

CleanCities



**Towards zero-emission transport in
European cities:**

Milan

Final Report



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Acronym list

B2C	Business-to-consumer
BEV	Battery Electric Vehicle
C-ITS	Cooperative Intelligent Transport System
CNG	Compressed Natural Gas
CO	Carbon Monoxide
DRT	Demand-Responsive Transport
EU	European Union
EV	Electric Vehicle
GHG	Greenhouse Gases
HDV	Heavy Duty Vehicle
LDV	Light Duty Vehicle
LEZ	Low Emission Zone
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LTZ	Limited Traffic Zone
MaaS	Mobility as a Service
NOx	Nitrogen oxides
PHEV	Plug-in Hybrid Electric Vehicle
pkm	Passengers-km
PM	Particulate Matter
PT	Public Transport
SUMP	Sustainable Urban Mobility Plan
vkm	Vehicle-km
VOC	Volatile Organic Compounds
ZEZ	Zero Emission Zone

1. Introduction

1.1 Study context and structure of the report

Between 1990 and 2019, greenhouse gas (GHG) emissions from transport have increased by around 24% in Europe [1] and urban transport is estimated to account for around 23% of all emissions from the EU transport sector [2].

Urban transport is not only a main driver of the climate emergency but is also directly responsible for a series of negative externalities at the city level, including air pollution, noise, and road traffic injuries/deaths. Many of these problems are expected to increase in the future without dedicated policy interventions, as cities continue to grow and face demographic changes such as ageing populations.

Different government levels have set distinct targets for sustainable urban transport to address these challenges. The 2019 *EU Green Deal* [3] mandates a 90% reduction in greenhouse gas emissions from transport for the EU to become a climate-neutral economy; this whilst working towards a zero-pollution ambition. The 2020 EC Communication *Smart and Sustainable Mobility Strategy* [4] calls for more sustainable, smart and resilient mobility. That includes boosting the uptake of zero-emission vehicles, making urban mobility healthier, stepping up safety and security across all modes, and providing better incentives for users to attain desirable changes in transport behaviour and choices.

In addition, 100 cities from the European Union and 12 cities from associated countries have been selected to join the *EU Mission for 100 Climate-neutral and smart cities by 2030* [5] to pursue ambitious goals to rapidly reduce emissions and implement innovative approaches with citizens and stakeholders.

Policymakers in European cities count on a broad set of options to achieve zero-emission transport. From offering more space for active mobility, improving public transport and scaling up shared mobility services to encouraging the transition to electric vehicles. The impact of these measures depends on the local context and the degree of combination of these alternatives. This has made it difficult for analysts and decision-makers to compare the routes through which European cities can achieve zero-emission urban mobility.

This is why the Clean Cities Campaign, a European coalition of more than 85 civil society organisations, has commissioned TRT to model scenarios that would enable European cities to achieve zero-emission urban mobility by around 2030.

The methodology and results of this analysis for Milan are presented in this report. The report is organised as follows. First, the study objective and the context of the study are presented. Secondly, the methodology is summarised. This includes an explanation of how the MOMOS model and its calculation framework work. Also, the rationale behind the design of the transition scenarios is explained, including the

input data collected, the definition of the different policy measures, the exogenous trends to account for, and the output indicators that the model generates. Finally, the results of the study are presented, and conclusions are drawn.

1.2 Objective of the study

Acknowledging both the magnitude of the challenge of the transition to sustainable urban mobility and its urgency, this study attempts to model transition scenarios towards zero-emission transport in European cities by around 2030. Each scenario is built on a different set of sustainable transport policies. The impacts of each set of policies are quantified through a series of indicators for each city and scenario.

As the target of zero-emission transport by around 2030 is very ambitious given the short timeframe, it is crucial to define a clear strategy. Through this exercise, it is possible to demonstrate to policymakers what efforts are needed and what the impact on citizens' mobility, the environment, and road safety will be. For the purpose of this study, zero emission urban transport is defined as mobility that emits zero tailpipe emissions from urban road and rail borne transport, including both passenger and freight transport. While upstream emissions from the production of fuels and vehicles should not be ignored and have been estimated in this study, these are usually outside of the cities' control and are therefore not in the focus of this study.

The research has been designed as a high-level analysis and the uncertainties and limitations are laid out in chapter 2.

It is important to stress that this study does not intend to present the most likely outcome nor attempt to forecast the future of urban mobility. Rather, it aims to define potential transition scenarios for the decarbonisation of urban transport and lays out what would be required to achieve this transition by around 2030 in a highly uncertain and constantly evolving context.

Five different metropolitan areas have been analysed for the study: the Brussels-Capital Region, the municipality of Madrid, the metropolitan county of Greater Manchester, as well as the municipalities of Milan and Warsaw. The cities have been chosen in order to have a representative set of large cities or metropolitan areas (more than 1 million inhabitants) from different parts of Europe and with different socio-economic and spatial characteristics. This report focuses on Milan. The reports for the other cities will be made available on the website of the Clean Cities Campaign.

2. Methodology

2.1 General approach

This study focuses on the following research question: *What changes are needed to achieve zero-emission urban transport in selected European cities by around 2030?*

This question has been addressed through a high-level quantitative analysis of different sets of policy measures, which were summarised in scenarios. TRT used their assessment tool [MOMOS](#) (Sustainable Urban MObility MOdel) to simulate the outcomes of different mobility transition scenarios. This has made it possible to quantify the impact of the scenarios on mobility behaviour, the transport system, the environment and road safety; as well as to estimate the economic resources needed to drive such a shift.

There are [four scenarios](#) that have been simulated. Each one consists of a specific combination of policy measures (see 3.4). These measures have been selected based on which policies are being implemented or have been planned in European cities and taking into account their effectiveness in reducing GHG emissions. In addition, the main EU initiatives in terms of sustainable urban mobility were used to construct a baseline (e.g., CIVITAS [6], ELTIS [7]).

The first two scenarios have a narrower focus: Incentivising active and collective mobility (Scenario 01) and fleet electrification (Scenario 02) respectively. The third one (Scenario 03) combines all policy measures from the previous two scenarios. The fourth one (Scenario 04) applies all policy measures at the same time and extends their reach to estimate the order of magnitude of changes needed to achieve zero-emission urban mobility by around 2030.

All scenarios were applied to the aforementioned [five European cities and metropolitan areas](#). Each one relied on in-depth data collection to reproduce the city's characteristics at the base year (2019), including socio-demographic data, the mobility features (e.g., fleet composition, public transport infrastructure, availability of innovative/shared services, traffic management solutions, etc.). When available, official sources were used. Where official sources were not available, the data has been interpolated or, where necessary, extrapolated. Other data – such as shared mobility services data – are not publicly available, and extrapolations were necessary.

The MOMOS simulation of the transition scenarios returns a series of [quantitative output indicators](#). Results are provided for both the horizon year (2030) and the base year (2019) that is used as reference point.

Greenhouse gas (GHG) emissions from transport, expressed in CO₂ equivalents, are the key output indicator. A total of 30 indicators is used to provide a thorough description of the possible mobility situation in 2030, and covers transport behaviour, transport activity, electric vehicle uptake, air pollutant emissions from transport and road safety. Both passenger and freight transport were included.

In addition, a multi-criteria [economic analysis has been conducted to](#) estimate the main costs and benefits associated with each scenario. These include costs (and revenues) for the city, the transport users, and freight operators as well as the external costs and savings resulting from reductions in GHG and air pollutant emissions, road traffic injuries/deaths, and noise.

2.2 The MOMOS model

TRT's assessment tool MOMOS (Sustainable Urban MObility MOdel) has been used for the simulation of the scenarios to evaluate the impact and pathway towards the goal of decarbonisation of urban transport in the selected cities and metropolitan areas.

The model was developed in the MS Excel environment and provides estimations of mobility trends in urban areas quantifying transport, environmental and economic impacts of policy measures from 2019 (base year) until 2030 (and beyond).

MOMOS is a [strategic and aggregated model](#), that can be adapted to different city contexts in European countries (EU27, UK, Norway and Switzerland), and allows the user to rapidly identify, develop, screen, and assess different measures and policy scenarios. This tool does not intend to replace sophisticated and detailed transport models but allows the user to compare alternative solutions. The tool has previously been used, for instance, to estimate the costs and benefits of the sustainable urban mobility transition in prototypes of 779 EU-27 cities in a study commissioned to TRT by EIT Urban Mobility [8].



Figure 1: Rationale and features of the MOMOS model

To represent the [urban characteristics](#) at the base year as well as [exogenous trends](#) that are outside of the scope of urban policies, MOMOS requires a set of input data to reproduce a specific city context. This namely includes socio-demographic aspects as well as mobility features (e.g., public transport infrastructure, innovative transport services, parking, traffic management solutions).

The model is calibrated, against observed data, to reproduce key urban mobility indicators (e.g., GHG emissions, energy consumption, trips by mode, road traffic injuries, etc.) at the base year in the study area.

MOMOS allows it to evaluate different urban mobility [policy measures](#), defining their intensity and temporal dimension. Policy measures can be simulated individually or

can be used to build policy packages and scenarios combining multiple measures. The model also allows it to simulate different scenarios, which are designed independently and can be compared.

To [assess the impact of mobility scenarios](#), the model estimates a set of output indicators, concerning different domains:

- Transport (modal split, vehicle fleet evolution, car ownership, etc.)
- Environment and safety (air pollutant and GHG emissions, energy consumption, road traffic injuries/deaths, etc.)
- Economy (cost and revenues for the city, monetisation of externalities, etc.)

The calculation framework of the MOMOS model consists of several components, as shown in Figure 2. The core of the calculation framework consists of:

- i) a component managing the estimation of transport demand for both passenger and freight (trips, modal split, passengers-km, tonne-km, etc),
- ii) a (road) vehicle fleet component,
- iii) a component related to transport cost, time and revenues
- iv) a component where social and environmental impact are estimated (road traffic injuries/deaths, GHG and pollutant emissions and energy consumption). The calculations made within these modules are affected by the urban policy measures selected and set-up for simulating different scenarios.

The definition of specific urban characteristics within the calculation framework allows for a more accurate representation of the urban context, whilst considering differences that can affect the trend of mobility, especially the impact of the policies.

At the spatial level, the study area is divided into two types of [zones](#) generating transport demand: (i) the urban core and (ii) peripheral areas. The separation of zones is mainly done through an estimation of the population density within each district of the study area. The two types of zones are defined in Annex I: Study area and input data.

The urban core includes the inner centre of the city and the main urban area. Peripheral areas are generally suburbs or neighbourhoods which are, to an extent, distinct from the city (they can also be different municipalities surrounding the main city in a metropolitan area). Trips generated in each area are distinguished but without origin-destination details.

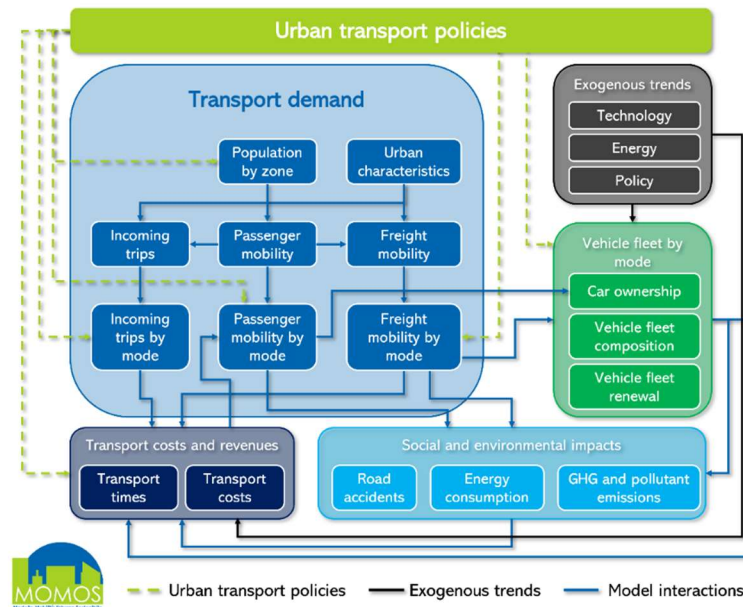


Figure 2: Calculation framework of the MOMOS model

Within the transport demand component, demographic developments by age group as well as the distribution of the population within the urban area, are simulated and used as the main inputs for passenger trips generation. **Passenger demand** segments are modelled by purpose (working, personal), period (peak, off-peak) and mode (pedestrian, bike, motorbike, car, bus, tram, metro, car sharing, bike sharing, e-scooter sharing and moped sharing). The mode split at the base year is based on the initial values - these differ by living area: i.e., within the urban core and the outskirts with a good level of public transport supply and the mode share of car is lower than in the outskirts with a poor level of public transport supply. Policy measures can change this trend and give rise to mode switches. Passenger-km numbers depend on average trip distances. Distances are different according to the living areas (shorter in the core urban area, longer in the outskirts). The estimation of vehicle-km depends on occupancy rates, which can also be affected by policies.

Passenger trips entering the city from other areas are treated separately in the model, as their relevance depends on the nature of the city. The share of multimodal trips (e.g., the use of public transport at urban level for the last leg of the trip) is explicitly taken into account. These trips are also included in the calculation of total passengers-km and vehicle-km by mode in the urban area (only the urban part of the overall trip distance is considered), and therefore affecting travel time, emissions and energy consumption.

Freight traffic in the urban area is calculated as a percentage of the total number of passenger car vehicles at the base year, evolving over time, based on growth rates. Freight demand is modelled considering the category of freight (distribution to retailers, mail services, for example movements of building materials), differentiated by vehicle type (light truck, heavy truck, and cargo-bike), and period (peak and off-

peak). This distinction is introduced for two reasons. First, several measures are focussed on urban deliveries and therefore affect only one component of freight traffic. Second, the types of vehicles used for mail distribution are different from the vehicles used for transporting input to an industry.

The module also calculates the transshipments (at a platform within the urban area where freight is consolidated). At these platforms, LDV and cargo-bikes are used for the final leg of delivery. Lastly, performances related to vehicle-km are estimated considering the urban part of the overall trip distance.

Road vehicle fleets are segmented by fuel type (gasoline, diesel, CNG, LPG, LNG plug-in hybrid electric, battery electric, fuel cells) and emission standards (Pre-Euro and Euro 1/I, Euro 2/II, Euro 3/III, Euro 4/IV, Euro 5/V, Euro 6/VI, and post Euro 6/VI). For some modes only some of the segmentations are available. The private car fleet is distinguished by the car sharing fleet (where it exists).

Road traffic injuries and deaths are estimated based on injury/fatality rates by mode of transport applied to demand performance (vehicles-km). The injury/fatality rates evolve over time in accordance with mode-specific trends; taking into account technical developments as well as other circumstances (speed limits, infrastructure quality, etc.), which may arise also from the implementation of policy measures (such as traffic calming, infrastructure for pedestrians, etc).

Energy consumption is estimated by fuel / energy type (gasoline, diesel, CNG, LPG, LNG, electricity, hydrogen). **Air pollutant emissions** are estimated for PM_{2.5}, PM₁₀, CO, NO_x and VOC related to exhaust emissions. For PM_{2.5} and PM₁₀, as well as emissions from vehicle tyre, brake wear and surface wear are considered. Both estimates considered the EMEP/EEA air pollutant emission inventory guidebook 2019 [9]. **Greenhouse gas emissions** (CO₂ equivalent) are estimated as well, applying the related carbon content by fuel / energy.

The model allows it to consider in the calculation several **exogenous trends** related to three domains: technology, energy and policy. Technology mainly refers to powertrain market penetration trends and average vehicle fuel consumption by vehicle type. The evolution driven by the EU FitFor55 scenario is one of the trends integrated in the model. Energy trends are mainly related to fuel prices and the energy mix for electricity generation. Policy trends include fuel duties and car ownership taxation. More details about the exogenous trends are included in section 3.6.

3 Model Application in Milan

3.1 Study area context



Source: Unsplash – Simon Pallard

The city of Milan accounted for 1.374.582 inhabitants in 2021 [10]. It is a city in northern Italy, capital of Lombardy, and the second-most populous city in Italy after Rome. The related metropolitan city has more than 3 million inhabitants, while its continuously built-up surrounding urban area is the fourth largest in the EU with 5.27 million inhabitants.

Milan, Italy's leading global city, boasts a diverse economy spanning art, commerce, design, finance, and fashion, hosting the stock exchange and numerous national and international banks and companies, contributing significantly to Italy's GDP. The city is also a fashion and media hub, a growing IT and tech industry center, and a major destination for tourism.

The city of Milan has been investing in urban access regulations for a long time now, being one of the first cities in Italy to implement a Limited Traffic Zone in the city centre and in a very densely populated and touristic area called Navigli, restraining traffic to both passenger and freight transport modes. Furthermore, since 2019 the city has implemented a [Low Emission Zone \(LEZ\)](#), which extends to almost the whole urban area (Area B) and since 2012 a Congestion Charging scheme applied in the city centre (Area C) [11]. Over the next years, the LEZ rules will limit traffic to more and more vehicles, with the aim of allowing access to clean vehicles only (e.g., hybrid or electric). Moreover, Milan is among the 100 cities in the EU 'Mission for climate-neutral and

smart cities by 2030, taking the opportunity to scale and speed up climate actions, learning also from other cities to meet the challenge.

Milan is a key transportation hub in Italy and southern Europe, with extensive rail services, including a subway network with the largest ridership in Italy, a well-developed tram and bus system, and multiple airports, including Malpensa Airport, one of the busiest in Italy. Despite both the mild continental weather and the absence of uphill make the city suitable for cycling, the infrastructure is not well designed for it. The municipality is promoting cycling – especially after the COVID-19 disease – with a growing network of bike paths (298 km in 2021) and bike-sharing system, but the transition needs time, especially in the citizens' habits.

In 2023, the public transport network of Milan has a length of 1,794 km, of which 102,4 km of metro network, 1,268 km of bus, 180.3 km of tramway and 38.8 km of trolleybus [12]. The city also offers both municipal and private bike sharing services, providing inhabitants with 15,000-20,000 traditional and electric bikes, in addition to mopeds (about 2,600) and other micromobility sharing services (about 4,400 scooters). Shared mobility is complemented with about 2,300 cars from different service providers. Combining Public Transport and shared mobility, every part of the city is well connected. For those who enter in the city from the surroundings, a large amount of parking slots is dedicated to Park&Ride scheme (about 17,000 in 2019). Incoming trips account for about 39% of the total trips, as reported in the Lombardia OD Matrix 2016 [13]. Therefore, it is crucial for the municipality to handle this kind of trips, and increase the supply related to Park&Ride to reduce the private cars entering in the core urban area.

Overall, Milan is facing a big transition both in terms of urban mobility and in terms of public space usage.

3.2 Input data

To properly represent the study area's characteristics at base year, the MOMOS tool requires a [comprehensive set of input data](#). Data has been collected for the base year (2019) from official sources, where available. Otherwise, input parameters were either extrapolated from previous years or interpolated from similar city contexts.

The collected input data includes the following groups:

- Population (age structure, growth, spatial distribution, etc.)
- Urban mobility features (motorization rate, modal split, incoming trips, freight share, etc.)
- Transport infrastructure (bike lanes, e-charging stations, park & ride, etc.)
- Public transport (offer, ticket price, cost, speed, network length, prioritizing systems, etc.)

- Parking (number of slots, pricing, etc.)
- Carsharing (fleet, pricing, etc.)
- Bike sharing (fleet, pricing, area coverage, etc.)
- Moped sharing (fleet, pricing, area coverage, etc.)
- Micromobility (fleet, pricing, etc.)
- Traffic control and management (low-traffic zones for passenger/freight, low-emission zones for passenger/freight, pedestrian areas, traffic-calming areas, etc.)
- Vehicle fleet composition (private cars, LDV/HDV, motorbikes, public buses, etc.)

As mentioned in the previous section, the study area is differentiated at the spatial level with two types of zones, mainly accounting for differences in the population density of each district. This allows for a more precise simulation, as the model endogenously estimates both the trips generated and the modal split separately for each zone. Policy input and characteristics at the base year also require such differentiation.

Table 8 (included in Annex I: Study area and input data) defines the area categorisation that has been assigned to each district of the study area.

The full list of collected input data is shown in Table 9. Each data is accompanied by a description, categorisation, value(s), and the source(s) used.

Finally, Table 10 lists the input unitary costs used for the monetization of externalities in the study area (referring to national values)

3.3 Policy measures

One of the core elements of the MOMOS model is the possibility to select from a wide range of [sustainable urban mobility measures](#) and adapt them to the specific study context.

The available measures are of a different nature and comprehensively cover the range of options that cities currently have available to promote the transition to sustainable urban mobility. The selection takes into account what is being implemented and planned in European cities, their effectiveness in reducing GHG emissions, as well as recent and important EU programmes and projects.

Table 1 illustrates the mobility measures that have been considered in this study and categorises them into seven groups. Also, it is worth noting that measures have been selected considering the time horizon of the study's simulation (2030). Therefore, a few innovative options (e.g., autonomous vehicles, hydrogen refuelling infrastructure) have not been included, as their full implementation is (in most cases) not foreseen

within the relatively short timeframe of the study. Their future roll-out and impact on urban mobility are subject to significant uncertainty.

For each measure, the **input values** are used to reflect the base year characteristics of the study area. MOMOS provides pre-set reference values for missing inputs according to the specific geographic/demographic/mobility context.

Also, measures are assigned a specific **starting year**, to take into account the temporal dimension while designing the intervention strategies, as well as a **ramp-up period** (if relevant), to consider the years required for its full implementation¹.

Finally, each policy is designed considering a specific **rationale** and related assumptions. These are explained in more detail in Table 11 included in Annex II: Policy measures rationale.

¹ Within this study, all policies have been assigned 2023 as starting year. In addition, it is expected that all policies run out their ramp-up period (i.e., are fully implemented) by 2030.

Table 1: List of policy measures available for the simulation

Vehicle fleet and charging infrastructure	Traffic management and control
Electric vehicle uptake	Prioritizing public transport
Electric vehicle charging infrastructure	Limited traffic zones (LTZ)
Green public transport fleet	Low-emission zones (LEZ)
Green logistics fleet	Traffic calming
Cooperative ITS	Pedestrian areas
Innovative and shared mobility services	Transport avoidance
Bike sharing	Working from home
Car sharing	Car-free days
Moped sharing	Pricing schemes
E-scooter sharing	Congestion and pollution charging
Mobility-as-a-Service (MaaS)	Parking pricing
Demand-responsive transport (DRT)	Public transport fare reduction
Transport infrastructure	Urban logistics
Cycling network expansion	Urban delivery centers
Bus network expansion	Delivery and servicing plan
Tram network expansion	Cargo bikes
Metro network expansion	
Park & Ride infrastructure	

The model allows simulating [policy packages](#), selecting and designing the intensity and timeline of different measures in a comprehensive strategy. When combined, there is a correlation in how they affect the same variables in the model (e.g., transport cost, transport time, modal split, vehicle stock, etc.). This can reduce or amplify the impact with respect to the case in which the policy is applied in isolation. For example, an increase of a cycling network would be beneficial and support the impact of expanding bike sharing services. Also, there is a correlation between public transport services and car sharing, due to their competition and attractiveness for similar passenger segments.

There might also be an indirect correlation among measures. For instance, low-emission zones have an impact on modal shift from private cars to other transport modes depending on the vehicle fleet composition, based on the access regulations

in place. If the renewal of vehicles fleet is boosted by other measures supporting, for example, the EV uptake, the related impact on modal shift will be smaller.

To summarise, it is important to point out that the combination of different policies would not necessarily lead to adding up the impacts of individual policies due to the reasons explained above.

3.4 Transition scenarios

The study has simulated potential transition scenarios, each one building on different sets of sustainable policy measures. Four scenarios have been modelled:

- **Scenario 1 (S01) “Active and Collective”**: this scenario aims to induce more sustainable travel behaviour by improving the public transport system, providing more and better walking and cycling infrastructure and encouraging shared mobility. This includes measures to discourage and restrict car use, such as parking and traffic management - as well as measures to improve urban logistics.
- **Scenario 2 (S02) “All-electric”**: this scenario is mainly focused on fleet electrification. It increases the uptake of e-vehicles in private, public, and logistics fleets and assumes the widespread creation of charging infrastructure. In addition, regulation and pricing policies that affect vehicles with internal combustion engines (e.g., LEZ) are also applied.
- **Scenario 3 (S03) “Everything all at once”**: this scenario combines all the available policy measures implemented in the previous two scenarios. Whereas one might assume that the results of this scenario could be the sum of S01 and S02, policies are not completely additive to each other and in some cases even cancel each other out (see above).
- **Scenario 4 (S04) “(E)Mission: Zero”**: this last scenario not only applies all the measures included in scenario 3, but also pushes them to the limits of feasibility for each policy, with the aim of getting as close as possible to the target of zero-emission urban mobility by 2030.

The following policies have been applied in all scenarios as they are widely used and represent cross-cutting interventions: green public transport, working from home, low-emissions zones (LEZ) and parking pricing.

Table 2 shows the composition of the four transition scenarios with the set of policies implemented in each of them.

Table 2: Policy composition of the four transition scenarios

Group	Policy	S01	S02	S03	S04
Vehicle fleet and charging infrastructure	Electric Vehicle (EV) uptake		✓	✓	✓
	EV charging infrastructure		✓	✓	✓
	Green public transport fleet	✓	✓	✓	✓
	Green logistics fleet		✓	✓	✓
	Cooperative ITS		✓	✓	✓
Innovative and shared mobility services	Bike sharing	✓		✓	✓
	Car sharing	✓		✓	✓
	Moped sharing	✓		✓	✓
	E-scooter sharing	✓		✓	✓
	Mobility-as-a-Service (MaaS)	✓		✓	✓
	Demand-responsive transport (DRT)	✓		✓	✓
Transport infrastructure	Cycling network expansion	✓		✓	✓
	Bus network expansion	✓		✓	✓
	Tram network expansion	✓		✓	✓
	Metro network expansion	✓		✓	✓
	Park & Ride	✓		✓	✓
Traffic management and control	Prioritizing public transport	✓		✓	✓
	Limited traffic zones (LTZ)	✓		✓	✓
	Low-emission zones (LEZ)	✓	✓	✓	✓
	Traffic calming	✓		✓	✓
	Pedestrian areas	✓		✓	✓
Transport avoidance	Working from home	✓	✓	✓	✓
	Car-free days	✓		✓	✓
Pricing schemes	Congestion and pollution charging	✓	✓	✓	✓
	Parking pricing	✓	✓	✓	✓
	Public transport fare reduction	✓		✓	✓
Urban logistics	Urban delivery centers	✓		✓	✓
	Delivery and servicing plan	✓		✓	✓
	Cargo bikes	✓		✓	✓

3.5 Intervention levels of the policies

To assess the sustainable urban mobility transition driven by the scenarios, each policy needs to be defined and constructed using a series of [parameters and pre-identified intervention levels](#). These levels have been set by considering what cities aim for in terms of their future mobility (e.g., SUMP objectives, specific goals, fleet evolution forecasts, etc.), as well as what is needed to reach the overall aim of the study (i.e., zero-emission urban mobility by 2030).

In principle, the same intervention levels have been applied to the five European cities modelled in this study. Nevertheless, specific circumstances have been taken into account for some policies (e.g., moped sharing services were not always implemented depending on the current mode share). This means that each policy implementation leads to different results, varying from city to city, depending also on the base year situation.

It is also worth underlining that there is a notable difference in the specific intervention levels depending on the scenario they are applied to. Policies in the [first three scenarios](#) are set at very ambitious, but clearly attainable levels, which are mostly in line with what has been defined in the mobility plans of various European cities. For example, the target for the cycling network has been set looking at the current values of trailblazing cities such as Amsterdam or Copenhagen.

[Scenario 4 contains the same policies as scenario 3 but goes further in the implementation levels by implementing these policies with much higher levels of ambition in order to get as close as possible to zero-emission urban mobility in 2030.](#)

In scenarios 1, 2, and 3, policies have been constructed to attain the following intervention levels in Milan:

Vehicle fleet and charging infrastructure.

- It simulated that an additional increase in [electric cars penetration](#) is accompanied by at least 1 [charging point](#) for every 8 EVs. Of these charging points, at least 50% are set up for fast charging.
- [Public transport](#) is set to be 100% electric by 2030.
- An additional increase in electric [LDV penetration](#) is foreseen.
- Implementing [Intelligent Transport Systems \(ITS\)](#) will also increase safety and efficiency in road transport. It is important to note that, across all policy targets, increases or reductions always refer to a change compared to the situation at the base year (2019).

Innovative and shared mobility services

Shared mobility fleets are all set to expand and grow. The assumed intervention level is to have at least:

- 6 bikes for every 1,000 inhabitants in the [bike sharing](#) system (In Milan, this target was already achieved at base year, so we foresaw an additional increase by 20%).
- 2 cars for every 1,000 inhabitants in the [car sharing](#) system (in Milan, this target was already achieved at base year, so we foresaw an additional increase by 20%).
- 1 moped for every 1,000 inhabitants in the [moped sharing](#) system (in Milan, this target was already achieved at base year, so we foresaw an additional increase by 20%).
- 4 e-scooters for every 1,000 inhabitants in the [shared e-scooters](#) fleet
- An increased integration between services (PT, sharing, etc.) and improved efficiency as a result of a Mobility-as-a-Service ([MaaS](#)) solution.
- The implementation of a [Demand-Responsive Transport](#) (DRT) system will cover at least 10% of the core urban area and 50% of peripheral areas.

Transport infrastructure

In terms of transport infrastructure, both network and service offer will be improved:

- Bike lanes are extended to have at least 600m of [bike lanes for](#) every 1,000 inhabitants.
- 90% of the [bus](#) network will have a 4-minute average frequency.
- 80% of the [tram](#) network will have a 5-minute average frequency.
- The length of the [metro](#) network will be increased by 10 km.
- There will be at least 5 [Park & Ride](#) spaces per 1,000 inhabitants (in Milan, this target was already achieved at base year, so we foresaw an additional increase by 10%).

Transport avoidance

- Incentivizing [working from home](#) will reduce transport demand by 20% for work-related trips.
- In addition, 1 [car-free day](#) per month will be established.

Pricing schemes

- [Parking fees](#) will be increased by 30%. At the same time, the number of [parking spaces](#) will be reduced to not exceed 2 per 10 inhabitants.
- In addition, a 20% reduction of the [public transport fare is simulated](#) for both young people (<18) and the elderly (>65)
- It is assumed that a [congestion charging scheme](#) is implemented in a limited area of the city (5% of the core urban area), applied to both cars and freight vehicles. The ticket is set to 7.5€, and it is free for green vehicles.

Traffic management and control

As far as traffic management and control concerns, different targets have been set for passengers and freights:

- The implementation of [Limited Traffic zones \(LTZs\)](#), for both passenger and freight, is set to cover at least 20% of the core urban area and 5% of peripheral areas.
- Besides that, a low-emission [Zone \(LEZ\)](#) will cover 100% of the total area. Passenger vehicles are banned up to EURO5 (gasoline) and up to EURO6 (diesel). Freight vehicles (both LDV and HDV) are banned up to EURO6.
- In terms of traffic calming, a [30km/h speed limit](#) is applied to at least 85% of the core urban area and 30% of peripheral areas.
- [Pedestrian areas](#) are implemented on at least 5% of the core urban area and 1% of peripheral areas.
- [Reserved public transport lanes](#) and [prioritizing systems](#) will cover, respectively, at least 15% and 30% of the public transport network.

Urban logistics

- In terms of urban logistics, [urban delivery centres](#) will see an increase of 25% in terms of managed freight.
- At the same time, [delivery and servicing plan](#) will reduce freight movements for retail by 10% (LDV) and by 5% (HDV).
- Finally, an increased share of freight is delivered by [cargo bikes](#): up to 5% (B2C) and 0.5% (Retail).

As anticipated above, in scenario 4, the intervention level of a few policies has been extended to achieve even more ambitious targets. These “boosted” policies have been selected by keeping into account their individual potential to reduce GHG emissions. All other policies keep the same targets and parameters presented for Scenario 1, 2 and 3.

The extended policy intervention levels include:

- at least 1 [charging point for](#) every 5 EVs
- An additional increase of 30% in bike lanes (compared to the target of scenario 1, 2, and 3)
- Establish 1 [car-free day](#) per week.
- Triple parking fees (compared to the price at base year)
- Reduce by 50% [public transport fares](#) for young people (<18) and the elderly (>65)

- Have **reserved public transport lanes** and **prioritizing systems** covering, respectively, at least 25% and at least 40% of the public transport network.
- Implement **Limited Traffic Zones (LTZs)**, for both passenger and freight, covering at least 40% of the core urban area and 10% of peripheral areas
- Implement a **zero-emission zone** covering 100% of study area, where only fuel cell, PHEV and BEV are allowed to circulate for both cars and trucks while granting exemptions to certain groups and on certain roads². By 2030, the % of fleet that can circulate corresponds to: 54% for cars, 78% for LDV and 37% for HDV.

Full details about the policy targets, including the key values of the policies at base year and the expected values in 2030 are included in Table 12 in Annex III: Intervention levels in the scenarios.

3.6 Exogenous trends: technology and energy

As mentioned in the calculation framework, MOMOS is designed to simulate scenarios under different **exogenous assumptions** related to technology, concerning the evolution of vehicle fleet composition over time. This aspect is relevant for driving the penetration of new technologies, influenced only partially by policies at the urban level.

Concerning **vehicle technology**, for the purpose of the assessment of the impacts in monetary terms, the transition scenarios' results have been compared with the **Business-As-Usual (BAU) scenario**. The assumptions of the BAU scenario are rather conservative, assuming that fleet renewal and innovative vehicle uptake is slowly evolving with respect to the current situation. A moderate improvement of vehicle efficiency is expected (about -7% in 2030 with respect to 2019 for cars and vans and -4% for HDVs). Within the BAU, no policy measures are applied.

The choice to compare the modelled scenarios with the BAU scenario is explained by the aim to assess the whole effort needed for the transition, also including national/EU policies even if they are not necessarily under the responsibility of local authorities. Table 3 provides the share of PHEV and BEV vehicles, at base year and in 2030, in the BAU scenario.

Table 3: Milan's EV uptake (PHEV and BEV) in Business-as-usual (BAU) scenario, exogenous trend

Vehicle	2019	2030
		BAU
Car	0.3%	2.7%

² Exemptions are granted for residents with special permits (e.g., disabilities) or emergency vehicles. Moreover, certain main roads and park and ride facilities remain available for traffic from or towards areas outside the zero-emission zone.

Vehicle	2019	2030
		BAU
Light-duty vehicle (LDV)	0.6%	5.3%
Heavy-duty vehicle (HDV)	0.0%	0.0%

Source: MOMOS Model

The transition scenarios simulated in this study build on the assumptions related to the vehicle fleet composition with an **ambitious penetration** of new vehicle technologies. The evolution of vehicle fleet composition is based on the assumptions of the EU “Fit for 55” strategy [14]. In this EU scenario, it is assumed that a significant reduction of the internal combustion engine vehicles takes place in the long-term, by replacing them with hybrid and zero-emission vehicles (fleet decarbonisation).

This exogenous trend assumes large improvements in energy efficiency of vehicles, resulting in a fuel consumption reduction of about 20% for ICE cars and LDV and of about 12% for HDV (considering both new and existing vehicles) between 2030 and 2019.

This trend is aligned with the implementation of the regulation on CO₂ emission standards for Light Duty Vehicles (LDVs) [15] and heavy-duty vehicles (HDVs) [16], resulting in more fuel-efficient vehicles being introduced into the market. These assumptions on the composition of the fleet are the same basis for all four transition scenarios, mentioned in the analysis as ‘**Technological innovation trend**’. For Italy, the values of battery electric vehicles (BEV) stock shares in the model are based on forecasts of T&E’s European Union Transportation Roadmap Model (EUTRM) [17]. As far as PHEV (plug-in hybrid vehicles) are concerned, the values are based on the EU Reference Scenario [18] projections. Thus, in Italy, PHEV and BEV in 2030 account for 16.4% for cars, 18.5% for LDVs and 1.9% for HDVs.

On top of this exogenous trend, the model considers the impact of the simulated policies on the speed of EV uptake and fleet renewal.

On the **energy** side, assumptions related to the fuel prices³ and energy mix for power generation are included to estimate the emissions on a well-to-wheel basis. The energy mix changes over time at the country level according to the exogenous energy trend: the transition scenarios simulated in this study considers both the current energy mix shares as well as the needed increase to reach the 69% renewables target, as set in the REPowerEU plan [19]. The same trend is assumed also in the BAU scenario.

³ Fuel prices follow the EU Reference Scenario [18] trend.

3.7 Output indicators

The outcome of the MOMOS simulation consists of a series of **quantitative indicators**. Indicators are calculated for each scenario at the simulation’s horizon year (2030) as well as compared to the values at base year (2019).

As the overall objective of the study is to simulate transition scenarios towards a zero-emission urban mobility by around 2030, the **key indicator** is the reduction in GHG emissions. In addition, a series of **core indicators** provide a more complete picture of the scenario simulations by outlining their effects on the transport, environment, social, and economic spheres.

Table 4 lists all the output indicators that have been calculated in the study.

Table 4: List of output indicators

Group	Indicator	Unit of measure
GHG emissions from transport	Total GHG emissions (tank-to-wheel, TTW) Total GHG emissions from all transport modes, considering trips within the urban area of residents, incoming city users and freight transport. Tank to wheel considers only the emissions related to the burning/usage of a fuel in a vehicle.	[kton CO2 eq / year]
	Per capita GHG emissions (tank-to-wheel) Ratio between total GHG emissions TTW (residents, incoming city users and freight transport) and inhabitants of the urban area.	[ton CO2 eq / capita per year]
	GHG emissions (well-to-wheel, WTW) Total GHG emissions from all transport modes, considering trips within the urban area of residents, incoming city users and freight transport. Well-to-wheel considers all the emissions, including related to the cascade of steps required to produce and distribute the energy carrier (starting from the primary energy resource), including vehicle refuelling.	[kton CO2 eq / year]
	Per capita GHG emissions (well-to-wheel) Ratio between total GHG emissions WTW (residents, incoming city users and freight transport) and inhabitants of the urban area.	[ton CO2 eq / capita per year]
	GHG emissions by sector (tank-to-wheel) (passenger and freight) Total GHG emissions TTW related to passengers (residents, incoming city users) and freight transport	[kton CO2 eq / year]
	GHG emissions by sector (well-to-wheel) (passenger and freight) Total GHG emissions WTW related to passengers (residents, incoming city users) and freight transport	[kton CO2 eq / year]

Group	Indicator	Unit of measure
Transport behaviour	<p>Aggregated internal modal split based on pkm Modal split estimated based on passenger-km within the urban area of residents only</p>	[%]
	<p>Aggregated internal modal split based on trips Modal split estimated based on the number of trips within the urban area of residents only</p>	[%]
	<p>Car ownership level Ownership of private cars compared to residents in the urban area, per 1,000 inhabitants</p>	[cars/1,000 inhab]
	<p>Private car vehicle-km Vehicle-km driven within the urban area by private cars, considering trips of both residents and incoming city users</p>	[million vkm/year]
Transport activity - Passenger	<p>Total Passenger-km Passenger-km travelling within the urban area by any mode, considering trips of both residents and incoming city users (urban segment only)</p>	[million pkm/year]
	<p>Total travel time Total time spent travelling within the urban area for all passenger trips related to both residents and incoming city users (urban segment)</p>	[million h / year]
	<p>Average travel time Average travel time related to passenger trips within the urban area for both residents and incoming city users (urban segment)</p>	[min / trip]
	<p>Total trips Total passenger trips related to both residents and incoming city users (urban segment)</p>	[million trips / year]
Transport activity - Freight	<p>Total vkm Total vehicle-km driven within the urban area by any type of freight vehicles</p>	[million vkm/year]
	<p>Vkm by mode (HDV, LDV, Cargo-bike) Vehicle-km driven within the urban area by freight vehicles (HDV, LDV, Cargo-bike)</p>	[million vkm / year]
Electric vehicles uptake	<p>EV uptake of private cars Share of electric vehicles (PHEV, BEV) in the total stock of private cars (related to residents)</p>	[%]
	<p>EV uptake of public buses Share of Electric vehicles (PHEV, BEV) in the total stock of buses for PT service</p>	[%]

Group	Indicator	Unit of measure
	<p>EV uptake of freight vehicles (LDV) Share of Electric vehicles (PHEV, BEV) in the total stock of LDV</p>	[%]
	<p>EV uptake of freight vehicles (HDV) Share of Electric vehicles (PHEV, BEV and FCEV) in the total stock of HDV</p>	[%]
	<p>EV uptake of private motorbikes Share of Electric vehicles (BEV) in the total stock of private motorbikes</p>	[%]
Air pollutant emissions from transport	<p>Emissions of PM2.5 Sum of total particulate matter (PM2.5) emissions from exhaust and brake and tyre wear, from all transport modes considering trips within the urban area of residents, incoming city users and freight transport.</p>	[g / capita]
	<p>Emissions of NOx Total exhaust emissions of NOx, from to all transport modes considering trips within the urban area of residents, incoming city users and freight transport.</p>	[g / capita]
	<p>Emissions of CO Total exhaust emissions of CO, from to all transport modes considering trips within the urban area of residents, incoming city users and freight transport.</p>	[g / capita]
	<p>Emissions of VOC Total exhaust emissions of VOC, from all transport modes considering trips within the urban area of residents, incoming city users and freight transport.</p>	[g / capita]
Energy	<p>Energy and fuel consumption Total energy and fuel consumption, related to all transport modes and fuel/energy type considering trips within the urban area of residents, incoming city users and freight transport.</p>	[million MJ/year]
Road Safety	<p>Road traffic deaths Ratio between persons killed in a road traffic crash, immediately or dying within 30 days, and the inhabitants of the urban area</p>	[road traffic deaths/100,000 inhab.]
	<p>Road traffic injuries Ratio between persons injured in a road traffic crash, who was hospitalised for a period of more than 24 hours., and the inhabitants of the urban area</p>	[road traffic injuries /100,000 inhab.]
	<p>Road traffic deaths/pkm: All Modes Ratio between road traffic deaths and total amount of passenger-km for all modes</p>	[road traffic deaths/1,000,000 pkm]

Group	Indicator	Unit of measure
	<p style="text-align: center;">Road traffic deaths/pkm: Cycling</p> <p>Ratio between road traffic deaths related to road traffic crashes involving bike and total passenger-km for cycling</p>	[road traffic deaths/1,000, 000 pkm]
Costs and savings	<p style="text-align: center;">City Costs</p> <p>Cost sustained by the city (including public administration, service providers, etc.) associated to the implementation of the transition scenario. All costs are cumulated (2019 - 2030), discounted (3%), and compared to BAU scenario</p>	[million €] [€/capita]
	<p style="text-align: center;">City Revenues</p> <p>Revenues obtained by the city (including public administration, service providers, etc.) associated to the implementation of the transition scenario. All revenues are cumulated (2019 - 2030), discounted (3%), and compared to BAU scenario</p>	[million €] [€/capita]
	<p style="text-align: center;">User Costs</p> <p>Cost sustained by the private user associated to the implementation of the transition scenario. All costs are cumulated (2019 - 2030), discounted (3%), and compared to BAU scenario</p>	[million €] [€/capita]
	<p style="text-align: center;">Freight Operators Costs</p> <p>Cost sustained by freight operators associated to the implementation of the transition scenario. All costs are cumulated (2019 - 2030), discounted (3%), and compared to BAU scenario</p>	[million €] [€/capita]
	<p style="text-align: center;">External Costs Savings</p> <p>Savings generated by a reduction of externalities associated to the implementation of the transition scenario. Externalities include: CO₂, air pollutants, road traffic injuries/deaths, and noise. All savings are cumulated (2019 - 2030), discounted (3%), and compared to BAU scenario</p>	[million €] [€/capita]

4 Results of the study

In this section, the main results of the study for Milan are presented and commented on. The full results, with the complete list of tables and figures, are included in Annex IV: Full results of the study.

4.1 GHG emissions

The core indicator of this study is GHG emissions. The model estimates both GHG **tank-to-wheel** emissions (i.e., only the emissions related to the burning/usage of a fuel in a vehicle) and **well-to-wheel** emissions (i.e., all the emissions related to the steps required to produce and distribute the energy carrier).

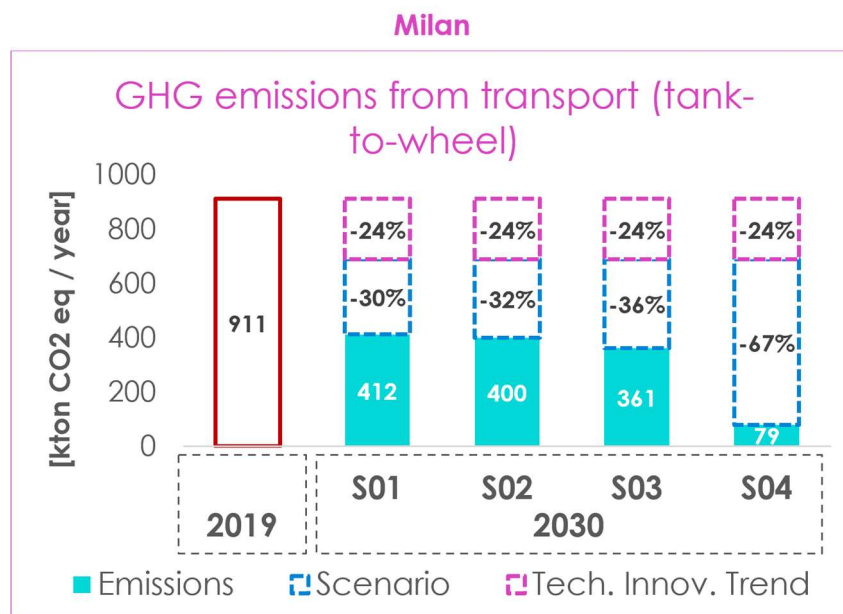


Figure 3: Tank-to-wheel greenhouse gases emissions from urban transport in Milan

Looking at the **tank-to-wheel GHG emissions**, it is possible to see the respective contribution of both the technology innovation trend and of the policy scenarios.

A reduction of about 24% is achieved by the technology innovation trend (described in chapter 3.6). This accounts for a reduction of about 223 kilotons of CO₂-equivalents in terms of yearly emissions (when comparing 2030 with 2019), thanks to vehicle fleet renewal and vehicle efficiency improvements.

The policy scenarios are responsible for the remaining reductions. In S01 and S02, they account for 30% and 32% respectively, leading to an overall 54% and 56% reduction in CO₂-equivalents. The policies in S03 add a 36% reduction, reaching a total reduction of 60%. In this respect, it seems possible to achieve similar results by either investing in behavioural change (S01) or in cleaner vehicles (S02). By combining these two approaches, a further reduction can be achieved as shown in S03.

Still, it is necessary to point out that the results of S03, which combines all the policies of S01 and S02, do not equal the sum of the results of the first two scenarios (see explanations in 3.3).

Despite these strong reductions in GHG emissions, none of the first three scenarios gets close to the zero-emission target. Based on the modelling, only when pushing these policies to the limits of feasibility in S04 (see 3.5) that it is possible to reach a reduction of about **91% of CO₂ emissions in 2030**.

All these results include both passengers and freight mobility. To better understand the contribution of each segment, it is worth underlining that about 70-75% of the remaining emissions in 2030 are related to passengers' mobility, and the remaining 25-30% to freight transport.

Looking at the **well-to-wheel emissions**, a slightly lower result is reached in terms of reduction compared to 2019. In Milan, assuming the exogenous renewable electricity target (see section 3.6), a reduction of 49% is estimated in S01 and S02, which becomes 53% in S03, and 79% in S04.

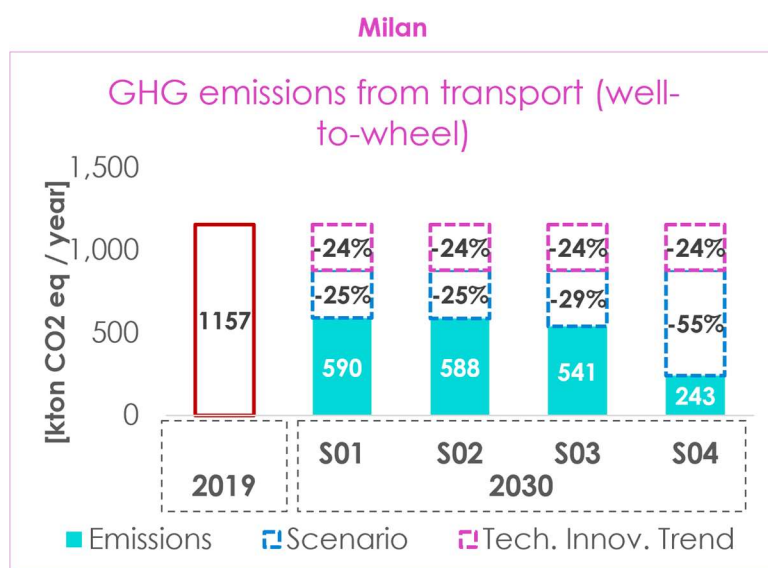


Figure 4: Well-to-wheel greenhouse gases emissions from urban transport in Milan

4.2 Transport

One of the other key transport output indicators is the **modal split (or modal share)**. This indicator captures the mobility patterns of residents of the study area. The modal split is calculated based on the share of passenger-km travelled by each mode. Only trips occurring within the study area are taken into account, thereby excluding trips originating outside of it. The four scenarios affect the modal split in different ways, and by shifting trips to low carbon modes, it contributes to the reduction of GHG emissions.

Transport modes are aggregated in four categories: Private Motorized (private cars, both as driver or passenger, and motorbikes), Public Transport (metro, tram, buses, and DRT, where implemented), Active Modes (walking, cycling and micro-mobility), and Shared Mobility (car, bike, moped and e-scooter sharing). Detailed results by mode are reported in Annex IV.

With respect to the base year 2019, both S01 and S03 indicate about 7 percentage points of reduction in the share of private cars and motorbikes. This reduction is mainly driven by traffic management measures, by improved accessibility, and by increased attractiveness of alternative modes, in line with the *Avoid-Shift-Improve* paradigm.

On the one hand, travelling by private cars is made more time-consuming due to traffic regulations (e.g., traffic calming) and more expensive due to parking pricing. On the other hand, people are encouraged to use more public transport thanks to measures that enhance and prioritize the service as well as lower its cost.

Additionally, active modes are made more attractive thanks to larger pedestrian areas and improved cycle paths, thus making it more comfortable and safer to use the bike or to walk. In particular, the bike modal share rises from 3.1% in 2019 to 4.5% in 2030 in both S01 and S03. It is worth underlining that bike sharing users are accounted for in the shared mobility category. Therefore, the actual number of people using a bike as their main mode of transport is actually even higher than shown in the active modes indicator.

In addition, there is an increased use of shared mobility (including car, bike, moped and e-scooter sharing), achieved through service improvements (i.e., more vehicles/devices available in the study area).

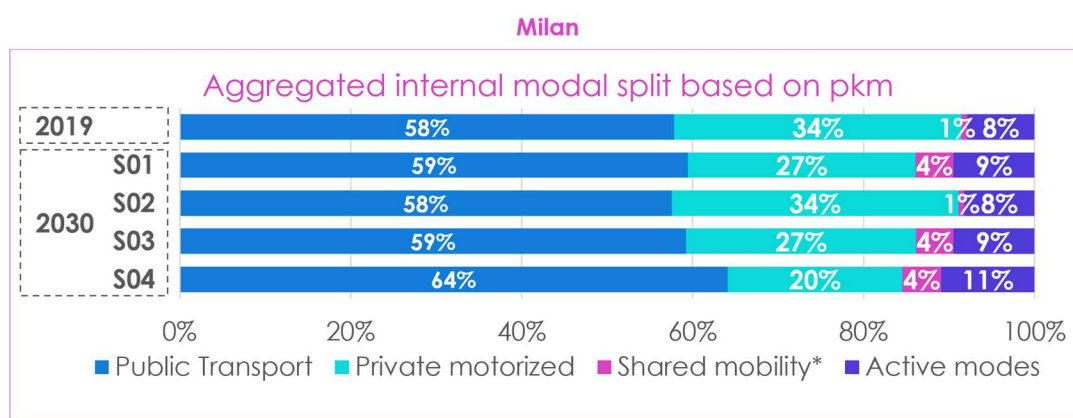


Figure 5: Aggregated internal modal split based on passengers-km in Milan.

*Shared mobility includes car, bike, moped and scooter sharing.

A slightly different result is achieved in S02. Since this scenario's main focus is on the **renewal of the vehicle fleet and the acceleration of the EV uptake**, smaller variations in the modal split are obtained. Shared mobility, public transport and active modes are not strongly incentivized, and the private motorized modes remain almost constant. This is mainly caused by the implementation of a low-emission zone (**LEZ**) over the whole urban area, which restricts access to cleaner vehicles only. The LEZ is the driver of change, encouraging car users to shift to an alternative mode of transport, to replace their vehicle with a less polluting one or to even forgo the trip altogether. Moreover, the congestion and pollution charging generates a similar effect, despite not being applied to the whole urban area.

These measures are implemented in all scenarios. Nevertheless, with respect to S01 and S03, the impact on modal split is less strong, because in S02, other policies also contribute to faster fleet renewal and EV uptake. The accelerated uptake of BEV and PHEV means that fewer vehicles are affected by the access restrictions imposed through the LEZ and, as a consequence, a smaller modal shift away from the car is observed in Scenario 2.

Looking at the modal split in S04, a **very strong change** in the mobility behaviour is expected. From 2019 to 2030, the share of private cars and motorbikes decreases by 14 percentage points. These trips shift mostly to public transport (+6 percentage points) but also to shared mobility (+4 percentage points) and walking and cycling (+3 percentage points).

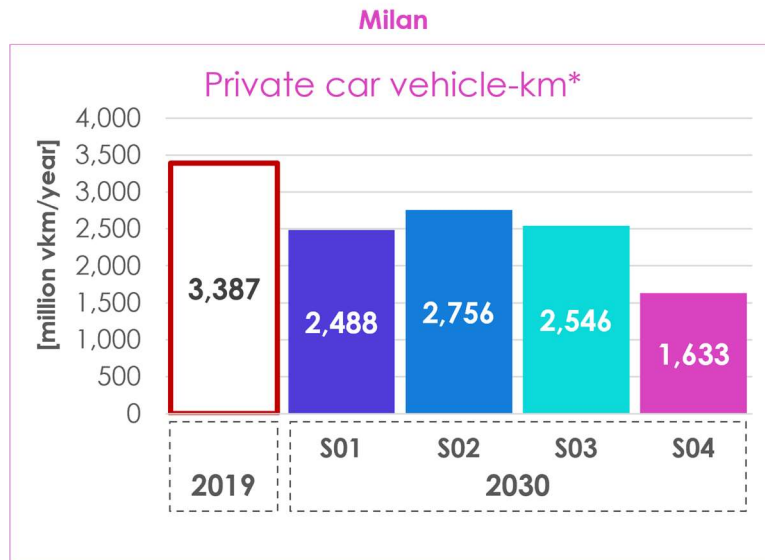


Figure 6: Private car vehicle-km in Milan

*Including both internal and incoming trips (city segment only)

Reducing [car dependency](#) in urban areas can improve the liveability of cities and provides many (co-)benefits. These include reduced GHG emissions (as seen in the previous section), lower levels of air and noise pollution, less congestion and road traffic crashes. In this sense, an important indicator is also the number of [car vehicle-km](#) travelled in the study area (including both internal and incoming trips).

S02, which is mainly focused on the renewal of the vehicle fleet, has the lowest reduction with -19% vehicle-km with respect to the base year. In S01 and S03, a larger reduction (-26% and -25%) is achieved, which is even larger in the ambitious S04 (-52%). S04's substantial reduction is mainly due to the impact of this scenario on incoming trips (modal shift, increased multimodality through Park&Ride facilities, diffusion of car-pooling and increased car-occupancy, and trips avoidance). In fact, it is worth noting that incoming trips contribute significantly to urban traffic in the Milan municipality, being estimated as about 39% of total trips in the area. As already mentioned for the modal split, S04 requires drastic changes in how people move, resulting in a higher reduction of private car usage.

Whereas the modal split of motorised transport, car-vehicle km, and [car ownership](#) are all interconnected, the scenarios generate smaller reductions in the number of cars owned over the years by residents in the urban area. In fact, at least in the short term, even if users might change their daily mobility habits, a smaller proportion is ready to abandon private cars. Indeed, a car might continue to be a necessity for certain types of trips (e.g., extra-urban, day trips, etc. where no alternative options can offer the same level of flexibility as the private vehicle). Compared to 2019, the level of car ownership decreases by about 5% in S02, and 10% in S01 and S03. On the other hand, S04 reaches a remarkable -27% of cars owned by 2030.

Modal shift and changes in private car usage also affect [travel time](#)⁴. Two different indicators are reported on this aspect: the average travel time per trip and the total travel time. The first one is affected by the mobility choices in terms of transport mode used, time performances of the services provided (also in terms of waiting time or time to pick up a shared vehicle) and road congestion. On the other hand, total travel time also considers the overall number of trips made within the city (considering both internal and city segments of incoming trips).

As a result of a shift towards (generally) slower transport modes, [average time per trip](#) increases slightly in all scenarios, ranging from +0.8% in S02 to about +8.5% in S04. Furthermore, the implementation of traffic-calming measures (expected to cover 85% of the core urban area in 2030) means slightly lower speed and higher travel times also for private cars.

[Total travel time](#) also increases with respect to the base year (between 4% and 10%). However, in this result, two components that act in opposite directions need to be considered. On the one hand, transport demand is growing over time as a direct

⁴ Due to the aggregated nature of the model, not including a detailed transport network and traffic assignment process, travel times are the results of an approximated approach.

impact of population growth. On the other hand, the implementation of [working from home](#) policies reduces the number of commuting trips made.

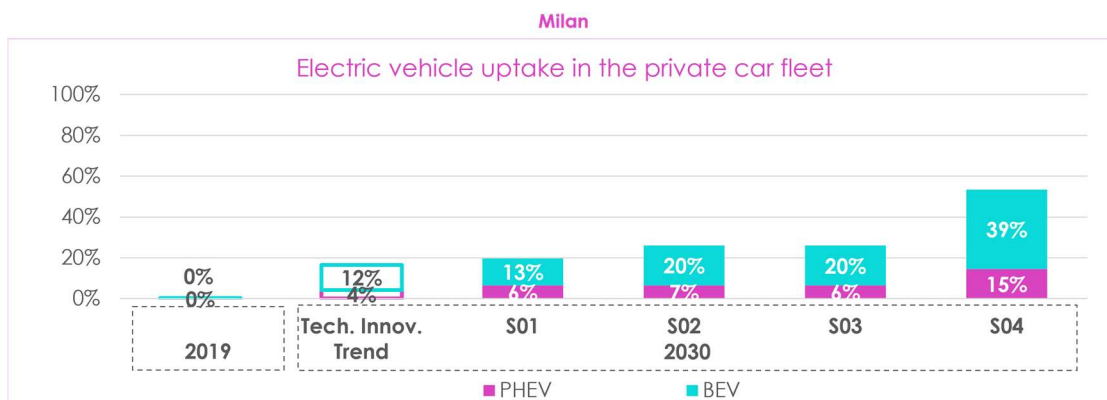


Figure 7: Electric Vehicles uptake in the private car fleet in Milan

As already mentioned, S02 is focused on fleet electrification and renewal as the core element for a sustainable transition. Therefore, it reaches a higher [uptake of electric private cars](#) with respect to S01. The uptake of electric vehicles reaches 20% and 7% for BEV and PHEV respectively in 2030. A similar result is also achieved in S03, where the same measures to incentivise electrification are applied. The Technological Innovation Trend contributes to a strong uptake of electric vehicles, resulting in a 12% share of BEV and a 4% share of PHEV with respect to the total stock.

An even larger uptake of electric vehicles is achieved in S04, where the zero-emission zone (ZEZ) alongside more ambitious policies supporting vehicle electrification are implemented. In this scenario, the share of BEV and PHEV in 2030 rises to 39% and 15% respectively. In the longer term and beyond 2030, it is expected that the share of PHEV will decrease, in favour of an even larger uptake of BEV vehicles.

Beside the passenger sector, [freight transport](#) is also relevant when it comes to analysing the impacts of a sustainable transition in urban mobility. In Milan, an estimated 20% of CO₂ emissions from transport was emitted by road freight vehicles in 2019.

Generally, two ways can be taken to reduce emissions and congestion from freight: one is fleet renewal and modal split change, the other is the efficiency increases. Dedicated policies (e.g., urban delivery services) help optimise goods per vehicles and reduce the number of shipments by increasing their efficiency. Additionally, freight vehicles can be pushed towards a greener fleet with the low-emission zone, and with specific policies for the renewal of the vehicle fleet.

Also, to avoid high investment costs, one can choose to move goods with alternative and more sustainable services (e.g., cargo-bikes). However, it is important to point out that not all categories of goods can be moved by cargo-bikes and therefore in these cases the shift from HDV or LDV is limited.

In MOMOS, freight transport is simulated considering shipments by both trucks (LDV and HDV) and cargo-bikes. When looking at the results of [freight vehicle-km](#), it is important to keep in mind the very different load factors according to the type of vehicle. Indeed, the shift from one vehicle to the other (especially if towards cargo-bikes) can lead to strong increase in the number of vehicles with lower capacity.

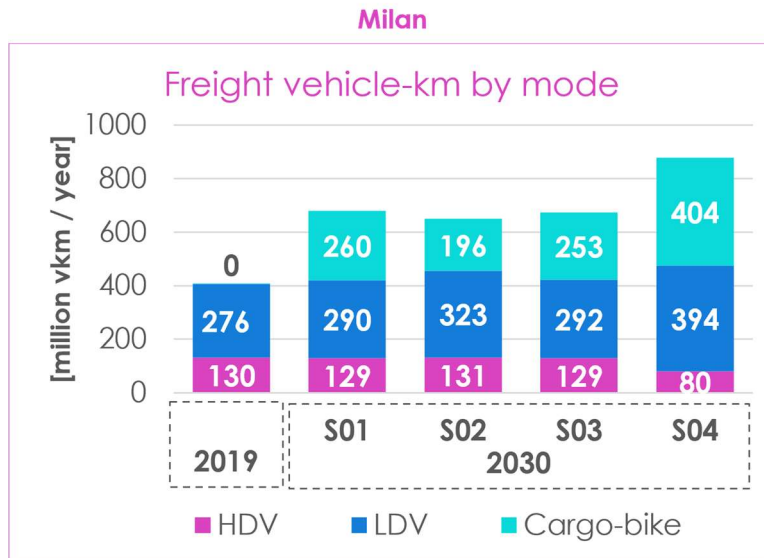


Figure 8: Freight vehicle-km by mode in Milan

Looking at the scenario results, all of them assume the diffusion of [cargo-bike](#) delivery services at different rates: S01 and S03 show similar values of vehicle-km for cargo-bike and LDV, resulting from several policies boosting the mode shift (e.g., LEZ) and promoting the uptake of cargo-bikes. The difference between S01 and S02 in the number of vehicle-km by cargo-bike is due to two factors. Firstly, in S02 there is no dedicated policy to further increase this typology of freight vehicles. Secondly, the higher vehicle fleet renewal and electrification of S02 (also affecting LDVs and HDVs) means that fewer freight vehicles are affected by the LEZ restrictions. With the boosted policies associated with S04, both freight vehicles electrification and cargo-bike vehicle-km significantly rise, whereas LDV and HDV vehicle-km are slightly decreased thanks also to the assumed enhanced optimization of load factors.

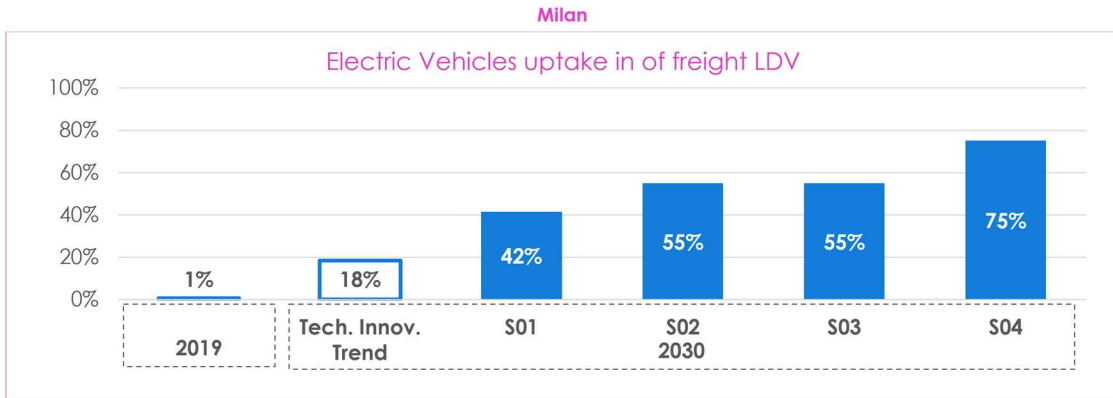


Figure 9: Electric Vehicles uptake in freight LDV in Milan

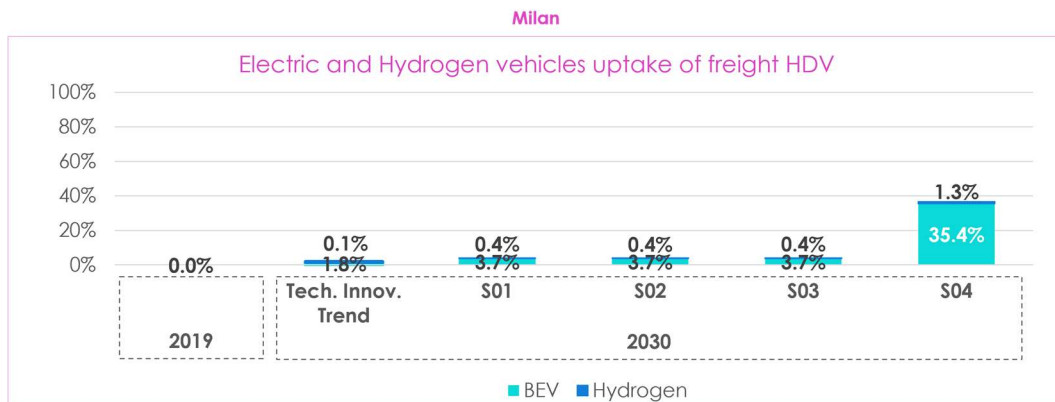


Figure 10: Electric and Hydrogen vehicles uptake of freight HDV in Milan

Across the four policy scenarios, the trend towards **electric Light Duty Vehicles (LDV)** is similar to the one in private cars: in 2030, S01 achieves a share of about 42% for PHEV/BEV LDV. S02 and S03 show a higher increase (55%), while in S04 an even larger EV uptake is expected (75%). The exogenous Technological Innovation Trend is responsible for about 18% of the electric share for LDV.

For High Duty Vehicles (HDV), both battery electric and hydrogen vehicles are worth mentioning in 2030. In the first three scenarios, these types of vehicles account for about 4.1% of the total fleet. With the more restrictive LEZ regulations of S04, the BEV share grows to 35% and the hydrogen's share to 1%.

Overall, these shares are higher with respect to passenger cars, assuming that commercial operators could be more receptive to renewing their fleet and to the shift caused by the implementation of an LEZ (and a ZEZ in S04). Of course, the model is simulating a very demanding renewal rate and investments on the LDV side. Additionally, compared to private cars, freight and logistic operators have fewer alternatives to keep moving goods inside the city context. Thus, in case of traffic

restrictions, besides replacing a portion of vehicles with cargo-bikes, the only alternative is a forced change to the vehicle technology with BEV (of PHEV) trucks.

The [energy and fuel consumption](#) is mainly driven by trends in transport demand and technology. From 2019 to 2030, the total energy consumption almost halves in the first three scenarios (-40% in S01, -39% in S02, -44% in S03) and decreases by 70% in S04. This result is the consequence of fleet renewal, traffic reduction, but also efficiency improvements of internal combustion engine vehicles (see 3.6).

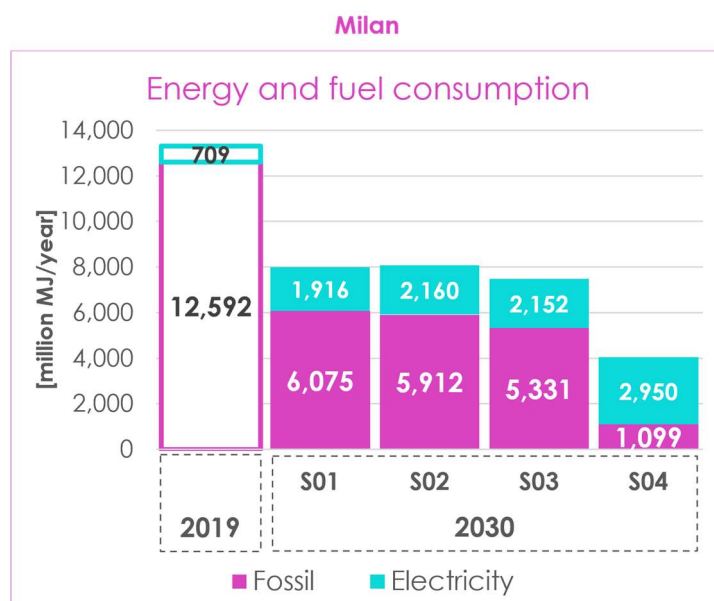


Figure 11: Energy and fuel consumption in Milan

It is also worth noting that, at the base year, only 5.33% of the energy consumed comes from electricity, while 94.67% comes from fossil fuels. In 2030, in turn, electricity will account for about 25% in S01, S02 and S03, and 73% in S04.

4.3 Air pollutant emissions

Beside GHG emissions, urban mobility generates air pollutant emissions that pose a risk to the health of citizens. For this reason, the model simulated emissions from road transport, including of PM2.5 (Particulate Matter), NOx (Nitrogen Oxides), VOC (Volatile Organic Compound) and CO (Carbon Monoxide).

For what concerns [PM2.5](#), all scenarios are expected to reduce PM2.5 emissions (considering both exhaust and non-exhaust components). It is worth noting that PM2.5 emissions are caused not only from fuel combustion, but also from tyre and brake wear. This way, an electric vehicle continues to produce PM2.5 emissions, especially due to tyre wear (brake wear can be reduced thanks to regenerative braking system).

Moreover, air pollutant emissions also depend on traffic demand. Combining fleet renewal, mode share change, and a drop in traffic demand, it is possible to explain the

results obtained. The reductions range from -39% in S01 to -57% in S04. In this respect, fleet renewal and EV uptake are responsible for reductions of about -30% in PM2.5 emissions between 2019 and 2030.

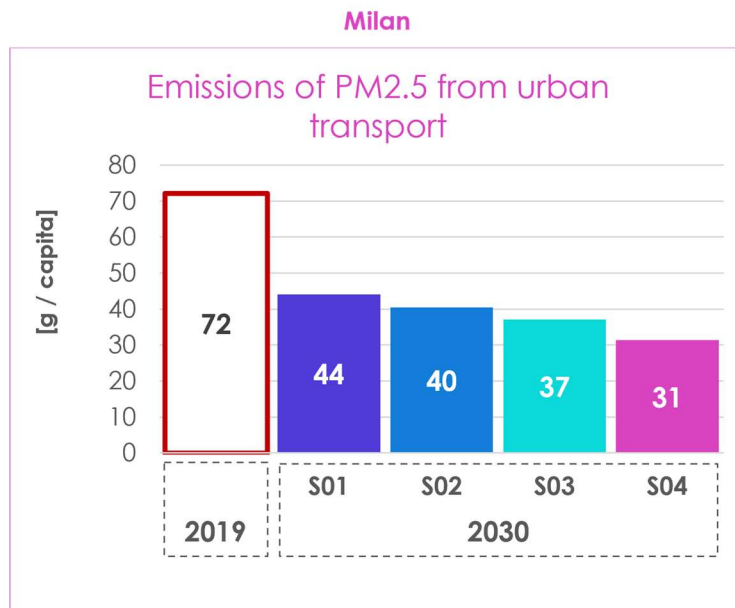


Figure 12: Emissions of PM2.5 in Milan

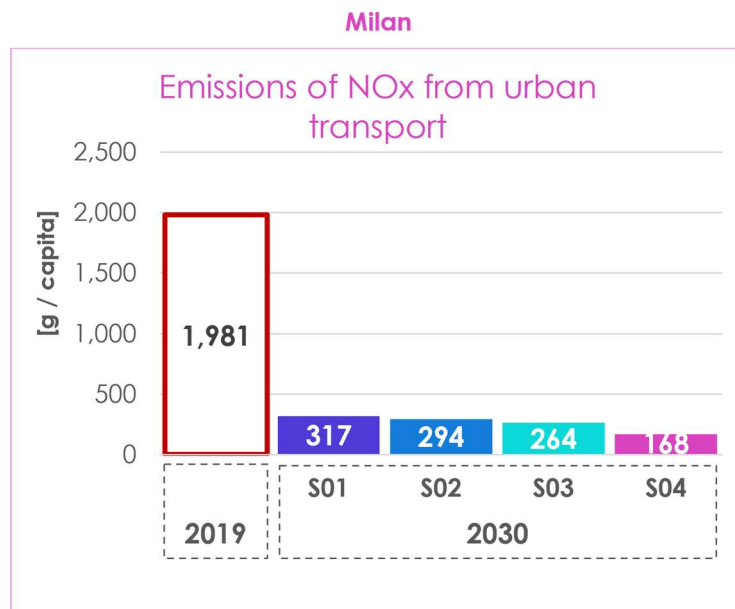


Figure 13: Emissions from NOx in Milan

Similar results are observed for the other pollutants, except for **NOx** emissions, which drop by more than 80% in the first three scenarios, and more than 90% in the S04. This is explained by reductions in traffic demand and by the renewal of the vehicle fleet (accounting for about -44%) with more restrictive emission limits set for newest engines concerning NOx [20].

Detailed results on the emissions of PM2.5, NOx, VOC, and CO are available in Annex IV: Full results of the study.

4.4 Road safety

Despite considerable improvements in road safety achieved in the past decades, the number of transport-related deaths and injuries is now stagnating at high levels, especially within many urban areas [21]. In fact, according to the European Green Deal, road traffic deaths should eventually tend towards zero by 2050.

In S01, S03 and S04, the implementation of policies aiming at improving safety for cycling and walking allows to achieve reductions of **road traffic deaths** above 40% with respect to the base year (-47% in S01, -48% in S03 and -49% in S04). In S02, those complementary measures are not in place and road traffic is larger than in the other scenarios, resulting in a lower reduction of road traffic deaths, of about 12%. It should also be noted that road traffic deaths shown in the chart below are in relation to the population size. However, the total amount of road traffic deaths also reflects the increase in the number of kilometers cycled. Therefore, to complement the analysis, the fatality rate (as ratio between road traffic deaths and kilometers cycled) is included in the Annex IV: Full results of the study.

To explain the impact of the different scenarios on road traffic deaths, it is worth noting that there are two main components affecting the trend. On the one hand, the reduction of private cars and trucks drives down the number of road traffic deaths, when more people are moving to safer modes, such as buses and metros. Furthermore, the construction of dedicated infrastructure (cycling lanes or pedestrian areas) as well as the implementation of traffic-calming can improve the safety of pedestrians and cyclists. On the other hand, cyclists are the most vulnerable road users, with the highest fatality rate. Therefore, in the expected decrease of road traffic deaths, the fact that more people are using the bike as a transport mode contrasts with the fact that the infrastructure is generally safer, thus limiting the overall reduction.

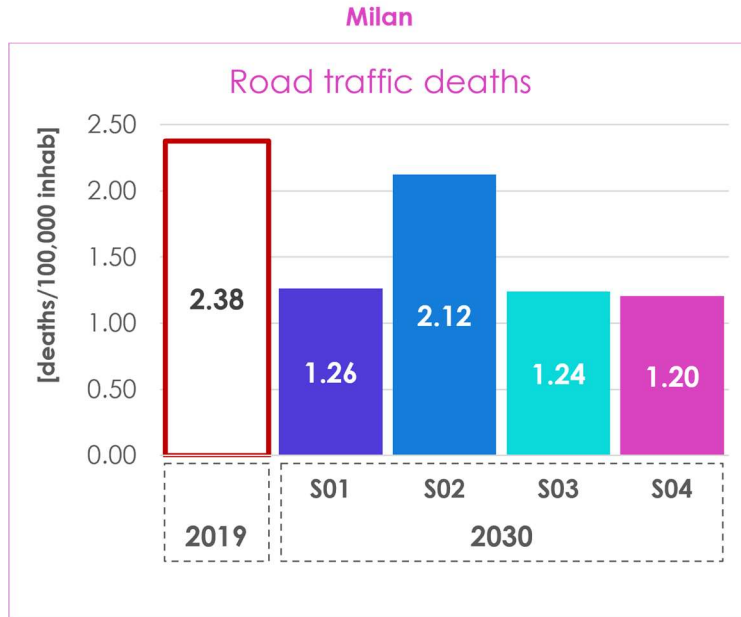


Figure 14: Road traffic deaths in road transport in Milan

In Annex IV: Full results of the study, other indicators related to safety are reported, such as road traffic serious injuries, road traffic deaths per passenger-km, both for all modes and with a focus on cycling only.

4.5 Costs and Savings

On the basis of the output provided by the MOMOS model, an [analysis of the impacts in monetary terms](#) has also been performed. The objective is to estimate costs and benefits associated with the transition scenarios.

Most of the policy measures implemented in the scenarios imply specific [costs](#) for the city (for the implementation and management of the measures) but also generate revenues. The analysis has quantified those costs and revenues⁵. Furthermore, it also included the monetisation of [externalities](#) (GHG emissions, air pollutant emissions, noise, and road traffic injuries/deaths) and savings or losses for [passengers and freight operators](#) in terms of [transport costs](#). The aim is to allow a comparison between the four transition scenarios, highlighting areas and aspects where scenarios perform better (e.g., environmental benefits) or worse (e.g., high costs).

⁵ As outlined in Milan Metropolitan City's SUMP, accounting for about 3.2 million inhabitants and 133 municipalities surrounding Milan, at the time horizon of 2030 about 2 billion euros are earmarked for Milan metro network extensions, respectively 13 and 22 million euros for urban and suburban PT by rail and buses/coaches, 178 million for roads and safety and 224 million for cycling.

The investments lead to reductions in air pollutants and GHG emissions, fewer road traffic deaths, and less noise⁶, generating benefits while improving the quality of life inside the urban area. By monetising these reductions, it is possible to assess the [external cost savings](#) associated with the implementation of the scenarios.

The monetisation of externalities has been performed in Euro₂₀₂₁ with reference to the unit costs published in the Handbook on external costs of transport [22] and the *Economic Appraisal Vademecum 2021-2027* [23]. The unitary values (applicable to Italy) are shown in Table 10 in Annex I: Study area and input data.

It is important to underline that all costs and revenues considered are only those associated with the implemented policies and are additional with respect to the business-as-usual (BAU) scenario (see 3.6). In the BAU scenario, no policy measures are simulated, and conservative exogenous trends are applied. Thus, costs and revenues do not represent the total costs and revenues, but only the incremental ones related to the specific set of policies, and those related to the fleet renewal of the technology innovation trend.

All costs are cumulated over the analysis period (2019 – 2030). This allows us to comprehend all the investments and maintenance costs needed, as well as benefits in terms of the reduction in externalities over time. A yearly discount rate of 3% has been applied, as also recommended by the *Economic Appraisal Vademecum 2021-2027*.

With respect to the [city](#), two components are presented: costs and revenues. [Costs refer](#) to the maintenance, management and implementation costs, such as the construction of new metro lines, cycle lanes, priority systems for buses, monitoring systems for traffic management, etc. On the other side, city users (residents, freight operators and people incoming from outside) pay for the services, leading to [city revenues](#).

Looking at the [city's costs and revenues](#), the amount of money invested by the city in S02 is significantly lower than the other scenarios, and also less than S02 revenues. The policies in this scenario are mainly focused on vehicle fleet renewal, paid by the city users. Instead, in S01, S03, and S04 the city costs are higher than the city revenues. In particular, it is worth mentioning that the metro network extension planned in Milan requires a large investment by the city. Still, S04's city revenues are quite close to the city's costs. This is not the case for S01 and S02 though.

⁶ Noise is calculated by multiplying the transport activity (per mode) by the Handbook's unitary cost (per pkm/vkm).

Table 5: Costs and revenues of the four scenarios in Milan

Costs and revenues in Milan				
[million euro]	2019 – 2030 (cumulated)			
	S01	S02	S03	S04
City costs	1,090	192	1,149	1,315
City revenues	525	518	521	1,040
User costs	320	1,027	454	1,152
Freight operators' costs	479	640	547	622
TOTAL Net cost	1,365	1,342	1,629	2,050

User costs include transport expenditure of residents of the study area, as well as those borne by incoming users for their mobility within the study area. The users' costs of the first three scenarios are basically aligned, whereas the higher intensity of S04's policies require higher economic effort from users. Among the main reasons, the higher fleet renovation requested for both residents and incoming city users (e.g., to comply with access restrictions).

Looking at costs borne by the **freight operators**, S01 is the least costly, followed by S03. The higher cost of S02 can be explained by the more ambitions and costly freight fleet renewal (compared to S01), without the compensation of policies to boost alternative modes.

Overall, looking at **total net costs** (calculated as the difference between total revenues and costs) and without taking into account external costs (see below), S02 is the cheapest (1.34 billion euros) and the S04 is the most expensive (2.05 billion euros).

Due to the different unitary costs associated, the **external costs savings** have different orders of magnitude. Road traffic injuries/deaths account for the larger portion of the savings, followed by GHG emissions reduction. Whereas S01 and S03 are quite similar in total savings, S02 shows an overall lower result. This is mainly due to a much lower reduction in road traffic crashes and is a direct consequence of lower reductions in the private car share and less emphasis on safe infrastructure for pedestrians and cyclists. Finally, in S04 the whole set of external costs savings is larger than the first three scenarios, as can be expected from the more ambitious target set in this scenario.

Table 6: External costs savings of the four scenarios in Milan

External costs savings in Milan

[million euro]	2019 – 2030 (cumulated)			
	S01	S02	S03	S04
GHG	551	540	600	1,071
Air pollutants	341	342	354	381
Road traffic injuries/deaths	2,242	824	2,251	3,036
Noise	115	68	118	179
TOTAL Savings	3,248	1,775	3,323	4,666

Table 7: Comparison between total net costs and total net savings in Milan

Costs vs net savings in Milan				
[million euro]	2019 – 2030 (cumulated)			
	S01	S02	S03	S04
TOTAL Net costs	1,365	1,342	1,629	2,050
TOTAL Savings	3,248	1,775	3,323	4,666

In all the policy scenarios, the total savings from externalities reduction generated by the policies' implementation outweigh the total net costs of the scenarios.

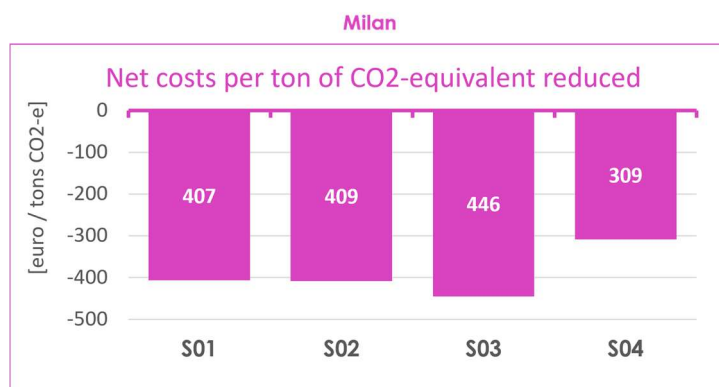


Figure 15: Net costs per ton of CO₂-equivalent reduced in Milan

The cost of each scenario can also be presented as costs per ton of CO₂-equivalent reduced. S02 achieves almost the same result of S01, while S03 shows a higher rate. However, in absolute terms, it is worth noting that S02 leads to the lowest abatement in GHG emissions. On the other hand, even if S04 has the largest costs associated, its very high abatement in GHG emissions results in the best ratio between costs and tons of GHG abated.

Finally, the time saving component requires a clarification. The aggregated nature of the model requires an approximation for the travel time indicators (Total travel time, Average travel time). Therefore, it is not appropriate to monetise travel time savings. In addition, some recent controversy emerged in scientific literature about the correct method to monetise small time savings (i.e., the most frequent typology of trips in urban contexts) [24]. Furthermore, in the transition scenarios, a part of the travel time savings is linked to a smaller number of trips due to cancelled activities commuting trips not carried out because of the “working from home” policy. It is still unclear how such travel time savings should be evaluated.

Moreover, the health benefits of higher levels of physical activity from increased walking and cycling are not quantified and monetised either, despite the scenarios S01, S03 and S04 showing a shift towards active travel which is likely to generate significant health benefits.

4.6 Policy effectiveness

The results of this study reflect the combined effects of different sets of policy measures implemented within the same scenario. As explained above, there is a strong correlation among policies, which can reduce or amplify each other’s effect.

Nevertheless, each single policy could be “isolated” from the scenario, and its individual effectiveness in reducing CO₂ emissions could be estimated. Of course, the effects of each single policy should be taken carefully as they are strongly linked to the base year situation as well as to the 2030 intervention levels foreseen for each policy in the specific context of application.

In Milan, the policies with the highest individual⁷ impact on GHG emission reductions between 2030 and 2019 are:

- a low-emission zone (LEZ) for passenger traffic and for freight
- Congestion and pollution charging
- Greening the public transport fleet
- a Limited Traffic Zone (LTZ) for passenger traffic
- Expanding cycling networks and facilities
- Greening the logistic fleet

⁷ Without taking into account synergies among policies

5 Conclusions

This study has assessed the transition towards a zero-emission urban mobility by 2030 in Milan. Similar analyses have been carried out for 4 other cities and metropolitan areas and are available in separate documents.

The simulation did not have the intention of presenting the most likely transition outcome but simulated potential transition scenarios in a context of large uncertainty (policies, trends, etc.) while demonstrating the efforts needed to reach (near) zero-emission urban transport by around 2030. The impact of the different scenarios on mobility patterns, the environment and road safety were also assessed.

The simulation results showed that reaching the zero-emission target by 2030 is very challenging in Milan, considering the magnitude of the needed interventions and the very short timeframe in which these changes need to be implemented.

The simulation of the most ambitious scenario (S04) suggests that with a set of highly ambitious and targeted policies, a 91% reduction of greenhouse gas (GHG) emissions is attainable. However, getting there implies strong changes in the mobility behaviour of citizens, especially in terms of their modal choice, primarily by reducing car use in favour of alternative modes of transport. A very strong uptake of zero-emission vehicles in the fleet is also essential for a successful transition. High fleet renewal rates as well as the decarbonisation of last-mile delivery with cargo-bikes and increased efficiency of freight transport are equally required.

Although they do not get close to the zero-emission target, scenarios S01 and S02 have both shown that a strong emissions reduction (-55% and -56% reduction of GHG respectively) can be achieved by either focusing on the improvement of urban transport infrastructure, shared mobility, and traffic regulation (S01) or on the uptake of electric vehicles in the fleets (S02). These results suggest that different pathways could be followed towards the goal of decarbonisation, prioritising different sets of measures. By applying the same policies altogether (S03) a -60% reduction of GHG emissions is obtained. Compared to S04, the policies included in the first three scenarios are comparatively less ambitious (though they remain ambitious in their own right). While this might help implementation and acceptance of these measures, neither of the three achieves the reductions in GHG emissions from urban transport that are required. This is only achieved by the most ambitious scenario, S04.

As explained above, this study only aims to illustrate potential scenarios for the sustainable mobility transition of European cities and clarify what measures and what level of ambition is required to switch to zero-emission urban mobility in European cities. This can help a better design of policy parameters, targets, and scenarios that are aligned with the local vision and near or long-term mobility and overarching objectives.

The main results and outcomes of this study are also available in this user-friendly [online dashboard](#).

6 References

1. European Environmental Agency (2023), Greenhouse gas emissions from transport in Europe:
<https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-transport>
2. European Commission (2021): Urban Mobility Framework Roadmap
https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12916-Sustainable-transport-new-urban-mobility-framework_en
3. European Commission, Secretariat-General (2019). The European Green Deal. COM (2019) 640 final. <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2019:640:FIN>
4. European Commission, Secretariat-General (2020). Sustainable and Smart Mobility Strategy – putting European transport on track for the future. COM (2020) 789 final. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0789&from=EN>
5. European Commission (2021), EU Mission Climate-Neutral and Smart Cities:
https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe/climate-neutral-and-smart-cities_en
6. CIVITAS Initiative: <https://civitas.eu/>
7. Eltis, The Urban Mobility Observatory: <https://www.eltis.org/in-brief/about-us>
8. EIT Urban Mobility, Costs and benefits of the sustainable urban mobility in Europe: <https://www.eiturbanmobility.eu/costs-and-benefits-of-the-sustainable-urban-mobility-transition-in-europe/> **Error! Hyperlink reference not valid.**
9. EMEP/EEA air pollutant emission inventory guidebook 2019:
<https://www.eea.europa.eu/publications/emep-eea-guidebook-2019>
10. Città metropolitana (2021), Dati statistico demografici dell'area di metropolitana di Milano:
https://www.cittametropolitana.mi.it/export/sites/default/statistica/doc/Statisti_che_demografiche_al_1_gennaio_2021.pdf
11. Municipality of Milan, vehicles allowed in Low Emission Zone:
<https://www.comune.milano.it/aree-tematiche/mobilita/area-b/area-b-veicoli-che-possono-entrare>

12. ATM, public transport services:
<https://www.atm.it/it/IlGruppo/ChiSiamo/Pagine/servizi.aspx>
13. Lombardia Region (2016), origin-destination matrixes about passenger's mobility: <https://www.dati.lombardia.it/Mobilit-e-trasporti/Matrice-OD2016-Passeggeri/tezw-ewgk>
14. European Council of the European Union, Fit For 55 strategy:
<https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/>
15. European Commission, (2023). REGULATION (EU) 2023/851 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R0851>
16. European Commission, (2019). Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles and amending Regulations (EC) No 595/2009 and (EU) 2018/956 of the European Parliament and of the Council and Council Directive 96/53/EC. <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R1242>
17. Transport and Environment, Transport emissions modelling and analysis:
<https://www.transportenvironment.org/transport-emissions-modelling-and-analysis/>
18. EU Reference scenario 2020: https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en
19. European Commission (2022), Implementing the RePowerEU action plan:
<https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022SC0230&from=EN>
20. European Commission (2022), Proposal for a regulation of the European Parliament and of the council: https://single-market-economy.ec.europa.eu/system/files/2022-11/SWD_2022_359_1_EN_impact_assessment_part3_v6.pdf
21. European Transport Safety Council: <https://etsc.eu/>
22. European Commission, Handbook of the external costs of transport (2019):
<https://op.europa.eu/en/publication-detail/-/publication/9781f65f-8448-11ea-bf12-01aa75ed71a1>
23. European Commission (2021), Economic Appraisal Vademecum 2021-2027 – General Principles and Sector Applications:
https://ec.europa.eu/regional_policy/en/information/publications/guides/2021/

[economic-appraisal-vademecum-2021-2027-general-principles-and-sector-applications](#)

24. Daly, Tsang, and Rohr (2014), The value of small time savings for non-business travel: <https://www.jstor.org/stable/24396326?typeAccessWorkflow=login>

Annex I: Study area and input data

Table 8: Districts categorization in Milan

Typology	District name
Urban Core Area	Centro Storico
Urban Core Area	Stazione Centrale, Gorla, Turro, Greco, Crescenzago
Urban Core Area	Città Studi, Lambrate, Porta Venezia
Urban Core Area	Porta Vittoria, Forlanini
Peripheral Area	Vigentino, Chiaravalle, Gratosoglio
Urban Core Area	Barona, Lorenteggio
Urban Core Area	Baggio, De Angeli, San Siro
Urban Core Area	Fiera, Gallaratese, Quarto Oggiaro
Urban Core Area	Porta Garibaldi, Niguarda

Table 9: List of the input indicators for Milan

Group	Input data	Description	Categori es	Values	Source
Urban context	Area typology	Type of the study area	City or Functional Urban Area	City	
	Population	Population of the city / FUA	//	1.37 m	Città Metropolitana Milano
	Population structure	Age distribution of the city population	a) <18 b) 18-65 c) >65	a) 18% b) 62% c) 19%	Comune di Milano
	Population growth	Expected trend of the population growth	//	+0.5%	PGT Milano 2030 (2022)
	Population distribution	Population distribution between city centre and outskirts	a) urban core area b) peripheral areas	a) 96% b) 4%	Comune di Milano
Urban mobility	Motorization rate	Number of private cars every 1,000 inhabitants	//	495	Osservatorio Mobilità Sostenibile Italia

Group	Input data	Description	Categori es	Values	Source
	Modal split	Modal split with respect to the urban area only	a) walk b) bike c) motorbike d) car e) bus f) tram g) metro	a) 17% b) 5% c) 5.8% d) 24.9% e) 15.3% f) 5.3% g) 26.8%	TRT elaboration from data of Matrice OD Lombardia 2016 and Mobilitaria 2020
	Congestion level	Qualitative description of road congestion in the city	1 = negligible 2 = only during rush hours 3 = significant	Significant (TomTom Index: congestion level 31%)	TRT elaboration from data of TomTom Index and TomTom Index 2019
	Incoming trips	Share of incoming trips in the urban area, with respect to the total amount of trips within the area	//	39%	TRT elaboration from data of Matrice OD Lombardia 2016
	Modal split of the incoming trips	Modal Split of the incoming trips into the urban area	a) private car b) train c) bus	a) 60% b) 6% c) 34%	TRT elaboration from data of Matrice OD Lombardia 2016
	Freight vehicles rate	Share of freight vehicles with respect to the total vehicles (freight and cars) travelling in the urban area	//	5.7%	TRT elaboration from data of Aggiornamento PGTU e PUP 2022 - Documento di indirizzo e orientamento (p. 32)
	Public transport	Ticket price	Average Ticket price per journey (€)	a) subscribers b) single users	a) 0.9 b) 2.2
Cost		Implementation and management costs for public transport operators (€/vkm)	a) bus b) tram c) metro	a) 1.0 b) 2.0 c) 5.4	ATM
Network		Length of the network (km)	//	1,794	ATM
Average speed		Average speed of the vehicles (km/h)	a) bus b) tram c) metro	a) 13 b) 11 c) 30	Aggiornamento PGTU e PUP 2022 and SUMP of the Municipality of Milan, 2015 (p. 277-279)
Transport service offer		Annual vehicle-kilometre (million vkm)	a) bus b) tram c) metro	a) 28.0 b) 2.4 c) 80.0	SUMP of the Metropolitan City of Milan (2019) (p.105) and Aggiornamento PGTU e PUP 2022

Group	Input data	Description	Categori es	Values	Source
	Public transport reserved lanes	Length of the public transport reserved lanes (km)	//	35	Comune di Milano
Transport infrastructure	Bike lanes	Length of the bike lanes in the urban area (km)	//	298	Data provided by CCC via cities or Openstreetmap data
	Electric charging stations	Number of electric charging stations	//	1,191	Eco-Movements
	Park & Ride capacity	Number of parking lots	//	16,889	ATM (Parking structure and parking map)
Parking	Paid parking	Number of paid parking lots in the urban area	//	163,450	SUMP of the Municipality of Milan, 2015 (p. 42-43)
	Parking price	Average hourly parking price (€)	//	2.5	ATM
Car sharing	Vehicle fleet	Number of car sharing vehicles	//	2,372	Data provided by CCC via cities and Fluctuo
	Tariff	Average tariff (€)	a) fixed b) hourly	a) 0.0 b) 10.3	E-vai , Ubeego , Enjoy , Zity , E-go , Share Now
Bike sharing	Vehicle fleet	Number of shared bicycles	//	16,060	Data provided by CCC via cities and Fluctuo
	Tariff	Fixed and hourly average tariff (€)	a) fixed b) hourly	a) 46.6 b) 5.5	BikeMi , Ridemovi , and Bike Sharing Comune di Milano
	Area coverage	% of the study area covered by the service at base year	//	80%	Bike Sharing Comune di Milano
Moped sharing	Vehicle fleet	Number of shared mopeds	//	2,600	Scooter Sharing Comune di Milano
	Tariff	Fixed and hourly average tariff (€)	a) fixed b) hourly	a) 0.0 b) 19.0	Scooter Sharing Comune di Milano
	Area coverage	% of the study area covered by the service at base year	//	27%	Scooter Sharing Comune di Milano
Micromobility	Vehicle fleet	Number of shared micromobility devices	//	4,475	Data provided by CCC via cities and Fluctuo
	Tariff	Fixed and hourly average tariff (€)	a) fixed b) hourly	a) 0.0 b) 13.4	Micromobility Comune di Milano
Traffic control and management	Limited Traffic Zone (LTZ) - Passenger	Quantification of the share of urban area under LTZ for passengers (%)	a) urban core area b) peripheral areas	a) 0.1% b) 0%	Urban Access Regulations , Comune di Milano

Group	Input data	Description	Categori es	Values	Source
	Limited Traffic Zone (LTZ) - Freight	Quantification of the share of urban area under LTZ for freights (%)	a) urban core area b) peripheral areas	a) 0.1% b) 0%	Urban Access Regulations, Comune di Milano
	LTZ time	Time of the day when LTZ is active for freight vehicles	0 = Never 1 = Peak 2 = Off peak 3 = All day	Peak	Urban Access Regulations, Comune di Milano
	LTZ modes - Freight	Type of vehicles banned from LTZ access	0 = None 1 = HDV 2 = LDV 3 = HDV & LDV	HDV & LDV	Urban Access Regulations, Comune di Milano
	Low Emission Zone (LEZ) - Passenger	Quantification of the share of urban area under LEZ for passengers (%)	a) urban core area b) peripheral areas	a) 100% b) 100%	Urban Access Regulations, Comune di Milano
	Low Emission Zone (LEZ) - Freight	Quantification of the share of urban area under LEZ for freights (%)	a) urban core area b) peripheral areas	a) 100% b) 100%	Urban Access Regulations, Comune di Milano
	Pedestrian areas	Quantification of the share of urban area with pedestrian areas (%)	a) urban core area b) peripheral areas	a) 0.5% b) 0%	Aggiornamento PGTU e PUP 2022
	Traffic calming area	Share of the urban area under 30 km/h speed limit (%)	a) urban core area b) peripheral areas	a) 1.6% b) 0%	Comune di Milano
Vehicle fleet composition	Private cars	Vehicle fleet composition by fuel type	a) gasoline b) diesel c) CNG d) LPG e) PHEV f) BEV	a) 63.1% b) 30.0% c) 0.7% d) 5.9% e) 0.0% f) 0.3%	ACI
	LDV	Vehicle fleet composition by fuel type	a) gasoline b) diesel c) BEV/PHEV	a) 6.6% b) 92.8% c) 0.6%	ACI

Group	Input data	Description	Categori es	Values	Source
	HDV	Vehicle fleet composition by fuel type	a) diesel b) CNG c) BEV	a) 98.5% b) 1.5% c) 0.0%	ACI
	Motorbikes/ Scooters	Vehicle fleet composition by fuel type	a) gasoline b) BEV	a) 99.9% b) 0.1%	Comune di Milano
	Public Buses	Composition of the fleet, with respect to the fuel type	a) diesel b) CNG c) PHEV d) BEV	a) 96.7% b) 0.0% c) 2.3% d) 1.0%	ATM

Table 10: Details of unitary cost factors for externalities (Italy values)

Element	Cost	Measure unit
Environment		
CO ₂	83 at 2019, 259 at 2030	€/ton
PM (cities with > 500,000 inhab.)	136,749	€/ton
CO	10	€/ton
NO _x	26,314	€/ton
VOC	1,140	€/ton
Safety		
Road traffic deaths	3,364,953	€/person
Road traffic injuries	519,539	€/person
Noise		
Motorbike	0.135	€/pkm
Car	0.009	€/pkm
Bus	0.135	€/vkm
Tram	0.107	€/vkm
Metro	0.000	€/vkm
HDV	0.009	€/tkm
LDV	0.032	€/tkm



Annex II: Policy measures rationale

Table 11: Rationale of policy measures

Policy	Rationale
Vehicle fleet and charging infrastructure	
EV uptake	The policy assumes an increased uptake of electric vehicles in the private car vehicle fleet, on top of the exogenous trend (accounted for in the Technological Innovation Trend) as a consequence of technology development, restrictions on conventional fuels and municipal or national subsidies.
EV charging infrastructure	An increased rollout of electric vehicle charging infrastructure results in more and better availability of charging points, that, in turn, increase the uptake of electric vehicles.
Green public transport fleet	The policy assumes an increased deployment of electric vehicles in the local bus fleet, on top of the exogenous trend.
Green logistics fleet	The policy assumes an increased uptake of electric vehicles in the light duty vehicle fleet used for logistics, on top of the exogenous trend driven by technology development.
Cooperative ITS	The diffusion of Cooperative Intelligent Transport Systems is expected to improve safety and efficiency in road transport, in terms of urban travel time, energy consumption, air pollutant emissions, etc. Thanks to this technology, the vehicles will be able to avoid collisions and use the engine in a more efficient way, resulting in less fuel consumption.
Innovative and shared mobility services	
Bike sharing	The policy assumes an enhancement of the bike sharing scheme already in place at the base year, both in terms of increased fleet size and of larger area covered by the service.
Car sharing	The policy assumes an enhancement of the car sharing scheme already in place at the base year, both in terms of increased fleet size and of larger area covered by the service.
Moped sharing	The policy assumes an enhancement of the moped sharing scheme already in place at the base year, both in terms of increased fleet size and of larger area covered by the service.
E-scooter sharing	The policy assumes the diffusion of e-scooters, also in the form of shared devices, both in terms of increased fleet size and of larger area covered by the service.
MaaS	The policy assumes that a MaaS (Mobility as a Service) platform is implemented in the city, allowing to integrate various forms of

Policy	Rationale
	<p>mobility services into a single and comprehensive service. MaaS offers end-users the added value of accessing mobility through a single application and a single payment channel. Furthermore, it is assumed that an integrated ticketing systems is in place, resulting in seamless travels and no requirement to buy tickets whilst switching either transport modes or services. It is assumed that the integration includes public transport, shared mobility services, and micromobility. The MaaS activation reduces both users' costs for transport services and travel time.</p>
DRT	<p>Demand-responsive transport is simulated as a new PT service, partially replacing the existing bus routes, but mostly adding a new service in areas where standard public transport cannot be very effective (e.g., low density areas, peripheries, etc.) Hence, with a small number of vehicles, it is possible to provide the Public Transport service in a wide area.</p>
Transport infrastructure	
Cycling network extension	<p>The policy is aimed at making cycling trips easier and safer. The implementation of the measure foresees that, when these facilities are provided, the bicycle modal share grows at the expense of competing modes</p>
Bus network extension	<p>The policy increases the reliability and attractiveness of the bus by increasing the service frequency over the entire network. The application of this measure incentivizes citizens to use public transport more at the expense of competing modes.</p>
Tram network extension	<p>The policy increases the reliability and attractiveness of the tram by increasing the service frequency over the entire network. The application of this measure incentivizes citizens to use public transport more at the expense of competing modes.</p>
Metro network extension	<p>The policy consists of making the metro transport services more accessible, mostly through an extension of the service and the construction of new lines/stations. Due to the complexity of such infrastructure measures and the short time frame, this is only applied to cities that have already planned and approved such extensions or constructions.</p>
Park & Ride	<p>The concept of Park & Ride assumes that parking spaces for commuters are provided at major public transport stops at the border of the city area. This means that a larger share of trips incoming from external zones by car will interchange to public transport.</p>

Policy	Rationale
Transport avoidance	
Working from home	The policy assumes an increasing adoption of working from home/teleworking, resulting in a reduction of travel to work trips per person. Also, rebound effects are modelled, taking into account an increase in trips for personal purposes when the commuting trip is avoided.
Car-free days	On car-free days, people are encouraged to travel by modes other than cars and car use is temporarily prohibited. Therefore, when the policy is applied, trips are shifted to other modes of transport, while taking into account that a share of trips is avoided or redistributed on other days.
Pricing schemes	
Congestion and pollution charging	It is assumed that a congestion charging scheme is implemented in a limited area of the city, applied to both cars and freight vehicles. The charge is in place during the day for all vehicles. Due its complexity, especially in terms of citizens' acceptance, this measure will only be applied to cities that already have such a scheme in place, i.e. Milan.
Parking pricing	The policy assumes an increase the price for parking in the urban area, with dedicated discounts to hybrid electric and electric vehicles. Also, the policy aims to reduce the overall number of parking spaces while increasing the share of paid parking (vs free parking).
Public transport fare reduction	The policy is designed to reduce the cost of public transport in a targeted way by providing a discounted tariff for young citizens (<18 years old) and for the elderly (> 65 years old) to incentivize travel by public transport.
Traffic management and control	
Prioritizing PT	The policy requires regulations but also appropriate infrastructures such as reserved lanes and automated traffic lights to give way to buses and trams when they approach crossroads. The result is an improvement of public transport speed, making PT more attractive.
Limited traffic zones (LTZ)	The policy aims at reducing the space available for using cars and for parking cars in order to increase the liveability of the urban space. The assumption is that the restrictions applied make it less convenient to use a car for some trips and so there is a reduction in the share of cars in traffic. The policy can be applied to cars, freight vehicles or both.

Policy	Rationale
Low emission zones (LEZ)	The policy aims at implementing low-emission zones, where access for certain some polluting vehicles is restricted. The policy allows for defining the restriction by vehicle type for cars and freight vehicles, resulting in a reduction of car and trucks transport demand (depending on the composition of the vehicle fleet) as well as an accelerated scrappage rate of vehicles not complying with the LEZ. If stepped up, it can be turned into in a zero-emission zone ZEZ) where only non-pollutant vehicles are allowed.
Traffic calming	The policy assumption is the implementation of traffic-calming measures in the city, making the use of cars less convenient and more time-demanding. A reduction in injury/fatality rates is also foreseen. Traffic-calming consists of regulations (e.g., zones with maximum allowable speed of 30 km/h) but also in various physical interventions (e.g., to restrict carriageways).
Pedestrian areas	The policy is aimed at making pedestrian trips easier and safer. The implementation of the measure assumes that when pedestrian areas are provided pedestrian trips grow at the expenses of competing modes. Furthermore, injury/fatality rates are also reduced.
Urban logistics	
Urban delivery centers	The policy is modelled assuming that urban freight consolidation centres are created at the border and within the urban area in appropriate locations to serve as hubs for the final distribution. A share of the shipments arriving from outside the city pass through the delivery centres, where loads are consolidated and distributed in a more efficient way, increasing the load factor of vehicles, shortening consignment routes and using cleaner vehicles. This results in fewer freight vehicle-km in the urban area.
Delivery and servicing plan	The policy represents the implementation of detailed plans to consolidate and reduce delivery and servicing vehicles accessing a site or building. The expected impact is a reduction of the number of goods vehicles entering the urban area as a result of more efficiency.
Cargo bikes	The policy simulates the diffusion of delivery services with cargo bikes within the urban area. It is therefore assumed that part of the freight demand delivered with LDVs can be shifted to cargo bikes.

Annex III: Intervention levels in the scenarios

Table 12: Milan's list of scenarios' intervention levels

Policy		Scenarios 1,2,3	Scenario 4
Vehicle fleet and charging infrastructure			
EV uptake	<i>Target</i>	Additional increase electric cars penetration compared to 2019 including Technological Innovation Trend	“
	% BEV/PHEV cars	3% → 23%	
EV charging infrastructure	<i>Target</i>	1 charging point / 8 EV 50% fast charging	1 charging point / 5 EV
	<i>No. charging points</i>	1,191 → 7,929	
Green public transport fleet	<i>Target</i>	100% of green public transport fleet by 2030	“
	% BEV/PHEV buses	3% → 100%	
Green logistics fleet	<i>Target</i>	Additional increase electric LDV penetration compared to 2019 including Technological Innovation Trend	“
	% BEV/PHEV LDV	0.6% → 30.7%	
Cooperative ITS	<i>Target</i>	Increase safety and efficiency in road transport	“
Innovative and shared mobility services			
Bike sharing	<i>Target</i>	6 bikes / 1,000 inhab. or +20% from base year	“
	<i>No. bikes</i>	16,060 → 19,272	
Car sharing	<i>Target</i>	2 cars / 1,000 inhab. or +20% from base year	“
	<i>No. cars</i>	2,372 → 2,846	
Moped sharing	<i>Target</i>	1 moped / 1,000 inhab. or +20% from base year	“
	<i>No. mopeds</i>	2,600 → 3,120	
E-scooter sharing	<i>Target</i>	4 devices / 1,000 inhab. or +20% from base year	“

Policy		Scenarios 1,2,3	Scenario 4
	<i>No. devices</i>	4,475 → 5,498	
MaaS	<i>Target</i>	Increase integration between services (TPL, sharing, etc.) and improve efficiency	“
DRT	<i>Target</i>	Implement DRT covering: 10% core urban area, 50% peripheral areas	“
Transport infrastructure			
Cycling network expansion	<i>Target</i>	0.6 km of bike lanes / 1,000 inhab.	Additional +30% increase
	<i>Km lanes</i>	298 → 825	
Bus network expansion	<i>Target</i>	90% of network with 4' average frequency	“
Tram network expansion	<i>Target</i>	80% of network with 5' average frequency	“
Metro network expansion	<i>Target</i>	Increase network by 10km	“
Park & Ride	<i>Target</i>	5 P&R spaces / 1,000 inhab. or +10% from base year	“
	<i>No. P&R spaces</i>	16,889 → 18,578	
Transport avoidance			
Working from home	<i>Target</i>	Reduce by 20% transport demand for working trips	“
Car-free days	<i>Target</i>	Establish 1 car-free day per month	Establish 1 car-free day per week
Pricing schemes			
Congestion and pollution charging	<i>Target</i>	5% of core urban area, €7.5 fixed fare (free for green vehicles)	“
Parking pricing	<i>Target</i>	Increase parking fee by 30% Reduce parking spaces to 2 / 10 inhab.	Triple parking fee
Public transport fare reduction	<i>Target</i>	Reduce by 20% fare for young people (<18) and the elderly (>65)	Reduce by 50% fare for young and elderly

Policy		Scenarios 1,2,3	Scenario 4
Traffic management and control			
Prioritizing PT	<i>Target</i>	Reserved lanes on 5% of network Prioritizing systems on 30% of network	Reserved lanes on 25% of network Prioritizing systems on 40% of network
	<i>Km reserved lanes</i>	35 → 90	
Limited traffic zones (LTZ)	<i>Target</i>	Passenger and freight LTZ covering: 20% core urban area, 5% peripheral areas	40% core urban area, 10% peripheral areas
	<i>% core urban</i>	0% → 20%	
Low emission zones (LEZ)	<i>Target</i>	LEZ covering 100% study area Passenger: banned up to EURO 5 (gasoline) and EURO 6 (diesel) Freight: banned up to EURO 6 (LDV & HDV)	Zero-emission zone covering 100% study area
	<i>% core urban (pax)</i>	100% → 100%	
Traffic calming	<i>Target</i>	30 km/h speed limit on: 85% core urban area, 30% peripheral areas	“
	<i>% core urban</i>	2% → 85%	
Pedestrian areas	<i>Target</i>	Pedestrian areas covering: 5% core urban area, 1% peripheral areas	“
	<i>% core urban</i>	1% → 5%	
Urban logistics			
Urban delivery centers	<i>Target</i>	25% increase of retail freights managed by delivery centers	“
Delivery and servicing plan	<i>Target</i>	Reduce by 10% (LDV) and by 5% (HDV) retail freight	“
Cargo bikes	<i>Target</i>	Share of carried freight: 5% (B2C), 0.5% (Retail)	“

Annex IV: Full results of the study





Milan

Greenhouse Gases Emissions from transport

GHG emissions (tank-to-wheel)

[kton CO₂ eq / year]

Scenario	2030
Base year	911
S01	412
S02	400
S03	362
S04	79
S01 - Diff base year	-54.8%
S02 - Diff base year	-56.1%
S03 - Diff base year	-60.3%
S04 - Diff base year	-91.3%

Per capita GHG emissions (tank-to-wheel)

[ton CO₂ eq / capita per year]

Scenario	2030
Base year	0.66
S01	0.28
S02	0.28
S03	0.25
S04	0.05
S01 - Diff base year	-57.2%
S02 - Diff base year	-58.4%
S03 - Diff base year	-62.4%
S04 - Diff base year	-91.8%

GHG emissions (well-to-wheel)

[kton CO₂ eq / year]

Scenario	2030
Base year	1,157
S01	590
S02	588
S03	541
S04	243
S01 - Diff base year	-49.0%
S02 - Diff base year	-49.2%
S03 - Diff base year	-53.2%
S04 - Diff base year	-79.0%

Per capita GHG emissions (well-to-wheel)

[ton CO₂ eq / capita per year]

Scenario	2030
Base year	0.84
S01	0.41
S02	0.40
S03	0.37
S04	0.17
S01 - Diff base year	-51.7%
S02 - Diff base year	-51.9%
S03 - Diff base year	-55.7%
S04 - Diff base year	-80.1%

GHG emissions by sector (tank-to-wheel)

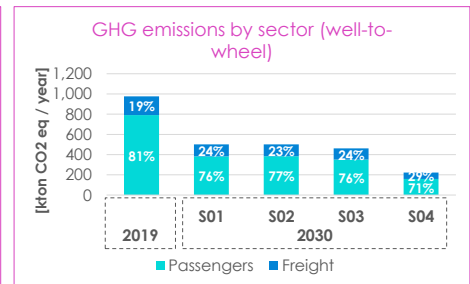
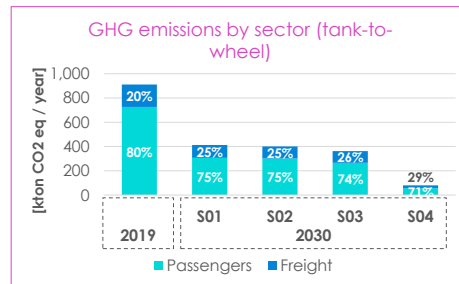
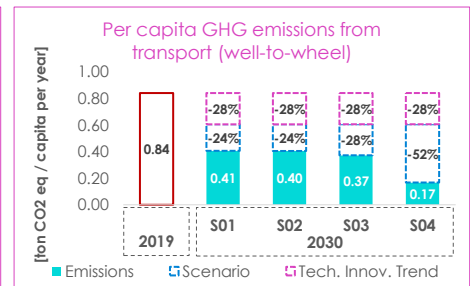
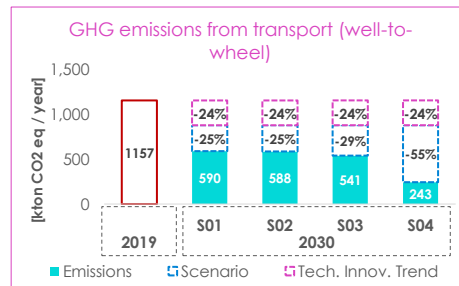
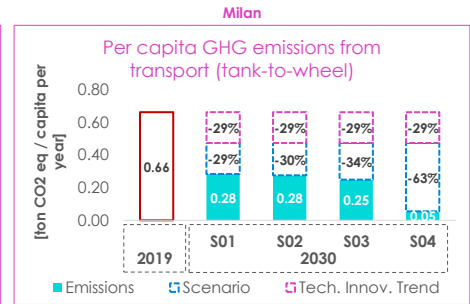
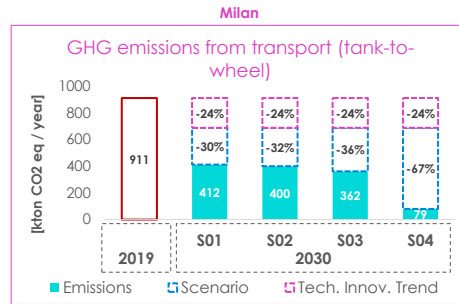
[kton CO₂ eq / year]

	2019	2030			
		S01	S02	S03	S04
Passengers	726	307	301	266	56
Freight	185	105	100	96	23
Passengers (%)	80%	75%	75%	74%	71%
Freight (%)	20%	25%	25%	26%	29%

GHG emissions by sector (well-to-wheel)

[kton CO₂ eq / year]

	2019	2030			
		S01	S02	S03	S04
Passengers	791	382	383	350	159
Freight	185	119	117	112	64
Passengers (%)	81%	76%	77%	76%	71%
Freight (%)	19%	24%	23%	24%	29%



Transport behaviour

Aggregated internal modal split based on pkm

[%]	2019	2030			
		S01	S02	S03	S04
Public Transport	57.9%	59.5%	57.6%	59.3%	64.1%
Private motorized	33.6%	26.6%	33.5%	26.9%	20.5%
Shared mobility*	0.7%	4.4%	0.7%	4.4%	4.5%
Bike	3.1%	4.5%	3.4%	4.4%	5.5%
Pedestrian	4.7%	5.0%	4.8%	5.0%	5.5%

Aggregated internal modal split based on trips

[%]	2019	2030			
		S01	S02	S03	S04
Public Transport	46.3%	47.1%	46.0%	47.0%	50.2%
Private motorized	31.0%	23.9%	30.6%	24.2%	18.2%
Shared mobility*	0.8%	4.5%	0.8%	4.4%	4.5%
Bike	4.4%	6.3%	4.8%	6.2%	7.6%
Pedestrian	17.5%	18.2%	17.8%	18.2%	19.5%

Car ownership level

[cars/1000 inhab]

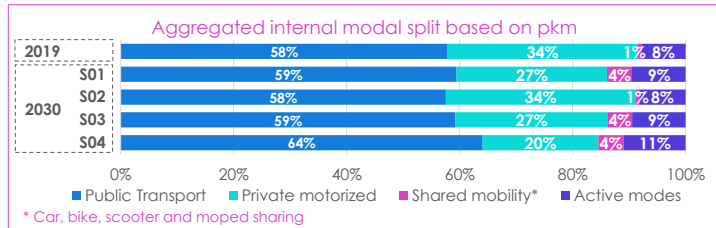
Scenario	2030
Base year	495
S01	445
S02	472
S03	445
S04	361
S01 - Diff base year	-10.2%
S02 - Diff base year	-4.7%
S03 - Diff base year	-10.1%
S04 - Diff base year	-27.1%

Private car vehicle-km*

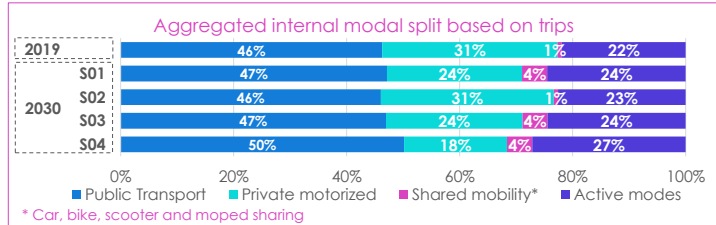
[million vkm/year]

Scenario	2030
Base year	3,387
S01	2,488
S02	2,756
S03	2,546
S04	1,633
S01 - Diff base year	-26.5%
S02 - Diff base year	-18.6%
S03 - Diff base year	-24.8%
S04 - Diff base year	-51.8%

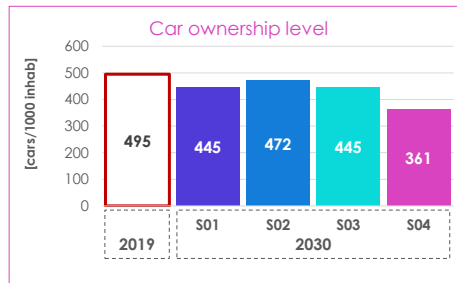
Milan



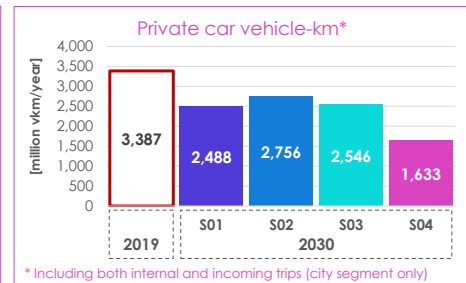
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Transport activity - Passenger

Total Passenger-km*

[million pkm/year]

Scenario	2030
Base year	12,711
S01	13,094
S02	13,244
S03	13,106
S04	13,005
S01 - Diff base year	3.0%
S02 - Diff base year	4.2%
S03 - Diff base year	3.1%
S04 - Diff base year	2.3%

Total travel time*

[million h / year]

Scenario	2030
Base year	646
S01	704
S02	669
S03	714
S04	712
S01 - Diff base year	9.0%
S02 - Diff base year	3.6%
S03 - Diff base year	10.6%
S04 - Diff base year	10.2%

Average travel time

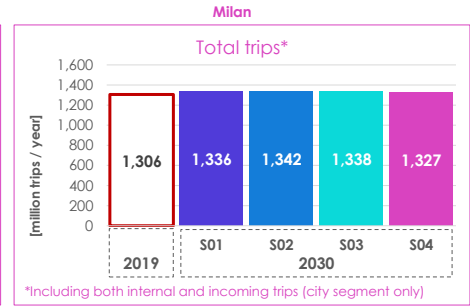
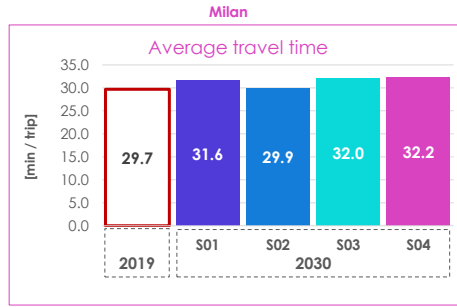
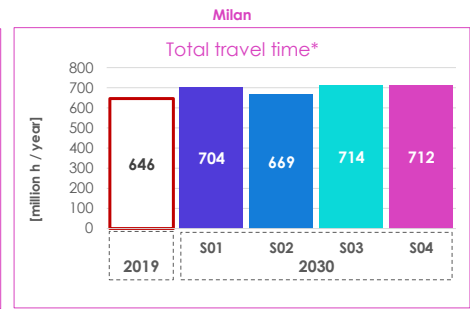
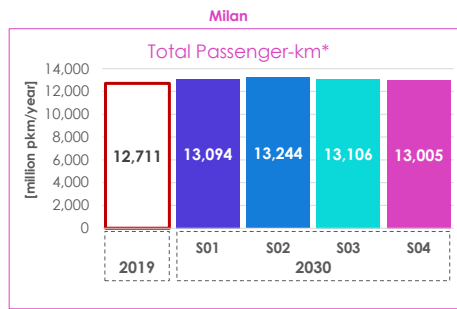
[min / trip]

Scenario	2030
Base year	29.7
S01	31.6
S02	29.9
S03	32.0
S04	32.2
S01 - Diff base year	6.5%
S02 - Diff base year	0.8%
S03 - Diff base year	7.9%
S04 - Diff base year	8.5%

Total trips*

[million trips / year]

Scenario	2030
Base year	1,306
S01	1,336
S02	1,342
S03	1,338
S04	1,327
S01 - Diff base year	2.3%
S02 - Diff base year	2.8%
S03 - Diff base year	2.5%
S04 - Diff base year	1.6%

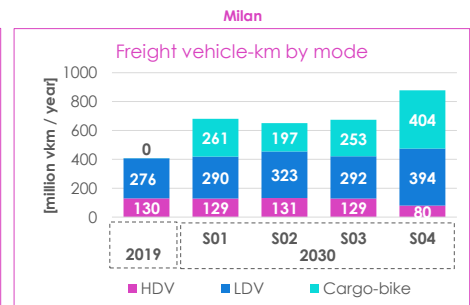
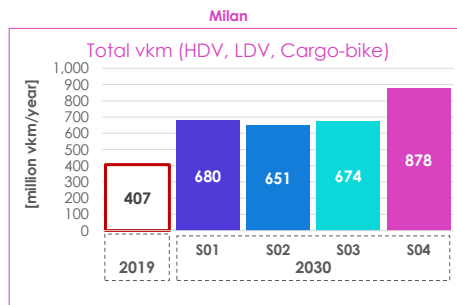


Transport activity - Freight

Total vkm (HDV, LDV, Cargo-bike)

[million vkm/year]

Scenario	2030
Base year	407
S01	680
S02	651
S03	674
S04	878
S01 - Diff base year	67.3%
S02 - Diff base year	60.1%
S03 - Diff base year	65.8%
S04 - Diff base year	115.9%



Vkm by mode

[million vkm / year]

	2019	2030			
		S01	S02	S03	S04
HDV	130	129	131	129	80
LDV	276	290	323	292	394
Cargo-bike	0	261	197	253	404



Electric vehicles uptake

EV uptake of private cars

Scenario		2030
Base year	PHEV	0%
Base year	BEV	0%
S01	PHEV	6%
S01	BEV	13%
S02	PHEV	7%
S02	BEV	20%
S03	PHEV	6%
S03	BEV	20%
S04	PHEV	15%
S04	BEV	39%

EV uptake of public buses

Scenario		2030
Base year	PHEV	2.3%
Base year	BEV	1.0%
S01	PHEV	2.1%
S01	BEV	97.9%
S02	PHEV	0.0%
S02	BEV	100.0%
S03	PHEV	0.0%
S03	BEV	100.0%
S04	PHEV	0.0%
S04	BEV	100.0%

EV uptake of freight vehicles (LDV)

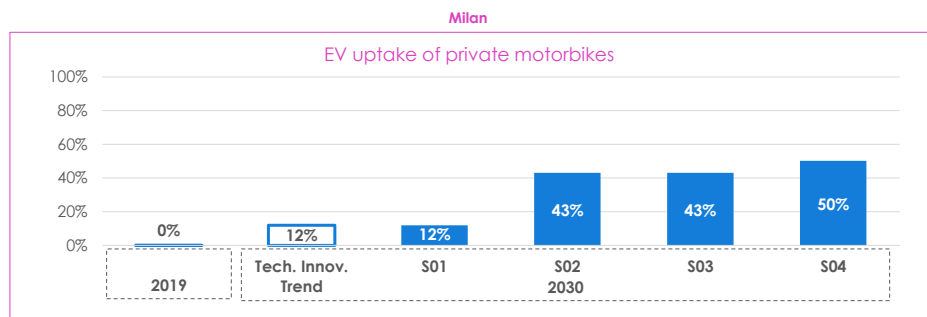
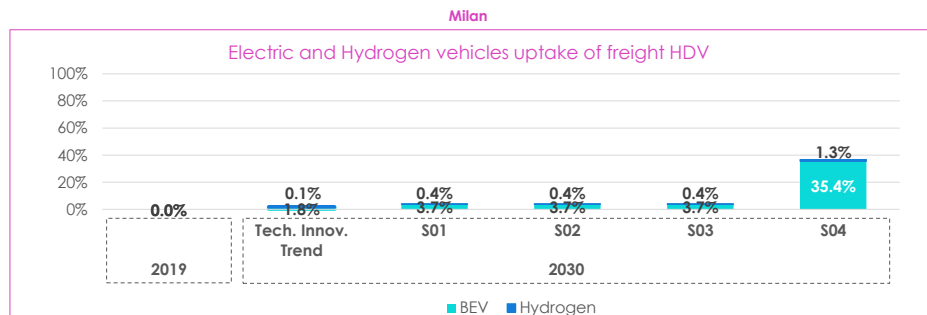
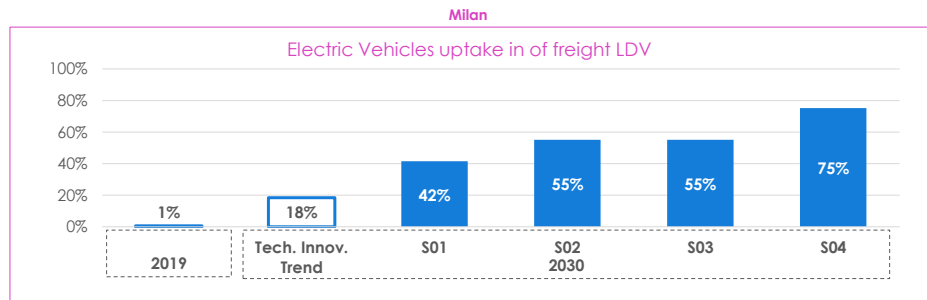
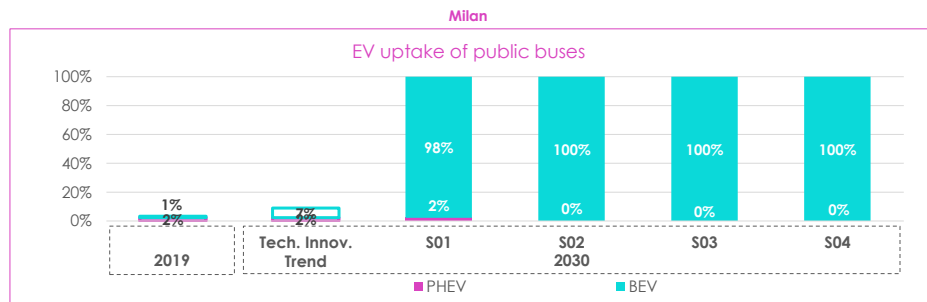
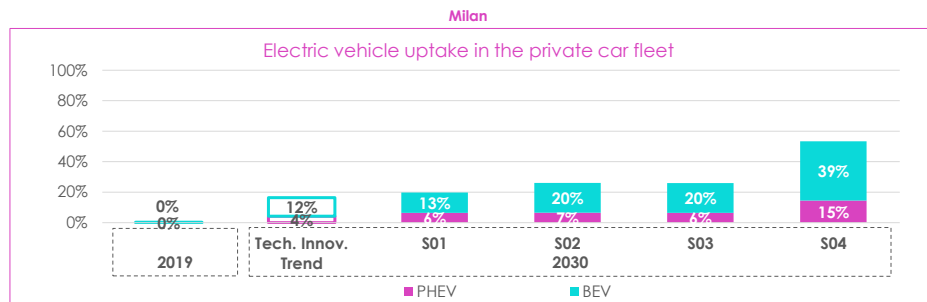
Scenario		2030
Base year	BEV	0.6%
S01	BEV	42%
S02	BEV	55%
S03	BEV	55%
S04	BEV	75%

EV uptake of freight vehicles (HDV)

Scenario		2030
Base year	BEV	0.0%
Base year	Hydrogen	0.0%
S01	BEV	3.7%
S01	Hydrogen	0.4%
S02	BEV	3.7%
S02	Hydrogen	0.4%
S03	BEV	3.7%
S03	Hydrogen	0.4%
S04	BEV	35.4%
S04	Hydrogen	1.3%

EV uptake of private motorbikes

Scenario		2030
Base year	BEV	0.1%
S01	BEV	12%
S02	BEV	43%
S03	BEV	43%
S04	BEV	50%

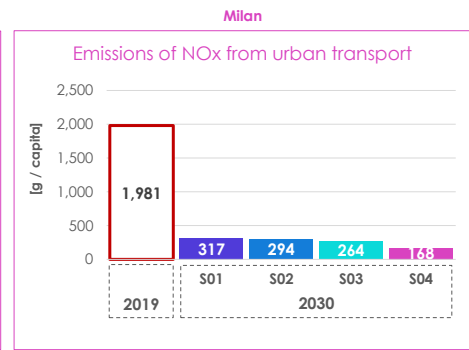
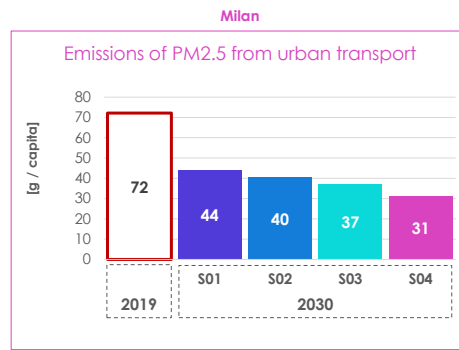


Air pollutant emissions from transport

Emissions of PM2.5 from urban transport

[g / capita]

Scenario	2030
Base year	72
S01	44
S02	40
S03	37
S04	31
S01 - Diff base year	-38.9%
S02 - Diff base year	-43.9%
S03 - Diff base year	-48.6%
S04 - Diff base year	-56.5%



Emissions of NOx from urban transport

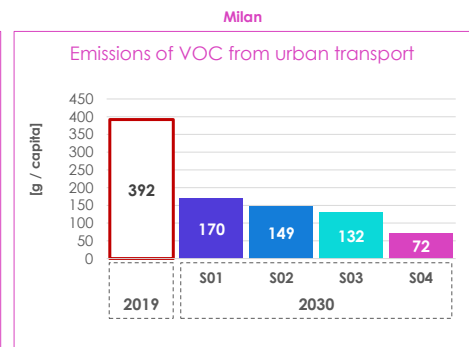
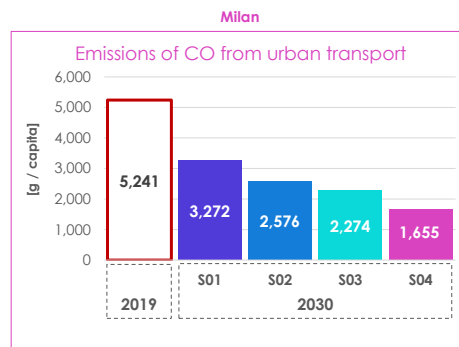
[g / capita]

Scenario	2030
Base year	1,981
S01	317
S02	294
S03	264
S04	168
S01 - Diff base year	-84.0%
S02 - Diff base year	-85.1%
S03 - Diff base year	-86.7%
S04 - Diff base year	-91.5%

Emissions of CO from urban transport

[g / capita]

Scenario	2030
Base year	5,241
S01	3,272
S02	2,576
S03	2,274
S04	1,655
S01 - Diff base year	-37.6%
S02 - Diff base year	-50.9%
S03 - Diff base year	-56.6%
S04 - Diff base year	-68.4%



Emissions of VOC from urban transport

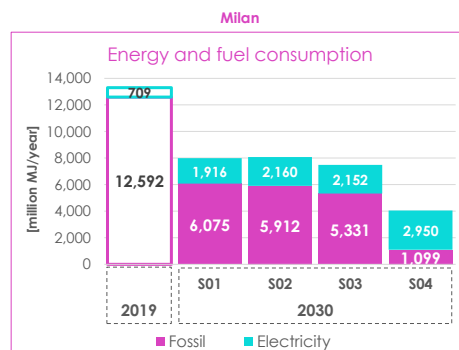
[g / capita]

Scenario	2030
Base year	392
S01	170
S02	149
S03	132
S04	72
S01 - Diff base year	-56.6%
S02 - Diff base year	-62.0%
S03 - Diff base year	-66.4%
S04 - Diff base year	-81.6%

Energy and fuel consumption

[million MJ/year]

Scenario	2030
Base year	13,301
S01	7,991
S02	8,073
S03	7,484
S04	4,049
S01 - Diff base year	-39.9%
S02 - Diff base year	-39.3%
S03 - Diff base year	-43.7%
S04 - Diff base year	-69.6%



Road Safety

Road traffic deaths

[deaths/100,000 inhab]

Scenario	2030
Base year	2.38
S01	1.26
S02	2.12
S03	1.24
S04	1.20
S01 - Diff base year	-46.9%
S02 - Diff base year	-10.6%
S03 - Diff base year	-47.8%
S04 - Diff base year	-49.3%

Road traffic injuries

[persons/100,000 inhab]

Scenario	2030
Base year	93.6
S01	44.1
S02	72.6
S03	43.8
S04	33.2
S01 - Diff base year	-52.9%
S02 - Diff base year	-22.5%
S03 - Diff base year	-53.2%
S04 - Diff base year	-64.5%

Road traffic deaths/pkm: All Modes

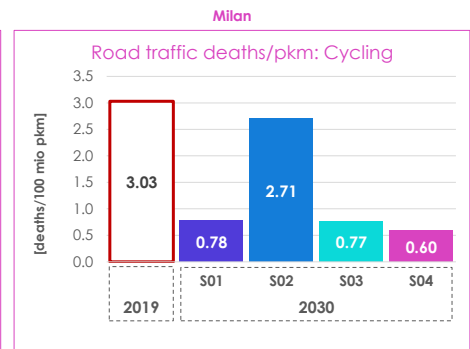
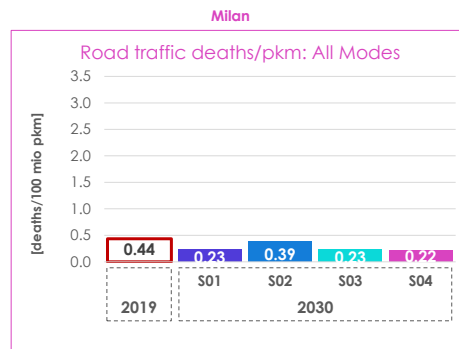
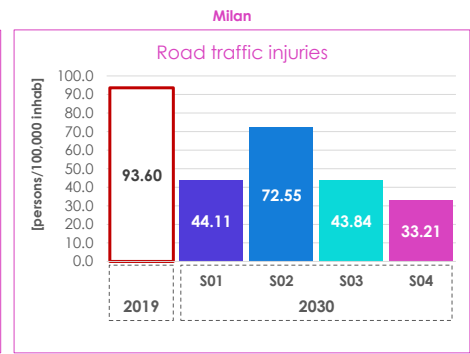
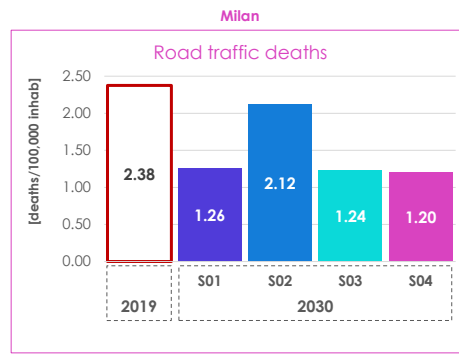
[deaths/100 mio pkm]

Scenario	2030
Base year	0.4
S01	0.2
S02	0.4
S03	0.2
S04	0.2
S01 - Diff base year	-46.9%
S02 - Diff base year	-11.2%
S03 - Diff base year	-47.7%
S04 - Diff base year	-49.2%

Road traffic deaths/pkm: Cycling

[deaths/100 mio pkm]

Scenario	2030
Base year	3.0
S01	0.8
S02	2.7
S03	0.8
S04	0.6
S01 - Diff base year	-74.1%
S02 - Diff base year	-10.7%
S03 - Diff base year	-74.7%
S04 - Diff base year	-80.4%



Economic analysis - City

All costs are cumulated (2019 - 2030), discounted (3%), and compared to Business-As-Usual scenario

Costs and revenues

[million euro]

	2019-2030			
	S01	S02	S03	S04
CITY costs	1,090	192	1,149	1,315
CITY revenues	525	518	521	1,040
USER costs	320	1,027	454	1,152
FREIGHT OPERATORS costs	479	640	547	622

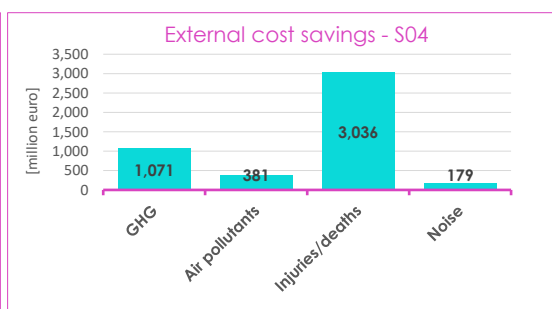
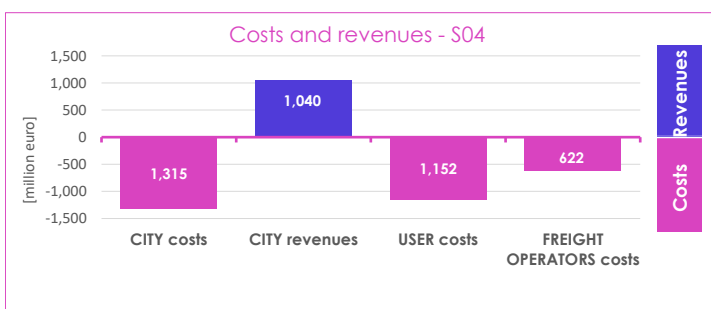
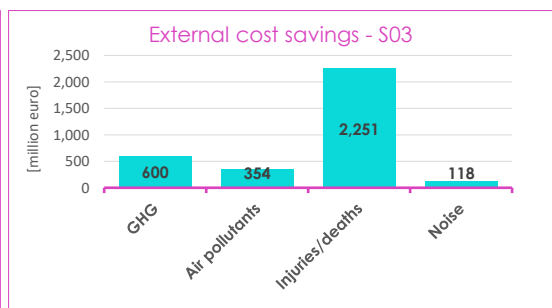
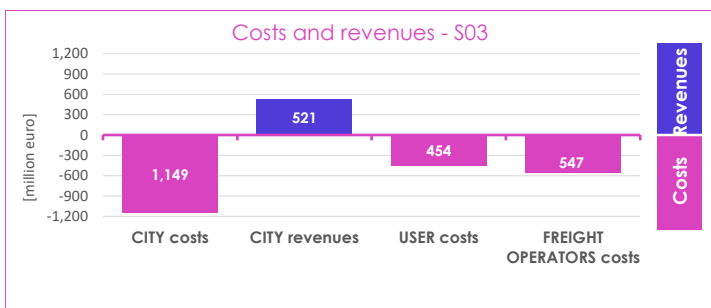
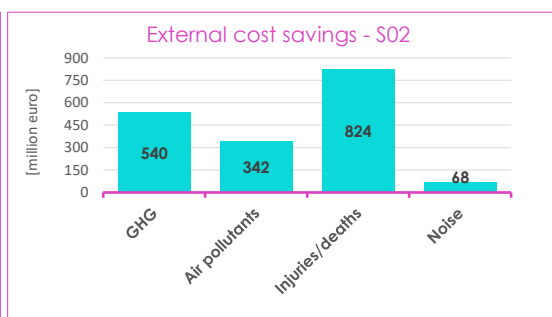
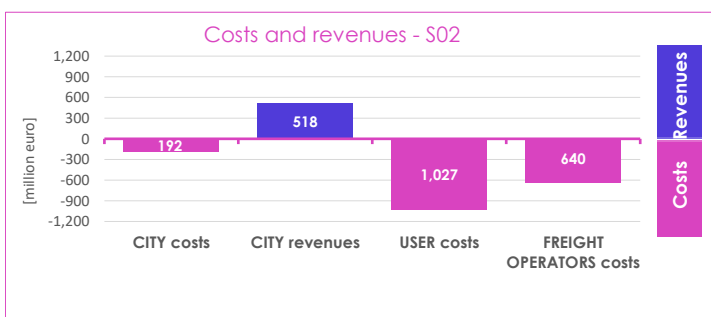
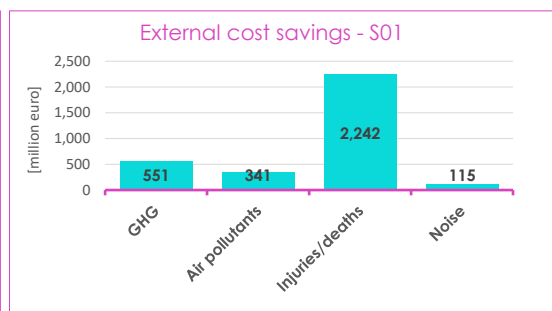
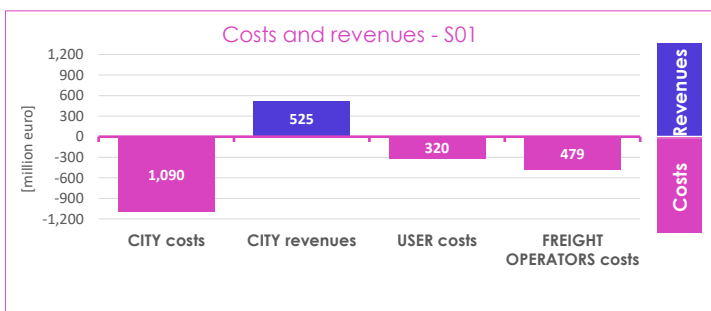
NET costs	1,365	1,342	1,629	2,050
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External cost savings

[million euro]

	2019-2030			
	S01	S02	S03	S04
GHG	551	540	600	1,071
Air pollutants	341	342	354	381
Injuries/deaths	2,242	824	2,251	3,036
Noise	115	68	118	179

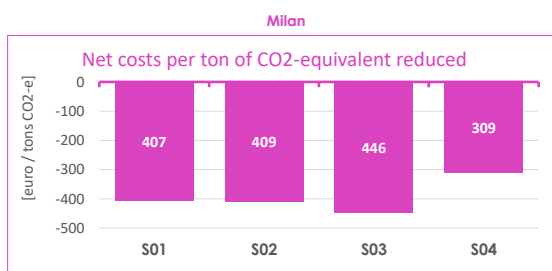
TOTAL savings	3,248	1,775	3,323	4,666
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Net costs per ton of CO2-equivalent reduced

[euro / tons CO2-e]

	2019-2030			
	S01	S02	S03	S04
TOTAL	407	409	446	309



Economic analysis - Per capita

All costs are cumulated (2019 - 2030), discounted (3%), and compared to Business-As-Usual scenario

Costs and revenues

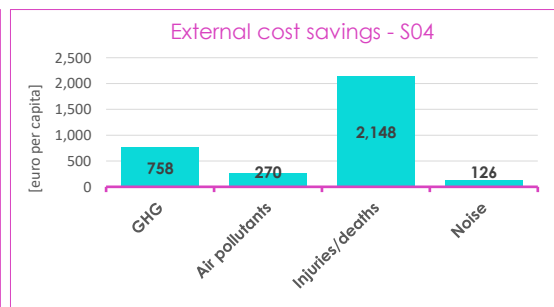
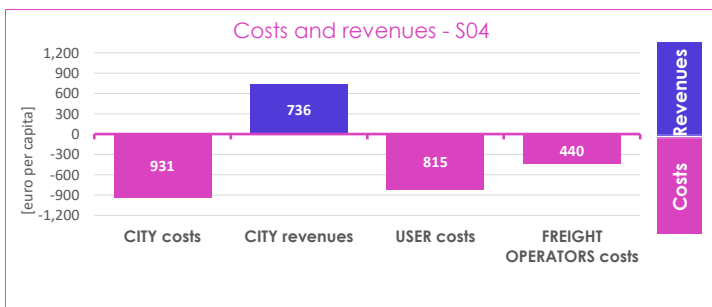
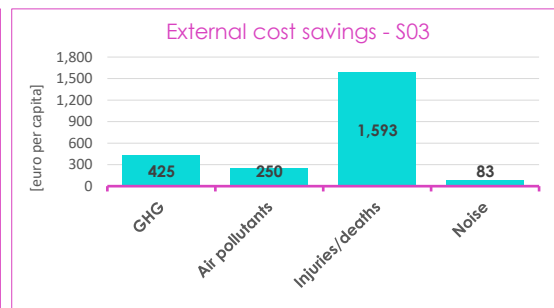
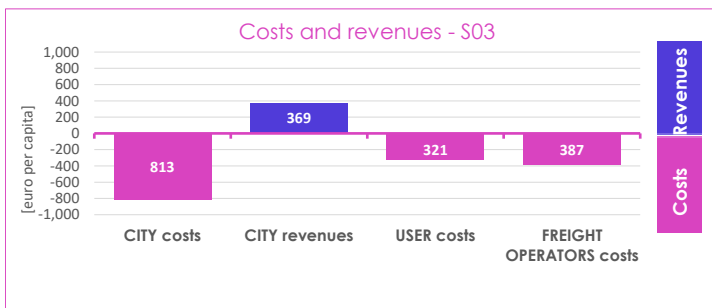
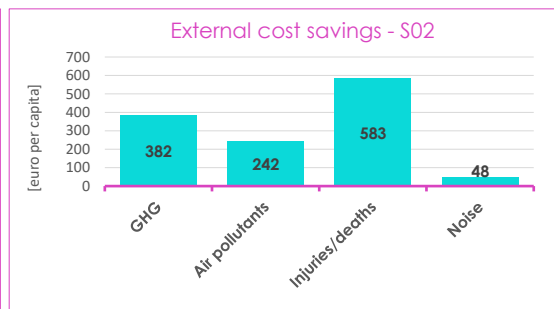
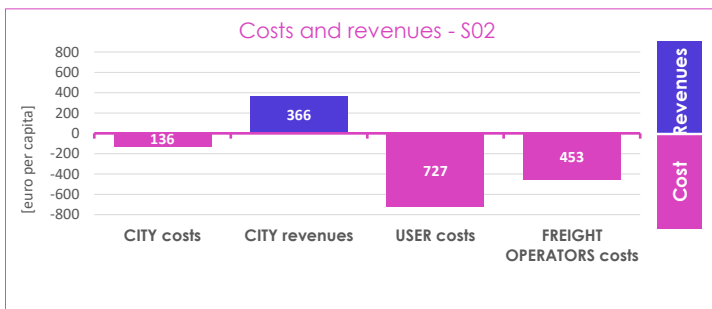
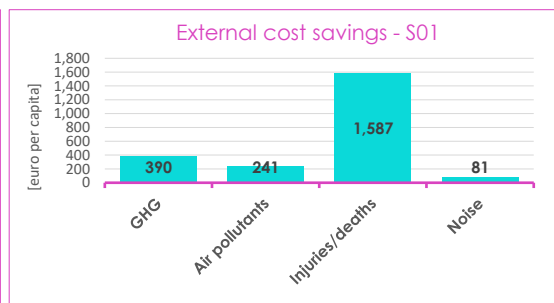
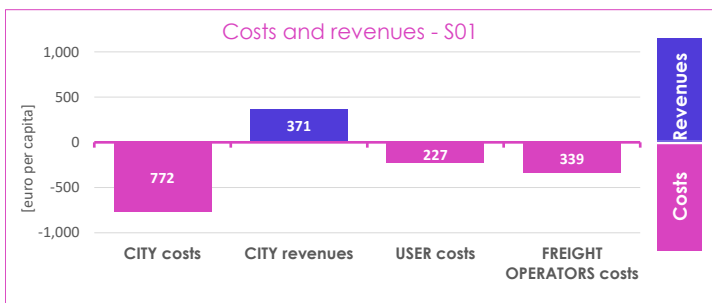
[euro per capita]

	2019-2030			
	S01	S02	S03	S04
CITY costs	772	136	813	931
CITY revenues	371	366	369	736
USER costs	227	727	321	815
FREIGHT OPERATORS costs	339	453	387	440
NET costs	966	950	1,153	1,451

External cost savings

[euro per capita]

	2019-2030			
	S01	S02	S03	S04
GHG	390	382	425	758
Air pollutants	241	242	250	270
Injuries/deaths	1,587	583	1,593	2,148
Noise	81	48	83	126
TOTAL savings	2,299	1,256	2,351	3,302



CleanCities

