1,620	3,724	4,396	4,985,315	36,133	12.17%	-1.80%	-6.67%
2023	2,396	6,117	4,082	6,846,766	35,471	11.51%	-3.60%	-13.33%
2024	3,158	9,268	3,768	8,329,045	34,809	10.83%	-5.40%	-20.00%
2025	3,852	13,107	3,454	9,313,455	34,146	10.12%	-7.20%	-26.67%
2026	4,446	17,527	3,140	9,773,527	33,484	9.38%	-9.00%	-33.33%
2027	4,927	22,414	2,826	9,746,253	32,822	8.61%	-10.80%	-40.00%
2028	5,293	27,609	2,512	9,307,299	32,159	7.81%	-12.60%	-46.67%
2029	5,557	33,035	2,198	8,550,186	31,497	6.98%	-14.40%	-53.33%
2030	5,739	38,539	1,884	7,569,445	30,835	6.11%	-16.20%	-60.00%
2031	5,867	43,708	1,570	6,447,743	30,172	5.20%	-18.00%	-66.67%
2032	5,968	48,693	1,256	5,246,985	29,510	4.26%	-19.80%	-73.33%
2033	6,071	53,144	942	4,003,383	28,848	3.27%	-21.60%	-80.00%
2034	6,202	56,949	628	2,726,501	28,185	2.23%	-23.40%	-86.67%
2035	6,379	60,171	0	0	26,861	0.00%	-27.00%	-100.00%
				96,087,004				

Table 150. Calculation Upfront Costs to incentive the EVs purchase in Zaragoza (Base scenario)

TALLINN (Base)	New Reg EVs	EV Stock	Incentive/EV	Total Investment	Average Cost	%Support	%Red Cost	%Red aid
2018	132	1,056						
2019	183	1,240						
2020	300	2,669						
2021	488	3,157	1,744	596,005	36,428	4.79%		
2022	807	3,963	1,628	919,406	35,772	4.55%	-1.80%	-6.67%
2023	1,170	5,122	1,511	1,237,731	35,116	4.30%	-3.60%	-13.33%
2024	1,533	6,654	1,395	1,496,790	34,460	4.05%	-5.40%	-20.00%
2025	1,871	8,512	1,279	1,675,114	33,805	3.78%	-7.20%	-26.67%
2026	2,170	10,656	1,163	1,765,980	33,149	3.51%	-9.00%	-33.33%
2027	2,421	13,037	1,046	1,773,096	32,493	3.22%	-10.80%	-40.00%
2028	2,622	15,606	930	1,706,860	31,838	2.92%	-12.60%	-46.67%
2029	2,776	18,315	814	1,581,178	31,182	2.61%	-14.40%	-53.33%
2030	2,889	21,126	698	1,410,862	30,526	2.29%	-16.20%	-60.00%
2031	2,973	24,006	581	1,209,584	29,871	1.95%	-18.00%	-66.67%
2032	3,036	26,937	465	988,408	29,215	1.59%	-19.80%	-73.33%
2033	3,092	29,910	349	754,885	28,559	1.22%	-21.60%	-80.00%
2034	3,150	32,928	233	512,718	27,904	0.83%	-23.40%	-86.67%
2035	3,219	35,964	0	0	26,592	0.00%	-27.00%	-100.00%
				17,628,617				

Table 151. Calculation Upfront Costs to incentive the EVs purchase in Tallinn (Base scenario)

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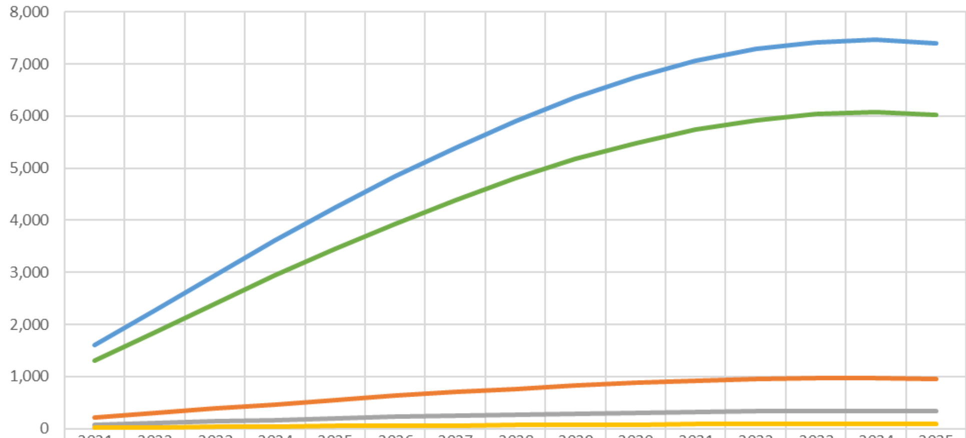
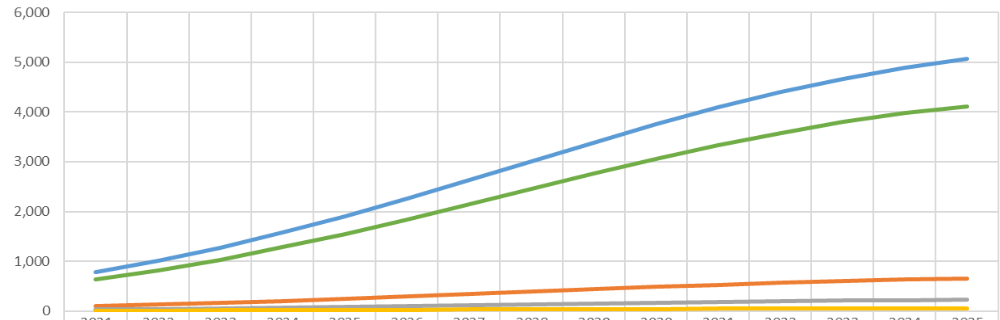
ANNEX 2. FORECAST PENETRATION CURVES OF EVs CHARGERS IN THE USE-CASE CITIES. Paris Central graph is included in the core document.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 1 (2.4-7 kW)	1,302	1,854	2,400	2,933	3,447	3,935	4,389	4,804	5,172	5,486	5,740	5,927	6,039	6,071	6,015
Level 2 (7-22 kW)	207	295	382	467	548	626	698	764	823	873	913	943	961	966	957
Level 3 (22-150 kW)	73	104	134	164	193	220	246	269	290	307	321	332	338	340	337
Level 4 (>120 kW)	18	26	34	41	48	55	61	67	72	77	80	83	85	85	84
TOTAL	1,600	2,278	2,949	3,605	4,237	4,836	5,395	5,904	6,356	6,743	7,055	7,284	7,423	7,462	7,394

Level 1 (2.4-7 kW) Level 2 (7-22 kW) Level 3 (22-150 kW) Level 4 (>120 kW) TOTAL

Figure 54. EVs Chargers' penetration curves at Paris Centre classified by level.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 1 (2.4-7 kW)	642	817	1,032	1,279	1,552	1,843	2,145	2,452	2,756	3,049	3,326	3,578	3,799	3,981	4,117
Level 2 (7-22 kW)	102	130	164	203	247	293	341	390	438	485	529	569	604	633	655
Level 3 (22-150 kW)	36	46	58	72	87	103	120	137	154	171	186	200	213	223	231
Level 4 (>120 kW)	9	11	14	18	22	26	30	34	39	43	47	50	53	56	58
TOTAL	789	1,004	1,268	1,572	1,907	2,265	2,637	3,014	3,387	3,748	4,088	4,398	4,669	4,893	5,061

Level 1 (2.4-7 kW) Level 2 (7-22 kW) Level 3 (22-150 kW) Level 4 (>120 kW) TOTAL

Figure 55. EVs Chargers' penetration curves at Turin classified by level.

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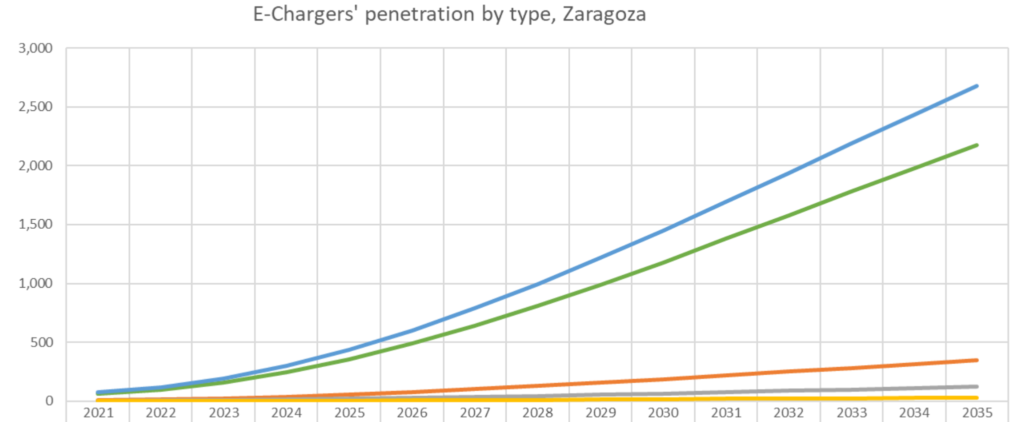
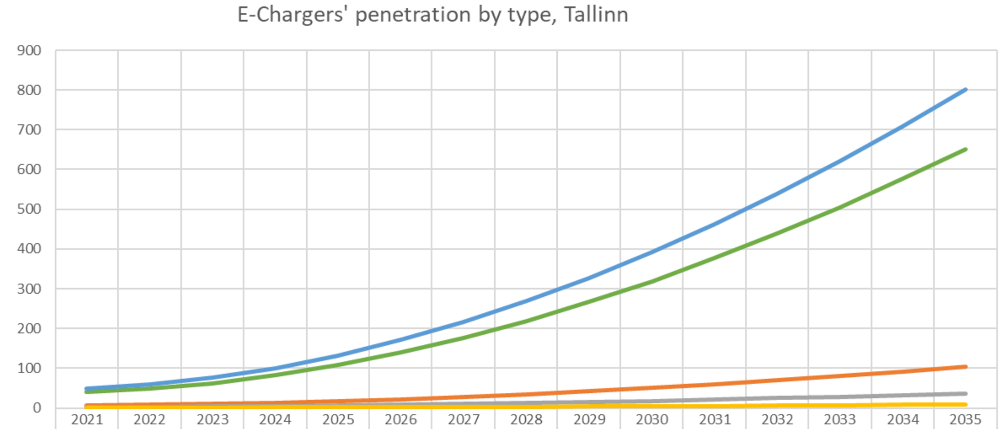


	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 1 (2.4-7 kW)	62	94	155	243	356	489	642	809	990	1,180	1,377	1,578	1,780	1,981	2,177
Level 2 (7-22 kW)	10	15	25	39	57	78	102	129	158	188	219	251	283	315	346
Level 3 (22-150 kW)	3	5	9	14	20	27	36	45	55	66	77	88	100	111	122
Level 4 (>120 kW)	1	1	2	3	5	7	9	11	14	17	19	22	25	28	31
TOTAL	77	115	190	299	437	602	789	995	1,217	1,450	1,693	1,940	2,188	2,435	2,675

Level 1 (2.4-7 kW) Level 2 (7-22 kW) Level 3 (22-150 kW) Level 4 (>120 kW) TOTAL

Figure 56. EVs Chargers' penetration curves at Zaragoza classified by level.



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Level 1 (2.4-7 kW)	40	48	62	82	108	139	176	219	266	319	376	439	505	576	651
Level 2 (7-22 kW)	6	8	10	13	17	22	28	35	42	51	60	70	80	92	104
Level 3 (22-150 kW)	2	3	3	5	6	8	10	12	15	18	21	25	28	32	37
Level 4 (>120 kW)	1	1	1	1	2	2	2	3	4	4	5	6	7	8	9
TOTAL	50	59	76	101	132	171	217	269	327	392	463	539	621	708	801

Level 1 (2.4-7 kW) Level 2 (7-22 kW) Level 3 (22-150 kW) Level 4 (>120 kW) TOTAL

Figure 57. EVs Chargers' penetration curves at Tallinn classified by level.

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ANNEX 3 – SUMI's USER GUIDES

i. Indicator 3: Air pollutant emissions

USER GUIDE FOR INDICATOR 3 "AIR POLLUTANT EMISSIONS"

Definition

Air pollutant emissions of all passenger and freight transport modes (exhaust and non-exhaust for PM2.5) in the urban area

Parameter

$$EHI = \frac{\sum_s Eeq_s * \left(\sum_{ij} A_{ij} * \left(NE_i + \sum_{ck} S_{ck} * E_{ijkcs} * I_k\right)\right) * 1000}{cap}$$

EHI = Emission harm equivalent index [kg PM2.5 eq./cap per year]
Eeq_s = Emission substance type PM2.5 equivalent health impact value [factor]
E_{ijkcs}= Emission of pollutants per vkm driven by transport mode i and vehicle type j for fuel type k, emission class c (g/km)
A_{ij}= Activity volume (distance driven by transport mode i and vehicle type j) [million vkm per year]
S_{ijk} = Share of fuel type k per vehicle type j and per transport mode i [fraction]
C_{ijkc} = Share of emission class c per fuel type k per vehicle type j and per transport mode i [fraction]
NE_{si} = Non-exhaust emissions of pollutant i per distance driven [g/km] (=0 for NOx)
cap = Capita or number of inhabitants in the urban area [#]
k = Energy type (petrol, diesel, bio-fuel, electricity, hydrogen, etc.) [type]
i = Vehicle type transport mode (passenger car, tram, bus, train, motorcycle, inland vessel, freight train, truck, etc.) [type]
j = Vehicle class (if available specified by model (e.g. SUV, etc.) [type]
s = Type of substance [type] limited to NOx and PM2.5
c = Emission class (euro norm) [type]
multiplication by 1000 to transform units from g to kg

Guidelines

The completion of this worksheet takes 3 steps:
Step 1: Provide information on transport volumes and vehicle stock composition, based on the available level of detail (see worksheet "example", rows 6 to 88). This step has been subdivided into three sections.
- Section a) is related to transport activity (at aggregate level),
- section b) to vehicle stock, with different level of details (first of all by fuel, secondarily by emission standard for gasoline and diesel),
- section c) to data on the number of inhabitants in the urban area. The blue cells should be filled.

Step 2: Data integration (completion, harmonisation, etc.). Where necessary, urban area coaches should integrate the missing data (e.g. more detailed Euro X) in the tables filled in by urban areas in step 1. Other data sources can be used as reference, e.g.:
- for vehicle fleet: data at country level (Eurostat for fuels, national statistics/ modelling for emission standard)
- for vkm, pkm, tkm by vehicle type: estimation from aggregated tool at urban level (related data input required from the urban area)
For LGV, if data is available in total but not by weight class, urban area coaches should integrate the table with appropriate assumptions.
The input tables are directly linked to the calculation table for the estimation of the indicator (see worksheet "example", from row 155).

Step 3: Formula application (see worksheet "example", row 104).

Comments

Ideally, information on the number of vehicle kilometres should be available for each combination of vehicle type, vehicle emission category (emission standard) and fuel type. This is, for example, the case when detailed (transport) models are available for the urban area and modelling results are further elaborated.
Nevertheless, this level of detail is hardly available in most cases, therefore it is requested that data is provided on transport activity by vehicle type, in combination with information on vehicle stock used to make an additional disaggregation towards the spread of "fuel type" and / or "emission standards".
In case data on transport activity by vehicle type and vehicle stock composition are not available for the urban areas, the city coaches should make reference to other existing data sources in order to integrate the input tables.

The shares of Euro classes for CNG, LPG, hybrids used for the calculation refer to average EU values.

The indicator is expressed in terms of Emission Harm Effect on health using PM2.5 equivalents, based on the methodology developed in the context of the Clean Air Programme/ National Emissions Ceilings Directive discussions.

The indicator value corresponding to this parameter value is on a scale from 0 to 10, with 0 indicating the worst condition of air pollutant emissions (when the value of the parameter is higher than 2.15 kg of PM2.5 equivalent per capita) and 10 indicating the best condition (when the value of the parameter is 0 kg of PM2.5 equivalent per capita).
The threshold of 2.15 kg of PM2.5 equivalent per capita has been defined considering the Gothenburg 2020 PM2.5 target, taking into account that about 30% of urban emissions are generated by road transport.

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ii. Indicator 4: Noise hindrance

USER GUIDE FOR INDICATOR 4 "NOISE HINDRANCE"

Definition

Hindrance of population by noise generated through urban transport.

Parameter

Percentage of population hindered by urban transport noise, based on hindrance factors for noise exposure data of population by noise bands.

$$NI = \frac{\sum_i HFLden_i * (\sum_m W_{im} * P_{im})}{\sum_{im} W_{im} * P_{im}}$$

NI = Noise hindrance index [% of population]
i = Average noise Lden of noise band [#]
P_{im} = Population exposed to noise band i for mode m (road, rail, airplane) [#]
W_{im} = High Annoyance weight factor for mode m and noise band i [%]
$HFLDen_i$ = Hindrance factor at average $Lden_i$ of the related noise band i

LDen= Average sound pressure level over all days, evenings and nights in a year (in this compound indicator the evening value gets a penalty of 5 dB and the night value of 10 dB).

Guidelines

The definition of the formula is based on the noise maps and noise exposure data available from the "Noise Observation and Information Service for Europe" of the European Environment Agency (EEA).

Step 1: Urban areas should check Information availability on noise maps and noise exposure data available from the EEA's "Noise Observation and Information Service for Europe", i.e. END's noise map data (https://www.eea.europa.eu/data-and-maps/data/data-on-noise-exposure-7/noise-exposure-information-under-the).
If data is available, they have to be used to fill directly the cells marked in blue related to population exposure by mode: cells B25-29 for roads, cells E25-29 for railways and cells H25-29 for airports in the 'Calculation' spreadsheet. In that case, step 3 can be skipped.

Step 2: If data is not available from the EEA database, integration is necessary with other available noise mapping data. Noise data could be elaborated by urban areas with a GIS-based calculation to estimate population exposure by noise band.
When data is available, they have to be used to fill the cells marked in blue related to population exposure by mode: cells B25-29 for roads, cells E25-29 for railways and cells H25-29 for airports in the 'Calculation' spreadsheet.

Step 3: The formula is applied and the parameter and indicator calculated.

Comments

The main input consists of data on noise exposure available from the EEA's "Noise Observation and Information Service for Europe".
This data is available for many agglomerations in Europe. In case an urban area is not included in the list, the information on population exposure by noise bands can be estimated from available noise mapping data elaborated with a GIS-based calculation.
Table 1 in the 'Calculation' spreadsheet provides Lden values for different sources with respect to high annoyance level, used in the formula to properly weight the exposure by mode.
The indicator value corresponding to this parameter value is on a scale from 0 to 10, with 0 indicating the worst condition of noise hindrance (when the value of the parameter is higher than 70%) and 10 indicating the best condition (when the value of the parameter is 0%).

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iii. Indicator 5: Road deaths

USER GUIDE FOR INDICATOR 5 "ROAD DEATHS"

Definition

Road deaths by all transport accidents in the urban area on a yearly basis.

Parameter

Number of deaths within 30 days after the traffic accident as a corollary of the event per annum caused by urban transport per 100,000 inhabitants of the urban area.

$$FR = \frac{\sum_i K_i * 100000}{Cap}$$

FR = Fatality rate [# per 100,000 urban area population per year]

K_i = Number of persons killed in transport mode i [# per year]

Cap = Capita or number of inhabitants in the urban area [#]

i = Transport mode

Guidelines

Road deaths are registered:
- per year
- per traffic mode they were using at time of the accident OR independent of the traffic mode they were using
- on public domain (i.e. roads, parking lots, or similar infrastructure which is publicly accessible)
- as 'road deaths 30 days': road deaths are registered as such if they occur within 30 days of the accident

Fatality rate (FR) is calculated per 100,000 inhabitants of the urban area

In relation to soft modes (pedestrians and cyclists), it may be required to use additional data sources on leisure or sport activities to obtain a complete overview of road deaths for these travel modes.

Urban areas are required to fill in the cells marked in blue in the calculation sheet. The number of inhabitants in the urban area is to be included in cell E11, and the number of persons killed per transport mode within the last completely registered year is to be included in column D.

Comments

The indicator value corresponding to this parameter value is on a scale from 0 to 10, with 0 indicating the lowest level of overall traffic safety and 10 indicating the highest level.

If the parameter has a value larger than 15, the indicator is set to 0. If the parameter has a value of 0, the indicator is set to 10. Values in between 15 and 0 are scaled to get a score between 0 and 10.

Please note that there are two indicators related to the number of road deaths (this one and indicator 13 "Traffic safety active modes"). The two indicators follow a different rationale:

This indicator (no. 5) aims at providing urban areas insight in the extent of the road safety problem, independent of urban area population size. It allows areas to identify whether or not road safety has reached a level which requires local measures, independent of the provenance of road deaths. As measures are concerned, it may be that urban areas can take full problem ownership (and implement their own measures), or could be required to contact other areas or administrative levels. This indicator helps identifying such cases.

Indicator 13 aims at providing urban areas insight in the extent to which a specific road safety problem exists for active modes, independent of the number of active mode trips. It allows areas to gain insight in the safety/ unsafety associated in particular to active modes. The choice to make a relative estimation over the number of trips stems from the correlation between (active mode) unsafety and the presence of few active mode trips. For example, unsafe biking infrastructure does not invite people to bike, hence leading to fewer biking trips. It is exactly this bias which is mitigated in indicator 13.

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iv. Indicator 7: Greenhouse gas emissions

USER GUIDE FOR INDICATOR 7 "GREENHOUSE GAS EMISSIONS"
Definition
Well-to-wheels GHG emissions by all urban area passenger and freight transport modes
Parameter
G = Greenhouse gas emission [tonnes CO2(eq.) /cap. Per year] T_k = Tank to wheel CO2 emission per energy type unit considered [kg/ℓ or kg/kWh] W_k = Well to tank CO2 equivalent emission per energy type unit considered [factor] A_{ij}= Activity volume (distance driven by transport mode i and vehicle type j) [million vkm per year] S_{ijk} = Share of fuel type k per vehicle type j and per transport mode i [fraction] C_{ijkc} = Share of emission class c per fuel type k per vehicle type j and per transport mode i [fraction] I_{jk} = Energy intensity per distance driven for vehicle type j and fuel type k [ℓ/km or MJ/km or kWh/km] Cap = Capita or number of inhabitants in the urban area [#] F_{ijk} = Non-CO2 GHG correction (CO2 equivalent) [factor] k = Energy type (petrol, diesel, bio-fuel, electricity, hydrogen, etc.) [type] i = Transport mode (passenger car, tram, bus, train, motorcycle, inland vessel, freight train, truck, etc.) [type] j = Vehicle class (if available, specified by model (e.g. SUV, etc.) [type] multiplication by 1000 to transform unit from kg to tonnes
Guidelines
The completion of this worksheet takes four steps: Step 1: Basic data. Verify energy content (Mj/l) for different fuel types (see worksheet "example", lines 12 to 22). This input requires the same values entered for indicator 9 "Energy efficiency". It is also requested to select the country of the urban area and to include the number of inhabitants of the urban area. Step 2: Data collection. Provide information on transport volumes, vehicle stock composition and fuel consumption factors, based on the available level of detail. This step has been subdivided into three sections. - section a) is related to transport activity (at aggregate level), - section b) to vehicle stock, with different level of details (first by fuel, secondly by emission standard for gasoline and diesel), - section c) fuel consumption factors. These inputs require the same values entered for indicator 9 "Energy efficiency" and indicator 3 "Air pollutant emissions". Step 3: Data integration (completion, harmonisation, etc.). Where necessary, urban area coaches should integrate the missing data (e.g. more detailed Euro X) of the tables filled by urban areas in previous steps. Other data sources can be used as reference, e.g.: - For vehicle fleet and fuel consumption factors: data at country level (Eurostat for fuels, national statistics / modelling for emission standard). Default values for fuel consumption can be found in the sheet "default values". - For vkm by vehicle type: estimation from aggregated tool at urban level (related data input required from the urban area). - For LGV, if data is available in total but not by weight class, urban area coaches should integrate the table with appropriate assumptions. The input tables are directly linked to the calculation table for the estimation of the indicator (see worksheet "example", from line 168). Step 4: Formula application (see worksheet "example", line 160).
Comments
Ideally, information on the number of vehicle kilometres should be available for each combination of vehicle type, vehicle emission category (emission standard) and fuel type. This is, for example, the case when detailed (transport) models are available for the urban area and modelling results are further elaborated. Nevertheless, this level of detail is hardly available in most cases, therefore it is requested that data is provided on transport activity by vehicle type, in combination with information on vehicle stock used to make an additional disaggregation towards the spread of "fuel type" and/ or "emission standards". In case data on transport activity by vehicle type and vehicle stock composition are not available for the urban areas, the urban area coaches should make reference to other existing data sources in order to integrate the input tables. The shares of Euro classes for CNG, LPG, hybrids used for the calculation refer to average EU values. The indicator is expressed in terms of GHG emissions using CO2 equivalents. The indicator value corresponding to this parameter value is on a scale from 0 to 10, with 0 indicating the worst condition of GHG emissions (when the value of the parameter is higher than 2.75 t of CO2 equivalent per capita) and 10 indicating the best condition (when the value of the parameter is 0 t of CO2 equivalent per capita).

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v. Indicator 8: Congestion and delays

USER GUIDE FOR INDICATOR 8 "CONGESTION AND DELAYS"

Definition

Delays in road traffic and in public transport during peak hours compared to off peak travel (private road traffic) and optimal public transport travel time (public transport).

Parameter

Weighted sum of delays over representative corridors for road private and public transport.
For road private transport, sum of weighted averages over 10 representative corridors for car trips as a ratio of peak period travel times to off-peak travel times.
For (road) public transport, sum of weighted averages over 10 representative corridors for public transport trips as a ratio of peak period travel times to estimated optimal travel time.

$$CD_{ij} = MS_{road} * \frac{\left(\sum_{i=1}^{10}\left(\frac{CT_i * PHT_i}{FFT_i}\right)\right)}{\sum_{i=1}^{10} CT_i} + MS_{PT} * \frac{\left(\sum_{j=1}^{10}\left(\frac{PT_j * PTPHT_j}{PTOT_j}\right)\right)}{\sum_{j=1}^{10} PT_j}$$

CDij = Congestion and delay index (percentage delay during peak hours) [% of delay]
CTi = Number of car trips during peak hours on main road corridor i [#]; If this information is missing, the number of lanes could be used as an alternative weighing factor
PHTi = Car travel time during peak hours on main road corridor i [minutes]
FFTi = Off-peak car travel time on main road corridor i [minutes]
PTj = Number of public transport trips during peak hours on transit corridor j [#]
PTPHTj = Public transport travel time during peak hours on main road corridor i [minutes]
PTOTj = Optimal Public Transport travel time on main road corridor i [minutes]
MSroad = Modal share road [%] (modal share as the number of persons which are travelling, modal share when only considering private car and PT as possible modes)
MSpt= Modal share public transport [%] (modal share as the number of persons which are travelling, modal share when only considering private car and PT as possible modes)

Guidelines

The parameter makes use of the delay between peak and off-peak travel time. This requires the definition of "peak" and "off-peak":
- peak-hour time (and off-peak time): this corresponds to the beginning and end of the working day, when large numbers of people are travelling to or from work. The corresponding hours depend on citizens' habits and working legislation.
- off-peak: often, night-time traffic is measured and used for the estimation of "off-peak". However, this may not be the most relevant time period for such measurements, as vehicles also tend to speed more at night and this would therefore not represent a realistic measurement. It is therefore recommended to measure off-peak travel speed during the middle of the morning or afternoon.
Optimal public transport travel time could be defined as estimated running times with a 'good' commercial speed estimation based on vehicle speed, intersections, number of stops, etc. The simplified calculation assumes that travel time of PT vehicles is composed of (1) time consumed on road sections within a corridor at constant speeds, (2) variable time spent at stops, and (3) delays at traffic signals. The addition of these allows for an estimation of the commercial speed as a mean measure of effectiveness of the selected public transport corridor.
The calculation can be made following the methodology suggested by, for example, Valencia (2012) [https://www.researchgate.net/publication/263888875_A_method_to_calculate_commercial_speed_on_bus_corridors]. Preferably, local PT operators can provide this information.
The indicator relies on the selection of 2 times 10 corridors:
- public transport: 10 corridors are to be selected which are relevant for public transport.
- private transport: 10 corridors are to be selected which are relevant for private transport.
Corridors should ideally comprise a mix of tangential and diagonal routes, crossing the urban area. Total traffic (vkm) for the corridors should account for a sufficiently high share of urban area traffic. The share is estimated based on most recent traffic monitoring, and can take into account existing delays, vehicle throughput, vehicle mileages, number of road users, etc. on corridors. In case of public transport, this can include public transport modes which are running on protected lanes.

The selection of corridors for public transport should follow two steps:
First, the 10 corridors should be allocated to the different modes according to their modal share. For example, if the modal share within public transport (measured by preference in passenger km instead of vehicle km) of bus is 60%, 6 bus corridors should be included.
Secondly, for each mode the busiest corridors should be selected.
For road traffic, 10 corridors with the most traffic should be selected. Corridors should be selected based on the characteristics of the urban area.
(The value of the "sufficiently high share" is to be discussed, and can change over time as this will be dependent on the urban area.)
In order to prevent selection biases (i.e. limiting the selection to very short road sections of relative free flow traffic, compared to an overall congested area), we suggest the following:
- For public transport, entire bus/tram/train/metro/... routes are selected insofar that they connect two clearly defined end stations or an end station and city centre (square, market, hub, etc.).
- For public transport one should be careful with including too many modes which run on a dedicated track (e.g. metro, tram) as this might bias the indicator. However, if such lanes are very relevant for the cities, they should be included as otherwise cities which invest in public transport using dedicated tracks/ lanes would be penalised.
- For private transport, road sections are selected insofar that they connect urban region or city borders with another urban region or city border or well-defined centre (square, ring-road, market, transport hub, etc.).
Car travel is considered for the selection of corridors for private transport and associated calculations.
All public transport modes can be considered for the public transport corridors and associated calculations. One does not have to stick to one type of public transport mode. For example, one could include 3 metro, 2 tram and 5 bus corridors.

Comments

The selection of (two times ten) corridors should aim at being as representative as possible. There are no real quantitative or qualitative definitions for representativeness of corridor selections compared to urban area road infrastructure or road use. Indeed, this is to be verified on a case-by-case basis.

As general guidelines, we provide the following tips:
- Choose corridors with a significantly share in the total number of daily commuting trips ran in the urban area. For example, where several public transport lines use a similar route as private transport, where the most significant access roads are to the city, where roads are the logical elongation of feeding roads from outside of the city, where major roads connect the busiest working or living quarters of an urban area, etc. Floating car/vehicle data can help estimate this percentage. Suggesting a target percentage is very much dependent on the spread of traffic in the area. Areas with a very heterogenous traffic volume spread (for example, where traffic is very much limited to access roads), can more easily provide a selection of corridors which represent a higher volume of traffic. Areas with a more homogenous traffic volume spread (for example, urban areas which have a lot of roads with similar use and composition, no clear high-density centres, etc.), will experience more problems in achieving this.
- Choose corridors which correspond to both lateral as well as tangential traffic movement. Lateral movement = between the area outskirts and the area centre (inwards/outwards). Tangential movement = ring-roads or main arteries outside of urban area centres.
The use of Floating Car Data, or data resulting from Floating Car Data, as a basis for the estimation of actual vehicle travel time (during all times of the day) is strongly suggested. Data can be provided, for example, by services such as Google Maps, Waze, etc.

Public transport includes all public transport modes such as bus, metro, tram, regional trains. We suggest not to include taxi and systems like Uber as their congestion is taken into account in the road corridors.

Based on the parameter, an indicator (with values between 0 and 10) is calculated. A high score for the parameter indicates more delays and is transformed to a low score for the indicator. The values used for calculating the indicator are 3 (min scale) and 1 (max scale).

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vi. Indicator 17: Mobility space usage

USER GUIDE FOR INDICATOR 17 "MOBILITY SPACE USAGE"
Definition
Proportion of land use, taken by all city transport modes, including direct and indirect uses.
Parameter
Square meters of direct and indirect mobility space usage per capita. $$LUM = \frac{\sum_i (LD_i + LI_i)}{Cap}$$ LUM = Land use for mobility applications [ha] LDi = Direct Land use for category i [ha] LIi = Indirect Land use for category i [ha] i = Mobility mode [#] Cap = Capita or number of inhabitants in the city [#]
Guidelines
This indicator aims to capture all transport space. Hence, other aspects, such as tram tracks, bus lanes, logistics centres, etc. shall be included in field E12 or E18, if not already accounted for in the road space surface. With respect to "roads", if there is no precise data on street surfaces, standard widths can be assumed (remember to add sidewalks and cycle lanes in field E12). Urban areas are encouraged to consider at least parking lots and petrol stations for representative results. As in the pilot phase it has proved challenging for urban areas to collect data on private parking, the calculation sheet will be accepted also with partial or no data for this entry. To estimate the parking space usage, it is possible to multiply the number of parking spaces by their surface (~13 to 18 m^2/car). To estimate the space used by petrol stations, it is possible to consider the average surface of a petrol station (e.g. in Brussels it is 800 m^2) and multiply it by the number of petrol stations registered. On-street parking is considered direct use, and is already included in the road space, unless you have more precise data on streets that differentiates between parking usage and mobility usage. All parking provided for public use is considered public parking, and accounted by parking space surface, even on multi-storey car parks. Private parking is all parking that is not open to the public, such as residential and office parking garages. Similarly, it is accounted by parking space surface. "Stations" are all stations that are not already accounted for when calculating the direct use. This depends on your data. In some cases, the surface area for roads might already include mass rapid transit stations, tram stations and railways might already include stations.
Comments
Please ensure to put ha into the input fields and to indicate the source of data used to feed the different entries.

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ANNEX 4 – CONCENTRATION AIR INDEX

	Scores per category				Score by city					Weighted Ratio by city (index, 1-3)				
	1	2	3		Paris	Utrecht	Turin	Zaragoza	Tallinn	Paris	Utrecht	Turin	Zaragoza	Tallinn
Air pollutant dispersion	**Low (L)**	**Regular (R)**	**High (H)**	**Weight**	**Value (L, R, H)**	**Value (L, R, H)**	**Value (L, R, H)**	**Value (L, R, H)**	**Value (L, R, H)**	**1.94**	**2.39**	**1.80**	**2.20**	**2.20**
Ground orography	Valley	Plain	Mountain	20%	R	R	R	R	R	2.00	2.00	2.00	2.00	2.00
Urban block orography (buildings height)	High (13 floors or above)	Mid (5 to 12 floors)	Low (4 floors or under)	20%	2% 28% 70%	1% 50% 49%	0% 100% 0%	10% 80% 10%	0% 5% 95%	2.68	2.48	2.00	2.00	2.95
Population density (inhab./km²)	> 5.000 inh./km²	1.500 - 5.000 inh./km²	< 1.500 inh./km²	10%	### 0% 0%	40% 30% 30%	### 0% 0%	0% 0% ###	0% 90% 10%	1.00	1.90	1.00	3.00	2.10
Average annual temperature (° C)	> 14 °C	6 - 14 °C	< 6 °C	10%	R	R	R	L	R	2.00	2.00	2.00	1.00	2.00
Average annual pluviometry (mm)	< 800 mm	800 - 1.600 mm	> 1.600 mm	10%	L	H	R	L	L	1.00	3.00	2.00	1.00	1.00
Mean wind speed (m/s) (https://globalwindatlas.info/)	< 3 m/s	3 - 6 m/s	> 6 m/s	20%	R	H	L	H	H	2.00	3.00	1.00	3.00	3.00
Green space coverage within city (%)	< 15 %	15 - 30 %	> 30 %	10%	R	R	H	H	L	2.00	2.00	3.00	3.00	1.00

Table 152. Characterization of Use-Case cities by topography considerations

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9. LIST OF FIGURES

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10. LIST OF TABLES

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