Societal Challenge: Improving the air quality and reducing the carbon footprint of European cities

ICARUS

Project: 690105 – ICARUS

Full project title:

Integrated Climate forcing and Air Pollution Reduction in Urban Systems

D.5.4 Final report on integrated assessment of policies

WP5 Integrated assessment for short to medium term policies and measures

Lead beneficiary: JSI

Date: August 2019

Nature: Report

Dissemination level: Public

Document Information

Grant Agreement Number	690105	**Acronym**	ICARUS
Full title	Integrated Climate forcing and Air pollution Reduction in Urban Systems		
Project URL	www.icarus2020.eu		
Project Officer	Mirjam Witschke - Mirjam.WITSCHKE@ec.europa.eu		

Delivery date	**Contractual**	May 2019	**Actual**	August 2019
Status	Draft ☐		Final x	
Nature	Demonstrator ☐ Report x Prototype ☐ Other ☐			
Dissemination level	Confidential ☐ Public x			

Responsible Author (Partners)	JSI			
Responsible Author	**Name** Davor Kontic		**Email**	davor.kontic@ijs.si
	Partner	JSI	**Phone**	
Other partners (Institution)	AUTH, UNEXE, USTUTT, EUC			

Document History

Name (Institution)	Date	Version
JSI	February 2019	First Draft
AUTH	April 2019	Second Draft
USTUTT, JSI, UNEXE	June 2019	Third revision
AUTH, JSI, UNEXE, USTUTT, EUC	August 2019	Final

Table of contents

1 INTRODUCTION 6

2 OVERVIEW OF SELECTED MEASURES/SCENARIOS 9

3 EMISSION MODELLING 16

3.1 General methodology 16

3.2 Assumptions and emission reduction potentials for the selected policy scenarios . 21

3.2.1 Athens 21

3.2.2 Basel 28

3.2.3 Brno 32

3.2.4 Ljubljana 37

3.2.5 Madrid 42

3.2.6 Milan 48

3.2.7 Stuttgart 54

3.2.8 Thessaloniki 63

3.3 Emission reductions of greenhouse gases for the city scenarios 67

4 POLLUTION MODELLING 71

4.1 Objective 71

4.2 Methodology 71

4.3 Results 72

4.4 Conclusions 73

5 HEALTH IMPACT ASSESSMENT 75

5.1 Background 75

5.2 Methodology for calculating disease burden 78

5.3 Pollution exposure levels 80

5.4 Population data 80

5.5 Baseline rate of disease 81

5.6 Concentration-Response functions ... 81
5.7 Results ... 87
6 MONETARY VALUATION OF IMPACTS AND COST-BENEFIT ANALYSIS 91
6.1 Overview of cost-benefit analysis and cost-effectiveness analysis ... 91
6.2 Cost and benefit data ... 91
6.3 General assumptions and Monetary Valuation of Impacts ... 92
6.4 Calculations and results ... 94
6.4.1 Athens (greater region – Attica) ... 94
6.4.2 Basel ... 100
6.4.3 Brno ... 103
6.4.4 Ljubljana ... 109
6.4.5 Madrid ... 113
6.4.6 Milan ... 114
6.4.7 Stuttgart ... 119
6.4.8 Thessaloniki ... 129
6.5 Discussion on CBA results ... 133
7 ASSESSMENT OF POLICIES/MEASURES/SCENARIOS - DISCUSSION .. 135
7.1 Energy: buildings & households ... 137
7.2 Transport ... 143
7.2.1 Car-independent lifestyles ... 149
7.2.2 Alternative fuels and driving technologies ... 151
7.2.3 Efficient urban logistics ... 152
7.2.4 Demand and traffic management strategies ... 153
7.2.5 Enhanced environmental conscious behaviour in traffic ... 154
7.3 Industry ... 155
7.4 Waste management ... 156
7.5 Land use ... 157
7.6 Discussion ... 158

8 CONCLUSIONS ... 168

9 REFERENCES ... 170

ANNEX 1: DETAILED ASSUMPTIONS AND EMISSION REDUCTION POTENTIALS FOR THE SELECTED POLICY SCENARIOS ... 177

ANNEX 2: AIR POLLUTION MODELLING RESULTS ... 306

ANNEX 3: HEALTH IMPACT ASSESSMENT RESULTS (TABLES) ... 355

ANNEX 4: HEALTH IMPACT ASSESSMENT RESULTS (CHARTS) ... 400

ANNEX 5: Targeted WRF and WRF/Chem Validation Present Studies ... 456

1 INTRODUCTION

This deliverable presents the core of the work performed within the WP5 - Integrated assessment for short to medium term policies and measures. The aim is to present the results of air quality improvements on environment, health and climate change brought by the potential implementation selected measures and policy options (as identified within the work in T5.1 and D5.2- Two databases of a) policies and b) measures towards integrated win-win solutions on the urban scale (measure/policy combinations) in an integrated manner, therefore, for each of the selected measure/policy, the following effects/impacts have been evaluated:

- Change in emissions of air pollutants including life cycle emissions in/outside cities for selected activities.
- Change in emissions of greenhouse gases including life cycle emissions in/outside city (thus changes in the carbon footprint caused by changes in sectorial activities).
- Changes in ambient concentration of air pollutants and greenhouse gases.
- Changes in the exposure to air pollutants taking into account important indoor sources.
- Changes in the associated impacts on human health.
- Societal and economic impacts, including costs for the emission source operator and for other actors of society, including health impacts, time losses or gains and wider impacts.

This process is outlined in the diagram below (Figure 1):

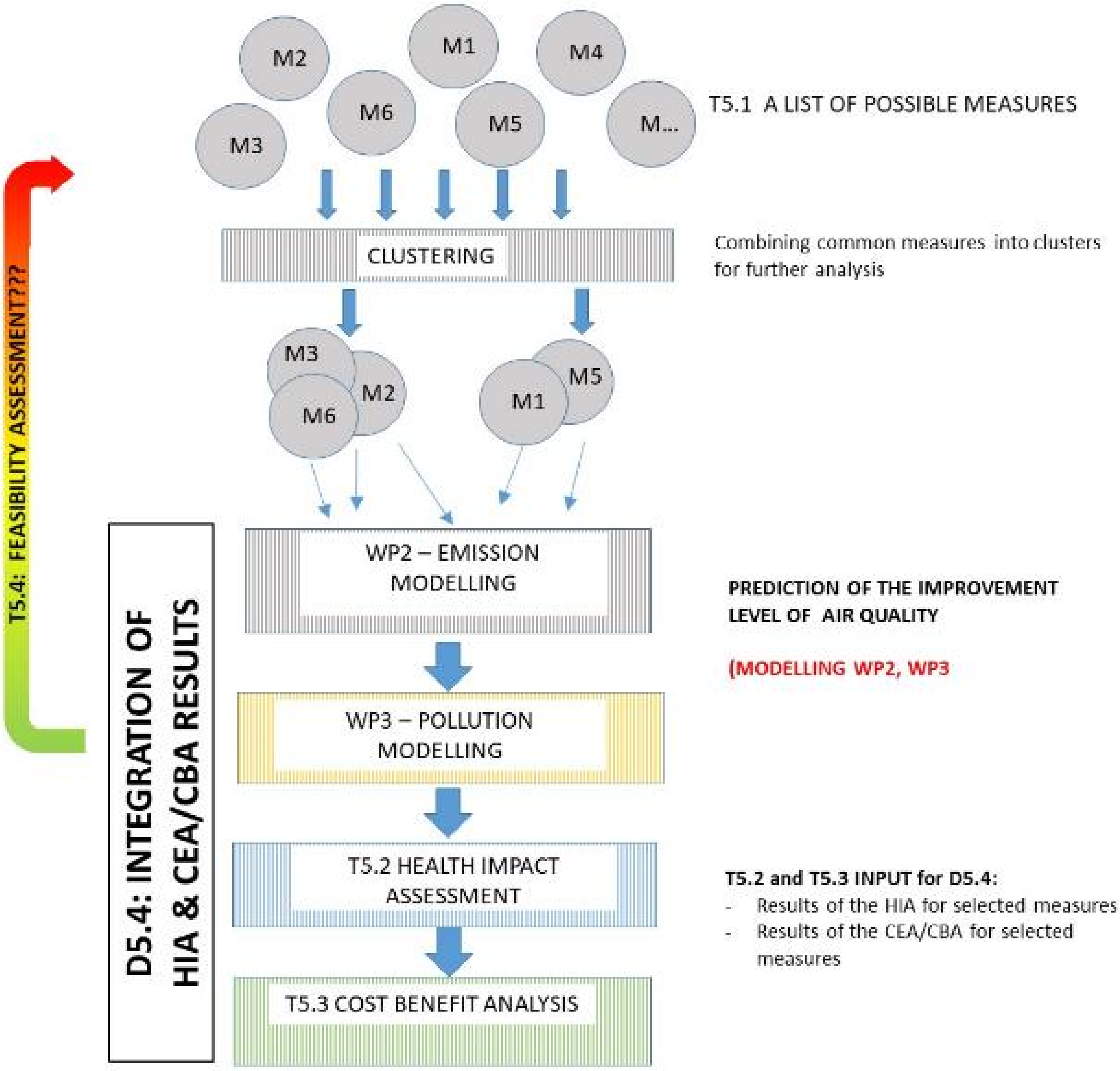


Figure 1: Schematic representation of the D5.4 concept and related work

The organization of the report also follows this structure; after the introductory chapter the Chapter 2 is dedicated to the presentation of the selected measures/policy scenarios which have been previously filtered down from a list of all possible measures (for details, please refer to the ICARUS deliverable D5.2 – "Two databases of a) policies and b) measures towards integrated win-win solutions on the urban scale"). Chapter 3 includes the work related to the modelling of emissions as suggested by the measures/policy scenarios. The chapter also includes the summary of the measure/policy scenario descriptions along with the presentation of the inputs and assumptions for emission reduction potential calculation.

Based on these calculations air pollution models for ICARUS cities are presented taking into consideration the climatic trends of the selected measures/policy scenarios in the long-term aspect (chapter 4). Following these results, a health impact assessment study has been conducted of which results are presented in Chapter 5. Chapter 6 consists of the monetary evaluation and Cost-Benefit Analysis and specifically takes into account the air pollution as well as the GHG on health and the environment. Chapter 7 summarises the findings of previous chapters in a form of an integrated policy assessment and provides a synthesis in terms of a decision-making support for the considered policy areas. Chapter 8 is dedicated to the conclusions and suggestions for future work in these fields.

2 OVERVIEW OF SELECTED MEASURES/SCENARIOS

This section provides an overview of urban policy scenarios chosen for the integrated assessment and further evaluation in ICARUS.

The total number of analysed policy scenarios is 40, with approximately 5 measure scenarios for each ICARUS city. The respective scenarios have been selected out of the policy and measure list as presented and described in Deliverable 5.2 – two databases of policies and measures at the city level. The policies and measures underlying the scenarios cover a wide range of possible abatement options for different emission source sectors.

More than half of the chosen policy scenarios are associated to the transport sector (23 out of 40). The most recurrent themes are:

- Reduction of motorized individual transportation by measures like
  - Promotion of a switch from road transportation to more environmentally friendly transportation modes like public transportation, walking and cycling
  - Introduction of new metro lines and further public transport infrastructure expansion
  - Reserved infrastructure for public transportation and dedicated bus lanes
  - Construction of metropolitan bike lanes
  - New parking regulations according to air quality criteria
- Introduction of Low Emission Zones and driving bans
- Increasing electrification of the urban fleet
- Renovation of the public passenger transport vehicle fleet (CNG, hybrid or electric buses)

Traffic reductions and sustainable transportation modes have been selected for further evaluation in all cities. A scenario representing the increasing electrification of the urban fleet – either private vehicles or urban buses – has been selected in Brno, Thessaloniki, Stuttgart, Ljubljana and Milan. The introduction of a Low Emission Zone has been chosen for further analysis in Stuttgart, Milan and Madrid – even though the specific design of the measure varies from city to city.

Apart from these major themes and strategies, actions with a specific relevance or interest have been analysed for selected cities. In Basel a scenario has been chosen that envisions the conversion of the shipping fleet to zero emission ships as the port areas contribute a considerable amount to the total city emissions. A scenario in Athens supporting walking and cycling simultaneously considers the promotion of eco-driving behaviour, whereas in Madrid one scenario is associated to a public-private collaboration in order to make urban logistics processes more efficient.

The scenarios of the transport sector are followed by the residential sector (in combination with the industrial sector) with more than one quarter of selected scenarios (12 out of 40). The most recurrent themes are:

- Replacement of fossil heating technologies by technologies like
  - High efficiency gas boilers
  - Heat pumps and solar heating
- Implementation of energy saving measures by insulation and renovation of the building stock
- Green infrastructure and bioclimatic design of buildings and neighbourhoods

The replacement of fossil heating technologies is analysed in the cities of Basel, Brno and Stuttgart. The implementation of energy saving measures by insulation and renovation of the building stock is chosen for evaluation in Brno, Stuttgart, Ljubljana, Milan, Athens. Promotion of building insulation accompanied by the implementation of green infrastructure is analysed in Madrid and Thessaloniki. Furthermore, one scenario in Basel deals with a hypothetical ban on small combustion of firewood, whereas one specific scenario concerning the conversion of residencies to nearly zero energy buildings has been analysed for the City of Athens.

The selected scenarios associated to the industrial sector are the reduction of biodegradable and recyclable waste in landfills in Thessaloniki and Athens as well as the use of refused derived fuels in Thessaloniki's cement industry (3 out of 40).

Two scenarios addressing the energy sector, or a combination of residential and energy sector, consider an increase of district heating systems and the replacement of existing coal combustion units for its generation (Milan and Ljubljana). Finally, one measure in Milan focuses on the urban greening and therefore causes an emission removal that cannot be assigned to one specific sector.

The policy scenarios with acronyms and short descriptions are briefly presented in Table 1. A more detailed description as well as a presentation of underlying assumptions for the modelling of the respective scenarios can be found in section 3.

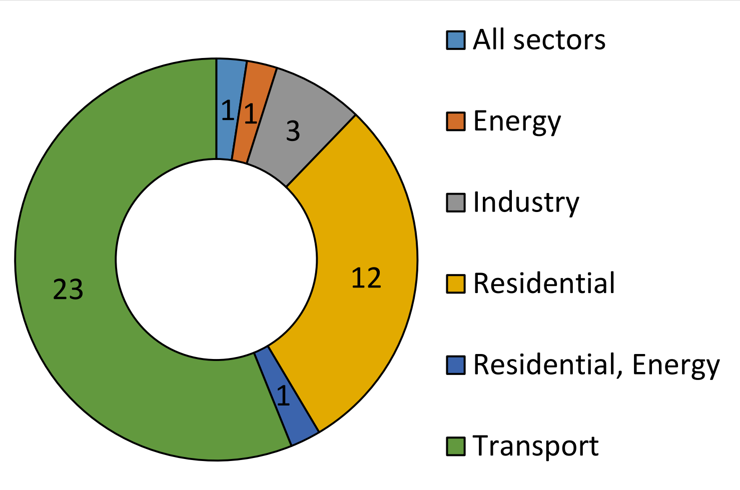


Figure 2: Emission source sectors of selected policy scenarios

Table 2-1: A Description of the city scenarios

CITY	SCENARIO NAME	SCENARIO DESCRIPTION
Athens (Attica)	BAU	Baseline scenario
	SusMob	Promotion of sustainable mobility through eco - driving. cycling and walking in the Greater Athens Area (Attica)
	SusMobPuT	Promotion of sustainable mobility through eco - driving. cycling and walking in the Greater Athens Area (Attica) as well as minimizing the use of private passenger cars in Athens metropolitan area by enhancing public transportation means
	EnEff	Increase of energy efficiency and renewable energy sources at residential and commercial buildings in the Greater Athens Area (Attica)
	EnEffZEB	Increase of energy efficiency and renewable energy sources at residential and commercial buildings in the Greater Athens Area (Attica) as well as additional promotion of Zero Energy Buildings in the City of Athens
	Waste	Reduction of Biodegradable and Recyclable waste going to landfill through the implementation of Green Points and Recycling & Training Centres for waste separation and pre - sorting

Basel	Basic	Baseline scenario
	NoHeat	Replacement of fossil heating technologies by heating pumps and solar heating (until 2020: 1/3 will be replaced; until 2030:100%)
	Traffic10	Introducing a traffic reduction law leads to a reduction of the traffic load by 10% in 2020 and 2030 compared to the baseline scenario
	FirewoodBan	Introduction of a ban on small combustion of firewood (2030 scenario)
	NoHeatFirewood	Replacement of fossil heating technologies combined with the introduction of a firewood ban (2030 scenario)
	ZeroEmissionShips	Conversion of the shipping fleet to zero emission ships by 2030 (2030 scenario)
Brno	BAU	Baseline scenario
	M1opti	Promoting low carbon electric vehicles
	M2opti	Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking. biking and using public transport)
	M2zero	Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking. biking and using public transport)
	M3slow	Switch of combustion techniques in residential and municipal buildings: Replacement of old coal - fired boilers in residential sector
	M4econ	Implementation of energy saving measures by insulation and renovation of the building stock
Ljubljana	BAU	Baseline scenario
	M1_DecreaseCAR	Decrease of personal car use (the combination of the car reduction measures and parking policy will lead to a decrease of personal cars on incoming roads/avenues by 20 %); specifically the promotion of electromobility is planned to result in an additional 2% of emission reduction (M1) (2030 scenario)

	M2_IncreasePT	Increased share of public transport use (increased use of PT on the account of better service and transfer from car users) (The renovation of the public passenger transport fleet and the reduction of personal car use is also integrated in this scenario) (2030 scenario)
	M3_PTfleet	Renovation of public passenger transport vehicle fleet (CNG. hybrid buses); the replacement of EURO 0.1.2 buses with CNG propulsion system (86 buses in total) (The reduction of personal car use is also integrated in this scenario. but no increase of public transport is assumed) (2030 scenario)
	M4_DistrHEAT	Increased utilization and expansion of district heating systems; renovation of the system - replacement of existing combustion units with more appropriate means (i.e. 70% reduction of coal use) (2030 scenario)
	M5_EfficientHEAT	More efficient use of domestic heating; decrease of fuel consumption by 15% by 2030) (2030 scenario)
Madrid	BAU_V2	Baseline scenario
	EnEf	Regeneration of neighbourhoods by improving energy efficiency and thermal insulation of the building stock and re - naturalization of the city
	Log	Public - private collaboration in order to make urban logistics processes more efficient
	Park	Parking regulation according to air quality criteria through an increase of discounts and penalties according to vehicle's emissions and new regulation systems
	PuT	Reserved infrastructure for public transport (extra bus and high occupancy vehicle lanes) connecting with modal interchange points such as park - and - ride car parks
	ZEZ	Delimitation of a closed Central Zone (Zero Emissions Central Area) with restricted access in which through traffic will be banned.
Milan	BAU_V2	Baseline scenario
	AREA B	Low Emission Zone (Area B): Control and tracking of access into the city by banning up to Euro 3 diesel cars (up to Euro 4

		from October 2019)
	ELECTRIC BUS	Conversion of all public buses to electric ones by 2030
	BUILDINGS	Improvement of energy efficiency in existing and new residential flats
	ENERGY	Incentive measures of new building regulation promote the use of photovoltaic solar power for buildings
	TREES	Increasing the green area and planting over 3 million new trees by 2030
Stuttgart	BAUv2	Baseline scenario
	FvH	Introduction of hardware update of diesel passenger cars and driving ban on diesel PC<Euro6 in the city centre
	Sc1	Increase of building insulation (+2%) and heating system exchange to high efficiency gas boilers
	ScEL	Promoting low carbon electric vehicles (share in vkm to 7% in 2020. 20% in 2030)
	ScUV	Promoting environmentally friendly transport modes (walking. cycling. PT) (decrease of individual transport by 7% in 2020; 20% in 2030) (2030 scenario)
Thessaloniki	M1	Promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings
	M2A	Promotion of cycling and walking. The measure foresees the construction of a metropolitan bike lane network and the expansion of the already existing one to increase the cycling and walking in the city.
	M2B	Promotion of green vehicles. Shifting to cleaner energy practices in Transport is important to the City of Thessaloniki. The Municipalities of Thessaloniki Regional Unit will proceed to the gradual replacement of all the old municipal vehicles with new electric ones. The measure additionally foresees the replacement of private passenger cars due to further incentives.
	M2C	Promotion of public transport and the use of metro by building an integrated urban mobility system. The introduction and operation of underground railway (Metro) is

		expected to change significantly the transportation mode in the city of Thessaloniki. The measure focuses on the establishment of an integrated urban mobility system and the promotion of public transport.
	M3	Promotion of eco-friendly waste management
	M4	Energy efficiency in the cement industry: Use of refuse derived fuels

3 EMISSION MODELLING

3.1 General methodology

The development of emission scenarios – baseline and policy scenarios – is generally based on activity-emission-factor-databases comprising all major anthropogenic emission sources for each city. The general approach follows the EMEP/EEA Air pollution emission inventory guidebook (EMEP/EEA, 2016). Basically, emissions of different species are estimated by multiplying respective activity levels with appropriate activity-specific emission factors. The development of the baseline emission scenarios is described in detail in ICARUS Deliverable 2.1 and 2.2. For each policy scenario the following steps have been made to predict the emission reduction potential and therefore generate new emission inventories/scenarios that can be compared against the business as usual scenario:

1. Description of mitigation measures for each scenario
    - Here, the underlying policy assumptions for each scenario are described based on existing plans and concepts or completely new ideas and targets for the city.
2. Identification of measure or scenario applicability
    - Defining the investigation area and modelling domain: The investigation area and modelling domain generally comprises the whole city area as described in ICARUS D2.2. The measure applicability depends on the specific design as a regional measure or a local measure which is only applied to specific city zones within the investigation area/city area.
    - Defining the investigation period: The investigation period is based on the year of the policy introduction and the respective measure duration. A possible tightening of the measure during the investigation period needs to be listed in the scenario description (1) and taken into account in the subsequent steps (3-5).
3. Identification of all affected sectors
    - Description of affected NFR09 sectors for comparability of scenarios and easy application to the emission inventories developed in ICARUS WP2
4. Identification and determination of scenario and modelling assumptions for each year, spatial area (step 2) and sector (step 3)

- Determination of the implementation potential for each affected activity per NFR sector based on willingness for behavioural change, technology uptake, compliance with regulations etc.
- Determination of the mitigation potential for each affected activity per NFR sector; either the activity level or the respective emission factor can be affected)
  - Defining the change in activity level
  - Defining the change in emission factor
- Description of further assumptions, e.g. interferences between measures or the effect on other (life cycle) sectors

5. Calculation of the emission reduction potential
   - The emission reduction potential is calculated for each NFR code (affected sector), year (milestone years 2020 and 2030) and each grid element within the modelling domain.

Based on the information above, emission reduction potentials can be estimated per NFR code, year and affected area within the modelling domain. Table 2 shows the sectors and their description (NFR09 Longname) for which the emission reduction potential has been generated; it follows the same structure as the activity emission factor databases. The emission reduction potential for each policy can be found in the dedicated description section.

Table 3-1: Sectors and description

Macrosectors for the air quality modelling	NFR09 Code (Sector structure of the emission inventories)	NFR09 Longname
Energy	1 A 1 a	Public electricity and heat production
	1 A 1 b	Petroleum refining
	1 A 1 c	Manufacture of solid fuels and other energy industries
Industry	1 A 2 a	Stationary combustion in manufacturing industries and construction: Iron and steel
	1 A 2 b	Stationary Combustion in manufacturing industries and construction: Non-ferrous metals
	1 A 2 c	Stationary combustion in manufacturing industries and construction: Chemicals
	1 A 2 d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print

	1 A 2 e	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco
	1 A 2 f i	Stationary combustion in manufacturing industries and construction: Other
	1 A 2 f ii	Mobile Combustion in manufacturing industries and construction
Transport	1 A 3 a ii (i)	Civil aviation (Domestic, LTO)
	1 A 3 a i (i)	International aviation (LTO)
	1 A 3 b i	Road transport: Passenger cars
	1 A 3 b ii	Road transport: Light duty vehicles
	1 A 3 b iii	Road transport: Heavy duty vehicles
	1 A 3 b iv	Road transport: Mopeds & motorcycles
	1 A 3 b v	Road transport: Gasoline evaporation
	1 A 3 b vi	Road transport: Automobile tyre and brake wear
	1 A 3 b vii	Road transport: Automobile road abrasion
	1 A 3 c	Railways
	1 A 3 d ii	National navigation (Shipping)
Residential	1 A 4 a i	Commercial / institutional: Stationary
	1 A 4 a ii	Commercial / institutional: Mobile
	1 A 4 b i	Residential: Stationary plants
	1 A 4 b ii	Residential: Household and gardening (mobile)
	1 A 4 c i	Agriculture/Forestry/Fishing: Stationary
	1 A 4 c ii	Agriculture/Forestry/Fishing: Off-road vehicles and other machinery
	1 A 5 a	Other stationary (including military)
	1 A 5 b	Other, Mobile (including military, land based and recreational boats)
Energy	1 B 1 a	Fugitive emission from solid fuels: Coal mining and handling
	1 B 1 b	Fugitive emission from solid fuels: Solid fuel transformation
	1 B 2 a i	Exploration, production, transport
	1 B 2 a iv	Refining / storage
	1 B 2 a v	Distribution of oil products
	1 B 2 b	Natural gas
	1 B 2 c	Venting and flaring
Industry	2 A 1	Cement production
	2 A 2	Lime production
	2 A 7 a	Quarrying and mining of minerals other than coal
	2 A 7 b	Construction and demolition
	2 A 7 c	Storage, handling and transport of mineral products

	2 B 1	Ammonia production
	2 B 2	Nitric acid production
	2 B 3	Adipic acid production
	2 B 4	Carbide production
	2 B 5 a	Other chemical industry
	2 B 5 b	Storage, handling and transport of chemical products
	2 C 1	Iron and steel production
	2 C 2	Ferroalloys production
	2 C 3	Aluminium production
	2 C 5 a	Copper production
	2 C 5 b	Lead production
	2 C 5 c	Nickel production
	2 C 5 d	Zinc production
	2 C 5 e	Other metal production
	2 D 1	Pulp and paper
	2 D 2	Food and drink
	2 D 3	Wood processing
Industry	3 A 1	Decorative coating application
	3 A 2	Industrial coating application
	3 B 1	Degreasing
	3 B 2	Dry cleaning
	3 C	Chemical products
	3 D 1	Printing
Residential	3 D 2	Domestic solvent use including fungicides
	3 D 3	Other product use
Industry	6 A	Solid waste disposal on land
	6 B	Waste-water handling
	6 B 1	Industrial Wastewater
	6 B 2	Domestic and Commercial Wastewater
	6 C a	Clinical waste incineration (d)
	6 C b	Industrial waste incineration (d)
	6 C c	Municipal waste incineration (d)
	6 C e	Small scale waste burning
	6 D	Other waste(e)

The application of the emission reduction potential on the respective sector, year and affected area leads to the generation of new emission projections for these characteristics. A combination of baseline emissions for unaffected sectors/years and the newly generated emissions for affected sectors/years results in complete emission scenarios for each policy. The emission scenarios then serve as input into the atmospheric modelling (air pollution modelling in WP3). The results at the city level comprising emissions of all source sectors (i.e. the complete list of NFR sectors shown above) can be found in the results section of the emission modelling part of this report. Here the changes in air pollutant emissions at the city level are presented contrary to the emission reduction potential at the sectoral level which is shown in the policy description section. Additionally, using the newly generated emission inventories, absolute reductions of greenhouse gases have been estimated. Therefore, the emissions of the policy scenario have been subtracted from the baseline emission inventory of the respective milestone year.

The modelling domain for the estimation of the emission reduction potential is generally the whole city area as described in D2.2 (Table 3). Whenever measures just apply on a locally restricted area within the city, the emission reduction potential is estimated for this area. The new emission inventory then consists of an area with modified emissions (area of measure application) and an area with unmodified baseline emissions. The spatial scale of the measure is described for each policy scenario under “applicability > city zones”.

Table 3-2: Emission modelling domain

City	Country	Country code	NUTS3 2006 code	Selected city level
Athens	Greece	GR	GR300	Athens region
Basel	Switzerland	CH	CH031	Canton Basel-Stadt
Brno	Czech Republic	CZ	CZ064	Brno-město region
Copenhagen	Denmark	DK	DK011	City of Copenhagen
Ljubljana	Slovenia	SI	SI021	Municipality of Ljubljana
Madrid	Spain	ES	ES300	City of Madrid
Milan	Italy	IT	ITC45	City of Milan
Stuttgart	Germany	DE	DE111	City of Stuttgart
Thessaloniki	Greece	GR	GR122	Thessaloniki region (14 municipalities)

The general methodology for generating activity-emission factor databases and baseline emission projections as well as underlying uncertainties can be found in D2.1 and D2.2. The

"Background document on the emissions needs at local scale" provided by FAIRMODE gives basic recommendations for urban baseline and policy emission projections (Lumbreras et al. 2011). In summary, to limit the uncertainty of the urban (baseline) emission inventories several guidelines have been followed:

- Emission estimates have been based on sound emission factor databases which are accepted and well documented.
- The activity data comes preferably from official, well-documented statistics; hereby emission measurements or facility-specific statistics have been preferred (bottom up data is preferably used instead of top down data).
- In case one more inventories exist for a specific urban area, a comparison has been made in order to understand the uncertainty sources (i.e. scope of the inventories, basic statistics used, methodological approaches used). City emission inventories have been, whenever possible, compared against official inventories at the local scale (Stuttgart, Madrid, Milan, Basel) or existing other studies (Ljubljana, Brno).
- Generally, emission projections have been developed meeting the same standards (methods/models used) as the reference year.

In summary, policy and measure scenarios have been simulated as accurately as possible highlighting critical hypotheses and parameters for each scenario. In the following section the underlying assumptions are described for all cities and scenarios as well as results in terms of emission reduction potentials are presented.

3.2 Assumptions and emission reduction potentials for the selected policy scenarios

In the following section descriptions of selected measures/policy scenarios are presented with along with the assumptions for emission reduction potential calculations; detailed information and related data are presented in Annex 1.

3.2.1 Athens

3.2.1.1 Policy scenario 1 - SusMob

Promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica)

Description of the scenario

This scenario considers the promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica).

The scenario relates to the policy for supporting the transition to a low-carbon economy in all sectors of the Regional Operational Program (ROP) Attica 2014-2020 and several municipalities of Attica Region have already included this measure in their Sustainable Energy Action Plans (SEAP). The measure focuses on training, informing and sensitizing the citizens in:

1. Promoting cycling and walking: promoting a population shift from using cars towards walking and cycling.
2. Eco-driving: Awareness campaigns on training the citizens in eco-driving practices. Eco-driving is a relatively low-cost and immediate measure to reduce fuel consumption and emissions significantly while it also offers numerous benefits. The main factors of eco-driving are acceleration/deceleration, driving speed, route choice and idling (Huang, Yuhan et al. 2018).

Change in activity

The scenario combines two separate measures, which differently affect activity and emission factor. The promotion of walking and cycling influences the activity level, while the effect of eco-driving is described as an emission factor change since the activity unit in the emission inventory is driven vehicle kilometres instead of fuel consumption.

Promoting cycling and walking:

The metropolitan Area of Athens is a region that is historically car dependent with a modal split highly relying on cars. In contrast, the share of trips by cars is much lower in other European cities[1]. The current share of 2011 is about 7% walking and cycling[2] The target share for walking and cycling is set to 10% in 2020 and 20% in 2030. This is in the same range as the

[1] https://www.eea.europa.eu/data-and-maps/daviz/modal-split-for-metropolitan-city-areas#tab-chart_1 (accessed on 07/29/.2019)

[2] IBM (2016): Athens, Greece: Smarter Cities Challenge Report.

target scenario of the more ambitious scenarios in the Thessaloniki sustainable urban mobility plan (SUMP) (15% in 2020) (Thessaloniki Public Transport Authority, 2014). Furthermore, it has been assumed that the reduction only affects vehicle kilometres travelled by private passenger cars and motorcycles, while public transportation usage is not reduced. This leads to a reduction of the activity level by 3 % in 2020 and 13 % in 2030.

Change in emission factors

Eco-driving:

The literature on eco-driving shows a wide variety in terms of reduced fuel saving and therefore emissions. A summary of eco-driving programs in different cities in the world shows potentials for reducing fuel and CO2 emissions mostly between 0%-15% (Huang, Yuhan et al.,2018, Fonseca, N. et al., 2010, Wang and Boggio-Marzet, 2018, Alessandrini, A. et al. 2012). A theoretical and practical training of bus drivers in Athens led to a reduction of about 6.5% (Huang, Yuhan et al. 2018). A study by Wang and Boggio-Marzet (2018) in Madrid shows a general fuel saving of 6.3% regardless of fuel and road type (Wang and Boggio-Marzet, 2018).

To determine the effect on the emission factor, SO2 and CO2 emission reductions are set as high as the fuel savings since emissions of both pollutants depend directly on the fuel consumption. Studies for measurements of pollutant reductions are rather limited and different approaches for the estimation of the emission reduction potential exist. Within the project CIVITAS MIMOSA fuel reductions have been directly used to calculate the emission reductions of all pollutants (Rannala, M.; et al. 2013). However, emissions of other pollutants depend not only on fuel consumption but also on the operation mode of the motor. A study by Fonseca et al. (2010) found no mitigating effect of eco-driving on NOx emissions (Fonseca, N. et al. 2010). Kugler (2012) assumes the emission reduction potentials as half as high as the reduction of exclusively consumption-dependent pollutants. This approach has been followed for the calculation of the emission reduction potential.

It has been assumed that the eco-driving does not lead to an increase in travel time (and therefore higher emissions of pollutants) but that the trainings focuses on the travel behaviour of the drivers. Furthermore, it has been assumed that trainings do continue throughout the whole life span of the measure so that no fading of the behavioural change is expected.

In 2020 we assume 10% of drivers to be reached by the program and changing their behaviour, while in 2030 we expect about 60% of drivers to be reached (5% per year). Based on the literature it has been assumed that the reduction potential is 5% for SO2 and CO2, while we assume 2.5% for other pollutants.

3.2.1.2 Policy scenario 2 – SusMobPuT

Promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica) as well as minimizing the use of private passenger cars in Athens metropolitan area by enhancing public transportation means

Description of the scenario

This scenario considers the promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica) as well as minimizing the use of private passenger cars in Athens metropolitan area by enhancing public transportation means.

This measure relates to the policy for supporting the transition to a low-carbon economy in all sectors of the Regional Operational Program (ROP) Attica 2014-2020. The measure focuses on training, informing and sensitizing the citizens in:

1. Promoting cycling and walking: promoting a population shift from using cars towards walking and cycling.
2. Eco-driving: Awareness campaigns on training the citizens in eco-driving practices.

Additionally, it targets the limited use of private passenger cars (PCs) in the wider area of Athens (metropolitan area) through the promotion of public and alternative transportation.

Change in activity

The activity change of sub-scenario SusMob can be found in the description of the respective scenario.

Sub-scenario PuT: It has been assumed that the promotion of public transportation by the introduction of new metro lines decreases the vehicle kilometres driven with private transportation means by 1 % in 2020 and 6% in 2030. The 6% decrease is in line with the measured reductions during the Olympics in Athens where efforts have been made to enhance the transportation system.

3.2.1.3 Policy scenario 3 – EnEff

Energetic renovation of residential and commercial buildings in the Greater Athens Area (Attica)

Description of the scenario

This scenario relates to the European Commission policy to face the significant contribution of the building sector on the final energy consumption in EU countries and aims at improving the energy efficiency of the building stock in residential and commercial sector. The new Greek Regulation on the Energy Performance of Buildings (REPB), which is in line with the European Directive 2010/31/EC and 2012/27/EC, has brought changes applying to construction techniques, construction costs and energy performance in the residential buildings. The REPB imposes minimum energy performance requirements for buildings and classifies them into nine energy classes (A+, A, B+, B, C, D, E, F, G) by comparing their energy performance with that of a reference building.

The scenario EnEff considers the energetic renovation of residential buildings in the Greater Athens Area (Attica) and extends the existing program to include also commercial buildings. It therefore leads to an improved energy efficiency in all buildings and increased use of renewable energy sources.

Change in activity

For residential energy renovations, according to statistics of previous years from funded programs, it is estimated to be feasible for the next twelve years (2018-2030) to carry out energy interventions at around 25,000 residencies annually, as referred in the “Long-term strategy report to mobilize investments for the renovation of the national building stock” of the Ministry of Energy and Environment[3]. This is in line with the target set to renovate 7% of the existing building stock until 2030. It therefore has been assumed that 2.5% and 7% of buildings in 2020 resp. 2030 are renovated. According to the average energy savings for residential buildings in Attica and experiences of EKO-I and EKO-II programs, it has been assumed that 45% of final energy can be saved for each building.

Based on above mentioned assumptions (implementation potential: 2.5 – 7% and mitigation potential: 45%), the measure leads to a reduction in final energy consumption of 1.13% in 2020 and 3.15% in 2030.

[3] https://ec.europa.eu/energy/sites/ener/files/documents/el_building_renov_2017_en.pdf (accessed on 07/29/2019)

3.2.1.4 Policy scenario 4 – EnEffZEB

Energetic renovation of residential and commercial buildings in the Greater Athens Area (scenario EnEff) as well as additional conversion of residencies to nearly zero energy buildings (nZEB) in the City of Athens

Description of the scenario

This scenario considers the energetic renovation of residential and commercial buildings in the Greater Athens Area (scenario EnEff) as well as additional conversion of residencies to nearly zero energy buildings (nZEB) in the City of Athens.

The City of Athens will support the conversion of 10% of the existing residential buildings to nearly zero-energy buildings until 2030. According to Article 9 of Law 4122/2013 (Directive 2010/31/EE on the energy performance of buildings), it is foreseen that as of 1.1.2021 all new buildings must be nearly zero-energy buildings, while for the new buildings they host services of the public and wider public sector, this obligation shall enter into force on 1.1.2019. The National Plan to increase the number of buildings with almost zero energy consumption[4] sets as a nearly zero-energy building the one that according to the Energy Performance Buildings Regulation:

- can be classified at least in energy class A, if it is a new building,
- can be classified at least in energy class B+, if it is an existing building.

The description of energetic renovation of residential and commercial buildings in the Greater Athens Area (Attica) can be found in scenario EnEff.

Change in activity

The energetic renovation of residential and commercial buildings in the Greater Athens Area (Attica) follows the same assumptions as described in the scenario EnEff. The activity change for this scenario can be found in the respective scenario description.

Additionally, 10% of the existing residential buildings will be transformed to nearly zero-energy buildings until 2030. The deep renovation of an existing building in order to become a nearly zero-energy building would mean an approx. 80-100% reduction in final energy consumption.

[4] http://www.ypeka.gr/LinkClick.aspx?fileticket=8S82W2L9SLw%3d&tabid=281&language=el-GR (accessed on 28/07/2019)

Based on above mentioned assumptions (implementation potential: 1% in 2020 and 10% in 2030 and mitigation potential: 80-100%), the measure ZEB leads to a reduction in final energy consumption of 0.8% in 2020 and 10% in 2030.

3.2.1.5 Policy scenario – Waste

Reduction of disposed biodegradable and recyclable waste in landfill through the implementation of Green Points and Recycling & Training Centres for waste separation at source and pre-sorting

Description of the scenario

The scenario relates to target set in the Regional Solid Waste Management for pre-treatment and pre-sorting of waste to promote recycling and reuse and contributes to the reduction of the disposition of biodegradable waste (bio-waste and packaging waste) in landfill through such actions that include separation at source, domestic compost, etc.

Furthermore, it includes the promotion of the "Green Points" network in Attica region, which aims at promoting pre-sorting and pre-treatment for specific waste streams. There are 4 types of Green Points:

a) Large Green points that are large environmental facilities (>3500m^2) for collecting recyclable material such as garden and pruning waste, domestic hazardous waste such as batteries, paints and varnishes, light bulbs etc., old furniture, electrical and electronic devices etc.

b) Small Green Points are areas of 250-750m^2

d) Recycling, Training and Sorting at Source Centres are areas of 250-1000m^2

c) Green points at neighbourhood should cover an area of 50-100m^2

Change in activity

The total disposed MSW to landfill at 2015 was 1,758,165tn with a constant amount in 2020 and 2030. The reduction of 63% (i.e. 1079351tn) leads to 678815tn waste in sector 6D. The reduced amount of landfill waste in 2020 and 2030 is 63%. The same is assumed for 2030.

3.2.1.6 Emission reduction potential – results Athens

In the Greater Athens Area, the scenario with the highest emission reductions for all pollutants is *SuSMobPuT* – the promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area as well as an enhanced usage of public transportation in Athens metropolitan area. A similar reduction of NMVOC emissions – however point source effect - is reached by the scenario Waste, which considers the reduction of landfill waste. The reductions of the scenarios for energy efficient building construction (*EnEff*) and nearly zero energy buildings (*ENEffZEB*) show significantly lower emission reductions for nitrogen oxide emissions, but a similar reduction potential as the transport related scenarios *SusMobPuT* and *SusMob* when considering particulate matter emissions. The emission reduction potential of all measures increases from 2020 to 2030 which is due to the continuous increase of energy renovation and transportation mode switch. The *Waste* scenario shows a slight increase in the reduction potential which is due to the fact that overall NMVOC emissions of other sectors are decreased by 2030.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 4.

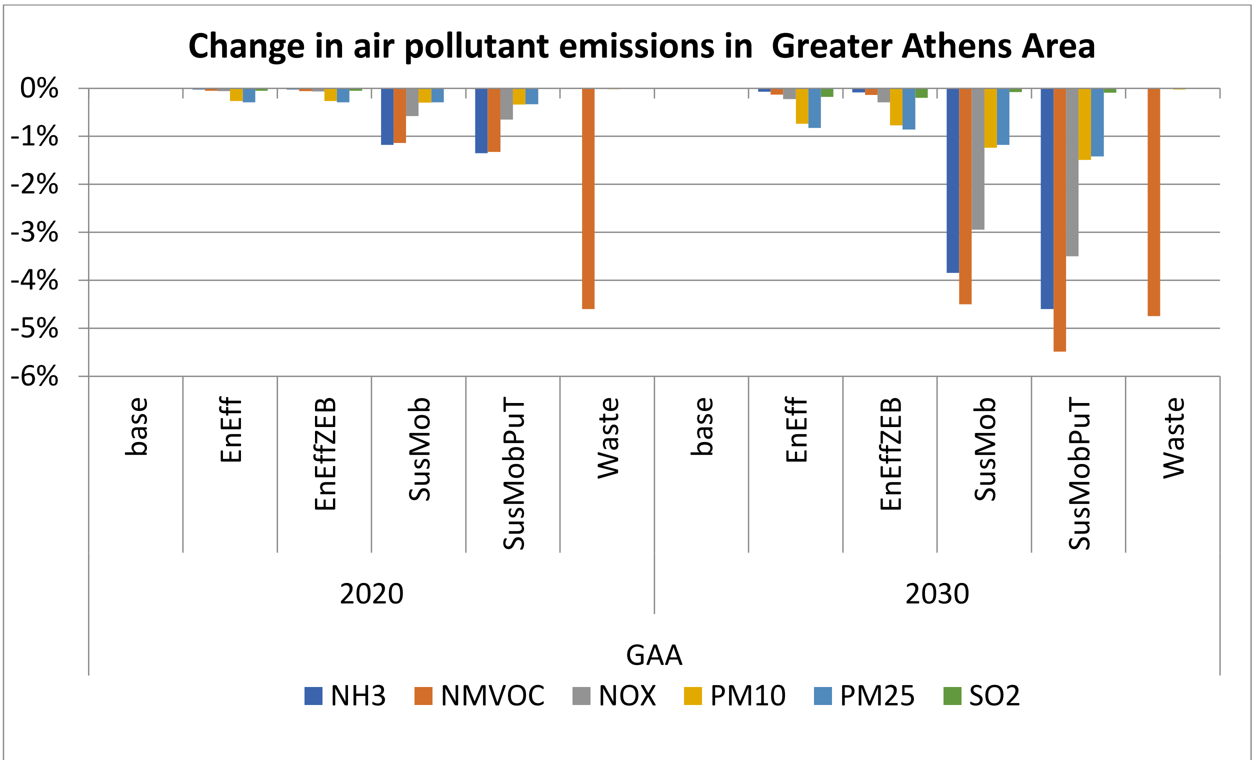


Figure 3: Change in air pollutant emissions in Greater Athens Area

3.2.2 Basel

3.2.2.1 Policy scenario 1 - NoHeat

Replacement of fossil heating technologies by heating pumps and solar heating (until 2020: 1/3 will be replaced; until 2030:100%)

Description of the scenario

This scenario considers the replacement of fossil heating technologies by heating pumps and solar heating. It foresees the replacement of one third until 2020 and full replacement until 2030.

Change in activity

For 2020 a third of all existing (baseline 2015) fossil heating units are replaced with renewable heating technologies (no direct emissions). For 2030 all fossil heating units are replaced. The final energy consumption of the respective sector is reduced accordingly to the replaced proportion.

Further assumptions

Fossil heating units are replaced by heating pumps or solar and not by fuelwood. Power generation by fossil fuels is not affected (heat from power generation goes into district heating).

3.2.2.2 Policy scenario 2 - Traffic10

Introducing a traffic reduction law leads to a reduction of the traffic load by 10% in 2020 and 2030 compared to the baseline scenario

Description of the scenario

This scenario aims to reduce traffic (all motorized traffic on all roads) by 10 percent equally and follows the reduction goal as stated in the environmental laws of Basel. (Traffic reduction compared to baseline 2015)

Change in activity

All motorized traffic volumes are reduced to 90 percent of the volume in 2015 in each street segment. No changes in tram or bus traffic volumes are considered. (This refers to 11.4% reduction compared to BAU 2020 scenario and 14.1% reduction compared to BAU 2030 scenario.)

Further assumptions

Changes in fleet composition are considered to be the same as in all scenarios. To simplify the scenario no increases in non-motorized traffic volumes are considered.

3.2.2.3 Policy scenario 3 – FirewoodBan

A ban on small combustion of firewood will be introduced until 2030. This is a hypothetical scenario to show the effects of firewood on air pollution. (2030 scenario)

Description of the scenario

This scenario assumes the introduction of a ban on small combustion of firewood will until 2030. It is a hypothetical scenario to show the effects of firewood on air pollution.

Change in activity

All small firewood combustion units are replaced by heating pumps and solar heating. The final energy consumption of the respective activity is set to zero.

Further assumptions:

Power generation by firewood is not affected (two large scale firewood heat and power plants in service). The reasoning behind this is the reduced emissions of large scale firewood plants due to flue gas treatment.

3.2.2.4 Policy scenario 4 – NoHeatFirewood

Replacement of fossil heating technologies combined with the introduction of a firewood ban until 2030. This is a combination of scenario NoHeat and Firewood. This is a hypothetical scenario to show the effects of small combustion on air pollution. (2030 scenario)

Description of the scenario

This scenario considers the replacement of fossil heating technologies combined with the introduction of a firewood ban until 2030. This is a combination of scenario NoHeat and Firewood. It is a hypothetical scenario to show the effects of small combustion on air pollution.

Change in activity

All fossil heating and small firewood combustion units are replaced by heating pumps and solar heating. More information about the activity changes can be found in the respective sub-scenario descriptions.

Further assumptions:

Power generation by fossil fuels or by firewood is not affected.

3.2.2.5 Policy scenario 5 – ZeroEmissionShips

Conversion of the shipping fleet to zero emission ships by 2030. This is a hypothetical scenario to show the effects of navigation on air pollution levels. (2030 scenario)

Description of the scenario

All ships (sector 1A3d) are replaced by 2030 with zero emission ships. This is a hypothetical scenario to show the effects of navigation on air pollution levels.

Change in emission factor

All emission factors are changed to 0 in sector 1A3d.

3.2.2.6 Emission reduction potential – results Basel

In Basel the policy scenario associated to the replacement of fossil heating technologies by heat pumps (*NoHeat*) shows the highest reduction of nitrogen oxide emissions in 2020 and 2030, while the hypothetical ban on small combustion of firewood (*NoFirewood*) shows comparable high reductions of particulates in 2030. The joint hypothetical scenario for 2030 *NoHeatFirewood* combines the reduction potentials of the single policy scenarios and therefore reaches highest reductions for all pollutants. The 2030 scenario *ZeroEmissionShips* shows the smallest reductions of particles compared to the other scenarios, but higher reductions of nitrogen oxide than *NoFirewood.* Even though emission reductions are rather small at the city level they occur very concentrated at the port area of Basel. The scenario associated to a 10% decrease of 2015 vehicle mileage *Traffic10* shows in contrast to the heating related measures no increase in the reduction potential from 2020 to 2030.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 4.

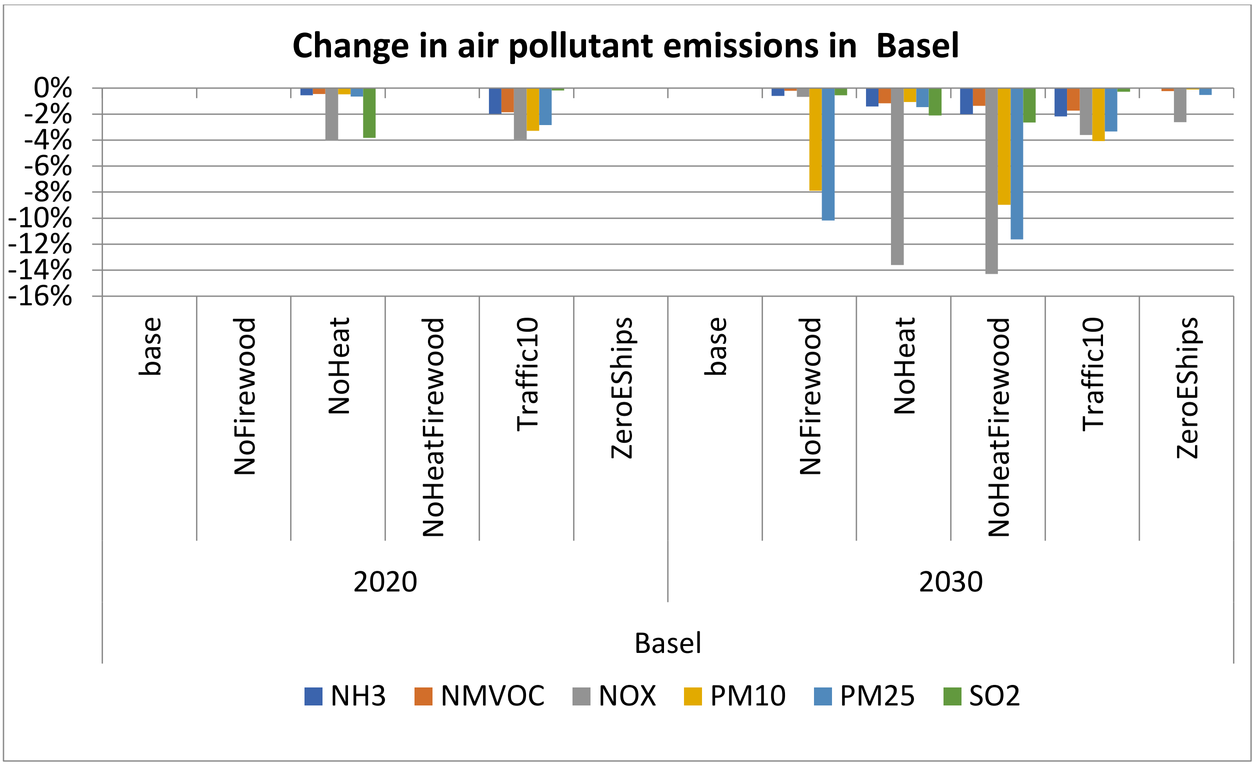


Figure 4: Change in air pollutant emissions in Basel

3.2.3 Brno

3.2.3.1 Policy scenario 1 - M1opti

Promoting low carbon vehicles

Description of the scenario

This scenario considers the promotion of low carbon vehicles. It follows an optimistic trend, which considers a rapid penetration of electric vehicles onto the Czech Market. In this scenario it is estimated that 7% and 12.5% of vkm driven by PCs in 2020 and 2030, respectively, will be done by electric vehicles.

Change in activity

For this scenario, no changes will be done for most vehicle categories (i.e. buses, heavy-duty vehicles (HDVs), light-duty vehicles (LDVs), tramways and motorcycles (MCs)), but the only change to occur will concern, as expected, personal cars (PCs). For PCs, compared to the baseline scenario, no changes will be done in terms of the total vkm driven, neither for the technology (i.e. pre-Euro, Euro1, …) of petrol and diesel vehicles, but only concerning the share of individual cars for which electric vehicles will represent a larger share compared to the baseline scenario. Two scenarios were developed in this regard:

- An optimistic scenario (OPTI) which considers a rapid penetration of electric vehicles onto the Czech Market.
- A more realistic scenario (REAL) in which it is estimated that the penetration of electric vehicles onto the Czech market will be a bit slower, and will occur with a delay of about 10 years compared to the OPTI scenario.

Given the almost 10-year delay in electric vehicles penetration of the REAL scenario compared to the OPTI one, we have estimated that within OPTI, in 2020 and in 2030, 7% and 12.5% of vkm driven by PCs will be done by electric vehicles. For further analysis and assessment of the policy scenario the OPTI scenario has been chosen.

Further assumptions

Within this measure, we have not considered the increase of electricity consumption due to the penetration of electric vehicles onto the market, but we have considered that this will happen at the national level and not at the city level, which is uncertain. Therefore, we should keep in mind that the reported emissions for that measure are an underestimation of the real emissions (however not for the city level).

3.2.3.2 Policy scenario 2 - M2zero

Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking, biking and using public transport) – ZERO scenario

Description of the scenario

This scenario considers the aim to reduce the number of PCs in the city, and to increase the number of people walking, biking or using public transport. In the scenario ZERO population and housing is developing as planned in the SUMP, but it assumes no planned traffic constructions (e.g. P+R, new highways, development of public transport).

Change in activity

Within this measure, no changes will be done in terms of HDVs, LDVs or MCs. A decrease of the activity (in terms of vkm) of PCs is assumed to be 20.6% and 21.6% for 2020 and 2030, respectively.

3.2.3.3 Policy scenario 3 - M2opti

Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking, biking and using public transport) – OPTI scenario

Description of the scenario

This scenario aims to reduce the number of PCs in the city, and to increase the number of people walking, biking or using public transport. For this scenario we decided to model a more optimistic scenario (OPTI) in which a larger shift from personal vehicles to public transportation would occur.

Change in activity

The scenario development is based on the same approach and basic data as described in the previous scenario M2zero. For this scenario we decided to model a more optimistic scenario (OPTI) in which a larger shift from personal vehicles to public transportation would occur. In OPTI scenario, we estimate that in 2020 and in 2030 the vkm reduction would be 35.2% and 42.0%, respectively.

3.2.3.4 Policy scenario 4 - M3slow

Switch of combustion techniques in residential and municipal buildings: Replacement of old coal-fired boilers in residential sector

Description of the scenario

This scenario aims at reducing anthropogenic emissions from domestic heating by replacing old coal-fired boilers by natural gas-fired boilers, biomass-fired boilers, heat pumps, district heating and solar thermal collectors and therefore affects the residential sector 1A4bi.

Change in activity

To estimate the change in emissions related to this measure, within the energy concept of the city of Brno a "GREEN scenario" has been chosen. It suggests introducing technologies that would replace coal-fired boilers; the shares are presented in Table 4.

Table 3-3: Share of technologies replacing coal-fired boilers

	Natural gas-fired boilers	Biomass-fired boilers	Heat pumps	Automatic coal fired boilers	Solar thermal collectors	Total

2. scenario - renewable energy sources (GREEN)	28%	42%	14%	12%	4%	100%

The Brno energy concept indicates that 100% of coal-fired boilers would be replaced by 2030. However, it is unclear how many of them would be replaced by 2020. Therefore, we have decided to model this measure with the sub-scenario SLOW in which only 20% of the coal-fired boilers would be replaced in 2020.

3.2.3.5 Policy scenario 5 - M4econ

Implementation of energy saving measures by insulation and renovation of the building stock

Description of the scenario

This scenario aims at reducing anthropogenic emissions related to the energy sector by promoting insulation and renovation, and therefore will affect three individual sectors: the residential sector (1A4bi), the commercial sector (1A4ci) and the industrial sector (1A2).

In the residential sector (1A4bi), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)

In the commercial sector (1A4ci), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)
- Modernisation of indoor lighting system
- Modernisation of ventilation and air conditioning systems

In industry sector (1A2) the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)
- Improving the energy efficiency of production technologies

Change in activity

These data are expressed for two different scenarios: TECHNICAL and ECONOMIC. The TECHNICAL scenario includes all measures examined, without economical limits. The

ECONOMIC scenario considers measures that are feasible from an economic perspective.

For the modelling of the effect of this measure on anthropogenic emissions, we have selected the ECONOMIC scenario; the expected relative energy consumption for 2020, 2030 and 2050 are presented in Table 3.

Table 3-4: Energy consumption for the residential (1A4bi), commercial (1A4ci) and industrial (1A2) sector compared to 2015 (100%)

		2020	2030	2050
ECONOMIC scenario	Residential sector	95.6%	91.3%	86.8%
	Commercial sector	93.9%	87.8%	81.8%
	Industrial sector	97.6%	95.3%	93.0%

3.2.3.6 Emission reduction potential – results Brno

In Brno the scenario with the highest emission reductions for all pollutants, except sulphur dioxide, is *M2* – the scenario associated to the implementation of measures leading to a reduction of the motorized vehicles in the city combined with the increase more environmental friendly transportation modes (i.e. walking, biking and using public transport). On average, the *M2OPTI* scenario resulted in decreases 1.7-2.0 x higher than those from the *M2ZERO* scenario. The promotion of low carbon vehicles in the Brno Metropolitan area (*M1opti*), would decrease total emissions of individual compounds investigated by 4-6%, with even smaller reductions for particulate matter emissions, which is due to the limited influence of exhaust emissions. The highest reductions for sulphur dioxide emissions shows scenario *M3slow*, which addresses the replacement of old coal-fired boilers in residential sector. It can also be seen that an increase of the emissions of ammonia related to this measure was found. This is due to higher emission factors from wood combustion. The emission reduction potential of all measures increases from 2020 to 2030 which is due to the continuous increase of energetic renovation, penetration with electric vehicles and transportation mode switch to environmentally friendly means.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 5.

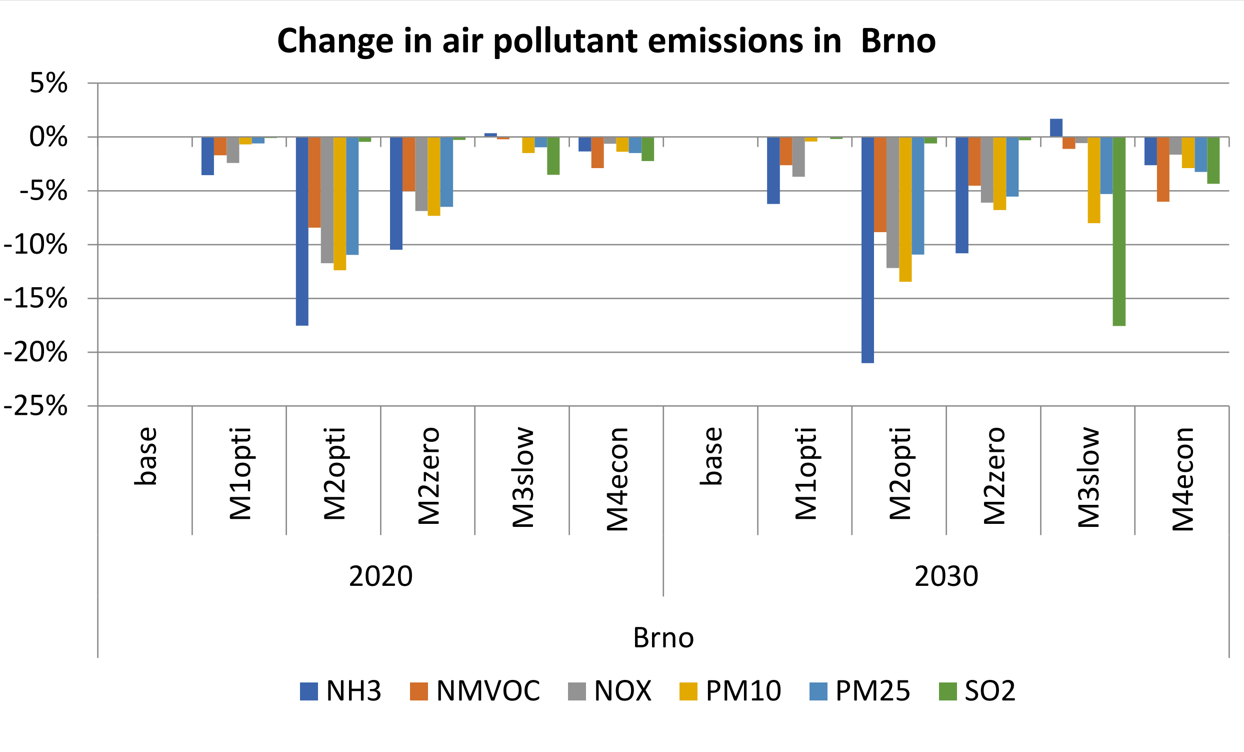


Figure 5: Change in air pollutant emissions in Brno

3.2.4 Ljubljana

3.2.4.1 Policy scenario 1 - M1_DecreaseCAR

Decrease of personal car use (the combination of the car reduction measures and parking policy will lead to a decrease of personal cars on incoming roads/avenues by 20 %); specifically, the promotion of electro mobility is planned to result in an additional 2% of emission reduction (2030 scenario)

Description of the scenario

This scenario comprises several measures with the main goal to reduce personal car use. They include particularly:

- Alternative parking policy; Street parking spaces will be intended primarily for residents. To this end, the municipality will gradually introduce parking zones in densely populated neighbourhoods and quarters, in which street parking spaces will be payable and limited to two hours. This measure will limit the possibility of parking for daily migrants in residential areas. Daily migrants will be provided with parking spaces at Park&Ride facilities at the outskirts of the city and in public garage houses);

- Ten largest employers in the city will prepare and implement their transport mobility plans to work after a third of the use of vehicles;
- Promotion of electro mobility; the electro mobility is estimated to represent the 2% of the entire fleet (ca 20.000 vehicles) in the near future.

Change in activity

It is estimated that the combination of the specified measure will lead to a decrease of personal cars on incoming roads/avenues by 20 %. Scenarios regarding the decrease of emissions related to the intensified use of electric vehicles are focused on the decrease of these 2% excluding the life cycle assessment of the electricity supply. Based on the expected decrease of personal car use by 20%, it is estimated that the reduction of pollution will also be 20% (taking into consideration that the shift will be primarily towards other means of transport – primarily cycling and walking). For particles (PM, BC, OC) the emission reduction potential remains by 20% as the introduction of electric vehicles does not contribute to a decrease in abrasion emissions, which have the main influence on particle emissions.

3.2.4.2 Policy scenario 2 - M2_IncreasePT

Increased share of public transport use (increased use of PT on the account of better service and transfer from car users); The renovation of the public passenger transport fleet and the reduction of personal car use is also integrated in this scenario (2030 scenario).

Description of the scenario

This scenario considers Ljubljana's aim for the coming decade to stop and reverse the trend in the decline in the number of trips made with public transport. In this regard the following measures are considered:

- Bus routes will be extended to neighbouring municipalities, while working migrants will be given the opportunity to park their car in one of the Park&Ride facilities on the outskirts of the municipality, from where they will reach the city centre quickly and easily during the traffic congestion.
- On three avenues with heavy traffic congestion, a faster travel time for the public transport buses compared to passenger cars will be ensured with public transport priority an intersections and dedicated bus lanes.

Furthermore, this scenario integrates also scenario M1_DecreaseCAR and scenario M3_PTfleet; i.e. the decrease of passenger cars by 20% in 2030 and the renovation of the bus fleet with CNG buses. In contrast to scenario 1 it includes the additional renovation of the bus fleet and the increase of 10% of bus kilometres. In contrast to scenario 3, this scenario includes 10% increase of bus kilometres.

Change in activity

The current number of travels with LPP should be increased by 30% until 2027 (the milestone is 10% increase by 2020). Since the public transport usage is increasing more slowly than expected the increase considered in the 2030 scenario is 10%. Two separate calculations have been made as a sensitivity analysis – a 0% increase in bus vkm which considers the 10% increase of passengers to fill the existing capacities of buses. The increase of 30% passengers is estimated to require an additional 10% of the increase of public transport services in terms of vkm (more buses, higher frequency). This scenario reflects the increase of 10% more vehicle kilometres for buses. Zero increase in vkm are considered in M3.

Furthermore, a decrease in private passenger cars is assumed as in M1.

Change in emission factors

The change in the emission factor is the same as in scenario M3. (CNG emission factors for buses)

3.2.4.3 Policy scenario 3 - M3_PTfleet

Renovation of public passenger transport vehicle fleet (CNG. hybrid buses); the replacement of EURO 0, 1, 2 buses with CNG propulsion system (86 buses in total)

(The reduction of personal car use is also integrated in this scenario. but no increase of public transport is assumed) (2030 scenario)

Description of the scenario

This scenario considers the renovation of the public passenger transport vehicle fleet and a traffic reduction.

Renovation of public passenger transport vehicle fleet (CNG, hybrid buses), utility vehicle fleet and city administration vehicle fleet. The renovation of the PT fleet considers the replacement of EURO 0, 1, 2 from the fleet; these will be replaced by 86 buses with CNG propulsion system. The reduction of personal car use is also integrated in this scenario, but no increase of public transport is assumed) (2030 scenario).

Change in activity

The changes in the activities of the sector 1A3bi is the same as in scenario M1_DecreaseCAR.

Change in emission factors

The scenario considers the replacement of EURO 0, 1, 2 emission factors by CNG emission factors.

3.2.4.4 Policy scenario 4 - M4_DistrHEAT

Increased utilization and expansion of district heating systems; renovation of the system - replacement of existing combustion units with more appropriate means (i.e. 70% reduction of coal use) (2030 scenario)

Description of the scenario

This scenario aims at increased utilization and expansion of district heating systems and a renovation of the system by replacing existing combustion units with more appropriate means (i.e. 70% reduction of coal use in district heat production plants). A significant increase of facilities connected to the gas network along with the installation of the gas unit at the Ljubljana thermal plant has been assumed. This new gas-steam unit, will replace two of the oldest of the three coal blocks in the TE-TOL unit. Coal block 3, which was processed in 2008 for the purpose of lowering carbon dioxide emissions by co-firing of coal and wood chips. Ljubljana thermal plant (Energetika Ljubljana TE-TOL) is the largest user of wood biomass for energy purposes in Slovenia - will remain in operation and will be able to use various primary fuels and renewable energy sources. The use of coal in Ljubljana will thus be reduced by more than 70 percent.

Change in activity

70% reduction of coal in sector 1A1a and replacement of the same activity level by natural gas.

3.2.4.5 Policy scenario 5 - M5_EfficientHEAT

More efficient use of domestic heating; decrease of fuel consumption by 15% by 2030 (2030 scenario)

Description of the scenario

This scenario aims at more efficient use of domestic heating and a decrease of fuel consumption. It is estimated that, given the current situation, with the proper use of devices and air-dried biomass, it is technically possible to reduce particulate emissions from existing small combustion plants by 50% on average, and fuel consumption by 15%. (By 2017, the goal was to achieve a 20% reduction in particulate matter emissions from small combustion plants to solid fuel, through education and awareness of citizens, while at the same time reducing the specific consumption of solid fuel by 10%).

Change in activity

Decreased fuel consumption/final energy in 1A4 by 15% is expected.

3.2.4.6 Emission reduction potential – results Ljubljana

In Ljubljana all scenarios are rather mid-term strategies, which is why the emission reduction calculation focuses on the year 2030. The most effective policy is the increased promotion of the public transportation accompanied by the renovation of the public transport fleet (*M3_PTfleet*). A slightly lower reduction shows the measure *M2_IncreasePT,* which solely concentrates on a higher public transportation usage. Highest reductions for sulphur dioxide can be found for measure *M4,* which deals with increased utilization and expansion of district heating systems and replacement of existing combustion units with more appropriate means. Smallest reductions for all pollutants except particulates come from the scenario *M5_EfficientHEAT* - more efficient use of domestic heating associated with a decrease of fuel consumption.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 6.

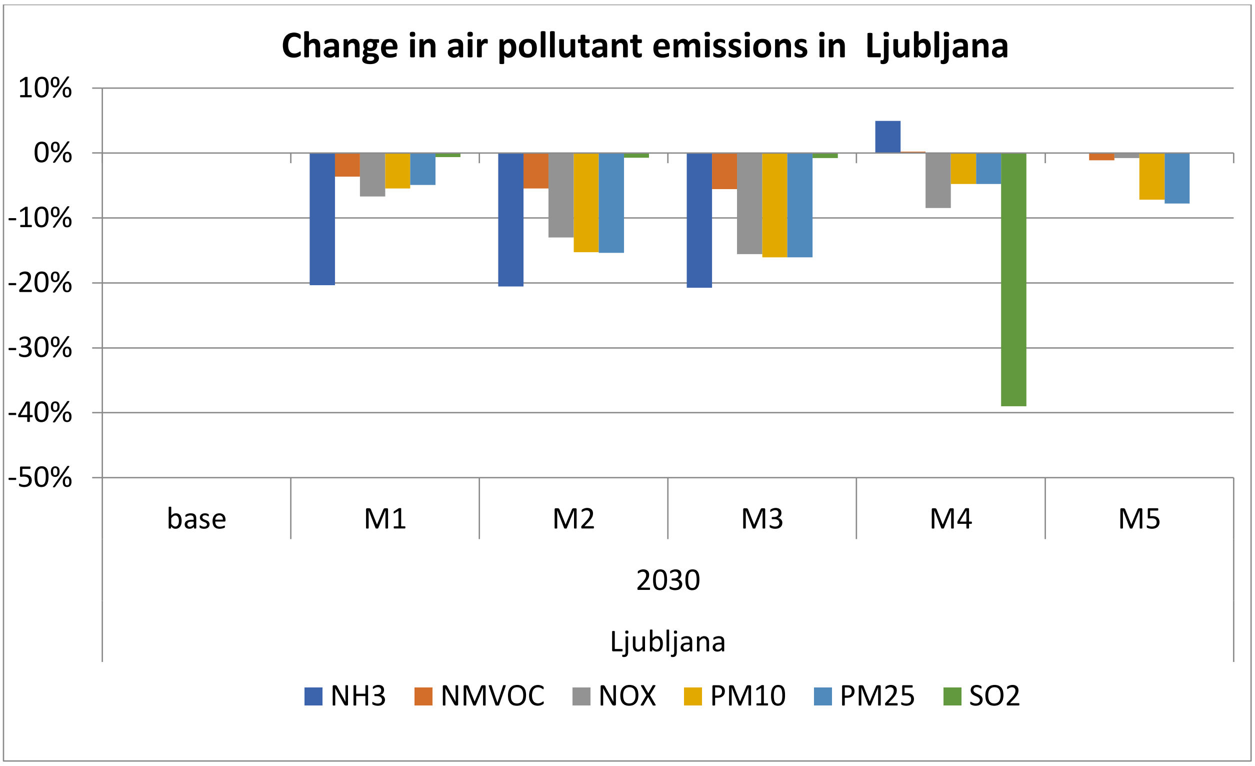


Figure 6: Change in air pollutant emissions in Ljubljana

3.2.5 Madrid

3.2.5.1 Policy scenario 1 - ZEZ

Delimitation of a closed Central Zone (Zero Emissions Central Area) with restricted access in which through traffic will be banned

Description of the scenario

This scenario foresees a delimitation of a closed perimeter Central Zone with restricted access in which through traffic will be banned. The creation of this area is focused on reducing the negative effects of car mobility in the centre of the city, encouraging the use of collective transport and non-motorized modes to the detriment of the use of private vehicles. Likewise, other potential sources of pollution will be acted upon, with the main objective of establishing an area of the city free of emissions.[5]

[5] https://www.madrid.es/UnidadesDescentralizadas/Sostenibilidad/CalidadAire/Ficheros/PlanAire&CC_Eng.pdf (accessed on 07/29/2019)

Change in activity

In the 2020 scenario, vehicles (cars and motorcycles) without sticker from non-residents are not allowed to circulate in the Zero Emission Zone. This means that the entry is forbidden for non-residential gasoline vehicles less than EURO 3 and non-residential diesel vehicles less than EURO 4. The proportion of non-resident cars is assumed to be 70% in 2020 (further assumptions); therefore 30% exclusion from the ban has been assumed.

3.2.5.2 Policy scenario 2 – Park

Parking regulation according to air quality criteria through an increase of discounts and penalties according to vehicle's emissions and new regulation systems

Description of the scenario

The limitation of parking at destination is a measure that has been proven effective to create a deterrent effect on the use of private vehicles. The Regulated Parking Service (SER) is a fundamental municipal tool to influence in this sense. The objective of the measure is to reduce emissions from the use of the private car by managing the supply of parking at destination in compliance with air quality criteria. (City of Madrid 2017)

This measure is a joint measure with different stages of the reorganization of the parking regulation. Within the first years it foresees a review of the tariff system combining on the one hand a 25% surcharge of the parking fee for high emitting vehicles without environmental badge and on the other hand a 50% discount for ECO vehicles. As of 2020, vehicles without an environmental distinction of the DGT (Spanish Directorate General for Traffic) may not use the seats in the scope of the Regulated Parking Service, except residents in their own neighbourhood (cf. 1.2). This limitation will apply from 2022 to vehicles that have the authorization of qualified groups of owners of commercial and industrial vehicles (Ayuntamiento de Madrid 2017).[6]

Change in activity

For the emission scenario 2020 the following assumptions have been made:

- Increase of discounts and penalties according to the vehicle's emissions in regulated parking zones

---

[6] Ayuntamiento de Madrid (2017): Plan de Calidad de aire y Cambio Climático, accessed on 12/6/2018.

  - The increase of the parking fee by 25% is expected to reduce the mileage of non-residential vehicles. The reduction potential for the increase of the parking fee is calculated by the transport elasticity. The price elasticity for car drivers commuting trips in urban regions is -0.04 for each vehicle kilometre (Litman 2013, 2017). Therefore, it will be assumed that a 25% increase of prices results in 1.2% vkm reduction in the city centre in 2020.
- Implementation of new systems regulating destination car parking and underground car parks with gradual increase in spaces for residents at the expense of short-stay spaces
  - No further data on how many parking spaces will be reduced is available. Therefore, a target share of reduced trips by parking management following the approach in Friedrich (2014) will be set . It has been assumed that the measure will result in a reduction of the mileage of non-residential passenger cars within the city boarders by 2%. This mileage will be replaced by slow mode walk, slow mode bicycle, bus, passenger train and metro/tram. Capacities of the public transportation means have been assumed to meet the need.

For the emission scenario 2030 the following assumptions have been made:

- Limitation of use: As of 2020, vehicles without an environmental distinction of the DGT may not use the seats in the scope of the Regulated Parking Service, except residents in their own neighbourhood. This limitation will apply from 2022 to vehicles that have the authorization of qualified groups of owners of commercial and industrial vehicles. Parking is forbidden for all gasoline cars less than EURO 3 and diesel cars less than EURO 4.
  - Specific data on how the parking limitations influence the vehicle kilometres within Madrid municipality is scarce.
  - A measure aiming at adaptive parking management based on energy efficiency and occupancy in the project ECCENTRIC is expected to result in a car traffic reduction of 6% by employees (Madrid City Council, 2018).
  - The parking restriction within the central district during pollution episodes is expected to cut journeys by 13.4% within the central district and reduce NO2 emissions by 6%.[7]
  - As a first estimate a 50% reduction of trips for all vehicles affected by the parking ban has been chosen. Applying this share on the activity traffic data leads to a

[7] https://endesavehiculoelectrico.com/en/espanol-nuevo-protocolo-de-contaminacion-de-madrid/ (accessed on 05/23/19)

passenger vkm reduction of about 5% in 2030 (but even higher emission reduction potential due to the ban of highly polluting vehicles).

The emission reduction potential is calculated with the activity bottom up data on transport and the reduction of the vehicles mileage.

It has been assumed that about 70% of the trips within the city area of Madrid come from non-residents in their own neighbourhood and will be affected by this measure (cf. measure ZEZ).

3.2.5.3 Policy scenario 3 - Log

Public-private collaboration in order to innovate and make urban logistics processes more efficient

Description of the scenario

This measure aims at establishing a communication and collaboration framework that allows the design and implementation of coordinated measures for a new model in the urban distribution of goods. The generation of knowledge, the development of innovation and the practical application of different solutions require a coordinated public-private effort. (Ayuntamiento de Madrid 2017)

The measure comprises several actions that have no direct quantifiable emission reduction effect. Description of the actions:

- Specific studies on urban distribution in Madrid with the participation of research centres, professional associations and urban logistics companies
- Circulating park
- Night-time download - Proposal for development and regulation
- Development of vehicle prototype for distribution with ultra-low emissions
- Support for the implementation of pilot micro-platforms for last mile distribution and vehicle recharge spaces
- Promotion of stable and representative channels and forums for communication and collaboration with the urban goods distribution sector.
- Weights and sizes of the last mile distribution
- Promoting the use of the bicycle for the last mile distribution

Change in activity

As a first estimate it has been assumed that due to better organization and replacement of the last mile by bicycles, LDV trips will be reduced by 4% in 2020 and 14% in 2030 (2%/year). The measure is expected to affect emissions of the whole city area.

3.2.5.4 Policy scenario 4 - PuT

Reserved infrastructure for public transport (extra bus and high occupancy vehicle lanes) connecting with modal interchange points such as park-and-ride car parks

Description of the scenario

Aim of the measure is to establish a framework of collaboration and coordination with other public authorities for egress roads to be provided with bus lanes and the creation of high capacity bus corridors or Bud Rapid Transit to interconnect districts.

Change in activity

A similar measure in Madrid fostering high-level public transport service corridors is expected at the city policy level to increase the modal share for public transport by 4% and increase the commercial speed by 10% [8] . The modal share in Madrid of 14 years old and above is 33% non-motorized trips, 38% public transport trips and 29% private car trips[9].

The relative travel time between different modes significantly affects mode choice (Litman, 2013, 2017). A decrease of 10% in public transport vehicle travel time was associated with a 2.3% increase in public transport for non-work tours and 3.9% for home based work tours (elasticity -0.29 transit in-vehicle time home based work tours, -0.23 transit in-vehicle time home based non-work tours), while the demand for alone driving was reduced by 2% for home based work tours (0% for non-work tours) (Frank, L et al, 2007).

Given the transport demand elasticity based on the travel time and the expected shift of the modal share, a 2% reduction of vkm of private passenger cars and motorcycles within the whole city area will be assumed for 2020 and due to increasing reserved infrastructure a 4% reduction for 2030. Furthermore, it will be assumed that no additional public transportation

[8] Madrid Regional Transport Consortium (CRTM), Municipal Transport Enterprise for Madrid (EMT) (2018): High-level public transport service corridors in peripheral districts. CIVITAS ECCENTRIC,

[9] https://civitas.eu/eccentric/madrid (accessed on 05/23/2019)

means have to be put into practice but that the capacities are enough to meet the travel demand. The measure is expected to affect emissions of the whole city area.

3.2.5.5 Policy scenario 5 - EnEf

Regeneration of neighbourhoods by improving energy efficiency and thermal insulation of the building stock and re-naturalization of the city

Description of the scenario

The measure aims at developing the urban regeneration strategy 'Madrid Regenerates' which addresses the rehabilitation of the building stock (Plan MAD-RE), the refurbishment of public space and re-naturalization of the city.

For the specific case of housing buildings, the MAD-Re (Madrid Recupera) Program of subsidies in preferential areas will be promoted, which is aimed at improving accessibility, energy efficiency and its state of conservation, and which in 2016 already launched a first announcement. With regard to energy efficiency, thermal insulation, the replacement of windows and air conditioning equipment, the use of renewable energies, the creation of green roofs, etc. will be subsidized.

Change in activity

The CO2 emissions reduction potential of the Madrid Recupera Plan is given with 30860 t CO2 per year[10]. It is assumed that the estimate holds true the year 2017, since the article is published in March 2018 and the measure is put into practice in 2017 (cf. Table 1). The CO2 emissions of SNAP 2 category in the baseline emission inventory account for 2149 kt in 2015 and 1947 kt in 2020. A linear interpolation between both values leads to 2068 t in 2017. Emission savings of 39.860 kt/year therefore account for 1.49% of emissions of SNAP 2 (non-industrial combustion) in 2017. The measure is expected to show the same reduction potential in the following years, which means that approximately 1.5% of emissions are reduced each year, leading to 6% emission reduction in 2020 and 21% in 2030 with the measure being put into practice in 2017. Since this measure only affects the total energy consumption and not the heating type distribution, the reduction potential (reduction in final energy) will be applied on all pollutants. The measure is expected to affect emissions of the whole city area.

[10] https://www.c40.org/case_studies/madrid-recupera (accessed on 05/23/2019)

3.2.5.6 Emission reduction potential – results Madrid

In Madrid the implementation of measures leading to the regeneration of neighbourhoods by improving energy efficiency and thermal insulation of the building stock and re-naturalization of the city (*EnEff*) shows on the average the highest emission reductions for all air pollutants. The scenario is followed by *PuTInfra* (reserved infrastructure for public transport) and *Logistics (*public - private collaboration to make urban logistics processes more efficient). The scenarios *ParkReg* and *ZEZ* show rather limited reductions, but this is because both measures apply on spatially restricted area within the whole city area. Therefore, local emission reductions are much higher (compare section 2 scenario descriptions). The emission reduction potential of all measures increases from 2020 to 2030 as a steady increase of renovation and transportation activities is assumed.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 7.

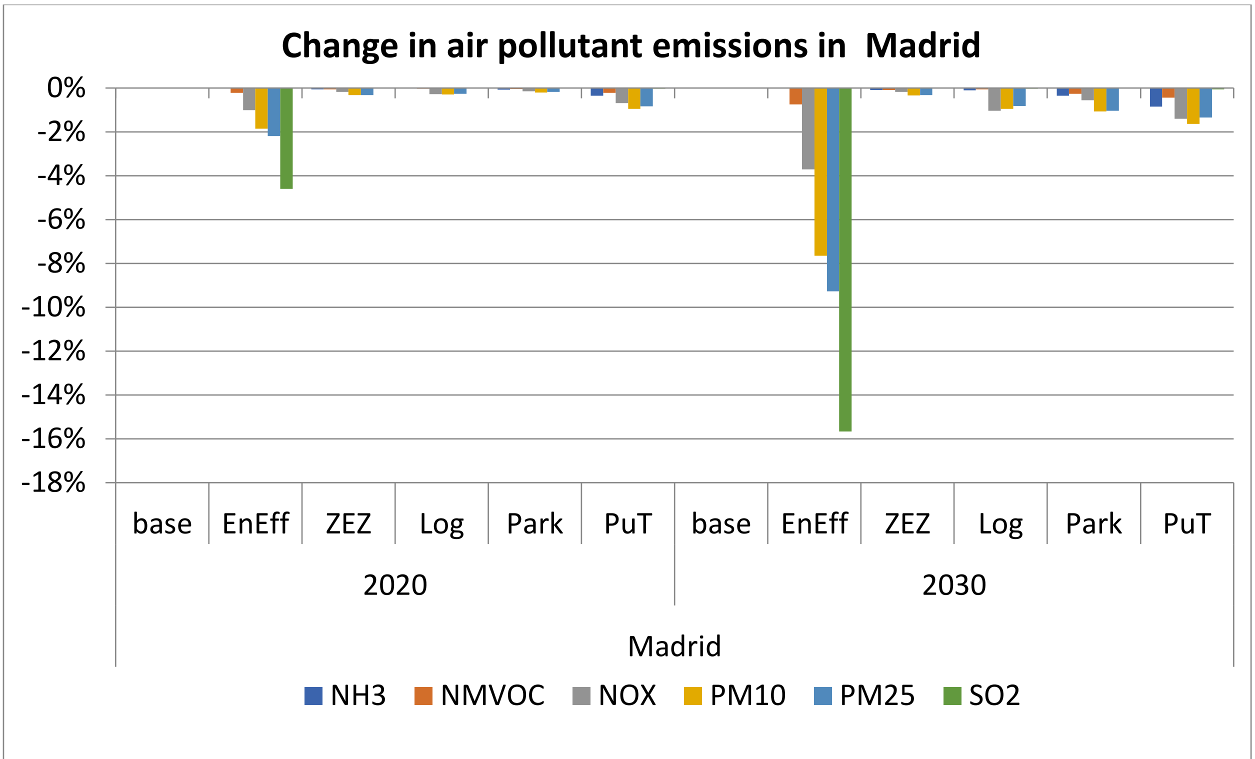


Figure 7: Change in air pollutant emissions in Madrid

3.2.6 Milan

3.2.6.1 Policy scenario 1 - AREAB

Low Emission Zone (Area B): Control and tracking of access into the city by banning up to Euro

3 diesel cars (up to Euro 4 from October 2019)

Description of the scenario

This scenario considers the introduction of a Low Emission Zone in the city of Milan. The positive experience of Area C, which over the last 3 years has seen a 10% decrease of the entrances within the historical centre, has promoted its reproduction on a city scale with AREA B as control and tracking of access into the city. It comprises the ban of up to Euro 3 diesel cars (up to Euro 4 from October 2019). The City of Milan is ready to start the implementation (February 2019) of this measure with an infrastructure of electronic gates (185) around and next to the municipal boundaries. The system (camera and on-board units) is set for the limitation of the most polluting vehicles, control, and management of the heaviest vehicles and the ones used for the transport of dangerous goods. In the second phase it will be targeted to manage also tourist buses and other kinds of big vehicles, and commercial ones as well. In this scenario a tightening of the measure is assumed that comprises the complete ban of diesel cars in 2030.

Change in activity

According to the scheduled banning steps, year by year, reported in the description of the scenario, the new activities (yearly kilometres run) have been calculated for each type of vehicles for 2020 and 2030 scenarios, subtracting from BAU scenario the activities that would have been run for vehicles banned in that year. In 2020 scenario, a 75% of compliance to the policy has been taken into account due to the fact it has just started and some citizens and people who come from outside the borders of the city can’t simply afford to respect the new regulation. In 2030 scenario, therefore in the long-term period, the assumption is that nearly half of the activities subtracted due to banned vehicles are added to others category of vehicles allowed (e.g. with gasoline as fuel; hybrid vehicles) within the same NFR code sector. Emissions due to road abrasion and gasoline evaporation have been recalculated in agreement with the assumptions described above.

3.2.6.2 Policy scenario 2 - ELECTRIC BUS

Conversion of public buses to electric ones

Description of the scenario

This scenario considers the conversion of the public bus fleet to an electric fleet and improvements of service and efficiency. The bus fleet will be completely electric by 2030. ATM, Milan’s municipal public transport company, has launched last year the most ambitious

Italian project to date aimed to the electrification of bus fleet. ATM plans to convert the whole fleet (1,200 buses) to zero emission electric drives by 2030. Now, 25 electric buses by Solaris company are running in the city. A 250 electric bus tender is underway. From 2020 on, ATM will buy only and exclusively electric vehicles.

Shortly diesel will disappear from the automotive fleet of ATM (local public transport company), which will consist of 1,200 new buses, all electric by 2030. Thus, Milan will be one of the first cities in Italy and Europe to provide a full electric public transport service.

Change in activity

For 2020 scenario the assumption is that 1/6 of the traditional buses will be converted into electric ones, according to data available from the municipality and public transport agency, therefore 1/6 of the activity related to buses (yearly kilometres run) has been subtracted from the BAU scenario and new emissions calculated. In 2030 scenario all buses are electric ones. In NFR sector code 1.A.3.b.iii there are both heavy duty trucks and buses: because of the structure of Milan Emission Inventory with emissions data referred to HDT and buses together, an estimate ratio of the activities between HDT and buses has been calculated in order to recalculate the activities of HDT which in BAU 2030 scenario were considered together with the buses. In both 2020 and 2030 scenarios, emissions from road abrasion due to buses are the same of BAU because electric buses will run the same kilometres of the previous ones.

(Future changes in EFs have been already considered in BAU 2020-2030 scenarios, and here the same changes have been taking into account for each type of vehicle.)

Further assumptions

The additional electricity production used for the new electric buses has not been taken into account in the new emission scenario, because it will be imported from outside the city boundaries.

3.2.6.3 Policy scenario 3 - BUILDINGS

Improvement of energy efficiency in existing and new residential flats

Description of the scenario

This scenario considers several improvements of the energy efficiency in existing and new residential flats.

A predominant share of energy consumption in the municipality (85%) consists of consumption in the civil sector. The term "civil sector" refers here to the sector it covers:

energy consumption for heating in buildings (residential and other destinations of use), domestic energy uses (gas and electricity) and energy uses in the private non-residential sector (mainly electricity with a minimum share of gas for process uses).

Specifically, regarding the year 2013, the civil sector represents a total of 85% of consumption and 84% of CO2 emissions in the municipality. In detail, the heating of buildings accounts for 51% of consumption and 43% of emissions, domestic uses account for 10% of consumption and 11% of emissions, the other energy uses of the private sector 24% of consumption and 30% of emissions.

Change in activity

In this scenario the focus is on "Residential plants" with calculation done in terms of reduction of activity-emissions for the fuel "natural gas", indeed in BAU scenarios 2020 – 2030 for the City of Milan, the usage of diesel and LPG in residential and commercial plants is already quite null due to previous policies.

The usage of wood and similar in BAU scenarios (and therefore in these scenarios as well) has been estimated yet with a reduction of 45-65% in the emissions due to the incoming policies-regulation (and related certification) about stoves efficiency.

Data available from Milan 2015 SEAP, with a 70% of the achievement/compliance for this set of measures, led to a -4,4% (vs. BAU2020) activity reduction for natural gas in residential plants for 2020, and no other data was available for future scenarios. Therefore, with the same assumptions, a reduction in this activity sector equal to -16,3 % has been considered for 2030 (vs. BAU2030).

Further assumptions

According to the SEAP CO2 emissions, are estimated at –295 kton per year. According to the SEAP, this policy would lead to an overall energy saving potential of 525,448 MWh/year heat fuels (45,189 tep/year) and 35,975 MWh/year of final electric (lower pump consumption) heating efficiency and lower consumption in household electrical uses). Electricity savings have not been taken into account because the production of the electricity is mainly outside the city boundaries.

3.2.6.4 Policy scenario 4 - ENERGY

Incentive measures of new building regulation promote the use of photovoltaic solar power for buildings and implementation of district heating

Description of the scenario

This scenario considers the introduction of solar power/photovoltaics for building uses and district heating. One of the strategic actions of the Municipal Administration aimed at reducing polluting emissions due to heating is the development of the heating system to serve the municipality, which has seen in recent years a significant increase in terms of heat delivered and buildings connected.

The action considers the completion of A2A's (local public energy agency) remote heating development program based on the efficient and renewable production available in the city, which is expected to almost double the spread of the system by 2020, compared to the level of 2013, until reaching a total supply of thermal energy for the city of Milan amounting to about 1,200 GWh/year, and, at the same time, prepare the future development towards an even higher penetration of the service at the Metropolitan level.

Change in activity

The improvements are considered in terms of energy saving. The reductions for each affected sector (per different fuels) ranges from 0.66-8.38% for 2020 and from 1.60-20-35% for 2030; details on changes in activity are reported in Annex 1.

Further assumptions

Data available from Milan 2015 SAEP, with a 70% of the achievement/compliance for these policies, led to activities reduction in 2020 scenario both in small combustion plants (SCP) than in large ones (LCP) because the improvement in the district heating and usage of renewable energies affect the energy production for public electricity and heat in local energy service plants located within the boundaries of the city.

These energy savings have been shared by different type of fuels (natural gas, diesel, LPG) considering their activity ratios in the specific sectors as reported in BAU 2020 scenario.

No official data was available for 2030 scenario, and therefore a linear regression for the calculation of future activities in these sectors has been taken into account. Electricity savings obtained with residential photovoltaic plants have not been considered for the new emission scenario because it replaces electricity consumption that did not affect BAU scenarios as well.

3.2.6.5 Policy scenario 5 - TREES

Increasing the green area and planting over 3 million new trees by 2030

Description of the scenario

This scenario considers the greening of the city of Milan due to planting about 25000 new trees per year. Milan has decided to promote a new green policy that involves planting 3 million trees on the metropolitan staircase. The very ambitious project aims to achieve this goal by the end of 2030.

The scenario aims to respond to different city issues. First, it aims to reduce emissions by plants' ability to absorb pollutants. However, try to cope with other challenges: countering the effect of heat islands and increasing the city's green cover. To date, Milan has a canopy tree that is only 7 percent, much less than half compared with other European and world cities such as New York. This massive intervention (also linked to the increase of green areas) will bring Milan to the levels of other cities, reaching 20-23%.

At the city level, in particular, the municipality has planned to plant 25,000 new trees per year, to reach a total of about 250 000 trees by 2030.

Further assumptions

Given the above mentioned assumptions, the scenario has been modelled by assuming a removal efficiency for different pollutants by the planted trees. Therefore, no change in activities or emission factors has been considered, but a decrease in absolute emissions. The absolute removal of pollutants for 2020 and 2030 is as follows:

Removal of pollutants		2020	2030
O3	t	2.3	25.7
PM10	t	1.0	11.2
NOx	t	0.4	4.9
CO	t	0.1	0.9
SO2	t	0.3	2.8
PM2.5	t	0.2	1.9
CO2	kt	0.8	8.8

3.2.6.6 Emission reduction potential – results Milan

In Milan the implementation of a Low Emission Zone (Area B) banning the entrance of the most polluted vehicles (e.g. up to Euro 4 diesel cars) through a system of tracking and access control (*AreaB*) shows by far the highest emission reductions for all pollutants – both in 2020 and 2030. Regarding nitrogen oxide emission reductions, the second most effective scenario is the conversion of all public buses to electric ones by 2030 (*ElectricBus*), which is followed by the introduction of solar power/photovoltaics for building uses and district heating (*Energy*). The scenario *Trees*, which addresses the greening of the city of Milan shows compared to the other measures especially in 2030 also high reductions of particulate matter removal. The emission reduction potential of all scenarios increases from 2020 to 2030, with a drastic increase for scenario *AreaB,* which is due to the fact that the scenario foresees a complete diesel ban by 2030.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 8.

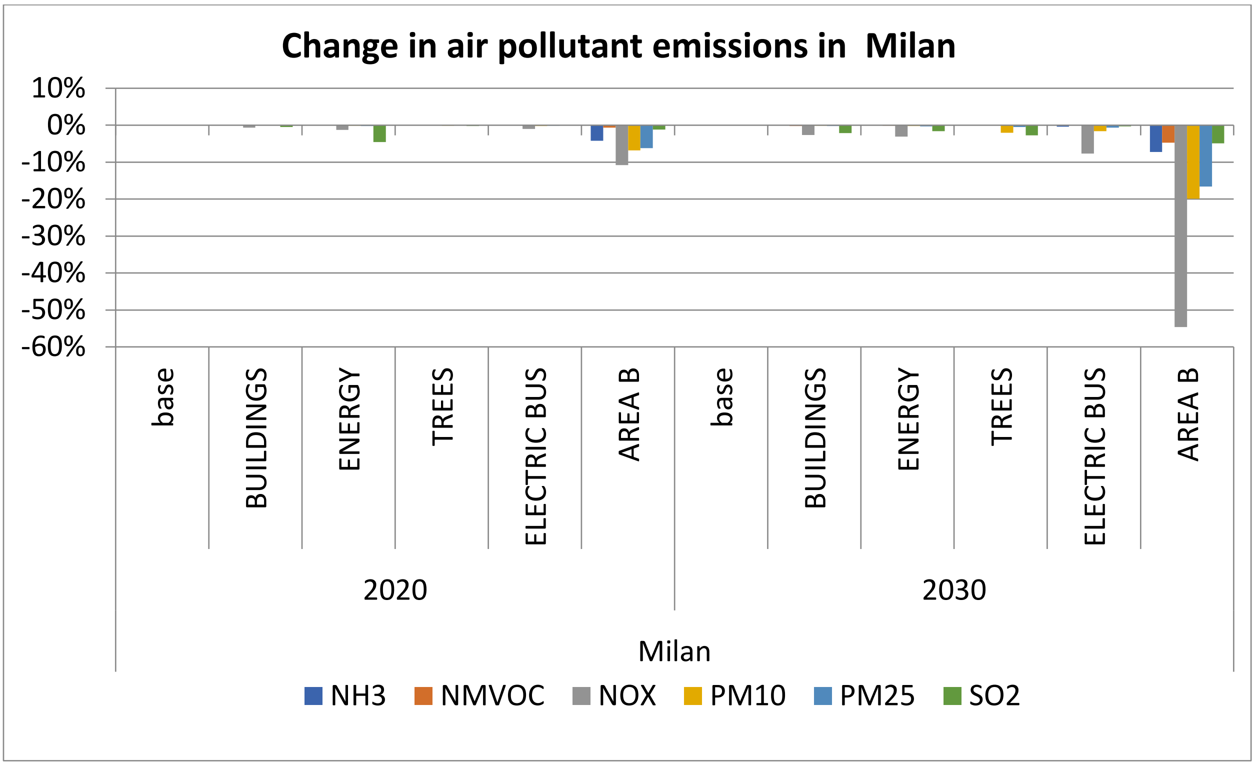


Figure 8: Change in air pollutant emissions in Milan

3.2.7 Stuttgart

3.2.7.1 Policy scenario 1 - Sc1

Increase of building insulation and heating system exchange from oil to high efficiency gas boilers, district heating and heat pumps in the residential and commercial sector

Description of the scenario

This policy scenario aims at reducing emissions related to the energy consumption of buildings by promoting insulation and renovation and the replacement of old heating systems. It therefore will affect two individual sectors: the residential sector (1A4bi) and the commercial sector (1A4ai).

In the residential sector (1A4bi), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)
- Mechanical ventilation system with heat recovery for later years

In the commercial sector (1A4ai), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope: façade, roof, ceilings; windows replacement)
- Modernisation of indoor lighting system
- Modernisation of ventilation (with heat recovers) and air conditioning systems

Furthermore, the scenario aims at reducing emissions from domestic heating by replacing old coal- and oil-fired boilers by natural gas-fired high efficiency boilers, heat pumps, district heating and solar thermal collectors and therefore affects the residential sector 1A4bi and non-residential sector 1A4ai. The replacement of coal or oil fired boilers in residential and non-residential buildings will be fostered by respective funding schemes[11]. The introduction of wood pellet or biomass boilers in the inner city centre is not promoted due to unfavourable particulate matter emissions.

Change in activity

The energetic renovation leads to a decrease of heating and cooling energy demand and therefore final energy consumption (i.e. the activity level). We expect the building renovation rate to increase from 1%/a to 3%/a and for the milestone year 2030 to a more ambitious target of 4%/a. The renovation rate of residential buildings increases by 2% until 2030 (start of the measure was in 2017). The reduction of final energy is estimated to be approx. 40% per renovated building until 2020. After 2020 the renovation rate increases even further, i.e. 3% increase compared to the business as usual scenario. The final energy consumption reduction for heating of renovated households after 2020 is estimated to be 30% as a decrease of the

[11] https://www.stuttgart.de/heizungsaustauschprogramm (accessed on July 28 2019)

energy saving potential for newer buildings has been assumed[12]. The efficiency increase of the heating system (after the gas heating system exchange) contributes with 10% to total final energy reductions. After 2020 the installation of mechanical ventilation systems with heat recovery contributes further 14% reductions in heating energy to each building equipped with the system.

The final energy consumption reduction of commercial buildings is estimated to be about 30% in 2030 (no reduction has been assumed until 2020). The high reduction potential partly can be explained by the renovation measures and subsequent reduction of energy demand and partly is due to the fact that the energy consumption of fuels drastically decreases due to the connection to district heating for building complexes.

The assumed final energy reduction is therefore 5% in 2020 and 19% in 2030 for residential buildings and 30% reduction for commercial buildings.

The replacement of coal and oil boilers leads to a shift in the activity categories from oil/coal fuels to gas and renewable energy sources. The shift in the fuel type and heating system type (gas to high efficiency boilers) has been modelled as an activity change under the assumption that the total amount of building heating systems remains constant in the city.

Further assumptions

It has been assumed that the exchange of the heating system takes place after reaching the end of the life span for each boiler.

3.2.7.2 Policy scenario 2 - FvH

Blue badge: Introduction of a driving ban on diesel vehicles less than Euro 6 standard and gasoline vehicles less than Euro 3 standard in the city of Stuttgart

Description of the scenario

This scenario analyses the effect of a potential ban on diesel cars with less than Euro 6 / VI standard and petrol vehicles with less than Euro 3 standard. Therefore, the introduction of a “blue badge” allows all motor vehicles with diesel engines from Euro 6 / VI onwards, all motor vehicles with petrol engines (petrol and gas-powered) from Euro 3, as well as all vehicles without internal combustion engine (pure electric and fuel cell vehicles) to enter the city.

The scenario additionally includes a retrofitting or hardware update of diesel passenger cars

[12] reduction potential for each building estimated according to a personal note from City of Stuttgart 5.12.2017

with Euro 6 and Euro 5 standard. The hardware update comprises the installation of an additional SCR system (selective catalytic reduction) for AdBlue injection. The SCR system aims at reducing the emitted NOx due to chemical transformation processes.

Change in activity

According to the banning regulation, reported in the description of the scenario, the new activities (yearly vehicle kilometres run) have been calculated for each type of vehicles for 2020 and 2030 scenarios, subtracting from BAU scenario the activities that would have been run for vehicles banned in that year and replacing them by activities of higher Euro standards. The vehicle kilometres of banned vehicles (Euro 1-5) have been assigned to Euro 6, 6dtemp, 6d standard categories maintaining the same proportion of vehicle kilometres between these types as they are currently present in the business as usual scenario.

The calculation assumes that 20 percent of vehicles that do not meet the requirements for a blue badge would be subject to exceptions from the ban (vehicles in classes Euro 3- Euro 5). This value is very generous, so as not to overestimate the effect of the blue environmental zone. For buses no exceptions have been assumed.

Emissions due to road abrasion and gasoline evaporation have been recalculated in agreement with the assumptions described above.

Change in emission factors

The assumed reduction potential for NOx emission is 75% and the potential for retrofitting among diesel passenger cars is assumed to be 91%, resp. 30%.[13]

---

[13] Bundesministerium für Verkehr und digitale Infrastruktur (Ed.) (2018a): Studie über das Potenzial einer Realisierung einer Hardware-Nachrüstung für Dieselfahrzeuge EU5 (EU4) zur NOx Reduzierung, accessed on 5/28/2018; Bundesministerium für Verkehr und digitale Infrastruktur (Ed.) (2018b): Wissenschaftliche Untersuchungen hardwareseitiger NOx Reduzierungsnachrüstmöglichkeiten im PKW Bereich und im Segment der leichten Nutzfahrzeuge. Kurzstudie, accessed on 5/28/2018.

LfU (2018): Luftreinhalteplanung - Maßnahmen gegen Feinstaub und Stickstoffoxide, accessed on 12/7/2018

UBA (Ed.) (2017): Ergänzung der Bewertung zu marktverfügbaren fahrzeugseitignen NOx-Nachrüsttechnologien und Bewertung der Nachbesserung, accessed on 12/17/2018.

https://www.autozeitung.de/euro-6-nachruesten-183792.html (accessed on 28/07/2019)

https://www.auto-motor-und-sport.de/verkehr/eu5-diesel-nachruestung-scr-kat-fahrverbote/ (accessed on 28/07/2019)

Further assumptions

The enforcement of the diesel ban has led to an alternated share of allowed types of vehicles; in this regard it has been assumed that banned vehicle kilometres will be replaced by all non-banned Euro standards to the proportion as present in the baseline scenario for the respective year (and not just by the latest available technology) represents a rather conservative scenario. The results in terms of emission reductions for this scenario therefore represent the lower boundary of possible reductions.

A more detailed description of related assumptions is presented in the relevant section in Annex 1.

3.2.7.3 Policy scenario 3 - ScUV

Promoting environmentally friendly transportation modes like walking, cycling and public transportation leading to a decrease of individual transport by 7% in 2020 and 20% in 2030

Description of the scenario

The aim of this scenario is to shift traffic demand from motorized private transport to alternative and more environmentally friendly transportation modes.

It therefore targets two main objectives:

- Promotion of public transport
- Promotion of walking and cycling

The current update of the Air Quality Plan Stuttgart[14] provides an extensive list of individual measures addressing these issues. They mainly comprise the expansion and promotion of buses and urban railways along with cycling infrastructure. Regarding the public transportation, an express bus has been set up between Bad-Cannstatt and the Stuttgart city centre, additional suburban trains are being run, the city rail service is being improved, and there are additional offers on regional rail services. In addition, a tariff reform of the public transport in April 2019 made travelling by public transportation up to 25% cheaper.

The scenario examined goes beyond currently decided interventions and expects further effort especially in soft factors (e.g. awareness campaigns) and hard components (e.g.

[14] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, accessed on 3/22/2019.

extension of infrastructure, new lines, new vehicles) and is oriented towards the proposed interventions of the Green City Plan[15]. It therefore aims at making mobility alternatives for motorized private transport more attractive. We assume that the measure bundles/clusters lead to a decrease of motorized private transport trips of 7% by 2020 and 20% by 2030.

Change in activity

This scenario is not modelled as a response to one specific city policy, but rather as a scenario with reduced motorized individual transportation. It will lead to an increase of trips by bicycle, walking and public transport. Trips in private transportation will be reduced respectively. The measure will have no impact on the vehicle fleet or on the exhaust emissions. No changes in terms of absolute person kilometres will be assumed.

It has been assumed that 7% of the motorized private transport trips in 2020 and 20% in 2030 are replaced by walking, cycling and public transport. Assumptions for 2020 are in line with the measure package “enhancement of the environmental alliance” in the air quality plan 2018 (Regierungspräsidium Stuttgart 2018)[16], while assumptions for milestone year 2030 are set to represent an ambitious target. To generate the new activity levels for each activity the following assumptions have been made:

- traffic load of motorized individual transport (MIV) is reduced by 7%
- trips by walking, cycling and public transport increase according to the reduction in MIV
- vehicle fleet composition remains unchanged
- person kilometres travelled within the city area of Stuttgart remain constant

Further assumptions

Within this measure, we have not considered an increase of electricity consumption due to the more frequent usage of public transportation means running with electricity. Furthermore, it has been assumed that the capacity of all public transportation means (buses, metro, tram) in the baseline scenario allows to take over the switch of person kilometres

---

[15] Landeshauptstadt Stuttgart, AVISO GmbH, Rau Ingenieurbüro (2018): Masterplan zur Gestaltung nachhaltiger und emissionsfreier Mobilität – Green City Plan

[16] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, accessed on 3/22/2019.

induced by the measure bundle, which means that no increase in the activity level of trains is expected. Emissions from cycling have not been taken into account. The scenario therefore can be considered as an optimistic scenario representing the upper range of expectable emission reductions.

3.2.7.4 Policy scenario 4 - ScEL

Promoting low carbon electric and hybrid vehicles (share of passenger car vehicle kilometres 7% in 2020 and 20% in 2030)

Description of the scenario

This scenario includes various sub-measures like the procurement of electric and hybrid vehicles for the municipal vehicle fleet, the promotion of willingness to switch to electric vehicles in taxi companies and the construction of charging infrastructure in semi-public and non-public areas for a further penetration of electric vehicles into the private passenger car fleet and parking fee reductions for electric vehicles. The measure is oriented towards the measure *EMIV* in the Green City Plan Stuttgart (2018)[17] but includes also further promotion to motivate private car owners to switch from conventionally fuelled vehicles to electric vehicles. The comprised sub-measures are as follows:

- Purchase of full electric vehicles for the municipal fleet
- Construction of charging infrastructure at public and non-public spaces by the City of Stuttgart
- Construction of further charging infrastructure by private companies
- Promotion of e-taxi fleet (according to Elektro-Taxi-Aktionsplan Stuttgart) (Vogt, M. et al., 2017)
- Promotion of taxi exclusive non-public fast charging stations
- Charging infrastructure concepts for specific objects
- Free parking for electric vehicles
- Subsidies for electric vehicles of 2.000€/vehicle

With the help of the measure package, an elevated share of electric vehicles in the passenger car fleet of 7% in 2020 and 20% in 2030 is expected. The scenario mainly aims at a high reduction of NOx emissions in the city of Stuttgart and on particularly polluted sections of the

[17] Landeshauptstadt Stuttgart, AVISO GmbH, Rau Ingenieurbüro (2018): Masterplan zur Gestaltung nachhaltiger und emissionsfreier Mobilität – Green City Plan

route that are achieved due to the increased use of lower-emission drive technologies.

Change in activity

For this measure, no changes occur for the most vehicle categories (like buses, LDVs, motorcycles and HDVs). The changes due to the increase of electrification only concern the passenger cars (PCs) of the municipal fleet, the taxi fleet and privately owned vehicles. Furthermore, neither changes in terms of absolute km driven nor changes in the technology (pre-EU, EU1, …) of petrol and diesel cars will be assumed. Only the share of individual cars for which electric vehicles will represent a larger share compared to the baseline scenario; the share of diesel vehicles is respectively reduced.

The scenario is not modelled as a response to one specific city policy, but rather as a scenario of a future higher share of electric vehicles that can be compared to a scenario reducing the private individual transportation and fostering the use of public transport. The higher share of electric vehicles on the road is fostered by different sub measures which have been described above. It has been assumed that 7% of the private passenger cars in 2020 and 20% of passenger cars in 2030 are electric. Assumptions for 2020 are in line with the impact assessment of proposed air quality plan measures by Regierungspräsidium Stuttgart (2018)[18]. The scenario assuming a share of 20% electric vehicles in 2030 is an ambitious scenario. However, the target scenario of ZSW et al. (2017)[19] foresees a market upturn to 60% share of new registrations in 2030. As a result of today's low level, the majority of electric vehicles will enter the fleet from 2025 on, so that in 2030 a total of 22% of the fleet will be reached. Under the given circumstances (higher effort for motivating private car owners to switch to e-cars, charging infrastructure) the scenario assuming 20% electric vehicles in 2030 has been considered as realistic.

Further assumptions

Within this measure, we have not considered the increase of electricity consumption due to the penetration of electric vehicles onto the market, but we have considered that this will happen at the national level and not at the city level, which is uncertain. Therefore, we should keep in mind that the reported emissions for that measure are an underestimation of the real

[18] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, accessed on 3/22/2019.

[19] ZSW; ifeu; Öko-Institut e.V.; Fraunhofer ISI; Hamburg Institut; Dr. Joachim Nitsch (2017): Forschungsvorhaben Energie- und Klimaschutzziele 2030: Endbericht, accessed on 1/15/2019.

emissions (however not for the city level). However, costs resulting from the additional electricity generation are considered in the cost/benefit analyses.

3.2.7.5 Emission reduction potential – results Stuttgart

In Stuttgart the most effective scenario in terms of emission reductions for all pollutants in 2030 is the *Sc1*, which addresses the increase of building insulation and heating system exchange to high efficiency gas boilers. On the contrary the highest nitrogen oxide emission reductions in 2020 can be found for the scenario *FvH*, which is associated with the introduction of hardware update of diesel passenger cars and driving ban on diesel PC < Euro6 in the city centre. Among the other policies the promotion of environmentally friendly transport modes (e.g. walking, cycling) along with the decrease of individual transport (*ScUV*) shows similar emission reductions as the increased electrification of the passenger car flee (*ScEL*), apart from an additional reduction of particulate matter emissions. The reductions increase for all measures from 2020 to 2030 which is due to a higher building renovation rate, transport mode switch and penetration with electric vehicles. On the contrary, the emission reduction of the driving ban scenario (*FvH*) decrease as fewer vehicles are affected in future years.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 9.

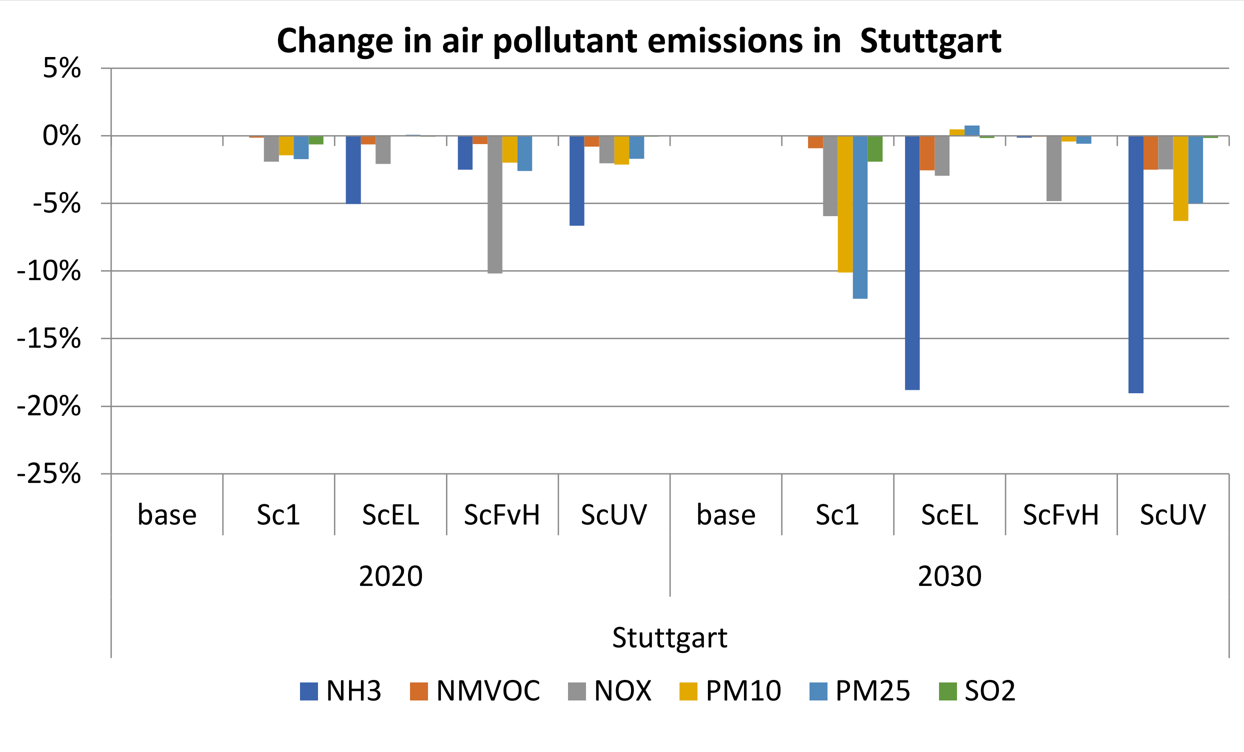


Figure 9: Change in air pollutant emissions in Stuttgart

3.2.8 Thessaloniki

3.2.8.1 Policy scenario 1 - M1

Promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings

Description of the scenario

The scenario considers the promotion of building insulation and renovation. Furthermore, green infrastructure and bioclimatic design of public buildings (including schools) and public open areas as well as the implementation of green roofs in public buildings are fostered.

Change in activity

The change in activities has been calculated based on energy savings for different interventions. Energy saving values have been adopted from the official Action Plans for Sustainable Energy of the Municipalities of Thessaloniki Regional Unit. New activity levels for 2020 are as follows:

NFR	Fuel	Technology	Activity (PJ) - Old	Activity Change	Activity (PJ) -

	type	description		(PJ)	New
1 A4ai	Natural Gas	Commercial (combustion)	0.590698215	6.90045E-05	0.590629211
1 A4ai	Oil (Diesel)	Commercial (combustion)	0.625149772	7.3029E-05	0.625076743
1 A4ai	LPG	Commercial (combustion)	0.042103882	4.91851E-06	0.042098964

No further reductions have been assumed for 2030.

3.2.8.2 Policy scenario 2 - M2A

Promotion of cycling and walking. The measure foresees the construction of a metropolitan bike lane network and the expansion of the already existing one to increase the cycling and walking in the city.

Description of the scenario

The scenario foresees the construction of a metropolitan bike lane network and the expansion of the already existing one to increase the cycling and walking in the city.

Change in activity

The measure is expected to change significantly the transport mode choice of the individuals and therefore the driven vehicle kilometre by private transportation means.

3.2.8.3 Policy scenario 3 - M2B

Promotion of green vehicles. Shifting to cleaner energy practices in Transport is important to the City of Thessaloniki. The Municipalities of Thessaloniki Regional Unit will proceed to the gradual replacement of all the old municipal vehicles with new electric ones. The measure additionally foresees the replacement of private passenger cars due to further incentives

Description of the scenario

This scenario foresees the shift to cleaner energy practices in Transport, which is particularly important to the City of Thessaloniki. The Municipalities of Thessaloniki Regional Unit will proceed to the gradual replacement of all the old municipal vehicles with new electric ones. The measure additionally foresees the replacement of private passenger cars by electric ones due to further incentives.

Change in activity

The measure foresees the replacement of passenger cars by electric ones.

3.2.8.4 Policy scenario 4 - M2C

Promotion of public transport and the use of metro by building an integrated urban mobility system. The introduction and operation of underground railway (Metro) is expected to change significantly the transportation mode in the city of Thessaloniki. The measure focuses on the establishment of an integrated urban mobility system and the promotion of public transport.

Description of the scenario

This scenario considers the promotion of public transport by an extended use of the metro and the building of an integrated urban mobility system. The introduction and operation of underground railway (Metro) is expected to change significantly the transportation mode in the city of Thessaloniki. The measure focuses on the establishment of an integrated urban mobility system and the promotion of public transport. The implementation of the measure is expected to be a joined effort of the Municipalities of Thessaloniki Regional Unit, the Metropolitan Authority and Thessaloniki Public Transport Authority (ThePTA).

Change in activity

The measure is expected to change significantly the transport mode choice of the individuals and therefore the driven vehicle kilometre by private transportation means and buses.

Further assumptions

The reduction potential per sector is calculated using the reduction potential per vehicle category and the proportion of the vehicle category on sector emissions (per year and pollutant) The proportion of the vehicle category for passenger cars and motorcycles is 1. Data on vehicle category and the share of buses/HDVs on 1 A 3 b iii emissions have been derived from the bottom up emission inventory for Thessaloniki.

3.2.8.5 Policy scenario 5 - M3

Promotion of eco-friendly waste management

Description of the scenario

The scenario focuses on eco-friendly waste management by pre-treating and pre-sorting waste into biodegradable and non-biodegradable material for further anaerobic digestion and composting. Residues end in landfill, whereas plastic, paper and ferrous material are recycled.

Change in activity

The activity level in sector 6A has been reduced by 50%.

3.2.8.6 Policy scenario 6 - M4

Energy efficiency in the cement industry: Use of refuse derived fuels

Description of the scenario

The scenario targets to increase the use of Refuse Derived Fuel (RDF) in cement industry. In 2015, the Cement industry had a percent of RDF use of 13%. The target share is 20% of RDF use by 2020 (a total of 30% of alternative fuels use is targeted, the rest 10% will have to be other alternative fuels), and to reach 30% of RDF use by 2030 (the total use of alternative fuels will be higher).

Change in emission factors

The changes in emission factors were calculated based on references (Genon and Brizio, 2008, Worrell E et al., 2001) and the EEA guidebook on EFs. Data from the references on the reduction potential for EFs following to two substitution (%)scenarios with RDF were used to derive linear equations per pollutant and interpolate the values to the specific percentages of targeted RDF use by 2020 and 2030. According to the interpolated values to the specific percentage of RDF use, the reduction potential was computed and applied to the current EFs. Lastly, the new EFs for 2020 and 2030 were used to calculate the new emissions.

3.2.8.7 Emission reduction potential – results Thessaloniki

In Thessaloniki the highest particle emission reductions are associated to improved energy efficiency in the cement industry through the use of refuse derived fuels (*M4*), while other air pollutants show highest reductions for transport related measures *M2*. The lowest reductions are associated to the promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings (*M1*) and, to a less extent, to the promotion of eco-friendly waste management (*M3*). Emission reductions of transport related measures do not increase from 2020 to 2030 due to a slightly lower emission reduction potential at the sector level and an overall decrease of baseline emissions at the city level.

Detailed emission reduction potential calculations are presented in Annex 1; the results are presented in Figure 10.

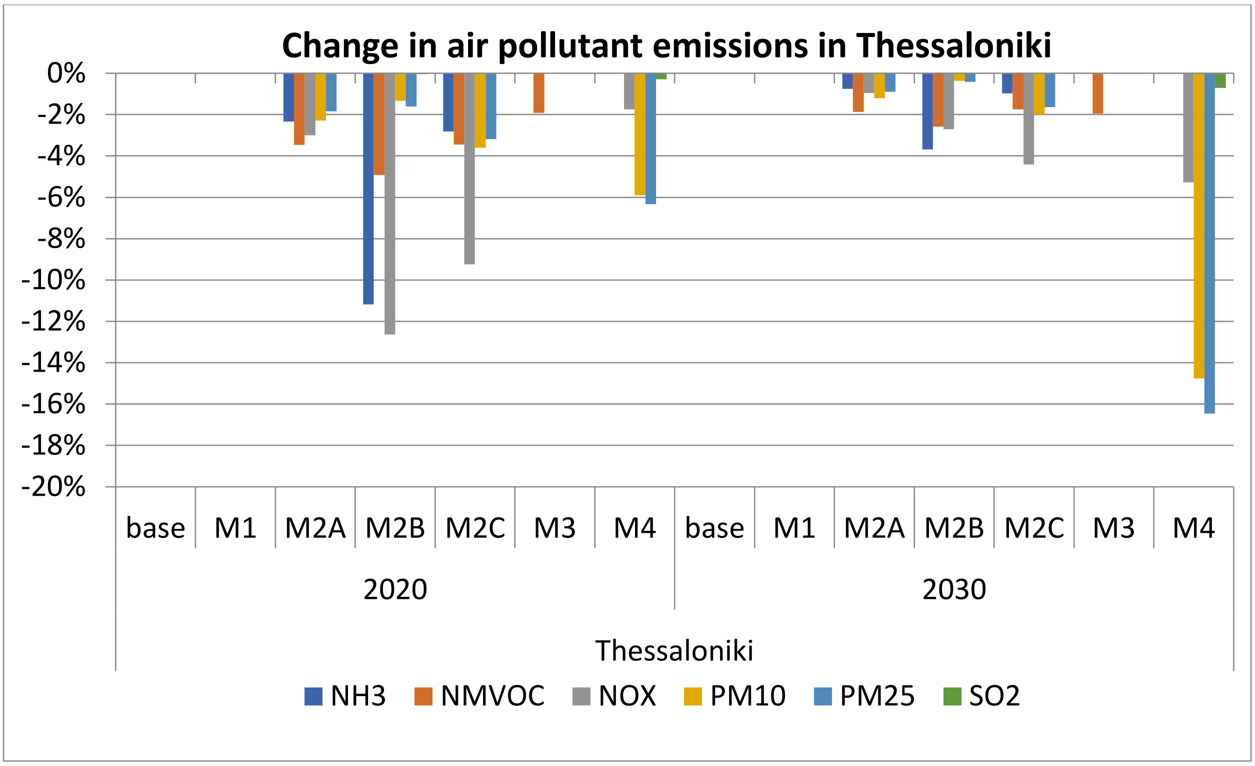


Figure 10: Change in air pollutant emissions in Thessaloniki

3.3 Emission reductions of greenhouse gases for the city scenarios

The results in terms of new air pollutant emission scenarios for each policy and city have been used within the concentration modelling. Furthermore, total reductions of greenhouse gases have been calculated for each policy scenario and fed into the cost-benefit analysis described in a later section of the report. The total reductions of greenhouse gases (CO_2, CH_4 and N_2O) are calculated by a comparison of policy and baseline emission inventory. The emissions of the policy scenario have been subtracted from the baseline emission inventory of the respective milestone year. Results are presented in the following table:

Table 3-5: Total greenhouse gas emission reductions in kg for the city scenarios

		2020			2030		
City	Measure name	CH4 [kg]	CO2 [kg]	N2O [kg]	CH4 [kg]	CO2 [kg]	N2O [kg]
Athens	EnEff	-13410	-19312669	-263	-	-50946315	-696

					26338		
Athens	EnEffZEB	-14391	-20788059	-271	-36291	-68939445	-761
Athens	SusMob	-28271	-255323119	-2104	-113926	-1288399152	-8422
Athens	SusMobPuT	-32674	-287832816	-2383	-137727	-1503027876	-9777
Athens	Waste	0	0	0	0	0	0
Brno	M1opti	-2157	-34263619	-689	-3515	-62961950	-1069
Brno	M2opti	-10653	-168247794	-3388	-11820	-209499940	-3540
Brno	M2zero	-6350	-99894886	-2013	-6069	-106495761	-1791
Brno	M3slow	765	-3049907	-27	3670	-14639553	-131
Brno	M4econ	-24345	-12334758	-114	-46160	-23252011	-214
Basel	FirewoodBan	0	0	0	-1470	0	-159
Basel	NoHeat	-5502	-89724499	-322	-12533	-223463710	-726
Basel	NoHeatFirewood	0	0	0	-14003	-223463710	-885
Basel	Traffic10	-2156	-26123662	-572	-2088	-32902958	-736
Basel	ZeroEmissionShi	0	0	0	0	-2451303	0

	ps						
Ljubljana	M1_DecreaseCAR	0	0	0	-4493	-89432382	-2225
Ljubljana	M2_IncreasePT	0	0	0	29421	-81619291	-2242
Ljubljana	M3_PTfleet	0	0	0	26019	-97534769	-2503
Ljubljana	M4_ DistrHEAT	0	0	0	115365	-67892736	-8446
Ljubljana	M5_ efficientHEAT	0	0	0	-59996	-24530471	-279
Milan	Buildings	-2876	-63281097	-1151	-10759	-236702720	-4303
Milan	ElectricBus	-171	-3057103	-192	-426	-9759901	-1385
Milan	Energy	-4083	-89419270	-1250	-8188	-198908550	-2539
Milan	Trees	0	-800000	0	0	-8800000	0
Milan	AreaB	-5085	-209950556	-8134	-16377	-653301684	-28283
Madrid	EnEff	-125310	-116820462	-505	-407814	-374024333	-1617
Madrid	Logistics	-72	-8268993	-264	-199	-28512747	-845
Madrid	PuTInfra	-2275	-34200993	-1101	-4487	-68138836	-2086
Madrid	ParkReg	-409	-7325565	-237	-1567	-17034492	-628

Madrid	ZEZ	-451	-5604019	-202	-609	-5208007	-182
Thessaloniki	M1	-5	-9548	0	-4	-9099	0
Thessaloniki	M2a	-35924	-317795505	-4282	-19202	-187411674	-1030
Thessaloniki	M2b	-105932	-1498785618	-19751	-56291	-855427025	-3733
Thessaloniki	M2c	-43335	-455498759	-7072	-24487	-276082110	-2655
Thessaloniki	M3	0	0	0	0	0	0
Thessaloniki	M4	0	-348733314	0	0	-388971773	0
Stuttgart	ScEL	-926	-31101038	-280	-3164	-82721283	-1128
Stuttgart	ScFv_H	-322	-4056749	-178	-29	-264054	22
Stuttgart	ScUV	-1232	-36098962	-490	-3233	-85366369	-1275
Stuttgart	SC1	4173	-40976202	-493	-26143	-159908726	-1073

4 POLLUTION MODELLING

4.1 Objective

The objective of this task is to examine the impact of the new emission inventories which were produced by the ICARUS measure policy scenarios on Air Quality. More specifically, to estimate the air quality changes focusing on nine (9) European cities; Athens, Basel, Brno, Ljubljana, Madrid, Milan, Stuttgart and Thessaloniki by examining major air pollutants (PM_{10}, $PM_{2.5}$, NO_2, O_3) under the RCP4.5 climate scenario.

4.2 Methodology

Trying to follow climatic changes on local meteorology and air quality while taking into consideration the measure scenarios that affects the anthropogenic emissions for the following years (up to 2050), the methodology which was developed in WP3 (described in details in D.3.3) was applied. To achieve that the following steps were followed:

1. Provide the necessary meteorological input for the future years following the IPCC scenarios based on the Fifth Assessment Report (AR5) and on the Representative Concentration Pathways (RCP). These RCPs are taking into consideration prescribed socio-economic, land use and emission scenarios to perform projections of changes in the climate system. The four RCPs (i.e. RCP2.6, RCP4.5, RCP6, RCP8.5) together span the range of year 2100 radiative forcing values found in the open literature i.e. from 2.6W/m2 to 8.5W/m2. (van Vuuren et al., 2011). The one selected for this analysis, RCP4.5, seems to be a realistic scenario for the cities considered in ICARUS. It is a low-to-moderate emissions scenario with GHG radiative forcing reaching 4.5W/m^2 near 2100.
2. Examine changes in 5-year period cluster frequencies of occurrence over the whole range of 50-year, following the concept of weather clustering/classification. The weather classification covers a 50 years period, from 2001 to 2050 and the weather data are derived from the Coordinated Regional Climate Downscaling Experiment (CORDEX). The weather parameters considered, include (1) the 2-meter temperature, (2) the daily temperature range , (3) the 2-meter relative humidity (%), (4) the surface pressure , (5) the precipitation , (6) the 10- meter U-component wind velocity , (7) the 10-meter V-component wind velocity, (8) the downward short-wave surface radiation and (9) the atmospheric boundary layer thickness. Then PCA analysis applied to these parameters to create uncorrelated variables. K-means cluster analysis was used to create clusters of days per city. Representatives Days (RDs) were selected per cluster and 5-year period (the day which is closest to each cluster centroid).

3. Produce the representative detailed results by using WRF-Chem methodology (description of the model in D3.3 and MS3.2) to provide hourly concentrations of air pollutants in both regional and local scale. More specifically two level multiple horizontal nesting has been adopted. An outer grid with dimensions 12x12km has been implemented over Europe. The Grid Projection has been defined as Lambert conformal Conic consisting of 303 x 303 cells. On the urban scale nine (9) nests with dimensions 2x2km have been used consisting of 42x42 grid cells each. Finally, in each city a local domain of an area 50km*50km is considered surrounding the city center.

More specifically for this task the applied methodology is described below:

1. Use as input the new emission inventories based on the policy/measure scenarios;
2. Perform detailed Air Quality Modeling using WRF-CHEM. For the representative days of each cluster and 5-year period based on the weather clustering.
3. Simulation results are hourly NO_2, O_3, PM_{10} and $PM_{2.5}$ concentrations at a 50x50 km area in 2x2km resolution per city per representative day;
4. The final results refer to the 5-year periods (2021-2025, 2026-2030, 2031-2035, 2036-2040) CR Concentrations as explained below[1]. For each city's 2x2km cell the daily average data are available as input for the Health Impact Assessment.

- [1]Pollutant representative air concentration (CR) defined as follows:

$$CR(\Delta\tau) = \sum_{n=1}^{N} f_n(\Delta\tau) \cdot CRD_n\,(\Delta\tau)$$

Where

N is the total number of Clusters

$f_n(\Delta\tau)$ is the frequency of occurrence of cluster n during the time period Δτ (5 years)

$CRD_n(\Delta\tau)$ is the concentration under study corresponding to the representative day of the cluster n during the time period Δτ (5 years)

4.3 Results

The results obtained from the modelling process are spatial hourly data of NO_2, O_3, PM_{10} $PM_{2.5}$ Representative Concentrations (CR) for the 5-year periods 2021-2025, 2026-2030, 2031-2035, 2036-2040 for all measure scenarios.

Please refer to Annex 2 for the graphical presentation of indicative results of the daily average concentration values of NO_2 and $PM_{2.5}$ for the wider area of each ICARUS city.

4.4 Conclusions

The developed (WP3) clustering methodology and detailed air quality modeling approach used to study air quality trends under specific climatic & measure scenarios. In general, the scenario variation during the 2036-2040 period showed slight differentiations. More specific, the following remarks could be pointed out:

Athens: All scenarios resulted in lower NO_2 levels. The scenarios SusMob and SusMobPut had higher impact on the reduction of NO_2. During 2036-2040 EnEffZEB scenario showed lower $PM_{2.5}$ levels.

Basel: NoHeat and Traffic10 scenarios showed the lowest level in $PM_{2.5}$. NoHeat scenario seems to result in lower NO_2 concentrations.

Brno: M2opti and M2zero scenarios presented lower NO_2 concentrations, while the M2opti had higher reduction on the concentrations. $PM_{2.5}$ concentrations seem not to be affected.

Ljubljana: M4_DistrHEAT measure scenario showed the highest reduction for NO_2 and $PM_{2.5}$ concentrations.

Milan: AREAB, ELECTRIC BUS and BUILDING scenarios resulted in lower NO_2 level in the wider area. AREAB seem to have a significant reduction. AREAB also presented lower $PM_{2.5}$ concentrations.

Madrid: EnEf scenario show a slight lower NO_2 level in a wider area.

Stuttgart: Al scenarios showed a slight decrease in the wider area for NO_2. For $PM_{2.5}$ the picture is mixed. Cell areas with high concentrations seem not to be affected.

Thessaloniki: M2b, M2cc and M4 measure scenarios resulted in lower NO_2 concentrations. Also, these scenarios showed lower $PM_{2.5}$ concentrations.

Further to these findings, a more detailed analysis focusing on the climatic trends (for all measure scenario) from 2021 to 2050 the following conclusions can be drawn:

- NO_2 showed a decrease for Athens, Basel, Ljubljana, Brno and Stuttgart. An increase was observed in Thessaloniki and a slight increase in Madrid.

- O_3 shows an increase in Stuttgart and a slight increase in Athens and Ljubljana. The picture is mixed for Madrid, Thessaloniki and Basel. In Milan there is a decrease the years 2021-2035 and then an increase.
- PM10-2.5 show a decrease in Ljubljana, Basel and Madrid (after the 5-year period 2026-2030) and an increase in Milan and Athens/Thessaloniki (for years 2021-2035). The picture is mixed for Stuttgart, Brno and Milan.

5 HEALTH IMPACT ASSESSMENT

5.1 Background

Air pollution is an important determinant of health (WHO Regional Office for Europe, 2006). Numerous epidemiological studies have found an association between air pollution and a wide range of adverse health effects in the general population; the effects have ranged from subtle subclinical effects to premature death.

To this end over the last decade, hundreds of epidemiological studies have linked exposure to outdoor air pollution (a) either short or long exposure; (b) the individual effects of each pollutant or cumulated effects of more pollutants with a wide range of adverse health outcomes (a) direct and indirect; (b) acute and chronic; (c) for individuals or population groups or general population.

Some groups – for example older adults, children, pregnant women and people with an underlying disease, such as asthma – may be more at risk, and may develop more severe health effects more quickly when exposed to air pollution. In addition, certain groups may be exposed to higher levels of outdoor air pollution, e.g. people living near busy traffic routes or those in specific occupational or socioeconomic groups (WHO Regional Office for Europe, 2005).

Epidemiological studies have examined the effects of air pollution on a significant number of adverse health outcomes, including in general increased mortality and morbidity levels and reduced life expectancy. Beside this, studies incorporated also specific type of healthcare services as emergency department visits and hospital admissions or indicators of lost workdays and restrictions in activity in the general population. These adverse health outcomes are related mainly to cardiovascular and respiratory diseases and a few vulnerable groups: infants, children, elderly, people with pre-existing heart and lung disease, asthmatics, and socially disadvantaged and poorly educated populations (Krewski et al., 2009).

A health hazard can be defined as a source of risk to human health or well-being (Department of Health, 2006). According to the World Health Organization a health impact assessment is the scientific evaluation of potential adverse health effects resulting from human exposure to a particular hazard. In the context of this report, the health hazard of interest is air pollution.

Quantitative Health Impact Assessment (HIA), in general, including that for air pollution, represents a comprehensive approach to the evaluation of the current state-of-the-environment and of future conditions following specific abatement scenarios. The importance of HIA is strongly endorsed by governments and it is recommended to quantitatively assess adverse health impacts and possible inequalities in the population. Furthermore, the importance of HIA has been recognised through Article 152 of the Amsterdam Treaty calling for the European Union to examine the possible impact of major policies on health (Dandstrom et al., 2005).

An Air Pollution Health Impact Assessment (AP-HIA) aims to estimate the risks of past, current or future exposure to air pollution and of changes in exposure that may result from planned policies or other modifications of air quality (Department of Health, 2006; HIP, 2014). An AP-HIA may be quantitative or qualitative; it generally assesses (i) the amount of air pollution present, i.e. pollutant concentrations, (ii) the amount of contact (exposure) of the targeted population, and (iii) how harmful the concentration is for human health, i.e. the resulting health risks to the exposed population (WHO, 2010). The estimates provided by an AP-HIA are intended to inform the decisions of policy-makers or other stakeholders.

An AP-HIA can aid to answer specific policy questions. Indeed, in many countries it is required as part of the decision-making process for new programmes, projects, regulations, and policies aimed at improving air quality that may affect air quality as a side- effect. In many other countries, it may be conducted as part of an assessment or research project, even though there is no legal requirement (WHO Regional Office for Europe, 2014).

It should also be noted that AP- HRAs generally include only the subset of health impacts that can be quantified, and do not deal with other health effects for which no Concentration-Response Functions (CRFs) are available. Ideally, to protect public health, an AP-HRA should be as inclusive as possible; however, in many cases, it is likely that the HRA will underestimate the actual risk.

In evaluations of air pollution health impact, Particulate Matter (PM) has often been used as a summary indicator of air quality, and the findings describe the burden imposed on health by PM pollution (mostly in urban settings), and in some cases the associated economic costs, under the assumption that PM might be responsible for direct effects but also partly capture the effects of other correlated pollutants. The cost-benefit question that underlies these evaluations is “what are the health gains potentially obtainable adopting policies of abatement of emissions of PM and other pollutants?”, a piece of information that policy makers and the public at large increasingly require to inform the decision-making process.

Following the WHO guidelines (WHO Regional Office for Europe, 2016) quantitative assessment of the health impact of outdoor air pollution is based on four key components (Figure 11):

- Air-pollution concentrations and exposure assessment.

- Size and composition of population groups exposed to current levels of air pollution.
- Background incidence of mortality and morbidity.
- Concentration-Response functions (or CR models).

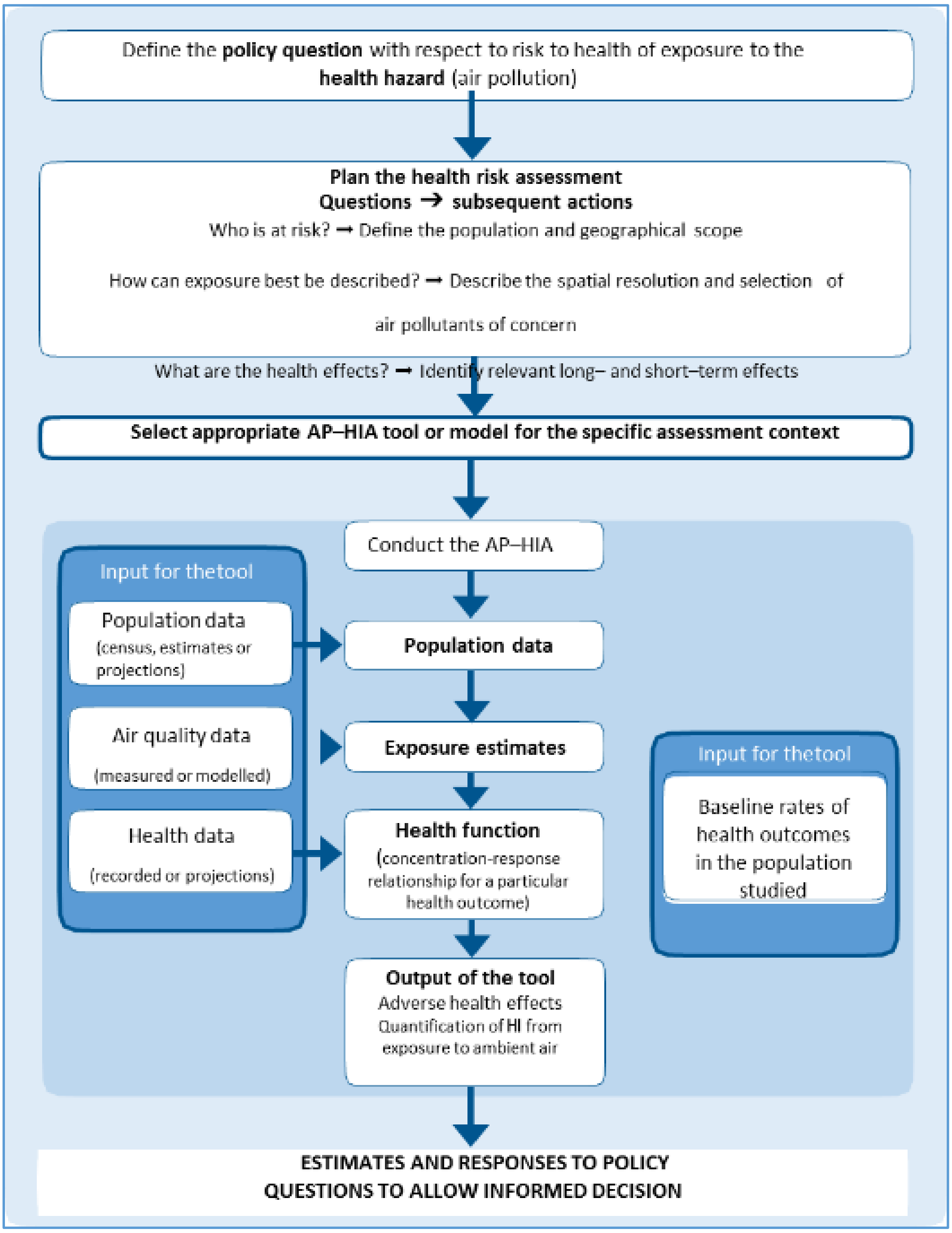


Figure 11: The main steps in the Health Impact Assessment (source: WHO 2005)

5.2 Methodology for calculating disease burden

Since the environmental exposure is the main driver in the health risk assessment and it is by its very nature determined in large part by location implying a spatial context, the study of interactions between humans and their environment requires spatial information and analysis. From this perspective environmental epidemiology can be seen as the area of epidemiology concerned with the study of associations between environmental exposures and health outcomes, with the purpose of further understanding the etiology of disease. The study of interactions between humans and the environment where they live requires spatial information and analysis.

The importance of geographic information science is increasingly recognized in relation to spatial epidemiologic research because it provides the fundamental geographic context to exploring spatial patterns in data. The geographic information system (GIS) provides an integrated set of tools that allow both the analytical manipulation and the visual representation of spatial data. In the context of epidemiology and public health, this provides a powerful aid to the analysis and understanding of the relationships between geography, the environment, and human health.

Indeed, disease mapping may be used to identify possible disease clusters, to define and monitor epidemics, to provide baseline data on health patterns, and to show changes in disease patterns over time. Disease mapping may also be useful for initial exploration of relationships between exposure and disease, particularly, acute health effects. Visualization with maps also helps increase the awareness of both the public and policy makers by conveying complex information in an easily understood format.

The methodology applied in ICARUS to quantify the health impact associated to exposure to air pollutants is based on the population attributable risk fraction concept.

The attributable fraction (AF), i.e. the fraction of the health outcome, which can be attributed to the exposure in a given population (assuming there is a causal association between the exposure and the health outcome and no major confounding effects on this association) for a certain time period can be calculated using the formula:

$$AF = \frac{\sum_i P_i \cdot RR_i - 1}{\sum_i P_i \cdot RR_i} \qquad (1)$$

where P_i is the proportion of the population at exposure category *i* and RR_i is the relative risk at exposure category *i* compared to the reference level. The above equation takes into account population exposed at different pollution levels.

Population exposure distribution can be derived from several information sources. In the simplest way it can be assessed from monitoring data using different geo-statistical methods ranging from the simple arithmetic mean until the more sophisticated kriging and co-kriging. Another approach makes use of the atmospheric dispersion models that provides ambient concentration of pollutants on a defined computational grid.

The relative risk (RR) for the selected health outcome is derived from the concentration-response function obtained from the epidemiological studies adjusted for any possible confounding factors. Estimating a certain baseline frequency of the selected health outcome in the population, I, the rate (or number of cases per population unit) attributed to the exposure in the population (IE) can be calculated as:

$$IE = I \cdot AF \qquad (2)$$

For a population of a given size N, this can be converted to the estimated number of cases attributed to the exposure (NE).

$$NE = IE \cdot N \qquad (3)$$

When the limits of the confidence interval for the RR estimate are used in formula, one can obtain the corresponding upper and lower limits of the AF estimate, and the respective range for the number of cases in the population, attributed to the specific exposure.

Applying equation (1) in a GIS environment we obtain the attributable fraction (AF) spatially resolved at the same spatial resolution of the pollutant concentration and the population data. Then applying equations (2) and (3) we can derive the absolute number of health outcome (e.g. number of deaths) due to the considered pollution exposure levels on a cell-by-cell basis. Having these results spatially resolved, the GIS allows for further processing of the data such as reckoning the sum of all events at specific geographic reference units (e.g. the ZIP code), allowing the calculation of the total number of events (deaths, hospital admissions, etc.) aggregated for specific city zones or areas. It is also possible to look for geographic correlation between variables or to cluster the data according to specific needs.

According to the methodology outlined above the basic data necessary to carry out a spatial environmental epidemiology study are:

- ✓ pollution concentration levels
- ✓ population data
- ✓ baseline rate of disease

- ✓ population attributable fraction

To avoid miscalculation, it is important that all the datasets above are spatially defined with same coordinate projection system. A more detailed spatial resolution of all the necessary datasets leads to a more spatially resolved representation of the actual phenomenon under study; yet, this condition does not jeopardise the applicability of the methodology, since the latter is applicable at the best spatial resolution possible given the availability of the respective necessary datasets.

5.3 Pollution exposure levels

Pollution exposure levels were derived from WRF-Chem model simulations carried out in WP3. Air pollution levels in each ICARUS city were calculated for all selected policies (5-6 policy scenarios, depending on the city). Annual averages concentration levels of $PM_{2.5}$, PM_{10}, NO_2 and O_3 have been calculated for the following 5-years periods 2021- 2025, 2026-2030, 2031-2035 and 2036-2040, which represents the *typical year* within each 5-year period taking also into account climate forcing as provided by the INERIS-WRF331F Regional Climate Model in the frame of the CORDEX program. Results provided on a regular grid of 2 by 2 km were interpolated through kriging geo-statistical methods to derive concentration fields at higher spatial resolution (ca.100 meters).

5.4 Population data

Current population data (i.e. 2016) at high spatial resolution (100 meters) has been gathered from JRC[20] at European level and then extracted for all ICARUS cities. Data was disaggregated with Corine land cover using a downscaling method described in Gallego (2010). The final spatial raster product depicts the population density, expressed as the number of people residing in each cell of the spatial domain. Population distribution in 5-year age classes needed to estimate the health impact for health end-points addressing specific population age groups was collected from Eurostat[21]. Population projections up to 2100 also disaggregated by age class were collated from Eurostat[22]. It should be pointed out that population data projections into the future are published at national level only in Europe; thus,

[20] http://cidportal.jrc.ec.europa.eu/ftp/jrc-opendata/GHSL/GHS_POP_EUROSTAT_EUROPE_R2016A/GHS_POP_SOURCE_EUROPE_R2016A_3035_100/V1-0/

[21] https://ec.europa.eu/eurostat/web/population-demography-migration-projections/data/database

[22] https://ec.europa.eu/eurostat/web/population-demography-migration-projections/population-projections-data

we applied the country-level trends to the ICARUS cities.

5.5 Baseline rate of disease

The baseline frequency of the health outcomes considered in ICARUS has been collated from the HRAPIE project (WHO Health risks of air pollution in Europe – HRAPIE project, 2013). The baseline rate of disease used are reported from Table 5-1 to Table 5-8 along with their literature references.

5.6 Concentration-Response functions

The HRAPIE project (WHO Health risks of air pollution in Europe – HRAPIE project, 2013) provided recommendations for CRFs for which there is sufficient evidence for causality of associations according to the prior REVIHAAP project conclusions. It focused on those air pollutants observed at concentrations causing health concerns, and which could be estimated at an appropriate spatial scale across Europe for the modelling of impacts. Each of the pollutant–outcome pairs recommended for cost–benefit analysis was classified into two categories (A and B) as hereinafter described.

HRAPIE recommendations considered specific conditions in EU countries—particularly in relation to the range of PM and NO_2 concentrations expected to be observed in the EU in 2020—as well as the availability of baseline health data. Therefore, for the health impact analysis in the EU, no extrapolation beyond the range covered by epidemiological studies on the effects is needed.

Given the time resolution of the pollution concentration fields derived from WP3, we focused our analysis on the long-term exposure. This is considered the most appropriate metric to properly capture the time horizon of the analysed city policies which generally goes up to 2040.

The health outcomes reported from Table 1 to Table 8 were selected, based on the availability of the C-R functions from HRAPIE/REVAPP project for long term Health Impact assessment. The tables below present the HRAPIE project recommendations for input into the cost–benefit analysis of the selected policy options. The experts agreed that, according to the REVIHAAP project report (WHO, 2013a), there is sufficient evidence to assert the causality of effects for each of the CRFs recommended. They classified the pollutant–outcome pairs recommended for cost–benefit analysis into two categories:

- Group A: pollutant–outcome pairs for which enough data are available to enable reliable quantification of effects;

- Group B: pollutant–outcome pairs for which there is more uncertainty about the precision of the data used for quantification of effects.

It is important to underline that some of the effects of a pollutant on one health outcome may be captured in an estimate of effect on another health outcome or their group (e.g. mortality due to a specific cause is a part of all-cause mortality). To minimize double counting in the calculation of the total costs and benefits for a pollutant, we followed a set of rules proposed by HRAPIE (WHO Health risks of air pollution in Europe – HRAPIE project, 2013). We identified with an asterisk (*) those effect estimates that contributed to the total cost and benefits (and assumed that their effects are additive) in either the limited set (Group A*) or the extended set (Group B*) of effects. Those without the asterisk were considered to reflect the effects already accounted for by summing those with the asterisk.

Table 5-1: Summary of recommendations for effects of long term PM2.5 exposure on all-cause mortality

Group	A*
Pollutant metric	Annual average $PM_{2.5}$
Population	Over 30 years
Effect	Mortality: Shortening healthy life expectancy to generate an estimate in terms of life years lost. Assumption of equivalence of life table outputs to generate number of deaths.
Relative risk	1.062, 95% CI 1.040 to 1.083 per 10 μg m^{-3} based on all-cause (natural) mortality rate. This range is accepted for CBA as it is generated from a meta-analysis using 13 studies, here considered to be a sufficient number to generate an appropriate range. A linear function is adopted, recognising the limited range of pollutant exposures in Europe. The relative risk is applied within national life tables to generate the estimated change in mortality per unit concentration.
Mortality and population data	WHO mortality database, http://data.euro.who.int/hfamdb/. The rates for deaths from all natural causes (ICD-10 chapters I-XVIII, codes A-R) in each of the 53 WHO EURO countries, for the latest year with available data.
References	Hoek et al (2013), Miller et al (2011)

Table 5-2: Summary of recommendations for effects of long term PM10 exposure on post neonatal infant mortality

Group	B*
Pollutant metric	Annual average PM_{10}
Population	Post neo-natal infants aged 1 month to 1 year.
Effect	Mortality expressed only as deaths.
Relative risk	1.04, 95% CI 1.02 to 1.07 per 10µg m^{-3}. The confidence in the quantitative estimate is described as 'low' and so there could be case for extending this range. However, infant mortality rates within the EU are low and changes to the range would have a negligible effect on results. The original study is from the USA, but did consider a large population, of 4 million infants.
Mortality and population data	WHO´s Health for All data base http://data.euro.who.int/hfadb/ and UN mid projections.
References	Woodruff et al (1997)

Table 5-3: Summary of recommendations for effects of long term PM10 exposure on bronchitis in children

Effect status	B*
Pollutant metric	Annual average PM_{10}
Population	Children aged 6 to 12 years. Whilst this age range has been applied, we note the text of the HRAPIE recommendation: In the cost–benefit analysis, this estimate is to be applied to all children aged 6–12 years (or 6–18 years if only this age category is available). Email exchange with the HRAPIE team indicated that the epidemiology studies stopped at age 12 in order to ensure that smokers were not enrolled into the study, though older individuals could be affected. The limitation of the quantification to the 6 to 12 age group therefore provides a potential underestimation of effect.

Effect	Childhood bronchitis. Acute bronchitis is swelling and irritation in a child's air passages. This irritation may cause coughing or other breathing problems. Acute bronchitis lasts about 2 weeks and is usually not a serious illness.
Relative risk	1.08, 95% CI 0.98 to 1.19 per 10 µg m^{-3}.
Population and incidence data	Average prevalence rate of 18.6% adopted as best estimate. PATY study notes a range from 6.2% to 41.5%. The effect as defined in the epidemiology study is “bronchitis in the past 12 months”. However, no information is available as to whether affected children typically suffer once, or more, each year. In the absence of data, it is assumed that each affected child experiences bronchitis once in a year, and that this does not lead to additional complications. This clearly errs on the conservative side.
References	Hoek et al (2012)

Table 5-4: Summary of recommendations for effects of long term PM_{10} exposure on the incidence of chronic bronchitis in adults

Group	B*
Pollutant metric	Annual average PM_{10}
Population	All >18 years
Effect	New incidence of chronic bronchitis, defined as having had symptoms of cough and/or sputum production on all or most days for at least 3 months per year for at least 2 years. Schikowski (2013) states that chronic bronchitis, defined on the basis of reported symptoms of cough and phlegm, is considered as a rather weak indication of clinically recognized COPD diagnosed on the basis of spirometry or clinical examination. However, leaving precise definitions to one side, the AHSMOG and SAPALDIA studies have detected an effect that is not covered elsewhere. To ignore it would provide a systematic bias to the results.
Relative risk	1.117, 95% CI 1.040 to 1.189 per 10 µg m^{-3}.

Population and incidence data	Incidence from the core studies used for the risk factor was 3.9 per 1000 adults at risk.
References	**Abbey et al (1995a, b), Schikowski (2013), Schindler et al (2009)**

Table 5-5: Summary of recommendations for effects of long term PM_{10} exposure on cardiac hospital admissions

Group	B*
Pollutant metric	Annual average PM_{10}
Population	All Ages
Effect	Cardiac hospital admissions
Relative risk	1.006, 95% CI 1.003 to 1.009 per 10 μg m^{-3}.
Population and incidence	723 emergency cardiac admissions per 100,000 population, all ages, per year (Hurley et al., 2005)
References	Hurley et al (2005)

Table 5-6: Summary of recommendations for effects of long term PM_{10} exposure on respiratory hospital admissions

Group	B*
Pollutant metric	Annual average PM_{10}
Population	All Ages
Effect	Respiratory hospital admissions
Relative risk	1.009, 95% CI 1.007 to 1.01 per 10 μg m^{-3}.
Population and incidence data	617 emergency respiratory hospital admissions per 100,000 population, all ages, per year (Hurley et al., 2005).
References	Hurley et al (2005)

Table 5-7: Summary of recommendations for effects of long term NO_2 exposure on all-cause mortality

Group	B*
Pollutant metric	Annual average NO_2 above 20 μg m^{-3}
Population	Over 30 years
Effect	Mortality: Shortening healthy life expectancy to generate an estimate in terms of life years lost. Assumption of equivalence of life table outputs to generate number of deaths.
Relative risk	1.055, 95% CI 1.031 to 1.08 per 10 μg m^{-3} based on all-cause (natural) mortality rate. Range accepted for CBA as it is generated from a meta-analysis using 11 studies, here considered to be a sufficient number to generate an appropriate range.
Mortality and population data	Historic mortality data from WHO 'Health for all' at http://data.euro.who.int/hfamdb/, covering deaths from all natural causes.
References	Hoek et al (2013) Miller et al (2011)

Table 5-8: Summary of recommendations for effects of long term NO_2 exposure on bronchitic symptoms in asthmatic children

Group	B*
Pollutant metric	Annual average NO_2
Population	Children aged 5 to 14 years.
Effect	Childhood bronchitis. Acute bronchitis is swelling and irritation in a child's air passages. This irritation may cause coughing or other breathing problems. Acute bronchitis lasts about 2 weeks and is usually not a serious illness. In the absence of data, it is assumed each affected child experiences bronchitis once in a year, and that this does not lead to additional complications. Both assumptions seem conservative.

Relative risk	1.021, 95% CI 099 to 1.06% per 10 μg m^{-3}. Generated from studies in 9 countries.
Population and incidence data	UN mid estimates for population. The background rate of asthmatic children: "asthma ever" in Lai et al (2009): Western Europe: 15.8%, SD 7.8%, Northern and Eastern Europe: 5.1% SD 2.7%. Prevalence of bronchitic symptoms among asthmatic children 21.1% to 38.7% (Migliore et al,2009, McConnell et al, 2003).
References	**Hoek et al (2012) Lai et al (2009)** **McConnell et al (2003) Migliore et al 2009)**

5.7 Results

Completed results from the Health Impact Assessment simulations in all the ICARUS cities are reported both in a tabular and graphical form respectively in Annex 1 and Annex 2. Both account for the number of cases expected on annual basis for the different health end-points considered covering the time horizon of application of the policy measures considered as discussed with the local stakeholders.

The policy scenarios are briefly described in table A-1 to allow the reader to easily link the scenario acronyms used with their description. Both tables and charts display the number of cases expected covering both the municipalities boundaries and the whole modelled domain (ca. 60 by 60 km). For Athens and Thessaloniki results refer to the whole modelling domain as the policy measures simulated are relevant to the metropolitan area (i.e. respectively, Greater Athens and Greater Thessaloniki area).

To capture the uncertainty in the C-R functions median estimates, results are reported together with their confidence interval (5% and 95%) in both the tables and the charts. The key conclusions that can be drawn from the results referring to different cities and policy measures are as follows:

In **Athens** the highest health benefits are associated with the implementation of the policy promoting sustainable mobility through eco–driving, cycling, walking and enhanced public transportation means leading to a reduction of use of passenger cars ("*SusMobPuT*" scenario) and with the policy associated with the increase of energy efficiency and renewable energy sources in residential and commercial buildings and promotion of Zero Energy Buildings ("*EnEffZEB*" scenario). The lowest benefits in terms of population health are associated to the implementation of policies leading to a reduction of biodegradable and recyclable waste going to landfill through the implementation of Green Points and Recycling & Training Centres for waste separation and pre-sorting ("*Waste*" scenario). Based on the prevalent meteorological conditions in the different 5-years periods modelled, the impact of all policies simulated in Athens show the highest values in the period 2031-2035 and the lowest in the period 2026-2030.

In **Basel** the policies measures associated to the replacement of fossil heating technologies by heating pumps and solar heating ("*NoHeat*" scenario) as well as the one leading to the introduction of a ban on small combustion of firewood ("*NoHeatFirewood*" scenario) result in the highest benefit in terms of population health both within the municipality borders and in the larger domain. On the contrary the lowest benefits have been estimated for the policy addressing the conversion of the shipping fleet to zero emission ships by 2030 ("*ZeroEmissionShips*" scenario). Looking at the health impact associated to exposure to NO_2 significant benefits are also associated to the introduction of traffic reduction measures leading to a reduction of the traffic load by 10% in 2020 and 2030 compared to the baseline scenario ("Traffic10"). Comparing the different 5-years periods the expected number of cases for most of the health end-points considered show a constantly decreasing trend with the highest values in the period 2021-2025 and the lowest in the periods 2031-2035 and 2036-2040.

In **Brno** the health benefits estimated do not show large variations among the analysed policies even though the measure to promote low carbon electric vehicles ("*M1opti*" scenario) as well as the one associated to the switch of combustion techniques in residential and municipal buildings through the replacement of old coal-fired boilers in residential sector ("*M3slow*" scenario) show on the average slightly higher benefits. Looking at the health impact associated with long term exposure to NO_2, higher health benefits result from the implementation of measures leading to a reduction of the motorized vehicles in the city combined with the increase more environment-friendly transportation modes (i.e. walking. biking and using public transport) ("*M2opti*" scenario). Similarly to Athens, the impact of the policies simulated show the highest values in the period 2031-2035 and the lowest in the period 2026-2030 due to the prevalent meteorological conditions, which may favour pollutant dispersion over more (or less) populated areas.

In **Ljubljana** the most effective policy in term of population health benefits is the one associated with increased utilization and expansion of district heating systems and replacement of existing combustion units with more appropriate means (i.e. 70% reduction of coal use) ("*M4*" scenario). Among the other policies analysed the one related to an increased share of public transport use along with the renovation of the public passenger transport fleet and the reduction of personal car use ("*M2*" scenario) shows slightly higher health benefit. The lowest benefit results from the implementation of the policy envisioning a more efficient use of domestic heating associated to a decrease of fuel consumption by 15% by 2030 ("*M5*" scenario).

In **Madrid** the implementation of measures leading to strengthen public - private collaboration to make urban logistics processes more efficient ("*Log*" scenario) shows on the average the highest health benefits. Policies associated with the creation of a closed Central Zone (Zero Emissions Central Area) with restricted access where traffic is banned ("*ZeZ*" scenario), as well as with the implementation of parking regulation through increased discounts and penalties according to vehicle emissions and new regulation systems ("*Park*" scenario), show slightly lower health benefits when compared with the "*Log"* scenario. Looking at the health impact associated with exposure to NO_2, higher health benefits result also from the implementation of measures leading to the regeneration of neighbourhoods by improving energy efficiency and thermal insulation of the building stock and re-naturalization of the city ("*EnEf*" scenario). Comparing the different 5-years periods the expected number of cases for all the health end-points considered show the highest values in the period 2021-2025 for exposure to PM_{10} and $PM_{2.5}$ and in the period 2026-2030 for NO_2.

In **Milan** the implementation of a Low Emission Zone (Area B) banning the entrance of the most polluted vehicles (e.g. up to Euro 4 diesel cars) through a system of tracking and access control ("*Area B"* scenario) show by far the highest health benefit compared to all the other policies analysed both within the municipality borders as well as in the whole computational domain. Among the other policies analysed, conversion of all public buses to electric ones by 2030 ("*Electric Bus*" scenario) and energy efficiency improvements in existing and new residential flats ("*Building*" scenario) show higher health benefits. The "*Area B*" and "*Electric Bus*" scenarios show even higher health benefits when looking at the health impact associated with long-term exposure to NO_2 due to the higher emission reduction of NO_2 resulting from these policies. Independently form the policy scenario considered, the impact of all policies simulated in Milan show the highest values in the periods 2031-2035 and 2036-2040 and the lowest ones in the period 2021-2025 due to prevalent meteorological conditions, which may favour the pollutants dispersion over more (or less) populated areas.

In **Stuttgart** the most effective policy in term of population health benefit is the one associated with the introduction of hardware update of diesel passenger cars and driving ban on diesel PC < Euro6 in the city centre ("*FvH"* scenario). Among the other policies promotion of environment-friendly transport modes (e.g. walking, cycling) along with the decrease of individual transport ("*ScUV"* scenario) show the higher health benefits even though this policy has been simulated only for the period 2031-2035. Looking at the health impact associated with exposure to NO_2, health benefits result also from the implementation of measures to promote low carbon electric vehicles (“*ScEL*“ scenario).

In **Thessaloniki** the highest health benefits are associated with the implementation of the policy promoting green vehicles towards the gradual replacement of all old municipal and private vehicles with new electric ones (“*M2B*” scenario). Among the other policies analysed improved energy efficiency in the cement industry through the use of refuse derived fuels assuming the adoption of state-of-the-art effluent gas cleaning technologies (“*M4*” scenario), as well as the promotion of public transport and use of metro by building an integrated urban mobility system (“*M2C*” scenario) show the higher health benefits. Lower health benefits are linked to promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings (“*M1*” scenario) and eco-friendly waste management (“*M3*” scenario).

Comparing the different 5-year periods, the expected number of cases for all the health end-points considered show the highest values in the period 2031-2035 and the lowest ones in the period 2021-2025 depending on the prevalent meteorological conditions. Results from the Health Impact Assessment modelling together with the estimated economic costs needed to implement the various policies analysed in the ICARUS cities are fed into the Cost-Benefit Analysis as reported in the next chapter to provide an overall assessment of the policies selected in each ICARUS cities. The final objective of this integrated health impact assessment scheme would be to inform and assist policy makers in prioritizing among different pollution control strategies or among more general options towards improving public health.

6 MONETARY VALUATION OF IMPACTS AND COST-BENEFIT ANALYSIS

In the following chapter, the results of the cost-benefit analysis and cost-effectiveness analysis are presented for the measures selected by the cities within ICARUS.

6.1 Overview of cost-benefit analysis and cost-effectiveness analysis

Cost-Benefit analysis (CBA) compares costs and benefits of a project expressing them in a common metric, i.e. in monetary values. CBA takes into account both the financial and economic costs and benefits. Among financial costs and benefits are capital costs, recurring costs (operational and maintenance costs) and financial revenues. Economic benefits reflect instead the contribution of the policy measure to social welfare (EC, 2008). The CBA takes an "incremental approach" (EC, 2014), as costs and benefits are computed with respect to the baseline scenario. Future costs and benefits are discounted to adjust them to the opportunity cost of capital.

Several performance indicators are computed and presented for each measure. In the following chapter we will present:

- the Net Present Value (NPV) of total discounted costs and benefits, which reflects the "overall performance" of a project (EC, 2014);
- the Benefit/Cost Ratio.

The cost-effectiveness analysis compares the costs of a measure with the achieved outcomes. In the following, two main indicators of cost-effectiveness will be computed and presented to compare costs per tonnes of carbon (CO2equivalent) saved, respect to the baseline scenario.

- Financial cost-effectiveness (FICOSTEF), financial cost per tC saved
- Full cost-effectiveness (FUCOSTEF), full cost (costs-benefit) per tC saved

6.2 Cost and benefit data

Costs data have been provided by the cities and/or partner experts. When costs are uncertain or not available, assumptions are drawn from secondary sources. To this end, a review of existing studies performing Cost-Benefit Analysis of interventions aiming at reducing carbon footprint and air pollution has been carried out.

Nevertheless, in a number of cases, costs data have not been made available by the city, or it has not been possible to estimate plausible costs data given the complexity of the measure, or the lack of information about the instruments that are going to be put into place by the city. In these cases, we have focused our attention only on the benefit side of the measure. Moreover, it should be noted that not in all cases a full understanding of the total benefits related to these measure has been possible. Nevertheless, each analysis will include health benefits and carbon savings.

6.3 General assumptions and Monetary Valuation of Impacts

Discounting

A discount rate of 3.5% has been used in the analysis, to reflect the opportunity cost of capital.

Time horizon of the CBA

The period over which costs and benefits are taken into account starts with the initial investment year and ends with the last year for which the Health Impact Assessment results are available (i.e. 2035, or 2040, depending on the different measures). All values are expressed in 2018 prices.

Monetary Valuation of Impacts

In order to input a monetary value to non-tangible impacts, the following assumptions have been made

Value of carbon

The Social Cost of Carbon (SCC) is set at $31 (€$_{2018}$29.03) as suggested by a study by Nordhaus (2017).

Health Endpoint valuation

The valuation of health endpoints builds on previous studies, and in particular on Hunt et al. (2011) that presents values for a range of health endpoints, providing both a central figure, and a low and high estimate (Table 13). Hunt's central estimates is used in the CBA.

Table 6-1: Estimated values used in CBA (Hunt et al. 2011)

Health End-Point	Low	Central	High	Unit (2010) per case	Reference
Sleep disturbance	480	1,240	1,570	Euro/year	Godet-Cayré et al. (2006); Ozminkowski et al. (2007)
Hypertension	880	950	1,110	Euro/year	Ramsey et al. (1997); Berto et al. (2002)
Acute myocardial infarction	4,675	86,200	436,200	Euro	Moïse et Jacobzone, 2003; Yasunga et al. (2006)
Increased mortality risk (infants)	1,120,000	2,475,000	11,200,000	Euro	Holland et. al. (2004)
Chronic bronchitis	43,000	60,000	100,000	Euro	Krupnick and Cropper (1992)
Severe COPD	70,000	120,000	260,000	Euro	Maca et al. (2011)
Increased mortality risk - Value Of Life Years acute	60,020	09,715	220,000	Euro	Alberini et. al. (2006)
Increased mortality risk - Value of Prevented Fatality acute	1,120,000	1,650,000	5,600,000	Euro	Alberini et. al. (2006)
Life expectancy reduction - Value of Life Years chronic	37,500	60,000	215,000	Euro	Alberini et. al. (2006), Desaigues et. al. (2011)
Respiratory hospital admissions	2,990	2,990	8,074	Euro	Navrud (2001); Holland et. al. (2004)
Cardiac hospital admissions	2,990	2,990	8,074	Euro	Navrud (2001); Holland et. al. (2004)
Work loss days (WLD)	441	441	441	Euro	Navrud (2001); Holland et. al. (2004)
Restricted activity days (RADs)	194	194	194	Euro	Navrud (2001); Holland et. al. (2004)
Minor restricted activity days (MRAD)	57	57	57	Euro	Navrud (2001); Holland et. al. (2004)
Lower respiratory symptoms	57	57	57	Euro	Navrud (2001); Holland et. al. (2004)
LRS excluding cough	57	57	57	Euro	Navrud (2001); Holland et. al. (2004)
Cough days	57	57	57	Euro	Navrud (2001); Holland et. al. (2004)
Medication use / bronchodilator use	74	80	96	Euro	Maca et al. (2011)
Lung cancer	70,000	720,000	4,200,000	Euro	Weissflog et al. (2001); Serup-Hansen et al. (2003); Scasny (2008); Jeanrenaud and Priez (1999); Aimola (1998)
Leukaemia	2,050,000	4,000,000	7,000,000	Euro	Aimola (1998)
Neuro development disorders	4,500	15,000	33,000	Euro/year	Ščasný et. al. (2008)
Skin cancer	11,000	14,000	27,000	Euro	Aimola (1998)
Osteoporosis	3,000	5,700	8,100	Euro	Kudrna and Krška (2005); Werner and Vered (2002)
Renal dysfunction	23,000	30,400	41,000	Euro	Bartaskova et al (2005); Sun-Mi et al. (2006)
Anaemia	750	750	750	Euro	Ossa et. al. (2007)

Health benefits from increased walking and cycling

Health benefits linked to the increased cycling and walking are measured using the WHO-Europe (2014) Health Economic Assessment Tool - HEAT for walking and cycling. HEAT has been developed for analysing the health benefits of regular walking and cycling via estimation of effects on mortality on the adult population (aged 20-74).

The main assumptions on which HEAT is built are the following:

- walking 168 minutes/week reduces mortality risk by 11%; cycling for 100minutes/week reduces mortality risk by 10%
- the relationship between volume of walking and reduction in mortality risk is linear, so if I double my time spent walking, I halve my mortality risk
- the benefit from walking is capped at 30%: walking more than 458 minutes a week does not reduce my mortality risk any further. This is 45% for cycling (i.e. 450 minutes).

The benefit of increased physical activity is measured in terms of number of deaths avoided, using the value of a statistical life in the selected country.

Noise

Noise reduction benefits can emerge in the case of traffic reductions or in the case of switching from conventional cars to electric vehicles. Noise reduction has been shown to positively affect both physical and mental health, and it can also be reflected into higher property values and increased productivity (Gössling et al. 2019). Following the study by Litman and Doherty (2011) a shift from conventional car to the following transport modes is assumed to be associated to the following benefit parameters

- Bus 0.00067 €$_{2018}$/pkm

- walking 0.0042 €$_{2018}$/pkm

- Cycling 0.0042 €$_{2018}$/pkm

Accidents

As pointed out by the literature, accidents costs include material damages, medical costs, cost of lives lost, cost of loss of productivity and cost of suffering (Gössling et al. 2019).

Following the Litman and Doherty (2011) a shift from conventional car to the following transport modes is assumed to be associated to the following benefit parameters

- Bus 0.045 €$_{2018}$/pkm

- walking 0.020 €$_{2018}$/pkm

- Cycling 0.020 €$_{2018}$/pkm

Travel time losses

Shifting from personal car use to the following transport modes is associated to extra travel time, and therefore in higher costs. The following cost factors are computed from Litman and Doherty (2011)

- Bus 0.082 €$_{2018}$/pkm

- walking 0.620 €$_{2018}$/pkm

- Cycling 0.150 €$_{2018}$/pkm

6.4 Calculations and results

6.4.1 Athens (greater region – Attica)

The costs and benefits included in the measure for Attica are summarised in the following table. Costs and benefits have been provided by the partner experts.

Measures/ policy	M1 SusMob	M2 SusMobPT	M3 EnEff	M4 EnEffZEB	M5 Waste
	Promotion of	M1+Promotion	Energy	M3+Promotion	Waste

scenarios	cycling and walking	of PT	efficiency improvements in residential sector	of Zero energy buildings (nZEB)	Management (Green Points network plus reduction in MSW going to landfill)
Costs	Construction and maintenance costs of new cycling route	Construction and maintenance costs of new cycling route, investment cost on the new Metro line 4, extension of metro line 3, extension of tram line from Faliro to Piraeu	Residential buildings renovation costs	Residential buildings renovation costs, nZEB renovation costs	Cost for Green Points Network, Separate collection systems of bio-waste, Municipal compost units, Separate Collection system of paper, Development of Network of domestic compost
Benefits	Health benefits Carbon savings Other benefits: health benefits due to increased walking and cycling, noise, accidents and extra travel	Health benefits Carbon savings Other benefits: health benefits due to increased walking and cycling, noise, accidents and extra travel time (cost)	Health benefits Carbon savings Energy savings	Health benefits Carbon savings Energy savings	Health benefits Carbon savings Landfill costs savings

	time (cost)				

6.4.1.1 *Policy scenario 1- **SusMob***

The policy scenario SusMob (Sustainable Mobility) relates to the policy for supporting the transition to a low-carbon economy in all sectors of the Regional Operational Program (ROP) Attica 2014-2020 and several municipalities of Attica Region have already included this measure in their Sustainable Energy Action Plans (SEAP). The measure focuses on training, informing and sensitizing the citizens in eco-driving and promoting cycling and walking. To this end, a metropolitan cycling route of 27 km is under construction to connect the north areas of Attica with the southern areas.

Costs

The costs included in the CBA include investment costs for the cycling route of 10mln€ (https://ypodomes.com/athina-pros-ylopoiisi-to-voreio-tmima-tou-mitropolitikoy-podilatodromou-gazi-kifisia/), which is assumed to be built over a 5-year period. Annual maintenance costs are set at approximately 3,900€ per km (same as cost provided for the city of Brno). It should be noted that for this measure cost data on Citizen Information campaign towards the promotion of eco-driving and active transport are not available. There is therefore not a full understanding of the overall costs associated to this measure.

Benefits

The benefits of this measure include: health benefits achieved through reduction of PM and NO2; carbon savings; carbon savings health benefits linked to the increased cycling and walking (measured by the HEAT tool); noise reduction benefits; accidents and extra travel time costs.

6.4.1.2 *Policy scenario 2 - **SusMobPT***

The measure SusMobPT (Sustainable mobility and Promotion of Public Transport) focuses on training, informing and sensitizing the citizens in eco-driving and promoting cycling and walking, as well as promoting Public Transport (i.e. it includes also M1).

Costs

Besides the costs related to the construction of the cycling route, it includes the investment cost on the new Metro line 4 (for over 3bn€), the extension of metro line 3 (for over 500mln€), as well as the extension of the tram line from Faliro to Piraeus (125mln €).

Benefits

The benefits of this measure include: health benefits achieved through reduction of PM and NO2; carbon savings; carbon savings health benefits linked to the increased cycling and walking (measured by the HEAT tool); noise reduction benefits; accidents and extra travel time costs

6.4.1.3 Policy scenario 3 - **EnEff**

The EnEff measure relates to energy efficiency improvements in residential building, carried out in the Attica region under the National program "EXOIKONOMO I&II (EKO I & EKO II)", for a total of 6,847 residencies to be renovated from energy class E-G to C-D in 2015-2020, as well as 4,400 residencies per year to be renovated from energy class E-G to C-D in the period 2020-2030 under the target set to renovate 7% of the existing national building stock until 2030.

Costs

Renovation costs are set at 32,000€ per single houses and 250,000€ for apartment buildings, following Gaglia A.G. et al. (2017).

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2, carbon savings, as well as energy savings, as provided by the partner experts.

6.4.1.4 Policy scenario 4 - **EnEffZEB**

The measure EnEffZEB includes M3 (EnEff) and also considers the conversion of 10% existing residential buildings to nearly zero-energy-buildings until 2030 in the City of Athens. Given that residential buildings in the City of Athens are 50,849 (source: ELSTAT), this means 5,085 residential buildings.

Costs

The costs related to the renovation of ZEB are unknown. To perform the CBA, we have assumed that the renovation costs are 40% higher than the renovation costs used for scenario EnEff.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2, carbon savings, as well as energy savings.

6.4.1.5 Policy scenario 5 - **Waste**

This measure (Waste) aims at the reduction of disposed biodegradable and recyclable waste in landfill through the implementation of Green Points and Recycling & Training Centres for waste separation at source and pre-sorting.

Costs

The costs considered for this measure include a total investment cost of 107mln€, assumed to be borne in 2017:

- Green Points Network 60,000,000€
- Separate collection systems of bio-waste 40,000,000€
- Municipal compost units 3,000,000€
- Separate Collection system of paper 3,000,000€
- Develop Network of domestic compost 1,000,000€

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2 and carbon savings. It also includes landfill costs savings through the reduction of 63% of MSW going to landfill. Landfill costs are set at 35€/tn, as per cost at EDSNA (Association of Municipalities in the Attica Region, Solid Waste Management) facilities.

6.4.1.6 Cost-Benefit Analysis results – Athens (greater región – Attica)

The following table summarises the results of the Cost-benefit analysis and Cost-effectiveness analysis for the Attica region.

Measures/ policy scenarios	M1 SusMob	M2 SusMobPT	M3 EnEff	M4 EnEffZEB	M5 Waste
	Promotion of cycling and walking	M1 +Promotion of PT	Energy efficiency improvements in residential sector	M3 +Promotion of Zero energy buildings (nZEB)	Waste Management
Net Present Costs	10,745,933	2,925,740,695	976,434,150	1,080,797,192	99,885,645

Net present health benefits	383,389,102	481,567,877	165,800,850	610,859,780	119,520,651
Net Present Other non-health benefits	892,937,188	2,855,967,025	490,307,899	848,358,242	688,295,910
Net Present Value Carbon savings	264,586,390	306,416,785	7,080,959	14,433,457	0
Net present total benefits	647,975,491	3,643,951,687	663,189,709	1,473,651,478	807,816,561
NPV	637,229,558	718,210,992	-313,244,441	392,854,286	707,930,917
B/C Ratio	60.30	1.25	0.68	1.36	8.09
FICOSTEF	1.18	277.20	4,003.38	2,173.95	
FUCOSTEF	-40.89	-39.02	1,313.33	-761.17	

The net present cost of the analysed measures range from 10.7mln€ for M1 to 99.9mln€ for M5, 976.4mln€ for M3, 1.08bn€ for M4 and 2.9bn€ for M2. Results also show that the most expensive measures are the ones that are associated with the highest health benefits (M2 and M4, with respectively 481mln€ and 610mln€). One of the analysed measures (EnEff) has a negative NPV, leading to a B/C ratio of 0.68, despite a health benefit value of 165.8mln€, 7mln€ carbon savings and 490.3mln energy savings.

M1 and M2 show very high levels of other benefits (892.9 mln€ and 2.9bn€). These are driven by the high levels of health benefit from increased physical activity and noise reduction, which are only partially offset by the cost of extra travel time. For these two measures the B/C is respectively 60.3 and 1.25. It should however be highlighted that for both M1 and M2 costs of an awareness campaign towards eco-driving and active transport modes have not been included in the analysis, as not available. These cost would reduce the NPV and B/C ratio of these measures.

Finally, M4 and M5 present B/C ratios of respectively 1.36 and 8.09.

The cost-effectiveness analysis suggests very high financial costs of EnEff and EnEffZEB (M3 and M4) scenarios. However, while for the latter the full cost per tC is actually negative (i.e. total benefits are higher than costs), it is not the case for the former. We note that we have not been able to value all of the benefits of every measure – the energy efficiency investments described under EnEff may have wider implications than the benefits we have been able to value. These include the potential value of the energy efficiency measures to residents beyond energy savings.

6.4.2 Basel

The costs and benefits included in the measure for the city of Basel are summarised in the following table. Costs and benefits factors have been estimated together with the partner experts.

Measures/ policy scenarios	NoHeat	Traffic 10	FirewoodBan	HoHeat-Firewood	Zero Emissions Ships
Costs	Capital and renewing costs of heating pumps; O&M and energy costs	No costs	Capital and renewing costs of heating pumps; O&M and energy costs	Capital and renewing costs of heating pumps; O&M and energy costs	
Benefits	Health benefits Carbon savings O&M and energy savings from replaced heating technology	Health benefits Carbon savings	Health benefits Carbon savings O&M and energy savings from replaced heating technology	Health benefits Carbon savings O&M and energy savings from replaced heating technology	Health benefits Carbon savings

6.4.2.1 Policy scenarios 1, 3 and 4 - NoHeat, FirewoodBan and NoHeatFirewood

Costs

Three of the measures put into place in Basel involve the replacement of heating technologies with heating pumps and solar heating (NoHeat, FirewoodBan and NoHeatFirewood) scenarios. The number of heating technologies to be replaced in each scenario is drawn from GWR - Gebäude- und Wohnungsregister, Bundesamt für Statistik. In particular, 11,847 gas boilers and 4,468 fuel oil boilers are to be replaced in the NOHeat and NOHeatFirewood scenarios. Moreover, 217 Fuelwood heating systems need to be replaced in the FirewoodBan and NOHeatFirewood scenarios.

The NOHeat scenario sees the replacement of one third of gas and fuel oil boilers by 2020, and the remaining boilers being replaced by 2030. The FirewoodBan and NOHeatFirewood scenarios are instead 2030 scenarios.

Capital costs data on the conversion of heating technologies and the installation of heat pumps are not available for Basel, and are therefore based on a review of the literature. The literature findings related to these technologies are quite heterogeneous. The cost of heat pumps and range from 6,900€ to 16,200€ (euros of 2018), depending on the type of technology. The initial investment for converting a heating system form oil boiler to HP costs approximately 15,300 €$_{2018}$ in a study on Sweden (Joelsson and Gustavsson, 2010). In Cyprus, Zachariadis et al. (2018) shows that the average investment cost for HP installation in single-family buildings is 6900€. Dows and Yu (2019) suggest that the price of a ASHP and a GSHP are respectively approximately 7,000€$_{2018}$ and 16,200€$_{2018}$ in the UK. For Basel, an investment cost of 10,000€ for heating pumps is assumed, with a renewing cost of 3,000€ every 15 years.

O&M costs and energy savings of heating pumps versus firewood, gas and fuel oil boilers are drawn from Iten et al. (2017).

As for the costs of solar heating, Bernardo et al. (2016) suggests that the costs of a domestic solar hot water system is approximately 4400 €$_{2018}$ – however this system does not provide ambient heating. Marszal and Heiselberg (2011) carry out a Life Cycle cost analysis of a residential ZEB in Denmark, with a HVAC system for both heating and hot water purposes, where heat is produced by photovoltaic panels in combination with photovoltaic/solar thermal system. However, it is difficult to derive assumptions from this case study, given the dimension (7,000 sqm) and complexity of the project. Moreover, Iten et al. does not provide information about O&M and energy costs of a solar system. For these reasons, it assumed that all heating systems will be replaced by heating pumps.

Benefits

The benefits of this measure include avoided O&M and energy costs due to the replacement of the dismissed heating technologies (drawn from Iten et al. 2017), and the health benefits achieved through reduction of PM and NO2, and carbon savings.

6.4.2.2 Policy scenarios 2 and 5 - Traffic10, ZeroEmissionShips

For the measure M2 (Traffic10) and M5 (ZeroEmissionShips) no cost data are available.

As for the former, the city of Basel in fact has not budgeted costs for this particular measure (with other traffic measures being already in place). Costs data for the ZeroEmissionShips measure are not available either. A study by UMAS and Lloyd's Register (2019) show that additional costs for Zero Emission Ships are very heterogeneous and depend on type of fuel and technology.

We will therefore focus only on the benefit side for these two measures.

6.4.2.3 Cost-Benefit Analysis results – Basel

The following table presents the results of the cost-benefit analysis and cost-effectiveness analysis.

Measures/ policy scenarios	M1	M2	M3	M4	M5
	NoHeat (replacement of fossil heating technologies)	Traffic10 (10% traffic reduction)	Firewood Ban	HoHeat-Firewood	Zero Emissions Ships
Net Present Costs	507,070,065	Not available	4,827,459	367,776,703	Not available
Net present health benefits	904,064,922	867,166,407	242,451,939	354,784,534	177,014,657
Net Present Other non-health benefits	571,250,772		4,964,686	403,670,755	
Net Present Value Carbon savings	60,064,014	12,033,894	14,254	38,356,740	419,581
Net present total benefits	1,535,379,708	879,200,301	247,430,879	796,812,029	177,434,237

NPV	1,028,309,642	879,200,301	242,603,421	429,035,326	177,434,237
B/C Ratio	3.03		51.25	2.17	
FICOSTEF	245.09		9,832.40	278.37	
FUCOSTEF	-468.00		-494,097.11	-295.70	

Net Present Costs of the three analysed measures are equal to 507mln€ for the NoHeat policy scenario, 4,8mln€ for the FirewoodBan and 367,8mln for the combined NoHeatFirewood scenario.

Results suggest a positive NPV for all the analysed measures and a favourable B/C ratio, respectively equal to 3.03, 51.25 and 2.17. The Firewoodban scenario has a particular positive results, which is driven by the high value of the health benefits, compared to the investment costs. The benefits estimated in terms of reduced mortality due to NO2 reductions are particularly high and dominate the results.

The cost-effectiveness analysis suggests that the financial cost per tC saved range from 245 per tC (NoHeat) to 278€ per tC (NoHeatFirewood) to 9,832€/tC (FirewoodBan). When the full cost of these measures is taken into account, though, carbon savings are matched by an overall cost reduction.

6.4.3 Brno

The costs data for the measures selected by the city of Brno have been estimated and provided by Enviros S.R.O. and RECETOX, Masaryk University.

Measures/ policy scenarios	M1	M2	M3	M4	M5
	M1_OPTI	M2_ZERO	M2_OPTI	M3_SLOW	M4_ECON
	Low carbon vehicle promotion	Reduction of motorized vehicles in the city (walking, cycling and PT)	Reduction of motorized vehicles in the city (walking, cycling and PT)	Replacement of old coal-fired boilers	Implementation of energy saving measures in residential, commercial, and industrial sector
Costs	Capital and	Capital and	Capital and	Capital and	Investment costs

	maintenance costs of charging stations and electric cars. Cost of promotion campaign for Electric Vehicles; External costs of electricity production	maintenance costs of public transport, and new cycle lanes and cycle ways	maintenance costs of public transport, and new cycle lanes and cycle ways	maintenance costs of new heating technologies	
Benefits	Health benefits Carbon savings; Diesel car fuel and maintenance cost savings	Health benefits Carbon savings; fuel savings; extra health benefits deriving from increased walking and cycling; benefits related to the lower congestion costs; travel time (costs)	Health benefits Carbon savings; fuel savings,; extra health benefits deriving from increased walking and cycling; benefits related to the lower congestion costs; travel time (costs)	Health benefits Carbon savings; maintenance and fuel savings from replaced technology	Health benefits Carbon savings Energy savings

6.4.3.1 Policy scenario 1 - M1_OPTI

The measure M1_OPTI aims at promoting low carbon vehicles (electric vehicles) in Brno.

Costs

The costs for this measure include the capital cost of the charging stations (approximately 18mln€ for 587 stations built by 2030 – including both fast charging stations and smaller city-tailored charging stations). The maintenance costs of the charging stations include the salary of a technician and the salary of an administrative employee (starting at approximately 23,000€ and 11,700€ and increasing with inflation), as well as the purchase of an electric car.

The city is also going to carry out a promotion campaign for Electric Vehicle in 2019-2020, costing approximately 110,000€, as assumed following the cost of a promotion campaign of the new residential parking system in the city of Brno which took place in 2018.

For the citizens, the additional costs for purchasing electric vehicles are taken into account, as well as the electricity costs. The extra cost of electric vehicles is set initially at approximately 7,800€[23], decreasing constantly to reach up to a 20% decrease in 2035[24]. The number of electric vehicles is assumed to increase from 160 in 2020 to approximately 7,700 in 2034.

External costs of electricity are also included in the CBA. Given that European estimates consider that for the Czech Republic energy mix the cost is 0.04-0.12 EUR/kWh, the average (i.e. 0.08 €/kWh) is considered in the analysis., considering a cost of 0.08€/kWh[25].

Benefits

The benefits of this measure include fuel savings (based on average consumption of gasoline and diesel cars) and maintenance costs savings of electric cars compared to conventional cars (approximately 140€ per car, according to the National Action Plan for Clean Mobility). Moreover, the health benefits achieved through reduction of PM and NO2, and carbon savings are taken into account.

6.4.3.2 Policy scenario 2 - M2_ZERO

M2_ZERO aims at promoting public transport and active transport through the investment in the cycling network.

Costs

Costs related to this measure include increased costs related to public transport (over 80mln € in 2020-2034); cost of additional cycle lanes and cycle ways (approximately 11mln€ for

[23] https://about.bnef.com/blog/electric-cars-reach-price-parity-2025/

[24] https://about.bnef.com/blog/electric-cars-reach-price-parity-2025/

[25] https://www.eon.cz/-a164675---WAJC-cEA/cenik-elektrina-k-1-1-2019-distribucni-uzemi-e-on-pdf

respectively 61 and 36 extra km); annual maintenance costs of the cycle ways (approximately 4,000€ per km per year, in line with the maintenance costs of the Czech city of Plzeň[26]).

Benefits

Besides benefits related to improved health and lower carbon emissions, fuel savings are considered, as well as benefits in the form of lower congestion, noise as well as accidents.

6.4.3.3 Policy scenario 3 - M2_OPTI

M2_OPTI aims at promoting public transport and active transport through the investment in the cycling network.

Costs

All costs in the OPTI scenario are assumed to be twice as much as the costs in the ZERO scenario.

Benefits

The same benefits as in the M2_ZERO scenario are included

6.4.3.4 Policy scenario 4 - M3_SLOW

This measure (M3_SLOW) involves the replacement of coal-fired boilers with Natural gas-fired boilers, Biomass-fired boilers, Heat pumps, Automatic coal-fired boilers as well as Solar thermal collectors. A total of 800 boilers are assumed to be replaced in the 2015-2030 period, with 20% of the boilers to be replaced by 2020 and 100% by 2030.

Costs

The costs taken into account for this measure are investment costs of the new technology; i.e. 2,300€ for solar thermal collectors; 3,650€ for natural gas-fired boilers; approximately 4,200€ for biomass-fired boilers and automatic coal-fired boilers; and 8,250€ for heating pumps. The replaced coal-fired boilers are all assumed to have reached the end of their life.

Costs and maintenance costs of the different technologies (taken from the TZB-info calculator[27]) are also taken into account, and these are compared to the fuel and maintenance

---

26 https://www.czp.cuni.cz/czp/images/stories/Vystupy/Seminare/2006%20LOS%20envi%20ekonomie/prezentace/bruhovakohlova.pdf

27 https://vytapeni.tzb-info.cz/tabulky-a-vypocty/138-porovnani-nakladu-na-vytapeni-teplou-vodu-a-elektrickou-energii-tzb-info

savings from the old coal-fired boilers.

Benefits

Besides fuel and maintenance savings from the dismissed old coal-fired boilers, benefits related to improved health and lower carbon emissions are considered.

6.4.3.5 Policy scenario 5 - M4_ECON

Policy scenario M4_ECON puts into place energy saving measures in the residential sector, the commercial sector, and the industrial sector. These include, among others, buildings insulation, replacement of lighting with LED80 and LED110; Installation of flue gas preheaters to boilers, installation of frequency invertors, installation of cogeneration units, installation of heat pumps, installation/replacement of compressors, replacement of coal boiler with more efficient coal boilers, decrease of losses in heat distribution and thermal insulation of building.

Costs

The total investment costs in the different sectors are taken into account for the period 2016-2030, increasing from 18mln€ per year in 2016-2020, to 20.5mln€ in 2021-2030.

Benefits

Benefits of this measure include the health benefits achieved through reduction of PM and NO2; carbon savings; as well as energy savings.

6.4.3.6 Cost-Benefit Analysis results – Brno

The results of the cost-benefit analysis and cost-effectiveness analysis for Brno are presented in the following table

Measures/ policy scenarios	M1	M2	M3	M4	M5
	M1_OPTI	M2_ZERO	M2_OPTI	M3_SLOW	M4_ECON
	Low carbon vehicle promotion (Electric car)	Reduction of motorized vehicles in the city (walking, cycling and PT) -	Reduction of motorized vehicles in the city (walking, cycling and PT) - Double investment to M2_ZERO	Replacement of old coal-fired boilers	Implementation of energy saving measures in residential, commercial, and industrial sector
Net Present Costs	94,259,087	74,139,364	148,278,728	9,239,018	233,297,400

Net present health benefits	100,598,889	77,931,018	64,929,048	72,406,515	60,537,103
Net Present Other non-health benefits	119,919,740	1,465,694,354	2,931,388,708	7,187,529	170,816,400
Net Present Value Carbon savings	19,173,848	42,629,911	76,988,355	2,717,154	6,414,649
Net present total benefits	239,692,477	1,586,255,283	3,073,306,112	82,311,197	237,768,153
NPV	145,433,390	1,512,115,919	2,925,027,384	73,072,179	4,470,753
B/C Ratio	2.54	21.40	20.73	8.91	1.02
FICOSTEF (Financial cost per tC)	142.72	50.49	55.92	98.72	1,055.88
FUCOSTEF (Full cost per tC)	-191.17	-1,000.75	-1073.982	-751.72	8.80

Each scenario is associated with a positive NPV and B/C ratio greater than 1: 1.02 for M4_ECON, 2.54 for M1_OPTI, 8.91 for M3_SLOW and over 20 for M2_OPTI and M2_ZERO.

Net Present Costs of the analysed measures range from approximately 9mln€ for M3_SLOW, to 74mln€ for M2_ZERO, 94.3mln€ for M1_OPTI, 148.3mln€ for M2_OPTI and 233.3mln€ for M4_ECON. The value of health benefits is the highest for the electric car measure (100.6mln€), followed by M2_ZERO (77.9mln€), M3_SLOW (72.4mln€), M2_OPTI (64.9mln€) and M4_ECON (60.5mln€). Carbon savings are the highest for the M2_ZERO and M2_OPTI scenarios (i.e. the active travel and PT measures), respectively 42.6mln€ ad 76.9mln€. For these two measures also very high values for other impacts are found (i.e. extra benefits from deriving from fuel savings, extra health benefits deriving from increased walking and cycling, benefits related to the lower congestion costs, which are only partially offset by extra travel time cost associated to shifting from the use of personal car). This is reflected into the very high B/C ratios of these two measures (21.4 and 20.7).

The cost-effectiveness analysis suggests that the financial cost per tC saved range from 50.47 per tC (M2_ZERO) to over 1,000€ per tC (M4_ECON). When the full cost of these measures is taken into account, however, carbon savings are matched by an overall cost reduction. This shows the importance of the valuation of co-benefits in this analysis. Considering simply the financial costs, the estimates here suggest costs per tC that are much higher than current estimates of the social cost of carbon, but when the wider health impacts are taken into account then in most cases a fairly solid case can be made for interventions.

6.4.4 Ljubljana

Measures/ policy scenarios	M1 _DecreseCAR (Decrease of personal car use and electromobility)	M2 _IncreasePT (Increased share of public transport use)	M3 _PTfleet (Renovation of public passenger transport vehicle fleet)	M4 _DistrHEAT (Increased utilization and expansion of district heating systems)	M5 _EfficientHEAT (Advice for efficient use of domestic heating)
Costs	Capital costs for: Traffic calming measures; Parking in neighbourhoods; SUMP for larger traffic generators; Promotion of electromobility; Electromobility strategy; as well as Electromobility infrastructure	Capital and maintenance costs for: P+R stations; Additional PT lines – connected to P+R; PT dedicated priority lanes; PT priority an intersection; Rapid bus transport + connection to P+R;	Purchase of new PT fleet	Capital and maintenance costs for: Connection of new buildings to the network (new heating stations And new piping network); Physical connection of new buildings to the	Cost for consultation with citizens about low emission heating; Education and web page launch; Awareness campaign about the use of appropriate fuels; Building insulation

		Construction and maintenance of the bus stops and associated infrastructure, real time info for bus arrivals…)		network; Promotion of furnace replacement (subsidies), promotion of RES;	improvements
Benefits	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings

6.4.4.1 Policy scenario 1 – M1_DecreaseCAR

This measure combines car reduction measures with an alternative parking policy, and in particular with the introduction of parking zones in densely populated neighbourhoods and quarters, in which street parking spaces will be payable and limited to two hours – and therefore limiting the possibility of parking for daily migrants in residential areas, Daily migrants will be provided with parking spaces at P & R facilities at the outskirts of the city and in public garage houses. This measure also involves the promotion of electromobility, with electric vehicles estimated to account for the 2% of the entire fleet by 2030.

Costs

The cost of this measure account for over 2mln€, assumed to be spent over a 5-year period. This includes the cost of traffic calming measures (500,000€), of Parking in neighbourhoods (1.5mln€) and of SUMP for larger traffic generators (50,000€), as well as the cost of Promotion of electromobility (10,000), Electromobility strategy (10,000), as well as Electromobility infrastructure (155,000).

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2 as well as carbon savings.

6.4.4.2 Policy scenario 2 – M2_IncreasePT

This measure extends bus routes to neighbouring municipalities and involves the construction of Park & Ride (P+R) stations, connected through bus routes to the city centre.

Costs

The costs for this scenario includes the following measures: Construction of P+R stations, construction of Additional PT lines connected to P+R, construction of Public Transport dedicated priority lanes, PT priority at intersections, Rapid bus transport + connection to P+R, Construction and maintenance of the bus stops and associated infrastructure (e.g. real time info for bus arrival). Total construction costs add up to 13,5mln€ and are assumed to be spent over a 5-year period, with 150,000€ annual O&M costs.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2 as well as carbon savings.

6.4.4.3 Policy scenario 3 – M3_PTfleet

This measure aims at the renovation of public passenger transport vehicle fleet

Costs

This measure aims at the renovation of the public passenger transport vehicle fleet (CNG, hybrid buses) with the replacement of 86 EURO 0, 1, 2 buses, with a total investment cost of 15mln€, assumed to be spread over a 5-year period.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2 as well as carbon savings.

6.4.4.4 Policy scenario 4 – M4_DistrHEAT

This scenario involves the expansion of district heating systems.

Costs

The costs of the following measures are taken into account: connection of new buildings to the network (new heating stations and new piping network for overall 5mln€), physical connection of new buildings to the network (2mln €), promotion of furnace replacement (subsidies) and promotion of RES (8mln€). The total investment costs of these measures add up to costs are 13,59mln€ over a 5-year period, with 151,000€ annual O&M costs.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2 as well as carbon savings.

6.4.4.5 Policy scenario 5 – M5_EfficientHEAT

Within this scenario, different measures are put into place aiming at improving efficiency of domestic heating.

Costs

These measures include: consultation with citizens about low emission heating (3mln€), education and web page launch (7,000€), awareness campaign about the use of appropriate (low emission) fuels (15,000€). The total cost of this measures add up to 3,022,000€, assumed to be spread over a 5-year period.

This scenario also includes measures aimed at increasing heating efficiency in buildings, with a 25mln€ investment towards decrease of energy losses through buildings insulation.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2 as well as carbon savings.

6.4.4.6 Cost-Benefit Analysis results – Ljubljana

The results of the cost-benefit analysis and cost-effectiveness analysis for Ljubljana are presented in the following table

Measures/ policy scenarios	M1 _DecreseCAR	M2 _IncreasePT	M3 _PTfleet	M4 _DistrHEAT	M5 _EfficientHEAT
	Decrease in PC use (parking measure) plus electromobility measures	Increased use of public transport	Renovation of PT fleet	District heating	Heating efficiency
Net Present Costs	1,721,974	11,332,303	11,608,815	11,407,852	21,686,815

Net present health benefits	61,223,210	145,690,313	57,615,705	1,472,272,733	-17,682,572
Net Present Value Carbon savings	15,430,286	13,931,164	16,683,501	11,451,174	4,498,988
Net present total benefits	76,653,495	159,621,477	74,299,206	1,483,723,907	-13,183,584
NPV	74,931,521	148,289,174	62,690,391	1,472,316,055	-34,870,399
B/C Ratio	44.51	14.09	6.40	130.06	0.61
FICOSTEF	3.24	23.62	20.20	28.92	139.94
FUCOSTEF	-111.95	-280.00	-80.06	-3,703.70	254.05

The Net Present Cost of the analysed measures range from approximately 1.7mln€ for M1, to approximately 11mln€ for M2, M3 and M4, and 21.6mln€ for M5. Results suggest a positive NPV for four out of the five analysed measures, with a particularly favourable B/C ratio (130.06) for M4 (District heating measure). This is driven by a particularly high value of the health benefits (1.4bn€) which more than offsets the net present costs of this measure. The large value of the health benefits here is driven by the reductions in mortality estimated due to NO2 reduction. As for the other measures, health benefits are much lower and range from 57mln€ (M3) to 145,7mln€ (M2). M5 instead shows a negative health results (-17.7mln€), leading to a NPV of -34.9mln€.

6.4.5 Madrid

Cost data are available for only the EnEff measure selected by the city of Madrid. A 49mln€ investment cost (over the period 2017-2019) towards the development of the urban regeneration strategy 'Madrid Regenerates' is taken into account in the CBA. This measure includes the rehabilitation of the building stock (Plan MAD-RE), the refurbishment of public spaces, local energy production, green and short distance mobility, the management of water and materials, and the re-naturalization of the city.

As for the measures on Efficient urban logistic processes, Parking Regulation, Reserved infrastructure for public transport, and implementation of a Zero Emissions Central Area, cost data are not available. Moreover, given the complexity of these measures it is not possible to make plausible assumptions on the cost of these measures. For this reason, for these measures we will focus only the benefit side (health benefit and carbon savings).

Cost-Benefit Analysis results – Madrid

Measures/ policy scenarios	EnEff	Logistic	ParkReg	PuTInfra	ZEZ
	Regeneration of neighbourhoods	Efficient urban logistic processes	Parking Regulation	Reserved infrastructure for public transport	Zero Emissions Central Area
Net Present Costs	48,549,864	unknown	unknown	unknown	unknown
Net present health benefits	1,749,884,043	2,499,809,750	1,837,424,144	1,556,039,332	1,285,750,872
Net Present Other non-health benefits					
Net Present Value Carbon savings	85,805,174	6,933,620	4,738,370	20,122,752	2,271,675
Net present total benefits	1,835,689,217	2,506,743,370	1,842,162,514	1,576,162,084	1,288,022,547
NPV	1,787,139,353	2,506,743,370	1,842,162,514	1,576,162,084	1,288,022,547
B/C Ratio	37.81				
FICOSTEF	16.43				
FUCOSTEF	-575.64				

The measure EnEff has a B/C ratio of 37.8, driven by a 48.5mln€ net present costs and overall benefits of over 1.8bn€, mainly driven by the very high health benefits connected to this measure. The cost-effectiveness analysis suggests a financial cost per tC saved of 16.4€, but a negative full cost of 575.6€ per tC. The key health benefit estimated was the reduced mortality due to NO2 reductions.

Health benefits for the Madrid measures range from 1.2bn€ for ZEZ to 2.5bn€ for Logistic over the period of the analysis. Similarly, carbon savings are lowest for the ZEZ measure (2.2mln€), are about 7mln€ for the Logistic measure, and are the highest, approximately 85.8mln€ for the EnEff measure.

6.4.6 Milan

The costs and benefits considered for Milan have been provided by the city together with partner experts and are shown in the table below.

Measures/ policy scenarios	Area B – Low emission Zone	E-Bus	Energy	Buildings	Trees
Costs	Capital and maintenance costs of cameras; Training and recruitment of human resources; technical costs of hardware and call centre dedicated; communication costs	Investment costs of the buses; cost of the recharging infrastructure; O&M costs for buses (battery replacement costs, electricity costs, tyres and lubricant costs).			Tree & planting, Pruning, Remove and Dispose, Pest and Disease, Infrastructure repair, Irrigation, Clean-up, Lability and Legal, Admin and Other.
Benefits	Health benefits Carbon savings Revenues from fines	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings

6.4.6.1 *Policy scenario 1 - **Area B***

The City of Milan has started the implementation of Area B, with the control and tracking of access into the city and the banning up to Euro 3 diesel cars (up to Euro 4 from October 2019), with an infrastructure of electronic gates (185) around and next to the municipal boundary. The systems (camera and on board units) is set for the limitation of the most polluting vehicles, control and management of the heaviest vehicles and the ones used for the transport of dangerous goods. In a second phase it will be targeted to manage also tourist buses and other kind of big vehicles, and commercial ones as well. Milan 2030: diesel cars won't be allowed in the city at all.

Area B entered into force on 25 February 2019, from 7.30 to 19.30 Monday to Friday, excluding holidays.

Costs

The costs of this measure have been provided by the municipality and by the partner experts. These include the costs for the 185 cameras that are placed on the gates of what has been described as the widest LEZ of all Italy (10,650,000€). Annual O&M costs for the cameras are unknown and assumed to be equal to 1% of the initial costs. Other costs include the cost for training and recruitment of human resources, technical costs of hardware and call centre dedicated (1,800,000€ in the first year), as well as communication costs (360,000€).

Benefits

The benefits of this measure include revenues from fines; the health benefits achieved through reduction of PM and NO2, and carbon savings. Revenues from fines are forecasted to be 1,850,000€ in 2019 by the municipality. It assumed that these will remain constant throughout the project time span. Lack of information on the impact of the new low emission zone on citizens' journey modes, times and distances travelled prevent us to include other impacts (e.g. time losses) in the analysis.

6.4.6.2 Policy scenario 2 – E-BUS

ATM, Milan's municipal public transport company, has launched in 2018 the most ambitious Italian project to date aimed to the electrification of bus fleet. ATM plans to convert the whole fleet (1,200 buses) to zero emission electric drives by 2030 (from the actual 25). From 2020 on, ATM will buy only and exclusively electric vehicles.

Costs

The capital costs included in the CBA are the costs of the buses (550,000€ per bus) and the cost of the recharging infrastructure (146,000€). O&M costs include battery replacement costs, electricity costs and maintenance costs including also tyres and lubricant costs. O&M costs are expressed with respect to diesel buses O&M costs. Assumptions on costs and timing of battery replacement are drawn from a study by Noel and McCormack (2014), which suggests a replacement cost of 24,000$2013, and an estimated life of 9 years.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2, and carbon savings.

6.4.6.3 Policy scenario 5 - TREES

This measure involves the planting 25,000 new trees every year between 2019-2030.

Costs

The cost of the policy is estimated using data derived from a study by McPherson et al. (2003), and including the following cost categories: Tree & planting, Pruning, Remove and Dispose, Pest and Disease, Infrastructure repair, Irrigation, Clean-up, Lability and Legal, Admin and Other. These cost categories add up to a total cost of 16,11€ per tree per year.

Benefits

The benefits of this measure include the health benefits achieved through reduction of PM and NO2, and carbon savings.

6.4.6.4 Policy scenario 3 and 4 – ENERGY, BUILDINGS

As for the two remaining measures for Milan (BUILDING and ENERGY scenarios) it has not been possible to collect costs data nor to draw assumptions on the costs, given the complexity and early stage of development of these measures in the city.

For these measures we are therefore going to focus only on the benefit side.

6.4.6.5 Cost-Benefit Analysis results – Milan

The following table summarises the results of the Cost-benefit analysis and Cost-effectiveness analysis for the city of Milan.

Measures/ policy scenarios	M1	M2	M3	M4	M5
	MILAN AREA B	MILAN E-Bus	MILAN ENERGY EFFICIENCY (ENERGY)	MILAN PHOTOVOLTAIC (BUILDINGS)	MILAN TREES
	Low Emission Zone	Replacement of entire bus fleet with electric buses	Energy efficiency improvements	Solar power in buildings	Green area and new trees
Net Present Costs	14,272,436	77,187,492	unknown	unknown	49,496,9

					00
Net present health benefits	11,964,987,522	2,454,269,532	632,400,540	761,524,521	83,830,490
Net Present Other non-health benefits	29,041,252				
Net Present Value Carbon savings	158,871,091	2,402,922	55,898,495	56,134,451	1,641,954
Net present total benefits	12,152,899,865	2,456,672,453	688,299,035	817,658,972	85,472,444
NPV	12,138,627,429	2,379,484,961	688,299,035.39	817,658,972	35,975,544
B/C Ratio	851.49	31.83			1.73
FICOSTEF	2.61	932.57			875.17
FUCOSTEF	-2,189.17	-28,719.75			-607.06

Net Present Costs of the three analysed measures are equal to 14.3mln€ for the policy scenario Area B, 49.5mln€ for the Tree scenario and 77.2mln€ for E-Bus scenario.

Results suggest a positive NPV for all the analysed measures, which are driven by very high health impacts compared to the costs, as well as – but to a much lower extent – by high carbon savings. Health savings are largely driven by reductions in mortality attributable to NO2 reductions over the period (although for certain measures over the time span there were increases in mortality estimated, over the period as whole reductions in NO2 mortality were estimated).

The Area B measure shows the highest NPV and B/C ratio, driven by health benefits valuing nearly 12bn€ and a relatively low level of costs.

The cost-effectiveness analysis suggests that the financial cost per tC saved range from 2.61 to 932€/tC. When the full cost of these measures is taken into account, though, we can see that this is negative (i.e. saved carbon is actually linked to an overall cost reduction).

6.4.7 Stuttgart

The costs for the measures selected for the city of Stuttgart have been provided by the city partners together with the experts from IER at USTUTT.

Measures/ policy scenarios	Sc1	FvH	ScUV	ScEl
	Increase of building insulation and heating system exchange from oil to high efficiency gas boilers, district heating and heat pumps in the residential and commercial sector	Blue badge: Introduction of a driving ban on diesel vehicles less than Euro 6 standard and gasoline vehicles less than Euro 3 standard in the city of Stuttgart	Promoting environmentally friendly transportation modes like walking, cycling and public transportation	Promoting low carbon electric and hybrid vehicles
Costs	Capital and maintenance cost of an insulation advice centre; provision of service for insulation and public outreach; Capital costs for insulation; costs for the replacement of the heating system (capital and lower O&M costs with respect to the reference system: oil	Cost for purchasing the hardware; costs due to higher fuel consumption; additional AdBlue consumption; signs set up for the driving ban; the purchase of new vehicles and value loss of old ones; recurring costs for the city administration.	Construction and maintenance of PuT, Walking and cycling infrastructure; Tariff system reform; Subsidies for Public Transportation; Cost of new PuT (e.g. additional metros etc.); Costs for the citizens for using public transport compared to private PC/ individual	Capital and O&M costs for the Electric charging infrastructure; cost of Electric car compared to conventional car (incl. Subsidies) Net energy costs (Electricity needed minus Fuel savings)

	heating).		transportation costs for walking/cycling compared to private PC, Variable costs for construction and maintenance of infrastructure	
Benefits/Other impacts	Health benefits; Carbon savings; energy savings due to insulation and heating system exchange	Health benefits Carbon savings	Health benefits Carbon savings Other impacts: Health benefits achieved from increased physical activity (additional walking and cycling), noise reduction benefits; accidents and extra travel time (costs)	Health benefits Carbon savings Other impacts: noise reduction benefit; damages from emissions due to higher electricity consumption (costs); Construction and demolition of EV compared to conventional car (construction, maintenance and disposal)

6.4.7.1 Policy scenario 1 – Sc1

This scenario (Sc1) involves the increase of building insulation and heating system exchange from oil to high efficiency gas boilers, district heating and heat pumps in the residential and commercial sector

Costs

The costs for this measure include: the cost of an insulation advice centre, which is set at 1mln€ for 2020 and 1mln€ for 2030, while a 30,000€ annual operational cost is assumed; the provision of service for insulation and public outreach, equal to 40,000€ per year; capital insulation costs, of approximately 47mln€ per year in 2020-2030 and 87.1mln€ in 2030-2040; capital costs for the replacement of the heating system is 2.2mln€ in 2020 and 3.2mln€ in 2030. The replacement of the heating system is associated to 230,000 lower O&M costs per year in 2020-2030 and 338,000€ in 2030-2040.

No direct data was available for the city of Stuttgart. Therefore, a comparison with insulation and sanitation campaigns in similar cities in Germany has been made. The city of Heidelberg (close to Stuttgart, but with significantly lower population) gives cost estimates for an insulation campaign ("Sanierungskampagne") in their concept for the Masterplan 100% climate protection; an initiative the City of Stuttgart is also part of (ifeu 2014). Maxima of the presented costs for the advice centre, public outreach and service for insulation are taken as a first estimate for required expenses in Stuttgart as a higher number of buildings/building owners needs to be addressed in Stuttgart. Capital costs for the insulation activities are estimated according to Sanierungsfahrplan-BW (2015) and include also subsidies for the respective activities (approximately 10%). Within the first years of the measure, only the insulation of the building envelope, thermal insulation and replacement of windows has been taken into account. In later years total renovation costs also comprise costs for a mechanical ventilation system with heat recovery. Costs for the replacement of the heating system (capital, operation and maintenance) are taken from Härdtlein et al. (2018).

Benefits

Benefits of this measure include the health benefits achieved through reduction of PM and NO2; carbon savings; as well as energy savings due to insulation and heating system exchange as provided by the partner experts.

Energy savings due to insulation and heating system exchange have been calculated on the basis of the reduced final energy consumption per energy carrier (see measure description and modelling assumptions) and fuel and heating technology specific consumption costs from Härdtlein et al. (2018).

*6.4.7.2 Policy scenario 2 - **FvH***

This scenario (FvH) introduces a driving ban on diesel vehicles less than Euro 6 standard and gasoline vehicles less than Euro 3 standard in the city of Stuttgart

Cost

The costs related to this measure include cost for the hardware purchase. This is assumed to cost 3,000€ per vehicle, which lies in the range of costs provided by ADAC (2018a) as well by the Bundesministerium für Verkehr und digitale Infrastruktur (2018a, 2018b). The total cost for the hardware purchase therefore adds up to 2.1mln€ per year in 2020-2030 and approximately 1mln€ per year in 2030-2040.

Other costs relate to the extra consumption costs due to the additional AdBlue consumption as well as approximately 5% higher diesel consumption for heating and dosage of the SCR system. These are estimated to be respectively approximately 714,000 and 718,000€ in 2020-2030 and respectively 343,000 and 337,000 in 2030-2040.

A capital cost of 86,000€ ca. for year 2020 and 2030 is assumed for the signs for the driving ban. An annual running cost of 730,000€ ca. is assumed to cover the maintenance costs of signs and personnel costs for city administration etc. The estimation is based on data given in Kugler (2012).

The cost for the purchase of new vehicles and value loss of old ones is estimated to be 227.3mln in 2020 and 106.8mln€ in 2030. The data for determining the costs of passenger cars are taken from the car cost calculator of the ADAC (ADAC, 2018b) under the assumption that vehicles are replaced in average 1.5 years before their end of life (in accordance with the assumption of Regierungspräsidium Stuttgart (2018).

Benefits

Benefits of this measure include the health benefits achieved through reduction of PM and NO2; carbon savings

6.4.7.3 Policy scenario 3 - ScUV

This measure (ScUV) aims at promoting environmentally friendly transportation modes like walking, cycling and public transportation.

Costs

The cost of this measure include the construction and long term maintenance of PuT infrastructure and Walking and Cycling promotion and infrastructure improvements, for a total investment cost of 38mln€ ca. in 2020 and in 2030. Total O&M costs for the PuT infrastructure and the walking and cycling infrastructure are set at 945,000€. This cost category includes the fix costs for construction and the long term maintenance of the infrastructure system, while marginal costs of public transportation compared to the reference scenario (conventional car and street usage) are taken into account as an extra cost category. Apart from infrastructure costs, vehicle costs due to the purchase of additional metros are estimated at 240mln€ in 2020 and 160mln€ in 2030. All costs related to infrastructural changes, public transport vehicle costs and further promotion measures for walking and cycling are taken from Landeshauptstadt Stuttgart, AVISO GmbH, Rau Ingenieurbüro (2018).

A tariff system reform has an estimated initial investment cost of 50,000€ and recurring O&M costs 24.5mln€ (Landeshauptstadt Stuttgart 2018). Subsidies for public transportation and the marginal cost of public funding are also taken into account, using a factor of 1.2 (Dahlby, Ferede 2011).

Individual (lower) transportation costs for using public transport compared to private PC/ individual transportation costs for walking/cycling compared to private PC are taken into account by comparing PuT ticket prices with vehicles O&M costs based on (ADAC (2018b) and VVS (2018)). This scenario is based on the assumption that the relatively low switch from private transportation to public transportation until 2030 does not result in a decrease of vehicle purchases, but that just the operation costs of a conventional PC are saved. From 2030 on, the assumption has been made that 50% of the persons using public transport decide not to purchase a new vehicle and therefore total vehicle cost savings have been assumed for this proportion, while 50% still save only operation costs. The shift towards walking and cycling does not affect the total vehicle costs, but it is expected to simply reduce vehicle operation costs. Given the described assumptions costs of -3.5mln€ per year in 2020-20203 and -66.7mln€ per year in 2030-2040 occur.

Variable costs for construction and maintenance of the infrastructure (for switching from private car to PuT) is estimated at 17.2mln€ per year in 2020-2030 and 50.8mln€ in 2030-2040 (Umweltbundesamt, 2013). The marginal costs of using existing railways express the cost burden in addition to traffic in the reference case. It has been compared to the marginal costs for the street infrastructure. Due to the lower marginal costs of the railway system this category results in cost savings compared to the reference scenario.

Benefits/other impacts

The benefits of this measure include health benefits achieved through reduction of PM and NO2 as well as carbon savings. Moreover, health benefits deriving from increased cycling and walking are included and measured using the HEAT tool (WHO, 2011). Other impacts include noise reduction benefits (using cost factors from Korzhenevych et al. 2014 and Maibach et al. 2008), additional costs due to higher accidents costs (Maibach et al. 2008) as well as extra travel time costs (based on Doll et al. 2013 and Maibach et al. 2008).

6.4.7.4 Policy scenario 4 - **ScEL**

This measure (ScEL) aims at promoting low carbon electric and hybrid vehicles. The following costs and benefits are included

Costs

The costs for this measure include capital and O&M costs for the Electric charging infrastructure. Capital costs are estimated to be 26.6mln€ in 2020 and 50mln€ ca. in 2030 for the 2,140 charging stations needed in 2020 and 4,317 stations needed in 2030. Annual O&M costs are estimated to be equal 1.3mln€ ca. The cost estimations are based on NPE (2015), Lasten et al. (2016) and e-mobil BW GmbH (2013).

The capital of Electric cars compared to conventional cars are respectively 173mln€ and 366.4mln€ in 2020 and 2030 (including the marginal cost of public fund with a factor of 1.2) ADAC (2018b). The net cost of electricity needed (taking into account fuel savings) is also included based on ADAC (2018b).

Benefits

The benefits of this measure include health benefits achieved through reduction of PM and NO2 as well as carbon savings. Noise reduction benefits deriving from switching from a conventional car to an electric vehicle (based on the approach by Klötzke et al. 2015 and Jurte et al. 2015) are also taken into account.

Other impacts

The external cost of electricity production is also estimated, as well as construction and demolition costs of EV compared to conventional car (construction, maintenance and disposal). Cost factors are taken from Matthey, A; Bünger, B. (2019).

6.4.7.5 Cost-Benefit Analysis results – Stuttgart

The results of the cost-benefit analysis and cost-effectiveness analysis for Stuttgart are presented in the following table

Measures/ policy scenarios	Sc1	FvH	ScUV	ScEl (1)
	Increase of building insulation and replacement of oil boilers to high efficiency gas boilers; district heating and	Introduction of a driving ban on diesel vehicles <Euro 6 and gasoline vehicles <Euro 3	Promotion of walking, cycling and Public Transport	Promoting low carbon electric and hybrid vehicles

	heat pumps			
Net Present Costs	984,556,514	341,165,635	122,247,537	30,248,583
Net present health benefits	10,726,649	306,740,892	70,774,797	-13,663,943
Net Present Other non-health benefits	427,318,917		34,760,045	9,284,805
Net Present Value Carbon savings	37,441,867	1,037,376	23,440,881	21,758,863
Net present total benefits	475,487,433	307,778,268	156,237,839	17,379,726
NPV	-509,069,082	-33,387,367	33,990,301	-12,868,857
B/C Ratio	0.48	0.90	1.28	0.57
FICOSTEF	763.41	9,547.84	151.41	40.36
FUCOSTEF	423.76	963.41	-13.07	46.20

The net present costs of the analysed measures range from 30.2mln€ for ScEL, to 122.2mln€ for ScUV, 341.2mln€ for FvH and 984mln for Sc1. The large investment in these measures, however, is not always reflected in high health benefits values. In particular, the electric vehicle measure shows a negative health effect – despite having the largest carbon savings effect -, while Sc1 has a positive but relatively low health effect (10mln€).

This leads to a negative NPV for 3 out of the 4 analysed measures, with B/C ratios of 0.48 for Sc1, 0.9 for FvH and 0.57 for ScEl.

In the ScUV scenario, the B/C ratio is instead positive and equal to 1.28. The overall benefits of this measure (156mln€ ca.) are driven by 70mln€ of health benefits, 23mln€ of carbon savings as well as 34.7mln€ of other benefits. The latter are driven by the health improvements linked to the increased walking and cycling and by noise reductions, and are only partially offset by the extra costs related to increased risk of accident and extra travel time.

The next table presents different versions of the CBA for the Promotion of environmentally friendly transportation according to the abandonment rate of private PCs. In scenario ScUV (2) the assumption of 50% of affected persons abandoning the PC is altered to 100%, while for ScUV (3) the assumption was made that all persons keep their PC despite using mainly PuT. In the case of ScUV (2) the B/C ratio slightly increases from 1.28 to 1.51. In contrast, the B/C analysis for ScUV (3) shows a ratio of 0.59. This implies that benefits of the measure do not offset the costs when the reduced usage of PCs does not result in a reduced purchase of vehicles. The total range of the B/C ratio for this measure is therefore 0.59 – 1.51; which also shows that underlying scenario assumptions hugely affect the final outcome of the CBA.

Measures/ policy scenarios	ScUV	ScUV (2)	ScUV (3)
	Promotion of walking, cycling and Public Transport	Promotion of walking, cycling and Public Transport (total abandonment of the private PC)	Promotion of walking, cycling and Public Transport (all affected persons keep the private PC)
Net Present Costs	122,247,537	1,356,481,860	1,356,481,860
Net present health benefits	70,774,797	70,774,797	70,774,797
Net Present Other non-health benefits	34,760,045	1,232,625,698	490,376,733
Net Present Value Carbon savings	23,440,881	23,440,881	23,440,881
Net present total benefits	156,237,839	2,054,483,198	800,598,340
B/C Ratio	1.28	1.51	0.59

The main factor influencing the CBA result for scenario Sc1 are assumed capital costs for insulation activities. The following table therefore shows an alternative scenario Sc1 (2) which considers the lower boundary of cost for insulation measures; i.e. only activities that are directly related to energy savings. The B/C ratio for this scenario is still unbeneficial (0.98) but benefits – mainly consisting of fuel savings – are almost as high as measure costs. This clearly shows that further investigations to derive consistent average costs for insulation and renovation activities within the study area are needed.

Measures/ policy scenarios	Sc1	Sc1 (2)
		Lower boundary of cost for insulation measures
Net Present Costs	750,576,298	481,697,673
Net present health benefits	10,726,649	10,726,649
Net Present Other non-health benefits	427,318,917	427,318,917
Net Present Value Carbon savings	36,130,014	36,130,014
Net present total benefits	474,175,580	474,175,580
B/C Ratio	0.63	0.98

Main influencing factor for the cost benefit analysis of scenario FvH is the assumed value loss for banned vehicles. In Regierungspräsidium Stuttgart (2018) it is stated that the ban is expected to only affect vehicles with less than 2 years life time remaining. The basic scenario FvH assumes therefore an average of 1.5 years to the end of the lifetime. The following table shows the results for further two scenarios: FvH (2) with 1.0 and FvH (3) with 3.0 years average life time of the vehicle. The B/C ratio range for all three scenarios is 0.48 – 1.27. For FvH (3) the B/C ratio decreases from 0.90 to 0.48; while for FvH (2) the B/C ratio is 1.27. The results therefore indicate that health benefits offset total measure costs only when assuming a value loss for clearly less than 2 years.

Measures/ policy scenarios	FvH	FvH (2)	FvH (3)
	1.5 years to end of lifetime of banned vehicles	1.0 years to end of lifetime of banned vehicles	3.0 years to end of lifetime of banned vehicles

Net Present Costs	341,165,635	242,712,852	636,523,983
Net present health benefits	306,740,892	306,740,892	306,740,892
Net Present Other non-health benefits			
Net Present Value Carbon savings	1,037,376	1,037,376	1,037,376
Net present total benefits	307,778,268	307,778,268	307,778,268
B/C Ratio	0.90	1.27	0.48

The next table presents three different versions of the CBA for the Electric Vehicle scenario. In particular, column 2 excludes the cost for electricity generation, while column 3 excludes the cost of construction and demolition of electric cars. As one can see, the B/C ratios is very much affected by the exclusion of these cost categories: it increases from 0.48 (column 1), to 2.01 (column 3) and to 3.49 (column 2). This shows that a complete understanding of all the costs and benefits related to the selected measures, as well as the choice regarding the cost and benefits categories to include in the analysis, plays an important role in the analysis itself. This is especially important for measures that go along with an increased electrification of the transport or heating system or a high material consumption.

Measures/ policy scenarios	ScEl (1)	ScEl (2)	ScEl(3)
	Promoting low carbon electric and hybrid vehicles	Promoting low carbon electric and hybrid vehicles (excluding costs for electricity generation)	Promoting low carbon electric and hybrid vehicles (excluding costs for construction and demolition of electric cars)
Net Present Costs	30,248,583	30,248,583	30,248,583
Net present health benefits	-13,663,943	- 13,663,942.63	- 13,663,942.63
Net Present Other non-health benefits	9,284,805	97,601,966.56	52,630,651.34

Net Present Value Carbon savings	21,758,863	21,758,862.83	21,758,862.83
Net present total benefits	17,379,726	105,696,886.76	60,725,571.55
B/C Ratio	0.57	3.49	2.01

6.4.8 Thessaloniki

Investment costs for the Thessaloniki measures have been made available by the partner experts and are also provided in the Database (Deliverable 5.2). These are presented in the following table.

Measures/ policy scenarios	M1 Insulation	M2a Cycling and walking	M2b Green vehicles	M2c PT	M3 Waste	M4 Industrial sector
	Promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings	Promotion of cycling and walking	Promotion of green vehicles	Promotion of public transport, the use of metro. Integrated urban mobility system	Promotion of eco-friendly waste management.	Industrial sector: Energy efficiency in the cement industry by switch of combustion techniques / use of fuel alternatives
Costs	The investment costs for this measure is equal to 59,345,655€[28]	the investment costs for this measure is equal to	the investment costs for this measure is equal to 14,456,315€	the investment costs for this measure is equal to	costs for this measure are unknown	the investment costs for this measure is equal to

[28] Sources:

Municipality of Thessaloniki: Action Plan for Sustainable Energy (2014). (in Greek)

		793,650€		1,4mln€		2,75mln€[29]
Benefits	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings	Health benefits Carbon savings Reduction of landfill costs through the reduction of 50% of waste going to landfill (using the same landfill cost factor used for	Health benefits Carbon savings

---

Municipality of Kalamaria: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Thermaikos: Action Plan for Sustainable Energy (2013). (in Greek)

Municipality of Pilea-Hortiati: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Pavlos Melas: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Ampelokipoi-Menemeni: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Neapoli-Sikies: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Thermi: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Kordelio-Evosmos: Action Plan for Sustainable Energy (2011). (in Greek)

Municipality of Lagadas: Action Plan for Sustainable Energy (2012). (in Greek)

Municipality of Halkidona: Action Plan for Sustainable Energy (2013). (in Greek)

Municipality of Volvi: Action Plan for Sustainable Energy (2015). (in Greek)

[29] Source:

Lechtenberg D. The Use of Alternative Fuels in the Cement Industry of Developing Countries – an opportunity to reduce production costs, Cement International 7 (2), 2009, 66-70.

					Athens, i.e. 35€/tn).	

As for the benefits of the measures carried out in Thessaloniki, we will mainly focus on the health benefits achieved through reduction of PM and NO2 and carbon savings.

Cost-Benefit Analysis results – Thessaloniki

The following table summarises the results of the cost-benefit and cost-effectiveness analysis

Measures/ policy scenarios	M1 Insulation	M2a Cycling and walking	M2b Green vehicles	M2c PT	M3 Waste	M4 Industrial sector
	Promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings	Promotion of Cycling and walking	Promotion of green vehicles	Promotion of public transport, the use of metro. Integrated urban mobility system	Promotion of eco-friendly waste management.	Industrial sector: Energy efficiency in the cement industry by switch of combustion techniques / use of fuel alternatives
Net Present Costs	59,345,655	793,650	14,456,315	1,400,000,000	unknown	2,750,000
Net present health benefits	10,343,518	44,763,048	175,837,392	103,735,119	14,723,872	81,384,200

Net Present Other non-health benefits					123,467,624	
Net Present Value Carbon savings	3,917	109,465,041	510,717,037	158,218,153	Emission reductions not estimated	150,779,608
Net present total benefits	10,347,435	154,228,089	686,554,429	261,953,272	138,191,497	232,163,808
NPV	-48,998,220	153,434,439	672,098,114	-1,138,046,728	138,191,497	229,413,808
B/C Ratio	0.17	194.33	47.49	0.19		84.42
FICOSTEF	439,877.11	0.21	0.82	256.89		0.53
FUCOSTEF	363,209.71	-11.66	-9.17	237.86		- 15.14

The NPV of two of the selected measures (M1 and M2c) for Thessaloniki is negative, leading to a B/C ratio of respectively 0.17 and 0.19. As for M1, the total health and carbon savings benefits (10.3mln€) are offset by a much higher level of costs (59.3mln€). Similarly, for the public transport measure M2c, the total health and carbon savings benefits are 261.9mln€ vs. an investment cost of 1.4mln€. The measure M2a, M2b and M4 instead display a positive NPV, with B/C as high as 194 for M2a.

Focusing only on the health benefits, one can see that M2b is the most favourable measure, with a health impact value of 175mln€. This is 103.7mln€ for M2c, 81.4mln€ for M4, 14.7mln€ for M3 and 10.3mln€ for M1. The most important health benefits differ between measures, with some having largest benefits in terms of the impacts of reduced PM on mortality and others the NO2 reduction on mortality. The values of carbon savings follow the same pattern, except for M3 that is not associated to any carbon savings.

The cost-effectiveness analysis suggests that both the full and financial cost per tC saved are extremely high for M1 and M2c, while the financial cost per tC saved is lower than 1€/tC for the other measures. The full cost of M2a, M2c and M4, moreover, is negative and ranging between 9 and 15€/tC. This implies the existence of an overall benefit per ton of carbon saved.

6.5 Discussion on CBA results

Drawing overall conclusions on the cost-benefit analysis carried out on the measures carried out by the cities in ICARUS is not straightforward, given that it has not always been possible to reach a complete understanding of all the costs and benefits related to the selected measures. In particular, some impacts included in some of the measures have not been included in other measures, due to the lack of data. For this reason, a cross-comparison of the benefit-cost ratios for different options is difficult – and within city comparison is probably more valid.

The choice regarding the cost and benefit categories to include in the analysis can highly affect the results of the analysis. This is shown for example by the results of Stuttgart's Electric vehicle measure: the inclusion and exclusion of some cost categories, in fact, can turn a negative NPV into a positive one, changing for Stuttgart ScEL the B/C from 0.57 to 2.01 or 3.49.

Nevertheless, some common patterns can be observed when looking at the monetary valuation of the impacts. The monetary valuation of the impacts allows to summarise several results in a common metric, making them easily comparable. Comparing the results within each city, it has for example been found that health benefits are usually highest for transport measures and energy efficiency measures. Measures aiming at reducing private car emissions (e.g. electric vehicles, zero emission zone, and diesel ban) are highest for Brno, Milan, Stuttgart and Thessaloniki. Energy efficiency (as well as district heating) measures have instead the highest health effect in Attica, Basel, Ljubljana. Measures related to public transport also generally show quite high health benefit.

The measures related to increase in public transport have the highest impact in Attica and Brno in terms of carbon savings. Milan, Stuttgart and Thessaloniki instead show the highest carbon savings for measures aiming at reducing private car emissions. Energy efficiency measures have particular high carbon savings in Basel, Ljubljana, Madrid and Stuttgart.

The active transport measures which have been introduced in some of the cities also carry significant positive co-benefits: despite the negative effect that shifting to personal car use to active travelling has on travel time, there is a positive effect especially on health, thanks to the increased level of physical activity associated to these measures, and to a much lower extent on noise reduction.

This analysis shows:

- The importance of the inclusion of health co-benefits in economic analysis of carbon mitigation strategies. Options that may appear costly in terms of the financial cost per tonne of carbon reduced become viable in many cases when co-benefits are considered;

- That different strategies in different cities may be appropriate – and hence the need for policy at an appropriate scale (the urban level) to address carbon mitigation; and
- The importance of gathering good cost data, and the gaps there are in understanding the costs of some carbon mitigation options shows the need for further work in this area.

7 ASSESSMENT OF POLICIES/MEASURES/SCENARIOS - DISCUSSION

All participating cities in ICARUS have shown an outstanding environmental consciousness and have developed plans addressing climate and energy aspects. The local/regional policies and measures described have a more short- and medium- term vision (2030) rather than a long-term vision (2050).

The estimates of the air pollution and greenhouse gas reduction potential and related effects as presented in this report are a result of impact assessments of local air pollution plans and energy or climate concepts. However, these plans exclusively focus on the emissions of NOx, PM10/PM2.5 and CO2; however, in ICARUS we took into account also further pollutants and GHGs; N2O and CH4 have been calculated as absolute emission reductions and taken into account in the CBA; other air pollutants like PM precursors have been taken into account in the air pollution modelling and therefore HIA.

The baseline city emission inventories of ICARUS show that the road traffic and energy/household sector has a moderate to high impact on the overall emissions. Therefore, various transport and energy-related measures have been selected as primary for detailed analysis. Energy consumption of households also account for a considerable amount of cities CO2 emissions, which is why energetic renovation of buildings and changes in the heating technologies have been given further attention. Besides these two categories, the measures from industry, waste management and climate change adaptation categories were also considered.

As the main focus of this chapter is the assessment of policies, the results are presented as thematic categories of measures, where each measure has been qualitatively assessed in terms of its:

- Air pollutant emission reduction potential
- impact on air pollution (both short/medium/long term)
- impact on public health
- effectiveness in economic terms (CBA analysis)
- GHG reduction potential

A special attention is also given to the potential of the measures up-scaling and transferability to other cities; this has been put in the foreground primarily to the fact that if a certain measure has been identified as having great potential to provide extensive benefits in majority of above listed points it is important to know how to implement in other locations in order to achieve this an even greater extent.

Tables 16-20 show the derived common policy thematic categories (in the database referred to as »policy«) and examples for related measures that have been chosen for the evaluation (in the database referred to as »measure description/policy intervention«). The sector buildings and households mainly includes measures focusing on insulation and renovation of private and municipal buildings, a switch to environmental friendly combustion technologies and the promotion of energy conscious behaviour. Policies related to transportation address a variety of different objective such as car-independent lifestyles, fuel alternatives and clean fuel vehicles, demand management strategies and the promotion of public transportation. The energy supply sector comprises policies regarding the promotion of renewable energies, efficiency improvements of thermal (district heating) plants and the expansion of district heating including co-generation plants. Chosen policies in the waste sector target the prevention of waste generation. Various measures regarding smart city strategies and general concepts like energy saving behaviour have also been considered. Policies in the land-use sector include the greening of the urban areas in order to aid in the efforts for the GHG reduction and/or establishing a better micro-climate in designated areas.

The summary of the results is presented in a qualitative manner based on the following criteria:

RATING	++	+	o	–
Emissions	significant positive impact; more than 10% emission reduction potential	minor possible positive impact; up to 10% emission reduction potential	no impact; no significant emission reduction potential (0-1%)	possible negative impact
Air Pollution	significant positive impact; more than 5% air pollution reduction	minor possible positive impact; up to 3% air pollution reduction	no impact; no significant air pollution reduction potential (0-1%)	possible negative impact
Health	significant positive impact;	minor possible positive impact;	no impact; no significant	possible negative

	more than 20% morbidity/ mortality reduction	up to 10% morbidity/ mortality reduction	morbidity/ mortality reduction (0-1%)	impact
Cost-benefit	significant positive impact; B/C ratio > 10	minor possible positive impact; 1< B/C ratio <10	no impact; B/C ratio = 1	possible negative impact B/C ratio < 1
GHG	significant positive impact;	minor possible positive impact;	no impact; no significant GHG emission reduction	possible negative impact
/ no data available				
inconclusive interpretation				

7.1 Energy: buildings & households

The results for energy – building and household related measures are presented in Table 16.

Table 7-1: Overview of effects of policies/measures – Energy-buildings & households

BUILDINGS AND HOUSEHOLDS						**Impacts**				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
Enhanced energy conscious behaviour	Energy conscious use of appliances Energy conscious use of domestic heating	Ljubljana	5	M5_ Efficient HEAT	More efficient use of domestic heating; decrease of fuel consumption by 15%	O			O	
Increase of building renovation and efficient design	Energetic renovation of residential buildings Energy efficient design of new buildings	Athens (Attica)	3	EnEff	Increase of energy efficiency and renewable energy sources at residential and commercial buildings				-	
		Brno	5	M4econ	Implementation of energy saving measures by insulation and renovation of the building stock				O	
		Stuttgart	4	Sc1	Increase of building insulation (+2%) and heating system exchange to high efficiency gas boilers (environmentally friendly heating technologies)	++			-	+
		Thessaloniki (region)	1	M1	Promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings				-	

BUILDINGS AND HOUSEHOLDS						Impacts				
Policy thematic category	Measures/ policy scenarios					Emissions	Air pollution	Health	CBA	GHG
		Milan	3	Buildings	Improvement of energy efficiency in existing and new residential flats	O			(+) / unknown costs	++
		Milan	4	Energy	Incentive measures of new building regulation promote the use of photovoltaic solar power for buildings				(+) / unknown costs	+
		Madrid	5	EnEff	Regeneration of neighbourhoods by improving energy efficiency and thermal insulation of the building stock	+			++	++
Environment friendly heating technologies	Switch to gas boilers Switch to solar heating Switch to heat pumps Switch to district heating	Basel	1	NoHeat	Replacement of fossil heating technologies by heating pumps and solar heating (until 2020: 1/3 will be replaced; until 2030:100%)	+		O	+	++
		Basel	3	Firewood Ban	Introduction of a ban on small combustion of firewood (2030 scenario)	O	O	O	++	
		Basel	4	NoHeat Firewood	Replacement of fossil heating technologies combined with the introduction of a firewood ban (2030 scenario)	+		O	+	++

BUILDINGS AND HOUSEHOLDS						Impacts				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
	Switch to biomass burning Switch to modern systems	Brno	4	M3slow	Switch of combustion techniques in residential and municipal buildings: Replacement of old coal-fired boilers in residential sector	O, - (NH_3)		O	+	
Promotion of district heating	Expansion of district heating networks	Ljubljana	4	M4_ DistrHEA T	Increased utilization and expansion of district heating systems; renovation of the system - replacement of existing combustion units with more appropriate means	+	+	+	++	

A high impact is evident from measures related to environment friendly heating technologies and the increase of building renovation and efficient design, primarily through enhancement and renovation of insulation. Especially the measures related to replacement of the heating technologies and fuels yields the highest benefits in terms of emission reduction potential and consequently in health impact and related economy. These measures target private buildings and specifically households and are related to the policy for a switch in combustion techniques in the building sector and the promotion of natural gas in the energy supply sector. The measures are primarily oriented at increasing the use of natural gas for heating in residential buildings and the expansion of the natural gas heating system, since, insofar, diesel/oil and coal were the dominant choice of fuel used for heating demands in residential buildings/households in the ICARUS cities in question. Specifically, measures include cooperation among city administration and the energy providers along with awareness raising activities in order to steer the households towards the use of natural gas heating systems. Apart from awareness raising activities, the cities also provide subsidies and incentives for the installation of natural gas systems (switch of combustion techniques). As a result, significant emission reduction potential is evident along with a relatively high expected impact on GHG reduction. In terms of impact on health it could be argued that the impacts are not evident to a large extent, perhaps because the shares of individual heating systems may be too low in the cities in question; i.e. the larger population density areas already are connected to the district heating systems or gas networks. Therefore, the emission reduction potential is evidently lost in the comparison of measure effects with the city-wide air pollution situation (e.g. from transport). What clearly speaks in favour of replacement of heating systems are the economics behind it – i.e. the benefits in terms of health clearly outweigh the associated investment costs (for example in Basel and Ljubljana). Even more so, the expansion and increased utilization of district heating as opposed to domestic heating (biomass burning or gas network) can raise the benefits to an even larger extent. However, such measures are inevitably connected to changing the users' habits and the unwillingness to change them. This represents a barrier that should be taken into account when the proposals for the implantation of such measures are prepared at the city administration.

The measures linked to promotion of insulation and renovation of private buildings are focused on reducing energy consumption at the city level due a higher standard of energy efficiency in private and municipal buildings. The cities have only indirect influence on the renovation of private buildings, therefore numerous energy consulting services (e.g. Stuttgart) and financial incentives (e.g. income related subsidies, interest-free loans, contracting concepts in Athens, Thessaloniki, Ljubljana and Stuttgart) are offered to citizens in order to carry out major interventions for improving their houses' energy efficiency (insulation of walls, facades, roofs; modernization of windows). The programs either set concrete objectives such as improving the energy performance of the household (Athens, Ljubljana,) or general objectives such as an increase in the renovation rate for the whole city (Stuttgart). It should also be emphasised here, that even though the incentives for undertaking such measures are encouraging, there is still some reluctance among the occupants/owners of private buildings to go into the project, which results in a slower pace of measure implementation.

In contrast to private buildings, the energy efficient renovation in municipal buildings and properties (school buildings, hospitals, administration buildings etc.) is a direct responsibility of the city. Most of them lack adequate thermal insulation resulting in high energy demands. Cities have implemented and will continue to implement energy retrofits and soft energy-saving actions within their building stock to improve efficiency and reduce energy costs. However, looking at the CBA results a close attention must be paid to the investment cost aspect. Since there is a significant lack of data in this regard, the results cannot serve as a clear orientation as to whether the implementation/operation of the insulation for the measures in question will in fact result in significant benefits.

Even though the extent of these measures (the number of buildings included) was relatively high, it has been shown that it resulted in a quite small impact on local background levels of air pollution so health effects were practically negligible. The reasons for this may be sought in the fact that the energy consumption reduction is dislocated from the users (i.e. the citizens) and the impact was not clearly shown in the modelling results. It could also be the case that the energy consumption of such buildings was not very high to begin with, since the majority of them only operate during the »working hours«. Rarely is there a need or an uninterrupted heating (with the exception hospital buildings). In this regard it should be emphasised, that focusing solely on public/municipal buildings is not enough for a significant improvement of health and other benefits within the city; more effort has to be made in encouraging occupants/owners of private buildings to act in a similar energy consumption reduction manner also with respect to the slow pace of measure implementation.

Various measures were also related to the promotion of energy saving behaviour and targeted the increase of citizens' awareness regarding their energy use. The measures include various information-sensitization-educational events on efficient energy use that are organized on a Municipality level. The events provide guidelines for selecting energy efficient heating systems, introducing RES in households, as well as advice on energy saving in homes. These measures have not resulted in a quantifiable air pollution reduction potential *per se*, but they can prove successful if they help in contributing to a higher rate of acceptance and, consequently, implementation of other air pollution reduction measures such as the replacement of heating technologies, energy efficient design and renovation of residential buildings etc.

7.2 Transport

The results for transport related measures are presented in Table 2.

Table 7-2: Overview of effects of policies/measures – Transport

TRANSPORT						Impacts				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
Car-independent lifestyles	Introduction of new underground railway/metro lines Expansion of bus lanes network Improving cycle networks Pedestrian friendly networks Price reductions in public transport Increased use of	Athens (Attica)	1	SusMob	Promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica)	+		O	++	++
		Athens (Attica)	2	SusMobPuT	Promotion of sustainable mobility through eco-driving, cycling and walking as well as minimizing the use of private passenger cars + enhancing public transportation means	+		+	O	++
		Basel	2	Traffic10	Introducing a traffic reduction law leads to a reduction of the traffic load by 10% in 2020 and 2030 compared to the baseline scenario	O	O	O	(++) / no costs assoc. to measure	
		Brno	2	M2opti	Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking, biking and using public transport)	++	+		++	++

TRANSPORT						Impacts				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
	car sharing Increased use of park and ride Integrated public transportation system	Brno	3	M2zero	Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking, biking and using public transport)	+			++	
		Ljubljana	1	M1_ Decrease CAR	Decrease of personal car use (car reduction measures, parking policy, electromobility, car sharing)	+		O	++	+
		Ljubljana	2	M2_ Increase PT	Increased share of public transport use (increased use of PT on the account of better service and transfer from car users)	++		O	++	
		Madrid	3	PuTInfra	Reserved infrastructure for public transport (extra bus and high occupancy vehicle lanes) connecting with modal interchange points such as park-and-ride car parks	O			(+) / unknown costs	
		Stuttgart	2	ScUV	Promoting environmentally friendly transport modes (walking, cycling, PT) (decrease of individual transport by 7%	O		+	O	

TRANSPORT						Impacts				
Policy thematic category	Measures/ policy scenarios					Emissions	Air pollution	Health	CBA	GHG
					in 2020; 20% in 2030) (2030 scenario)					
		Thessaloniki (region)	2	M2	Promotion of cycling/walking, green vehicles and public transport	+	+	+	++, - (PT)	++

TRANSPORT						Impacts				
Policy thematic category	Measures/ policy scenarios					Emissions	Air pollution	Health	CBA	GHG
Alternative fuels and driving technologies (e-mobility, hybrids, CNG, LPG)	Penetration of electric vehicles Penetration of hybrid vehicles Penetration of CNG	Basel	5	Zero Emission Ships	Conversion of the shipping fleet to zero emission ships by 2030 (2030 scenario)				(+) / unknown costs	
		Brno	1	M1opti	Promoting low carbon electric vehicles			O	+	
		Ljubljana	3	M3_ PTfleet	Renovation of public passenger transport vehicle fleet (CNG, hybrid buses); the replacement of EURO 0,1,2 buses with CNG	++	O		++	+

TRANSPORT						Impacts				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
	Penetration of LPG				propulsion system					
	Renovation of public transport fleet (electrified/hybrid/CNG buses, taxis)	Milan	2	ElectricBus	Conversion of all public buses to electric ones by 2030	+	O	+	++	
		Stuttgart	1	ScEL	Promoting low carbon electric vehicles (share in vkm to 7% in 2020, 20% in 2030)	O			-,+ (depends on scenario/ sensitivity	
Efficient logistics	Efficient urban logistics	Madrid	4	Logistics	Public-private collaboration in order to make urban logistics processes more efficient			+	(++) / unknown costs	
Demand and traffic management strategies	Low emission zone City toll/congestion charge Parking regulations	Madrid	1	ZEZ	Delimitation of a closed Central Zone (Zero Emissions Central Area) with restricted access in which through traffic will be banned.			O	(+) / unknown costs	
		Madrid	2	ParkReg	Parking regulation according to air quality criteria through an increase of discounts and penalties according to vehicle's emissions and new regulation systems			O	(+) / unknown costs	

TRANSPORT						Impacts				
Policy thematic category	Measures/ policy scenarios					Emissions	Air pollution	Health	CBA	GHG
	Traffic reduction Redesign of traffic routes	Milan	1	AreaB	Low Emission Zone (Area B): Control and tracking of access into the city by banning up to Euro 3 diesel cars (up to Euro 4 from October 2019)	++	+	+	++	++
	Blue-Badge area – Diesel car ban/ Retrofitting of old cars	Stuttgart	3	ScFvH	Introduction of hardware update of diesel passenger cars and driving ban on diesel PC<Euro6 in the city centre			O	–	
Enhanced environmental conscious behaviour in traffic	Eco-driving	Athens (Attica)	1	SusMob	Promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica)	+		O	++	++

The transport policies considered were encouraging car-independent lifestyles (active transport and public transport, discouraging car use) promoting alternative fuels and driving technologies (e-mobility, hybrids, CNG, LPG, cars with lower emissions), organising and managing transport demand and how to influence traffic behaviour.

7.2.1 Car-independent lifestyles

The provision of alternatives to car usage is an essential component of any comprehensive strategy for transport related air pollution reduction in the cities.

Among these, public transport and measures for decreased car ownership/usage (car sharing) are the two groups of policy measures considered. Parallel to this, cycling and walking related measures are recognised as a valid alternative for the promotion of this behavioural shift.

Public transport

Public transport network measures (introduction of new underground railway/metro lines, expansion of bus lanes network.) aim to strengthen all transport modes and involve promotional activities as well. Most of the measures have demonstrated a significant emission reduction potential (including GHG), and health benefits. Typically, the renovation/reorganisation and redesign of a PT network and its infrastructure can be carried out on any scale, therefore to achieve even greater benefits in terms of air quality the measure should be implemented to encompass the whole city. As PT infrastructure measures are usually associated with higher implementation and operation costs, an even higher benefits can be achieved by combining the PT with walking and cycling as an additional transport mode (i.e. last mile mode) which further contributes to higher health benefits.

The implementation of public transport measures could face institutional, financial and spatial barriers, and these generally become apparent in the initial phases of implementation. To help the implementation process in other ICARUS/European cities, for example, extra investments and/or institutional adjustments are often required, and it is usual for political drivers to play an important role in all phases of implementation.

Car-sharing

The core objective of establishing a car-sharing service was to reduce private car use and deliver primarily environmental as well economic benefits. Car sharing scheme has proven beneficial in areas with high congestion levels, parking costs, shortage of parking spaces and high costs of owning a car. Because the schemes have not yet reached their full potential in terms of helping to achieve a significant air pollution reduction in cities a combination of other car usage reduction options must be simultaneously put in force (low emission zones, parking regulation, etc.).

Cycling

Measures aiming at the promotion of bicycle travel are related to extension of the bicycle path network, improvement in the connection among existing paths, the use of new bike-sharing systems and incentives for the purchase of bicycles. The aim of these policy measures is to encourage bicycle use by improving the overall quality of cycling infrastructure and conditions. In general, the provision of new cycling facilities combined with the promotion activities leads to an increase in the number of cyclists, which in turn decreases the burden of motorised traffic pollution, consequently resulting in an unparalleled health benefits. The majority of the considered interventions were shown to be beneficial from a long-term economic perspective as well (Athens, Brno, Ljubljana, Stuttgart, Thessaloniki). The enhancement of cycling infrastructure is hampered by several barriers at various stages. Political and cultural aspects present the greatest difficulties during the preparation phase of the construction project – a perceived lack of safety associated with cycling; cycling is often viewed as solely a leisure activity and not taken seriously as a means of transport. Financial and planning barriers are highest during the implementation stage, while cultural factors are more influential in the operational phase. Stable political support, resulting in tailor-made legislation and combined with very early workshops, encourages potential stakeholder involvement and contributes to successful implementation. In addition, strong benefits in terms of CBA results have proven, that the wider improvement and provision of cycle and pedestrian infrastructure should be considered as a feasible component of future transport policies in most cities. Such measures will bring greater benefits to all aspect of sustainability – environment, social aspects and economy.

In general, measures aimed at creating or improving existing cycling infrastructure are suitably transferable to other cities. However, three aspects must be taken into account:

• **City topography**: Hilly terrain will require extra investment, e.g. synergies with vertical transport might be necessary. Gain detailed insight beforehand into costs and feasibility to avoid any unpleasant surprises.

• **Support levels**: Political leadership is vital in places that lack public and legislative support for cycling and pedestrian infrastructure. It is also needed in order to approve extra investments and to ensure meaningful stakeholder involvement.

• **Multimodal possibilities**: It is helpful if cycling and walking are embedded in the mobility system and are seen as part of a multimodal system. This does not mean that a whole network has to be created at once (little steps are always helpful), but a multimodal perspective should always be borne in mind.

7.2.2 Alternative fuels and driving technologies

The measures in this section include the introduction of alternative fuels and driving technologies into public and private vehicle fleets and consist of penetration of electric and hybrid vehicles, penetration of CNG and LPG etc. Vehicle fleets using new vehicles have positive impacts on the environment, though the results differ greatly, depending on the technology considered. An assessment of CNG use in buses, for example, revealed a significant reduction in particulate emissions and slight decreases in CO2 and NOx emissions, but increased CO emissions. For hybrid and electric technologies, the emission reduction potential is higher, however, they have been proven costlier in terms of investment and operation.

The results support conclusions that the use of alternative fuels has great potential to reduce vehicle emissions except for fine particles (Ljubljana, Milan and Stuttgart). In terms of their air pollution and health benefit potential in could be concluded, that the public transport fleet undergoing the changes usually represents a relatively small share of the emission sources originating from transport and therefore cannot contribute largely to the reduction of air pollution burden. Additionally, the investment costs are generally high, especially for those fuel types which require the building of new refuelling stations; the results of CBA have clearly proven that the introduction of cleaner technologies without the need for an additional refuelling stations has presented an economically attractive solution (Ljubljana). Usually, the costs to introduce and operate clean vehicles (hybrid in particular) are significantly higher than those for traditional vehicle types; and clean vehicles (CNG vehicles, for example) are only rarely found to justify the investment. In this context, hybrid vehicles are of particular interest, as they have great potential to reduce fossil fuel consumption and environmental emissions in the long term. In terms of cost, the retrofitting of buses is shown to be a cost-effective way of extending the life of buses currently in service while, at the same time, lowering emissions (Milan). A major driver in this regard appears to be a strong political will to support and implement these measures together with a set of financial and organisational factors which inherently affect the real potential of the measure. Barriers are concentrated on technological gaps, absence of legislation, lack of political support and insufficient planning. From the technical side, much depends on staff knowledge and experience (or lack thereof).

Retrofitting old cars

The retrofitting of diesel passenger cars/LDVs, EURO 5, is a technical measure that is related to the policy targeting the retrofitting of older cars. Here it must be noted, that for those applications which have proven more effective in terms of results, up-scaling is crucial. Apart from testing a small number of innovative vehicles, the challenge lies in a vehicle rollout for the entire fleet that requires change. Building on these concerns, this appears to be the best way to achieve tangible results in terms of emissions and fuel consumption savings.

Turning to fuels and technologies that are more environmentally sustainable is possible in most situations to. However, operating conditions, costs involved in implementation, operational and performance characteristics, fuel availability and the extent to which a fuel meets environmental objectives present certain limits. Other factors that play a role include legacy systems, training, and public or political acceptance. Cities that have achieved impressive results have already taken the initiative to assess up-scaling potential. On the other hand, it is not easy to transfer measures promoting alternative fuels to other cities because a number of conditions need to be met. The relative attractiveness of fuel alternatives depends on tax rates, legislation and regulation, supply reliability, and general technical and operational competences.

7.2.3 Efficient urban logistics

Although more efficient freight distribution methods resulted in reduced fuel consumption and reductions in emissions of pollutants in Madrid, due to a small scale of the measure the impacts were less pronounced. Costs, especially for ultra-low emission vehicles, could also be too high to attract private investment, making these measures viable only for public ownership. Operational costs could be optimised by subcontracting operations to established logistics providers that already have suitably located depots and/or fleets of clean vehicles.

New distribution schemes have good up-scaling potential, and in general there are always possibilities for other cities to develop new distribution schemes. The most relevant barrier for the organisation of freight distribution schemes was insufficient partnership arrangements, which made it difficult to develop strategies to improve goods distribution throughout the city before and during implementation of the measure. An important driver for vehicle and driver-support measures, in all implementation phases, is good planning. Technology is also a relevant driver for these measures because it is important to have access to real-time data available and solid IT support.

7.2.4 Demand and traffic management strategies

Low emission zone

The low emission zone/city toll is a non-technical measure and relates to demand management strategies. It describes an area where highly polluting vehicles are restricted from entering based on their European emission standard. The ban addresses different vehicle types like heavy duty vehicles, commercial vehicles or diesel cars. As a rule, access restrictions have positive effects also on driver behaviour (for the better) and increases pedestrian modal shares, thus pollutant emissions have decreased significantly, allowing for a proportional increase of health benefits (most evident in Milan case). Another strong argument for the implementation of low emission zones are also the results from CBA analysis, where it has been shown that relatively small net present costs can result in an extensive amount of benefits.

The main drawback of such measures is (observed in most cases in Europe), that access management is often unpopular with the public, both in financial and spatial terms. As a result, political support and excellent communication with the public are powerful drivers. Accurate measurement, up-to-date technology and good quality data are important drivers at the operational stage.

Regarding the transferability, if a measure proposes the introduction of a payment system to enforce access limitations, there will be strong political and public opposition. Moreover, the feasibility of such a measure depends to a large extent on local and national legal norms, such as privacy legislation regarding the use of cameras and data. European legislation must also be taken into account at this stage.

Parking management

Parking measures have achieved positive results by significantly redistributing parking supply and demand. This has resulted in fewer drivers seeking parking opportunities in congested areas, which immediately resulted in lesser number of cars entering the city, consequently lesser emissions and smaller amount of population being exposed to air pollution as a result of congestion; a moderate health benefit is evident from the HIA results. Time based tariffs, meanwhile, have proven effective by reducing demand for parking in congested areas and by discouraging illegal parking. Whenever a measure proposes to introduce a payment system to change parking behaviour, considerable opposition from politicians and the general public is to be expected. An important factor for success in these cases is to obtain public support and to engage in clear dialogue with the public.

7.2.5 Enhanced environmental conscious behaviour in traffic

The objective of changing traffic behaviour through eco-driving is to reduce average speed levels and minimise acceleration and deceleration, thereby reducing fuel consumption (air pollution emissions), noise and costs. On the air pollution side, eco-driving training is an effective measure in reducing fuel consumption in the short term, although longer-term analyses indicate that the impact is reduced over time. In certain circumstances, the means of eco-driving can be more effective in decreasing the air pollution burden than, for example, trying to induce a modal shift, because this requires only a minor behavioural change. Fuel saving and speed reduction are the two targets achieved by these measures, with accident numbers and noise levels decreasing as a consequence. In both cases, cost-benefit analysis results show that the measure is very effective, especially when combined with an increased share of walking and cycling as it was the case in the greater Athens Area (Attica).

7.3 Industry

Table 7-3: Overview of effects of policies/measures – Industry

INDUSTRY						Impacts				
Policy thematic category	Measures/ policy scenarios					Emissions	Air pollution	Health	CBA	GHG
Use of fuel alternatives	Use of refuse derived fuel	Thessaloniki (region)	4	M4	Energy efficiency in the cement industry: Use of refuse derived fuels	++		O	++	+

The measure has presented a significant impact in emission reduction aspect. This has been supported by the findings of CBA as well, however the health benefits have been pronounced to a smaller extent. This is due to the locally limited effect on less populated areas, however the greenhouse gas reduction potential leads to a positive CBA outcome.

7.4 Waste management

Table 7-4: Overview of effects of policies/measures – Waste management

WASTE MANAGEMENT						Impacts				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
Eco-friendly waste management with citizens participation	Eco-friendly waste management with citizens participation	Athens (Attica)	5	Waste	Reduction of Biodegradable and Recyclable waste going to landfill through the implementation of Green Points and Recycling & Training Centres for waste separation and pre-sorting	O			+	
		Thessaloniki (region)	3	M3	Promotion of eco-friendly waste management				(O) / unknown costs	

The measure has resulted in a moderate localised impact in emission reduction aspect. Although the CBA results have shown a positive economic situation, this is only to a smaller extent. It should also be noted, that from the life cycle perspective, this measure entails further benefits not directly included into the assessment scheme.

7.5 Land use

Table 7-5: Overview of effects of policies/measures – Land-use

LAND-USE						Impacts				
Policy thematic category	**Measures/ policy scenarios**					**Emissions**	**Air pollution**	**Health**	**CBA**	**GHG**
Climate change adaption	Bioclimatic renovation of public areas	Milan	5	Trees	Increasing the green area and planting over 3 million new trees by 2030				+	
	Re-naturalization measures	Madrid	5	EnEff	Regeneration of neighbourhoods / re-naturalization of the city				++	

The measures have not shown an impact in any of the impact categories, except in CBA results, which can be attributed primarily to the benefits related to indirect positive health effects of the Madrid case, due to the integration of rehabilitation of the building stock, the refurbishment of public spaces, local energy production, green and short distance mobility, the management of water and materials, and the re-naturalization of the city.

7.6 Discussion

In terms of decision-making – only a small number of measures, mainly from sustainable transport sector (car independent lifestyle, mobility measures) covering all population groups or the large-scale implementation of alternatives (transport, energy sector) have the potential to contribute to a significant AP improvement. However, these measures still require an additional check in terms of feasibility within the planners, operators etc. in order to verify their full potential.

Discussion on uncertainties and decision-making about the policies

Assessment of the impacts (health, economic, financial, spatial development, etc.) in timescales of several decades in the future is subject to significant uncertainties. Therefore, the results of these assessments are necessarily associated with explicitly estimated uncertainties that need to be recognised when interpreting results within the overall evaluation and city administration decision-making. The approach eventually requires the identification, characterisation and propagation through the assessment of those uncertainties with the potential to significantly affect the quantitative results obtained.

In the context of the work performed within the WP5 uncertainties arise from the range of scenarios that were adopted as a basis for the assessment. The choices of conceptual and mathematical models of future city situations represented in these scenarios are of key relevance, together with both variability-associated (aleatory) and lack-of-knowledge-related (epistemic) uncertainty in the parameter values that have been used in the mathematical models for, e.g., emission and concentration/pollution projections, specific exposures assumptions and related population data management for the cities/countries, as well as cost categories assumptions for the period of policies implementation.

The following types of uncertainty have been considered in the context of the impact assessments described in D5.4:

- Uncertainty about the broad future evolution of the city situations (different scenarios of possible future conditions). Examples of uncertainties that were typically addressed through different scenarios include alternative developments in transport, energy savings, waste management, urbanisation, etc. These are mostly epistemic types of uncertainty.
- Uncertainty about the way in which contaminant migration, accumulation and potential exposures are most appropriately modelled taking into account different climate sequences. These are related to different amounts and temporal patterns of future e.g. greenhouse gas emissions, alternative landscape evolutions and possible alternative future human activities and actions. Here, both epistemic and aleatory types of uncertainty are included.

- Uncertainty about the values of model parameters (e.g. specific risk ratios applied in calculating mortality rates for infants due to exposures to PM10). This includes aleatory uncertainty.

Transparent identification of all of the uncertainties and the documented approach to addressing them, are important steps in building enough confidence in the results to support decisions. Fundamental to that is sufficient understanding of the nature of the decisions to be made and the associated level of confidence that is needed. In this context it has been recognised that city administrations expect condensed information about the impacts of alternative scenarios/policies to decide about their adoption, budgeting, and implementation. For example, the differences in the air concentration of specific pollutants compared to a baseline scenario presented with the variation/precision of two decimal points, or mortality rate difference of only one case in the whole period of 20 years for all the scenarios in Athens, is not effective for ultimate decision-making. Cities rather need summarised evaluation of the credibility of the overall modelling results, particularly exposing recognisable benefits and costs of each of the scenarios/policies. In this view the benefits relate to the air quality achievements, climate change avoidance and mitigation, energy savings, and potentials for public health improvements. So, these categories are highlighted in Tables 16-20 in Chapter 7. Cost categories, on the other hand, are mostly related to the assumptions regarding scenario/policy implementation and their monetary evaluation, for example capital and maintenance costs of public transport, and new cycle lanes, or capital and maintenance costs of new heating technologies. More detailed insight into each type of the uncertainty related to individual modelling steps is presented in Sections 3, 4, 5, and 6.

Uncertainties related to emission modelling

Apart from general uncertainties of urban emission inventories, the specific modelling of future policy measures encompasses several levels of uncertainty:

- Uncertainties due to scenario assumptions in terms of implementation and mitigation
    - Assumptions regarding technology uptake, induced behavioural change (uncertainties due to the implementation potential)
    - Assumptions regarding the change in activity rate or emission factor (uncertainties due to the mitigation potential)
- Uncertainties due to simulation and modelling
    - Level of detail of scenario modelling (level of activity and sector disaggregation)
    - Simulation and computation methods used
    - Change in temporal or spatial emission patterns

Especially non-technical measures and policies eliciting a behavioural change are subject to great uncertainty in the scenario assumptions. Technical measures based on standards have a fairly predictable easily calculated effect on future emissions; but non-technical measures are more uncertain *per se* (Sternhufvud, Astroem 2006). However, non-technical emission reduction measures gain more and more importance and therefore have primarily been chosen for further evaluation. To address this issue, different scenarios have been created taking into account different rates of technology update (e.g. electrification of the vehicle fleet) or willingness for behavioural change (e.g. eco-driving acceptance). Afterwards, the scenarios have been analysed in terms of plausibility and main interest by the scientific city partners before deciding for one scenario that undergoes the full impact assessment as described in this report. It therefore may also be the case that more ambitious scenarios have been chosen over realistic scenarios whenever the maximum effect of a policy introduction is of main interest (e.g. Basel scenario NoHeatFirewood). Furthermore, information regarding methods considered to assess the measures mitigation potential is necessary for transparency. Assumptions for activity level or emission factor changes of specific measures are based on experiences of the respective city and/or dedicated literature reviews. For the sake of transparency, respective assumptions in terms of emission factor and activity changes – either between activity categories or activity levels – have been described in detail in the emission modelling section of this report. Generally, variations in emission factors and activity levels have been well documented and supported by activity level projections, emission databases and plan targets.

Furthermore, the representativeness of the emission projections depends on the accuracy of the simulation/modelling of the emission reduction that a particular policy would have if implemented. Therefore, the modelling of the policy scenario follows the following guidelines as mentioned in Lumbreras et al. (2011):

- The level of detail is consistent with the corresponding detail in the base year emission inventory and in accordance with the measures to be implemented. This means that, as far as possible, measures are modelled as activity changes in the lowest disaggregation level. For example, the introduction of a low emission zone has been modelled by disaggregating the policy effect into vehicle type, technology etc.
- Future-year emission estimates for the baseline scenario and policy scenario are based on the same computation methods. This has been reached by using the activity-emission factor databases previously generated within WP2.
- It has been checked whether there are any changes expected on either temporal or spatial emission patterns for each policy.

Uncertainties related to AQ modelling and validation of the results

Based on the state of the art of such models and the present exercise (deliverable D3.3) the expected uncertainty to be within the factor of two is greater than 30% (COST Action ES1006).

WRF and WRF/Chem models are well established and widely used in regional/urban scale wind and air quality studies. In the evaluation exercise Meteorology and Air Quality results were compared to measurement observations (ANNEX 5). For the test case in Stuttgart, the meteorological parameters of temperature, humidity, wind speed and wind direction the modeling results are more or less as expected with relatively small discrepancies compared against observations. For NO_2 and O_3 concentrations model trends follow to a large extend the observation ones. PM_{10} concentrations were compared in the area of Kozani, where an extensive network of meteorological station is available. A three-month simulation has been performed from 1.1.2017 to 31.3.2017. Consistency was observed in concentration trends within some degree of under prediction probably due the model spatial filtering.

In general terms, modeling results are quite satisfactory compared with observation data. The obtained comparison results proved to be rather satisfactory and well within the state of the art. The observed uncertainties in terms of model vs observation discrepancies are well within the accepted margins.

Uncertainties related to health Impact assessment

There are many uncertainties involved in estimating the health effects associated with outdoor air pollution. Over time, some of these has been reduced as new research has been conducted. However, some uncertainty will be inherent in any estimate. For many of these issues, the bias could be either positive or negative. They are mainly related to

- Concentration-response Functions (CRFs)
- Background rate of mortality or morbidity
- Population data
- Air quality data

With regard to CRF, upper and lower estimates could be obtained by applying the upper and lower coefficients of the confidence intervals for estimating the relative risks. In this context HRAPIE distinguishes effects according to the perceived reliability of the underlying data. Effects that can be quantified with the highest confidence are given an ‘A’ rating, those with lesser confidence a ‘B’ rating. HRAPIE also denotes which effects can be added to provide an overall estimate of quantified effects by appending a ‘*’ to the A and B ratings.

In the present report, to capture the uncertainty in the C-R functions median estimates, results are reported together with their confidence interval (5% and 95%) in both the tables and the charts to reflect the heterogeneity of the population involved as well as of the epidemiological studies.

There is also uncertainty concerning the baseline rates of the health outcomes in the studied population. In the present report we used well consolidated and accepted background rate of mortality and morbidity as per recommendation of WHO- HRAPIE study. When suggested, like for *prevalence of bronchitic symptoms in asthmatic children,* country level of background morbidity rate has been used. It has been anyhow underlined that the background data on all-cause mortality have greater precision than the cause-specific data. The latter may be affected by misclassification of causes of death in mortality registration across the range of countries included in the analysis (Mathers et al., 2005). As a result, with cause-specific impact estimates, the uncertainty related to background health data will add to the CRF uncertainty, complicating interpretation of the impact assessment.

Population data at high spatial resolution used in the present study combined population data per commune with CORINE Land Cover available for all countries of the European Union. The land cover map used is the 100 meters resolution raster version of CORINE Land Cover (CLC). CLC has been produced, with common rules in all EU countries, by photo-interpretation of Landsat ETM (Enhanced Thematic Mapper) satellite images.

The model assumes that the population density in each grid cell can be expressed as:

$$Y_{cm} = U_{ch} W_m$$

Where Y_{cm} is the density of population for land cover type *c* in commune *m* that belongs to stratum *h*. The coefficient U_{ch} depends on the land cover class. W_m is a factor that ensures that the total population attributed to pixels in each commune matches the known commune population.

$$W_m = \frac{X_m}{\sum_c S_{cm} U_{ch}}$$

Where X_m is the population in commune m and S_{cm} is the area of land cover c in commune m.

An accuracy assessment has been carried out for five countries for which a very reliable 1-km population density grid exists; the improvement, compared with the choropleth map (i.e. homogeneous density in each commune) per commune, ranges between 20% for the weakest result in Finland and 62% for the best result in the Netherlands. The disagreement indicator was computed as:

$$\Delta_m = \sum_j \left| Y_{j,m} - Y_{j,ref} \right|$$

The values obtained for the disagreement are reported in the table below.

Disagreement of dasymetric maps with reference data in 5 countries (in millions)

Dasymetric map	Austria	Denmark	Finland	Sweden	Netherlands
Country population	8.03	5.35	5.18	8.88	15.99
Communes (choropleth)	8.96	6.08	6.79	12.48	18.72

CLC-LUCAS	4.35	3.95	5.03	8.07	7.08

This table indicates that downscaling commune-level population density significantly reduces the disagreement with reference data; yet, it does not eliminate this disagreement because the heterogeneity of population density for areas in the same commune and same land cover type in CLC is not always captured. The table below reports some average densities for the Netherlands (densely populated) and Finland (scarcely populated).

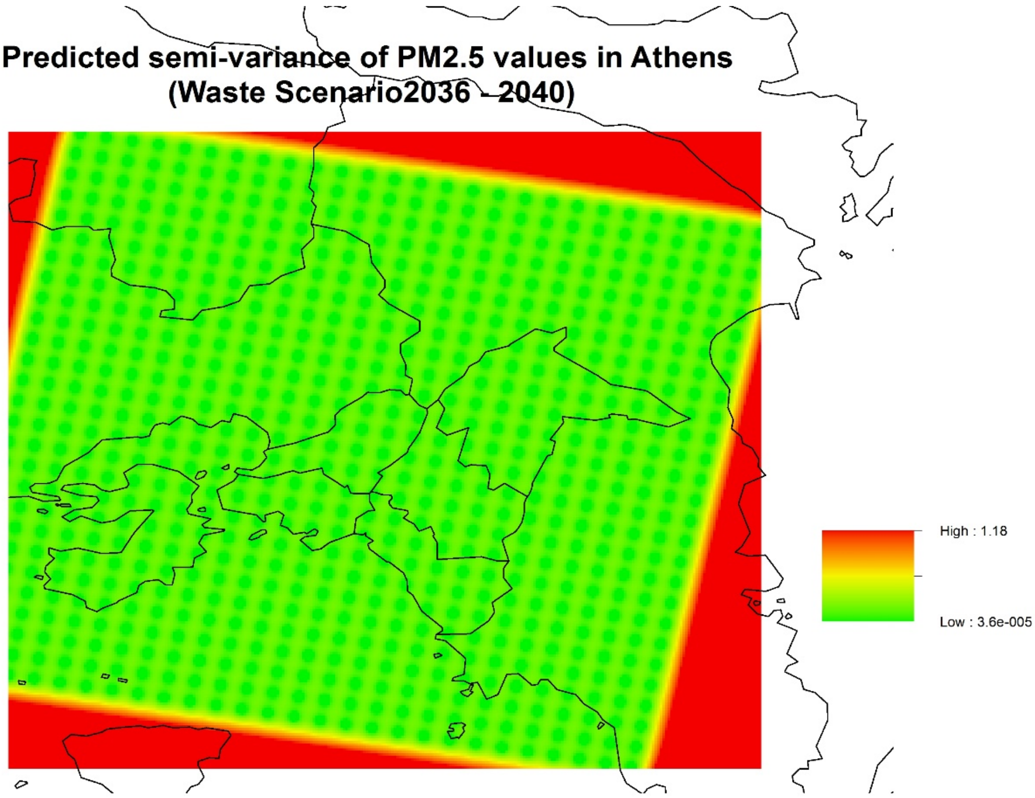
Average population density in different types of 1 km^2 cells of the Netherlands and Finland according to the dominant land cover type

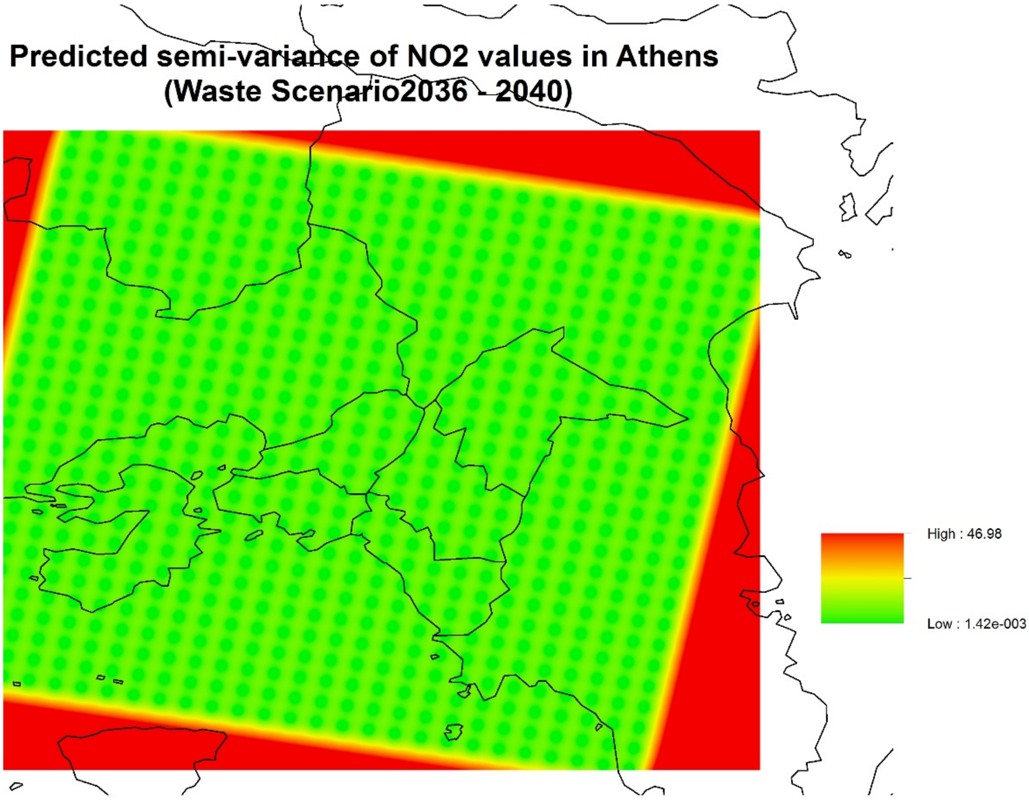
CLC type	Reference data	Choropleth (non-disaggregated)	CLC- LUCAS
Netherlands			
Urban	5331	1640	4725
Infrastructure	340	1194	600
Agricultural	75	282	101
Heterogeneous	104	332	166
Forest and natural vegetation	27	365	38
Finland			
Urban	3358	1252	3108
Infrastructure	135	980	184
Agricultural	9	17	14
Heterogeneous	18	11	14
Forest and natural vegetation	0.2	3	0.4

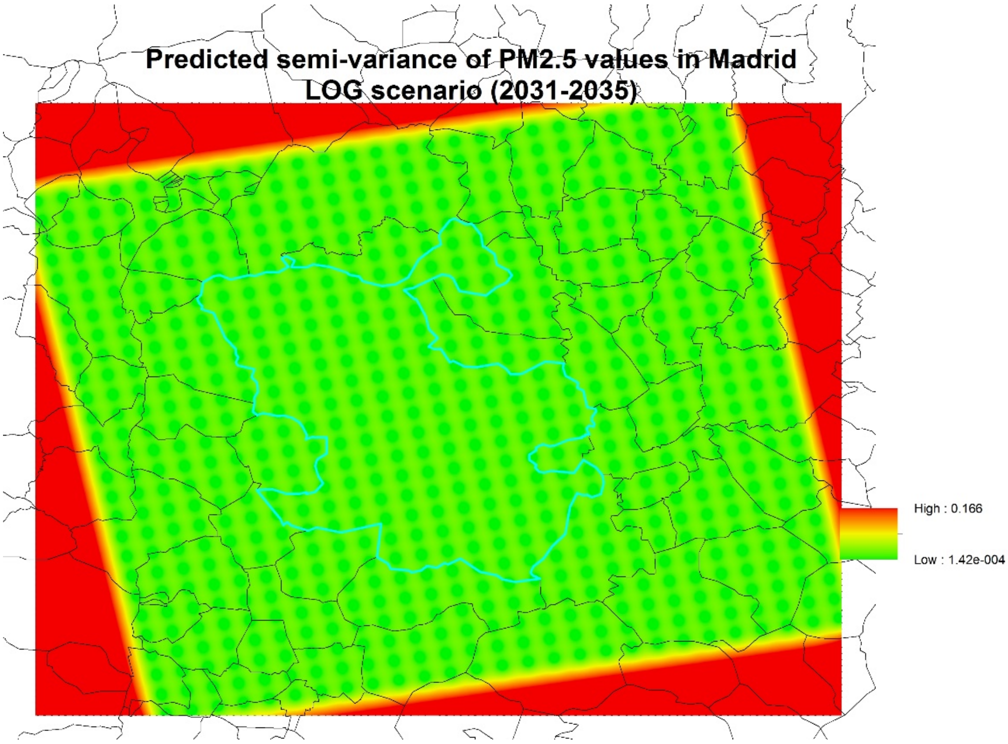
The downscaling method generally underestimates the population attributed to “urban discontinuous”. Better results in urban classes are decisive in the Netherlands, because the urban class has a strong weight. The opposite happens for agricultural and forest classes, where the downscaling method tends to overestimate the density in these classes. The method in general tends to overestimate the population in agricultural, heterogeneous and forest areas.

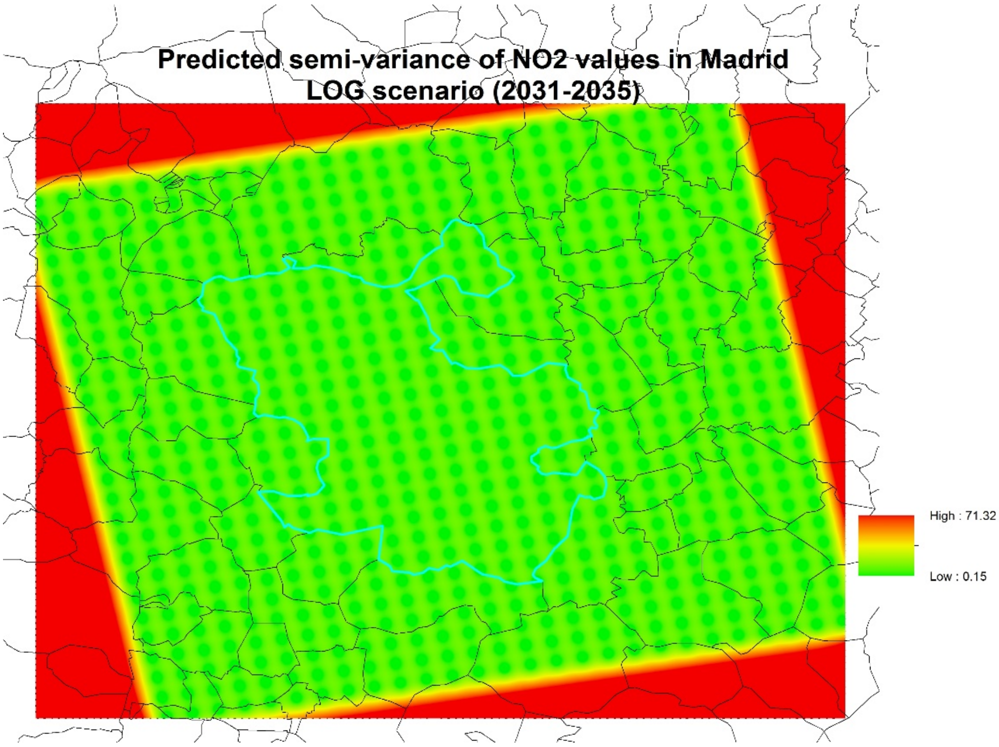
Air quality concentration maps represent a further source of uncertainty in the HIA process. As the present study deals with future projections of AQ levels in the ICARUS cities it was clearly not possible to carry out quantitative comparison between measured and predicted values. In this case, after deriving AQ concentration levels over the study areas through ordinary kriging interpolation we estimated the intrinsic statistical variance associated with the interpolation technique used through the calculation of maps where each cell contains the predicted semi-variance values for that location. Low values within the output variance of prediction raster indicate a high degree of confidence in the predicted value. High values may indicate a need for more data points. In general the semi-variance derived in each ICARUS city and scenario is very low in the area corresponding to the computational grid (lower than 2% of the predicted values) and increases moving close to the borders of the domain (ranging from around 10% in the yellow areas up to around 100% in the red areas in the maps below).

By way of example some maps of the predicted semi-variance for PM2.5 and NO2 concentration are reported hereinafter. It should be noted that patterns of the predicted semi-variance are very similar for the various ICARUS cities.




Predicted semi-variance of NO2 values in Athens
(Waste Scenario2036 - 2040)
High : 46.98
Low : 1.42e-003


Predicted semi-variance of PM2.5 values in Madrid
LOG scenario (2031-2035)
High : 0.166
Low : 1.42e-004



Uncertainties related to monetary evaluation

Uncertainty enters in the CBA of the measures in ICARUS in a number of ways. First, there is uncertainty with regard to the elements of cost and benefit that are selected and included in the analysis. In particular, it has not been possible to take into consideration all possible impacts of the selected policies.

In the case of Milan Area B measure, for example, it has not been possible to investigate – and hence include – the effect of the introduction of a new low emission zone on the travelling habits of the citizens (e.g. journey modes, times and distances travelled). It has therefore not been possible to include impacts such as time losses or increase in active travel – and therefore health effects due to increased physical activity. Moreover, as suggested by Gössling and Choi (2015), walkable city centres are highly valued by tourists and have positive branding effects. Similarly, for Thessaloniki M2a measure - that aims at the promotion of cycling and walking – it has not been possible to estimate the increase in citizens' walking and cycling. This will lead to an underestimation of the whole health benefits of this measure.

In the case of measures relating to the replacement of heating technology (put forward in the cities of Stuttgart, Basel and Brno, among others), it has not been possible to include and value factors such as increased thermal comfort. Milan's Tree measure may have impacts that have not been included in this analysis, such as positive branding effects for the city of Milan, possible trees' cooling effects, as well as positive effect on the value of properties located in proximity to the new green areas.

Second, the cost data provided by the cities and project partners are subject to uncertainty. In most cases, in fact, actual cost data are not available, and these are assessed based on assumptions drawn from a number of secondary sources. Moreover, in the cases in which there is uncertainty about the instruments that the city will put into place to reach its objectives, costs have been marked as "unknown". This is for example the case of Basel's ZeroEmissionShips measure, for which, to make assumptions on the cost of zero emission vessels, it would be necessary to have information on the type of fuel and technology utilized. Moreover, this is still a developing technology for which future costs are difficult to forecast (UMAS and Lloyd's Register 2019).

For the Madrid and Milan case studies, a number of measures have been put forward, but either their level of complexity is such that it is not possible to make plausible assumptions on the total costs of the measures, or they are only at an initial phase of development. It is therefore premature to draw conclusions on the total costs of these measures.

Third, uncertainty also affects the monetary quantification of impacts. As non-tangible benefits cannot be valued using market values, we have need to rely on studies using stated or revealed preference methods to assign monetary values to non-marketed goods. Nevertheless, as pointed out by Gössling et al. (2019) the valuation of cost and benefit factors also depend on the context and are based on a literature that is constantly developing. We are able to quantify some of these uncertainties – and in the results we have tried in each case to highlight the key factors driving the results. In some cases, for example, the mortality impact of NO_2 is critical to the results - and so the estimation of the health endpoints and valuation of mortality are most important in these cases.

8 CONCLUSIONS

Air pollution

Measures such as large scale/city-wide sustainable mobility interventions covering synergetic effects of PT, walking, cycling focusing on all population groups combined with clean vehicles, combined with greater use of alternative fuels, have shown the greatest potential for significant reductions in pollutant emissions and consequently health effects. In addition, further steps to make some of these clean technologies more profitable and accessible still need to be taken. What also speaks in favour of these measures is the fact that they can be easily up-scaled to address the needs of a larger share of users in the city, helping to achieve even better AP reduction results without major changes of the system in future. Other important gains in this domain have been attained through the implementation of demand management strategies, such as access restrictions. Additional air pollution reduction advances could be reached through policy measures that encourage cycling, either by improving cycling infrastructure or increasing the availability of bike-sharing systems and especially through their further integration with public transport.

Efficient logistics and freight distribution are policy measures that have shown significant environmental improvement potential – although their impact on air pollution is relatively small, they contribute to the quality of life and wellbeing in cities. In most cases, up-scaling might help to maximise their potential benefits.

Assessment of impacts has proved to be problematic in some cases, because the distribution of small-scale measure effects has been diluted in the city-wide air pollution model. In such cases full-scale deployment of the measure should be taken into consideration in order to show the potential long-term effects.

In the energy sector, significant air pollution and health-related improvements are only evident from a large-scale implementation, such as the enhancement of district heating, which could be further increased by addressing the fuel technologies behind them. Although individual policies often produced limited positive air pollution reduction and related health impacts, the combined effects of policies are inevitably greater than presented in this report (i.e. synergies between measures/policies). Due to the complexity of the matter this was not taken into consideration in this stage, however an integrated view in this regard will be a part of the work performed in transition between WP5-WP6 in the future.

Economy

The results concerning the economic dimension are promising as the majority of the measures have shown a positive cost-benefit ratio. However, drawing the overall conclusions on the cost-benefit analysis carried out in ICARUS is not straightforward, given that it has not always been possible to reach a complete understanding of all the costs and benefits related to the selected measures. In particular, some impacts included in some of the measures have not been included in other measures, due to the lack of data. Based on this, additional steps can be taken in the future planning/implementation of measures to plan for the monitoring/assessment of costs as well as to identifying the right indicators for the considered policy/measure. While this poses a challenge, such efforts would produce reliable and comprehensive evidence on costs and benefits, which in turn can be useful for facilitating up-scaling and transferability as well as for winning acceptance among stakeholders.

In terms of economic sustainability, the most critical situations usually emerge when measures involved larger infrastructural development. This is the case with measures that included the introduction of clean technologies and fuels (vehicles and energy sector), expansion the public transport infrastructure and network, construction and improvement of cycling and walking networks and facilities and this is where special attention should be put in the future.

Social factors

An important factor of successful measure implementation is also the social dimension, i.e. the factor of public acceptance. Namely, the behavioural changes take time to happen — and only work if they are adequately backed by awareness and acceptance. Citizens living in ICARUS cities have so far demonstrated a positive attitude towards proposed policy interventions. There were, however, a few measures dealing with pricing and restrictions or changing of behaviour (transport modes, changing heating technologies, insulation in buildings), which are usually quite sensitive in terms of public acceptance, but have nonetheless generated positive reactions (Stuttgart, Milan, Brno, Madrid) if not at the planning stages then certainly after the positive effects have become evident. This confirms that even measures that are traditionally considered controversial can be implemented successfully, if they are built on stakeholder engagement from the initial phase of the planning process. Based on this, some policy measures still require additional assessment in terms of their public/stakeholder awareness/acceptance before their full-scale implementation and this will be a part of the future work within the task T5.4 – feasibility evaluation of strategies/options on the city level.

9 REFERENCES

Abbey DE et al. (1995a). Estimated long-term ambient concentrations of PM10 and development of respiratory symptoms in a non-smoking population. *International Archives for Occupational and Environmental Health*, 50(2):139–152.

Abbey DE et al. (1995b). Chronic respiratory symptoms associated with estimated long-term ambient concentrations of fine particulates less than 2.5 microns in aerodynamic diameter (PM2.5) and other air pollutants. *Journal of Exposure Analysis and Environmental Epidemiology*, 5(2):137–159.

ADAC (2018a): NOx-Reduzierung an Euro 5 Dieselfahrzeugen durch Hardwarenachrüstung. Vermessung der Abgasemissionen im Zulassungszyklus WLTC und Realbetrieb (RDE) vor und nach Hardwareumrüstung. ADAC Württemberg e.V.

ADAC (2018b): ADAC Autokosten Herbst/Winter 2018/2019. Stand 10-2018.

Alessandrini, A. et al. (2012): Driving style influence on car CO2 emissions

Ayuntamiento de Madrid (2017): Plan de Calidad de aire y Cambio Climático, accessed on 12/6/2018.

Bernardo, L.R., H. Davidsson and E. Andersson (2016). Retrofitted Solar Domestic Hot Water Systems for Swedish Single-Family Houses—Evaluation of a Prototype and Life-Cycle Cost Analysis. Energies 9: 953.

Bundesministerium für Verkehr und digitale Infrastruktur (2018a): Wissenschaftliche Untersuchungen hardwareseitiger NOx Reduzierungsnachrüstmöglichkeiten im PKW Bereich und im Segment der leichten Nutzfahrzeuge.

Bundesministerium für Verkehr und digitale Infrastruktur (2018b): Studie über das Potenzial einer Realisierung einer Hardware-Nachrüstung für Dieselfahrzeuge EU5 (EU4) zur NOx Reduzierung.

COST ES1006 Model evaluation protocol (2015): Evaluation, improvement and guidance for the use of local-scale emergency prediction and response tools for airborne hazards in built environments (http://elizas.eu/images/Documents/Model%20Evaluation%20Protocol_web.pdf)

Dahlby, Ferede (2011): What Does it Cost Society to Raise a Dollar of Tax Revenue? The Marginal Cost of Public Funds.

Dandstrom T, Nowak D, and van Bree L. Health effects of coarse particles in ambient air: messages for research and decision-making. *Eur Respir J* 2005; 26:187–188.

Department of Health (2006) Health risk assessment in Western Australia. Perth, Government of

Western Australia (http://www.public.health.wa.gov.au/cproot/1499/2/Health_Risk_Assessment.pdf).

Doll, Claus; Hartwig, Johannes; Senger, Florian; Maibach, Markus; Sutter, Daniel; Bertschmann, Damaris Lambrecht, Udo (2013): Wirtschaftliche Aspekte nichttechnischer Maßnahmen zur Emissionsminderung im Verkehr. (Economic aspects of non-technical measures to reduce traffic emissions). PExMo-Tool UBA-FB 001728

Dowds, M. and S. You (2019). Economic Analysis of the routes for fulfilment of net-zero energy buildings (NZEBs) in the UK. Energy Procedia 158: 3541-3546.

EC (2008) "Guide to COST-BENEFIT ANALYSIS of investment projects" Directorate General Regional Policy. Available online at: https://ec.europa.eu/regional_policy/en/information/publications/evaluations-guidance-documents/2008/guide-to-cost-benefit-analysis-of-investment-projects

EC (2014) "Guide to Cost-Benefit Analysis of Investment Projects. Economic appraisal tool for Cohesion Policy 2014-2020" Directorate-General for Regional and Urban policy. Available online at: https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/cba_guide.pdf

EMEP/EEA (2016): EEA Report No 21/2016. EMEP/EEA air pollutant emission inventory guidebook 2016.

E-mobil BW GmbH (2013): Systemanalyse BWe mobil 2013. IKT- und Energieinfrastruktur für innovative Mobilitätslösungen in Baden-Württemberg.

Fonseca, N. et al. (2010): Influence of Driving Style on Fuel Consumption and Emissions in Diesel-Powered Passenger Car. International Symposium Transport and Air Pollution.

Frank,L; Bradley, M.; Kavage, S.; Chapman, J.; Lawton, T. K. (2007): Urban form, travel time, and cost relationships with tour complexity and mode choice. In Transportation 35 (1), pp. 37–54. DOI: 10.1007/s11116-007-9136-6.

Friedrich, R. (2014): TRANSPHORM Deliverable 5.2.1 Systematic analysis of policies and measures. Transport related Air Pollution and Health impacts -Integrated Methodologies for Assessing Particulate Matter. Deliverable D5.2.1, accessed on 3/23/2018.

Gaglia A.G.et al. (2017) “The impact of the energy performance regulations’ updated on the construction technology, economics and energy aspects of new residential buildings: The case of Greece”, Energy and Buildings 155, 225–237.

Gallego F.J., 2010, A population density grid of the European Union, Population and Environment. 31: 460-473.

Genon G., Brizio E. 2008. Perspectives and limits for cement kilns as a destination for RDF. Waste

Management 28 (2008), 2375–2385

Gössling, S. and A.S. Choi (2015). Transport transitions in Copenhagen: comparing the cost of cars and bicycles. Ecological Economics 113: 106–113.

Gössling, S., A.S. Choi, K. Dekker and D. Metzler (2019). The Social Cost of Automobility, Cycling and Walking in the European Union. Ecological Economics 158: 65-74.

Härdtlein, M., Reith, S., Kirch, F., Eltrop, L. (2018): Datengrundlagen und Konzeption für den Online-Wärmekostenrechner für Wohn- und Nichtwohngebäude, Teilprojekt im Rahmen des Vorhabens „Maßnahmenpaket Bioenergie-Wärme“ der AEE, Berlin.

HIP (2014) Frequently asked questions about integrating health impact assessment into environmental impact assessment [online]. Human Impact Partners (http://www.epa.gov/region9/nepa/PortsHIA/pdfs/FAQIntegratingHIA-EIA.pdf).

Hoek G et al. (2012). PM10, and children’s respiratory symptoms and lung function in the PATY study. *European Respiratory Journal*, 40(3):538–547

Hoek G et al. (2013). Long-term air pollution exposure and cardio-respiratory mortality: a review. *Environmental Health*, 12:43.

Huang, Yuhan et al. (2018): Eco-driving technology for sustainable road transport: A review. Renewable and Sustainable Energy Reviews.

Hunt, A., Navrud, S., Maca, V. and M. Scasny (2011) Monetary values for health end points used in the HEIMSTA/INTARESE common case study. Deliverable D4.1.2. of the HEIMSTA project.

Hurley, F., Hunt, A., Cowie, H., Holland, Miller, B., Pye, S.. and Watkiss, P. (2005) Development of Methodology for the CBA of the Clean Air For Europe (CAFE) Programme, Volume 2: Health Impact Assessment. http://www.cafe-cba.org/assets/volume_2_methodology_overview_02-05.pdf. Section 3.3.4.

Ifeu (2014): Konzept für den Masterplan 100 % Klimaschutz für die Stadt Heidelberg. Endbericht. Im Auftrag der Stadt Heidelberg. Heidelberg.

Iten et al. (2017) "Auswirkungen eines subsidiären Verbots fossiler Heizungen Grundlagenbericht für die Klimapolitik nach 2020".

Joelsson, A. and L. Gustavsson (2010). Energy efficiency measures and conversion of fossil fuel boiler systems in a detached house. Energy Efficiency 3: 223-236.

Kasten, P. et al (2016): Erarbeitung einer fachlichen Strategie zur Energieversorgung des Verkehrs bis zum Jahr 2050. UBA-FB 002396. Endbericht.

Klötzke, M, Kugler, U., Bühne, J., Kurte, J., Esser, K., (2015): Exploration of the impact of electric vehicle policies on vehicle registrations, emissions and cost-benefit-analysis

Korzhenevych, A., Dehnen, N., Bröckner, J. Holtkamp, M., Meier, H., Gibson, G.,Varma, A., Cox, V., (2014): Update of the Handbook on External Costs of Transport (The Country-specific values are provided in Excel tables as Annexes to the Handbook on External Costs of Transport)

Krewski D, Jarrett M, Burnett RT et al. Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. *Res Rep Health Eff Inst* 2009; 140:5-114; discussion 115–36.

Kugler, U. (2010): Straßenverkehrsemissionen in Europa – Emissionsberechnung und Bewertung von Minderungsmaßnahmen. D 93 (Dissertation der Universität Stuttgart). Stuttgart.

Kugler, U. (2012): Straßenverkehrsemissionen in Europa – Emissionsberechnung und Bewertung von Minderungsmaßnahmen. Universität Stuttgart.

Kurte, J., Esser, K.; Baum, H.; Heinl, F.; Balke, I.; Järvi, T.; Auvinen, H.; Kugler, U.; Klötzke, M.; Gis, W. (2015): Evaluation of scenarios for electromobility with an integrated quantitative assessment and multi criteria analysis. eMAP project. D7.1.

Lai CK et al. (2009). Global variation in the prevalence and severity of asthma symptoms: phase three of the International Study of Asthma and Allergies in Childhood (ISAAC). *Thorax*, 64(6):476–483.

Landeshauptstadt Stuttgart, AVISO GmbH, Rau Ingenieurbüro (2018): Masterplan zur Gestaltung nachhaltiger und emissionsfreier Mobilität – Green City Plan

Litman T. A. (2017): Understanding Transport Demands and Elasticities. How prices and Other Factors Affect Travel Behaviour, accessed on 5/20/2019.

Litman, T. (2013): Transport Elasticities: Impacts on Travel Behaviour. Understanding Transport Demand to Support Sustainable Travel Behaviour. Sustainable Urban Transport Technical Document #11. Edited by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), accessed on 6/5/2018.

Litman, T.A., Doherty, E., 2011. Transportation Cost and Benefit Analysis - Techniques, Estimates and Implications. VTPI Victoria Transport Policy Institute, Victoria. http://www.vtpi.org/tca/.

Litman, Todd Alexander (2017): Understanding Transport Demands and Elasticities. How prices and Other Factors Affect Travel Behaviour, accessed on 5/20/2019.

Lumbreras et al. 2011: Lumbreras, J.; Borge, R.; Tarrason, L.; Rodriguez, E.: Emission needs at local scale for air quality modelling. 14th National Conference on Harmonisation within Atmospheric Dispersion Modellung for Regulatory Purposes, Parallel Sesssion FAIRMODE. Ocotber 2011. Greece.

Madrid City Council (Ed.) (2018): Adaptive parking management based on energy efficiency and occupancy. Project CIVITAS ECCENTRIC, accessed on 5/23/2019.

Maibach, M.; Schreyer, D.; Sutter, D.; van Essen, H.P.; Boon, B.H.; Smokers, A.; Schroten, A.; Doll, C.; Pawlowska, B. (2008): Handbook on estimation of external costs in the transport sector. Internalisation Measures and Policies for All external Cost of Transport. IMPACT D1 Version 1.1.

Marszal, A.J. and P. Heiselberg (2011). Life cycle cost analysis of a multi-storey residential Net Zero Energy Building in Denmark. Energy 36: 5600-5609.

Matthey, A; Bünger, B. (2019): Methodenkonvention 3.0 zur Ermittlung von Umweltkosten Kostensätze Stand 02/2019

McConnell R et al. (2003). Prospective study of air pollution and bronchitic symptoms in children with asthma. *American Journal of Respiratory and Critical Care Medicine*, 168(7):790–797

McPherson, E.G., Simpson, J.R., Peper, P.J., Maco, S.E., Xiao, Q. and P.J. Hoefer (2003). "Northern Mountain and Prairie Community Tree Guide: Benefits, Costs and Strategic Planting". Davis, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Center for Urban Forest Research.

Migliore E et al. (2009). Respiratory symptoms in children living near busy roads and their relationship to vehicular traffic: results of an Italian multicenter study (SIDRIA 2). *Environmental Health*, 8:27.

Miller, B., Hurley, F., Shafrir, A. Health Impact Assessment for the National Emissions Ceiling Directive (NECD) – Methodological Issues (2011)

Noel, L. and R. McCormack (2014). A cost benefit analysis of a V2G-capable electric school bus compared to a traditional diesel school bus. Applied Energy 126: 246–255.

Nordhaus (2017) "Revisiting the social cost of carbon" PNAS – Proceedings of the National Academy of Science of the United States of America, 14(7): 1518–1523

NPE (2015): Ladeinfrastruktur für Eölektrofahrzeuge in Deutschland. Nationale Plattform Elektromobilität (NPE)

Rannala, M.; Metsvahi, T.; Orntlich, A. (2013): Measure Evaluation Results. TAL 6.1 Eco Driving

Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, accessed on 3/22/2019.

Sanierungsfahrplan-BW (2015): https://um.baden-wuerttemberg.de/de/energie/informieren-beraten-foerdern/sanierungsfahrplan-bw/mustersanierungsfahrplan-und-drucktool/ (accessed on 07/31/2019).

Schikowski T et al. (2013). Ambient air pollution – a cause for COPD? *European Respiratory Journal* (doi:10.1183/09031936.00100112).

Schindler C et al. (2009). Improvements in PM10 exposure and reduced rates of respiratory symptoms in a cohort of Swiss adults (SAPALDIA). *American Journal of Respiratory and Critical Care Medicine*, 179(7):579–587

Sternhufvud, Astroem 2006: Sternhufvud, C.; Astrom, S.: Workshop on the importance of Non-Technical Measures for reductions in emissions of air pollutants and how to consider them in Integrated Assessment Modelling. 7-8 December 2005. IVL Swedish Environmental Research Institute. Report 1664. Stockholm.

Thessaloniki Public Transport Authority (2014): Sustainable Urban Mobility Plan for the Metropolitan Area of Thessaloniki

UMAS and Lloyd's Register (2019), " Zero-Emission Vessels: Transition Pathways" Low Carbon Pathways 2050 series. Available at: https://www.europeanpolicysolutions.com/zero-emission-vessels-transition-pathways/

Umweltbundesamt (2013): Wirtschaftliche Aspekte nichttechnischer Maßnahmen zur Emissionsminderung im Verkehr (accessed on 2/1/2019).

Vogt M, Hager K, Tözün R, Schmid M. Rid W. (2017): Umsetzungsstudie Elektro Taxi Aktionsplan Stuttgart, 2017

VVS (2018): http://www.vvs.de/no_cache/rundum-mobil/preisvergleichsrechner/ (accessed on 07/31/2019)

Wang, Y; Boggio-Marzet, A. (2018): Evaluation of Eco-Driving Training for Fuel Efficiency and Emissions Reduction According to Road Type. Sustainability

WHO (2010) WHO human health risk assessment toolkit: chemical hazards. IPCS harmonization project document; no.8. Geneva; World Health Organization (http://www.who.int/ipcs/publications/methods/harmonization/toolkit.pdf?ua=1).

WHO (2011): Health economic assessment tools (HEAT) for walking and for cycling. Methodology and user guide. URL: http://www.euro.who.int/en/what-we-do/health-topics/environment-and-health/Transport-and-health/publications/2011/health-economic-assessment-tools-heat-for-walking-and-for-cycling.-methodology-and-user-guide (accessed on 07/22/2019).

WHO (2013a). Review of evidence on health aspects of air pollution – REVIHAAP project: technical report. Copenhagen, WHO Regional Office for Europe (http://www.euro.who.int/__data/assets/pdf_file/0004/193108/REVIHAAP-Finaltechnicalreport.pdf).

WHO Health risks of air pollution in Europe – HRAPIE project. Recommendations for concentration–response functions for cost–benefit analysis of particulate matter, ozone and nitrogen dioxide. WHO Regional Office for Europe, Copenhagen, Denmark, 2013

WHO Regional Office for Europe (2005). Health effects of transport-related air pollution. Copenhagen

WHO Regional Office for Europe (2006) *Air quality guidelines for particular matter, ozone, nitrogen dioxide and sulphur dioxide. Global update 2005*. Copenhagen (http://www.euro.who.int/data/assets/pdf_file/0005/78638/E90038.pdf).

WHO Regional Office for Europe (2014) WHO Expert Meeting. Methods and tools for assessing the health risks of air pollution at local, national and international level. Copenhagen (http://www.euro.who.int/__data/assets/pdf_file/0010/263629/WHO-Expert-Meeting-Methods-and-tools-for-assessing-the-health-risks-of-air-pollution-at-local,-national-and-international-level.pdf?ua=1)

WHO Regional Office for Europe (2016). Health risk assessment of air pollution – general principles. Copenhagen

WHO. Air quality guidelines for particulate matter, ozone, nitrogen and sulphur dioxide. Global update, 2005

WHO-Europe (2014) Health economic assessment tools (HEAT) for walking and for cycling. Methodology and user guide. Economic assessment of transport infrastructure and policies. 2014 Update. Available online at: http://www.euro.who.int/__data/assets/pdf_file/0010/256168/ECONOMIC-ASSESSMENT-OF-TRANSPORT-INFRASTRUCTURE-AND-POLICIES.pdf

Woodruff TJ, Grillo J, Schoendorf KC (1997). The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States. *Environmental Health Perspectives*, 105(6):608–12.

Worrell E. , Price L., Martin N., Hendriks C. and Meida L. O. 2001. Carbon Dioxide Emissions from the Global Cement Industry, Annu. Rev. Energy

Zachariadis, T., A. Michopoulos, Y. Vougiouklakis, K. Piripitsi, C. Ellinopoulos and B. Struss (2018). Determination of Cost-Effective Energy Efficiency Measures in Buildings with the Aid of Multiple Indices. Energies 11: 191.

ANNEX 1: DETAILED ASSUMPTIONS AND EMISSION REDUCTION POTENTIALS FOR THE SELECTED POLICY SCENARIOS

Athens: Policy scenario 1 - SusMob

Promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica)

Description of the scenario

This scenario considers the promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica).

The scenario relates to the policy for supporting the transition to a low-carbon economy in all sectors of the Regional Operational Program (ROP) Attica 2014-2020 and several municipalities of Attica Region have already included this measure in their Sustainable Energy Action Plans (SEAP). The measure focuses on training, informing and sensitizing the citizens in:

- Promoting cycling and walking: promoting a population shift from using cars towards walking and cycling.
- Eco-driving: Awareness campaigns on training the citizens in eco-driving practices. Eco-driving is a relatively low-cost and immediate measure to reduce fuel consumption and emissions significantly while it also offers numerous benefits. The main factors of eco-driving are acceleration/deceleration, driving speed, route choice and idling.[30]

Applicability

Years: 2020, 2030

City zones: All (Greater Athens Area)

Assumptions for emission modelling

Affected sector: 1A3bi - 1A3biv

Change in activity

The scenario combines two separate measures, which differently affect activity and emission factor. The promotion of walking and cycling influences the activity level, while the effect of ecodiriving is

[30] Huang, Yuhan et al. (2018): Eco-driving technology for sustainable road transport: A review. Renewable and Sustainable Energy Reviews.

described as an emission factor change since the activity unit in the emission inventory is driven vehicle kilometres instead of fuel consumption.

Promoting cycling and walking:

The metropolitan Area of Athens is a region that is historically car dependent with a modal split highly relying on cars. In contrast, the share of trips by cars is much lower in other European cities[31]. The current share of 2011 is about 7% walking and cycling[32] The target share for walking and cycling is set to 10% in 2020 and 20% in 2030. This is in the same range as the target scenario of the more ambitious scenarios in the Thessaloniki sustainable urban mobility plan (SUMP) (15% in 2020)[33]. Furthermore, it has been assumed that the reduction only affects vehicle kilometres travelled by private passenger cars and motorcycles, while public transportation usage is not reduced. This leads to a reduction of the activity level by 3 % in 2020 and 13 % in 2030.

Change in emission factors

Eco-driving:

The literature on eco-driving shows a wide variety in terms of reduced fuel saving and therefore emissions. A summary of eco-driving programs in different cities in the world shows potentials for reducing fuel and CO2 emissions mostly between 0%-15%[34]. A theoretical and practical training of bus drivers in Athens led to a reduction of about 6.5%[35]. A study by Wang and Boggio-Marzet (2018)

---

[31] https://www.eea.europa.eu/data-and-maps/daviz/modal-split-for-metropolitan-city-areas#tab-chart_1 (checked on 07/29/.2019)

[32] IBM (2016): Athens, Greece: Smarter Cities Challenge Report.

[33] Thessaloniki Public Transport Authority (2014): Sustainable Urban Mobility Plan for the Metropolitan Area of Thessaloniki

[34] Huang, Yuhan et al. (2018): Eco-driving technology for sustainable road transport: A review. Renewable and Sustainable Energy Reviews.
Alessandrini, A. et al. ():Driving style influence on car CO2 emissions

Fonseca, N. et al. (2010): Influence of Driving Style on Fuel Consumption and Emissions in Diesel-Powered Passenger Car. International Symposium Transport and Air Pollution.

Wang, Y; Boggio-Marzet, A. (2018): Evaluation of Eco-Driving Training for Fuel Efficiency and Emissions Reduction According to Road Type. Sustainability

[35] Huang, Yuhan et al. (2018): Eco-driving technology for sustainable road transport: A review. Renewable and Sustainable Energy Reviews.

in Madrid shows a general fuel saving of 6.3% regardless of fuel and road type [36].
To determine the effect on the emission factor, SO2 and CO2 emission reductions are set as high as the fuel savings since emissions of both pollutants depend directly on the fuel consumption. Studies for measurements of pollutant reductions are rather limited and different approaches for the estimation of the emission reduction potential exist. Within the project CIVITAS MIMOSA fuel reductions have been directly used to calculate the emission reductions of all pollutants[37]. However, emissions of other pollutants depend not only on fuel consumption but also on the operation mode of the motor. A study by Fonseca et al. (2010) found no mitigating effect of eco-driving on NOx emissions[38]. Kugler (2012) assumes the emission reduction potentials as half as high as the reduction of exclusively consumption-dependent pollutants.[39] This approach has been followed for the calculation of the emission reduction potential.

It has been assumed that the eco-driving does not lead to an increase in travel time (and therefore higher emissions of pollutants) but that the trainings focuses on the travel behaviour of the drivers. Furthermore, it has been assumed that trainings do continue throughout the whole life span of the measure so that no fading of the behavioural change is expected.
In 2020 we assume 10% of drivers to be reached by the program and changing their behaviour, while in 2030 we expect about 60% of drivers to be reached (5% per year). Based on the literature it has been assumed that the reduction potential is 5% for SO2 and CO2, while we assume 2.5% for other pollutants. Given the above mentioned assumptions, the emission reduction is as follows:

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3bi - 1A3biv	2020	CO2, SO2	0.65
1A3bi - 1A3biv	2020	all other pollutants	0.325
1A3bi - 1A3biv	2030	CO2, SO2	3.90
1A3bi - 1A3biv	2030	all other	1.95

[36] Wang, Y; Boggio-Marzet, A. (2018): Evaluation of Eco-Driving Training for Fuel Efficiency and Emissions Reduction According to Road Type. Sustainability

[37] Rannala, M.; Metsvahi, T.; Orntlich, A. (2013): Measure Evaluation Results. TAL 6.1 Eco Driving

[38] Fonseca, N. et al. (2010): Influence of Driving Style on Fuel Consumption and Emissions in Diesel-Powered Passenger Car.

[39] Kugler, U. (2012): Straßenverkehrsemissionen in Europa – Emissionsberechnung und Bewertung von Minderungsmaßnahmen. Universität Stuttgart.

		pollutants	

The assumed reductions are in line with Kugler (2012) who expects long term reductions of CO2 of 3%.

Further assumptions

First the reduction in private transport trips has been calculated and afterwards the emission reduction potential of eco-driving has been applied on the remaining trips in order to avoid a double counting of emission reductions.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i, 1 A 3 b iv	2020	CO2, SO2	3.63
1 A 3 b i, 1 A 3 b iv	2020	all other pollutants	3.32
1 A 3 b ii, 1 A 3 b iii	2020	CO2, SO2	0.65
1 A 3 b ii, 1 A 3 b iii	2020	all other pollutants	0.32
1 A 3 b i, 1 A 3 b iv	2030	CO2, SO2	16.39
1 A 3 b i, 1 A 3 b iv	2030	all other pollutants	14.70
1 A 3 b ii, 1 A 3 b iii	2030	CO2, SO2	3.90
1 A 3 b ii, 1 A 3 b iii	2030	all other pollutants	1.95

Athens: Policy scenario 2 - SusMobPuT

Promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica) as well as minimizing the use of private passenger cars in Athens metropolitan area by enhancing public transportation means

Description of the scenario

This scenario considers the promotion of sustainable mobility through eco-driving, cycling and walking in the Greater Athens Area (Attica) as well as minimizing the use of private passenger cars in Athens metropolitan area by enhancing public transportation means.

This measure relates to the policy for supporting the transition to a low-carbon economy in all sectors of the Regional Operational Program (ROP) Attica 2014-2020. The measure focuses on training, informing and sensitizing the citizens in:

3. Promoting cycling and walking: promoting a population shift from using cars towards walking and cycling.
4. Eco-driving: Awareness campaigns on training the citizens in eco-driving practices.

Additionally, it targets the limited use of private passenger cars (PCs) in the wider area of Athens (metropolitan area) through the promotion of public and alternative transportation.

Applicability

Years: 2020, 2030

City zones: SusMob applicable to whole Greater Athens Area, PuT to the metropolitan area of Athens

Assumptions for emission modelling

Affected sector: 1A3bi - 1A3biv

Change in activity

The activity change of sub-scenario SusMob can be found in the description of the respective scenario.

Sub-scenario PuT: It has been assumed that the promotion of public transportation by the introduction of new metro lines decreases the vehicle kilometres driven with private transportation means by 1 % in 2020 and 6% in 2030. The 6% decrease is in line with the measured reductions during the Olympics in Athens where efforts have been made to enhance the transportation system.

Change in emission factors

The emission factors' change of sub-scenario SusMob (eco-driving) can be found in the description of the respective scenario.

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

The emission reduction potential for the sub-measure PuT is as follows:

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i, 1 A 3 b iv	2020	All	1.00
1 A 3 b i, 1 A 3 b iv	2030	All	6.00

The emission reduction potential for the scenario SusMobPuT can be derived from the reduction potential of measure SusMob and sub-measure PuT.

Athens: Policy scenario 3 - EnEff

Energetic renovation of residential and commercial buildings in the Greater Athens Area (Attica)

Description of the scenario

This scenario relates to the European Commission policy to face the significant contribution of the building sector on the final energy consumption in EU countries and aims at improving the energy efficiency of the building stock in residential and commercial sector. The new Greek Regulation on the Energy Performance of Buildings (REPB), which is in line with the European Directive 2010/31/EC and 2012/27/EC, has brought changes applying to construction techniques, construction costs and energy performance in the residential buildings. The REPB imposes minimum energy performance requirements for buildings and classifies them into nine energy classes (A+, A, B+, B, C, D, E, F, G) by comparing their energy performance with that of a reference building.

The scenario EnEff considers the energetic renovation of residential buildings in the Greater Athens Area (Attica) and extends the existing program to include also commercial buildings. It therefore leads to an improved energy efficiency in all buildings and increased use of renewable energy sources.

Applicability

Years: 2020, 2030

City zones: All (Greater Athens Area)

Assumptions for emission modelling

Affected sector: 1A4 (incl. all subsectors)

Change in activity

For residential energy renovations, according to statistics of previous years from funded programs, it is estimated to be feasible for the next twelve years (2018-2030) to carry out energy interventions at around 25,000 residencies annually, as referred in the "Long-term strategy report to mobilize investments for the renovation of the national building stock" of the Ministry of Energy and Environment[40]. This is in line with the target set to renovate 7% of the existing building stock until 2030. It therefore has been assumed that 2.5% and 7% of buildings in 2020 resp. 2030 are renovated. According to the average energy savings for residential buildings in Attica and experiences of EKO-I and EKO-II programs, it has been assumed that 45% of final energy can be saved for each building.

Based on above mentioned assumptions (implementation potential: 2.5 – 7% and mitigation potential: 45%), the measure leads to a reduction in final energy consumption of 1.13% in 2020 and 3.15% in 2030.

Change in emission factors

None

Further assumptions

A simultaneous change of heating technology or fuel type has not been assumed.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A4	2020	All	1.13
1A4	2030	All	3.15

[40] https://ec.europa.eu/energy/sites/ener/files/documents/el_building_renov_2017_en.pdf (checked on 07/29/2019)

Athens: Policy scenario 4 - EnEffZEB

Energetic renovation of residential and commercial buildings in the Greater Athens Area (scenario EnEff) as well as additional conversion of residencies to nearly zero energy buildings (nZEB) in the City of Athens

Description of the scenario

This scenario considers the energetic renovation of residential and commercial buildings in the Greater Athens Area (scenario EnEff) as well as additional conversion of residencies to nearly zero energy buildings (nZEB) in the City of Athens.

The City of Athens will support the conversion of 10% of the existing residential buildings to nearly zero-energy buildings until 2030. According to Article 9 of Law 4122/2013 (Directive 2010/31/EE on the energy performance of buildings), it is foreseen that as of 1.1.2021 all new buildings must be nearly zero-energy buildings, while for the new buildings they host services of the public and wider public sector, this obligation shall enter into force on 1.1.2019. The National Plan to increase the number of buildings with almost zero energy consumption[41] sets as a nearly zero-energy building the one that according to the Energy Performance Buildings Regulation:

- can be classified at least in energy class A, if it is a new building,
- can be classified at least in energy class B+, if it is an existing building.

The description of energetic renovation of residential and commercial buildings in the Greater Athens Area (Attica) can be found in scenario EnEff.

Applicability

Years: 2020, 2030

City zones: EnEff applicable to whole Greater Athens Area, ZEB to Athens city centre

[41] http://www.ypeka.gr/LinkClick.aspx?fileticket=8S82W2L9SLw%3d&tabid=281&language=el-GR (checked on 28/07/2019)

Assumptions for emission modelling

Affected sector: 1A4 (incl. all subsectors)

Change in activity

The energetic renovation of residential and commercial buildings in the Greater Athens Area (Attica) follows the same assumptions as described in the scenario EnEff. The activity change for this scenario can be found in the respective scenario description.

Additionally, 10% of the existing residential buildings will be transformed to nearly zero-energy buildings until 2030. The deep renovation of an existing building in order to become a nearly zero-energy building would mean an approx. 80-100% reduction in final energy consumption.

Based on above mentioned assumptions (implementation potential: 1% in 2020 and 10% in 2030 and mitigation potential: 80-100%), the measure ZEB leads to a reduction in final energy consumption of 0.8% in 2020 and 10% in 2030.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

The emission reduction potential of the single measure ZEB within the city centre of Athens is as follows:

NFR sector code	Year	Pollutant	Emission reduction potential [%] (only ZEB)
1A4	2020	All	0.8
1A4	2030	All	10

The reduction potential of the scenario EnEffZEB consists of the reduction potential of the scenario EnEff and the emission reduction potential of the single measure ZEB. The potential for Athens city centre is as follows:

NFR sector code	Year	Pollutant	Emission reduction potential [%] (EnEffZEB city centre)
1A4	2020	All	1.93
1A4	2030	All	13.15

The reduction potential of the scenario EnEffZEB consists of the reduction potential of the scenario EnEff and the emission reduction potential of the single measure ZEB. The potential for Greater Athens Area is as follows:

NFR sector code	Year	Pollutant	Emission reduction potential [%] (EnEffZEB Greater Athens Area)
1A4	2020	All	1.14
1A4	2030	All	3.26

Athens: Policy scenario 5 - Waste

Reduction of disposed biodegradable and recyclable waste in landfill through the implementation of Green Points and Recycling & Training Centres for waste separation at source and pre-sorting

Description of the scenario

The scenario relates to target set in the Regional Solid Waste Management for pre-treatment and pre-sorting of waste to promote recycling and reuse and contributes to the reduction of the disposition of biodegradable waste (bio-waste and packaging waste) in landfill through such actions that include separation at source, domestic compost, etc.

Furthermore, it includes the promotion of the “Green Points” network in Attica region, which aims at promoting pre-sorting and pre-treatment for specific waste streams. There are 4 types of Green Points:

a) Large Green points that are large environmental facilities (>3500m^2) for collecting recyclable material such as garden and pruning waste, domestic hazardous waste such as batteries, paints and varnishes, light bulbs etc., old furniture, electrical and electronic devices etc.

b) Small Green Points are areas of 250-750m^2

d) Recycling, Training and Sorting at Source Centres are areas of 250-1000m^2

c) Green points at neighbourhood should cover an area of 50-100m^2

Applicability

Years: 2020, 2030

City zones: All (Greater Athens Area)

Assumptions for emission modelling

Affected sector: 6A

Change in activity

The total disposed MSW to landfill at 2015 was 1,758,165tn with a constant amount in 2020 and 2030. The reduction of 63% (i.e. 1079351tn) leads to 678815tn waste in sector 6D. The reduced amount of landfill waste in 2020 and 2030 is 63%. The same is assumed for 2030.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
6 D	2020	All	63.0
6 D	2030	All	63.0

Basel: Policy scenario 1 - NoHeat

Replacement of fossil heating technologies by heating pumps and solar heating (until 2020: 1/3 will be replaced; until 2030:100%)

Description of the scenario

This scenario considers the replacement of fossil heating technologies by heating pumps and solar heating. It foresees the replacement of one third until 2020 and full replacement until 2030.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A4ai, 1A4bi

Change in activity

For 2020 a third of all existing (baseline 2015) fossil heating units are replaced with renewable heating technologies (no direct emissions). For 2030 all fossil heating units are replaced. The final energy consumption of the respective sector is reduced accordingly to the replaced proportion.

Change in emission factor

None

Further assumptions

Fossil heating units are replaced by heating pumps or solar and not by fuelwood. Power generation by fossil fuels is not affected (heat from power generation goes into district heating).

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 4 a i	2020	As	-
1 A 4 a i	2020	BC	-19.2
1 A 4 a i	2020	Benzo(a)pyrene	-
1 A 4 a i	2020	Cd	-

1 A 4 a i	2020	CH4	-31.2
1 A 4 a i	2020	CO	-20.6
1 A 4 a i	2020	CO2	-33.0
1 A 4 a i	2020	CO2_biog	0.0
1 A 4 a i	2020	Hg	-
1 A 4 a i	2020	N2O	-28.3
1 A 4 a i	2020	NH3	-24.8
1 A 4 a i	2020	NMVOC	-29.6
1 A 4 a i	2020	NOX	-31.7
1 A 4 a i	2020	OC	0.0
1 A 4 a i	2020	Pb	-
1 A 4 a i	2020	PCDD/F	-
1 A 4 a i	2020	PM10	-4.2
1 A 4 a i	2020	PM2.5	-4.4
1 A 4 a i	2020	SO2	-31.7
1 A 4 a i	2030	As	-
1 A 4 a i	2030	BC	-53.0
1 A 4 a i	2030	Benzo(a)pyrene	-
1 A 4 a i	2030	Cd	-
1 A 4 a i	2030	CH4	-94.0
1 A 4 a i	2030	CO	-61.5
1 A 4 a i	2030	CO2	-100.0
1 A 4 a i	2030	CO2_biog	0.0
1 A 4 a i	2030	Hg	-
1 A 4 a i	2030	N2O	-84.0
1 A 4 a i	2030	NH3	-74.0

1 A 4 a i	2030	NMVOC	-88.6
1 A 4 a i	2030	NOX	-95.8
1 A 4 a i	2030	OC	0.0
1 A 4 a i	2030	Pb	-
1 A 4 a i	2030	PCDD/F	-
1 A 4 a i	2030	PM10	-10.5
1 A 4 a i	2030	PM2.5	-11.1
1 A 4 a i	2030	SO2	-82.1
1 A 4 b i	2020	As	-
1 A 4 b i	2020	BC	-12.5
1 A 4 b i	2020	Benzo(a)pyrene	-
1 A 4 b i	2020	Cd	-
1 A 4 b i	2020	CH4	-28.5
1 A 4 b i	2020	CO	-15.1
1 A 4 b i	2020	CO2	-33.0
1 A 4 b i	2020	CO2_biog	0.0
1 A 4 b i	2020	Hg	-
1 A 4 b i	2020	N2O	-27.9
1 A 4 b i	2020	NH3	-23.1
1 A 4 b i	2020	NMVOC	-27.8
1 A 4 b i	2020	NOX	-31.5
1 A 4 b i	2020	OC	0.0
1 A 4 b i	2020	Pb	-
1 A 4 b i	2020	PCDD/F	-
1 A 4 b i	2020	PM10	-6.8
1 A 4 b i	2020	PM2.5	-7.0

1 A 4 b i	2020	SO2	-31.7
1 A 4 b i	2030	As	-
1 A 4 b i	2030	BC	-26.4
1 A 4 b i	2030	Benzo(a)pyrene	-
1 A 4 b i	2030	Cd	-
1 A 4 b i	2030	CH4	-80.7
1 A 4 b i	2030	CO	-40.1
1 A 4 b i	2030	CO2	-100.0
1 A 4 b i	2030	CO2_biog	0.0
1 A 4 b i	2030	Hg	-
1 A 4 b i	2030	N2O	-78.6
1 A 4 b i	2030	NH3	-65.0
1 A 4 b i	2030	NMVOC	-80.1
1 A 4 b i	2030	NOX	-94.0
1 A 4 b i	2030	OC	0.0
1 A 4 b i	2030	Pb	-
1 A 4 b i	2030	PCDD/F	-
1 A 4 b i	2030	PM10	-15.6
1 A 4 b i	2030	PM2.5	-16.2
1 A 4 b i	2030	SO2	-73.9

Basel: Policy scenario 2 - Traffic10

Introducing a traffic reduction law leads to a reduction of the traffic load by 10% in 2020 and 2030 compared to the baseline scenario

Description of the scenario

This scenario aims to reduce traffic (all motorized traffic on all roads) by 10 percent equally and follows the reduction goal as stated in the environmental laws of Basel. (Traffic reduction compared to baseline 2015)

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3b

Change in activity

All motorized traffic volumes are reduced to 90 percent of the volume in 2015 in each street segment. No changes in tram or bus traffic volumes are considered. (This refers to 11.4% reduction compared to BAU 2020 scenario and 14.1% reduction compared to BAU 2030 scenario.)

Change in emission factor

None

Further assumptions

Changes in fleet composition are considered to be the same as in all scenarios. To simplify the scenario no increases in non-motorized traffic volumes are considered.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3b	2020	All	-11.4
1A3b	2030	All	-14.1

Basel: Policy scenario 3 - FirewoodBan

A ban on small combustion of firewood will be introduced until 2030. This is a hypothetical scenario to show the effects of firewood on air pollution. (2030 scenario)

Description of the scenario

This scenario assumes the introduction of a ban on small combustion of firewood will until 2030. It is a hypothetical scenario to show the effects of firewood on air pollution.

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A4ai, 1A4bi

Change in activity

All small firewood combustion units are replaced by heating pumps and solar heating. The final energy consumption of the respective activity is set to zero.

Change in emission factor

None

Further assumptions:

Power generation by firewood is not affected (two large scale firewood heat and power plants in service). The reasoning behind this is the reduced emissions of large scale firewood plants due to flue gas treatment.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 4 a i	2020	All	0
1 A 4 a i	2030	As	-
1 A 4 a i	2030	BC	-47.0
1 A 4 a i	2030	Benzo(a)pyrene	-

1 A 4 a i	2030	Cd	-
1 A 4 a i	2030	CH4	-6.0
1 A 4 a i	2030	CO	-38.5
1 A 4 a i	2030	CO2	0.0
1 A 4 a i	2030	CO2_biog	-100.0
1 A 4 a i	2030	Hg	-
1 A 4 a i	2030	N2O	-16.0
1 A 4 a i	2030	NH3	-26.0
1 A 4 a i	2030	NMVOC	-11.4
1 A 4 a i	2030	NOX	-4.2
1 A 4 a i	2030	OC	-100.0
1 A 4 a i	2030	Pb	-
1 A 4 a i	2030	PCDD/F	-
1 A 4 a i	2030	PM10	-89.5
1 A 4 a i	2030	PM2.5	-88.9
1 A 4 a i	2030	SO2	-17.9
1 A 4 b i	2020	All	0
1 A 4 b i	2030	As	-
1 A 4 b i	2030	BC	-73.6
1 A 4 b i	2030	Benzo(a)pyrene	-
1 A 4 b i	2030	Cd	-
1 A 4 b i	2030	CH4	-19.3
1 A 4 b i	2030	CO	-59.9
1 A 4 b i	2030	CO2	0.0
1 A 4 b i	2030	CO2_biog	-100.0
1 A 4 b i	2030	Hg	-

1 A 4 b i	2030	N2O	-21.4
1 A 4 b i	2030	NH3	-35.0
1 A 4 b i	2030	NMVOC	-19.9
1 A 4 b i	2030	NOX	-6.0
1 A 4 b i	2030	OC	-100.0
1 A 4 b i	2030	Pb	-
1 A 4 b i	2030	PCDD/F	-
1 A 4 b i	2030	PM10	-84.4
1 A 4 b i	2030	PM2.5	-83.8
1 A 4 b i	2030	SO2	-26.1

Basel: Policy scenario 4 - NoHeatFirewood

Replacement of fossil heating technologies combined with the introduction of a firewood ban until 2030. This is a combination of scenario NoHeat and Firewood. This is a hypothetical scenario to show the effects of small combustion on air pollution. (2030 scenario)

Description of the scenario

This scenario considers the replacement of fossil heating technologies combined with the introduction of a firewood ban until 2030. This is a combination of scenario NoHeat and Firewood. It is a hypothetical scenario to show the effects of small combustion on air pollution.

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A4ai, 1A4bi

Change in activity

All fossil heating and small firewood combustion units are replaced by heating pumps and solar heating. More information about the activity changes can be found in the respective sub-scenario descriptions.

Change in emission factor

None

Further assumptions:

Power generation by fossil fuels or by firewood is not affected.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A4ai	2020	All	0
1A4ai	2030	All	100
1A4bi	2020	All	0
1A4bi	2030	All	100

Basel: Policy scenario 5 - ZeroEmissionShips

Conversion of the shipping fleet to zero emission ships by 2030. This is a hypothetical scenario to show the effects of navigation on air pollution levels. (2030 scenario)

Description of the scenario

All ships (sector 1A3d) are replaced by 2030 with zero emission ships. This is a hypothetical scenario to show the effects of navigation on air pollution levels.

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3d

Change in activity

None

Change in emission factor

All emission factors are changed to 0 in sector 1A3d.

Further assumptions:

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 d ii	2020	All	0
1 A 3 d ii	2030	All	100

Brno: Policy scenario 1 - M1opti

Promoting low carbon vehicles

Description of the scenario

This scenario considers the promotion of low carbon vehicles. It follows an optimistic trend, which considers a rapid penetration of electric vehicles onto the Czech Market. In this scenario it is estimated that 7% and 12.5% of vkm driven by PCs in 2020 and 2030, respectively, will be done by electric vehicles.

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A3b

Change in activity

For this scenario, no changes will be done for most vehicle categories (i.e. buses, heavy-duty vehicles (HDVs), light-duty vehicles (LDVs), tramways and motorcycles (MCs)), but the only change to occur will concern, as expected, personal cars (PCs). For PCs, compared to the baseline scenario (derived within Work Package 2 (WP2)), no changes will be done in terms of the total vkm driven, neither for the technology (i.e. pre-Euro, Euro1, …) of petrol and diesel vehicles, but only concerning the share of individual cars for which electric vehicles will represent a larger share compared to the baseline scenario.

The estimation of the change of primary emissions related to this measure is based on the available report about the prognosis of the vehicle fleet composition until 2040 done by ATEM company (Ateliér ekologických modelů s. r. o.) for the Road and Motorway Directorate of the Czech Republic under the Ministry of Transport, published in January 2016. This document presents the change in vehicle fleet composition for the Czech Republic from 2014 to 2040 based on different scenarios including business as usual and elaborated visions.

Within this document, two scenarios, based on the three strategic documents published by the Czech Ministry of Industry and Trade, were developed for this measure:

- An optimistic scenario (OPTI), named “Vize silniční dopravy v roce 2030” (Vision of the road traffic in 2030), which considers a rapid penetration of electric vehicles onto the Czech Market.
- A more realistic scenario (REAL) relying on data from the National Action Plan for Clean Mobility („Národní akční plán čisté mobility“, NAP CM), prepared in cooperation with the

Ministry of Environment, and the National action plan of Czech Republic for the usage of the energy from the renewable sources ("Národní akční plán České republiky pro energii z obnovitelných zdrojů") based on the analysis of the Roland Berger company , in which it is estimated that the penetration of electric vehicles onto the Czech market will be a bit slower, and will occur with a delay of about 10 years compared to the OPTI scenario.

For the implementation of this measure the OPTI scenario has been chosen, which is based on the estimation of the REAL scenario. For the REAL scenario, the estimation of electric vehicles among PCs in 2020 and 2030 is estimated from available data from the ATEM report, shown in Figure 1, considering that the share in Brno will be the same as the one for the Prague district and highways. Therefore, it is estimated that 1% and 8% of vkm driven by PCs in 2020 and 2030, respectively, will be done by electric vehicles.

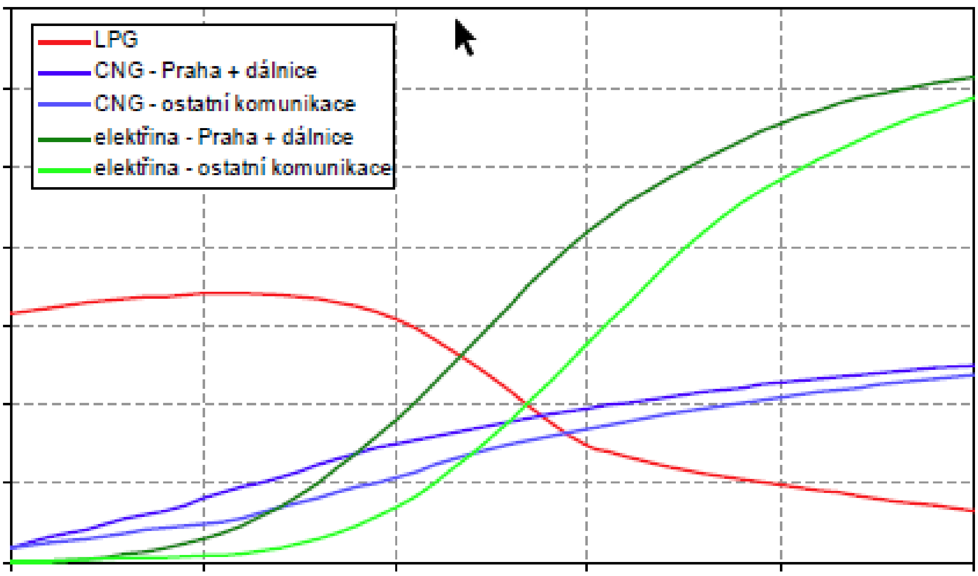


Figure 1: Share of cars equipped with alternative propulsion among personal cars in 2015-2040. The two green lines concern changes for electric vehicles, with the darker one representing Prague and highways, while the lighter green one concerns other communications in the Czech Republic. Red line stands for LPG (Liquified Petroleum Gas) and blue lines are for CNG (Compressed Natural Gas) driven vehicles.

Given the almost 10-year delay in electric vehicles penetration of the REAL scenario compared to the OPTI one, we have estimated that within OPTI, in 2020 and in 2030, 7% and 12.5% of vkm driven by PCs will be done by electric vehicles.

A summary of the share of vkm done by electric vehicles compared to PCs for the both scenarios and the two modelled years is presented in Table 1.

Table 1: Share of vkm of PCs done by electric vehicles in 2020 and 2030 with the REAL and OPTI scenario

	REAL	OPTI
2020	1%	7%
2030	8%	12.5%

For further analysis and assessment of the policy scenario the OPTI scenario has been chosen.

Change in emission factor

None

Further assumptions

Within this measure, we have not considered the increase of electricity consumption due to the penetration of electric vehicles onto the market, but we have considered that this will happen at the national level and not at the city level, which is uncertain. Therefore, we should keep in mind that the reported emissions for that measure are an underestimation of the real emissions (however not for the city level).

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b	2020	As	6.00
1 A 3 b	2020	BC	2.55
1 A 3 b	2020	Benzo(a)pyrene	5.99
1 A 3 b	2020	Cd	0.37
1 A 3 b	2020	CH4	6.31
1 A 3 b	2020	CO	6.43
1 A 3 b	2020	CO2	5.41
1 A 3 b	2020	Hg	5.68

1 A 3 b	2020	N2O	4.96
1 A 3 b	2020	NH3	6.34
1 A 3 b	2020	NMVOC	6.26
1 A 3 b	2020	NOx	4.23
1 A 3 b	2020	OC	-10.10
1 A 3 b	2020	Pb	0.02
1 A 3 b	2020	PM10	1.40
1 A 3 b	2020	PM2.5	1.38
1 A 3 b	2020	SO2	5.40
1 A 3 b	2030	As	10.81
1 A 3 b	2030	BC	-12.19
1 A 3 b	2030	Benzo(a)pyrene	10.71
1 A 3 b	2030	Cd	0.68
1 A 3 b	2030	CH4	11.55
1 A 3 b	2030	CO	11.55
1 A 3 b	2030	CO2	9.79
1 A 3 b	2030	Hg	10.25
1 A 3 b	2030	N2O	8.22
1 A 3 b	2030	NH3	11.30
1 A 3 b	2030	NMVOC	11.41
1 A 3 b	2030	NOx	8.83
1 A 3 b	2030	OC	-36.28
1 A 3 b	2030	Pb	0.03
1 A 3 b	2030	PM10	0.96
1 A 3 b	2030	PM2.5	-0.08
1 A 3 b	2030	SO2	9.77

Brno: Policy scenario 2 - M2zero

Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking, biking and using public transport) – ZERO scenario

Description of the scenario

This scenario considers the aim to reduce the number of PCs in the city, and to increase the number of people walking, biking or using public transport. In the scenario ZERO population and housing is developing as planned in the SUMP, but it assumes no planned traffic constructions (e.g. P+R, new highways, development of public transport).

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A3bi

Change in activity

Within this measure, no changes will be done in terms of HDVs, LDVs or MCs. A decrease of the activity (in terms of vkm) of PCs and an increase of the activity of buses, trams and trolleys will occur compared to the baseline scenario developed in WP2.

To derive the change in activities, data from the Sustainability Mobility Plan (SUMP) published in January 2017 and developed by AF-CITYPLAN, s.r.o. for the city of Brno were used. All documents used in this study are available at http://www.mobilitabrno.cz/.

In that document, the modal split of different types of transport is provided based on prognosis of the economic growth, migration and proposed traffic measures and is modelled for 2023 and 2030 (Table 2). Within this document, two scenarios were available:

- The scenario ZERO in which population and housing is developing as planned in the SUMP, but it assumes no planned traffic constructions (e.g. P+R, new highways, development of public transport).
- The scenario PLAN in which all the proposed measures including traffic constructions are assumed to be realized.

Table 2: Modal split of different types of transport including public transport (PT), personal cars (PC), pedestrians and cyclists in 2015, 2023 and 2030

	PT	PC	Pedestrians	Cyclists
2015	42.7	52.7	4.1	0.6

2023(Plan)	47.6	36.1	12	4.3
2023(Zero)	46.6	39.1	12.2	2.1
2030(Plan)	50.6	31.8	12.1	5.5
2030(Zero)	46.7	38.5	12.2	2.6

One of the difficulties was to convert the change in modal split (e.g. moving from 52.7% to 36.1% (i.e. share of personal vehicles used from 2015 to 2023), i.e. 31.5% reduction) onto a change of activity. To overcome this issue, we have decided to use the coefficient of occupancy of passenger cars of 1.25, as suggested by the City of Brno since 2004, to normalize the decreases of personal vehicles. For example, the 31.5% reduction of personal vehicles from 2015 to 2023 would be divided by 1.25 and this would result in a decrease of 25.2% of activity done by PCs during this time period.

Based on these data and on the occupancy of passenger cars in Brno, the estimated changes of activities (in terms of vkm) that will be considered for this measure and that will be apply to PCs are summarized in Table 3. This scenario M2zero refers to ZERO in the table.

Table 3: Decrease (in terms of %) of the activity (in terms of vkm) that will be modelled for 2020 and 2030 by the REAL and OPTI scenarios

	ZERO	PLAN	OPTI
2020	20.6	25.2	34.5
2030	21.6	31.7	42

Regarding the changes of activities of all public transportation considered (i.e. buses and tramways), it is extremely important to keep in mind the limitation of the public transport system which currently runs at almost its maximal capacity as well as the current relatively low occupancy of the public transport in non-rush-hours period (personal communication). Based on that, we have estimated that the changes of activities (in terms of vkm) of all public transport related systems (i.e. buses and tramways) would be an increase of 5% in 2020 and of 10% in 2030 for both scenarios investigated. The increase of buses activity concerns both public and private buses. No increase in the activity of trains was done.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b	2020	As	17.63
1 A 3 b	2020	BC	14.06
1 A 3 b	2020	Benzo(a)pyrene	18.13
1 A 3 b	2020	Cd	14.75
1 A 3 b	2020	CH4	18.58
1 A 3 b	2020	CO	18.96
1 A 3 b	2020	CO2	15.76
1 A 3 b	2020	Hg	16.61
1 A 3 b	2020	N2O	14.49
1 A 3 b	2020	NH3	18.74
1 A 3 b	2020	NMVOC	18.45
1 A 3 b	2020	NOx	12.03
1 A 3 b	2020	OC	12.61
1 A 3 b	2020	Pb	14.27
1 A 3 b	2020	PM10	14.56
1 A 3 b	2020	PM2.5	14.48
1 A 3 b	2020	SO2	15.74
1 A 3 b	2030	As	18.51
1 A 3 b	2030	BC	11.31
1 A 3 b	2030	Benzo(a)pyrene	18.92
1 A 3 b	2030	Cd	15.25
1 A 3 b	2030	CH4	19.94

1 A 3 b	2030	CO	19.94
1 A 3 b	2030	CO2	16.55
1 A 3 b	2030	Hg	17.44
1 A 3 b	2030	N2O	13.77
1 A 3 b	2030	NH3	19.54
1 A 3 b	2030	NMVOC	19.69
1 A 3 b	2030	NOx	14.60
1 A 3 b	2030	OC	14.68
1 A 3 b	2030	Pb	14.70
1 A 3 b	2030	PM10	15.34
1 A 3 b	2030	PM2.5	15.37
1 A 3 b	2030	SO2	16.53

Brno: Policy scenario 3 - M2opti

Reduction of the motorized vehicles in the city and increase of the usage of clean transportation (i.e. walking, biking and using public transport) – OPTI scenario

Description of the scenario

This scenario aims to reduce the number of PCs in the city, and to increase the number of people walking, biking or using public transport. For this scenario we decided to model a more optimistic scenario (OPTI) in which a larger shift from personal vehicles to public transportation would occur. In OPTI scenario, we estimated that in 2023 and in 2030, only 30% and 25%, respectively, of the transportation would be done by PCs. This assumption is partially based on the Vision 2030, which is part of the preparation documents used to construct the SUMP. This Vision 2030 was approved by the City Council in December 2015 as an ideal vision for future of the Brno transport.

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A3bi

Change in activity

The scenario development is based on the same approach and basic data as described in the previous scenario M2zero. Further assumptions are:

For this scenario we decided to model a more optimistic scenario (OPTI) in which a larger shift from personal vehicles to public transportation would occur. In OPTI scenario, we estimated that in 2023 and in 2030, only 30% and 25%, respectively, of the transportation would be done by PCs. This assumption is partially based on the Vision 2030, which is part of the preparation documents used to construct the SUMP. This Vision 2030 was approved by the City Council in December 2015 as an ideal vision for future of the Brno transport.

In this study, given that no specific data were available for 2020, we have allocated the ones available for 2023 to 2020.

One of the difficulties was to convert the change in modal split (e.g. moving from 52.7% to 36.1% (i.e. share of personal vehicles used from 2015 to 2023), i.e. 31.5% reduction) onto a change of activity. To overcome this issue, we have decided to use the coefficient of occupancy of passenger cars of 1.25, as suggested by the City of Brno since 2004, to normalize the decreases of personal vehicles. For example, the 31.5% reduction of personal vehicles from 2015 to 2023 would be divided by 1.25 and this would result in a decrease of 25.2% of activity done by PCs during this time period.

Based on these data and on the occupancy of passenger cars in Brno, the estimated changes of activities (in terms of vkm) that will be considered for this measure and that will be apply to PCs are summarized in Table 4. This scenario M2opti refers to OPTI in the table.

Table 4: Decrease (in terms of %) of the activity (in terms of vkm) that will be modelled for 2020 and 2030 by the REAL and OPTI scenarios

	ZERO	PLAN	OPTI
2020	20.6	25.2	34.5
2030	21.6	31.7	42

Regarding the changes of activities of all public transportation considered (i.e. buses and tramways), it is extremely important to keep in mind the limitation of the public transport system which currently runs at almost its maximal capacity as well as the current relatively low occupancy of the public transport in non-rush-hours period (personal communication). Based on that, we have estimated that the changes of activities (in terms of vkm) of all public transport related systems (i.e. buses and tramways) would be an increase of 5% in 2020 and of 10% in 2030 for both scenarios investigated. The increase of buses activity concerns both public and private buses. No increase in the activity of trains was done.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b	2020	As	29.61
1 A 3 b	2020	BC	23.87
1 A 3 b	2020	Benzo(a)pyrene	30.42
1 A 3 b	2020	Cd	24.87
1 A 3 b	2020	CH4	31.17
1 A 3 b	2020	CO	31.79
1 A 3 b	2020	CO2	26.55
1 A 3 b	2020	Hg	27.94
1 A 3 b	2020	N2O	24.38
1 A 3 b	2020	NH3	31.39
1 A 3 b	2020	NMVOC	30.94
1 A 3 b	2020	NOx	20.48
1 A 3 b	2020	OC	21.43

1 A 3 b	2020	Pb	24.09
1 A 3 b	2020	PM10	24.57
1 A 3 b	2020	PM2.5	24.47
1 A 3 b	2020	SO2	26.51
1 A 3 b	2030	As	36.20
1 A 3 b	2030	BC	23.37
1 A 3 b	2030	Benzo(a)pyrene	36.95
1 A 3 b	2030	Cd	30.11
1 A 3 b	2030	CH4	38.84
1 A 3 b	2030	CO	38.83
1 A 3 b	2030	CO2	32.56
1 A 3 b	2030	Hg	34.22
1 A 3 b	2030	N2O	27.21
1 A 3 b	2030	NH3	38.02
1 A 3 b	2030	NMVOC	38.35
1 A 3 b	2030	NOx	29.05
1 A 3 b	2030	OC	29.33
1 A 3 b	2030	Pb	29.11
1 A 3 b	2030	PM10	30.26
1 A 3 b	2030	PM2.5	30.35
1 A 3 b	2030	SO2	32.51

Brno: Policy scenario 4 - M3slow

Switch of combustion techniques in residential and municipal buildings: Replacement of old coal-fired boilers in residential sector

Description of the scenario

This scenario aims at reducing anthropogenic emissions from domestic heating by replacing old coal-fired boilers by natural gas-fired boilers, biomass-fired boilers, heat pumps, district heating and solar thermal collectors and therefore affects the residential sector 1A4bi.

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A4bi

Change in activity

To estimate the change in emissions related to this measure, within the energy concept of the city of Brno (not officially available yet, likely will be published within few months), three different scenarios were considered:

- GAS scenario: In this scenario, it is estimated that most of the coal-fired boilers would be replaced by natural gas-fired boilers
- GREEN scenario: In this scenario, it is estimated that most of the coal-fired boilers would be replaced by biomass-fired boilers and by heat pumps
- DISTRICT scenario: In this scenario, it is estimated that most of the coal-fired boilers would be replaced by district heating.

However, in this document, it is stated that the GREEN scenario is the most likely one. We therefore decided to use this scenario for modelling purposes.

For the GREEN scenario, we have used the share of technologies replacing coal-fired boilers available for the Jihomoravský region where Brno is located, available from a document about the evaluation of the national programme boiler replacement (Table 5).

Table 5: Share of technologies replacing coal-fired boilers

	Natural gas-fired boilers	Biomass-fired boilers	Heat pumps	Automatic coal fired boilers	Solar thermal collectors	**Total**
2. scenario - renewable energy sources (GREEN)	28%	42%	14%	12%	4%	**100%**

The Brno energy concept indicates that 100% of coal-fired boilers would be replaced by 2030.

However, it is unclear how many of them would be replaced by 2020. Therefore, we have decided to model this measure with the sub-scenario SLOW in which only 20% of the coal-fired boilers would be replaced in 2020.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 4 b i	2020	As	5.99
1 A 4 b i	2020	BC	0.57
1 A 4 b i	2020	Benzo(a)pyrene	6.36
1 A 4 b i	2020	Cd	-1.09
1 A 4 b i	2020	CH4	-0.14
1 A 4 b i	2020	CO	3.21
1 A 4 b i	2020	CO2	1.47
1 A 4 b i	2020	Hg	8.34
1 A 4 b i	2020	N2O	1.49
1 A 4 b i	2020	NH3	-1.15
1 A 4 b i	2020	NMVOC	0.32
1 A 4 b i	2020	NOX	0.73
1 A 4 b i	2020	OC	-0.53
1 A 4 b i	2020	Pb	6.16
1 A 4 b i	2020	PCDD/F	4.96
1 A 4 b i	2020	PM10	5.11

1 A 4 b i	2020	PM2.5	2.98
1 A 4 b i	2020	SO2	14.62
1 A 4 b i	2030	As	29.94
1 A 4 b i	2030	BC	2.83
1 A 4 b i	2030	Benzo(a)pyrene	31.80
1 A 4 b i	2030	Cd	-5.46
1 A 4 b i	2030	CH4	-0.72
1 A 4 b i	2030	CO	16.03
1 A 4 b i	2030	CO2	7.35
1 A 4 b i	2030	Hg	41.71
1 A 4 b i	2030	N2O	7.46
1 A 4 b i	2030	NH3	-5.73
1 A 4 b i	2030	NMVOC	1.61
1 A 4 b i	2030	NOX	3.65
1 A 4 b i	2030	OC	-2.67
1 A 4 b i	2030	Pb	30.82
1 A 4 b i	2030	PCDD/F	19.76
1 A 4 b i	2030	PM10	25.57
1 A 4 b i	2030	PM2.5	14.92
1 A 4 b i	2030	SO2	73.08

Brno: Policy scenario 5 - M4econ

Implementation of energy saving measures by insulation and renovation of the building stock

Description of the scenario

This scenario aims at reducing anthropogenic emissions related to the energy sector by promoting insulation and renovation, and therefore will affect three individual sectors: the residential sector (1A4bi), the commercial sector (1A4ci) and the industrial sector (1A2).

In the residential sector (1A4bi), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)

In the commercial sector (1A4ci), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)
- Modernisation of indoor lighting system
- Modernisation of ventilation and air conditioning systems

In industry sector (1A2) the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)
- Improving the energy efficiency of production technologies

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A4bi, 1A4ci, 1A2

Change in activity

These data are expressed for two different scenarios: TECHNICAL and ECONOMIC. The TECHNICAL scenario includes all measures examined, without economical limits. The ECONOMIC scenario considers measures that are feasible from an economical perspective.

Within the Energy concept of the city of Brno (not officially available yet, likely will be published within few months), it has been estimated that until 2050, 17- 31% of energy could be saved by each sector with the TECHNICAL scenario while it would be 7-18% with the ECONOMIC scenario (Table 6).

Table 6: Energy savings potential in terms of technicity and economy for each sector (data from the Energy concept of the city of Brno, 2018), in which the reference scenario is 2015

	Technical energy savings potential until 2050	Economic energy savings potential until 2050
	GJ	GJ

Residential	18.7%	13.2%
Services (including public buildings)	30.5%	18.2%
Industry	17.0%	7.0%

No specific data were available for intermediate years and specific data for 2020 and 2030 were estimated using logarithmic regression.

The lowest energy savings potential is in the industry sector, since most of the energy efficiency measures have already been implemented in the past.

For the modelling of the effect of this measure on anthropogenic emissions, we have selected the ECONOMIC scenario, taken from the Brno Energy Concept:

- An economic scenario (ECONOMIC) which assumes that only economic energy savings potential will be achieved by 2050

The temporal reduction in terms of activities (i.e. energy used) for the ECONOMIC scenario in each sector is based on logarithmic regressions from the available data for 2015 and 2050 from the Energy concept of the city of Brno (Table 7).

Table 7: Reduction in energy consumption for the residential (1A4bi), commercial (1A4ci) and industrial (1A2) sector compared to 2015 (100%)

		2020	2030	2040	2050
ECONOMIC scenario	Residential sector	95.6%	91.3%	88.7%	86.8%
	Commercial sector	93.9%	87.8%	84.2%	81.8%
	Industrial sector	97.6%	95.3%	93.9%	93.0%

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A4bi	2020	All	4.4
1A4bi	2030	All	8.7
1A4ci	2020	All	6.1
1A4ci	2030	All	12.2
1A2	2020	All	2.4
1A2	2030	All	4.7

Ljubljana: Policy scenario 1 - M1_DecreaseCAR

Decrease of personal car use (the combination of the car reduction measures and parking policy will lead to a decrease of personal cars on incoming roads/avenues by 20 %); specifically, the promotion of electro mobility is planned to result in an additional 2% of emission reduction (2030 scenario)

Description of the scenario

This scenario comprises several measures with the main goal to reduce personal car use. They include particularly:

- Alternative parking policy; Street parking spaces will be intended primarily for residents. To this end, the municipality will gradually introduce parking zones in densely populated neighbourhoods and quarters, in which street parking spaces will be payable and limited to two hours. This measure will limit the possibility of parking for daily migrants in residential areas. Daily migrants will be provided with parking spaces at Park&Ride facilities at the outskirts of the city and in public garage houses);
- Ten largest employers in the city will prepare and implement their transport mobility plans to work after a third of the use of vehicles;
- Promotion of electro mobility; the electro mobility is estimated to represent the 2% of the entire fleet (ca 20.000 vehicles) in the near future.

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1 A 3 b i

Change in activity

It is estimated that the combination of the specified measure will lead to a decrease of personal cars on incoming roads/avenues by 20 %. Scenarios regarding the decrease of emissions related to the intensified use of electric vehicles are focused on the decrease of these 2% excluding the life cycle assessment of the electricity supply. Based on the expected decrease of personal car use by 20%, it is estimated that the reduction of pollution will also be 20% (taking into consideration that the shift will be primarily towards other means of transport – primarily cycling and walking). For particles (PM, BC, OC) the emission reduction potential remains by 20% as the introduction of electric vehicles does not contribute to a decrease in abrasion emissions, which have the main influence on particle emissions.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i	2020	All (except PM, BC, OC)	0.0
1 A 3 b i	2030	All (except PM, BC, OC)	22.0
1 A 3 b i	2020	PM, BC, OC	0.0
1 A 3 b i	2030	PM, BC, OC	20.0

Ljubljana: Policy scenario 2 - M2_IncreasePT

Increased share of public transport use (increased use of PT on the account of better service and transfer from car users); The renovation of the public passenger transport fleet and the reduction of personal car use is also integrated in this scenario - 2030)

Description of the scenario

This scenario considers Ljubljana's aim for the coming decade to stop and reverse the trend in the decline in the number of trips made with public transport. In this regard the following measures are considered:

- Bus routes will be extended to neighbouring municipalities, while working migrants will be given the opportunity to park their car in one of the Park&Ride facilities on the outskirts of the municipality, from where they will reach the city centre quickly and easily during the traffic congestion.
- On three avenues with heavy traffic congestion, a faster travel time for LPP buses compared to passenger cars will be ensured with public transport priority an intersections and dedicated bus lanes.

Furthermore, this scenario integrates also scenario M1 and scenario M3; i.e. the decrease of passenger cars by 20% in 2030 and the renovation of the bus fleet with CNG buses. In contrast to scenario 1 it includes the additional renovation of the bus fleet and the increase of 10% of bus kilometres. In contrast to scenario 3, this scenario includes 10% increase of bus kilometres.

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1 A 3 b iii, 1 A 3 b i

Change in activity

The current number of travels with LPP should be increased by 30% until 2027 (the milestone is 10% increase by 2020). Since the public transport usage is increasing more slowly than expected the increase considered in the 2030 scenario is 10%. Two separate calculations have been made as a sensitivity analysis – a 0% increase in bus vkm which considers the 10% increase of passengers to fill the existing capacities of buses. The increase of 30% passengers is estimated to require an additional 10% of the increase of public transport services in terms of vkm (more buses, higher frequency). This scenario reflects the increase of 10% more vehicle kilometres for buses. Zero increase in vkm are considered in M3.

Furthermore, a decrease in private passenger cars is assumed as in M1.

Change in emission factor

The change in the emission factor is the same as in scenario M3. (CNG emission factors for buses)

Further assumptions

None

Emission reduction potential

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3biii	2020	All	0.0
1A3biii	2030	As	9.8
1A3biii	2030	BC	29.5
1A3biii	2030	Benzo(a)pyrene	8.5
1A3biii	2030	Cd	13.8
1A3biii	2030	CH4	-964.2
1A3biii	2030	CO	12.2
1A3biii	2030	CO2	-4.7
1A3biii	2030	Hg	9.8
1A3biii	2030	N2O	0.6
1A3biii	2030	NH3	9.7
1A3biii	2030	NMVOC	36.8
1A3biii	2030	NOx	16.6
1A3biii	2030	OC	40.4
1A3biii	2030	Pb	13.9
1A3biii	2030	PM10	22.0
1A3biii	2030	PM2.5	24.7

1A3biii	2030	SO2	9.8
1 A 3 b i	2020	All (except PM, BC, OC)	0.0
1 A 3 b i	2030	All (except PM, BC, OC)	22.0
1 A 3 b i	2020	PM, BC, OC	0.0
1 A 3 b i	2030	PM, BC, OC	20.0

Ljubljana: Policy scenario 3 - M3_PTfleet

Renovation of public passenger transport vehicle fleet (CNG. hybrid buses); the replacement of EURO 0, 1, 2 buses with CNG propulsion system (86 buses in total)

(The reduction of personal car use is also integrated in this scenario. but no increase of public transport is assumed) (2030 scenario)

Description of the scenario

This scenario considers the renovation of the public passenger transport vehicle fleet and a traffic reduction.

Renovation of public passenger transport vehicle fleet (CNG, hybrid buses), utility vehicle fleet and city administration vehicle fleet. The renovation of the PT fleet considers the replacement of EURO 0, 1, 2 from the fleet; these will be replaced by 86 buses with CNG propulsion system. The reduction of personal car use is also integrated in this scenario, but no increase of public transport is assumed) (2030 scenario).

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1 A 3 b iii, 1 A 3 b vi, 1 A 3 b vii

Change in activity

The changes in the activities of the sector 1A3bi is the same as in scenario M1.

Change in emission factor

The scenario considers the replacement of EURO 0, 1, 2 emission factors by CNG emission factors.

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3biii	2020	All	0.0
1A3biii	2030	As	18.0
1A3biii	2030	BC	35.9
1A3biii	2030	Benzo(a)pyrene	16.8
1A3biii	2030	Cd	21.6
1A3biii	2030	CH4	-867.4
1A3biii	2030	CO	20.2
1A3biii	2030	CO2	4.8
1A3biii	2030	Hg	18.0
1A3biii	2030	N2O	9.6
1A3biii	2030	NH3	17.9
1A3biii	2030	NMVOC	42.5
1A3biii	2030	NOx	42.5
1A3biii	2030	OC	24.2
1A3biii	2030	Pb	45.8
1A3biii	2030	PM10	21.7
1A3biii	2030	PM2.5	29.1
1A3biii	2030	SO2	31.5
1 A 3 b i	2020	All (except PM, BC, OC)	0

1 A 3 b i	2030	All (except PM, BC, OC)	22
1 A 3 b i	2020	PM, BC, OC	0
1 A 3 b i	2030	PM, BC, OC	20

Ljubljana: Policy scenario 4 - M4_DistrHEAT

Increased utilization and expansion of district heating systems; renovation of the system - replacement of existing combustion units with more appropriate means (i.e. 70% reduction of coal use) (2030 scenario)

Description of the scenario

This scenario aims at increased utilization and expansion of district heating systems and a renovation of the system by replacing existing combustion units with more appropriate means (i.e. 70% reduction of coal use in district heat production plants). A significant increase of facilities connected to the gas network along with the installation of the gas unit at the Ljubljana thermal plant has been assumed. This new gas-steam unit, will replace two of the oldest of the three coal blocks in the TE-TOL unit. Coal block 3, which was processed in 2008 for the purpose of lowering carbon dioxide emissions by co-firing of coal and wood chips. Energetika Ljubljana (TE-TOL) thermal plant is the largest user of wood biomass for energy purposes in Slovenia - will remain in operation and will be able to use various primary fuels and renewable energy sources. The use of coal in Ljubljana will thus be reduced by more than 70 percent.

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A1a

Change in activity

70% reduction of coal in sector 1A1a and replacement of the same activity level by natural gas.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A1a	2020	All	0.0
1A1a	2030	As	69,2
1A1a	2030	BAP	34,3
1A1a	2030	BC	-158,2
1A1a	2030	Cd	69,9
1A1a	2030	CH4	-172,2
1A1a	2030	CO	-16,5
1A1a	2030	CO2	26,0
1A1a	2030	Hg	66,7
1A1a	2030	N2O	67,7
1A1a	2030	NH3	-176,5
1A1a	2030	NMVOC	-21,1
1A1a	2030	NOX	53,3
1A1a	2030	OC	-168,3
1A1a	2030	Pb	70,0
1A1a	2030	PCDD/F	65,3
1A1a	2030	PM10	68,5
1A1a	2030	PM2.5	68,4
1A1a	2030	SO2	69,9

Ljubljana: Policy scenario 5 - M5_EfiicientHEAT

More efficient use of domestic heating; decrease of fuel consumption by 15% by 2030 (2030 scenario)

Description of the scenario

This scenario aims at more efficient use of domestic heating and a decrease of fuel consumption. It is estimated that, given the current situation, with the proper use of devices and air-dried biomass, it is technically possible to reduce particulate emissions from existing small combustion plants by 50% on average, and fuel consumption by 15%. (By 2017, the goal was to achieve a 20% reduction in particulate matter emissions from small combustion plants to solid fuel, through education and awareness of citizens, while at the same time reducing the specific consumption of solid fuel by 10%).

Applicability

Years: 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A4

Change in activity

Decreased fuel consumption/final energy in 1A4 by 15%.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A4	2020	All	0.0
1A4	2030	All	15.0

Madrid: Policy scenario 1 - ZEZ

Delimitation of a closed Central Zone (Zero Emissions Central Area) with restricted access in which through traffic will be banned

Description of the scenario

This scenario foresees a delimitation of a closed perimeter Central Zone with restricted access in which through traffic will be banned. The creation of this area is focused on reducing the negative effects of car mobility in the centre of the city, encouraging the use of collective transport and non-motorized modes to the detriment of the use of private vehicles. Likewise, other potential sources of pollution will be acted upon, with the main objective of establishing an area of the city free of emissions.[42]

Applicability

Years: 2020, 2030

City zones: Zero Emission Zone / Central Area of Madrid

Assumptions for emission modelling

Affected sector: 1A3bi, 1A3biv in 2020, 1A3b in 2030 (1A3)

Change in activity

In the 2020 scenario, vehicles (cars and motorcycles) without sticker from non-residents are not allowed to circulate in the Zero Emission Zone. This means that the entry is forbidden for non-residential gasoline vehicles less than EURO 3 and non-residential diesel vehicles less than EURO 4 for (cf. Table 8). The proportion of non-resident cars is assumed to be 70% in 2020 (further assumptions); therefore 30% exclusion from the ban has been assumed.

For the 2030 scenario, also vans and HGVs are affected by the measure (see table below), which means that now all vehicle types are restricted according to their emission sticker. Furthermore, cars also from residents are not allowed to enter the zone from 2025 on and are therefore excluded in the 2030 emission scenario.

Vehicle kilometres of the restricted vehicle classes are accordingly reduced.

Table 8: Access to Madrid Central under ZEZ[43]

Who is allowed into Madrid Central?					
sticker	**Cero**	**ECO**	**C**	**B**	**not meeting the standards to get a sticker**

[42] https://www.madrid.es/UnidadesDescentralizadas/Sostenibilidad/CalidadAire/Ficheros/PlanAire&CC_Eng.pdf (checked on 07/29/2019)

[43] http://urbanaccessregulations.eu/countries-mainmenu-147/spain/madrid-access-restriction (checked on 05/23/19)

residents	√	√	√	√	√
guests of residents	√	√	√	√	√ (until 31 December 2019)
cars of non-residents	√ - without limit of parking and circulation	Parking in private garage or parking; max. 2h in SER	Access only allowed to park in private garage or parking	Access only allowed to park in private garage or parking	X
motorcycles of non-residents	√ - without time limit	√ - without time limit	√ - from 07:00 - 22:00	√ - from 07:00 - 22:00	X
vans services and suppliers (until 31 December 2019)	√ - without time limit	√ - from 07:00 - 23:00	√ - from 07:00 - 21:00	√ - from 07:00 - 15:00 (until 31 December 2021)	√ - from 07:00 - 13:00 (until 31 December 2019)
HGV services and suppliers (until 31 December 2019)	√ -without time limit	√ - from 07:00 - 21:00	√ - from 07:00 - 17:00	√ - from 07:00 - 15:00 (until 31 December 2024)	√- from 07:00 - 13:00 (until 31 December 2022)
owner of parking spot in CM	√	√	√	√	√ (until 31 December 2019)
disabled	√	√	√	√	√

Change in emission factor

None

Further assumptions

The area of the central zero emission zone has been extracted from the municipal area by an intersect of the 1x1km grid with the georeferenced shapefile provided by the Madrid ICARUS Team based on the selection of the attribute “centro” of the column nombre and a comparison with maps of the zero emission zone. The proportion that is located within the central district has been calculated for each grid element. The emission reduction potential of the measure has been applied on that proportion of the grid element. The proportion of each grid element for the area can be found in Table 9.

Table 9: Spatial share of each grid element on the zero emission zone in Madrid

ZEZ_share	
GRIDCODE	ZEZ_share
44400121	0.19
44400122	0.04
44407801	0.69
44407802	0.93
44407803	0.13
44415481	1.00
44415482	0.92
44415483	0.01
44423160	0.01
44423161	0.40
44423162	0.45

Diegmann and Pfäfflin (2015) conclude that effects not related to low emission zones can influence fleet changes more strongly than low emission zones itself[44]. Since the restricted area in Madrid is additionally a rather small area within the whole municipality, it has been assumed that the fleet renewal effect is negligible. Furthermore, public transportation is assumed to be available in sufficient capacity to avoid additional emissions from introducing new public transportation means apart from the ones already considered in Madrid PLAN A. It has also been assumed that there are enough free parking spaces at the boundaries of the zero emission zone to avoid additional parking search traffic. This is in line with the intention of the City of Madrid to create a parking system that contributes to the reduction of car traffic by building 10.000 parking spaces at the city boundaries[45]. After the introduction of low emission zones the traffic flows have been found to remain constant in most cases, which is therefore also assumed in this case for the larger Madrid area outside of the

[44] Diegmann, V.; Pfäfflin, F. (2015): Auswertung der Wirkung von Umweltzonen auf die Erneuerung der Fahrzeugflotten in deutschen Städten

[45] https://www.zeit.de/2018/19/madrid-verkehrspolitik-luftverschmutzung-strassenplanung-zukunft/komplettansicht (checked on 05/23/19)

city centre.[46]

Furthermore, it has to be differentiated between resident and non-resident vehicles of specific districts, which are treated differently by the measures Central Zero Emission Zone and Parking regulation according to air quality criteria. The PLAN A Madrid states that 65% of NOx, 72 % of particles and 73% of carbon dioxide origin from tourism type vehicles, which means from non-residential vehicles[47]. This leads to the assumption that about 60 - 70 % of the vehicles on the road are non-residential vehicles; with a lower share when assuming that the vehicle fleet of Madrid citizens has a higher emission standard as the national average. Pérez et al. (2019) found that only 53.4% of mileage within the city boundary is made by drivers registered in the municipality of Madrid[48]. However, data for the district level is not available. Therefore, it has been assumed that about 30% of the trips within the city area of Madrid origin from residents of the specific district and non-residents (outside of Madrid and other district within Madrid) account for 70%.

Spain has four emission stickers. Cities can use them also for incentives or bans of certain vehicles (cf. Table 9). The distribution of routes by emission sticker/hallmark can be found in Table 6. The distribution of vehicle stickers in the ICARUS database can be derived by comparison with the EURO standard (cf. Table 9).

Table 9: Emission stickers in Spain and related Euro standard

Name of the sticker	colour	Date of registration	Euro standard	Vehicles
Null Emission	blue			EV, plug-in-hybrid (minimum range 40 km), fuel cell
ECO	blue and green	petrol: from 2006 diesel: from	petrol: Euro 4, 5 und 6	Plug-in-hybrid (minimum range < 40 km), hybrid: gas: CNG, LNG, LPG. These vehicles have to fulfil standards for green sticker C.

[46] https://urbanaccessregulations.eu/low-emission-zones-main/impact-of-low-emission-zones (checked on 05/23/19)

[47] City of Madrid (2017): Plan A . English Version, checked on 3/20/2019.

[48] Pérez, Javier; Andrés, Juan Manuel de; Borge, Rafael; La Paz, David de; Lumbreras, Julio; Rodríguez, Encarnación (2019): Vehicle fleet characterization study in the city of Madrid and its application as a support tool in urban transport and air quality policy development. In Transport Policy 74, pp. 114–126. DOI: 10.1016/j.tranpol.2018.12.002.

		2014	diesel: Euro 6	
c	green	petrol: from 2006 diesel: from 2014	petrol: Euro 4, 5 und 6 diesel: Euro 6	
B	yellow	petrol: from January 2000 diesel: from January 2006	petrol: Euro 3 diesel: Euro 4 und 5	

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3b	2020	As	0.23
1A3b	2020	As road	0.30
1A3b	2020	As wear	0.26
1A3b	2020	BC	0.71
1A3b	2020	Benzo(a)pyrene	0.37
1A3b	2020	Benzo(a)pyrene wear	0.25
1A3b	2020	Cd	0.22
1A3b	2020	Cd road	0.27
1A3b	2020	Cd wear	0.25
1A3b	2020	CH4	0.29
1A3b	2020	CO	0.49

1A3b	2020	CO2	0.26
1A3b	2020	Hg	0.25
1A3b	2020	Hg road	
1A3b	2020	Hg wear	0.26
1A3b	2020	N2O	0.31
1A3b	2020	NH3	0.32
1A3b	2020	NMVOC	0.52
1A3b	2020	NOx	0.34
1A3b	2020	OC	0.74
1A3b	2020	Pb	0.23
1A3b	2020	Pb road	0.08
1A3b	2020	Pb wear	0.25
1A3b	2020	PM10	0.54
1A3b	2020	PM25	0.60
1A3b	2020	SO2	0.27
1A3b	2030	As	0.26
1A3b	2030	As road	0.26
1A3b	2030	As wear	0.24
1A3b	2030	BC	1.20
1A3b	2030	Benzo(a)pyrene	0.27
1A3b	2030	Benzo(a)pyrene wear	0.24
1A3b	2030	Cd	0.26
1A3b	2030	Cd road	0.25
1A3b	2030	Cd wear	0.24
1A3b	2030	CH4	0.41

1A3b	2030	CO	0.69
1A3b	2030	CO2	0.25
1A3b	2030	Hg	0.25
1A3b	2030	Hg road	
1A3b	2030	Hg wear	0.24
1A3b	2030	N2O	0.28
1A3b	2030	NH3	0.42
1A3b	2030	NMVOC	0.76
1A3b	2030	NOx	0.39
1A3b	2030	OC	1.05
1A3b	2030	Pb	0.26
1A3b	2030	Pb road	0.17
1A3b	2030	Pb wear	0.24
1A3b	2030	PM10	0.64
1A3b	2030	PM25	0.77
1A3b	2030	SO2	0.25

Madrid: Policy scenario 2- Park

Parking regulation according to air quality criteria through an increase of discounts and penalties according to vehicle's emissions and new regulation systems

Description of the scenario

The limitation of parking at destination is a measure that has been proven effective to create a deterrent effect on the use of private vehicles. The Regulated Parking Service (SER) is a fundamental municipal tool to influence in this sense. The objective of the measure is to reduce emissions from the use of the private car by managing the supply of parking at destination in compliance with air quality criteria. (City of Madrid 2017)

This measure is a joint measure with different stages of the reorganization of the parking regulation. Within the first years it foresees a review of the tariff system combining on the one hand a 25% surcharge of the parking fee for high emitting vehicles without environmental badge and on the other hand a 50% discount for ECO vehicles. As of 2020, vehicles without an environmental distinction of the DGT (Spanish Directorate General for Traffic) may not use the seats in the scope of the Regulated Parking Service, except residents in their own neighbourhood (cf. 1.2). This limitation will apply from 2022 to vehicles that have the authorization of qualified groups of owners of commercial and industrial vehicles.[49]

Applicability

Years: 2020, 2030

City zones: Regulated Parking Service (SER M-30) zone within Calle 30

Assumptions for emission modelling

Affected sector: 1A3bi

Change in activity

For the emission scenario 2020 the following assumptions have been made:

- Increase of discounts and penalties according to the vehicle's emissions in regulated parking zones
    - The increase of the parking fee by 25% is expected to reduce the mileage of non-residential vehicles. The reduction potential for the increase of the parking fee is calculated by the transport elasticity. The price elasticity for car drivers commuting trips in urban regions is -0.04 for each vehicle kilometre[50]. Therefore, it will be assumed that a 25% increase of prices results in 1.2% vkm reduction in the city centre in 2020.
- Implementation of new systems regulating destination car parking and underground car parks with gradual increase in spaces for residents at the expense of short-stay spaces
    - No further data on how many parking spaces will be reduced is available. Therefore, a target share of reduced trips by parking management following the approach in Friedrich (2014) will be set[51]. It has been assumed that the measure will result in a reduction of

---

[49] Ayuntamiento de Madrid (2017): Plan de Calidad de aire y Cambio Climático, checked on 12/6/2018.

[50] Litman, Todd (2013): Transport Elasticities: Impacts on Travel Behaviour. Understanding Transport Demand to Support Sustainable Travel Behaviour. Sustainable Urban Transport Technical Document #11. Edited by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), checked on 6/5/2018.

Litman, Todd Alexander (2017): Understanding Transport Demands and Elasticities. How prices and Other Factors Affect Travel Behaviour, checked on 5/20/2019.

[51] Friedrich, Rainer (2014): TRANSPHORM Deliverable 5.2.1 Systematic analysis of policies and measures. Transport related Air Pollution and Health impacts -Integrated Methodologies for Assessing Particulate Matter. Deliverable D5.2.1, checked on 3/23/2018.

the mileage of non-residential passenger cars within the city boarders by 2%. This mileage will be replaced by slow mode walk, slow mode bicycle, bus, passenger train and metro/tram. Capacities of the public transportation means have been assumed to meet the need.

For the emission scenario 2030 the following assumptions have been made:

- Limitation of use: As of 2020, vehicles without an environmental distinction of the DGT may not use the seats in the scope of the Regulated Parking Service, except residents in their own neighbourhood. This limitation will apply from 2022 to vehicles that have the authorization of qualified groups of owners of commercial and industrial vehicles. Parking is forbidden for all gasoline cars less than EURO 3 and diesel cars less than EURO 4.
    - Specific data on how the parking limitations influence the vehicle kilometres within Madrid municipality is scarce.
    - A measure aiming at adaptive parking management based on energy efficiency and occupancy in the project ECCENTRIC is expected to result in a car traffic reduction of 6% by employees[52].
    - The parking restriction within the central district during pollution episodes is expected to cut journeys by 13.4% within the central district and reduce NO2 emissions by 6%.[53]
    - As a first estimate a 50% reduction of trips for all vehicles affected by the parking ban has been chosen. Applying this share on the activity traffic data leads to a passenger vkm reduction of about 5% in 2030 (but even higher emission reduction potential due to the ban of highly polluting vehicles).

The emission reduction potential is calculated with the activity bottom up data on transport and the reduction of the vehicles mileage.

Change in emission factor

None

Further assumptions

The area of the SER M-30 parking zone has been calculated using the road network for Madrid from OpenStreetMap and the area within Calle 30. The proportion that is located within the SER M-30 zone has been calculated for each grid element. The emission reduction potential of the measure has been applied on that proportion of the grid element. The proportion of each grid element for

---

[52] Madrid City Council (Ed.) (2018): Adaptive parking management based on energy efficiency and occupancy. Project CIVITAS ECCENTRIC, checked on 5/23/2019.

[53] https://endesavehiculoelectrico.com/en/espanol-nuevo-protocolo-de-contaminacion-de-madrid/ (checked on 05/23/19)

the area can be found in Table 10.

Table 10: Spatial share of each grid element on the SER M-30 zone in Madrid

SER_share	
GRIDCODE	SER_share
44446203	0.04
44446202	0.09
44438524	0.07
44438523	0.71
44438522	0.85
44438521	0.02
44430845	0.00
44430844	0.79
44430843	1.00
44430842	1.00
44430841	0.58
44430840	0.01
44423165	0.37
44423164	1.00
44423163	1.00
44423162	1.00
44423161	1.00
44423160	0.63
44415485	0.84
44415484	1.00
44415483	1.00
44415482	1.00

44415481	1.00
44415480	0.57
44407806	0.00
44407805	0.90
44407804	1.00
44407803	1.00
44407802	1.00
44407801	1.00
44407800	0.61
44407799	0.00
44400126	0.14
44400125	1.00
44400124	1.00
44400123	1.00
44400122	1.00
44400121	1.00
44400120	1.00
44400119	0.36
44392446	0.09
44392445	1.00
44392444	1.00
44392443	1.00
44392442	1.00
44392441	1.00
44392440	1.00
44392439	0.45
44384766	0.08

44384765	1.00
44384764	1.00
44384763	1.00
44384762	1.00
44384761	1.00
44384760	1.00
44384759	0.46
44377086	0.00
44377085	0.91
44377084	1.00
44377083	1.00
44377082	1.00
44377081	1.00
44377080	1.00
44377079	0.59
44369405	0.64
44369404	1.00
44369403	1.00
44369402	1.00
44369401	1.00
44369400	1.00
44369399	0.77
44361725	0.43
44361724	0.80
44361723	0.94
44361722	0.76
44361721	0.36

44361720	0.33
44361719	0.54

It has been assumed that about 70% of the trips within the city area of Madrid come from non-residents in their own neighbourhood and will be affected by this measure (cf. measure ZEZ).

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3b	2020	As	0.37
1A3b	2020	As road	0.39
1A3b	2020	As wear	0.33
1A3b	2020	BC	0.34
1A3b	2020	BC road	0.43
1A3b	2020	BC wear	0.43
1A3b	2020	Benzo(a)pyrene	0.40
1A3b	2020	Benzo(a)pyrene wear	0.33
1A3b	2020	Cd	0.38
1A3b	2020	Cd road	0.36
1A3b	2020	Cd wear	0.33
1A3b	2020	CH4	0.26
1A3b	2020	CO	0.35
1A3b	2020	CO2	0.34
1A3b	2020	Hg	0.36
1A3b	2020	Hg road	

1A3b	2020	Hg wear	0.34
1A3b	2020	N2O	0.37
1A3b	2020	NH3	0.41
1A3b	2020	NMVOC	0.35
1A3b	2020	NOx	0.28
1A3b	2020	OC	0.34
1A3b	2020	OC road	0.43
1A3b	2020	OC wear	0.43
1A3b	2020	Pb	0.37
1A3b	2020	Pb road	0.11
1A3b	2020	Pb wear	0.33
1A3b	2020	PM10	0.34
1A3b	2020	PM25	0.34
1A3b	2020	SO2	0.35
1A3b	2030	As	0.86
1A3b	2030	As road	0.89
1A3b	2030	As wear	0.77
1A3b	2030	BC	3.87
1A3b	2030	Benzo(a)pyrene	0.95
1A3b	2030	Benzo(a)pyrene wear	0.76
1A3b	2030	Cd	0.87
1A3b	2030	Cd road	0.82
1A3b	2030	Cd wear	0.77
1A3b	2030	CH4	1.06
1A3b	2030	CO	2.04

1A3b	2030	CO2	0.80
1A3b	2030	Hg	0.83
1A3b	2030	Hg road	
1A3b	2030	Hg wear	0.78
1A3b	2030	N2O	0.98
1A3b	2030	NH3	1.57
1A3b	2030	NMVOC	2.29
1A3b	2030	NOx	1.19
1A3b	2030	OC	3.21
1A3b	2030	Pb	0.87
1A3b	2030	Pb road	0.25
1A3b	2030	Pb wear	0.76
1A3b	2030	PM10	2.05
1A3b	2030	PM25	2.45
1A3b	2030	SO2	0.82

Madrid: Policy scenario 3 - Log

Public-private collaboration in order to innovate and make urban logistics processes more efficient

Description of the scenario

This measure aims at establishing a communication and collaboration framework that allows the design and implementation of coordinated measures for a new model in the urban distribution of goods. The generation of knowledge, the development of innovation and the practical application of different solutions require a coordinated public-private effort. (Ayuntamiento de Madrid 2017)

The measure comprises several actions that have no direct quantifiable emission reduction effect. Description of the actions:

- Specific studies on urban distribution in Madrid with the participation of research centres, professional associations and urban logistics companies
- Circulating park
- Night-time download - Proposal for development and regulation
- Development of vehicle prototype for distribution with ultra-low emissions

- Support for the implementation of pilot micro-platforms for last mile distribution and vehicle recharge spaces
- Promotion of stable and representative channels and forums for communication and collaboration with the urban goods distribution sector.
- Weights and sizes of the last mile distribution
- Promoting the use of the bicycle for the last mile distribution

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A3bii

Change in activity

As a first estimate it has been assumed that due to better organization and replacement of the last mile by bicycles, LDV trips will be reduced by 4% in 2020 and 14% in 2030 (2%/year). The measure is expected to affect emissions of the whole city area.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3bii	2020	All	4.0
1A3bii	2030	All	14.0

Madrid: Policy scenario 4 - PuT

Reserved infrastructure for public transport (extra bus and high occupancy vehicle lanes) connecting with modal interchange points such as park-and-ride car parks

Description of the scenario

Aim of the measure is to establish a framework of collaboration and coordination with other public authorities for egress roads to be provided with bus lanes and the creation of high capacity bus corridors or Bud Rapid Transit to interconnect districts.

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A3bi, 1A3biv

Change in activity

A similar measure in Madrid fostering high-level public transport service corridors is expected at the city policy level to increase the modal share for public transport by 4% and increase the commercial speed by 10% [54] . The modal share in Madrid of 14 years old and above is 33% non-motorized trips, 38% public transport trips and 29% private car trips[55].

The relative travel time between different modes significantly affects mode choice[56]. An decrease of 10% in public transport vehicle travel time was associated with a 2.3% increase in public transport for non-work tours and 3.9% for home based work tours (elasticity -0.29 transit in-vehicle time home based work tours, -0.23 transit in-vehicle time home based non-work tours), while the demand for alone driving was reduced by 2% for home based work tours (0% for non-work tours)[57].

---

[54] Madrid Regional Transport Consortium (CRTM), Municipal Transport Enterprise for Madrid (EMT) (2018): High-level public transport servicecorridors in peripheral districts. CIVITAS ECCENTRIC, checked on 5/20/2019.

[55] https://civitas.eu/eccentric/madrid (checked on 05/23/2019)

[56] Litman, Todd (2013): Transport Elasticities: Impacts on Travel Behaviour. Understanding Transport Demand to Support Sustainable Travel Behaviour. Sustainable Urban Transport Technical Document #11. Edited by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), checked on 6/5/2018.

Litman, Todd Alexander (2017): Understanding Transport Demands and Elasticities. How prices and Other Factors Affect Travel Behaviour, checked on 5/20/2019.

[57] Frank, Lawrence; Bradley, Mark; Kavage, Sarah; Chapman, James; Lawton, T. Keith (2007): Urban form, travel time, and cost relationships with tour complexity and mode choice. In Transportation 35 (1), pp. 37–54. DOI: 10.1007/s11116-007-9136-6.

Given the transport demand elasticity based on the travel time and the expected shift of the modal share, a 2% reduction of vkm of private passenger cars and motorcycles within the whole city area will be assumed for 2020 and due to increasing reserved infrastructure a 4% reduction for 2030. Furthermore, it will be assumed that no additional public transportation means have to be put into practice but that the capacities are enough to meet the travel demand. The measure is expected to affect emissions of the whole city area.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3bi, 1A3biv	2020	All	2.0
1A3bi, 1A3biv	2030	All	4.0

Madrid: Policy scenario 5 - EnEf

Regeneration of neighbourhoods by improving energy efficiency and thermal insulation of the building stock and re-naturalization of the city

Description of the scenario

The measure aims at developing the urban regeneration strategy ‘Madrid Regenerates’ which addresses the rehabilitation of the building stock (Plan MAD-RE), the refurbishment of public space and re-naturalization of the city.

For the specific case of housing buildings, the MAD-Re (Madrid Recupera) Program of subsidies in preferential areas will be promoted, which is aimed at improving accessibility, energy efficiency and its state of conservation, and which in 2016 already launched a first announcement. With regard to energy efficiency, thermal insulation, the replacement of windows and air conditioning equipment, the use of renewable energies, the creation of green roofs, etc. will be subsidized.

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A4

Change in activity

The CO2 emissions reduction potential of the Madrid Recupera Plan is given with 30860 t CO2 per year[58]. It is assumed that the estimate holds true the year 2017, since the article is published in March 2018 and the measure is put into practice in 2017 (cf. Table 1). The CO2 emissions of SNAP 2 category in the baseline emission inventory account for 2149 kt in 2015 and 1947 kt in 2020. A linear interpolation between both values leads to 2068 t in 2017. Emission savings of 39.860 kt/year therefore account for 1.49% of emissions of SNAP 2 (non-industrial combustion) in 2017. The measure is expected to show the same reduction potential in the following years, which means that approximately 1.5% of emissions are reduced each year, leading to 6% emission reduction in 2020 and 21% in 2030 with the measure being put into practice in 2017. Since this measure only affects the total energy consumption and not the heating type distribution, the reduction potential (reduction in final energy) will be applied on all pollutants. The measure is expected to affect emissions of the whole city area.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A4	2020	All	6.0
1A4	2030	All	21.0

[58] https://www.c40.org/case_studies/madrid-recupera (checked on 05/23/2019)

Milan: Policy scenario 1 - AREAB

Low Emission Zone (Area B): Control and tracking of access into the city by banning up to Euro 3 diesel cars (up to Euro 4 from October 2019)

Description of the scenario

This scenario considers the introduction of a Low Emission Zone in the city of Milan. The positive experience of Area C, which over the last 3 years has seen a 10% decrease of the entrances within the historical centre, has promoted its reproduction on a city scale with AREA B as control and tracking of access into the city. It comprises the ban of up to Euro 3 diesel cars (up to Euro 4 from October 2019). The City of Milan is ready to start the implementation (February 2019) of this measure with an infrastructure of electronic gates (185) around and next to the municipal boundaries. The system (camera and on-board units) is set for the limitation of the most polluting vehicles, control, and management of the heaviest vehicles and the ones used for the transport of dangerous goods. In the second phase it will be targeted to manage also tourist buses and other kinds of big vehicles, and commercial ones as well. In this scenario a tightening of the measure is assumed that comprises the complete ban of diesel cars in 2030.

The protection of the territory and the residence takes place through three levels:

- Prohibition of access for the most polluting vehicles - Monday - Friday from 7:30 a.m. to 7:30 p.m. excluding holidays
- Prohibition of bulky vehicles entering, over 12 meters - Monday - Friday from 7:30 a.m. to 7:30 p.m. excluding holidays
- Controlled access and monitoring of vehicles carrying dangerous goods - Monday - Sunday - 0:00 a.m. to 24:00

It should be specified that there will be a gradual circulation change following the following rules:

Vehicles registered person and goods

- February 2019: gasoline euro 0, diesel euro 0, 1, 2, 3;

- October 2019: Euro 4 and diesel cars 0, 1, 2, 3, 4 with FAP approved euro 4 installed after 31.12.2018;

- October 2020: gasoline euro 1, diesel goods euro 4 and diesel 0.1,2,3,4 with FAP approved euro 4 installed after 31.12.2018;

- October 2022: euro 2 petrol car and diesel euro 5 and diesel 0.1,2,3,4 with FAP approved euro 4 installed by 31.12.2018;

- October 2024. gasoline goods euro 2 and diesel euro 5 and diesel 0.1,2s,3,4 with FAP approved euro 4 installed by 31.12.2018;

- October 2025: gasoline euro 3, cars and light goods diesel euro 6 A, B, C purchased after 31.12.2018, diesel euro 6 A, B, C purchased by 31.12.2018 with exemption until 1 October 2028, diesel euro 6 D-TEMP, D with exemption to 1 October 2030; Euro VI and Euro V heavy diesel with euro VI-approved FAP with exemption to 1 October 2030; Diesel euro 0, 1, 2, 3, 4, 5, 6 special or service machines with FAP or with declaration of inability to put the FAP off to 1 October 2030;

- October 2028: gasoline euro 4.

Mopeds and Motorcycles

- February 2019: mopeds and motor vehicles “2-stroke engine” euro 0, 1

- October 2019: mopeds and diesel motor vehicles Euro 0, 1

- October 2024: mopeds and motor vehicles “2-stroke engine” Euro 2; mopeds and diesel-powered motor vehicles Euro 2; mopeds and motor vehicles gasoline at 4-stroke euro 0, 1;

- October 2025: mopeds and motor vehicles “2-stroke engine” Euro 3; mopeds and diesel-powered motor vehicles Euro 3; mopeds and motor vehicles gasoline at 4-stroke euro 2; mopeds and motor vehicles 2-stroke euro 4 derogations to 1 October 2030; mopeds and diesel-powered motor vehicles Euro 4 and 5 derogations to 1 October 2030;

- October 2028: mopeds and motor vehicles gasoline 4-stroke euro 3

Applicability

Years: 2020, 2030

(policy time horizon 2019 – 2030)

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi, 1A3bii, 1A3biii, 1A3biv, 1A3bvii, 1A3bv

Road Transport: passenger cars, light duty vehicles, heavy duty vehicles and buses, mopeds and motorcycles, road abrasion and gasoline evaporation

Change in activity

According to the scheduled banning steps, year by year, reported in the description of the scenario, the new activities (yearly kilometres run) have been calculated for each type of vehicles for 2020 and 2030 scenarios, subtracting from BAU scenario the activities that would have been run for vehicles banned in that year. In 2020 scenario, a 75% of compliance to the policy has been taken into account due to the fact it has just started and some citizens and people who come from outside the borders of the city can’t simply afford to respect the new regulation. In 2030 scenario, therefore in the long-term period, the assumption is that nearly half of the activities subtracted due to banned vehicles are added to others category of vehicles allowed (e.g. with gasoline as fuel; hybrid vehicles) within the same NFR code sector. Emissions due to road abrasion and gasoline evaporation have been recalculated in agreement with the assumptions described above.

Change in emission factor

None

(Future changes in EFs have been already considered in BAU 2020-2030 scenarios, and here the same changes have been taking into account for each type of vehicle.)

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1.A.3.b.i	2020	Hg	-
1.A.3.b.i	2020	SO2	-21.1
1.A.3.b.i	2020	PM10	-29.6
1.A.3.b.i	2020	EC	-30.4
1.A.3.b.i	2020	OC	-28.5
1.A.3.b.i	2020	BaP	-28.6
1.A.3.b.i	2020	N2O	-26.5
1.A.3.b.i	2020	NH3	-9.8
1.A.3.b.i	2020	Cd	-17.9
1.A.3.b.i	2020	NOx	-28.2
1.A.3.b.i	2020	VOC	-8.9
1.A.3.b.i	2020	PM2.5	-29.6
1.A.3.b.i	2020	CH4	-5.8
1.A.3.b.i	2020	CO	-8.3
1.A.3.b.i	2020	CO2	-19.6
1.A.3.b.i	2020	As	-

1.A.3.b.i	2020	Pb	-23.6
1.A.3.b.ii	2020	Hg	-
1.A.3.b.ii	2020	SO2	-19.3
1.A.3.b.ii	2020	PM10	-20.2
1.A.3.b.ii	2020	EC	-20.2
1.A.3.b.ii	2020	OC	-20.0
1.A.3.b.ii	2020	BaP	-20.0
1.A.3.b.ii	2020	N2O	-19.2
1.A.3.b.ii	2020	NH3	-12.4
1.A.3.b.ii	2020	Cd	-18.2
1.A.3.b.ii	2020	NOx	-20.0
1.A.3.b.ii	2020	VOC	-16.4
1.A.3.b.ii	2020	PM2.5	-20.2
1.A.3.b.ii	2020	CH4	-3.6
1.A.3.b.ii	2020	CO	-10.1
1.A.3.b.ii	2020	CO2	-18.7
1.A.3.b.ii	2020	As	-
1.A.3.b.ii	2020	Pb	-19.6
1.A.3.b.iii	2020	Hg	-
1.A.3.b.iii	2020	SO2	-2.7
1.A.3.b.iii	2020	PM10	-2.7
1.A.3.b.iii	2020	EC	-2.7
1.A.3.b.iii	2020	OC	-2.7
1.A.3.b.iii	2020	BaP	-2.7
1.A.3.b.iii	2020	N2O	-2.7
1.A.3.b.iii	2020	NH3	-2.7
1.A.3.b.iii	2020	Cd	-2.7

1.A.3.b.iii	2020	NOx	-2.7
1.A.3.b.iii	2020	VOC	-2.7
1.A.3.b.iii	2020	PM2.5	-2.7
1.A.3.b.iii	2020	CH4	-2.7
1.A.3.b.iii	2020	CO	-2.7
1.A.3.b.iii	2020	CO2	-2.7
1.A.3.b.iii	2020	As	-
1.A.3.b.iii	2020	Pb	-2.7
1.A.3.b.iv	2020	Hg	-
1.A.3.b.iv	2020	SO2	-3.9
1.A.3.b.iv	2020	PM10	-3.9
1.A.3.b.iv	2020	EC	-3.9
1.A.3.b.iv	2020	OC	-3.9
1.A.3.b.iv	2020	BaP	-3.9
1.A.3.b.iv	2020	N2O	-3.9
1.A.3.b.iv	2020	NH3	-3.9
1.A.3.b.iv	2020	Cd	-3.9
1.A.3.b.iv	2020	NOx	-3.9
1.A.3.b.iv	2020	VOC	-3.9
1.A.3.b.iv	2020	PM2.5	-3.9
1.A.3.b.iv	2020	CH4	-3.9
1.A.3.b.iv	2020	CO	-3.9
1.A.3.b.iv	2020	CO2	-3.9
1.A.3.b.iv	2020	As	-
1.A.3.b.iv	2020	Pb	-3.9
1.A.3.b.vii	2020	Hg	-
1.A.3.b.vii	2020	SO2	-

1.A.3.b.vii	2020	PM10	-13.9
1.A.3.b.vii	2020	EC	-13.9
1.A.3.b.vii	2020	OC	-14.0
1.A.3.b.vii	2020	BaP	-14.4
1.A.3.b.vii	2020	N2O	-
1.A.3.b.vii	2020	NH3	-
1.A.3.b.vii	2020	Cd	-14.2
1.A.3.b.vii	2020	NOx	-
1.A.3.b.vii	2020	VOC	-
1.A.3.b.vii	2020	PM2.5	-13.9
1.A.3.b.vii	2020	CH4	-
1.A.3.b.vii	2020	CO	-
1.A.3.b.vii	2020	CO2	-
1.A.3.b.vii	2020	As	-14.1
1.A.3.b.vii	2020	Pb	-14.1
1.A.3.b.v	2020	VOC	-2.3
1.A.3.b.i	2030	Hg	-
1.A.3.b.i	2030	SO2	-54.7
1.A.3.b.i	2030	PM10	-87.5
1.A.3.b.i	2030	EC	-92.5
1.A.3.b.i	2030	OC	-85.1
1.A.3.b.i	2030	BaP	-89.3
1.A.3.b.i	2030	N2O	-84.4
1.A.3.b.i	2030	NH3	-13.4
1.A.3.b.i	2030	Cd	-43.1
1.A.3.b.i	2030	NOx	-88.2
1.A.3.b.i	2030	VOC	7.1

1.A.3.b.i	2030	PM2.5	-87.5
1.A.3.b.i	2030	CH4	12.2
1.A.3.b.i	2030	CO	0.2
1.A.3.b.i	2030	CO2	-50.4
1.A.3.b.i	2030	As	-
1.A.3.b.i	2030	Pb	-66.3
1.A.3.b.ii	2030	Hg	-
1.A.3.b.ii	2030	SO2	-84.2
1.A.3.b.ii	2030	PM10	-98.6
1.A.3.b.ii	2030	EC	-99.6
1.A.3.b.ii	2030	OC	-96.2
1.A.3.b.ii	2030	BaP	-96.8
1.A.3.b.ii	2030	N2O	-89.4
1.A.3.b.ii	2030	NH3	-10.2
1.A.3.b.ii	2030	Cd	-74.8
1.A.3.b.ii	2030	NOx	-97.8
1.A.3.b.ii	2030	VOC	-10.2
1.A.3.b.ii	2030	PM2.5	-98.6
1.A.3.b.ii	2030	CH4	66.3
1.A.3.b.ii	2030	CO	140.6
1.A.3.b.ii	2030	CO2	-79.8
1.A.3.b.ii	2030	As	-
1.A.3.b.ii	2030	Pb	-90.3
1.A.3.b.iii	2030	Hg	-
1.A.3.b.iii	2030	SO2	-75.0
1.A.3.b.iii	2030	PM10	-75.0
1.A.3.b.iii	2030	EC	-75.0

1.A.3.b.iii	2030	OC	-75.0
1.A.3.b.iii	2030	BaP	-75.0
1.A.3.b.iii	2030	N2O	-75.0
1.A.3.b.iii	2030	NH3	-75.0
1.A.3.b.iii	2030	Cd	-75.0
1.A.3.b.iii	2030	NOx	-75.0
1.A.3.b.iii	2030	VOC	-75.0
1.A.3.b.iii	2030	PM2.5	-75.0
1.A.3.b.iii	2030	CH4	-75.0
1.A.3.b.iii	2030	CO	-75.0
1.A.3.b.iii	2030	CO2	-75.0
1.A.3.b.iii	2030	As	-
1.A.3.b.iii	2030	Pb	-75.3
1.A.3.b.iv	2030	Hg	-
1.A.3.b.iv	2030	SO2	-75.0
1.A.3.b.iv	2030	PM10	-75.0
1.A.3.b.iv	2030	EC	-75.0
1.A.3.b.iv	2030	OC	-75.0
1.A.3.b.iv	2030	BaP	-75.0
1.A.3.b.iv	2030	N2O	-75.0
1.A.3.b.iv	2030	NH3	-75.0
1.A.3.b.iv	2030	Cd	-75.0
1.A.3.b.iv	2030	NOx	-75.0
1.A.3.b.iv	2030	VOC	-75.0
1.A.3.b.iv	2030	PM2.5	-75.0
1.A.3.b.iv	2030	CH4	-75.0
1.A.3.b.iv	2030	CO	-75.0

1.A.3.b.iv	2030	CO2	-75.0
1.A.3.b.iv	2030	As	-
1.A.3.b.iv	2030	Pb	-74.6
1.A.3.b.vii	2030	Hg	-
1.A.3.b.vii	2030	SO2	-
1.A.3.b.vii	2030	PM10	-28.4
1.A.3.b.vii	2030	EC	-28.4
1.A.3.b.vii	2030	OC	-28.3
1.A.3.b.vii	2030	BaP	-28.3
1.A.3.b.vii	2030	N2O	-
1.A.3.b.vii	2030	NH3	-
1.A.3.b.vii	2030	Cd	-28.5
1.A.3.b.vii	2030	NOx	-
1.A.3.b.vii	2030	VOC	-
1.A.3.b.vii	2030	PM2.5	-28.3
1.A.3.b.vii	2030	CH4	-
1.A.3.b.vii	2030	CO	-
1.A.3.b.vii	2030	CO2	-
1.A.3.b.vii	2030	As	-28.0
1.A.3.b.vii	2030	Pb	-28.0
1.A.3.b.v	2030	VOC	6.0

Milan: Policy scenario 2 - ELECTRIC BUS

Conversion of public buses to electric ones

Description of the scenario

This scenario considers the conversion of the public bus fleet to an electric fleet and improvements of service and efficiency. The bus fleet will be completely electric by 2030. ATM, Milan's municipal public transport company, has launched last year the most ambitious Italian project to date aimed to the electrification of bus fleet. ATM plans to convert the whole fleet (1,200 buses) to zero emission electric drives by 2030. Now, 25 electric buses by Solaris company are running in the city. A 250 electric bus tender is underway. From 2020 on, ATM will buy only and exclusively electric vehicles.

Shortly diesel will disappear from the automotive fleet of ATM (local public transport company), which will consist of 1,200 new buses, all electric by 2030. Thus, Milan will be one of the first cities in Italy and Europe to provide a full electric public transport service.

The Investment Plan approved by the ATM goes beyond the "simple" electrification of the busses. The main goal is to "improve service, efficiency, accessibility" in addition to the zero emissions target. More than 70% of the resources will be dedicated to environmentally sustainable investments.

The farewell to the diesel will come in 4 moves:

1. 1200 electric buses
2. Renewal of current deposits
3. 4 new full electric hubs
4. Charging infrastructure

Milan will go even further, because the entire fleet will be electric, even the one that will serve the suburbs and territories of the Metropolitan City. And to accommodate, maintain and operate the new buses, three depots will be renovated, four innovative structures will be built, and two former diesel depots will be converted.

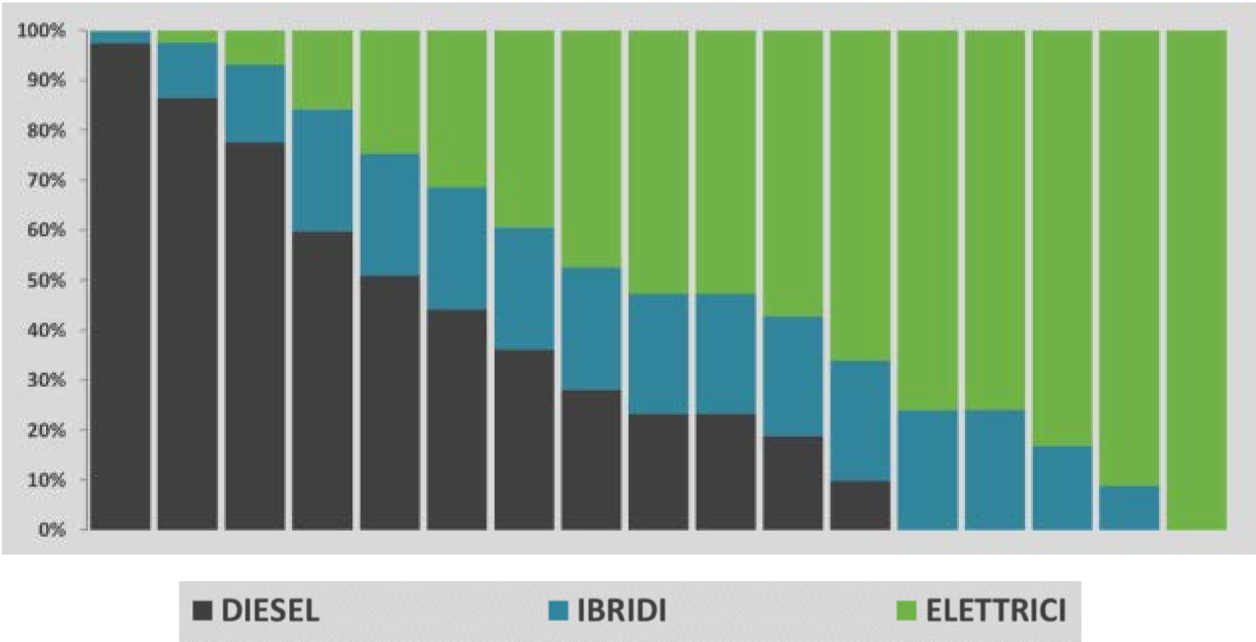
A first step has already been taken with the purchase of 25 electric buses and 22 new hybrid buses. The new 12-meter electric buses were purchased as a result of a public evidence tender process that saw the award to Solaris Bus & Coach SA. They are equipped with air conditioning, video-surveillance and station for transport of people with disability without lift thanks to the fully low floor.

The new buses are in line with fleet-related emission reduction programs to be used in local public transport in the urban area of Milan. They are powered by lithium-iron-phosphorus batteries (with a total capacity of 240 kWh) that guarantee a range of about 180 km, without producing any kind of polluting emission (zero particulate matter, zero nitrogen oxides, zero carbon monoxide and carbon dioxide).

Batteries are recharged in about 5 hours on the way back to storage, thanks to a charging column with a power of 80 kW.

When Milan has abandoned diesel, it will consume 30 million litres less of diesel per year and the production of carbon dioxide will be reduced by almost 75,000 tonnes per year.

Below is the graph on the renewal of the fleet until 2030:



Applicability

Years: 2020, 2030

(policy time horizon 2018 – 2030)

City zones: All

Assumptions for emission modelling

Affected sector: 1A3biii

Transport: Heavy Duty Trucks and Buses

Change in activity

For 2020 scenario the assumption is that 1/6 of the traditional buses will be converted into electric ones, according to data available from the municipality and public transport agency, therefore 1/6 of the activity related to buses (yearly kilometres run) has been subtracted from the BAU scenario and new emissions calculated. In 2030 scenario all buses are electric ones. In NFR sector code 1.A.3.b.iii there are both heavy duty trucks and buses: because of the structure of Milan Emission Inventory with emissions data referred to HDT and buses together, an estimate ratio of the activities between HDT and buses has been calculated in order to recalculate the activities of HDT which in BAU 2030 scenario were considered together with the buses. In both 2020 and 2030 scenarios, emissions from road abrasion due to buses are the same of BAU because electric buses will run the same kilometres of the previous ones.

Change in emission factor

None

(Future changes in EFs have been already considered in BAU 2020-2030 scenarios, and here the same changes have been taking into account for each type of vehicle.)

Further assumptions

The additional electricity production used for the new electric buses has not been taken into account in the new emission scenario, because it will be imported from outside the city boundaries.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1.A.3.b.iii	2020	All	3.7
1.A.3.b.iii	2030	All	35.5

Milan: Policy scenario 3 - BUILDINGS

Improvement of energy efficiency in existing and new residential flats

Description of the scenario

This scenario considers several improvements of the energy efficiency in existing and new residential flats.

A predominant share of energy consumption in the municipality (85%) consists of consumption in the civil sector. The term "civil sector" refers here to the sector it covers: energy consumption for heating in buildings (residential and other destinations of use), domestic energy uses (gas and electricity) and energy uses in the private non-residential sector (mainly electricity with a minimum share of gas for process uses).

Specifically, regarding the year 2013, the civil sector represents a total of 85% of consumption and 84% of CO2 emissions in the municipality. In detail, the heating of buildings accounts for 51% of consumption and 43% of emissions, domestic uses account for 10% of consumption and 11% of emissions, the other energy uses of the private sector 24% of consumption and 30% of emissions.

The energy redevelopment of existing buildings is, therefore, a priority and an opportunity for Milan.

The laws and guidelines at the national and regional level are oriented in this direction, recognizing in the energy renovation of buildings not only a need linked to energy saving and environmental protection, but also an opportunity for the economic development of the territory. A package of regulations to promote energy efficiency in the residential sector (existing and new buildings) has been taken into account:

- reduction of infrastructure charges for operations that enhance energy savings and use of renewable sources in new buildings or in existing buildings under renovation or enlargement;

- incentives for operations enhancing energy efficiency in private buildings, that are being introduced in the new planning tools under approval by the Local Administration (Master Plan of the Municipality of Milan, Building Regulation);

- financial incentives to replace or renovate heating plants and promote infrastructural operations on the building system;

- as the new building regulation enters into force and a set of regulations is already in operation (i.e. reduction of infrastructure charges), it is possible to foresee that new flats will be more energy efficient, in comparison with performance they would have had under previous regulations.

Sector	Electricity [GWh]	Natural Gas [GWh]	Diesel [GWh]	Gasoline [GWh]	LPG [GWh]	fluid thermo vector [GWh]	Total [GWh]
Buildings	1349	10474	2058	0	40	642	14563
Residential use	*1349*	*1061*	*0*	*0*	*0*	*0*	***2410***
Residential Heating	*0*	*6239*	*1364*	*0*	*27*	*426*	***8055***
tertiary and industrial heating	*0*	*3174*	*694*	*0*	*14*	*216*	***4098***
Public lighting	112	0	0	0	0	0	112
Industrial/tertiary uses	5138	586	0	0	0	0	5724
Transportation	281	79	1672	1319	163	0	3515
Public transport	*281*	*0*	*218*	*0*	*0*	*0*	***499***
Private Transport	*0*	*79*	*1454*	*1319*	*163*	*0*	***3016***
Total	6879	11139	3730	1319	204	642	23913

Applicability

Years: 2020, 2030

(policy time horizon 2015 – 2030)

City zones: All

Assumptions for emission modelling

Affected sector: 1A4bi, 1A4ai-1A5a

Change in activity

In this scenario the focus is on “Residential plants” with calculation done in terms of reduction of activity-emissions for the fuel “natural gas”, indeed in BAU scenarios 2020 – 2030 for the City of Milan, the usage of diesel and LPG in residential and commercial plants is already quite null due to previous policies.

The usage of wood and similar in BAU scenarios (and therefore in these scenarios as well) has been estimated yet with a reduction of 45-65% in the emissions due to the incoming policies-regulation (and related certification) about stoves efficiency.

Data available from Milan 2015 SEAP, with a 70% of the achievement/compliance for this set of measures, led to a -4,4% (vs. BAU2020) activity reduction for natural gas in residential plants for 2020, and no other data was available for future scenarios. Therefore, with the same assumptions, a reduction in this activity sector equal to -16,3 % has been considered for 2030 (vs. BAU2030).

Change in emission factor

None

Further assumptions

According to the SEAP CO2 emissions, are estimated at –295 kton per year. According to the SEAP, this policy would lead to an overall energy saving potential of 525,448 MWh/year heat fuels (45,189 tep/year) and 35,975 MWh/year of final electric (lower pump consumption) heating efficiency and lower consumption in household electrical uses). Electricity savings have not been taken into account because the production of the electricity is mainly outside the city boundaries.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1.A.4.b.i	2020	Hg	-4.6

1.A.4.b.i	2020	SO2	-2.7
1.A.4.b.i	2020	PM10	-0.5
1.A.4.b.i	2020	EC	-0.3
1.A.4.b.i	2020	OC	-0.7
1.A.4.b.i	2020	BaP	0.0
1.A.4.b.i	2020	N2O	-4.5
1.A.4.b.i	2020	NH3	0.0
1.A.4.b.i	2020	Cd	0.0
1.A.4.b.i	2020	NOx	-4.7
1.A.4.b.i	2020	VOC	-3.5
1.A.4.b.i	2020	PM2.5	-0.5
1.A.4.b.i	2020	CH4	-3.3
1.A.4.b.i	2020	CO	-3.1
1.A.4.b.i	2020	CO2	-4.7
1.A.4.b.i	2020	As	-4.7
1.A.4.b.i	2020	Pb	-0.1
1.A.4.b.i	2030	Hg	-2.7
1.A.4.b.i	2030	SO2	-3.7
1.A.4.b.i	2030	PM10	-62.4
1.A.4.b.i	2030	EC	-65.1
1.A.4.b.i	2030	OC	-60.1
1.A.4.b.i	2030	BaP	-19.6
1.A.4.b.i	2030	N2O	-4.3
1.A.4.b.i	2030	NH3	-42.3
1.A.4.b.i	2030	Cd	-42.2
1.A.4.b.i	2030	NOx	-1.4
1.A.4.b.i	2030	VOC	-41.8

1.A.4.b.i	2030	PM2.5	-60.1
1.A.4.b.i	2030	CH4	-17.8
1.A.4.b.i	2030	CO	-36.3
1.A.4.b.i	2030	CO2	-1.5
1.A.4.b.i	2030	As	-1.9
1.A.4.b.i	2030	Pb	-41.9
1.A.4.a.i ; 1.A.5.a	2020	Hg	-4.0
1.A.4.a.i ; 1.A.5.a	2020	SO2	-2.7
1.A.4.a.i ; 1.A.5.a	2020	PM10	-0.1
1.A.4.a.i ; 1.A.5.a	2020	EC	-0.1
1.A.4.a.i ; 1.A.5.a	2020	OC	-0.2
1.A.4.a.i ; 1.A.5.a	2020	BaP	0.0
1.A.4.a.i ; 1.A.5.a	2020	N2O	-3.8
1.A.4.a.i ; 1.A.5.a	2020	NH3	0.0
1.A.4.a.i ; 1.A.5.a	2020	Cd	0.0
1.A.4.a.i ; 1.A.5.a	2020	NOx	-4.1
1.A.4.a.i ; 1.A.5.a	2020	VOC	-1.5
1.A.4.a.i ; 1.A.5.a	2020	PM2.5	-0.1
1.A.4.a.i ; 1.A.5.a	2020	CH4	-2.2
1.A.4.a.i ; 1.A.5.a	2020	CO	-1.5
1.A.4.a.i ; 1.A.5.a	2020	CO2	-4.2
1.A.4.a.i ; 1.A.5.a	2020	As	-4.2
1.A.4.a.i ; 1.A.5.a	2020	Pb	0.0
1.A.4.a.i ; 1.A.5.a	2030	Hg	-17.8
1.A.4.a.i ; 1.A.5.a	2030	SO2	-16.5
1.A.4.a.i ; 1.A.5.a	2030	PM10	-0.8
1.A.4.a.i ; 1.A.5.a	2030	EC	-0.6

1.A.4.a.i ; 1.A.5.a	2030	OC	-1.2
1.A.4.a.i ; 1.A.5.a	2030	BaP	0.0
1.A.4.a.i ; 1.A.5.a	2030	N2O	-17.0
1.A.4.a.i ; 1.A.5.a	2030	NH3	0.0
1.A.4.a.i ; 1.A.5.a	2030	Cd	-0.1
1.A.4.a.i ; 1.A.5.a	2030	NOx	-18.1
1.A.4.a.i ; 1.A.5.a	2030	VOC	-8.1
1.A.4.a.i ; 1.A.5.a	2030	PM2.5	-0.9
1.A.4.a.i ; 1.A.5.a	2030	CH4	-11.0
1.A.4.a.i ; 1.A.5.a	2030	CO	-8.1
1.A.4.a.i ; 1.A.5.a	2030	CO2	-18.3
1.A.4.a.i ; 1.A.5.a	2030	As	-18.1
1.A.4.a.i ; 1.A.5.a	2030	Pb	-0.2

Milan: Policy scenario 4 - ENERGY

Incentive measures of new building regulation promote the use of photovoltaic solar power for buildings and implementation of district heating

Description of the scenario

This scenario considers the introduction of solar power/photovoltaics for building uses and district heating. One of the strategic actions of the Municipal Administration aimed at reducing polluting emissions due to heating is the development of the heating system to serve the municipality, which has seen in recent years a significant increase in terms of heat delivered and buildings connected.

The action considers the completion of A2A's (local public energy agency) remote heating development program based on the efficient and renewable production available in the city, which is expected to almost double the spread of the system by 2020, compared to the level of 2013, until reaching a total supply of thermal energy for the city of Milan amounting to about 1,200 GWh/year, and, at the same time, prepare the future development towards an even higher penetration of the service at the Metropolitan level.

To ensure this service, A2A plans to:

- saturate production capacity and optimize the efficiency of the management of existing plants distributed on the urban territory, with the creation of three large interconnected systems: Milan

West, Milan East, and Milan North/Sesto;

- integrate heat sources, otherwise dispersed into the environment, available in the environment (e.g. geothermal sources and third-party heat) into the system. In this sense, a heat recovery plant is being built today dispersed in the environment in the fumes at the Glassware;

- support the innovative design of the new building's user systems where possible, to promote the use of efficient local heating and cooling networks, to maximize the use of sources of energy. Renewables, heat recovery and energy efficient systems, both on the production side of the thermal carrier and demand side, also implementing exchange and reserve services of these systems from the integrated heating system.

Several photovoltaic projects have recently been started up. Incentive measures of the new building regulation could promote a further development of investments in this field, based on projects that have already been planned up to now.

One of the objectives of SEAP is the promotion and encouragement of energy production from renewable sources, such as solar thermal and photovoltaic, geothermal heat pumps. To do this the municipality has implemented some measures for its promotion such as:

- information to citizens and businesses, both permanent, in the context of energy counter activities, and at events or through ad hoc information campaigns;

- training activities for technicians, designers and installers, in collaboration with trade associations;

- simplification of authorization and administrative procedures.

Applicability

Years: 2020, 2030

(policy time horizon 2015 – 2030)

City zones: All

Assumptions for emission modelling

Affected sector: 1A1a, 1A2a-1A2f, 1A4bi, 1A4ai-1A5a

Change in activity

The improvements are considered in terms of energy saving. The summary for each affected sector affected (per different fuels) in terms of var.% compared to BAU scenarios 2020 and 2030 is reported in the next table.

Sector (NFR label)	**Fuel**	**Activity var.% compared to BAU 2020**	**Activity var.% compared to BAU 2030**
Public electricity and heat production	natural gas	-8.38	-20.35
Residential plants	natural gas	-5,77	-14,02
Residential plants	diesel	-3.91	n.a.
Residential plants	LPG	-3.91	n.a.
Commercial and institutional plants	diesel	-3.91	n.a.
Commercial and institutional plants	natural gas	-0.66	-1.60
Industry - Combustion in boilers, gas turbines and stationary engines (EF)	natural gas	-4.97	-12.08

Change in emission factor

None

Further assumptions

Data available from Milan 2015 SAEP, with a 70% of the achievement/compliance for these policies, led to activities reduction in 2020 scenario both in small combustion plants (SCP) than in large ones (LCP) because the improvement in the district heating and usage of renewable energies affect the energy production for public electricity and heat in local energy service plants located within the boundaries of the city.

These energy savings have been shared by different type of fuels (natural gas, diesel, LPG) considering their activity ratios in the specific sectors as reported in BAU 2020 scenario.

No official data was available for 2030 scenario, and therefore a linear regression for the calculation of future activities in these sectors has been taken into account. Electricity savings obtained with residential photovoltaic plants have not been considered for the new emission scenario because it replaces electricity consumption that did not affect BAU scenarios as well.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1.A.1.a	2020	Hg	-5.6
1.A.1.a	2020	SO2	-5.5
1.A.1.a	2020	PM10	-5.6
1.A.1.a	2020	EC	-5.6
1.A.1.a	2020	OC	-5.6
1.A.1.a	2020	BaP	-5.6
1.A.1.a	2020	N2O	-5.6
1.A.1.a	2020	NH3	-
1.A.1.a	2020	Cd	-3.4
1.A.1.a	2020	NOx	-5.6
1.A.1.a	2020	VOC	-5.6
1.A.1.a	2020	PM2.5	-5.6
1.A.1.a	2020	CH4	-5.6

1.A.1.a	2020	CO	-5.6
1.A.1.a	2020	CO2	-5.6
1.A.1.a	2020	As	-5.6
1.A.1.a	2020	Pb	-4.3
1.A.1.a	2030	Hg	-9.3
1.A.1.a	2030	SO2	-9.1
1.A.1.a	2030	PM10	-9.3
1.A.1.a	2030	EC	-9.3
1.A.1.a	2030	OC	-9.3
1.A.1.a	2030	BaP	-9.3
1.A.1.a	2030	N2O	-9.3
1.A.1.a	2030	NH3	-
1.A.1.a	2030	Cd	-5.7
1.A.1.a	2030	NOx	-9.3
1.A.1.a	2030	VOC	-9.3
1.A.1.a	2030	PM2.5	-9.3
1.A.1.a	2030	CH4	-9.3
1.A.1.a	2030	CO	-9.3
1.A.1.a	2030	CO2	-9.3
1.A.1.a	2030	As	-9.3
1.A.1.a	2030	Pb	-7.1
1.A.4.b.i	2020	Hg	-6.6
1.A.4.b.i	2020	SO2	-29.6
1.A.4.b.i	2020	PM10	-1.9
1.A.4.b.i	2020	EC	-4.5
1.A.4.b.i	2020	OC	-1.1
1.A.4.b.i	2020	BaP	-0.1

1.A.4.b.i	2020	N2O	-6.8
1.A.4.b.i	2020	NH3	0.0
1.A.4.b.i	2020	Cd	0.0
1.A.4.b.i	2020	NOx	-6.8
1.A.4.b.i	2020	VOC	-4.7
1.A.4.b.i	2020	PM2.5	-1.9
1.A.4.b.i	2020	CH4	-5.2
1.A.4.b.i	2020	CO	-4.3
1.A.4.b.i	2020	CO2	-6.8
1.A.4.b.i	2020	As	-6.2
1.A.4.b.i	2020	Pb	-0.2
1.A.4.b.i	2030	Hg	-12.4
1.A.4.b.i	2030	SO2	-37.0
1.A.4.b.i	2030	PM10	-75.7
1.A.4.b.i	2030	EC	-77.8
1.A.4.b.i	2030	OC	-74.0
1.A.4.b.i	2030	BaP	-48.8
1.A.4.b.i	2030	N2O	-15.5
1.A.4.b.i	2030	NH3	-63.3
1.A.4.b.i	2030	Cd	-63.2
1.A.4.b.i	2030	NOx	-10.7
1.A.4.b.i	2030	VOC	-56.7
1.A.4.b.i	2030	PM2.5	-74.3
1.A.4.b.i	2030	CH4	-35.9
1.A.4.b.i	2030	CO	-52.7
1.A.4.b.i	2030	CO2	-10.5
1.A.4.b.i	2030	As	-10.6

1.A.4.b.i	2030	Pb	-63.0
1.A.4.a.i ; 1.A.5.a	2020	Hg	-1.0
1.A.4.a.i ; 1.A.5.a	2020	SO2	-18.4
1.A.4.a.i ; 1.A.5.a	2020	PM10	-0.3
1.A.4.a.i ; 1.A.5.a	2020	EC	-0.8
1.A.4.a.i ; 1.A.5.a	2020	OC	-0.1
1.A.4.a.i ; 1.A.5.a	2020	BaP	0.0
1.A.4.a.i ; 1.A.5.a	2020	N2O	-1.2
1.A.4.a.i ; 1.A.5.a	2020	NH3	0.0
1.A.4.a.i ; 1.A.5.a	2020	Cd	0.0
1.A.4.a.i ; 1.A.5.a	2020	NOx	-1.1
1.A.4.a.i ; 1.A.5.a	2020	VOC	-0.3
1.A.4.a.i ; 1.A.5.a	2020	PM2.5	-0.3
1.A.4.a.i ; 1.A.5.a	2020	CH4	-0.8
1.A.4.a.i ; 1.A.5.a	2020	CO	-0.3
1.A.4.a.i ; 1.A.5.a	2020	CO2	-1.1
1.A.4.a.i ; 1.A.5.a	2020	As	-0.8
1.A.4.a.i ; 1.A.5.a	2020	Pb	-0.1
1.A.4.a.i ; 1.A.5.a	2030	Hg	-97.2
1.A.4.a.i ; 1.A.5.a	2030	SO2	-1.8
1.A.4.a.i ; 1.A.5.a	2030	PM10	-0.1
1.A.4.a.i ; 1.A.5.a	2030	EC	-0.1
1.A.4.a.i ; 1.A.5.a	2030	OC	-0.1
1.A.4.a.i ; 1.A.5.a	2030	BaP	0.0
1.A.4.a.i ; 1.A.5.a	2030	N2O	-1.8
1.A.4.a.i ; 1.A.5.a	2030	NH3	0.0
1.A.4.a.i ; 1.A.5.a	2030	Cd	0.0

1.A.4.a.i ; 1.A.5.a	2030	NOx	-1.9
1.A.4.a.i ; 1.A.5.a	2030	VOC	-0.9
1.A.4.a.i ; 1.A.5.a	2030	PM2.5	-0.1
1.A.4.a.i ; 1.A.5.a	2030	CH4	-1.2
1.A.4.a.i ; 1.A.5.a	2030	CO	-0.9
1.A.4.a.i ; 1.A.5.a	2030	CO2	-2.0
1.A.4.a.i ; 1.A.5.a	2030	As	-1.9
1.A.4.a.i ; 1.A.5.a	2030	Pb	0.0
1.A.2.a - 1.A.2.f	2020	Hg	-2.7
1.A.2.a - 1.A.2.f	2020	SO2	-0.2
1.A.2.a - 1.A.2.f	2020	PM10	-1.0
1.A.2.a - 1.A.2.f	2020	EC	-0.3
1.A.2.a - 1.A.2.f	2020	OC	-2.6
1.A.2.a - 1.A.2.f	2020	BaP	0.0
1.A.2.a - 1.A.2.f	2020	N2O	-2.1
1.A.2.a - 1.A.2.f	2020	NH3	0.0
1.A.2.a - 1.A.2.f	2020	Cd	0.0
1.A.2.a - 1.A.2.f	2020	NOx	-4.2
1.A.2.a - 1.A.2.f	2020	VOC	-0.8
1.A.2.a - 1.A.2.f	2020	PM2.5	-1.1
1.A.2.a - 1.A.2.f	2020	CH4	-3.0
1.A.2.a - 1.A.2.f	2020	CO	-3.1
1.A.2.a - 1.A.2.f	2020	CO2	-4.8
1.A.2.a - 1.A.2.f	2020	As	-1.3
1.A.2.a - 1.A.2.f	2020	Pb	0.0
1.A.2.a - 1.A.2.f	2030	Hg	-7.5
1.A.2.a - 1.A.2.f	2030	SO2	-0.7

1.A.2.a - 1.A.2.f	2030	PM10	-2.8
1.A.2.a - 1.A.2.f	2030	EC	-0.9
1.A.2.a - 1.A.2.f	2030	OC	-7.2
1.A.2.a - 1.A.2.f	2030	BaP	0.0
1.A.2.a - 1.A.2.f	2030	N2O	-5.8
1.A.2.a - 1.A.2.f	2030	NH3	0.0
1.A.2.a - 1.A.2.f	2030	Cd	0.0
1.A.2.a - 1.A.2.f	2030	NOx	-11.1
1.A.2.a - 1.A.2.f	2030	VOC	-2.2
1.A.2.a - 1.A.2.f	2030	PM2.5	-3.2
1.A.2.a - 1.A.2.f	2030	CH4	-8.2
1.A.2.a - 1.A.2.f	2030	CO	-8.5
1.A.2.a - 1.A.2.f	2030	CO2	-12.6
1.A.2.a - 1.A.2.f	2030	As	-3.8
1.A.2.a - 1.A.2.f	2030	Pb	0.0

Milan: Policy scenario 5 - TREES

Increasing the green area and planting over 3 million new trees by 2030

Description of the scenario

This scenario considers the greening of the city of Milan due to planting about 25000 new trees per year. Milan has decided to promote a new green policy that involves planting 3 million trees on the metropolitan staircase. The very ambitious project aims to achieve this goal by the end of 2030.

The scenario aims to respond to different city issues. First, it aims to reduce emissions by plants' ability to absorb pollutants. However, try to cope with other challenges: countering the effect of heat islands and increasing the city's green cover. To date, Milan has a canopy tree that is only 7 percent, much less than half compared with other European and world cities such as New York. This massive intervention (also linked to the increase of green areas) will bring Milan to the levels of other cities, reaching 20-23%.

At the city level, in particular, the municipality has planned to plant 25,000 new trees per year, to reach a total of about 250 000 trees by 2030.

Applicability

Years: 2020, 2030

(policy time horizon 2018 – 2030)

City zones: All

Assumptions for emission modelling

Affected sector: All

Change in activity

None (please see Further assumptions)

Change in emission factor

None (please see Further assumptions)

Further assumptions

It should be specified that this policy is really new and it was recently introduced by the City of Milan, which entrusted its development to the Polytechnic University of Milan and, in particular, by Studio Boeri company. At present, there are still no estimates of how much this measure will affect the health of the city and therefore the reduction of emissions.

Investigations of similar policies around the world were carried out to make an estimate as close to the reality as possible of the quantity of pollutants removed from the atmosphere by plants. The literature in this area is very extensive but at the same time gaping. The following data are therefore the set of multiple documents and studies carried out mainly in the United States where similar policies are also widespread in contrast to land use.

In particular, we used the paper "Calculating the value of Boulder's Urban Forest"[59] chapter four prepared by the City of Boulder that shows the annual benefits of the forestation program done in the city.

We estimated a subtraction of pollutants (O3, SO3, NO2, PM10, CO) libre/acre tree canopy per year. We relied on the objective of increasing the tree canopy from the current 18% to 26% by 2030 with a constant increase of 0.8% per annum up to 2030 and thus multiplying the values for the number of acres implemented each year.

For emissions/removal of CH_4 and VOCs by trees the debate is still open in scientific literature as well. Specifically, from one side they can be considered as emitters of these pollutants, from the other side, considering them useful for climate mitigation, they can avoid emission from combustion

[59] http://bcn.boulder.co.us/basin/boulder/urbanforest/onthispage.pdf

plants / electricity production (heating/cooling). Nowadays, scientific papers that match together the effects of trees as solid barriers for deposition of pollutants/ pollutants sequestration/ emitters/ energy savers cannot be found. Therefore here the assumption is to consider the reduction/contribution by trees for VOC and CH_4 as zero, in order to balance the positive and negative effects of them.

Given the above mentioned assumptions, the scenario has been modelled by assuming a removal efficiency for different pollutants by the planted trees (see section Emission reduction potential). Therefore, no change in activities or emission factors has been considered, but a decrease in absolute emissions. The absolute removal of pollutants for 2020 and 2030 is as follows:

Removal of pollutants		2020	2030
O3	t	2.3	25.7
PM10	t	1.0	11.2
NOx	t	0.4	4.9
CO	t	0.1	0.9
SO2	t	0.3	2.8
PM2.5	t	0.2	1.9
CO2	kt	0.8	8.8

Emission reduction potential

The emission reduction potential for this measure is given as emission removal efficiency. The emission removal efficiency for the different pollutants compared to the total emissions in Milan city area is as follows:

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission removal efficiency [%]
All	2020	SO2	0.33
All	2020	PM10	0.25
All	2020	NOx	0.01
All	2020	PM2.5	0.06
All	2020	CO	0.001

All	2020	CO2	0.03
All	2030	SO2	4.57
All	2030	PM10	3.42
All	2030	NOx	0.09
All	2030	PM2.5	0.85
All	2030	CO	0.02
All	2030	CO2	0.28

Stuttgart: Policy scenario 1 - Sc1

Increase of building insulation and heating system exchange from oil to high efficiency gas boilers, district heating and heat pumps in the residential and commercial sector

Description of the scenario

This policy scenario aims at reducing emissions related to the energy consumption of buildings by promoting insulation and renovation and the replacement of old heating systems. It therefore will affect two individual sectors: the residential sector (1A4bi) and the commercial sector (1A4ai).

Several sub-measures like municipal subsidies, founding of an energy advice centre for public outreach, energy performance contracting and energy consulting for building owners aim at increasing the renovation rate of residential buildings in Stuttgart. To achieve ambitious climate protection targets it is also necessary to energetically modernize non-residential buildings. On the city level, there are two measures that lead to the energetic renovation of non-residential buildings. i.e. the municipal promotion program for Stuttgart companies and commitment of the Stuttgart companies to climate protection in corporate management.[60]

The renovation of residential buildings in the early years comprises mainly the thermal insulation of the buildings envelop and the window replacement. After 2030, we expect that the insulation is accompanied by the installation of a mechanical ventilation system with heat recovery unit whenever the building meets necessary criteria.

In the residential sector (1A4bi), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope, windows replacement)
- Mechanical ventilation system with heat recovery for later years

In the commercial sector (1A4ai), the energy saving measure consists of:

- Improving the energy efficiency of buildings (thermal insulation of the entire building envelope: façade, roof, ceilings; windows replacement)
- Modernisation of indoor lighting system
- Modernisation of ventilation (with heat recovers) and air conditioning systems

Furthermore, the scenario aims at reducing emissions from domestic heating by replacing old coal- and oil-fired boilers by natural gas-fired high efficiency boilers, heat pumps, district heating and solar thermal collectors and therefore affects the residential sector 1A4bi and non-residential sector 1A4ai. The replacement of coal or oil fired boilers in residential and non-residential buildings will be

[60] Fraunhofer-Institute für Bauphsik IBP, Universität Stuttgart: Masterplan 100% Klimaschutz der Landeshauptstadt Stuttgart. 2017, https://www.stuttgart.de/img/mdb/item/620298/129654.pdf, 10.11.2018

fostered by respective funding schemes[61]. The introduction of wood pellet or biomass boilers in the inner city centre is not promoted due to unfavourable particulate matter emissions.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A4bi, 1A4ai

Change in activity

The energetic renovation leads to a decrease of heating and cooling energy demand and therefore final energy consumption (i.e. the activity level). We expect the building renovation rate to increase from 1%/a to 3%/a and for the milestone year 2030 to a more ambitious target of 4%/a. The renovation rate of residential buildings increases by 2% until 2030 (start of the measure was in 2017). The reduction of final energy is estimated to be approx. 40% per renovated building until 2020. After 2020 the renovation rate increases even further, i.e. 3% increase compared to the business as usual scenario. The final energy consumption reduction for heating of renovated households after 2020 is estimated to be 30% as a decrease of the energy saving potential for newer buildings has been assumed[62]. The efficiency increase of the heating system (after the gas heating system exchange) contributes with 10% to total final energy reductions. After 2020 the installation of mechanical ventilation systems with heat recovery contributes further 14% reductions in heating energy to each building equipped with the system.

The final energy consumption reduction of commercial buildings is estimated to be about 30% in 2030 (no reduction has been assumed until 2020). The high reduction potential partly can be explained by the renovation measures and subsequent reduction of energy demand and partly is due to the fact that the energy consumption of fuels drastically decreases due to the connection to district heating for building complexes.

The assumed final energy reduction is therefore 5% in 2020 and 19% in 2030 for residential buildings and 30% reduction for commercial buildings.

The replacement of coal and oil boilers leads to a shift in the activity categories from oil/coal fuels to gas and renewable energy sources. The shift in the fuel type and heating system type (gas to high efficiency boilers) has been modelled as an activity change under the assumption that the total amount of building heating systems remains constant in the city.

---

[61] https://www.stuttgart.de/heizungsaustauschprogramm (checked on July 28 2019)

[62] reduction potential for each building estimated according to a personal note from City of Stuttgart 5.12.2017

Change in emission factor

None

Further assumptions

It has been assumed that the exchange of the heating system takes place after reaching the end of the life span for each boiler.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 4 a i	2020	BC	29
1 A 4 a i	2020	CH4	-74
1 A 4 a i	2020	CO	4
1 A 4 a i	2020	CO2	4
1 A 4 a i	2020	N2O	18
1 A 4 a i	2020	NH3	-
1 A 4 a i	2020	NMVOC	16
1 A 4 a i	2020	NOx	21
1 A 4 a i	2020	OC	8
1 A 4 a i	2020	PM10	19
1 A 4 a i	2020	PM25	21
1 A 4 a i	2020	SO2	23
1 A 4 b i	2020	BC	3
1 A 4 b i	2020	CH4	2
1 A 4 b i	2020	CO	2
1 A 4 b i	2020	CO2	7
1 A 4 b i	2020	N2O	8
1 A 4 b i	2020	NH3	-

1 A 4 b i	2020	NMVOC	2
1 A 4 b i	2020	NOx	8
1 A 4 b i	2020	OC	2
1 A 4 b i	2020	PM10	2
1 A 4 b i	2020	PM25	2
1 A 4 b i	2020	SO2	7
1 A 4 a i	2030	BC	64
1 A 4 a i	2030	CH4	8
1 A 4 a i	2030	CO	35
1 A 4 a i	2030	CO2	33
1 A 4 a i	2030	N2O	55
1 A 4 a i	2030	NH3	-
1 A 4 a i	2030	NMVOC	46
1 A 4 a i	2030	NOx	55
1 A 4 a i	2030	OC	37
1 A 4 a i	2030	PM10	49
1 A 4 a i	2030	PM25	51
1 A 4 a i	2030	SO2	55
1 A 4 b i	2030	BC	21
1 A 4 b i	2030	CH4	15
1 A 4 b i	2030	CO	20
1 A 4 b i	2030	CO2	20
1 A 4 b i	2030	N2O	27
1 A 4 b i	2030	NH3	-
1 A 4 b i	2030	NMVOC	20
1 A 4 b i	2030	NOx	29
1 A 4 b i	2030	OC	21

1 A 4 b i	2030	PM10	21
1 A 4 b i	2030	PM25	21
1 A 4 b i	2030	SO2	26

Stuttgart: Policy scenario 2 - FvH

Blue badge: Introduction of a driving ban on diesel vehicles less than Euro 6 standard and gasoline vehicles less than Euro 3 standard in the city of Stuttgart

Description of the scenario

This scenario considers the introduction of a driving ban on diesel vehicles less than Euro 6 / VI standard and gasoline vehicles less than Euro 3 standard in the city of Stuttgart.

Since January 1, 2019, the Stuttgart environmental zone - entire city area – is subject to a traffic ban for all vehicles with diesel engines less than the Euro 4 / IV emission standard. Local residents in Stuttgart are affected by the diesel traffic ban since 1 April 2019. Currently, Euro 5 / V diesel cars are excluded from the ban. A possible traffic ban also for such vehicles is currently being prepared by the state of Baden-Württemberg on the basis of a decision of the Administrative Court of Baden-Württemberg of November 2018. Whether a traffic ban for Euro 5 / V vehicles is actually required, will be decided after a review of current pollutant levels in mid-2019. This scenario analysis the effect of a potential ban on diesel cars with less than Euro 6 / VI standard and petrol vehicles with less than Euro 3 standard. Therefore, the introduction of a "blue badge" allows all motor vehicles with diesel engines from Euro 6 / VI onwards, all motor vehicles with petrol engines (petrol and gas-powered) from Euro 3, as well as all vehicles without internal combustion engine (pure electric and fuel cell vehicles) to enter the city.

The scenario additionally includes a retrofitting or hardware update of diesel passenger cars with Euro 6 and Euro 5 standard. The hardware update comprises the installation of an additional SCR system (selective catalytic reduction) for AdBlue injection. The SCR system aims at reducing the emitted NOx due to chemical transformation processes.

This scenario combines elements of technical and non-technical measures. The driving ban is clearly a non-technical measure affecting the vehicle stock and therefore the vehicle level of certain emission standards. The retrofitting of diesel passenger cars, less than Euro 6, is a technical measure that changes the emission factors of the respective vehicles. Made assumptions for both categories are described below.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi, 1A3bii, 1A3biii

Change in activity

According to the banning regulation, reported in the description of the scenario, the new activities (yearly vehicle kilometres run) have been calculated for each type of vehicles for 2020 and 2030 scenarios, subtracting from BAU scenario the activities that would have been run for vehicles banned in that year and replacing them by activities of higher Euro standards. The vehicle kilometres of banned vehicles (Euro 1-5) have been assigned to Euro 6, 6dtemp, 6d standard categories maintaining the same proportion of vehicle kilometres between these types as they are currently present in the business as usual scenario.

The calculation assumes that 20 percent of vehicles that do not meet the requirements for a blue badge would be subject to exceptions from the ban (vehicles in classes Euro 3- Euro 5). This value is very generous, so as not to overestimate the effect of the blue environmental zone. For buses no exceptions have been assumed.

Emissions due to road abrasion and gasoline evaporation have been recalculated in agreement with the assumptions described above.

Change in emission factor

The assumed reduction potential for NOx emission is 75% and the potential for retrofitting among diesel passenger cars is assumed to be 91%, resp. 30%.[63]

---

[63] Bundesministerium für Verkehr und digitale Infrastruktur (Ed.) (2018a): Studie über das Potenzial einer Realisierung einer Hardware-Nachrüstung für Dieselfahrzeuge EU5 (EU4) zur NOx Reduzierung, checked on 5/28/2018.

Bundesministerium für Verkehr und digitale Infrastruktur (Ed.) (2018b): Wissenschaftliche Untersuchungen hardwareseitiger NOx Reduzierungsnachrüstmöglichkeiten im PKW Bereich und im Segment der leichten Nutzfahrzeuge. Kurzstudie, checked on 5/28/2018.

LfU (2018): Luftreinhalteplanung - Maßnahmen gegen Feinstaub und Stickstoffoxide, checked on 12/7/2018

UBA (Ed.) (2017): Ergänzung der Bewertung zu marktverfügbaren fahrzeugseitignen NOx-Nachrüsttechnologien und Bewertung der Nachbesserung, checked on 12/17/2018.

https://www.autozeitung.de/euro-6-nachruesten-183792.html (checked on 28/07/2019)

https://www.auto-motor-und-sport.de/verkehr/eu5-diesel-nachruestung-scr-kat-fahrverbote/ (checked on

Further assumptions

Due to the fact that the introduction of the diesel ban for vehicles less than Euro 5 has already put into force from 2019 on, the Stuttgart fleet has undergone a significant change in the share of diesel and passenger cars. The diesel share of cars passing the Neckartor is now at the same level as in 2013: at 42%, the dynamic total fleet is at 48%. This means that journeys with diesel passenger cars are again decreasing, as petrol cars are increasing. Other types of fuel remain at a very low level[64]. This trend has also been taken into account in the baseline scenario future years, despite the fact that the future development is quite difficult to predict as the long-term effect of the banning is inherently subject to uncertainties. Additionally, the assumption that banned vehicle kilometres will be replaced by all non-banned Euro standards to the proportion as present in the baseline scenario for the respective year (and not just by the latest available technology) represents a rather conservative scenario. The results in terms of emission reductions for this scenario therefore represent the lower boundary of possible reductions.

Furthermore, a retrofitting or hardware update of diesel passenger cars with Euro 6 and Euro 5 standard is part of the scenario. A retrofitting of Euro 4 vehicles is considered to be economically unfeasible due to limited space, higher costs for the installation of the system (higher time requirements, technical issues) and a low residual value of the vehicle.[65] The time horizon of the measure is not completely definable, since the possibility of a widespread market launch is still questionable (for newly developed systems 3-4 years)[66]. Furthermore, the technical implementation in all vehicle types (engine sizes) is still under discussion due to limitations of the installation space. Taken into account the points described above, the measure is applied to the vehicle fleet in 2020 and 2030.

At present the construction and transport of the SCR system, the fuel transport to the city due to higher fuel consumption of the cities, the disposal of the SCR system additionally to a conventional car, and the emissions resulting from the additional AdBlue production are not included into the scenario assessment. The heating and dosage of the urea (AdBlue) leads to an increased energy consumption of the vehicle (about 5%). All these factors play a role in a holistic assessment of the

28/07/2019)

[64] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, checked on 3/22/2019.

[65] Bundesministerium für Verkehr und digitale Infrastruktur (Ed.) (2018b): Wissenschaftliche Untersuchungen hardwareseitiger NOx Reduzierungsnachrüstmöglichkeiten im PKW Bereich und im Segment der leichten Nutzfahrzeuge. Kurzstudie, checked on 5/28/2018.

[66] Bundesministerium für Verkehr und digitale Infrastruktur (Ed.) (2018b): Wissenschaftliche Untersuchungen hardwareseitiger NOx Reduzierungsnachrüstmöglichkeiten im PKW Bereich und im Segment der leichten Nutzfahrzeuge. Kurzstudie, checked on 5/28/2018.

measure, but the effect is expected to be rather negligible when considering the city level.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i	2020	BC	-68,2%
1 A 3 b i	2020	CH4	-1,8%
1 A 3 b i	2020	CO	-1,4%
1 A 3 b i	2020	CO2	-0,7%
1 A 3 b i	2020	N2O	-1,4%
1 A 3 b i	2020	NH3	-2,6%
1 A 3 b i	2020	NMVOC	-4,9%
1 A 3 b i	2020	NOx	-24,6%
1 A 3 b i	2020	OC	-20,0%
1 A 3 b i	2020	PM10	-4,9%
1 A 3 b i	2020	PM25	-8,1%
1 A 3 b i	2020	SO2	-0,7%
1 A 3 b i	2030	BC	-38,9%
1 A 3 b i	2030	CH4	-0,1%
1 A 3 b i	2030	CO	-0,1%
1 A 3 b i	2030	CO2	-0,1%
1 A 3 b i	2030	N2O	-0,1%
1 A 3 b i	2030	NH3	-0,1%
1 A 3 b i	2030	NMVOC	-0,4%
1 A 3 b i	2030	NOx	-24,0%
1 A 3 b i	2030	OC	-4,7%

1 A 3 b i	2030	PM10	-1,0%
1 A 3 b i	2030	PM25	-1,7%
1 A 3 b i	2030	SO2	-0,1%
1 A 3 b ii	2020	BC	-71,0%
1 A 3 b ii	2020	CH4	-1,5%
1 A 3 b ii	2020	CO	-1,3%
1 A 3 b ii	2020	CO2	-0,5%
1 A 3 b ii	2020	N2O	0,0%
1 A 3 b ii	2020	NH3	0,0%
1 A 3 b ii	2020	NMVOC	-26,8%
1 A 3 b ii	2020	NOx	-47,9%
1 A 3 b ii	2020	OC	-24,2%
1 A 3 b ii	2020	PM10	-5,0%
1 A 3 b ii	2020	PM25	-8,5%
1 A 3 b ii	2020	SO2	-0,5%
1 A 3 b ii	2030	BC	-48,5%
1 A 3 b ii	2030	CH4	-0,6%
1 A 3 b ii	2030	CO	-0,4%
1 A 3 b ii	2030	CO2	-0,1%
1 A 3 b ii	2030	N2O	0,0%
1 A 3 b ii	2030	NH3	0,0%
1 A 3 b ii	2030	NMVOC	-23,2%
1 A 3 b ii	2030	NOx	-22,6%
1 A 3 b ii	2030	OC	-6,2%
1 A 3 b ii	2030	PM10	-1,0%
1 A 3 b ii	2030	PM25	-1,8%
1 A 3 b ii	2030	SO2	-0,1%

1 A 3 b iii	2020	BC	-64,8%
1 A 3 b iii	2020	CH4	-9,5%
1 A 3 b iii	2020	CO	-45,7%
1 A 3 b iii	2020	CO2	-0,2%
1 A 3 b iii	2020	N2O	-1,3%
1 A 3 b iii	2020	NH3	0,0%
1 A 3 b iii	2020	NMVOC	-7,1%
1 A 3 b iii	2020	NOx	-8,4%
1 A 3 b iii	2020	OC	-27,9%
1 A 3 b iii	2020	PM10	-6,6%
1 A 3 b iii	2020	PM25	-11,1%
1 A 3 b iii	2020	SO2	-0,2%
1 A 3 b iii	2030	BC	-52,8%
1 A 3 b iii	2030	CH4	-3,8%
1 A 3 b iii	2030	CO	-13,3%
1 A 3 b iii	2030	CO2	0,1%
1 A 3 b iii	2030	N2O	0,4%
1 A 3 b iii	2030	NH3	0,0%
1 A 3 b iii	2030	NMVOC	-4,3%
1 A 3 b iii	2030	NOx	-1,4%
1 A 3 b iii	2030	OC	-9,1%
1 A 3 b iii	2030	PM10	-1,3%
1 A 3 b iii	2030	PM25	-2,3%
1 A 3 b iii	2030	SO2	0,1%

Stuttgart: Policy scenario 3 - ScUV

Promoting environmentally friendly transportation modes like walking, cycling and public transportation leading to a decrease of individual transport by 7% in 2020 and 20% in 2030

Description of the scenario

The aim of this scenario is to shift traffic demand from motorized private transport to alternative and more environmentally friendly transportation modes.

It therefore targets two main objectives:

- Promotion of public transport
- Promotion of walking and cycling

The current update of the Air Quality Plan Stuttgart[67] provides an extensive list of individual measures addressing these issues. They mainly comprise the expansion and promotion of buses and urban railways along with cycling infrastructure. Regarding the public transportation, an express bus has been set up between Bad-Cannstatt and the Stuttgart city centre, additional suburban trains are being run, the city rail service is being improved, and there are additional offers on regional rail services. In addition, a tariff reform of the public transport in April 2019 made travelling by public transportation up to 25% cheaper.

The scenario examined goes beyond currently decided interventions and expects further effort especially in soft factors (e.g. awareness campaigns) and hard components (e.g. extension of infrastructure, new lines, new vehicles) and is oriented towards the proposed interventions of the Green City Plan[68]. It therefore aims at making mobility alternatives for motorized private transport more attractive. We assume that the measure bundles lead to a decrease of motorized private transport trips of 7% by 2020 and 20% by 2030.

[67] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, checked on 3/22/2019.

[68] Landeshauptstadt Stuttgart, AVISO GmbH, Rau Ingenieurbüro (2018): Masterplan zur Gestaltung nachhaltiger und emissionsfreier Mobilität – Green City Plan

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi

Change in activity

This scenario is not modelled as a response to one specific city policy, but rather as a scenario with reduced motorized individual transportation. It will lead to an increase of trips by bicycle, walking and public transport. Trips in private transportation will be reduced respectively. The measure will have no impact on the vehicle fleet or on the exhaust emissions. No changes in terms of absolute person kilometres will be assumed.

It has been assumed that 7% of the motorized private transport trips in 2020 and 20% in 2030 are replaced by walking, cycling and public transport. Assumptions for 2020 are in line with the measure package "enhancement of the environmental alliance" in the air quality plan 2018 (Regierungspräsidium Stuttgart 2018)[69], while assumptions for milestone year 2030 are set to represent an ambitious target. To generate the new activity levels for each activity the following assumptions have been made:

- traffic load of motorized individual transport (MIV) is reduced by 7%
- trips by walking, cycling and public transport increase according to the reduction in MIV
- vehicle fleet composition remains unchanged
- person kilometres travelled within the city area of Stuttgart remain constant

Change in emission factor

None

Further assumptions

Within this measure, we have not considered an increase of electricity consumption due to the more frequent usage of public transportation means running with electricity. Furthermore, it has been assumed that the capacity of all public transportation means (buses, metro, tram) in the baseline scenario allows to take over the switch of person kilometres induced by the measure bundle, which means that no increase in the activity level of trains is expected. Emissions from cycling have not been taken into account. The scenario therefore can be considered as an optimistic scenario

[69] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, checked on 3/22/2019.

representing the upper range of expectable emission reductions.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A3bi	2020	All	7.0
1A3bi	2030	All	20.0

Stuttgart: Policy scenario 4 - ScEL

Promoting low carbon electric and hybrid vehicles (share of passenger car vehicle kilometres 7% in 2020 and 20% in 2030)

Description of the scenario

This scenario includes various sub-measures like the procurement of electric and hybrid vehicles for the municipal vehicle fleet, the promotion of willingness to switch to electric vehicles in taxi companies and the construction of charging infrastructure in semi-public and non-public areas for a further penetration of electric vehicles into the private passenger car fleet and parking fee reductions for electric vehicles. The measure is oriented towards the measure *EMIV* in the Green City Plan Stuttgart (2018)[70] but includes also further promotion to motivate private car owners to switch from conventionally fuelled vehicles to electric vehicles. The comprised sub-measures are as follows:

- Purchase of full electric vehicles for the municipal fleet
- Construction of charging infrastructure at public and non-public spaces by the City of Stuttgart
- Construction of further charging infrastructure by private companies
- Promotion of e-taxi fleet (according to Elektro-Taxi-Aktionsplan Stuttgart[71])
- Promotion of taxi exclusive non-public fast charging stations
- Charging infrastructure concepts for specific objects
- Free parking for electric vehicles

[70] Landeshauptstadt Stuttgart, AVISO GmbH, Rau Ingenieurbüro (2018): Masterplan zur Gestaltung nachhaltiger und emissionsfreier Mobilität – Green City Plan

[71] Vogt, M. et al. (2017): Umsetzungsstudie Elektro Taxi Aktionsplan Stuttgart

- Subsidies for electric vehicles of 2.000€/vehicle

With the help of the measure package, an elevated share of electric vehicles in the passenger car fleet of 7% in 2020 and 20% in 2030 is expected. The scenario mainly aims at a high reduction of NOx emissions in the city of Stuttgart and on particularly polluted sections of the route that are achieved due to the increased use of lower-emission drive technologies.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi

Change in activity

For this measure, no changes occur for the most vehicle categories (like buses, LDVs, motorcycles and HDVs). The changes due to the increase of electrification only concern the passenger cars (PCs) of the municipal fleet, the taxi fleet and privately owned vehicles. Furthermore, neither changes in terms of absolute km driven nor changes in the technology (pre-EU, EU1, …) of petrol and diesel cars will be assumed. Only the share of individual cars for which electric vehicles will represent a larger share compared to the baseline scenario; the share of diesel vehicles is respectively reduced.

The scenario is not modelled as a response to one specific city policy, but rather as a scenario of a future higher share of electric vehicles that can be compared to a scenario reducing the private individual transportation and fostering the use of public transport. The higher share of electric vehicles on the road is fostered by different sub measures which have been described above. It has been assumed that 7% of the private passenger cars in 2020 and 20% of passenger cars in 2030 are electric. Assumptions for 2020 are in line with the impact assessment of proposed air quality plan measures by Regierungspräsidium Stuttgart (2018)[72]. The scenario assuming a share of 20% electric vehicles in 2030 is an ambitious scenario. However, the target scenario of ZSW et al. (2017)[73] foresees a market upturn to 60% share of new registrations in 2030. As a result of today's low level, the majority of electric vehicles will enter the fleet from 2025 on, so that in 2030 a total of 22% of the fleet will be reached. Under the given circumstances (higher effort for motivating private car owners to switch to e-cars, charging infrastructure) the scenario assuming 20% electric vehicles in

[72] Regierungspräsidium Stuttgart (2018): Luftreinhalteplan für den Regierungsbezirk Stuttgart Teilplan Landeshauptstadt Stuttgart. 3. Fortschreibung des Luftreinhalteplanes zur Minderung der PM10- und NO2-BelastungenNovember, checked on 3/22/2019.

[73] ZSW; ifeu; Öko-Institut e.V.; Fraunhofer ISI; Hamburg Institut; Dr. Joachim Nitsch (2017): Forschungsvorhaben Energie- und Klimaschutzziele 2030: Endbericht, checked on 1/15/2019.

2030 has been considered as realistic.

Change in emission factor

None

Further assumptions

Within this measure, we have not considered the increase of electricity consumption due to the penetration of electric vehicles onto the market, but we have considered that this will happen at the national level and not at the city level, which is uncertain. Therefore, we should keep in mind that the reported emissions for that measure are an underestimation of the real emissions (however not for the city level). However, costs resulting from the additional electricity generation are considered in the cost/benefit analyses.

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i	2020	BC	7.1
1 A 3 b i	2020	CH4	5.3
1 A 3 b i	2020	CO	5.4
1 A 3 b i	2020	CO2	6.0
1 A 3 b i	2020	N2O	6.9
1 A 3 b i	2020	NH3	5.3
1 A 3 b i	2020	NMVOC	5.5
1 A 3 b i	2020	NOx	6.8
1 A 3 b i	2020	OC	6.7
1 A 3 b i	2020	PM10	-0.1
1 A 3 b i	2020	PM25	-0.3
1 A 3 b i	2020	SO2	6.0
1 A 3 b i	2030	BC	16.1
1 A 3 b i	2030	CH4	19.3
1 A 3 b i	2030	CO	19.7

1 A 3 b i	2030	CO2	18.4
1 A 3 b i	2030	N2O	16.0
1 A 3 b i	2030	NH3	19.7
1 A 3 b i	2030	NMVOC	20.4
1 A 3 b i	2030	NOx	16.7
1 A 3 b i	2030	OC	16.9
1 A 3 b i	2030	PM10	-1.5
1 A 3 b i	2030	PM25	-3.0
1 A 3 b i	2030	SO2	18.5

Thessaloniki: Policy scenario 1 - M1

Promotion of building insulation and renovation, green infrastructure and bioclimatic design of public buildings

Description of the scenario

The scenario considers the promotion of building insulation and renovation. Furthermore, green infrastructure and bioclimatic design of public buildings (including schools) and public open areas as well as the implementation of green roofs in public buildings are fostered.

Applicability

Years: 2020, 2030

City zones: all

Assumptions for emission modelling

Affected sector: 1A4ai

Change in activity

The change in activities has been calculated based on energy savings for different interventions. Energy saving values have been adopted from the official Action Plans for Sustainable Energy of the Municipalities of Thessaloniki Regional Unit ([74] [75] [76] [77] [78] [79] [80] [81] [82] [83] [84] [85]).

Measure 1

[74] Municipality of Thessaloniki: Action Plan for Sustainable Energy (2014). (in Greek)

[75] Municipality of Kalamaria: Action Plan for Sustainable Energy (2011). (in Greek)

[76] Municipality of Pilea-Hortiati: Action Plan for Sustainable Energy (2011). (in Greek)

[77] Municipality of Pavlos Melas: Action Plan for Sustainable Energy (2011). (in Greek)

[78] Municipality of Ampelokipoi-Menemeni: Action Plan for Sustainable Energy (2011). (in Greek)

[79] Municipality of Neapoli-Sikies: Action Plan for Sustainable Energy (2011). (in Greek)

[80] Municipality of Thermi: Action Plan for Sustainable Energy (2011). (in Greek)

[81] Municipality of Kordelio-Evosmos: Action Plan for Sustainable Energy (2011). (in Greek)

[82] Municipality of Lagadas: Action Plan for Sustainable Energy (2012). (in Greek)

[83] Municipality of Halkidona: Action Plan for Sustainable Energy (2013). (in Greek)

[84] Municipality of Volvi: Action Plan for Sustainable Energy (2015). (in Greek)

[85] Municipality of Thermaikos: Action Plan for Sustainable Energy (2013). (in Greek)

Intervention	Energy saving (GWh/a)	Energy Saving (PJ/a)
Building Envelope	38.96	0.000140256
Heating systems	1.86	0.000006696
Electrical Appliances-lighting	1.85	0.00000666
SUM	42.67	0.000153612

New activity levels for 2020 are as follows:

NFR	Fuel type	Technology description	Activity (PJ) - Old	Activity Change (PJ)	Activity (PJ) - New
1 A4ai	Natural Gas	Commercial (combustion)	0.590698215	6.90045E-05	0.590629211
1 A4ai	Oil (Diesel)	Commercial (combustion)	0.625149772	7.3029E-05	0.625076743
1 A4ai	LPG	Commercial (combustion)	0.042103882	4.91851E-06	0.042098964

No further reductions have been assumed for 2030.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A4ai	2020	All	0.012
1 A4ai	2030	All	0.012

Thessaloniki: Policy scenario 2 - M2A

Promotion of cycling and walking. The measure foresees the construction of a metropolitan bike lane network and the expansion of the already existing one to increase the cycling and walking in the city.

Description of the scenario

The scenario foresees the construction of a metropolitan bike lane network and the expansion of the already existing one to increase the cycling and walking in the city.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi, 1A3biv

Change in activity

The measures are expected to change significantly the transport mode choice of the individuals and therefore the driven vehicle kilometre by private transportation means.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i	2020	As	18.0
1 A 3 b i	2020	BaP	19.0
1 A 3 b i	2020	BC	13.0
1 A 3 b i	2020	Cd	18.0

1 A 3 b i	2020	CH4	19.0
1 A 3 b i	2020	CO	17.0
1 A 3 b i	2020	CO2	18.0
1 A 3 b i	2020	Hg	18.0
1 A 3 b i	2020	N2O	17.0
1 A 3 b i	2020	NH3	20.0
1 A 3 b i	2020	NMVOC	18.0
1 A 3 b i	2020	NMVOC Evaporation	20.0
1 A 3 b i	2020	NOX	13.0
1 A 3 b i	2020	OC	17.0
1 A 3 b i	2020	Pb	18.0
1 A 3 b i	2020	PM10	18.0
1 A 3 b i	2020	PM25	17.0
1 A 3 b i	2020	SO2	18.0
1 A 3 b i	2030	As	18.0
1 A 3 b i	2030	BaP	18.0
1 A 3 b i	2030	BC	9.0
1 A 3 b i	2030	Cd	17.0
1 A 3 b i	2030	CH4	18.0
1 A 3 b i	2030	CO	16.0
1 A 3 b i	2030	CO2	17.0
1 A 3 b i	2030	Hg	17.0
1 A 3 b i	2030	N2O	14.0
1 A 3 b i	2030	NH3	18.0
1 A 3 b i	2030	NMVOC	17.0

1 A 3 b i	2030	NMVOC Evaporation	19.0
1 A 3 b i	2030	NOX	11.0
1 A 3 b i	2030	OC	16.0
1 A 3 b i	2030	Pb	17.0
1 A 3 b i	2030	PM10	17.0
1 A 3 b i	2030	PM25	16.0
1 A 3 b i	2030	SO2	17.0
1 A 3 b iv	2020	As	18.0
1 A 3 b iv	2020	BaP	19.0
1 A 3 b iv	2020	BC	13.0
1 A 3 b iv	2020	Cd	18.0
1 A 3 b iv	2020	CH4	19.0
1 A 3 b iv	2020	CO	17.0
1 A 3 b iv	2020	CO2	18.0
1 A 3 b iv	2020	Hg	18.0
1 A 3 b iv	2020	N2O	17.0
1 A 3 b iv	2020	NH3	20.0
1 A 3 b iv	2020	NMVOC	18.0
1 A 3 b iv	2020	NMVOC Evaporation	20.0
1 A 3 b iv	2020	NOX	13.0
1 A 3 b iv	2020	OC	17.0
1 A 3 b iv	2020	Pb	18.0
1 A 3 b iv	2020	PM10	18.0
1 A 3 b iv	2020	PM25	17.0
1 A 3 b iv	2020	SO2	18.0

1 A 3 b iv	2030	As	18.0
1 A 3 b iv	2030	BaP	18.0
1 A 3 b iv	2030	BC	9.0
1 A 3 b iv	2030	Cd	17.0
1 A 3 b iv	2030	CH4	18.0
1 A 3 b iv	2030	CO	16.0
1 A 3 b iv	2030	CO2	17.0
1 A 3 b iv	2030	Hg	17.0
1 A 3 b iv	2030	N2O	14.0
1 A 3 b iv	2030	NH3	18.0
1 A 3 b iv	2030	NMVOC	17.0
1 A 3 b iv	2030	NMVOC Evaporation	19.0
1 A 3 b iv	2030	NOX	11.0
1 A 3 b iv	2030	OC	16.0
1 A 3 b iv	2030	Pb	17.0
1 A 3 b iv	2030	PM10	17.0
1 A 3 b iv	2030	PM25	16.0
1 A 3 b iv	2030	SO2	17.0

Thessaloniki: Policy scenario 3 - M2B

Promotion of green vehicles. Shifting to cleaner energy practices in Transport is important to the City of Thessaloniki. The Municipalities of Thessaloniki Regional Unit will proceed to the gradual replacement of all the old municipal vehicles with new electric ones. The measure additionally foresees the replacement of private passenger cars due to further incentives

Description of the scenario

This scenario foresees the shift to cleaner energy practices in Transport, which is particularly important to the City of Thessaloniki. The Municipalities of Thessaloniki Regional Unit will proceed to the gradual replacement of all the old municipal vehicles with new electric ones. The measure additionally foresees the replacement of private passenger cars by electric ones due to further incentives.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi

Change in activity

The measure foresees the replacement of passenger cars by electric ones.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i	2020	As	85.00
1 A 3 b i	2020	BaP	84.00
1 A 3 b i	2020	BC	54.00
1 A 3 b i	2020	Cd	5.00
1 A 3 b i	2020	CH4	72.00
1 A 3 b i	2020	CO	69.00
1 A 3 b i	2020	CO2	88.00
1 A 3 b i	2020	Hg	84.00
1 A 3 b i	2020	N2O	82.00

1 A 3 b i	2020	NH3	96.00
1 A 3 b i	2020	NMVOC	41.00
1 A 3 b i	2020	NMVOC Evaporation	85.00
1 A 3 b i	2020	NOX	60.00
1 A 3 b i	2020	OC	25.00
1 A 3 b i	2020	Pb	0.00
1 A 3 b i	2020	PM10	12.00
1 A 3 b i	2020	PM25	18.00
1 A 3 b i	2020	SO2	83.00
1 A 3 b i	2030	As	81.00
1 A 3 b i	2030	BaP	75.00
1 A 3 b i	2030	BC	19.00
1 A 3 b i	2030	Cd	6.00
1 A 3 b i	2030	CH4	69.00
1 A 3 b i	2030	CO	56.00
1 A 3 b i	2030	CO2	82.00
1 A 3 b i	2030	Hg	79.00
1 A 3 b i	2030	N2O	59.00
1 A 3 b i	2030	NH3	89.00
1 A 3 b i	2030	NMVOC	34.00
1 A 3 b i	2030	NMVOC Evaporation	83.00
1 A 3 b i	2030	NOX	41.00
1 A 3 b i	2030	OC	25.00
1 A 3 b i	2030	Pb	0.00
1 A 3 b i	2030	PM10	6.00

1 A 3 b i	2030	PM25	9.00
1 A 3 b i	2030	SO2	78.00

Thessaloniki: Policy scenario 4 - M2C

Promotion of public transport and the use of metro by building an integrated urban mobility system. The introduction and operation of underground railway (Metro) is expected to change significantly the transportation mode in the city of Thessaloniki. The measure focuses on the establishment of an integrated urban mobility system and the promotion of public transport.

Description of the scenario

This scenario considers the promotion of public transport by an extended use of the metro and the building of an integrated urban mobility system. The introduction and operation of underground railway (Metro) is expected to change significantly the transportation mode in the city of Thessaloniki. The measure focuses on the establishment of an integrated urban mobility system and the promotion of public transport. The implementation of the measure is expected to be a joined effort of the Municipalities of Thessaloniki Regional Unit, the Metropolitan Authority and Thessaloniki Public Transport Authority (ThePTA).

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 1A3bi, 1A3biii, 1A3biv

Change in activity

The measures are expected to change significantly the transport mode choice of the individuals and therefore the driven vehicle kilometre by private transportation means and buses.

Change in emission factor

None

Further assumptions

The reduction potential per sector is calculated using the reduction potential per vehicle category and the proportion of the vehicle category on sector emissions (per year and pollutant) The proportion of the vehicle category for passenger cars and motorcycles is 1. Data on vehicle category and the share of buses/HDVs on 1 A 3 b iii emissions have been derived from the bottom up emission inventory for Thessaloniki.

The share of the vehicle category bus on the emissions of the whole NFR sector 1A3biii is as follows:

Vehicle category	Year	Pollutant	Share
Bus	2020	As	0.59
Bus	2020	As road	0.20
Bus	2020	As wear	0.55
Bus	2020	BC	0.14
Bus	2020	BC	-
Bus	2020	BC road	-
Bus	2020	Benzo(a)pyrene	0.49
Bus	2020	Benzo(a)pyrene wear	0.47
Bus	2020	Cd	0.59
Bus	2020	Cd road	0.24
Bus	2020	Cd wear	0.58
Bus	2020	CH4	0.08
Bus	2020	CO	0.37
Bus	2020	CO2	0.59
Bus	2020	Hg	0.59
Bus	2020	Hg road	-
Bus	2020	Hg wear	0.53
Bus	2020	N2O	0.48
Bus	2020	NH3	0.30

Bus	2020	NMVOC	0.15
Bus	2020	NMVOC evaporation	-
Bus	2020	NOx	0.30
Bus	2020	OC	0.09
Bus	2020	OC road	-
Bus	2020	OC wear	-
Bus	2020	Pb	0.59
Bus	2020	Pb road	0.24
Bus	2020	Pb wear	0.60
Bus	2020	PM10	0.13
Bus	2020	PM10 road	0.55
Bus	2020	PM10 wear	0.55
Bus	2020	PM2.5	0.13
Bus	2020	PM2.5 road	0.53
Bus	2020	PM2.5 wear	0.53
Bus	2020	SO2	0.59
Bus	2030	As	0.63
Bus	2030	As road	0.23
Bus	2030	As wear	0.59
Bus	2030	BC	0.01
Bus	2030	BC	-
Bus	2030	BC road	-
Bus	2030	Benzo(a)pyrene	0.54
Bus	2030	Benzo(a)pyrene wear	0.52
Bus	2030	Cd	0.63

Bus	2030	Cd road	0.27
Bus	2030	Cd wear	0.63
Bus	2030	CH4	0.09
Bus	2030	CO	0.23
Bus	2030	CO2	0.63
Bus	2030	Hg	0.63
Bus	2030	Hg road	-
Bus	2030	Hg wear	0.58
Bus	2030	N2O	0.50
Bus	2030	NH3	0.36
Bus	2030	NMVOC	0.17
Bus	2030	NMVOC evaporation	-
Bus	2030	NOx	0.11
Bus	2030	OC	0.06
Bus	2030	OC road	-
Bus	2030	OC wear	-
Bus	2030	Pb	0.63
Bus	2030	Pb road	0.28
Bus	2030	Pb wear	0.65
Bus	2030	PM10	0.05
Bus	2030	PM10 road	0.60
Bus	2030	PM10 wear	0.60
Bus	2030	PM2.5	0.05
Bus	2030	PM2.5 road	0.58
Bus	2030	PM2.5 wear	0.58

Bus	2030	SO2	0.63

Emission reduction potential

The emission reduction potential for the NFR codes and vehicle types is as follows:

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Vehicle Category	Year	Pollutant	Emission reduction potential [%]
1 A 3 b i	PC	2020	NH3	24.0
1 A 3 b i	PC	2020	NMVOC	20.0
1 A 3 b i	PC	2020	NOX	17.0
1 A 3 b i	PC	2020	PM10	22.0
1 A 3 b i	PC	2020	PM25	21.0
1 A 3 b i	PC	2020	SO2	23.0
1 A 3 b iv	MC	2020	NH3	24.0
1 A 3 b iv	MC	2020	NMVOC	20.0
1 A 3 b iv	MC	2020	NOX	17.0
1 A 3 b iv	MC	2020	PM10	22.0
1 A 3 b iv	MC	2020	PM25	21.0
1 A 3 b iv	MC	2020	SO2	23.0
1 A 3 b i	PC	2030	NH3	23.0
1 A 3 b i	PC	2030	NMVOC	19.0
1 A 3 b i	PC	2030	NOX	13.0
1 A 3 b i	PC	2030	PM10	21.0
1 A 3 b i	PC	2030	PM25	20.0
1 A 3 b i	PC	2030	SO2	22.0
1 A 3 b iv	MC	2030	NH3	23.0

1 A 3 b iv	MC	2030	NMVOC	19.0
1 A 3 b iv	MC	2030	NOX	13.0
1 A 3 b iv	MC	2030	PM10	21.0
1 A 3 b iv	MC	2030	PM25	20.0
1 A 3 b iv	MC	2030	SO2	22.0
1 A 3 b iii	bus	2020	NH3	24.0
1 A 3 b iii	bus	2020	NMVOC	20.0
1 A 3 b iii	bus	2020	NOX	17.0
1 A 3 b iii	bus	2020	PM10	22.0
1 A 3 b iii	bus	2020	PM25	21.0
1 A 3 b iii	bus	2020	SO2	23.0
1 A 3 b iii	bus	2030	NH3	23.0
1 A 3 b iii	bus	2030	NMVOC	19.0
1 A 3 b iii	bus	2030	NOX	13.0
1 A 3 b iii	bus	2030	PM10	21.0
1 A 3 b iii	bus	2030	PM25	20.0
1 A 3 b iii	bus	2030	SO2	22.0
1 A 3 b i	PC	2020	NMVOC Evaporation	24.0
1 A 3 b iv	MC	2020	NMVOC Evaporation	24.0
1 A 3 b i	PC	2030	NMVOC Evaporation	23.0
1 A 3 b iv	MC	2030	NMVOC Evaporation	23.0
1 A 3 b iii	bus	2020	NMVOC Evaporation	24.0

1 A 3 b iii	bus	2030	NMVOC Evaporation	23.0
1 A 3 b i	PC	2020	CH4	22.0
1 A 3 b i	PC	2020	CO	21.0
1 A 3 b i	PC	2020	N2O	22.0
1 A 3 b i	PC	2020	CO2	23.0
1 A 3 b i	PC	2020	As	23.0
1 A 3 b i	PC	2020	Cd	23.0
1 A 3 b i	PC	2020	Hg	23.0
1 A 3 b i	PC	2020	Pb	23.0
1 A 3 b i	PC	2020	OC	18.0
1 A 3 b i	PC	2020	BC	17.0
1 A 3 b i	PC	2020	BaP	24.0
1 A 3 b i	PC	2030	CH4	22.0
1 A 3 b i	PC	2030	CO	18.0
1 A 3 b i	PC	2030	N2O	19.0
1 A 3 b i	PC	2030	CO2	22.0
1 A 3 b i	PC	2030	As	22.0
1 A 3 b i	PC	2030	Cd	22.0
1 A 3 b i	PC	2030	Hg	22.0
1 A 3 b i	PC	2030	Pb	22.0
1 A 3 b i	PC	2030	OC	18.0
1 A 3 b i	PC	2030	BC	11.0
1 A 3 b i	PC	2030	BaP	22.0
1 A 3 b iv	MC	2020	CH4	22.0
1 A 3 b iv	MC	2020	CO	21.0
1 A 3 b iv	MC	2020	N2O	22.0

1 A 3 b iv	MC	2020	CO2	23.0
1 A 3 b iv	MC	2020	As	23.0
1 A 3 b iv	MC	2020	Cd	23.0
1 A 3 b iv	MC	2020	Hg	23.0
1 A 3 b iv	MC	2020	Pb	23.0
1 A 3 b iv	MC	2020	OC	18.0
1 A 3 b iv	MC	2020	BC	17.0
1 A 3 b iv	MC	2020	BaP	24.0
1 A 3 b iv	MC	2030	CH4	22.0
1 A 3 b iv	MC	2030	CO	18.0
1 A 3 b iv	MC	2030	N2O	19.0
1 A 3 b iv	MC	2030	CO2	22.0
1 A 3 b iv	MC	2030	As	22.0
1 A 3 b iv	MC	2030	Cd	22.0
1 A 3 b iv	MC	2030	Hg	22.0
1 A 3 b iv	MC	2030	Pb	22.0
1 A 3 b iv	MC	2030	OC	18.0
1 A 3 b iv	MC	2030	BC	11.0
1 A 3 b iv	MC	2030	BaP	22.0
1 A 3 b iii	bus	2020	CH4	22.0
1 A 3 b iii	bus	2020	CO	21.0
1 A 3 b iii	bus	2020	N2O	22.0
1 A 3 b iii	bus	2020	CO2	23.0
1 A 3 b iii	bus	2020	As	23.0
1 A 3 b iii	bus	2020	Cd	23.0
1 A 3 b iii	bus	2020	Hg	23.0
1 A 3 b iii	bus	2020	Pb	23.0

1 A 3 b iii	bus	2020	OC	18.0
1 A 3 b iii	bus	2020	BC	17.0
1 A 3 b iii	bus	2020	BaP	24.0
1 A 3 b iii	bus	2030	CH4	22.0
1 A 3 b iii	bus	2030	CO	18.0
1 A 3 b iii	bus	2030	N2O	19.0
1 A 3 b iii	bus	2030	CO2	22.0
1 A 3 b iii	bus	2030	As	22.0
1 A 3 b iii	bus	2030	Cd	22.0
1 A 3 b iii	bus	2030	Hg	22.0
1 A 3 b iii	bus	2030	Pb	22.0
1 A 3 b iii	bus	2030	OC	18.0
1 A 3 b iii	bus	2030	BC	11.0
1 A 3 b iii	bus	2030	BaP	22.0

Thessaloniki: Policy scenario 5 - M3

Promotion of eco-friendly waste management

Description of the scenario

The scenario focuses on eco-friendly waste management by pre-treating and pre-sorting waste into biodegradable and non-biodegradable material for further anaerobic digestion and composting. Residues end in landfill, whereas plastic, paper and ferrous material are recycled.

Applicability

Years: 2020, 2030

City zones: All

Assumptions for emission modelling

Affected sector: 6A

Change in activity

The activity level in sector 6A has been reduced by 50%.

Change in emission factor

None

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
6A	2020	All	50.0
6A	2020	All	50.0

Thessaloniki: Policy scenario 6 - M4

Energy efficiency in the cement industry: Use of refuse derived fuels

Description of the scenario

The scenario targets to increase the use of Refuse Derived Fuel (RDF) in cement industry. In 2015, the Cement industry had a percent of RDF use of 13%. The target share is 20% of RDF use by 2020 (a total of 30% of alternative fuels use is targeted, the rest 10% will have to be other alternative fuels), and to reach 30% of RDF use by 2030 (the total use of alternative fuels will be higher).

Applicability

Years: 2020, 2030

City zones: Àll

Assumptions for emission modelling

Affected sector: 1A2fi

Change in activity

None

Change in emission factor

The changes in emission factors were calculated based on references [86] [87] and the EEA guidebook on EFs. Data from the references on the reduction potential for EFs following to two substitution (%)scenarios with RDF were used to derive linear equations per pollutant and interpolate the values to the specific percentages of targeted RDF use by 2020 and 2030. According to the interpolated values to the specific percentage of RDF use, the reduction potential was computed and applied to the current EFs. Lastly, the new EFs for 2020 and 2030 were used to calculate the new emissions.

Further assumptions

None

Emission reduction potential

Reduction potential (emission reduction in percent compared to BAU scenario at NFR09 level)

NFR sector code	Year	Pollutant	Emission reduction potential [%]
1A2fi	2020	BC	0.00
1A2fi	2020	CO2	49.72
1A2fi	2020	NOX	10.04
1A2fi	2020	PM2.5	25.22
1A2fi	2020	CH4	-
1A2fi	2020	N2O	-
1A2fi	2020	OC	0.00
1A2fi	2020	SO2	11.26
1A2fi	2020	CO	44.47
1A2fi	2020	NMVOC	-
1A2fi	2020	PM10	27.19

[86] G. Genon, E. Brizio 2008. Perspectives and limits for cement kilns as a destination for RDF. Waste Management 28 (2008), 2375–2385

[87] Worrell E. , Price L., Martin N., Hendriks C. and Meida L. O. Carbon Dioxide Emissions from the Global Cement Industry, Annu. Rev. Energy

1A2fi	2030	BC	0.00
1A2fi	2030	CO2	55.45
1A2fi	2030	NOX	24.37
1A2fi	2030	PM2.5	65.15
1A2fi	2030	CH4	-
1A2fi	2030	N2O	-
1A2fi	2030	OC	0.00
1A2fi	2030	SO2	27.37
1A2fi	2030	CO	91.74
1A2fi	2030	NMVOC	-
1A2fi	2030	PM10	66.05

ANNEX 2: AIR POLLUTION MODELLING RESULTS

The results are spatial hourly data of NO_2, O_3, PM_{10} $PM_{2.5}$ Representative Concentrations (CR) for the 5-year periods 2021-2025, 2026-2030, 2031-2035, 2036-2040 for all measure scenarios.

In the following Figures (1-96) are presented indicative results of the daily average concentration values of NO_2 and $PM_{2.5}$ for the wider area of each ICARUS city for the period 2036-2040 (in case of Stuttgart 2031-2035).

Air pollution modelling results – Athens

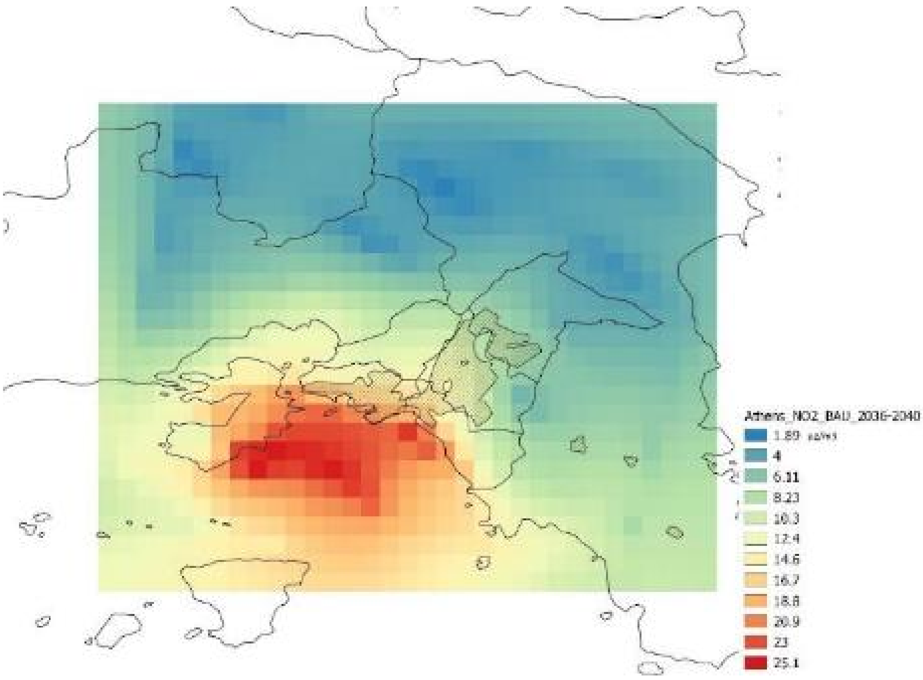


Figure 1: NO_2 Concentration map of the wider area of Athens – BAU scenario

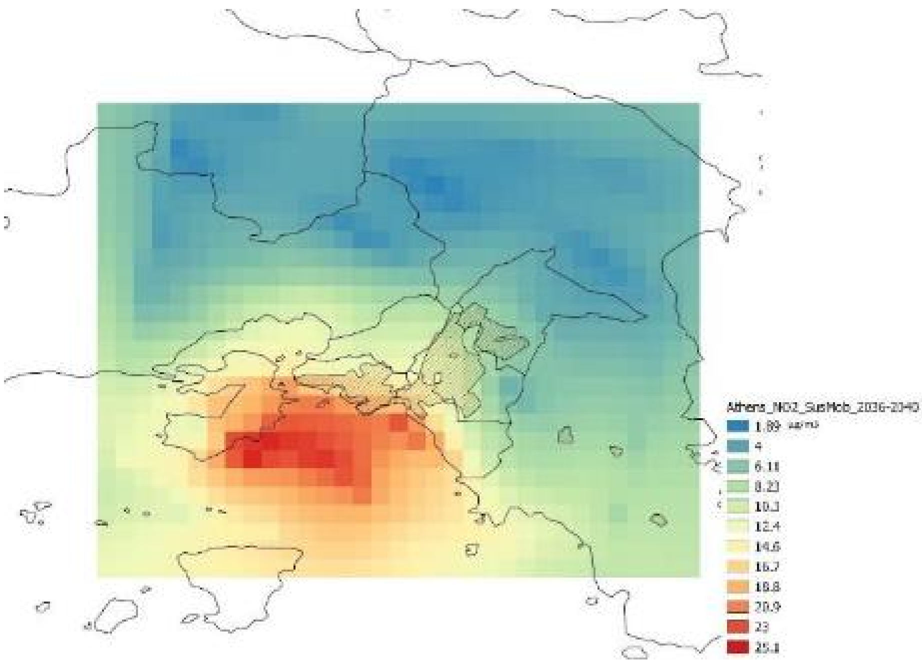


Figure 2: NO_2 Concentration map of the wider area of Athens – SusMob scenario

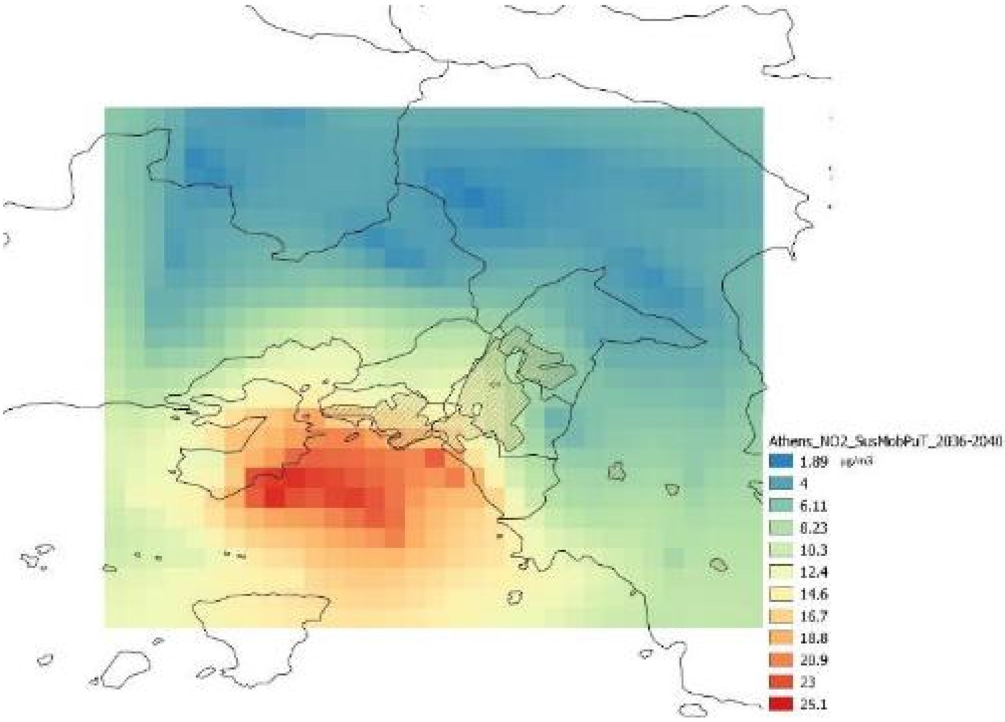


Figure 3: NO$_2$ Concentration map of the wider area of Athens – SusMobPuT scenario

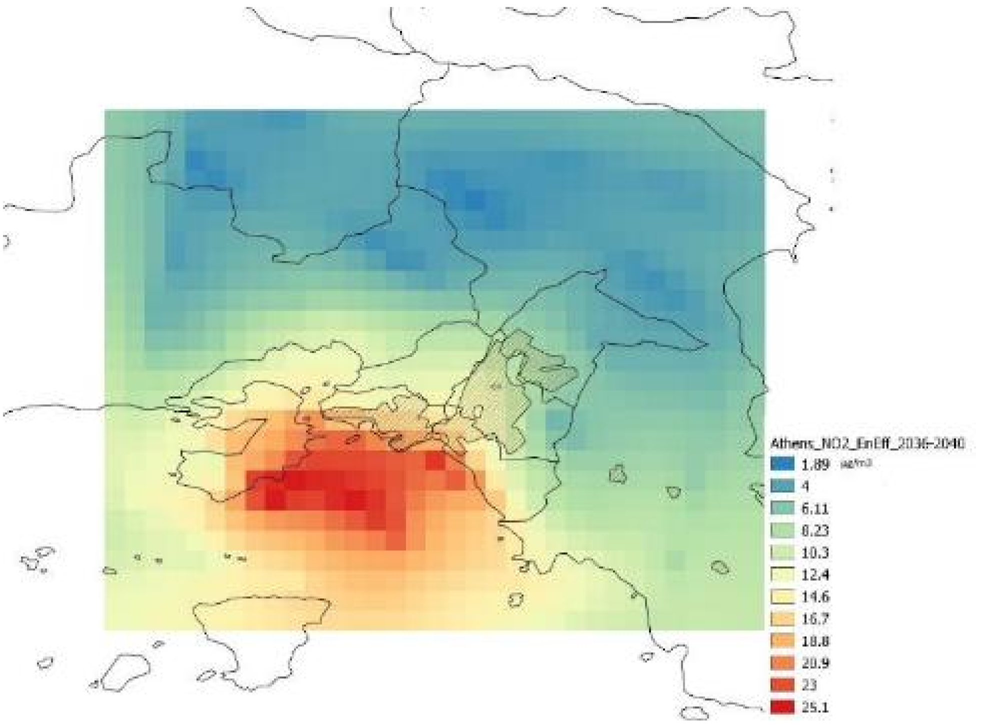


Figure 4: NO$_2$ Concentration map of the wider area of Athens – EnEff scenario

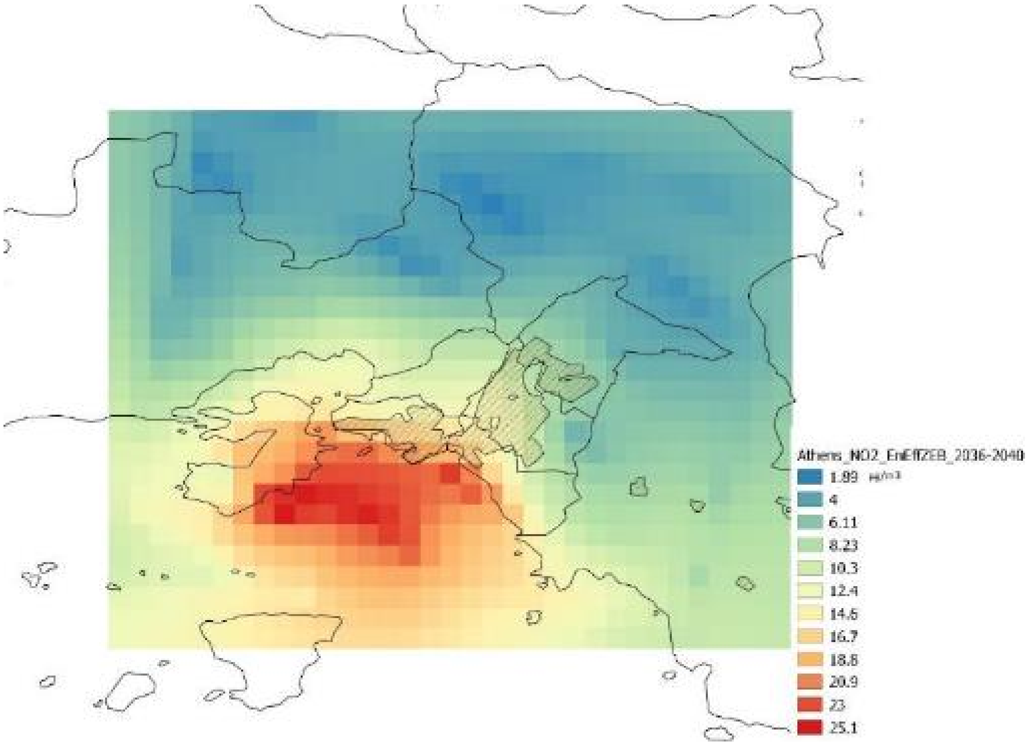


Figure 5: NO_2 Concentration map of the wider area of Athens – EnEffZEB scenario

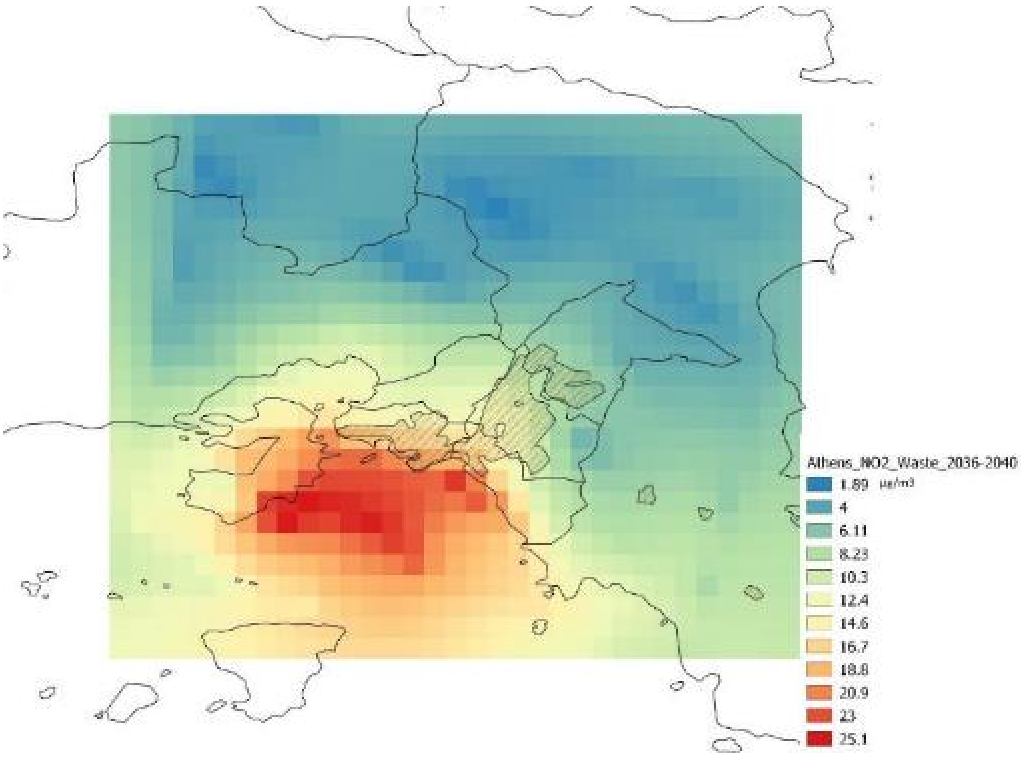


Figure 6: NO_2 Concentration maps of the wider area of Athens – Waste scenario

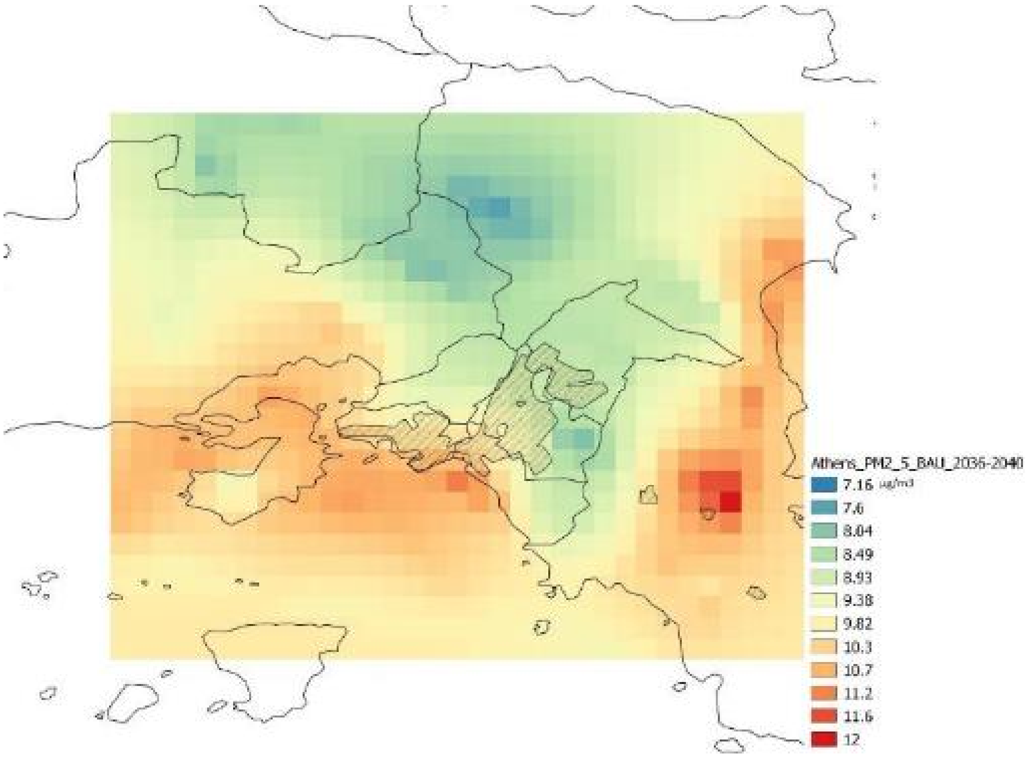


Figure 7: $PM_{2.5}$ Concentration maps of the wider area of Athens – BAU scenario

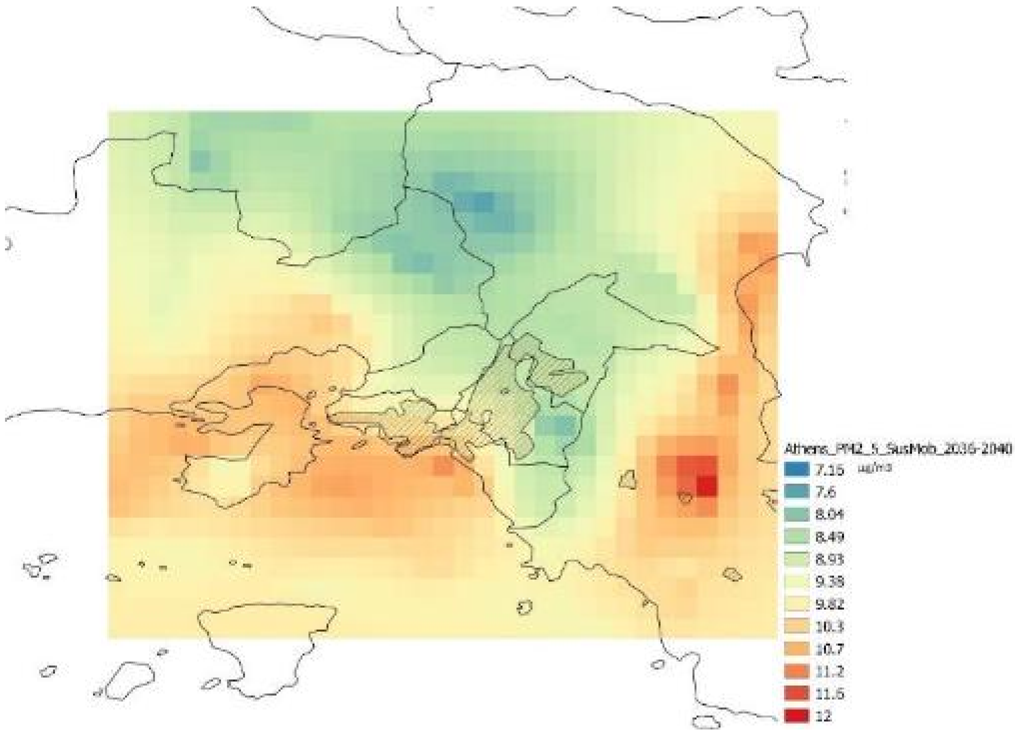


Figure 8: $PM_{2.5}$ Concentration maps of the wider area of Athens – SusMob scenario

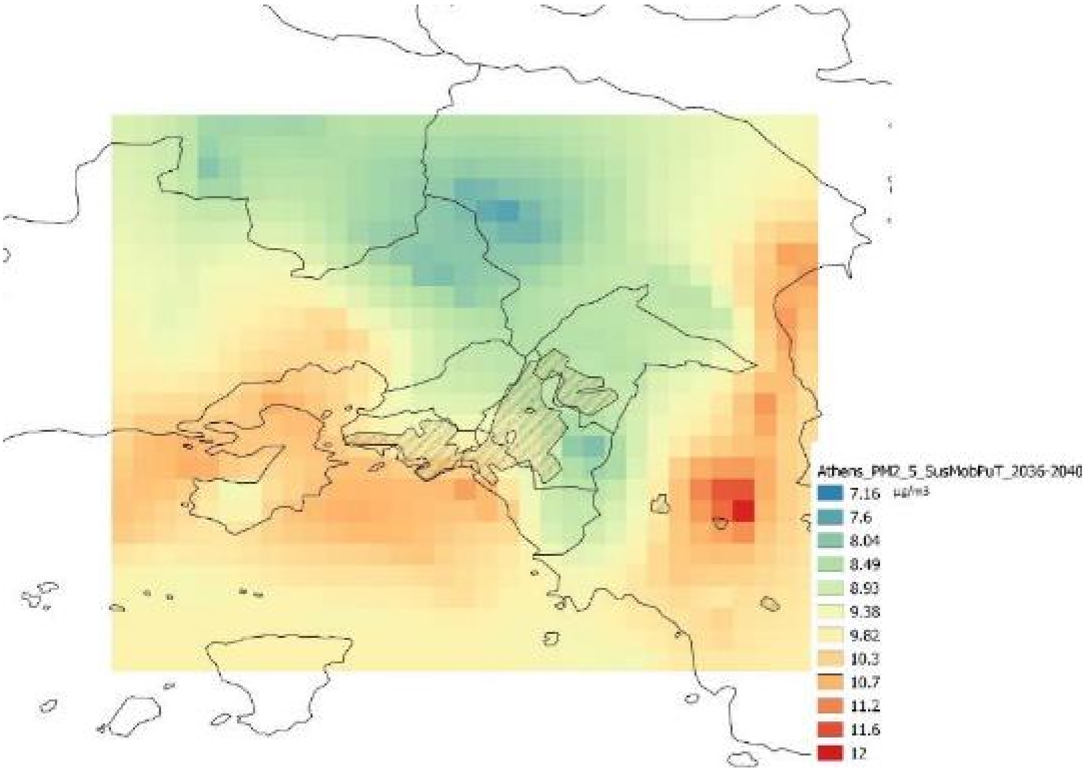


Figure 9: $PM_{2.5}$ Concentration map of the wider area of Athens – SusMobPuT scenario

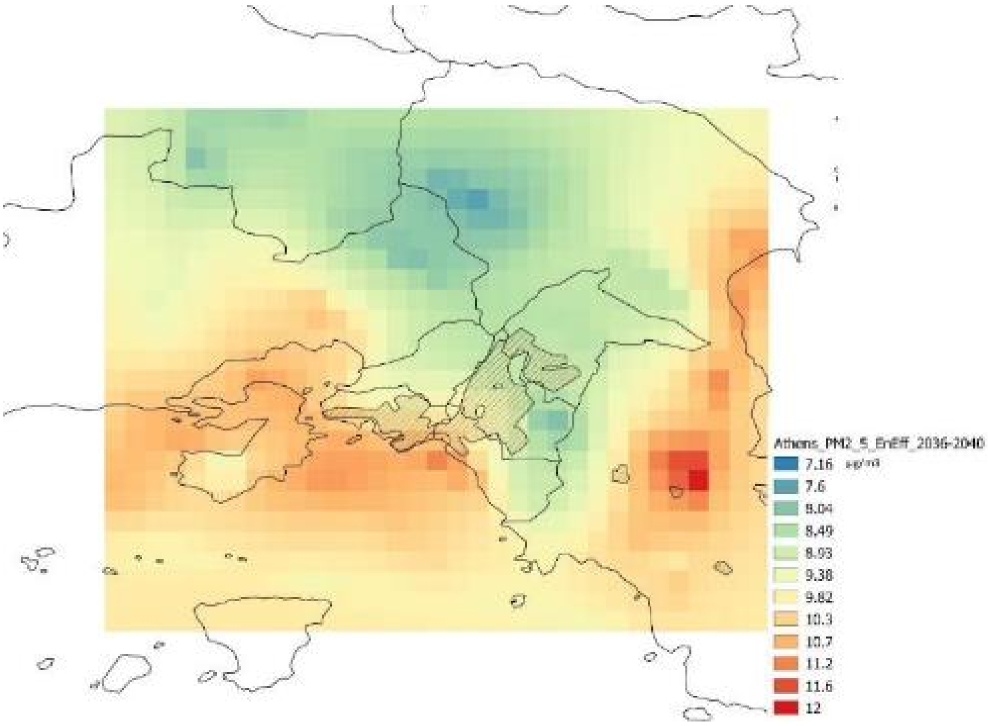


Figure 10: $PM_{2.5}$ Concentration map of the wider area of Athens – EnEff scenario

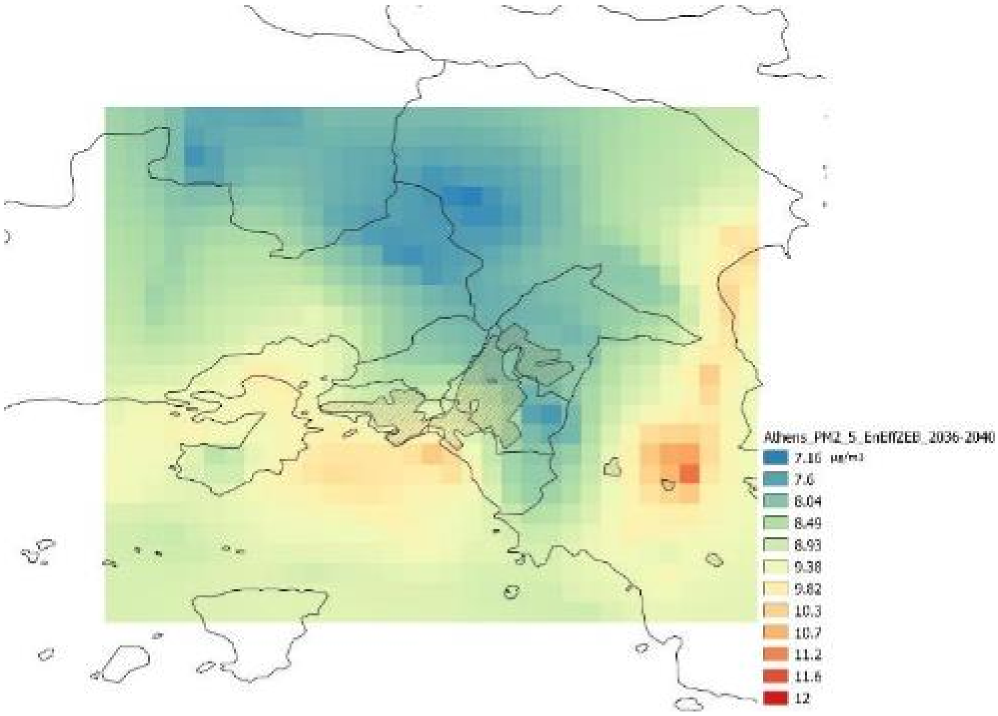


Figure 11: $PM_{2.5}$ Concentration map of the wider area of Athens – EnEffZEB scenario

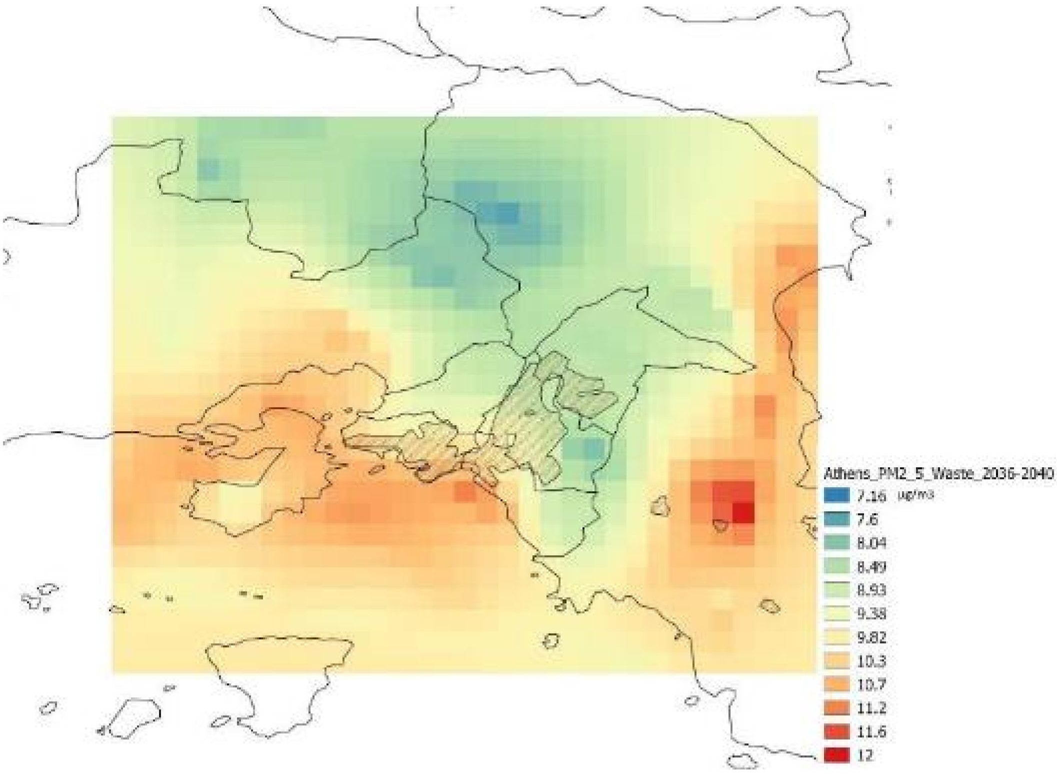


Figure 12: $PM_{2.5}$ Concentration map of the wider area of Athens – Waste scenario

Air pollution modelling results - Basel

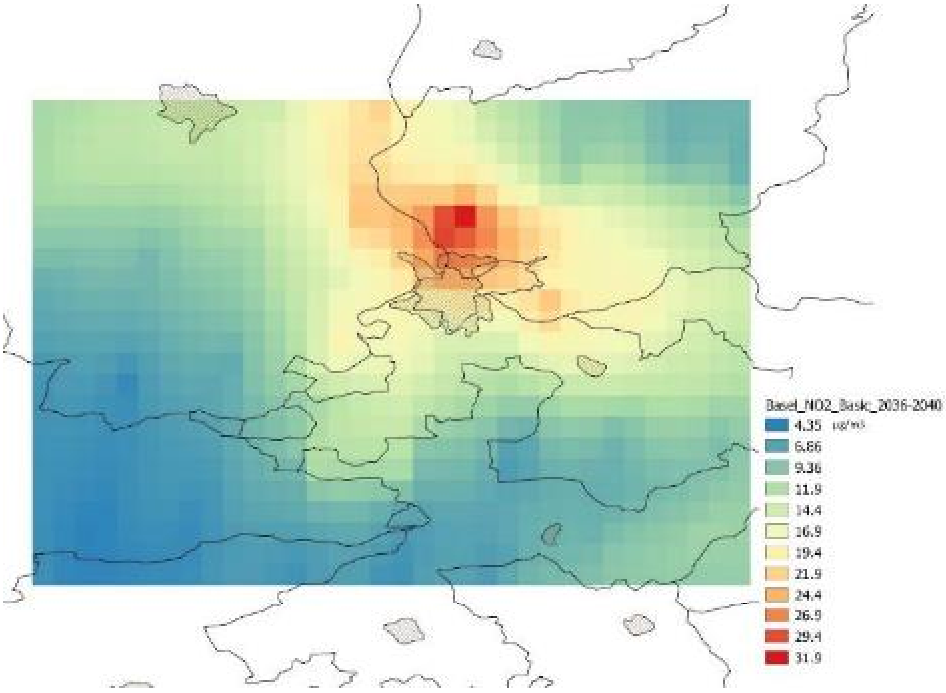


Figure 13: NO_2 Concentration map of the wider area of Basel – Basic scenario

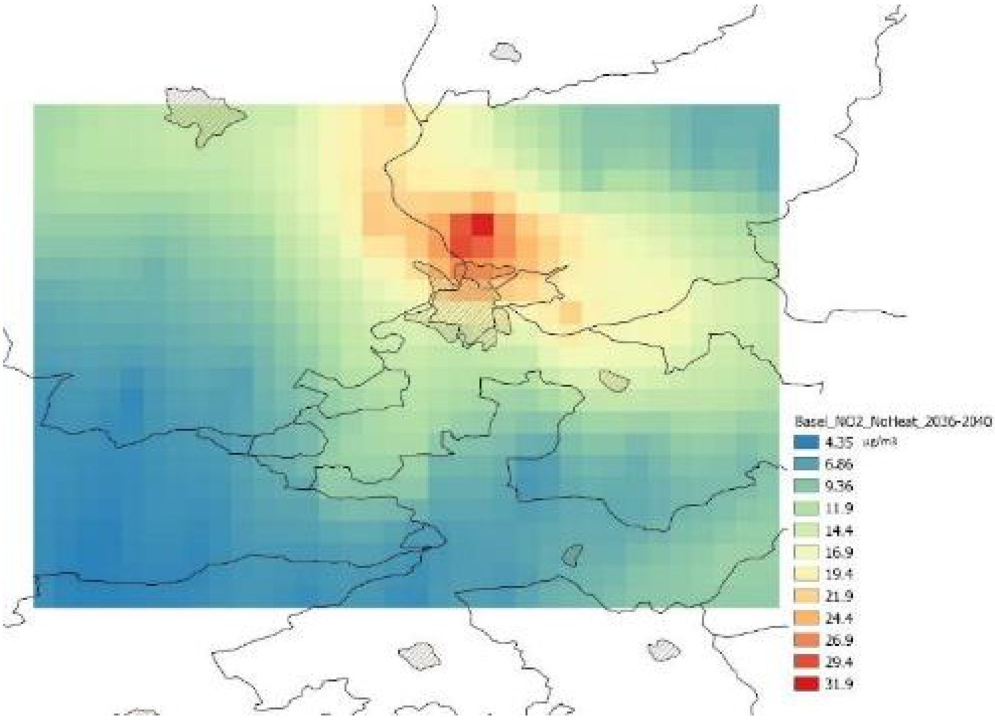


Figure 14: NO_2 Concentration map of the wider area of Basel – NoHeat scenario

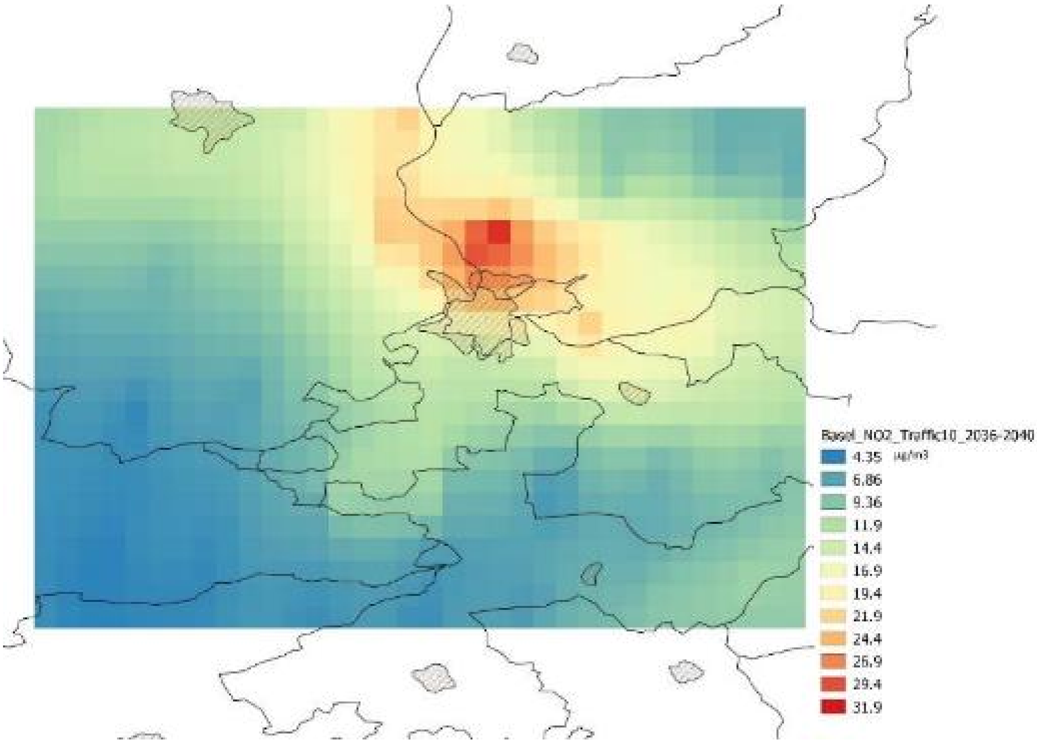


Figure 15: NO_2 Concentration map of the wider area of Basel – Traffic10 scenario

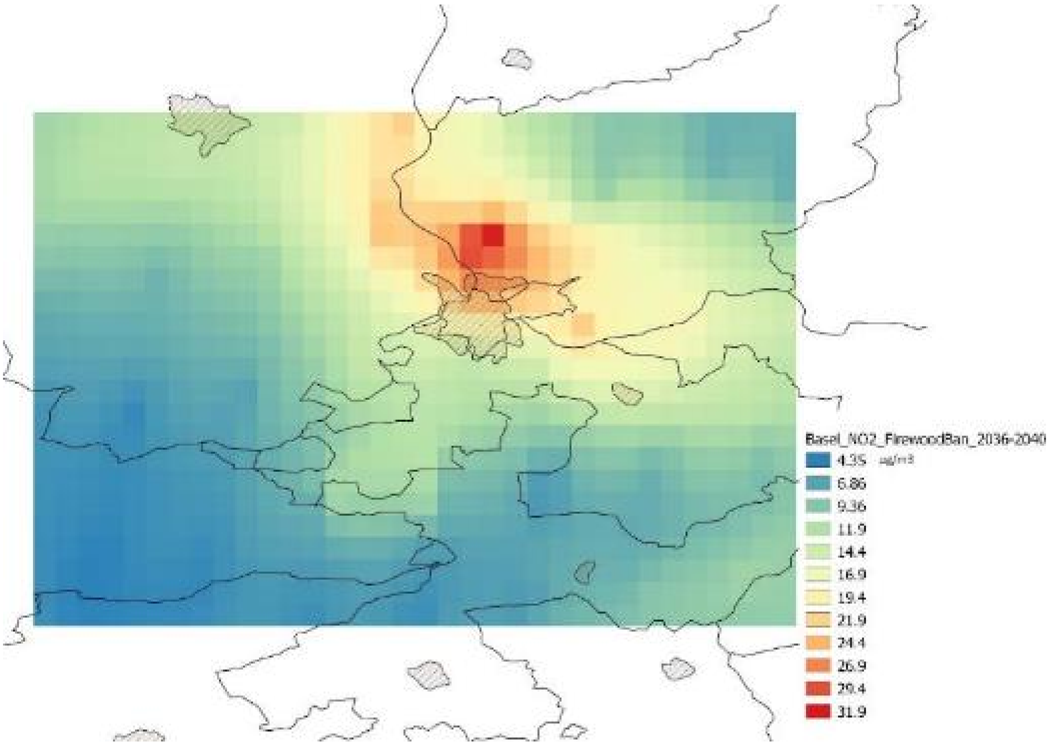


Figure 16: NO_2 Concentration map of the wider area of Basel – FirewoodBan scenario

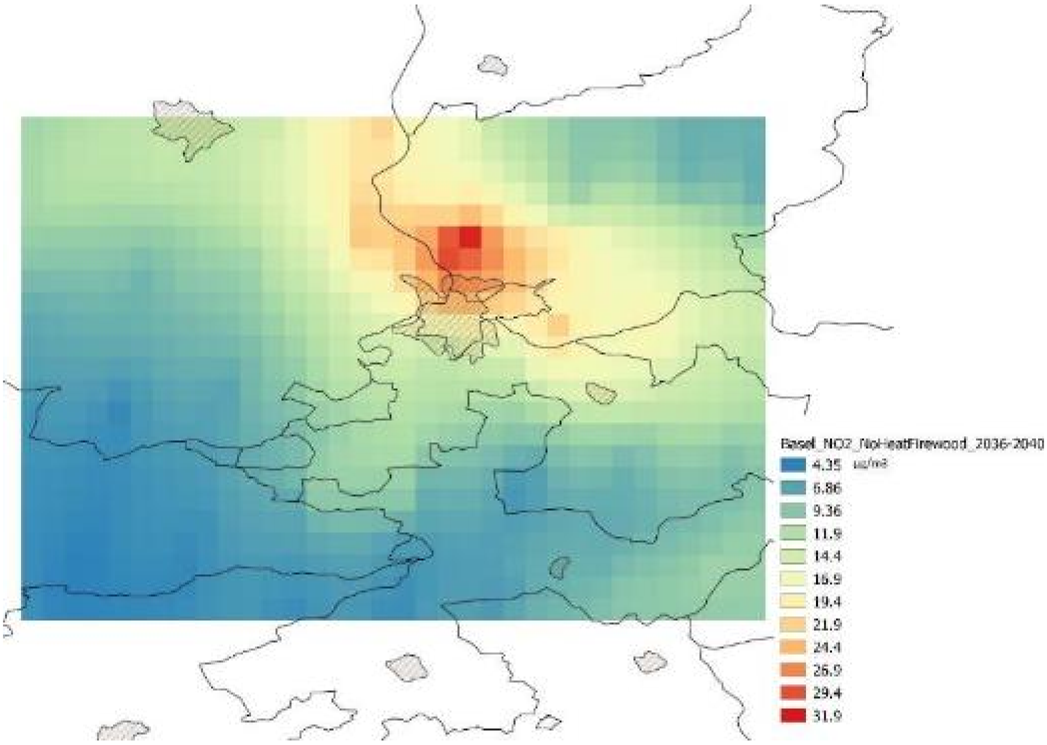


Figure 17: NO_2 Concentration map of the wider area of Basel – NoHeatFirewood scenario

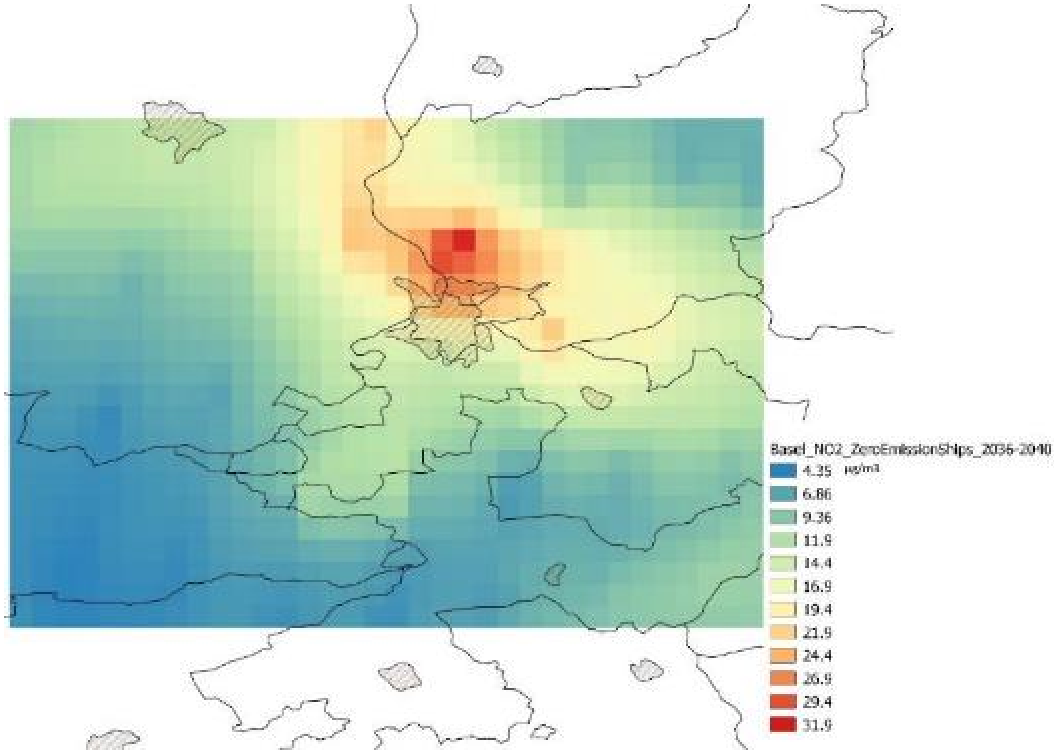


Figure 18: NO_2 Concentration map of the wider area of Basel – ZeroEmissionShips scenario

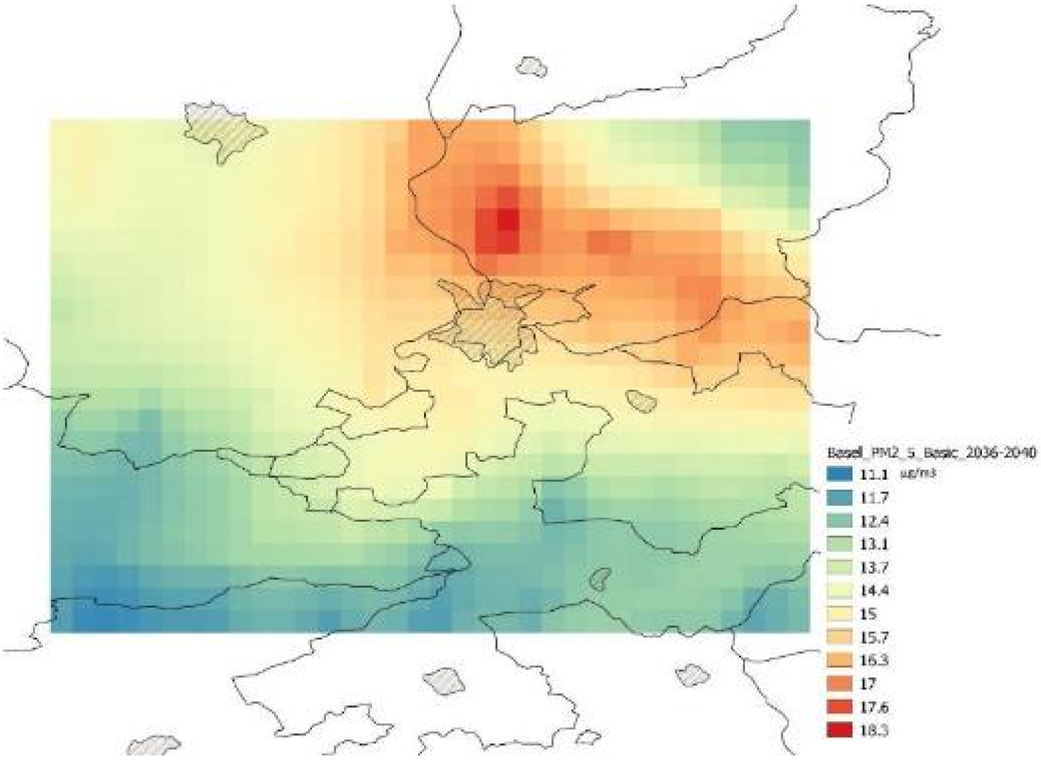


Figure 19: $PM_{2.5}$ Concentration map of the wider area of Basel – Basic scenario

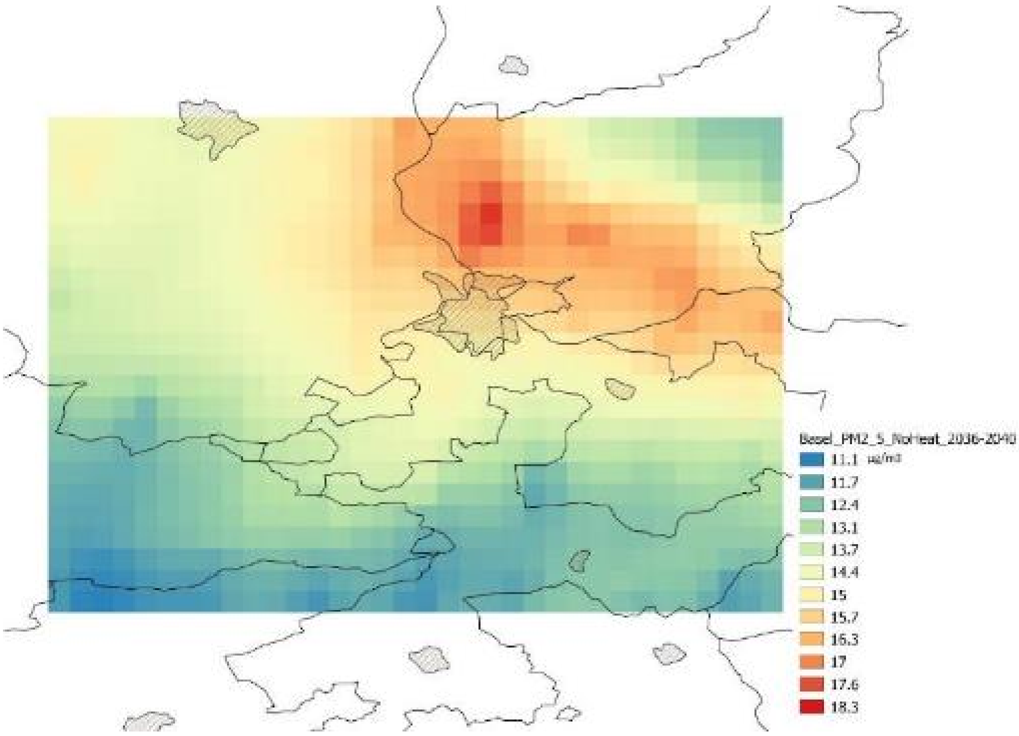


Figure 20: $PM_{2.5}$ Concentration map of the wider area of Basel – NoHeat scenario

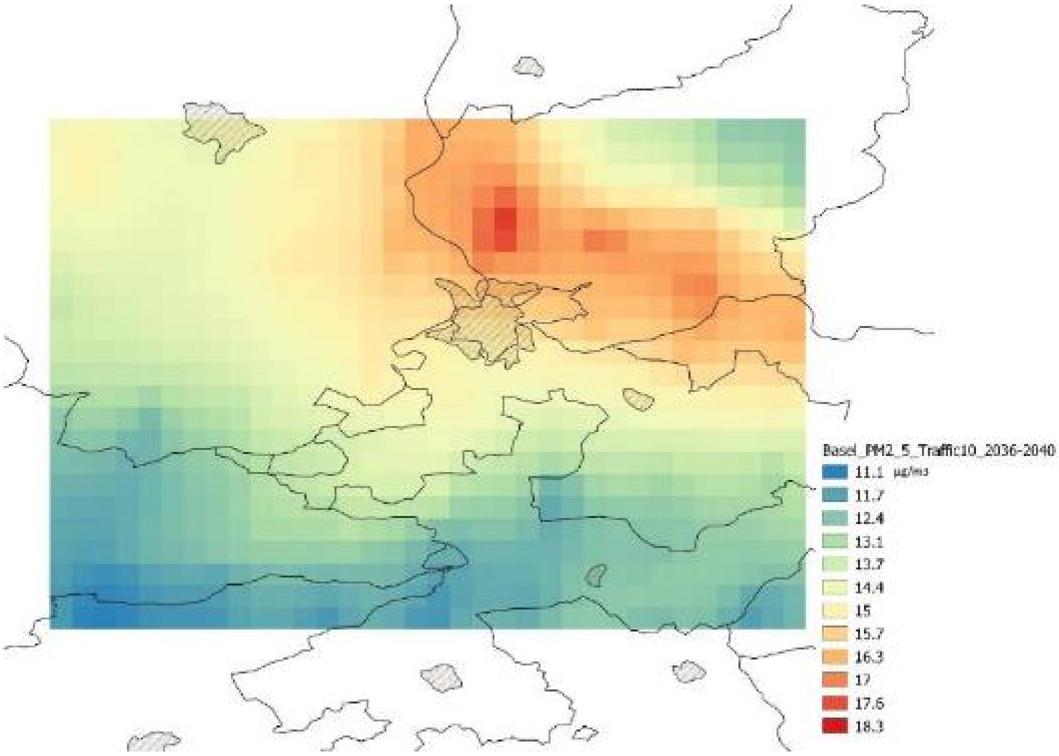


Figure 21: $PM_{2.5}$ Concentration map of the wider area of Basel – Traffic10 scenario

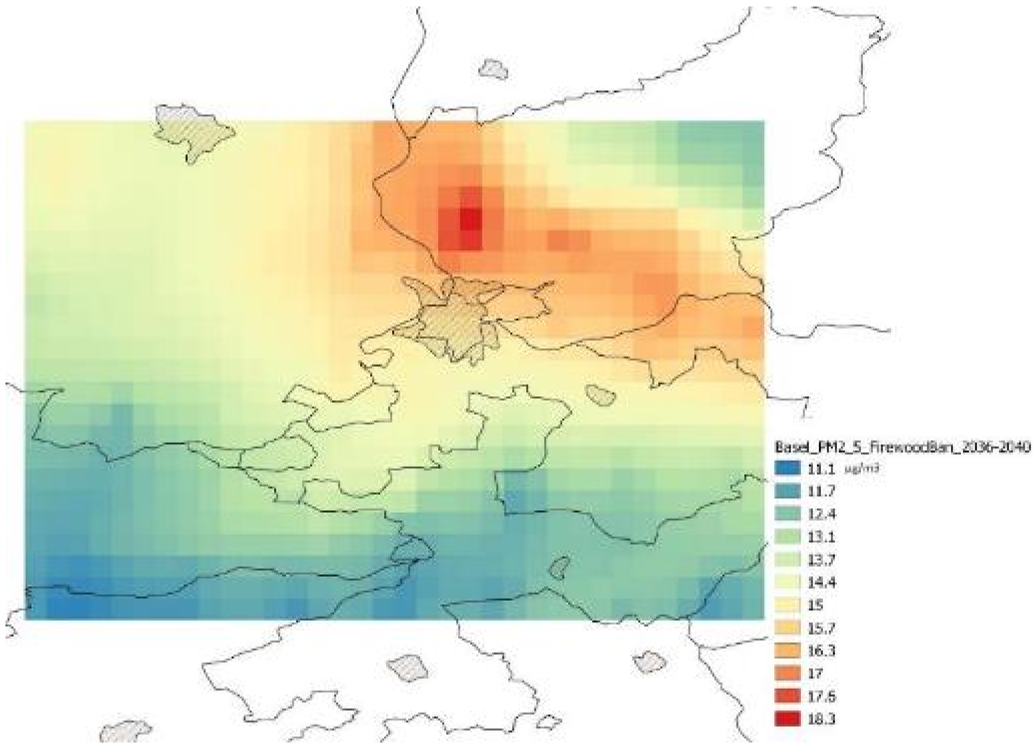


Figure 22: $PM_{2.5}$ Concentration map of the wider area of Basel – FirewoodBan scenario

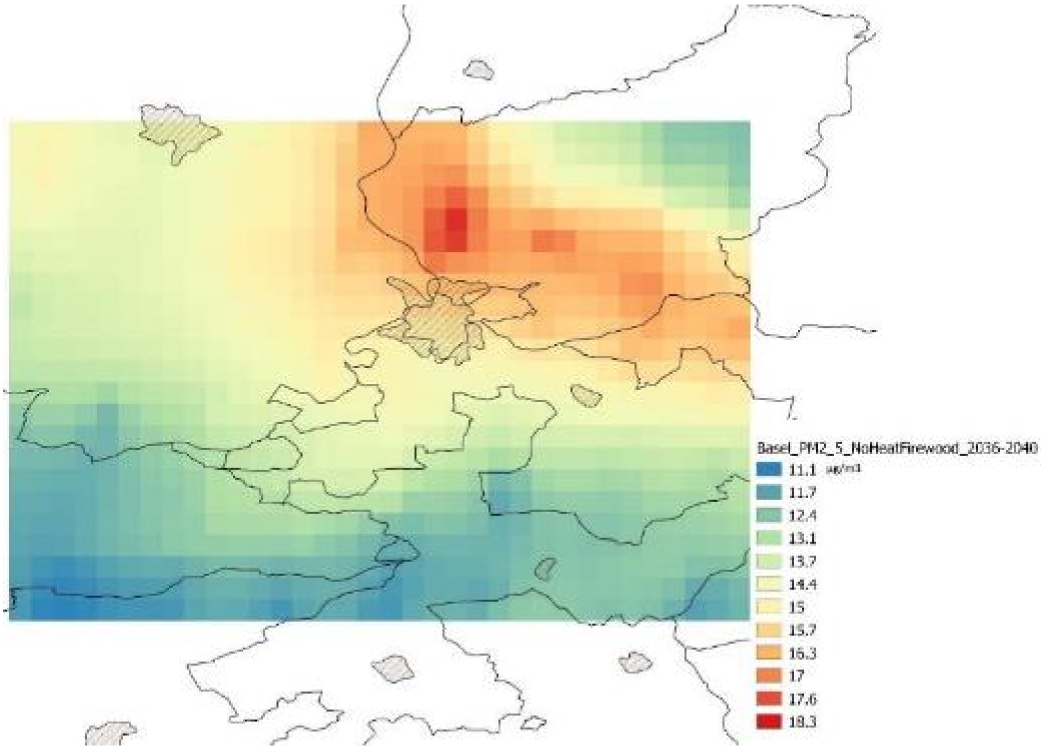


Figure 23: $PM_{2.5}$ Concentration map of the wider area of Basel – NoHeatFirewood scenario

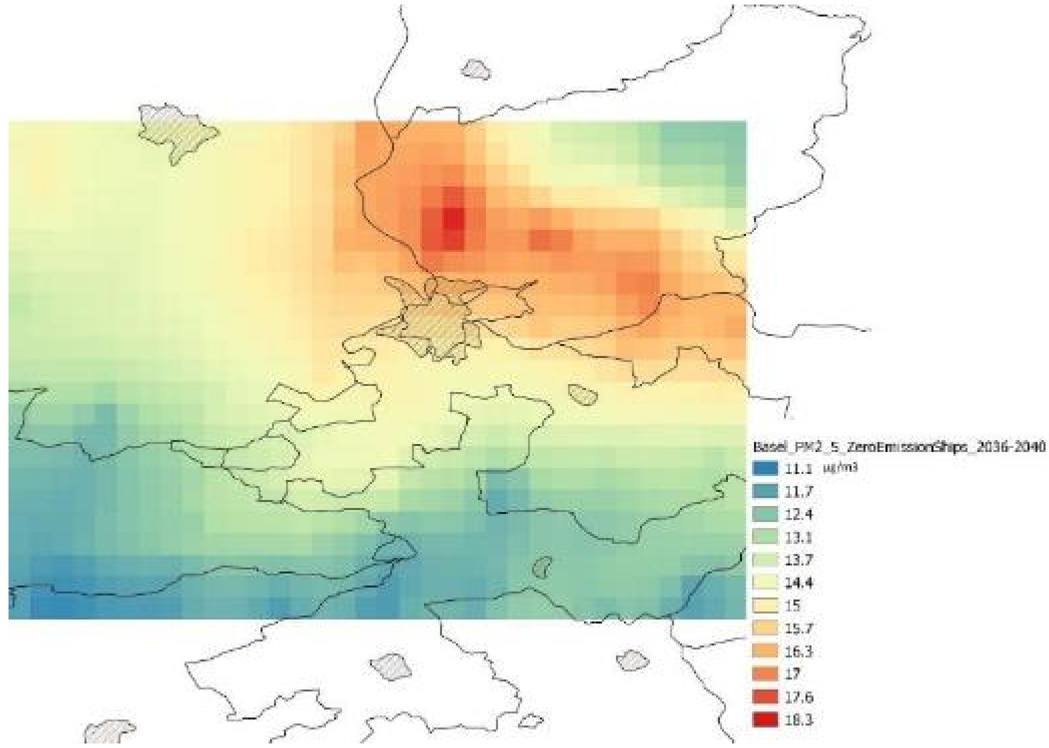


Figure 24: $PM_{2.5}$ Concentration map of the wider area of Basel – ZeroEmissionShip scenario

Air pollution modelling results - Brno

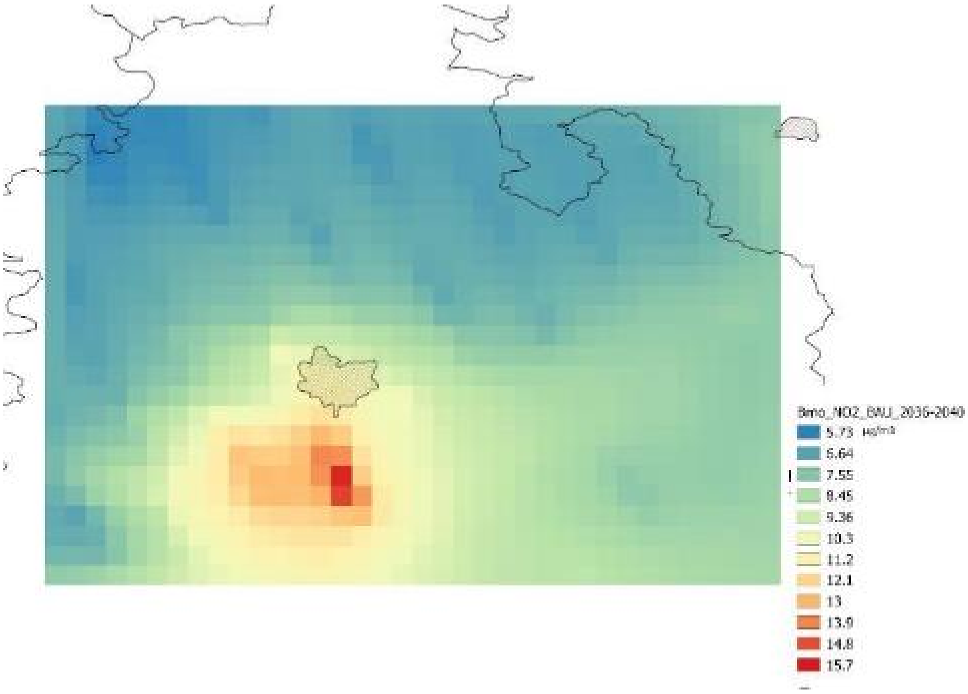


Figure 25: NO_2 Concentration map of the wider area of Brno – BAU scenario

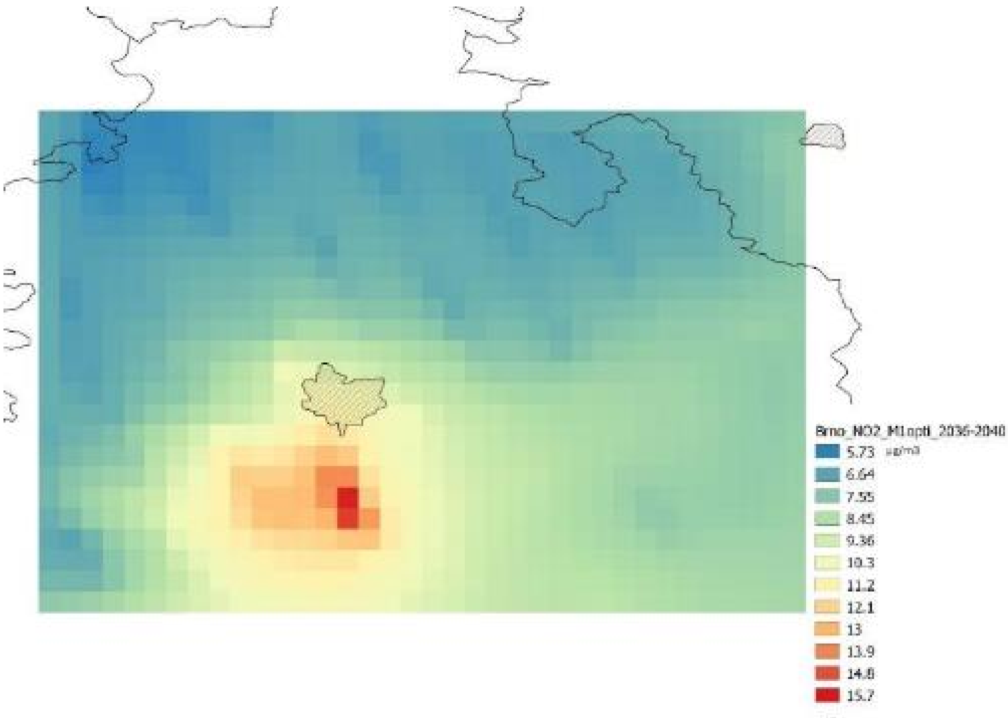


Figure 26: NO_2 Concentration map of the wider area of Brno – M1opti scenario

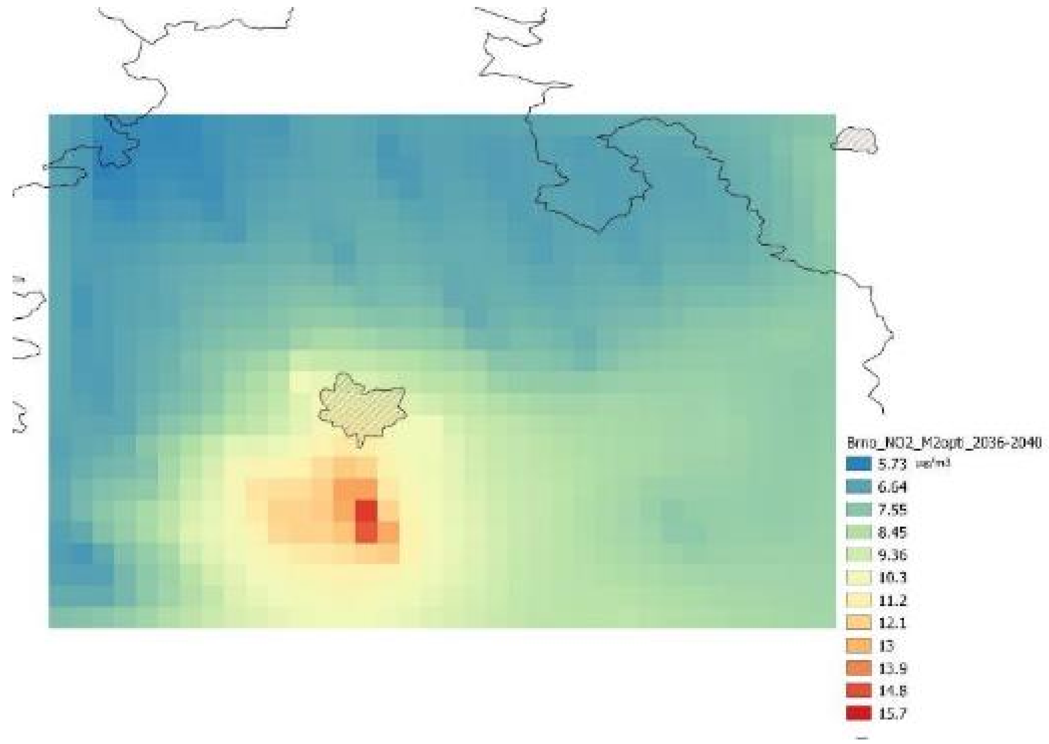


Figure 27: NO_2 Concentration map of the wider area of Brno – M2opti scenario

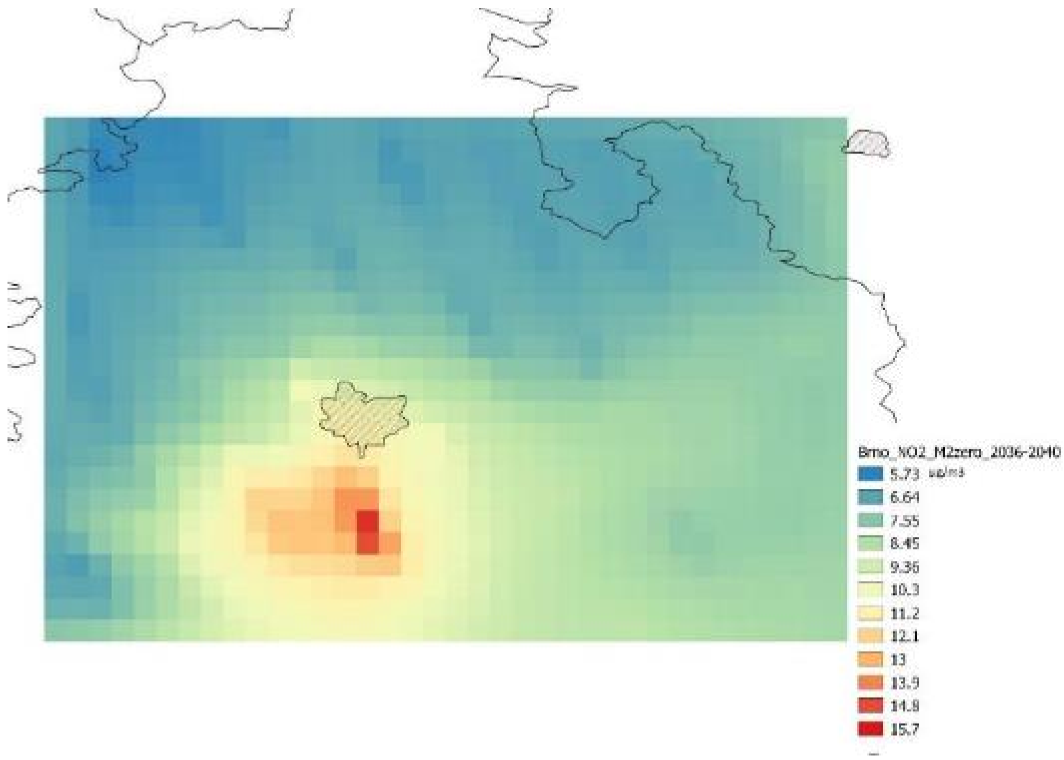


Figure 28: NO_2 Concentration map of the wider area of Brno – M3zero scenario

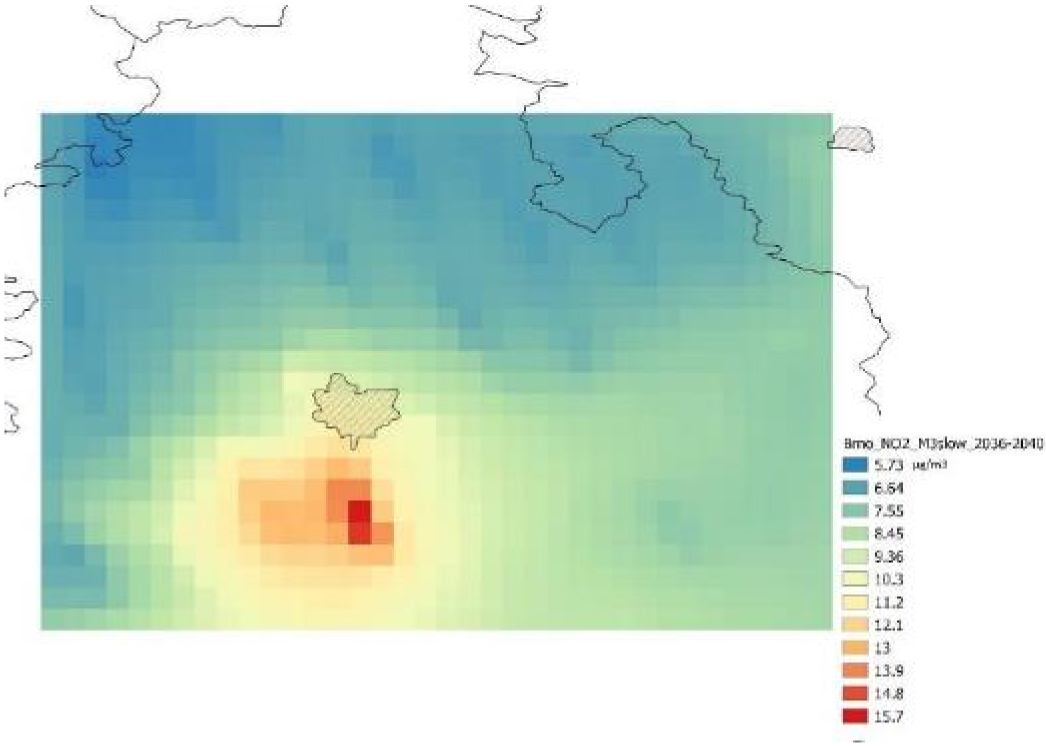


Figure 29: NO_2 Concentration map of the wider area of Brno – M3slow scenario

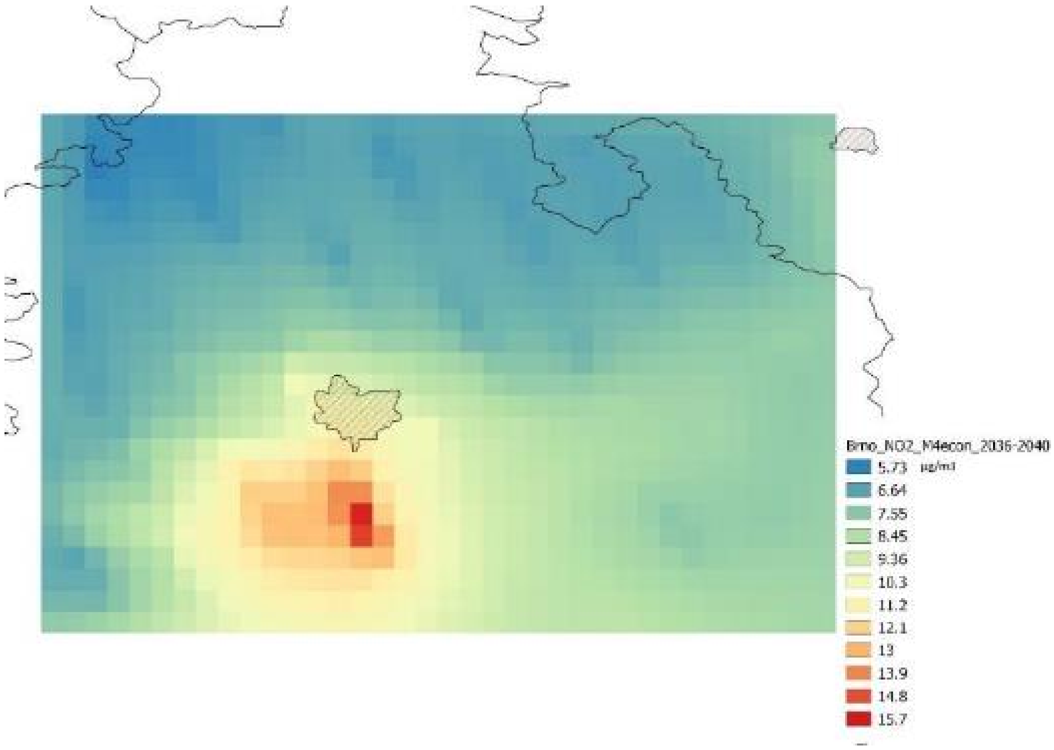


Figure 30: NO_2 Concentration map of the wider area of Brno – M4econ scenario

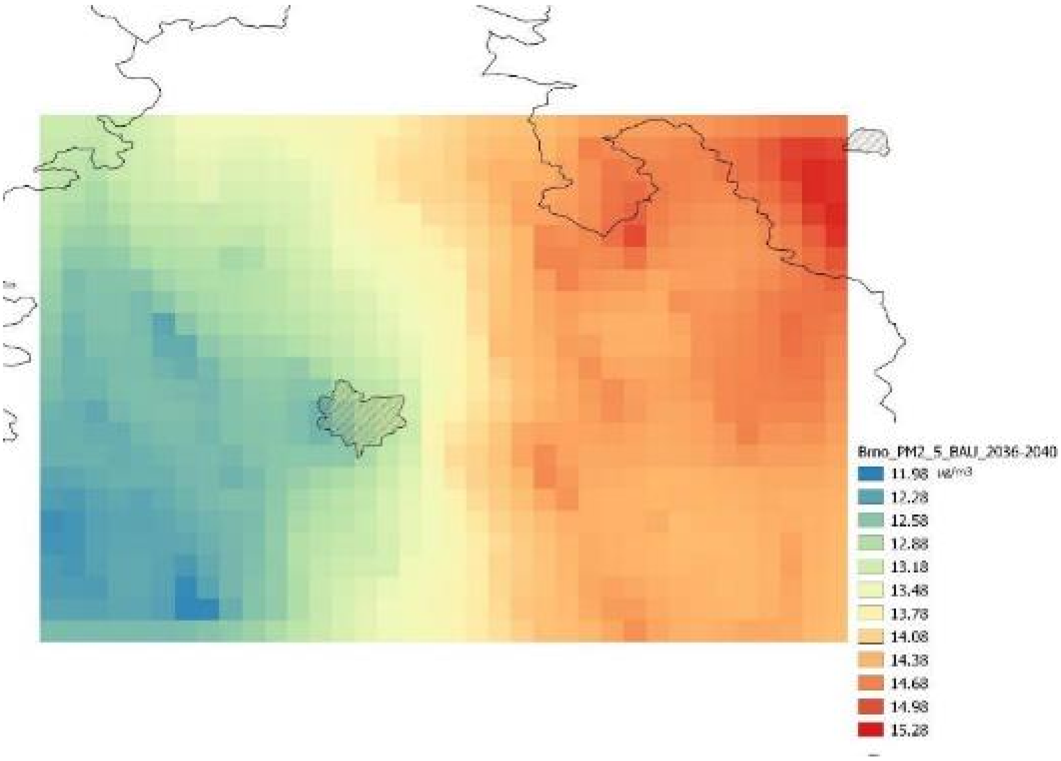


Figure 31: $PM_{2.5}$ Concentration map of the wider area of Brno – BAU scenario

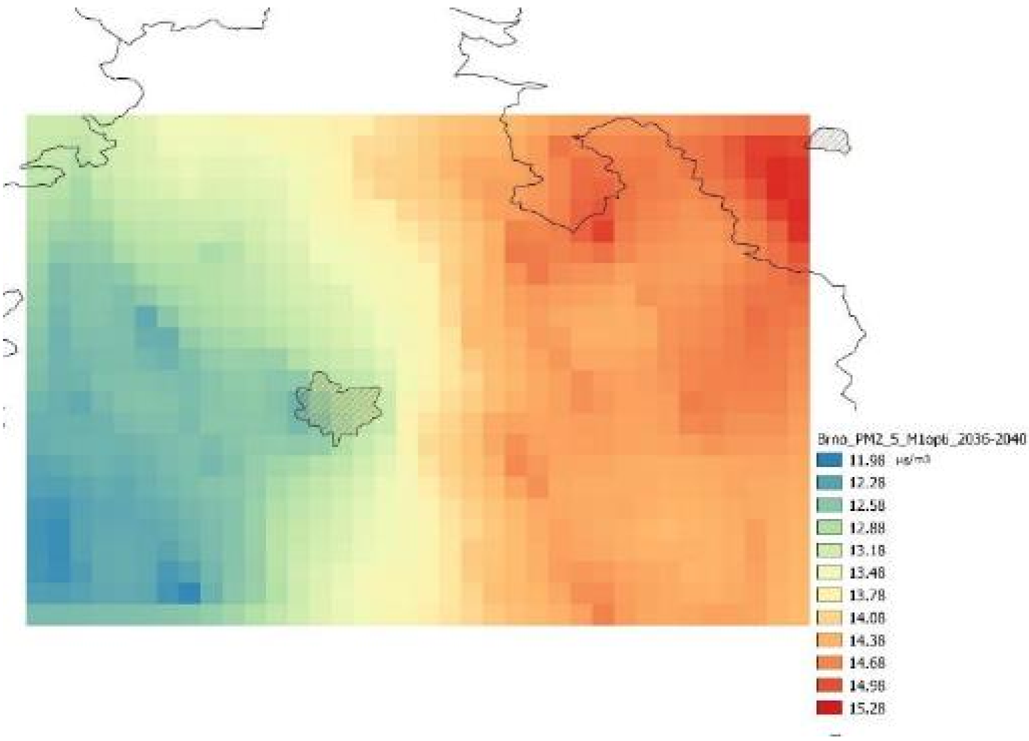


Figure 32: $PM_{2.5}$ Concentration map of the wider area of Brno – M1opti scenario

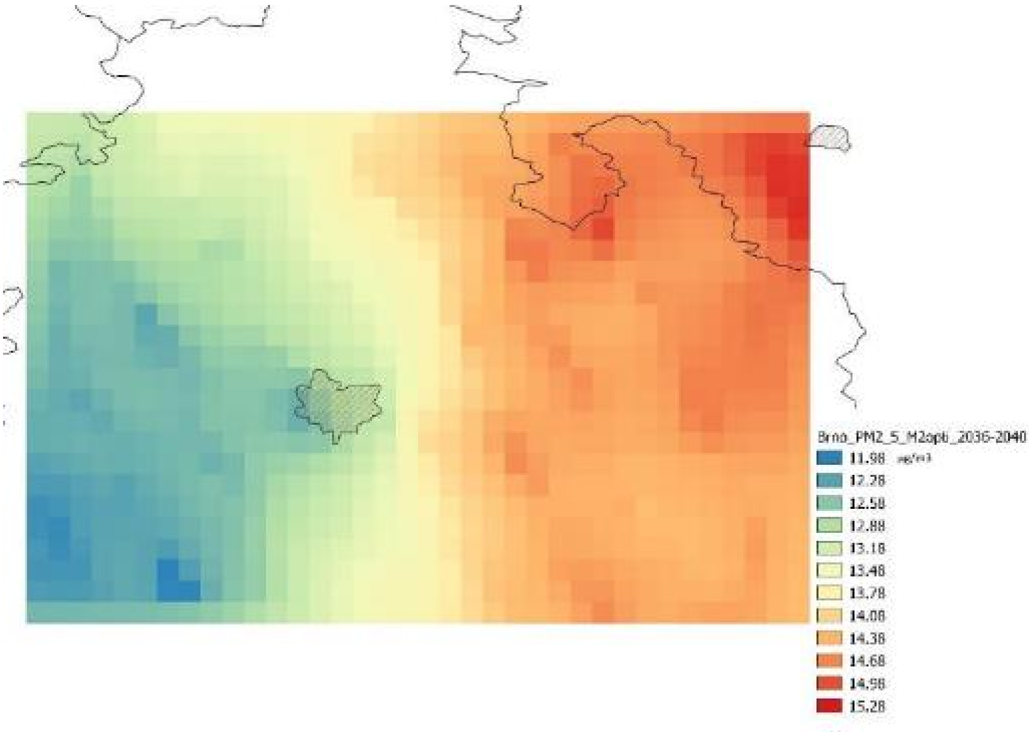


Figure 33: PM$_{2.5}$ Concentration map of the wider area of Brno – M2opti scenario

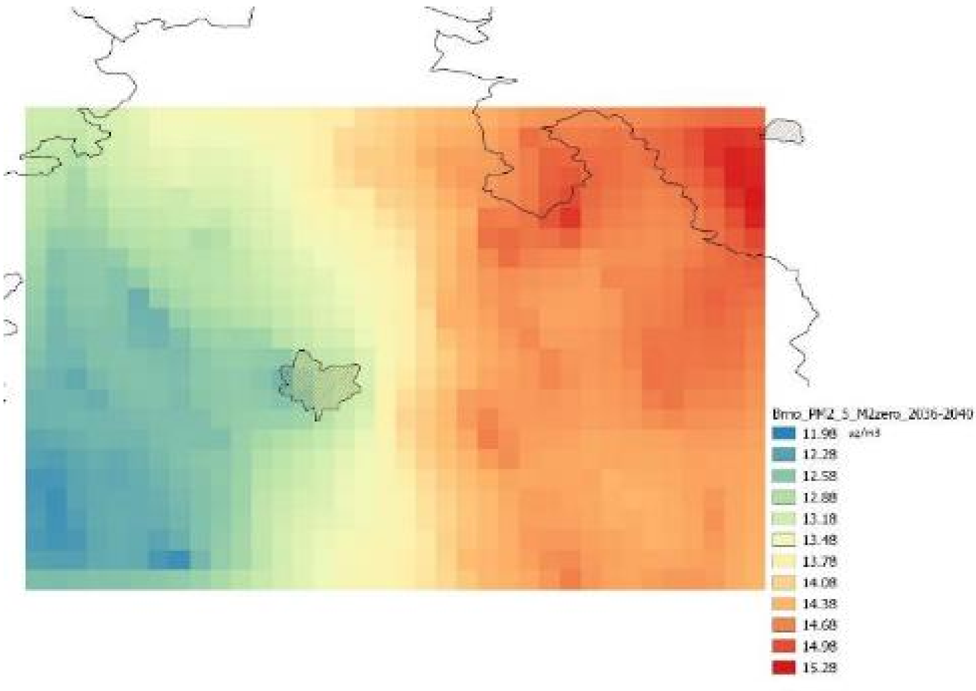


Figure 34: PM$_{2.5}$ Concentration map of the wider area of Brno – M2zero scenario

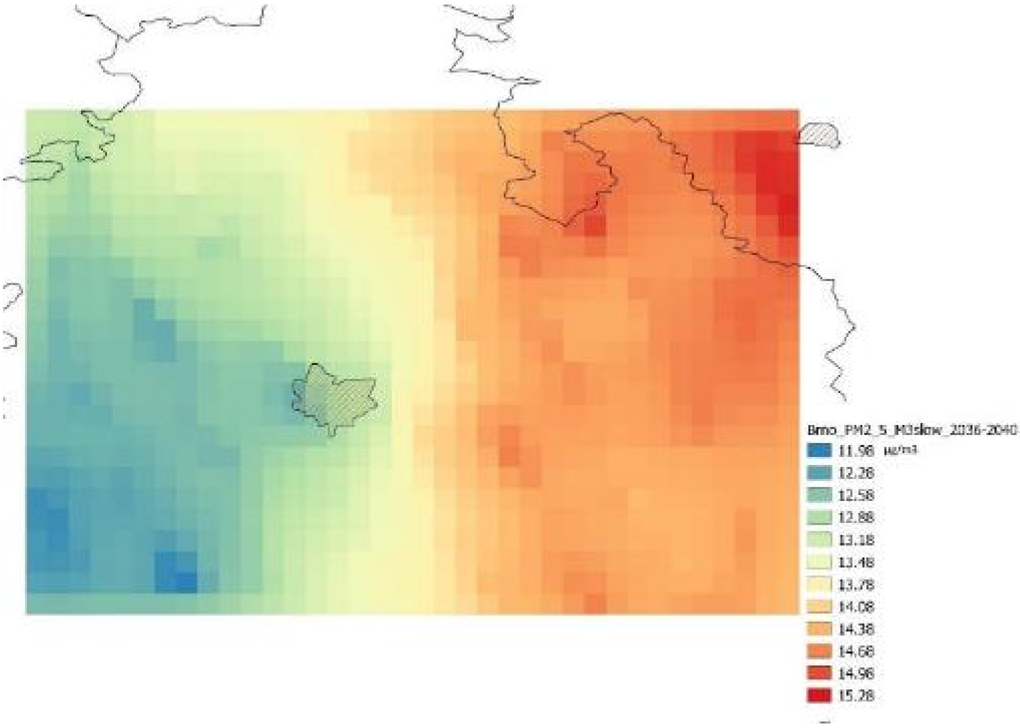


Figure 35: $PM_{2.5}$ Concentration map of the wider area of Brno – M3slow scenario

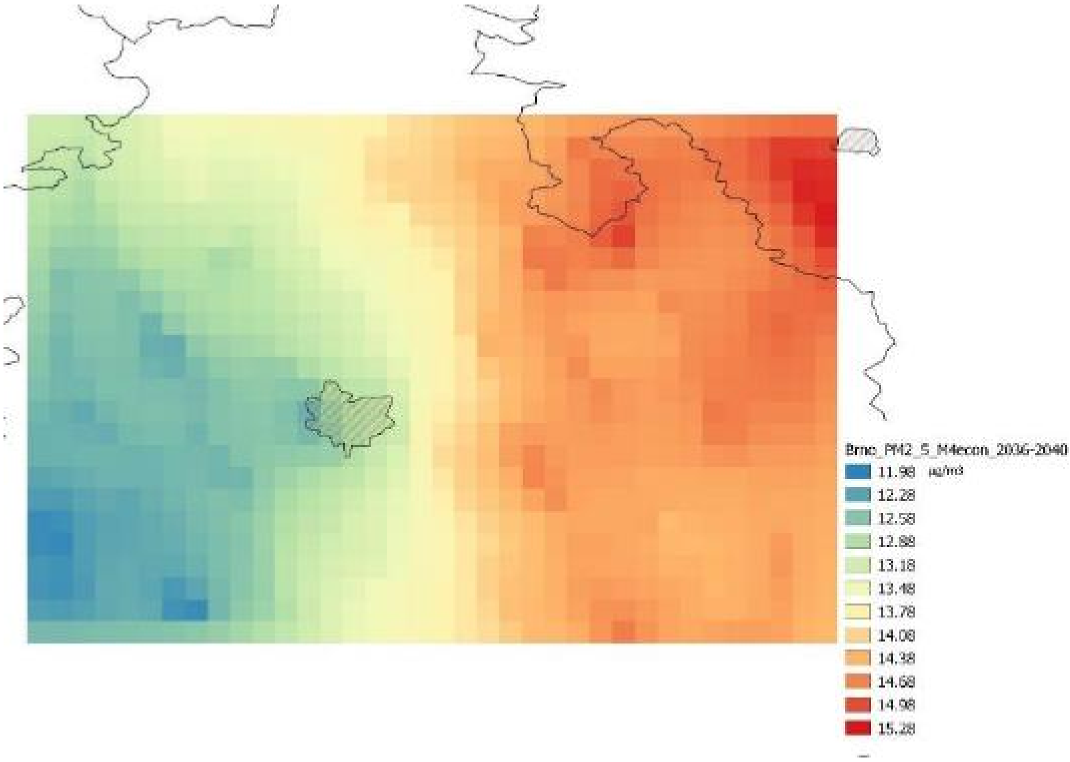


Figure 36: $PM_{2.5}$ Concentration map of the wider area of Brno – M4econ scenario

Air pollution modelling results - Ljubljana

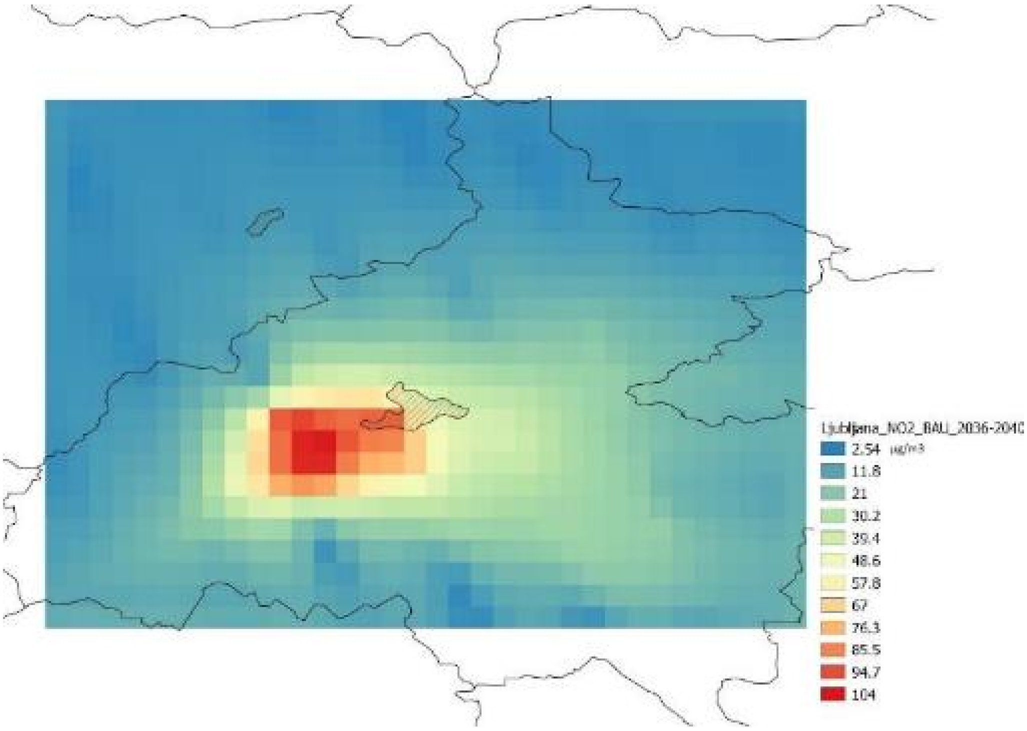


Figure 37: NO_2 Concentration map of the wider area of Ljubljana– BAU scenario

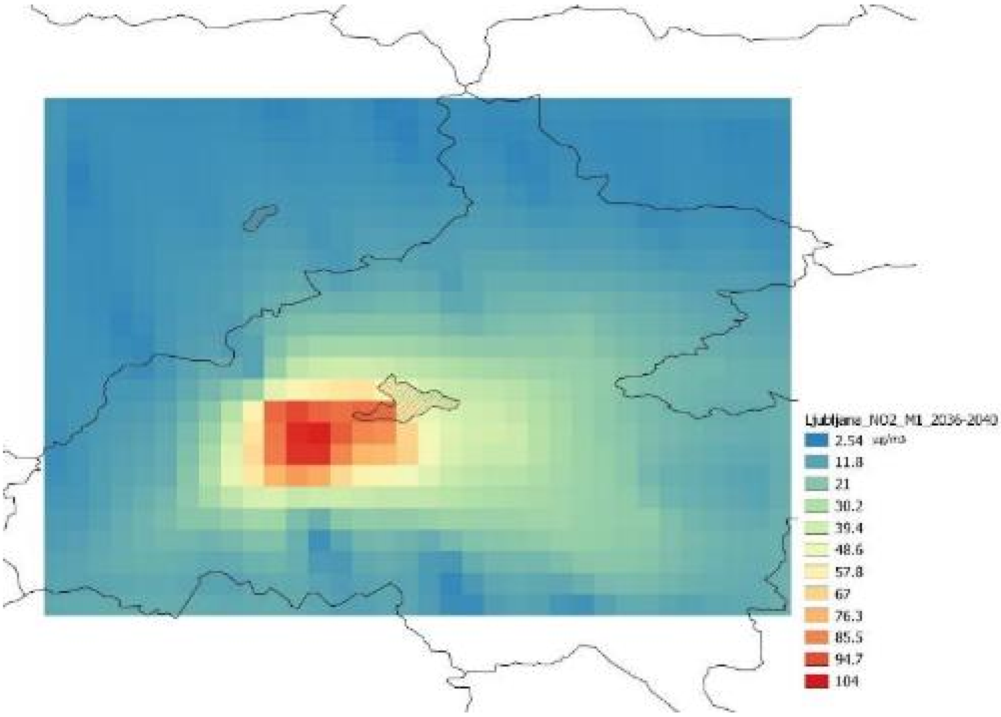


Figure 38: NO_2 Concentration map of the wider area of Ljubljana – M1_DecreaseCAR scenario

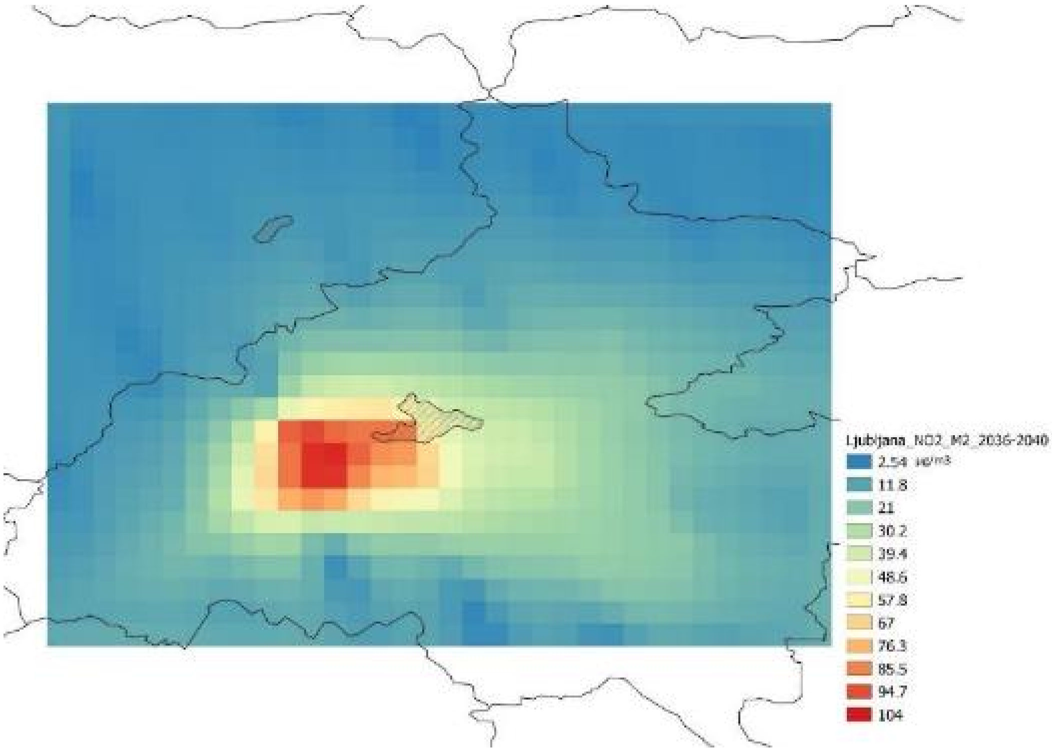


Figure 39: NO_2 Concentration map of the wider area of Ljubljana – M2_IncreasePT scenario

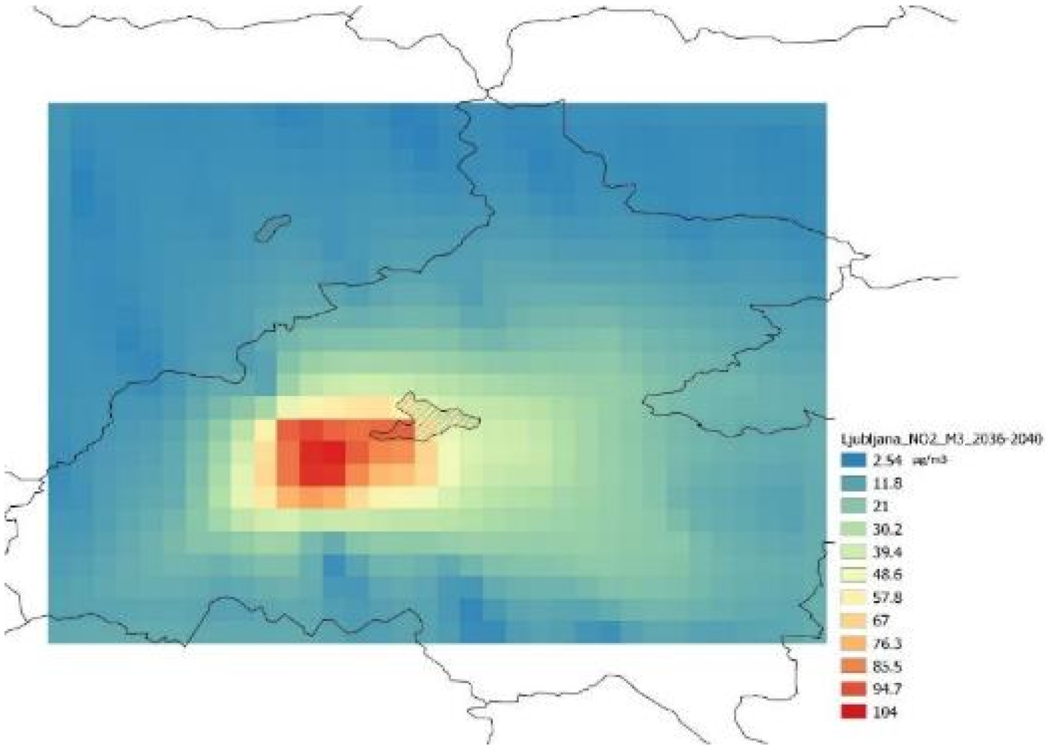


Figure 40: NO_2 Concentration map of the wider area of Ljubljana – M3_PTfeet scenario

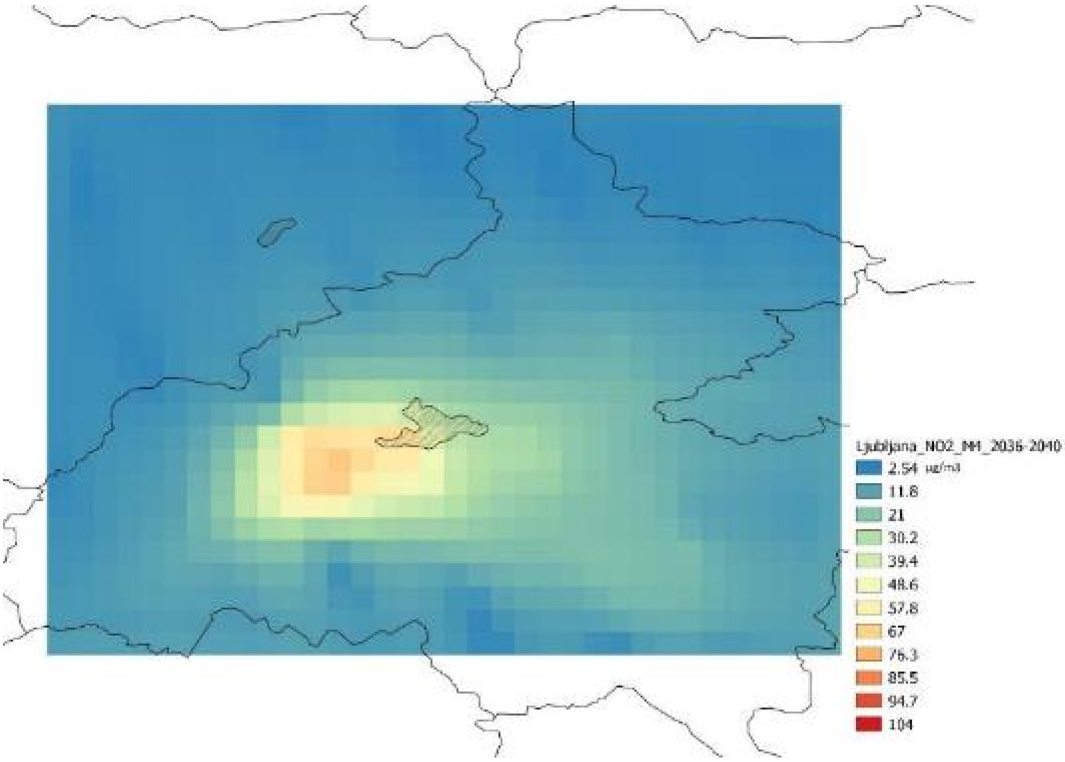


Figure 41: NO_2 Concentration map of the wider area of Ljubljana – M4_DistrHEAT scenario

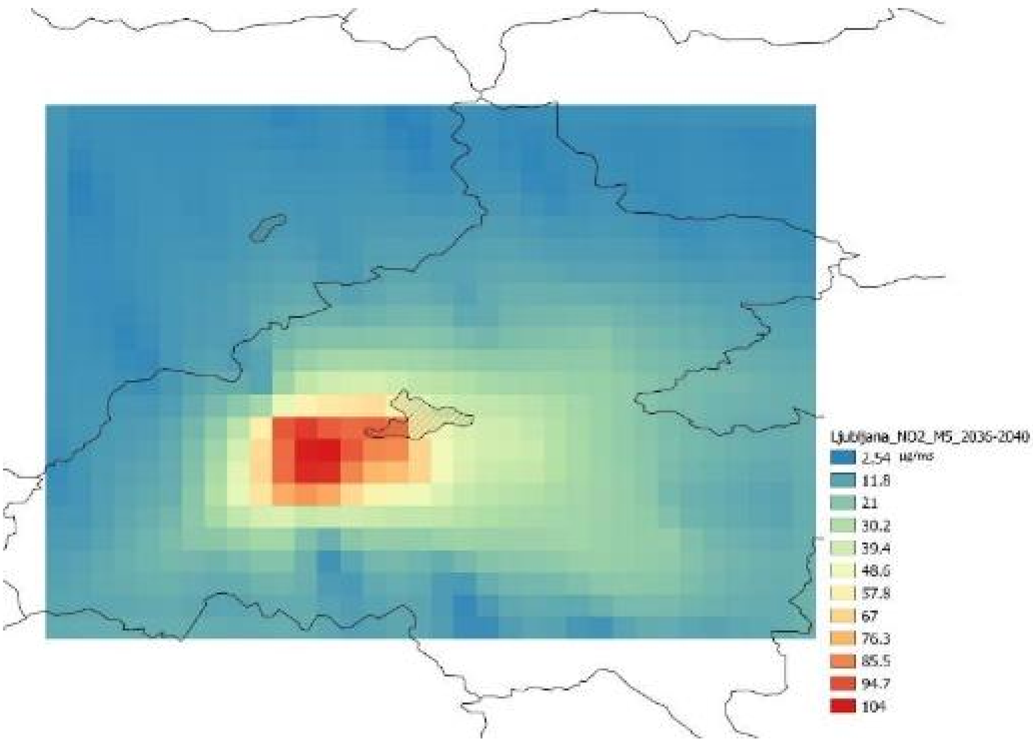


Figure 42: NO_2 Concentration map of the wider area of Ljubljana – M5_EfficientHEAT scenario

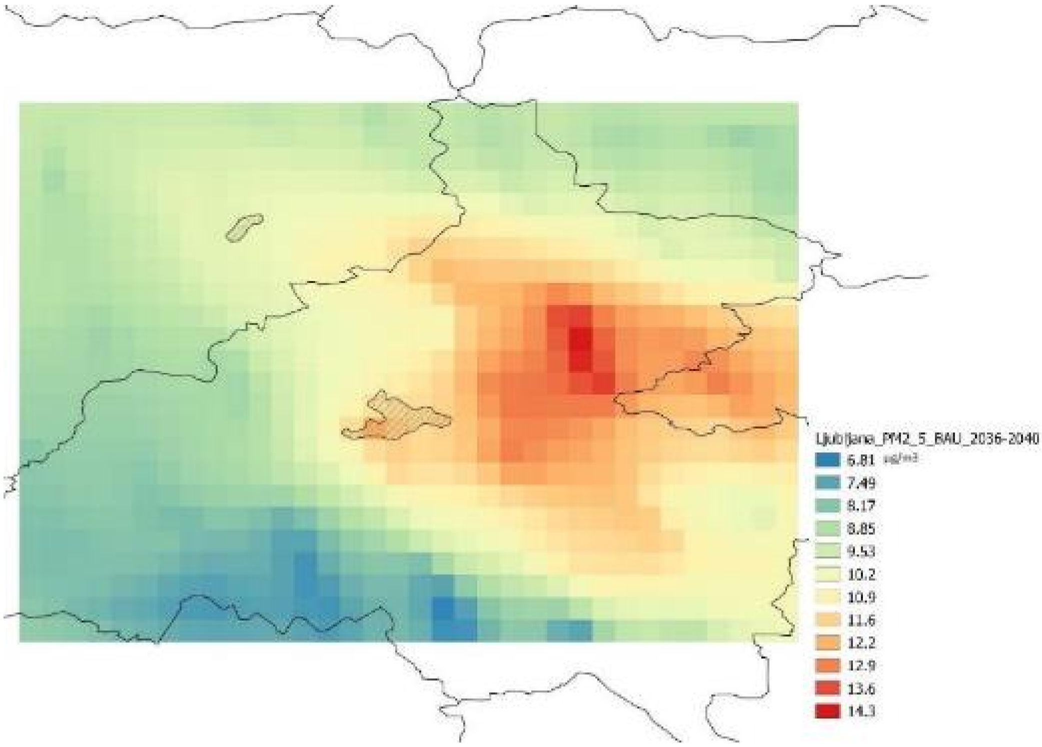


Figure 43: $PM_{2.5}$ Concentration map of the wider area of Ljubljana – BAU scenario

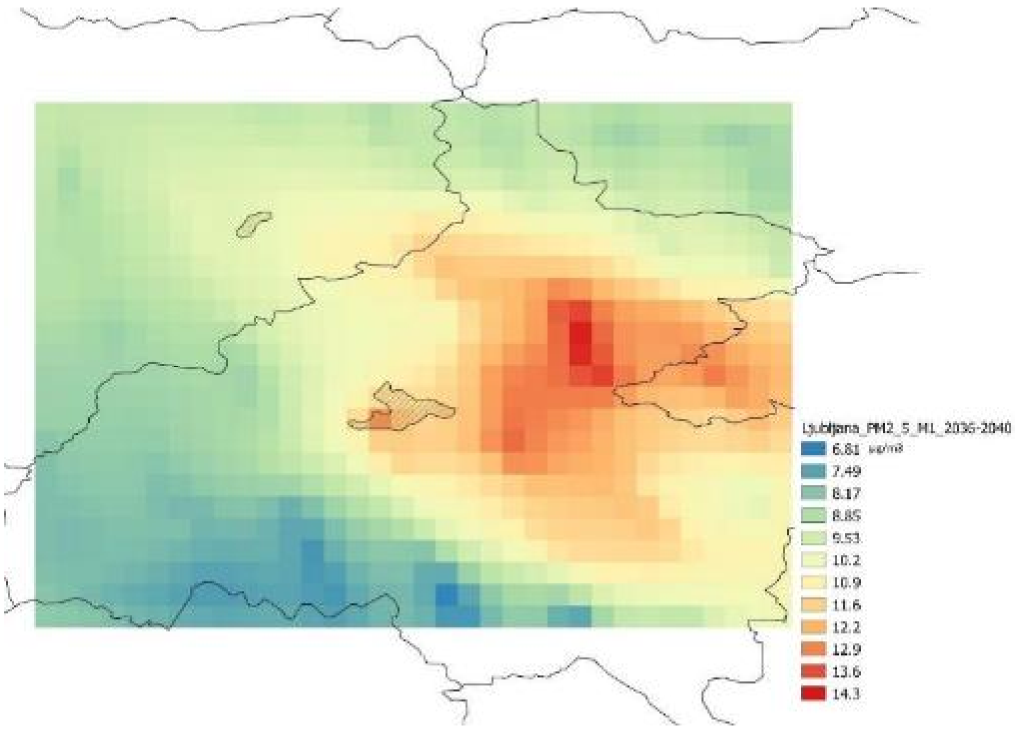


Figure 44: $PM_{2.5}$ Concentration map of the wider area of Ljubljana – M1 DecreaseCAR scenario

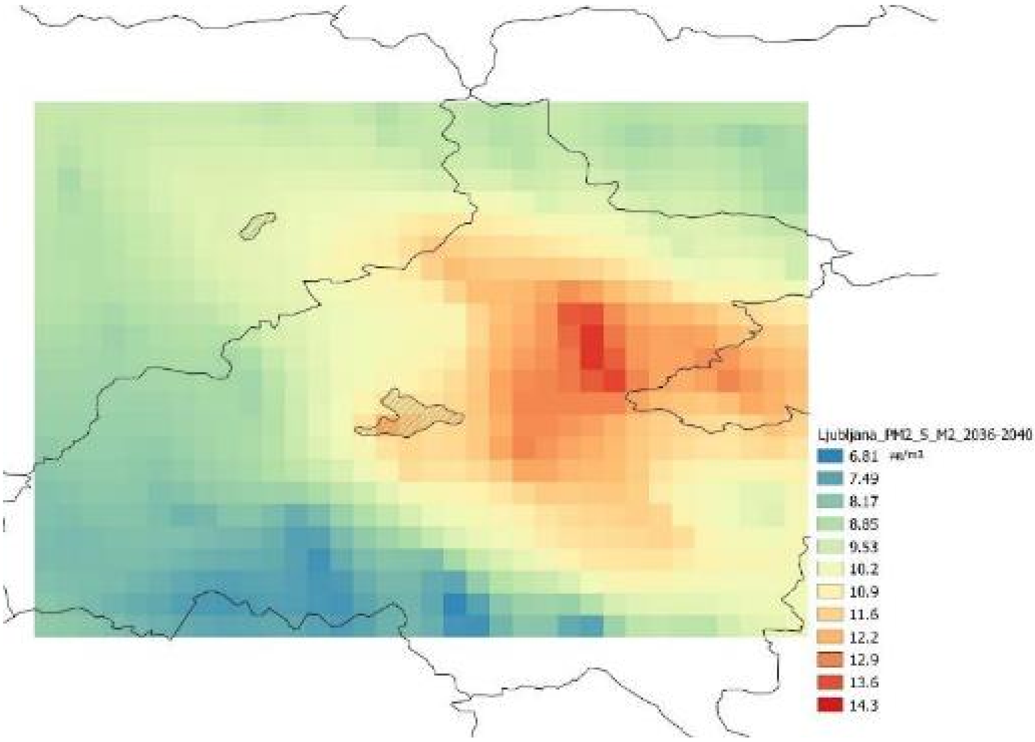


Figure 45: PM$_{2.5}$ Concentration map of the wider area of Ljubljana – M2_IncreasePT scenario

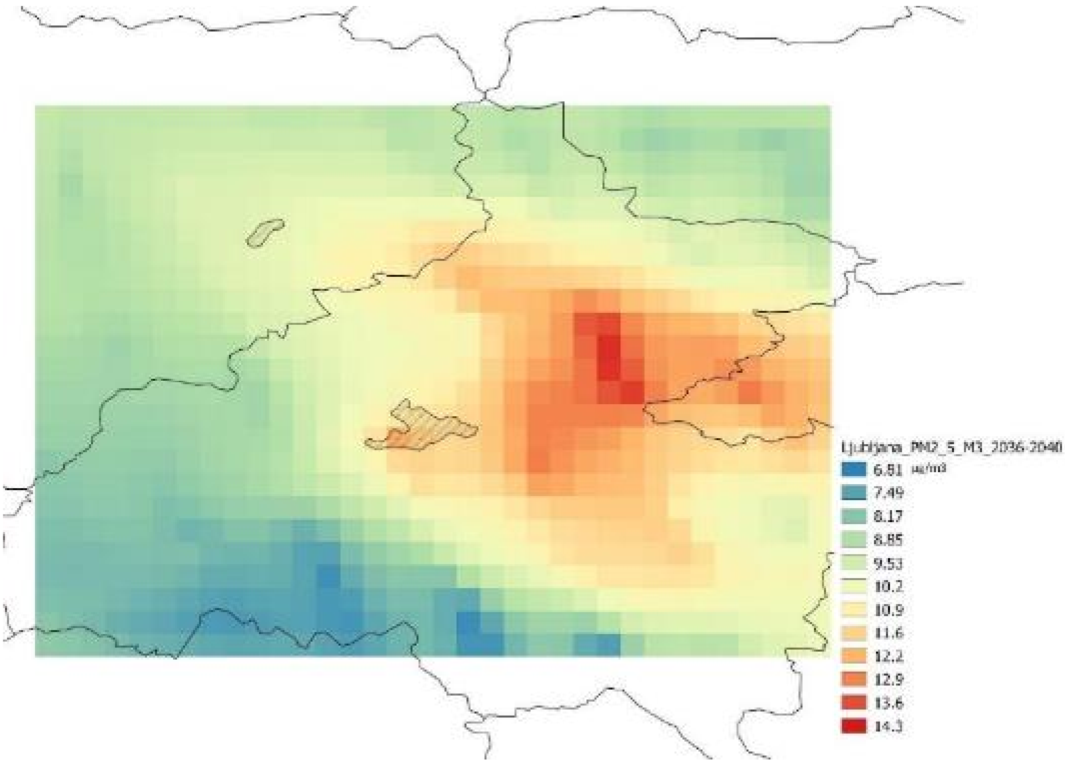


Figure 46: PM$_{2.5}$ Concentration map of the wider area of Ljubljana – M3_PTfeet scenario

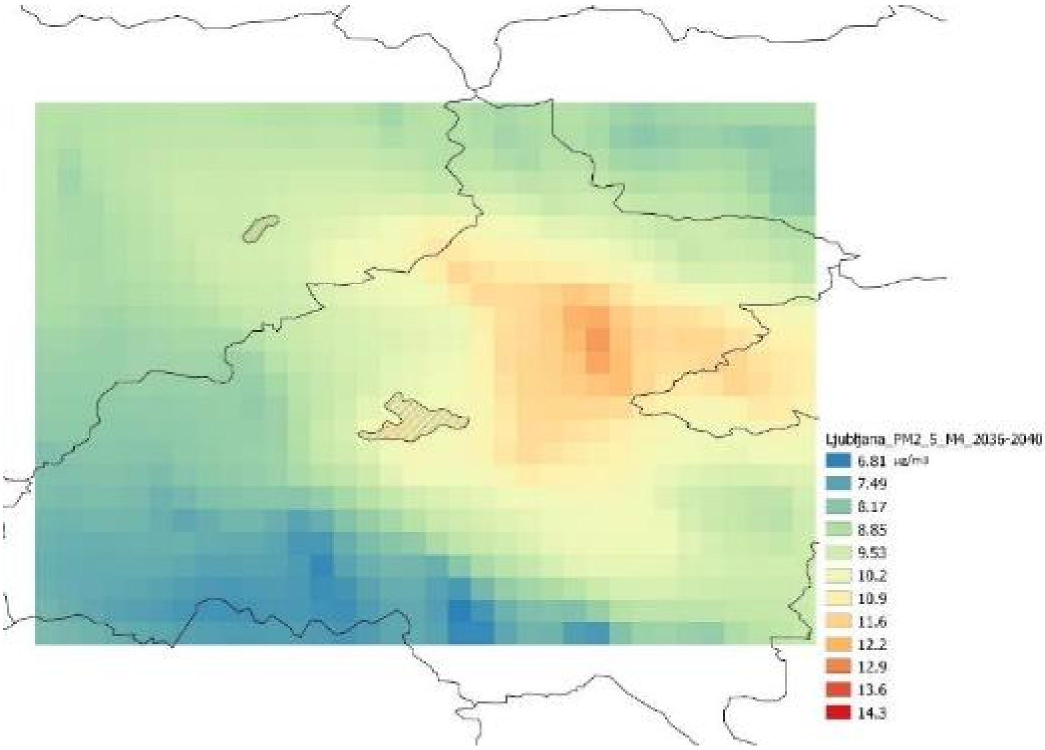


Figure 47: PM$_{2.5}$ Concentration map of the wider area of Ljubljana – M4_DistrHEAT scenario

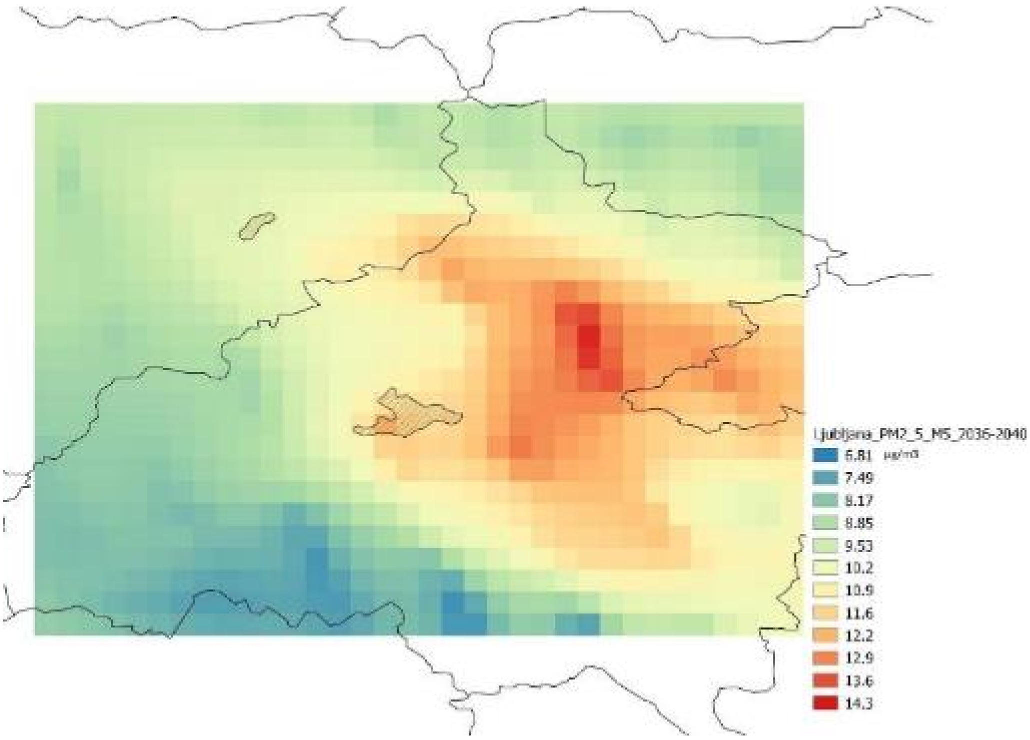


Figure 48: PM$_{2.5}$ Concentration map of the wider area of Ljubljana – M5_EfficientHEAT scenario

Air pollution modelling results - Madrid

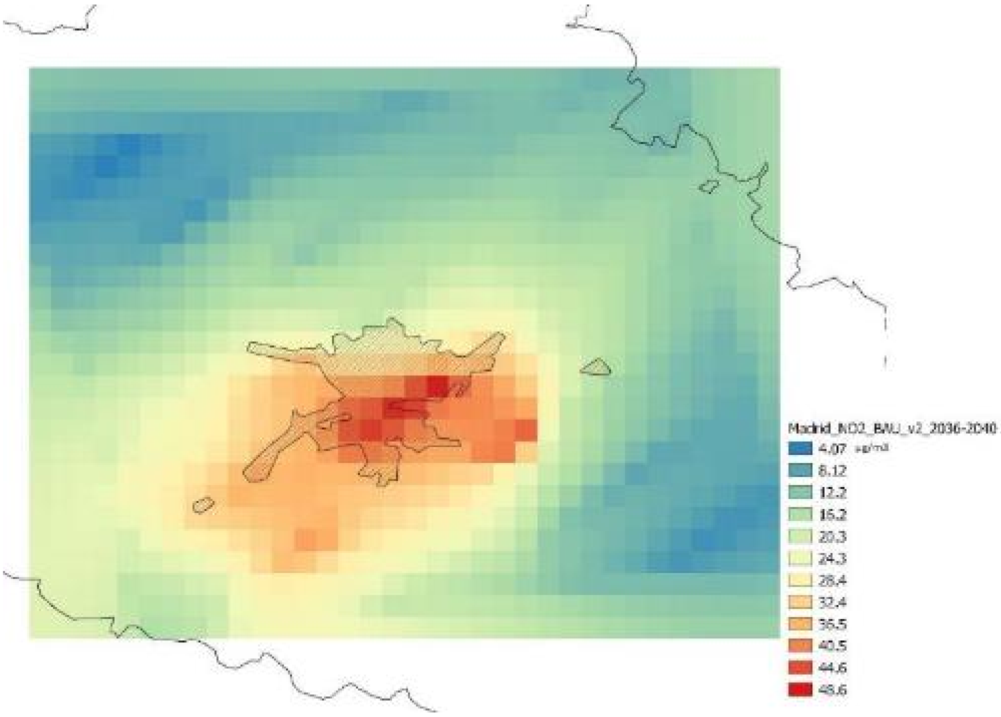


Figure 49: NO_2 Concentration map of the wider area of Madrid– BAUv2 scenario

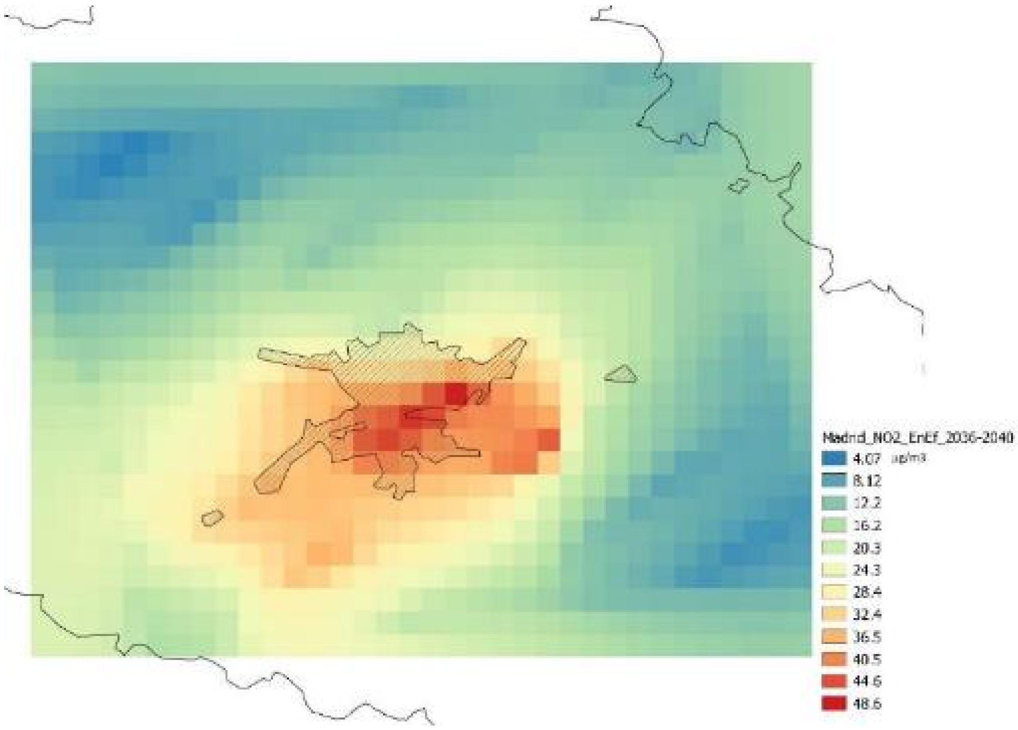


Figure 50: NO_2 Concentration map of the wider area of Madrid– EnEf scenario

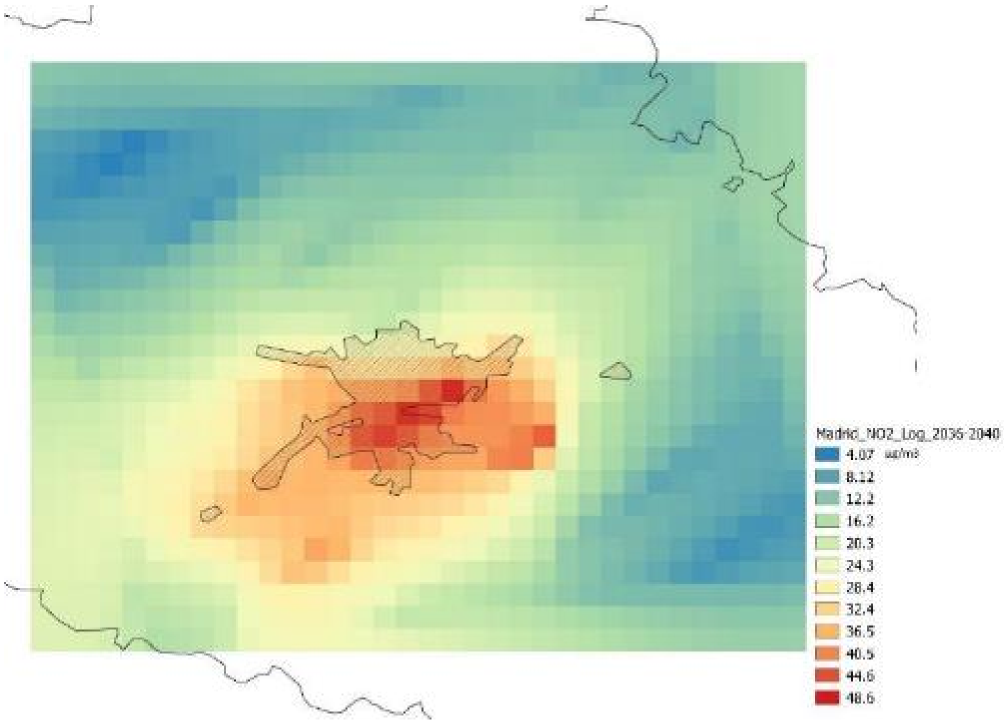


Figure 51: NO_2 Concentration map of the wider area of Madrid– Log scenario

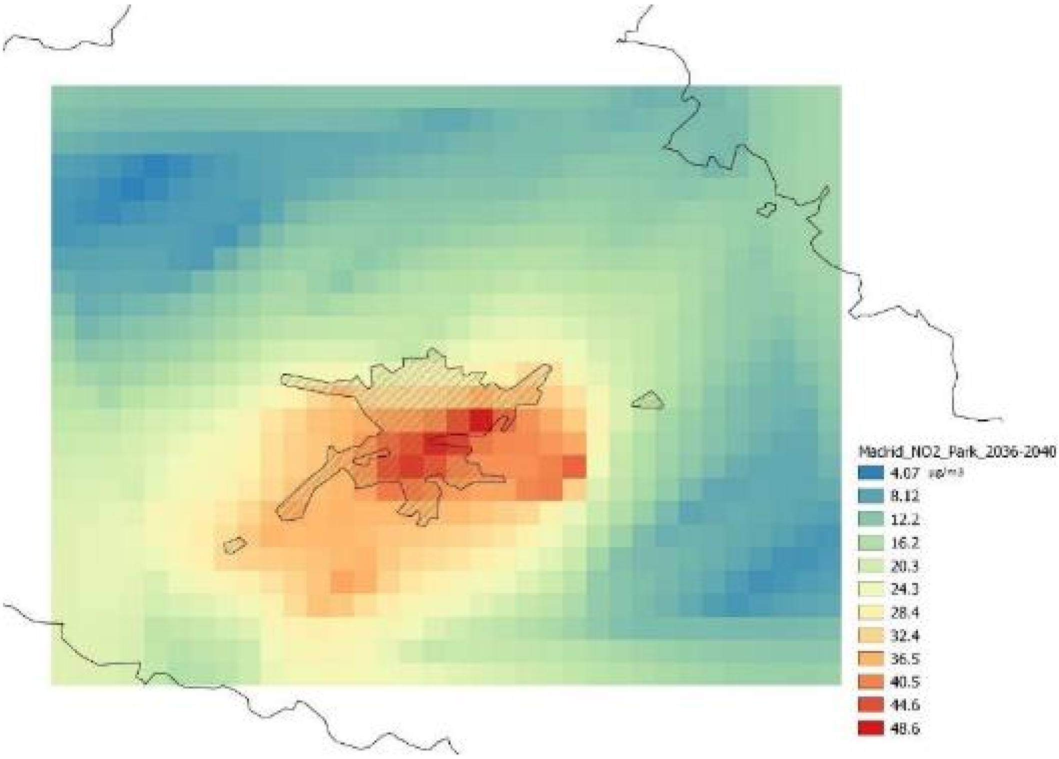


Figure 52: NO_2 Concentration map of the wider area of Madrid– Park scenario

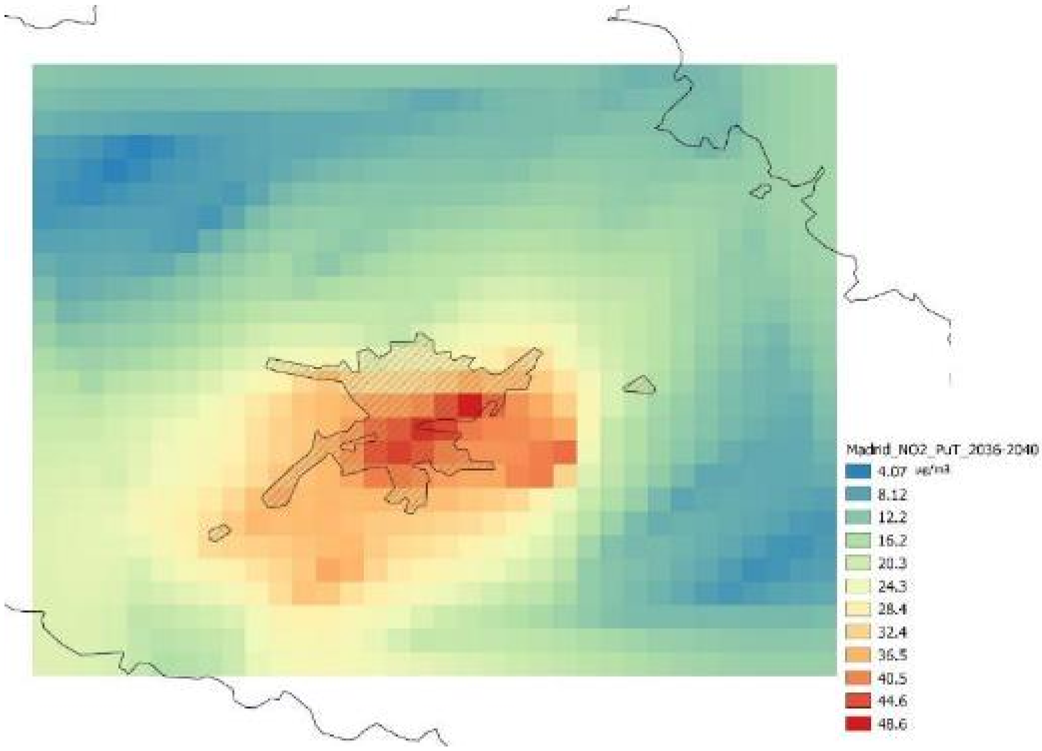


Figure 53: NO_2 Concentration map of the wider area of Madrid– PuT scenario

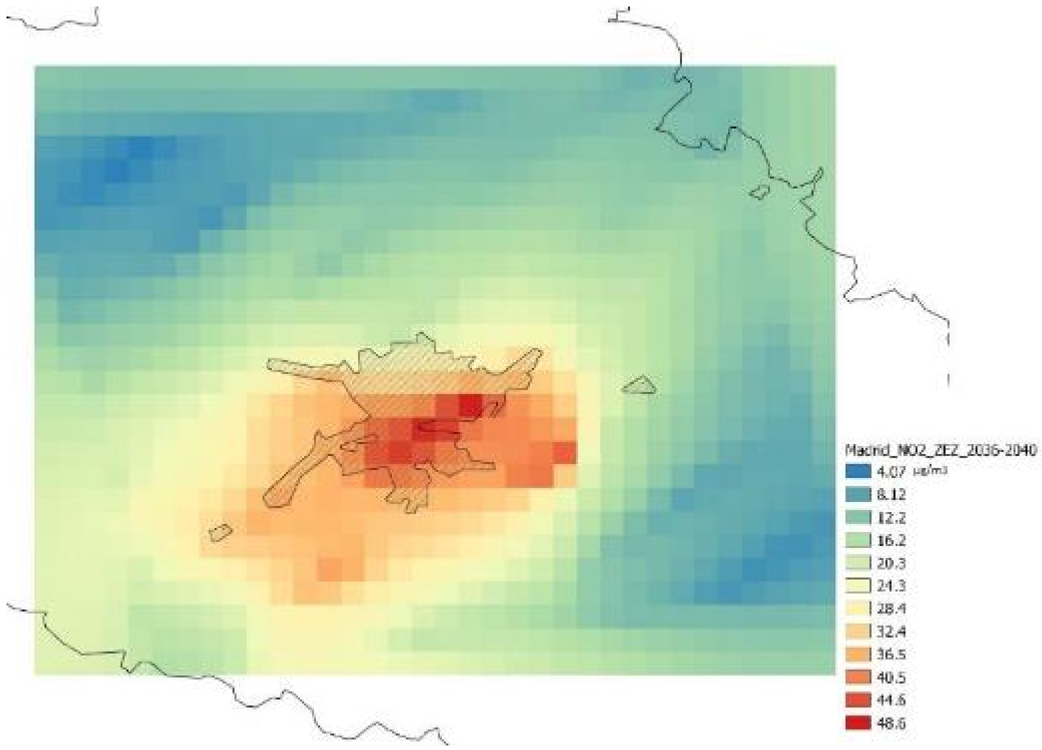


Figure 54: NO_2 Concentration map of the wider area of Madrid– ZEZ scenario

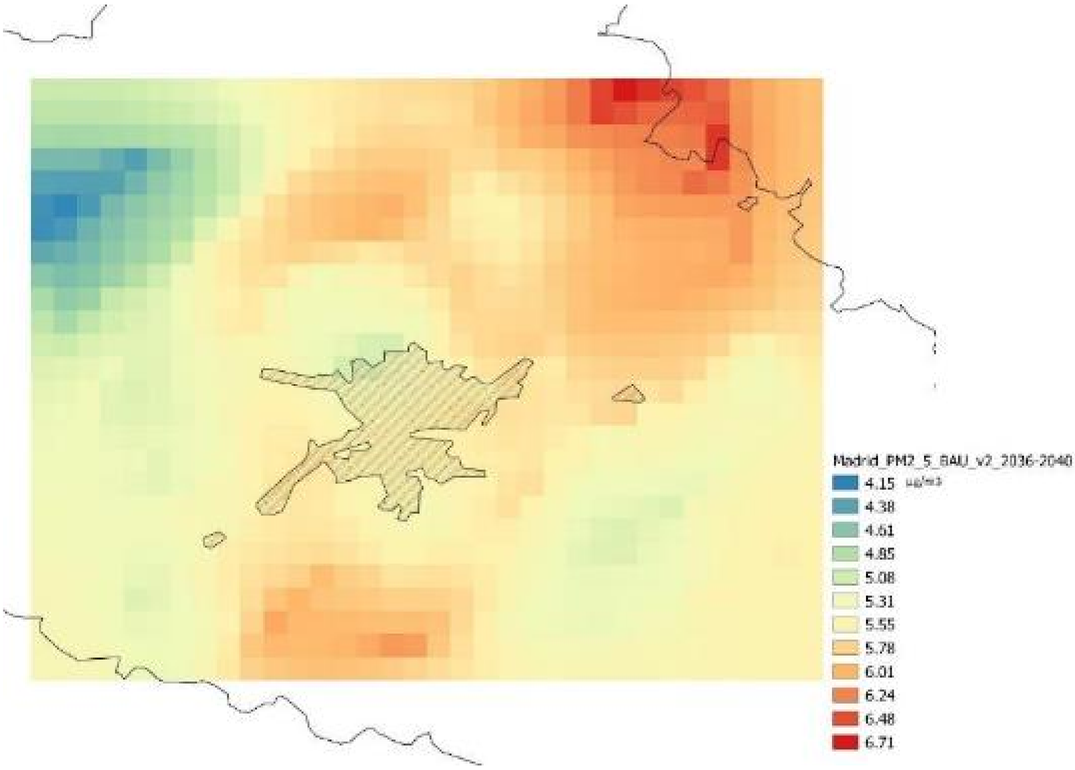


Figure 55: $PM_{2.5}$ Concentration map of the wider area of Madrid – BAUv2 scenario

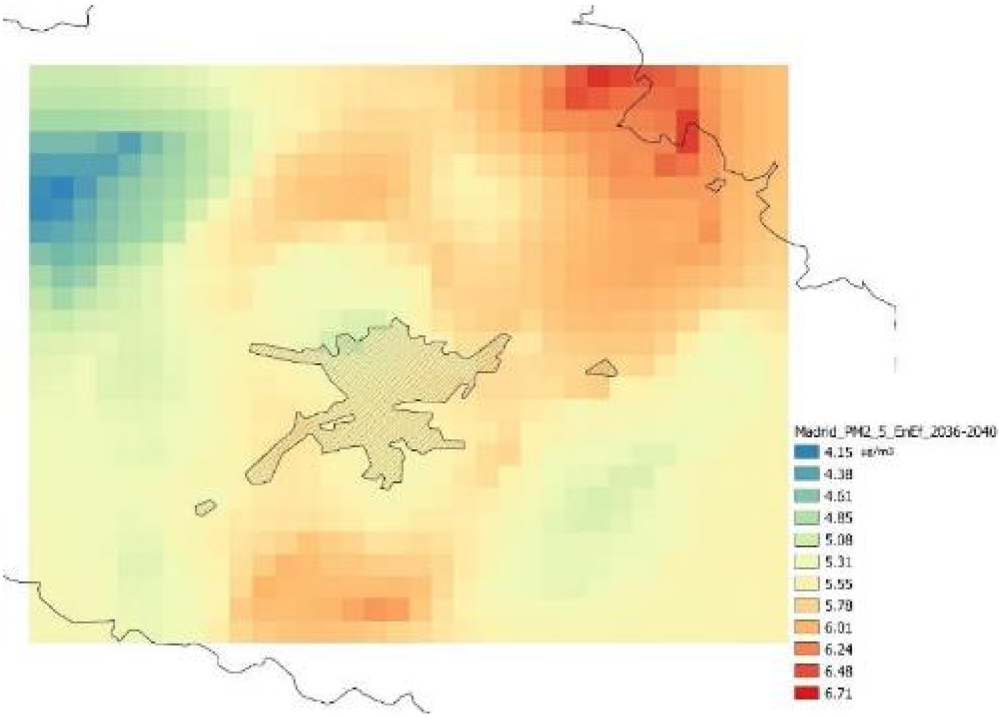


Figure 56: $PM_{2.5}$ Concentration map of the wider area of Madrid – EnEf scenario

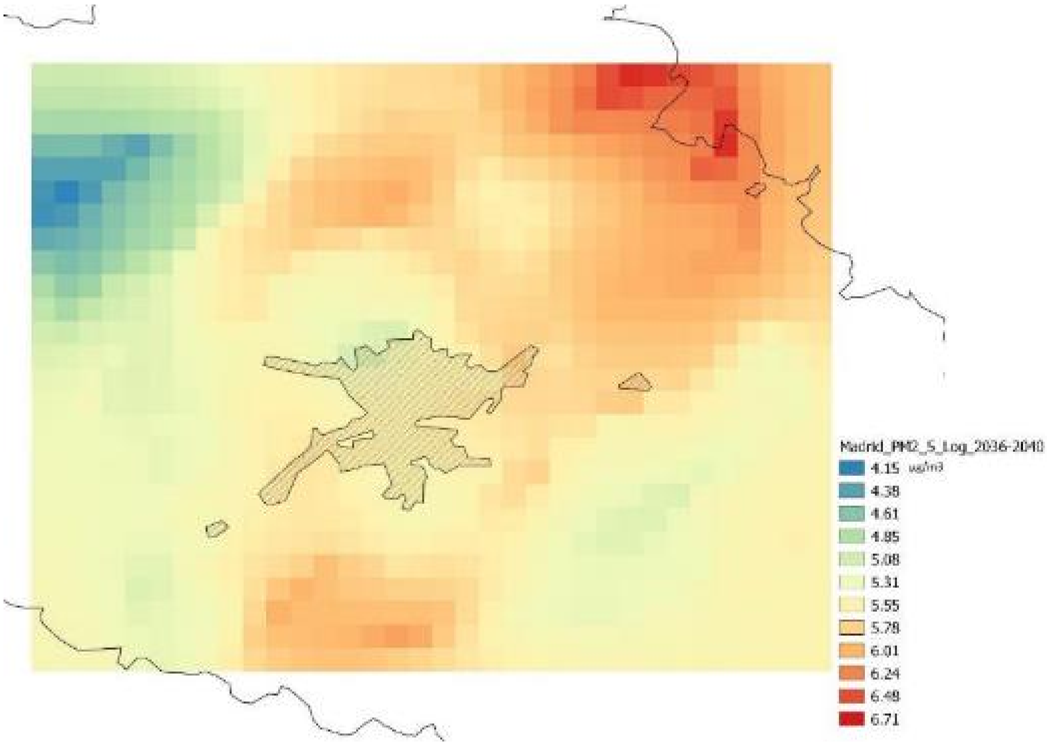


Figure 57: $PM_{2.5}$ Concentration map of the wider area of Madrid – Log scenario

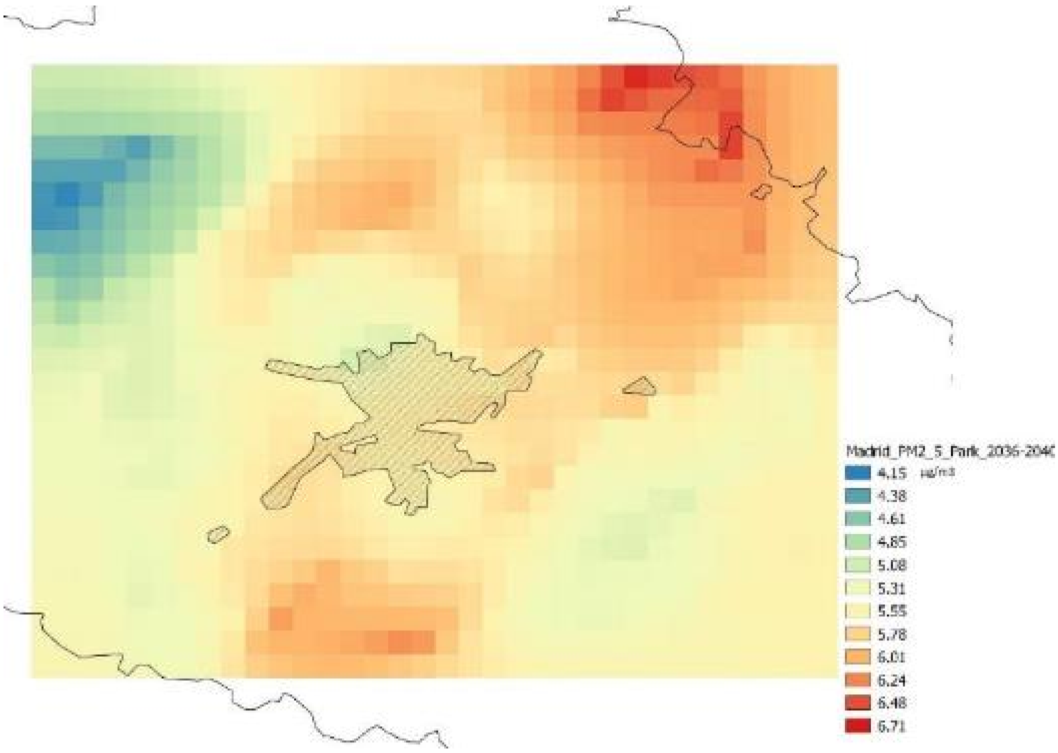


Figure 58: $PM_{2.5}$ Concentration map of the wider area of Madrid – Park scenario

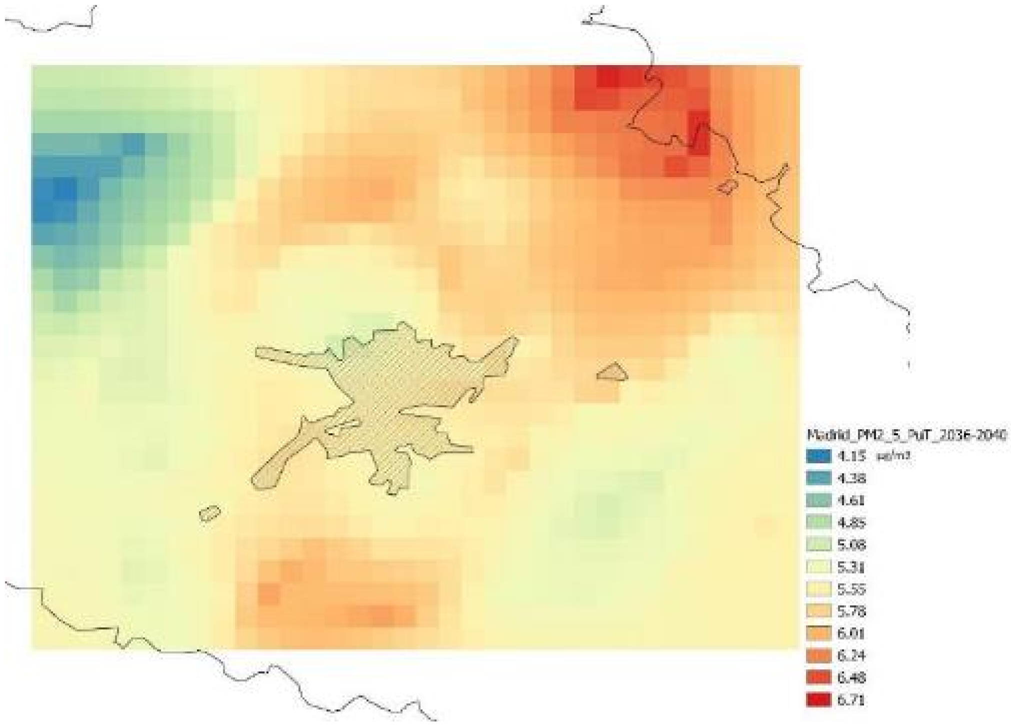


Figure 59: $PM_{2.5}$ Concentration map of the wider area of Madrid – PuT scenario

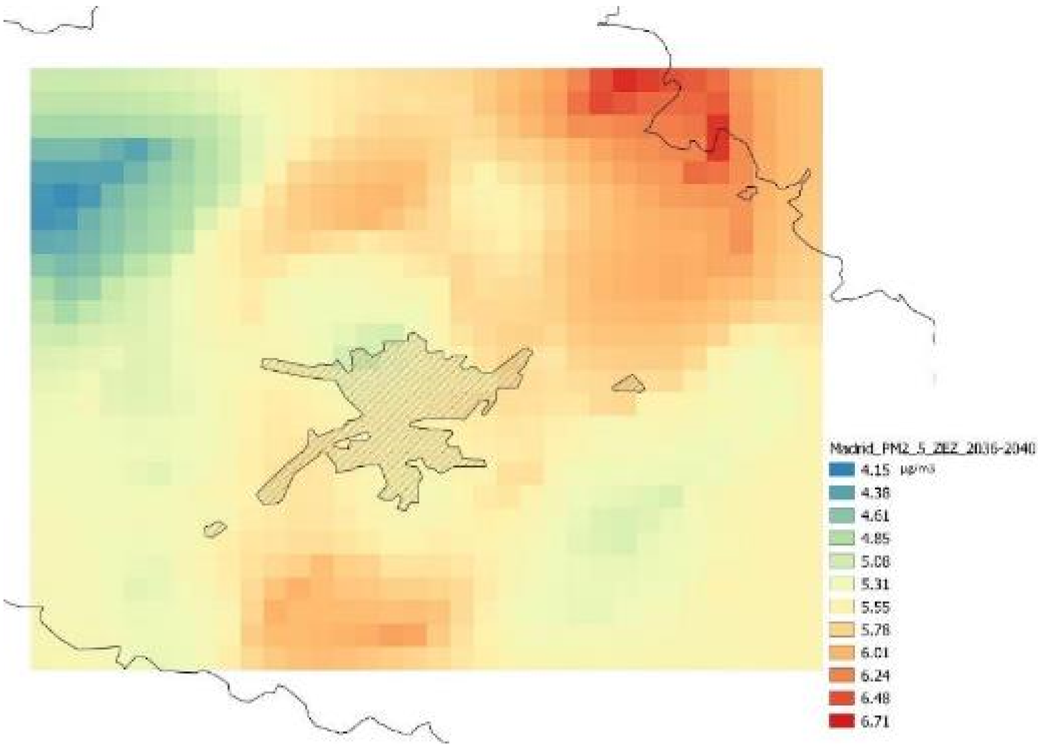


Figure 60: $PM_{2.5}$ Concentration map of the wider area of Madrid – ZEZ scenario

Air pollution modelling results - Milan

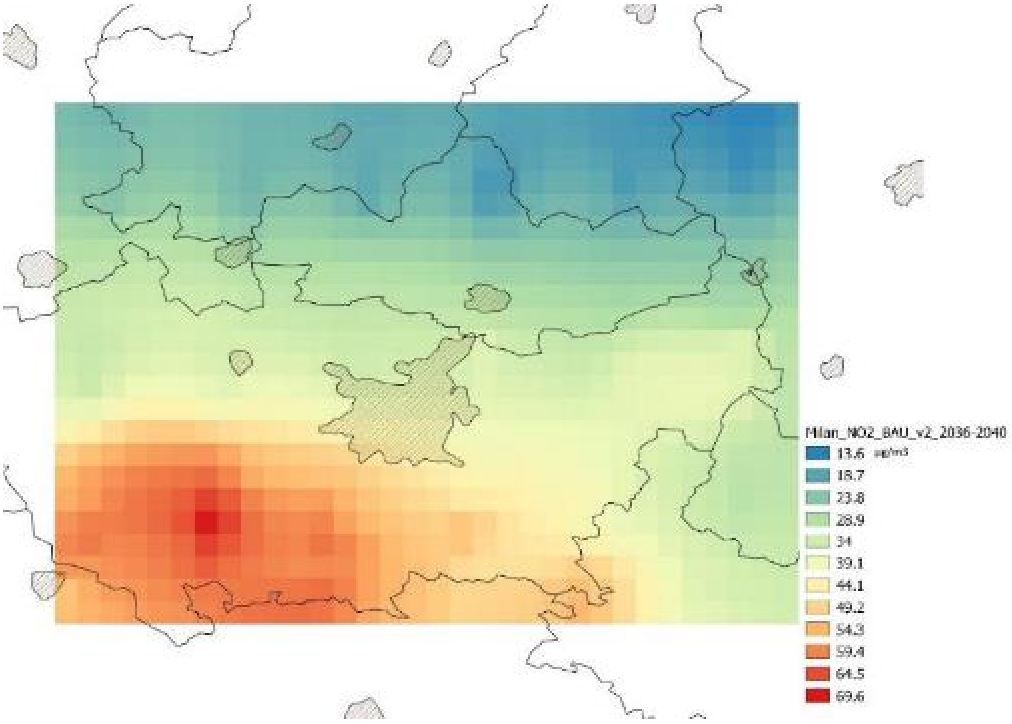


Figure 61: NO_2 Concentration map of the wider area of Milan – BAUv2 scenario

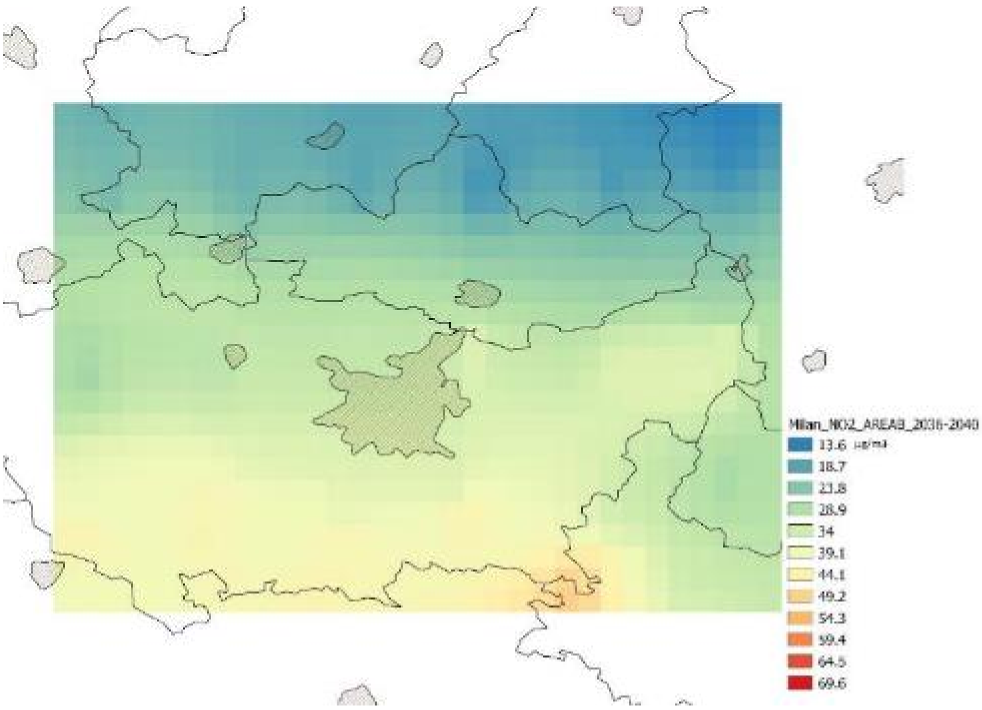


Figure 62: NO_2 Concentration map of the wider area of Milan – AREAB scenario

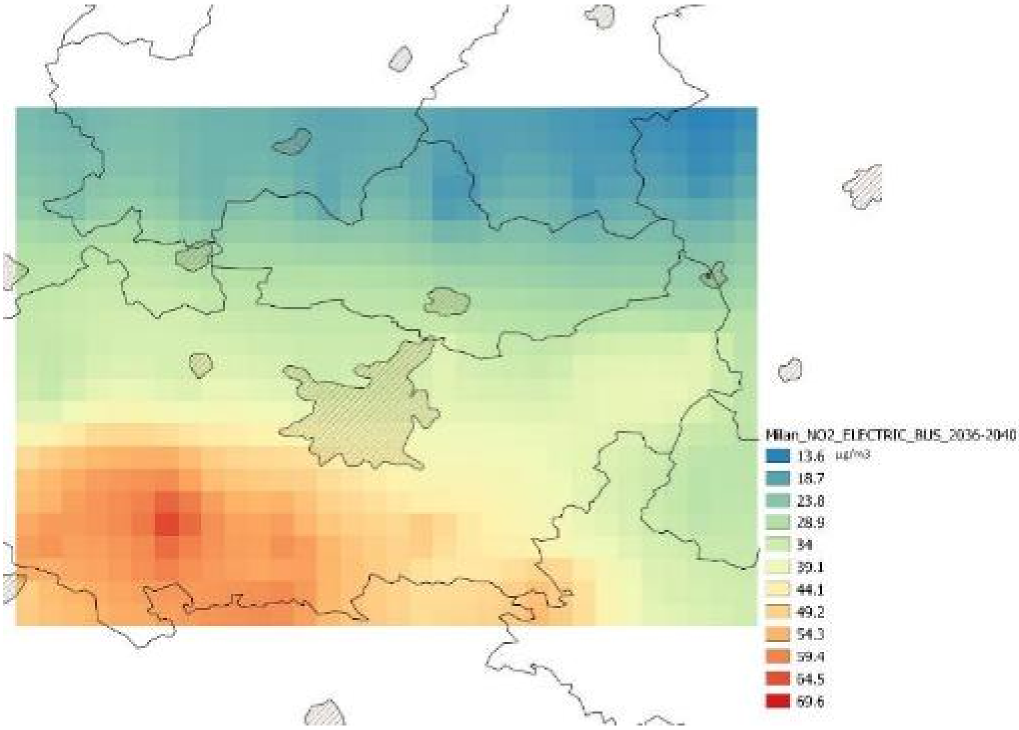


Figure 63: NO_2 Concentration map of the wider area of Milan – ELECTRICBUS scenario

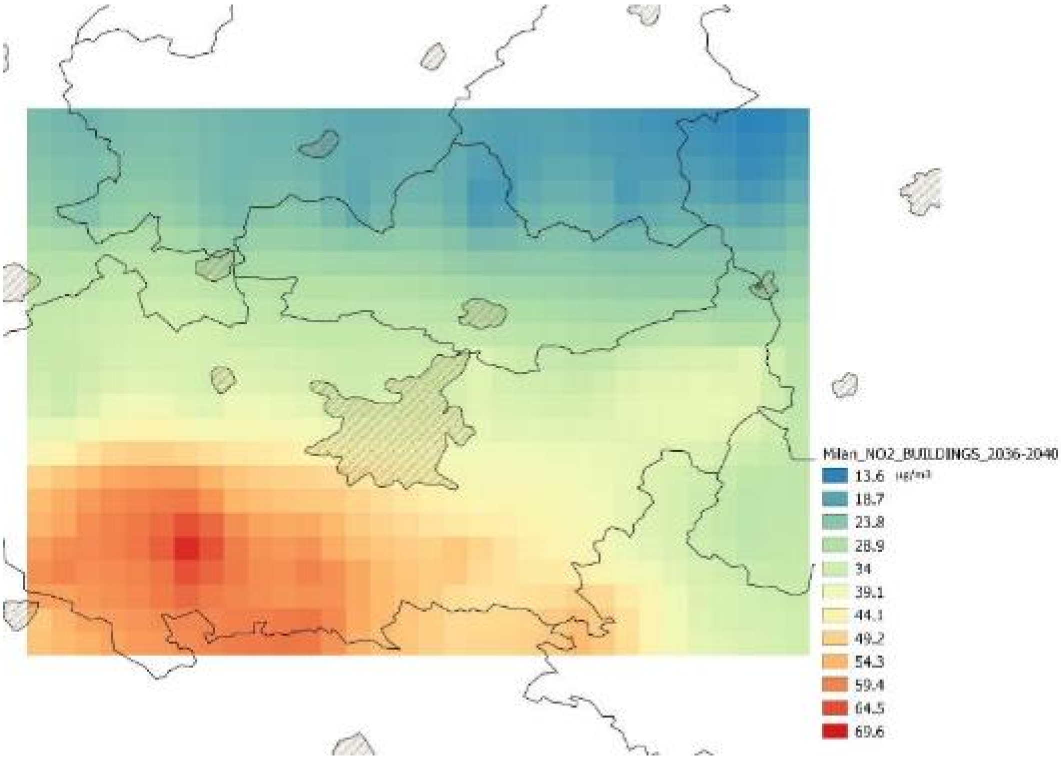


Figure 64: NO_2 Concentration map of the wider area of Milan – BUILDINGS scenario

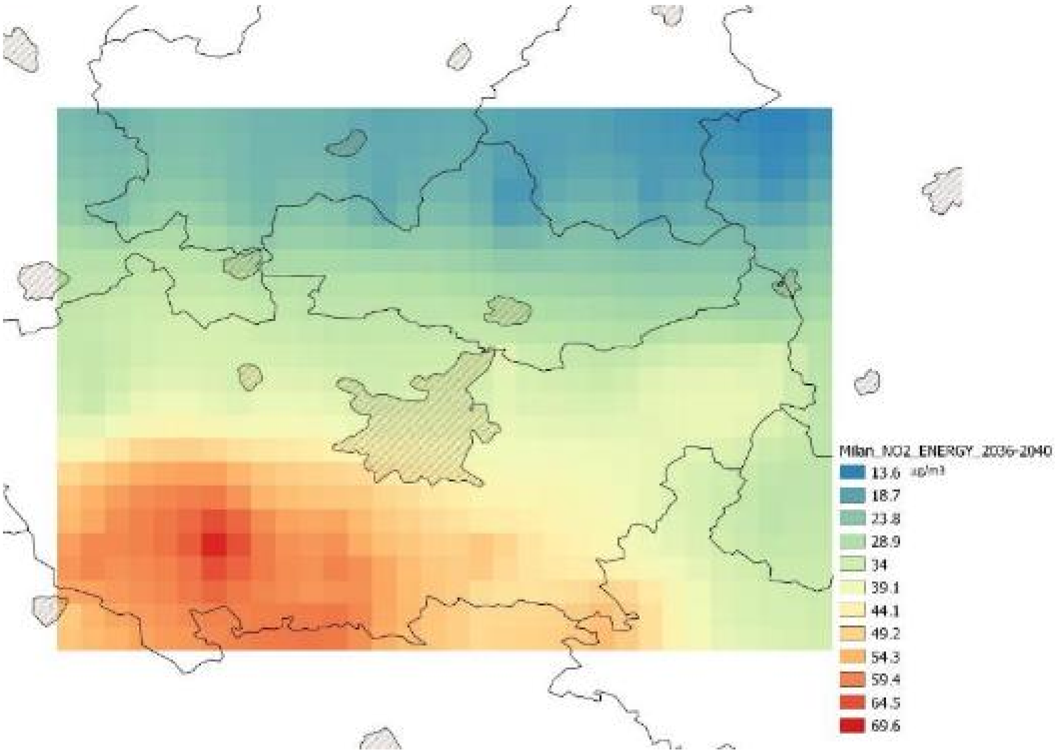


Figure 65: NO_2 Concentration map of the wider area of Milan – ENERGY scenario

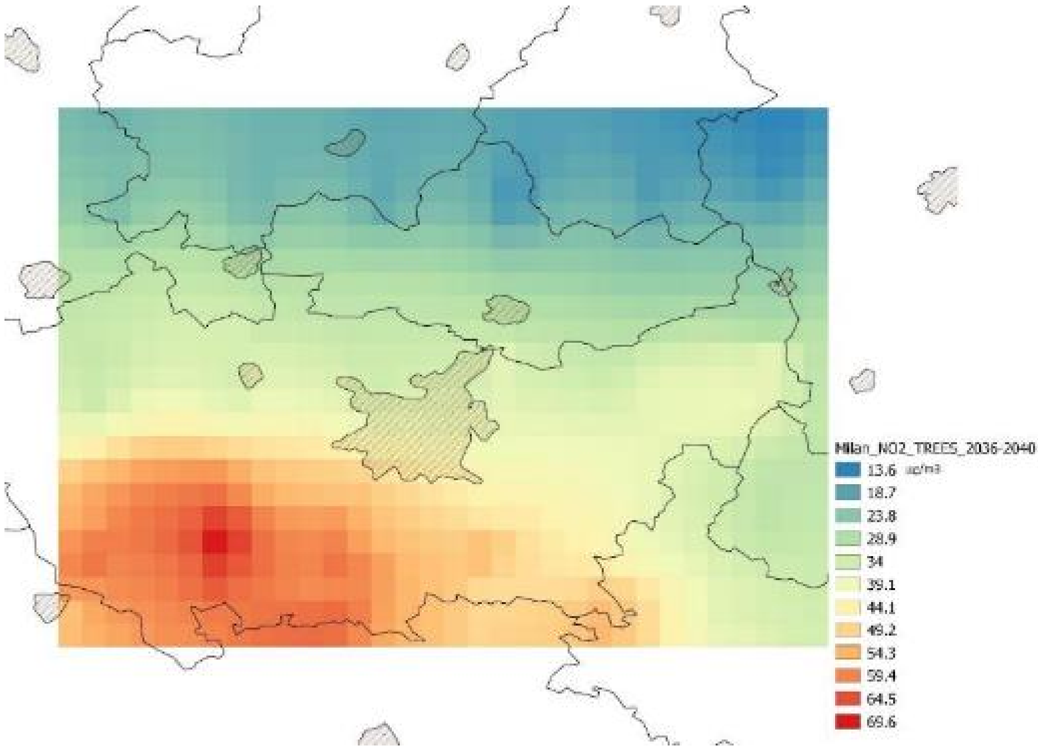


Figure 66: NO_2 Concentration map of the wider area of Milan – TREES scenario

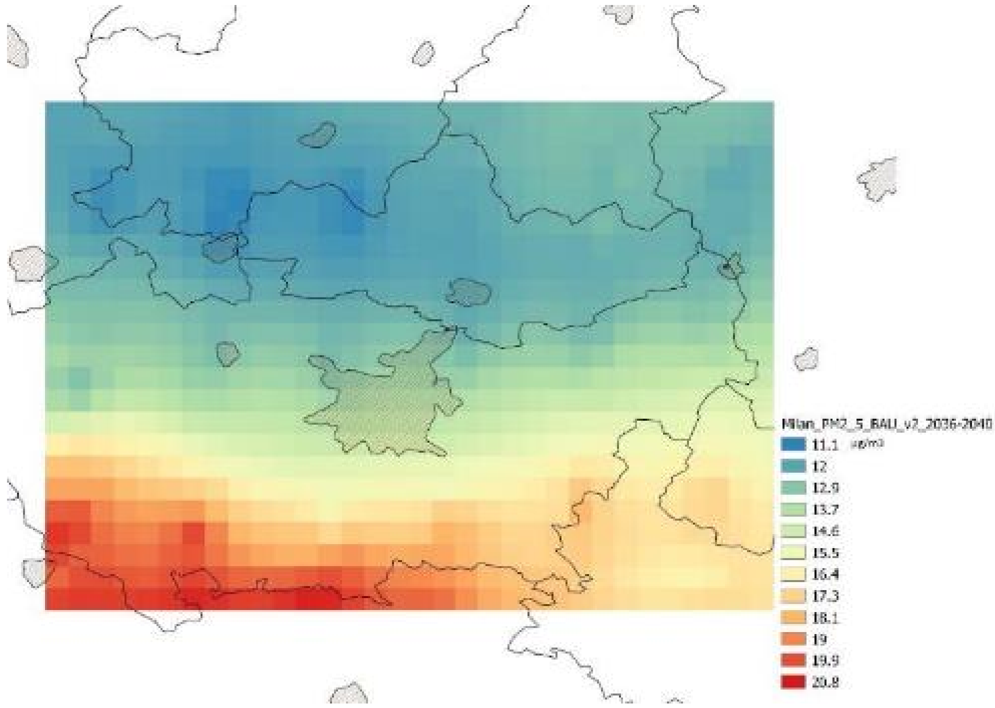


Figure 67: $PM_{2.5}$ Concentration map of the wider area of Milan – BAUv2 scenario

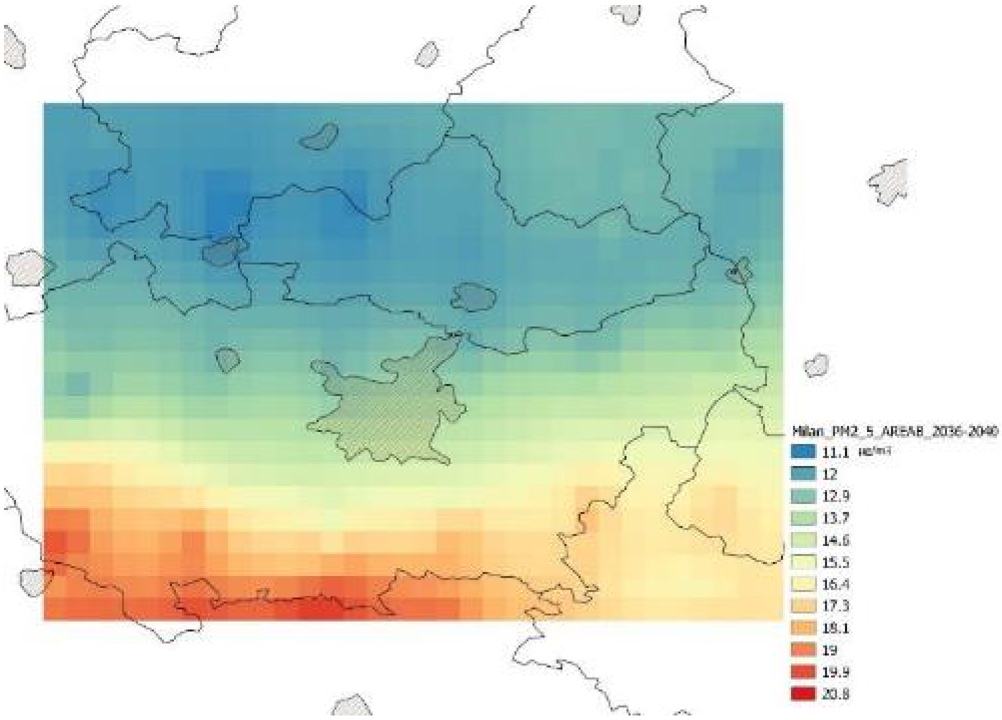


Figure 68: $PM_{2.5}$ Concentration map of the wider area of Milan – AREAB scenario

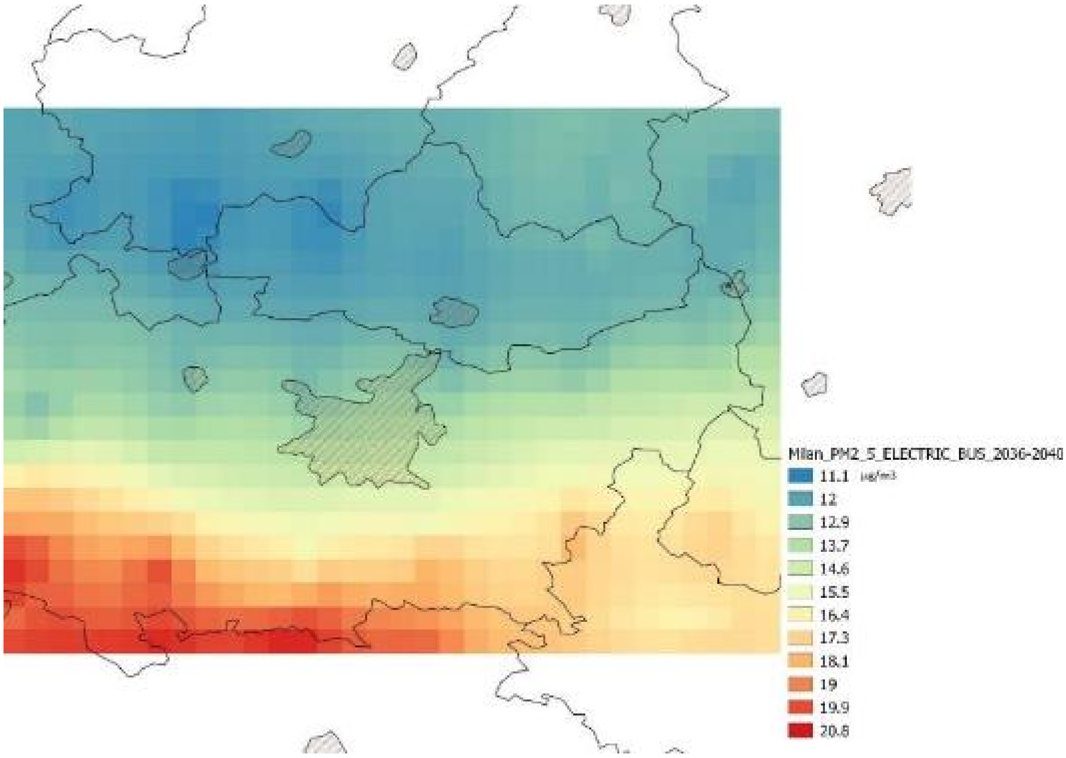


Figure 69: $PM_{2.5}$ Concentration map of the wider area of Milan – ELETRICBUS scenario

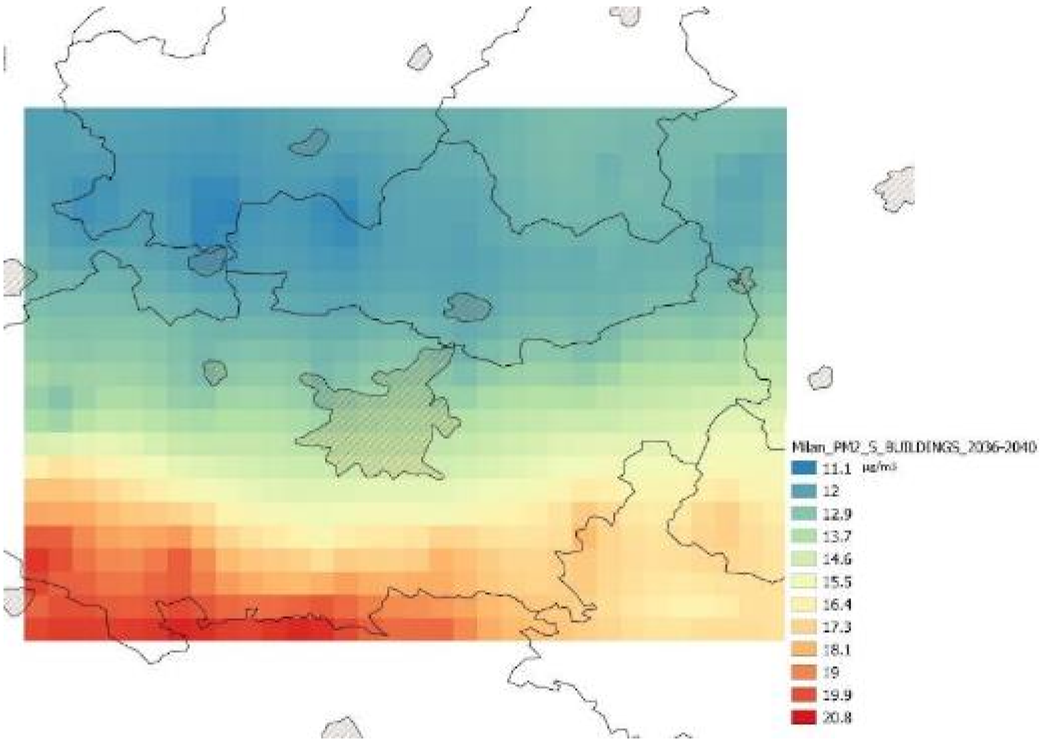


Figure 70: $PM_{2.5}$ Concentration map of the wider area of Milan – BUILDINGS scenario

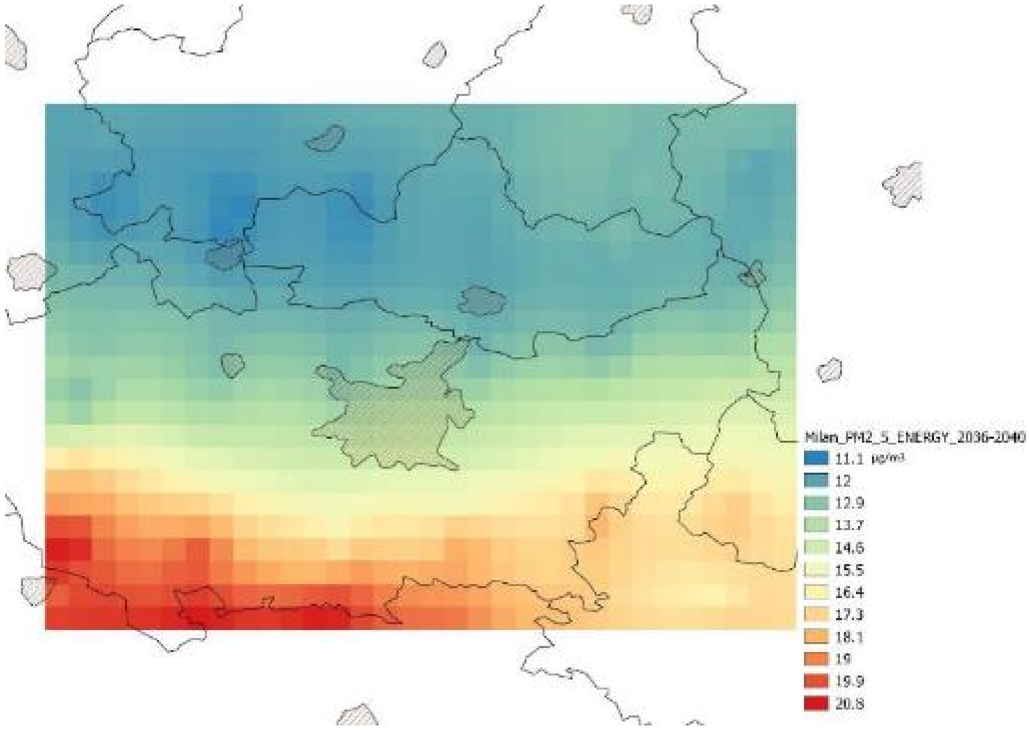


Figure 71: $PM_{2.5}$ Concentration map of the wider area of Milan – ENERGY scenario

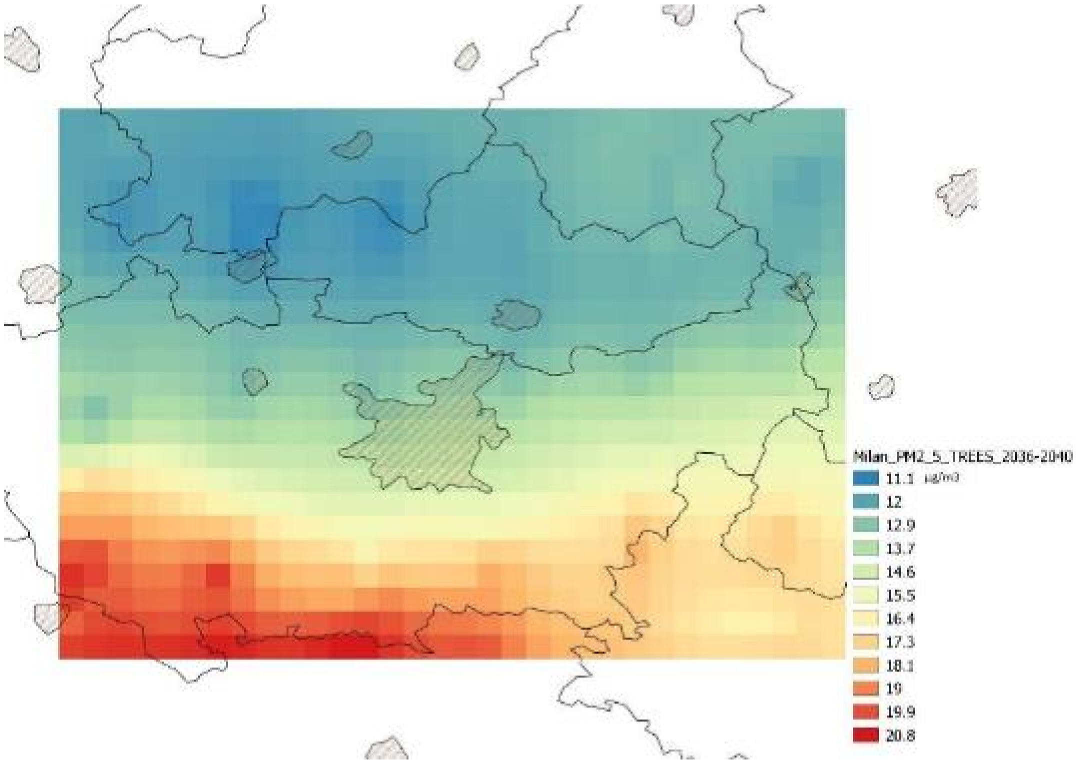


Figure 72: $PM_{2.5}$ Concentration map of the wider area of Milan – TREES scenario

Air pollution modelling results - Stuttgart

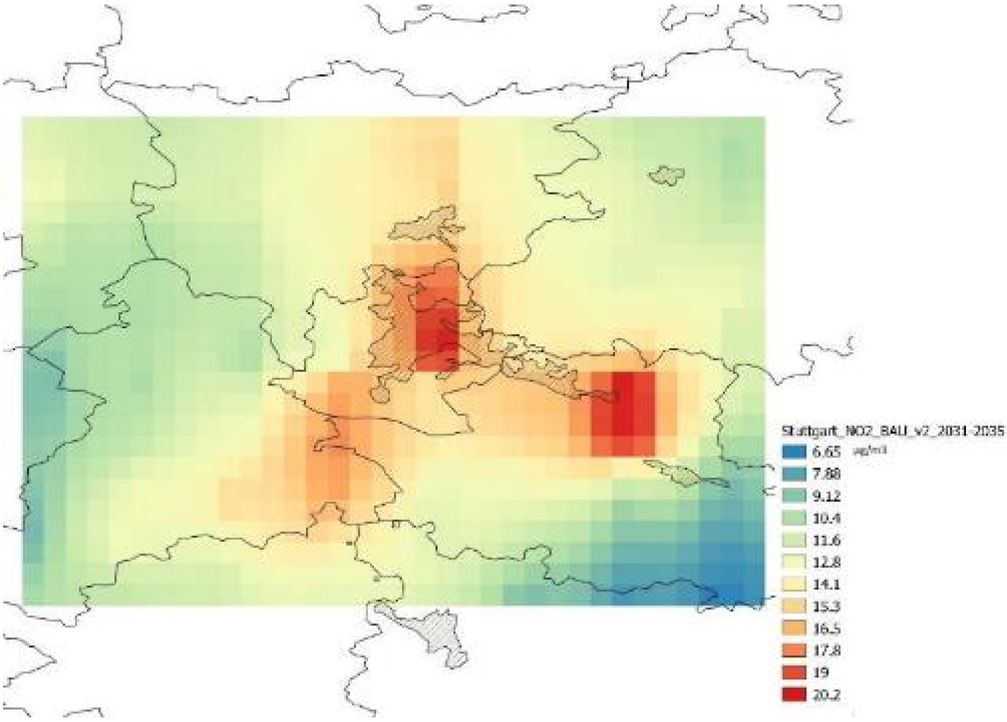


Figure 73: NO_2 Concentration map of the wider area of Stuttgart – BAUv2 scenario

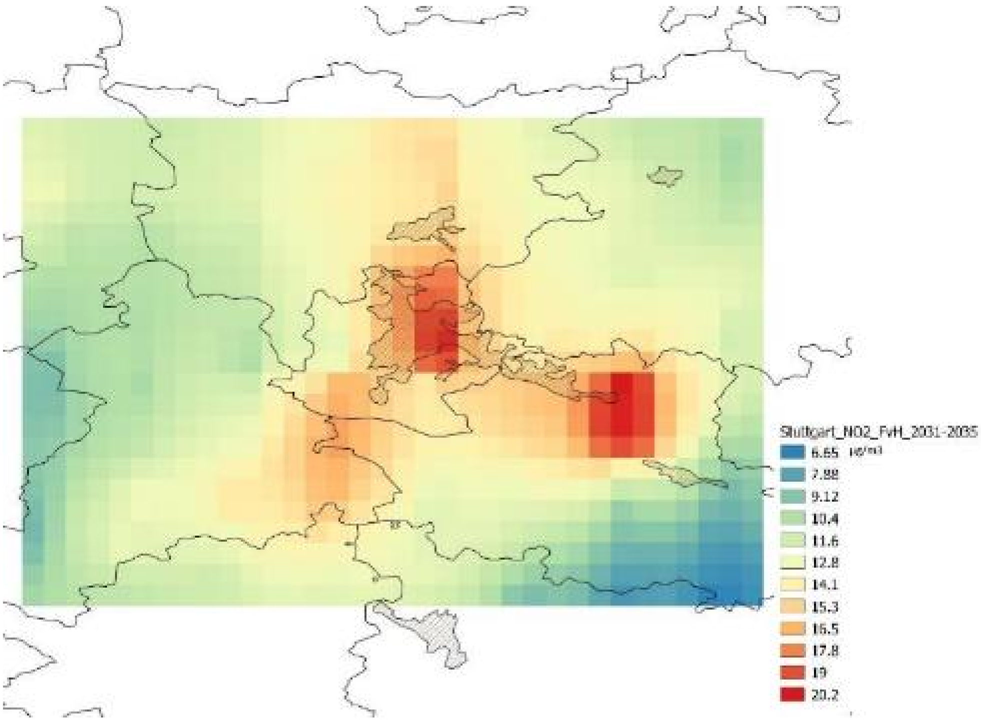


Figure 74: NO_2 Concentration map of the wider area of Stuttgart – FvH scenario

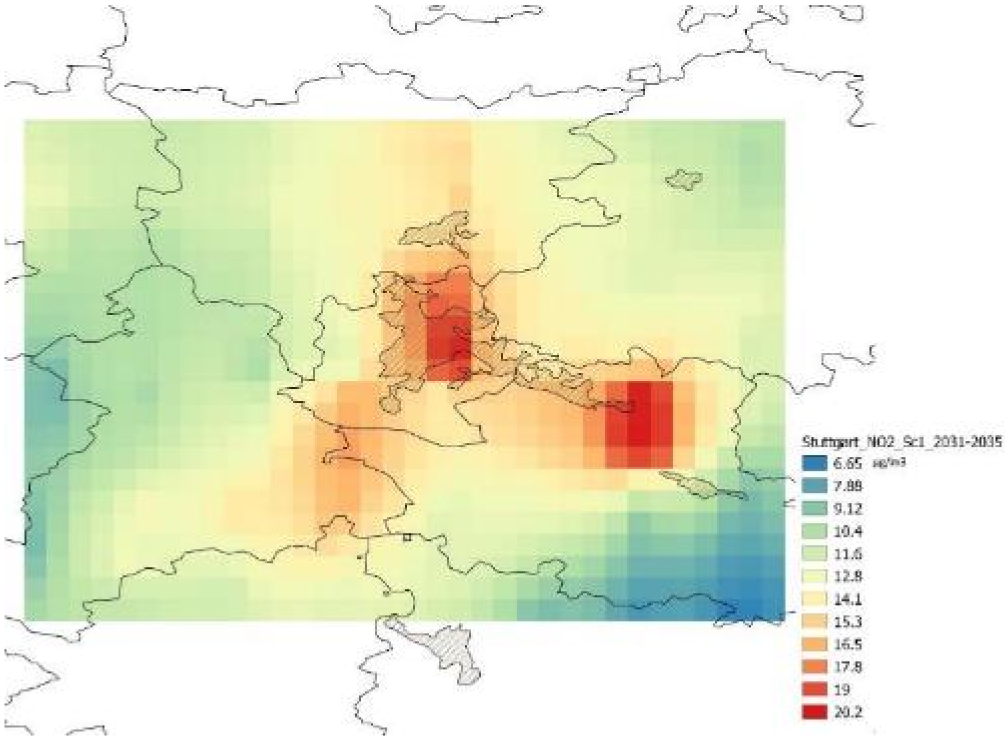


Figure 75: NO_2 Concentration map of the wider area of Stuttgart – Sc1 scenario

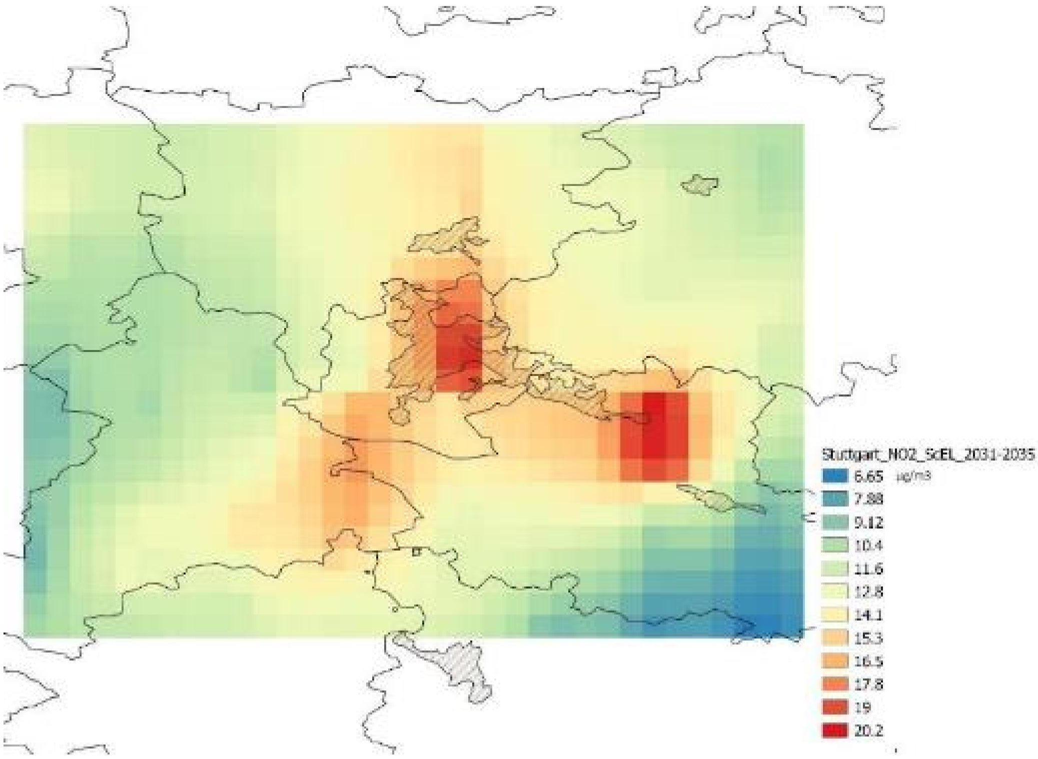


Figure 76: NO_2 Concentration map of the wider area of Stuttgart – ScEL scenario

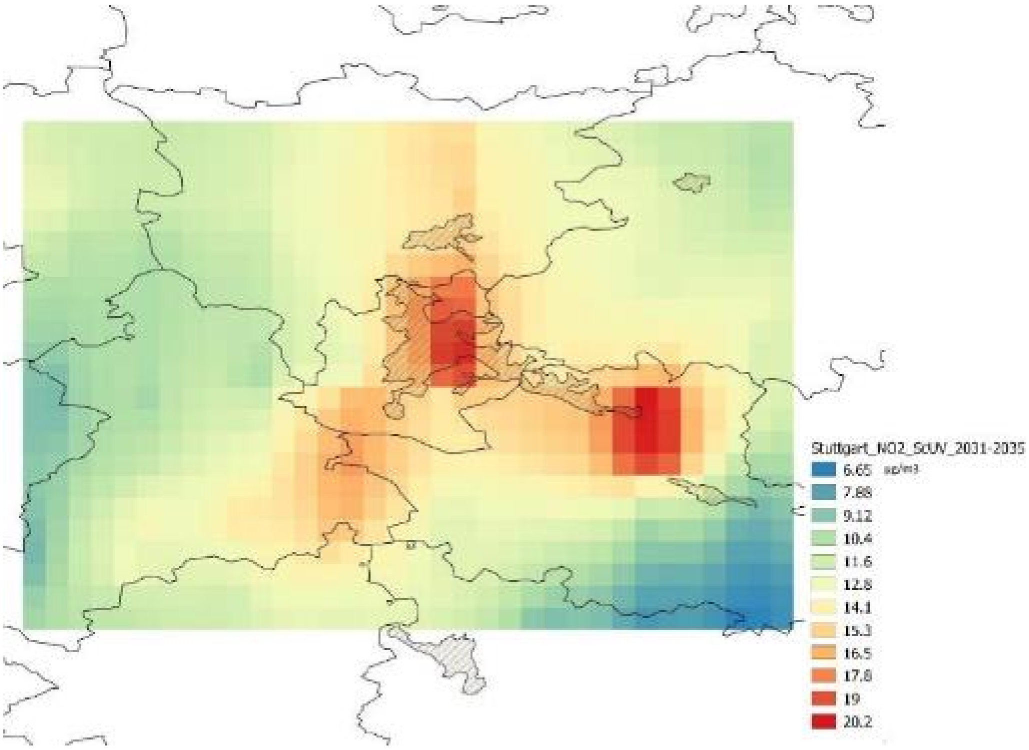


Figure 77: NO_2 Concentration map of the wider area of Stuttgart – ScUV scenario

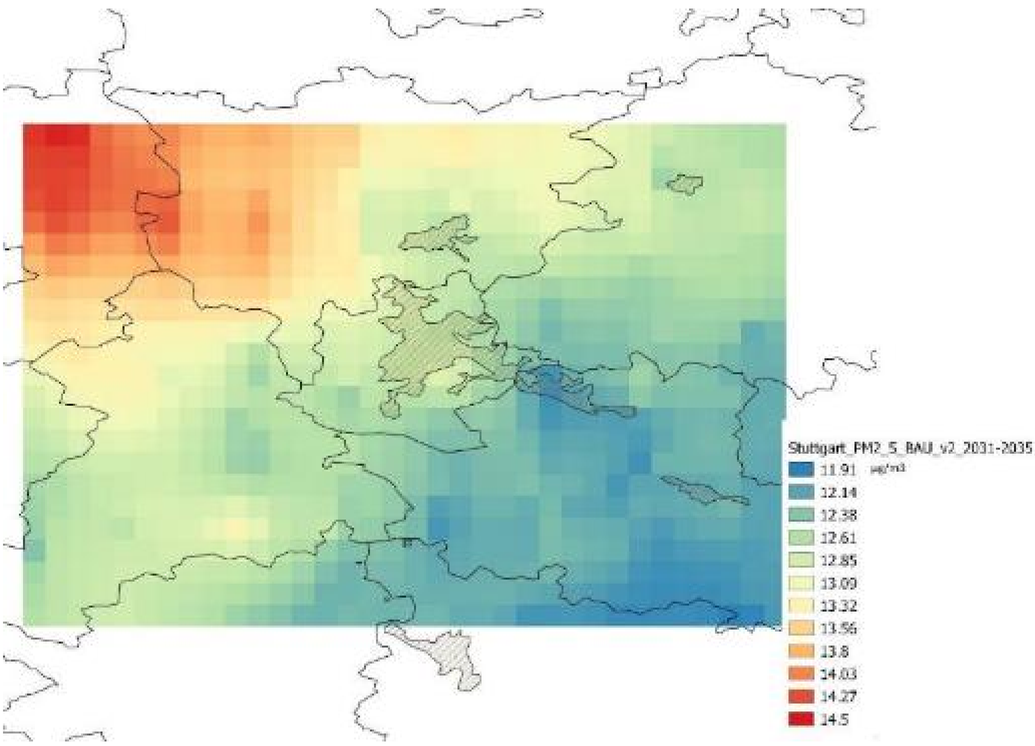


Figure 78: $PM_{2.5}$ Concentration map of the wider area of Stuttgart – BAUv2 scenario

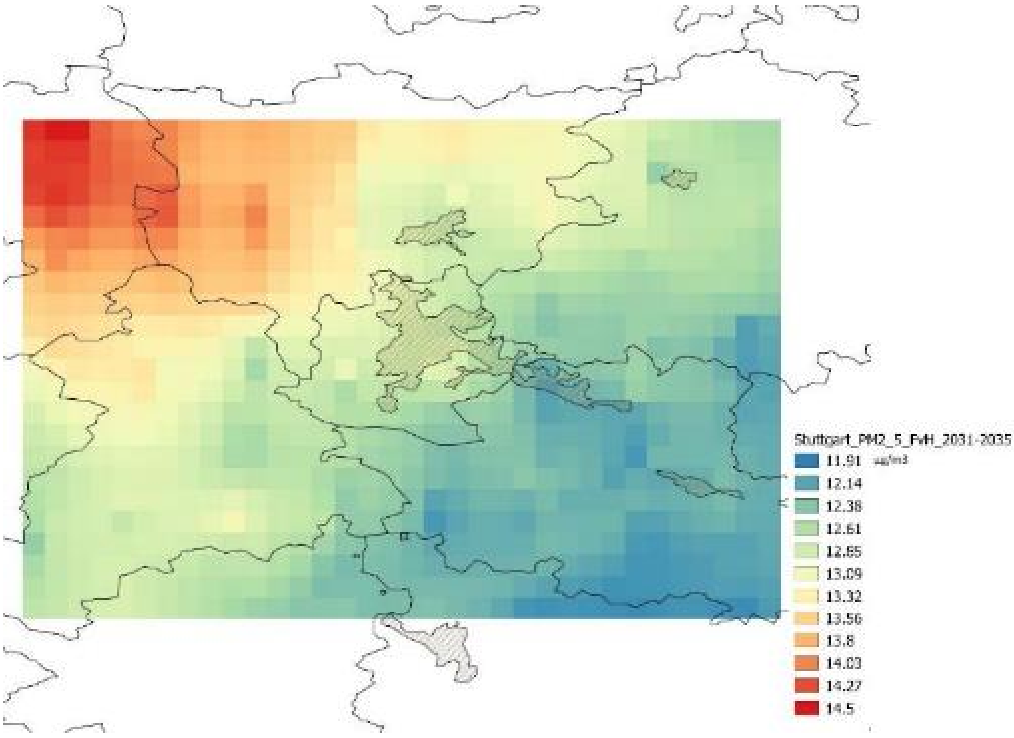


Figure 79: $PM_{2.5}$ Concentration map of the wider area of Stuttgart – FvH scenario

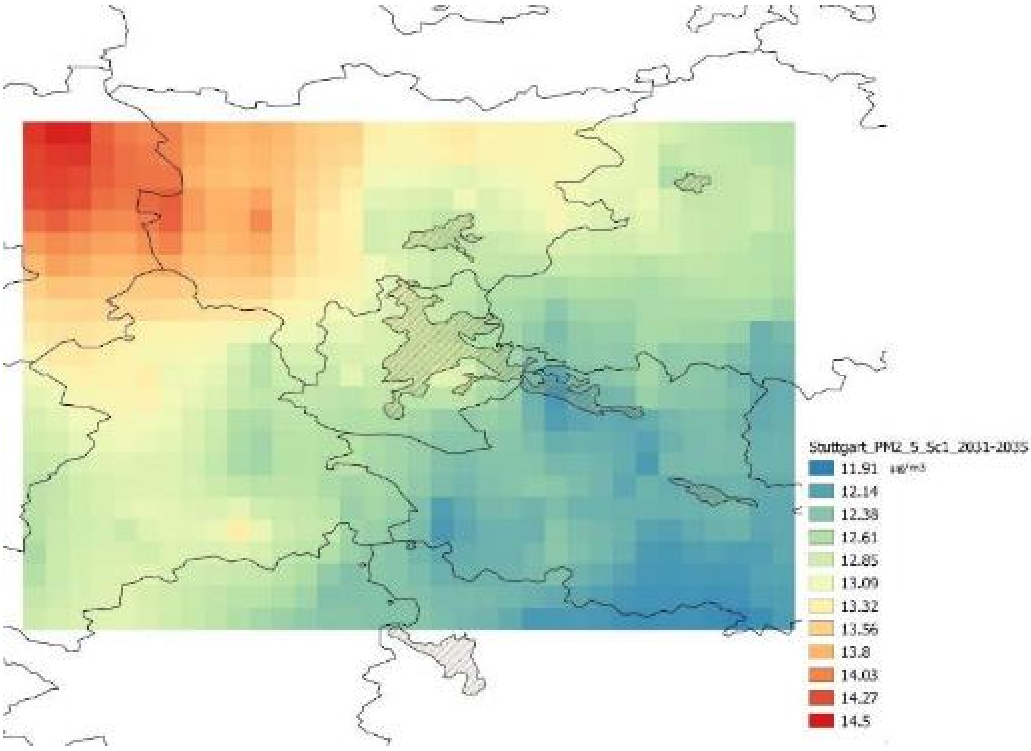


Figure 80: $PM_{2.5}$ Concentration map of the wider area of Stuttgart – Sc1 scenario

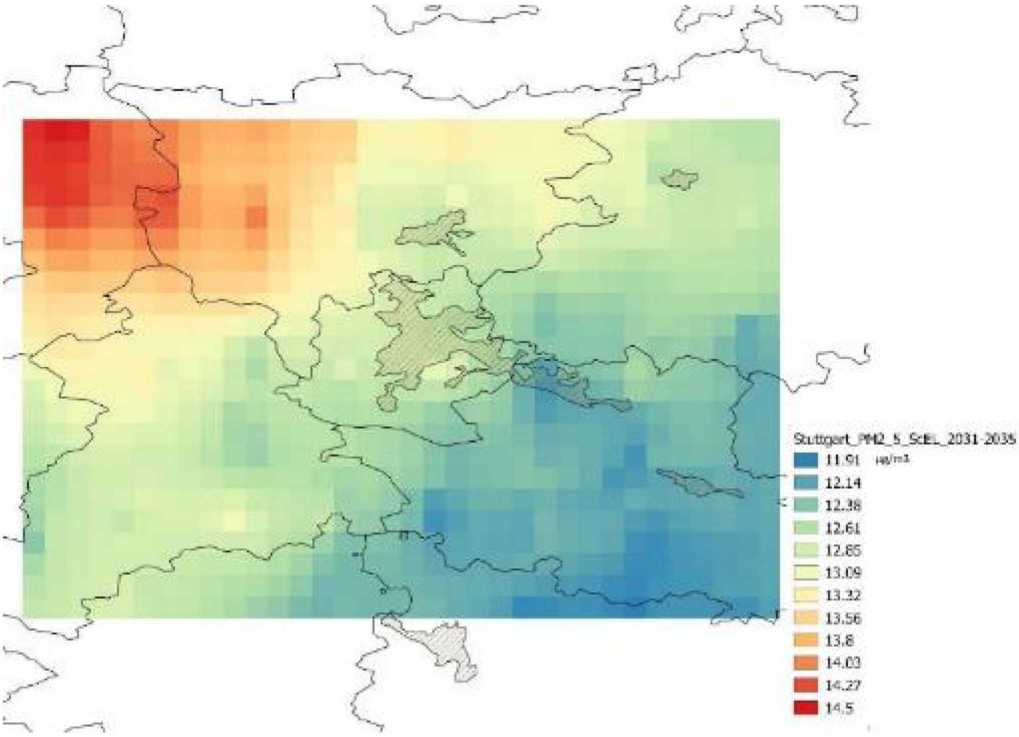


Figure 81: $PM_{2.5}$ Concentration map of the wider area of Stuttgart – ScEL scenario

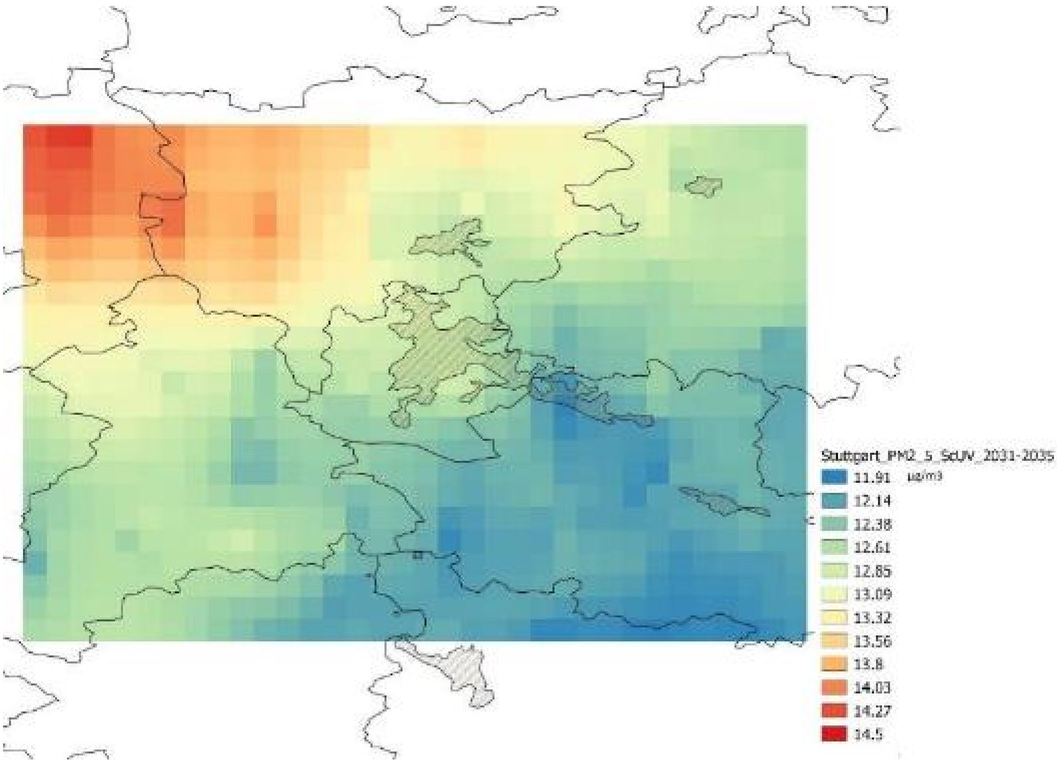


Figure 82: $PM_{2.5}$ Concentration map of the wider area of Stuttgart – ScUV scenario

Air pollution modelling results - Thessaloniki

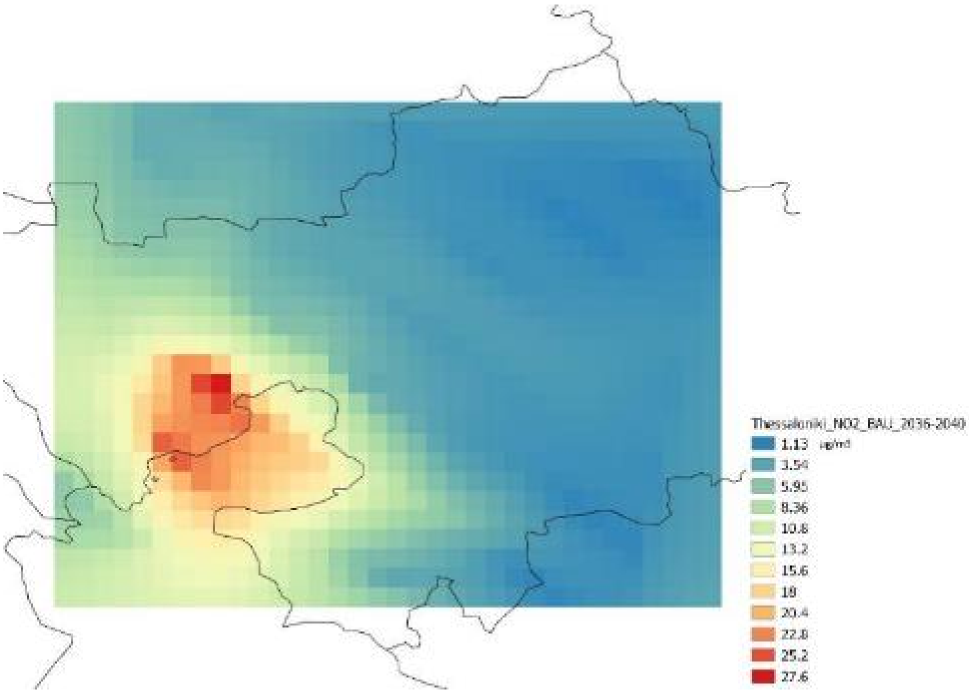


Figure 83: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – BAU scenario

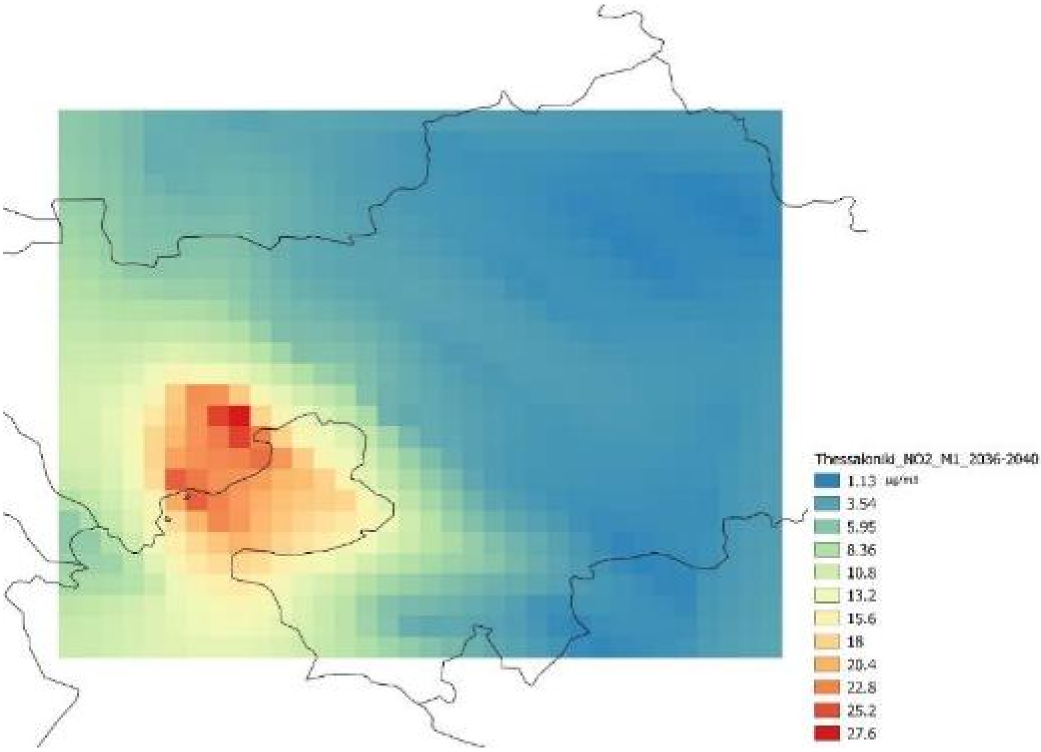


Figure 84: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M1 scenario

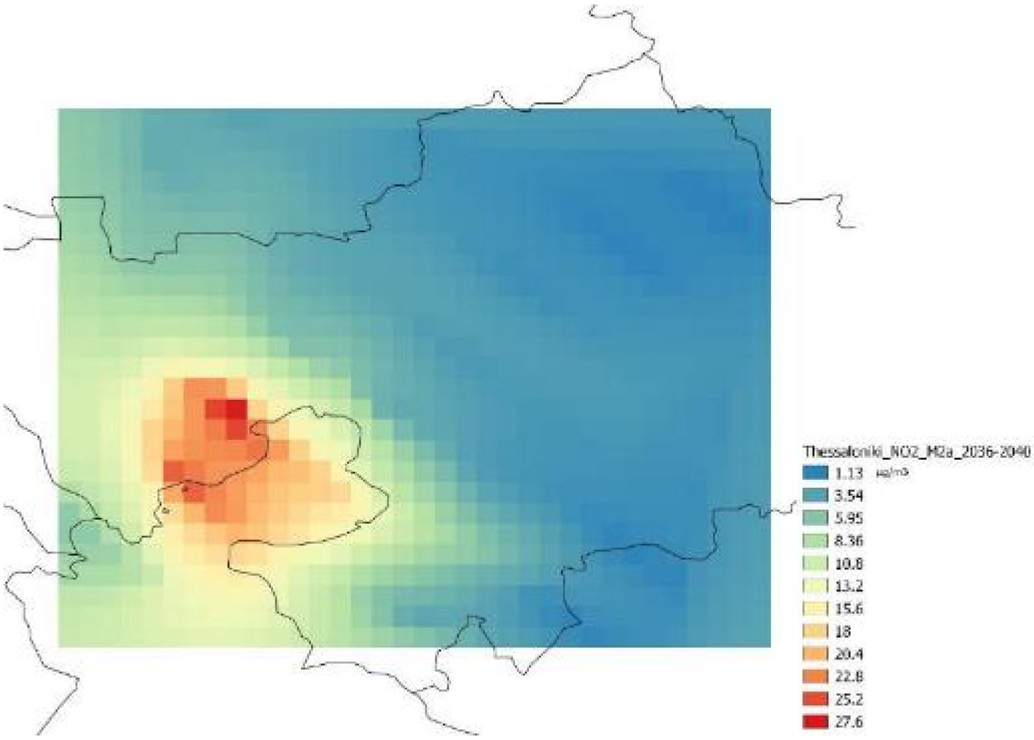


Figure 85: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M2a scenario

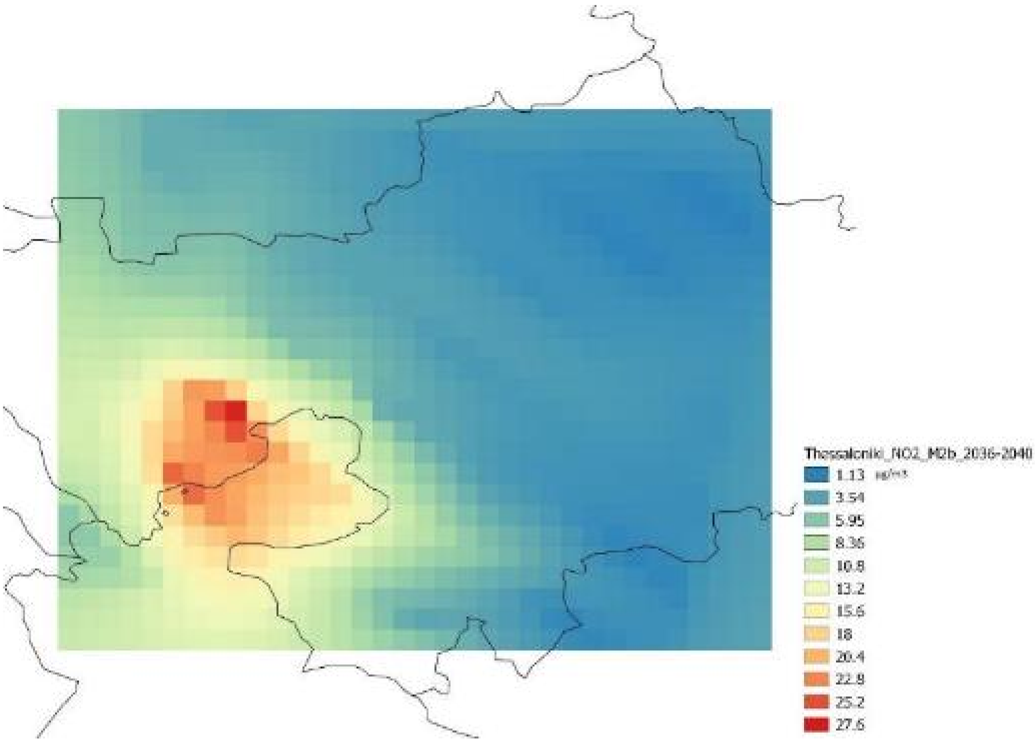


Figure 86: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M2b scenario

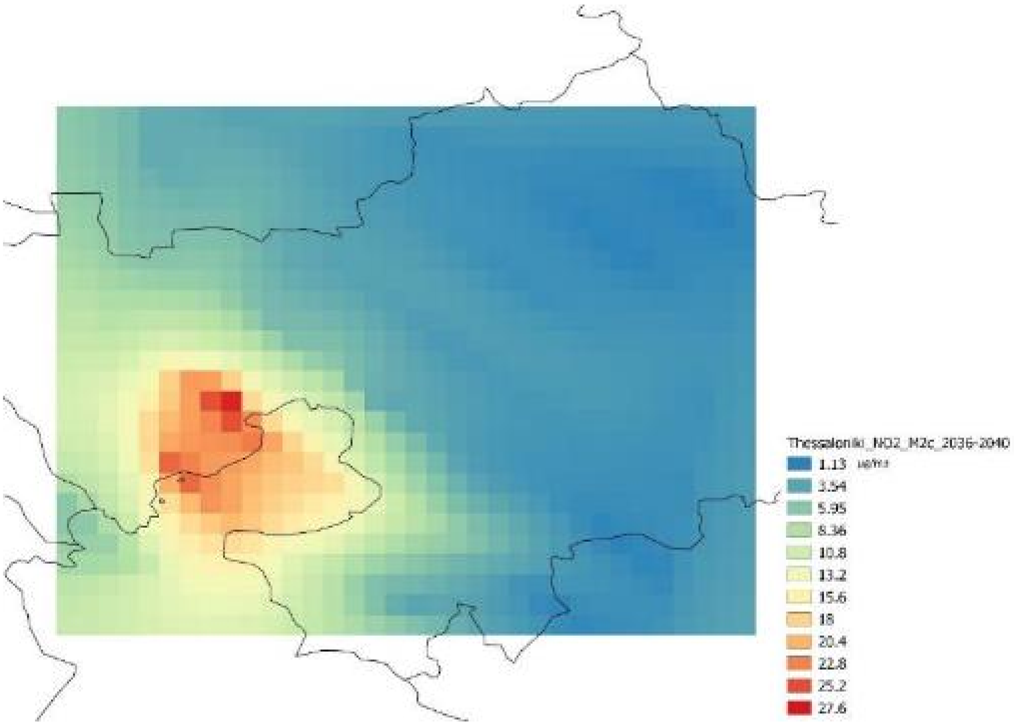


Figure 87: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M2c scenario

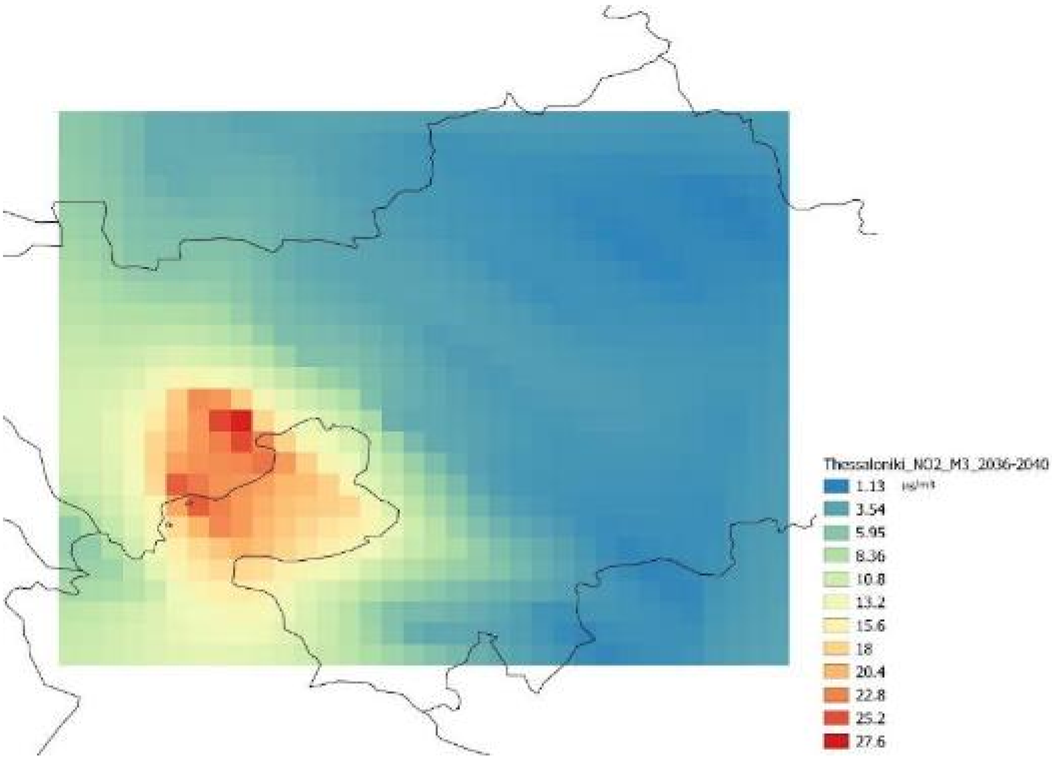


Figure 88: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M3 scenario

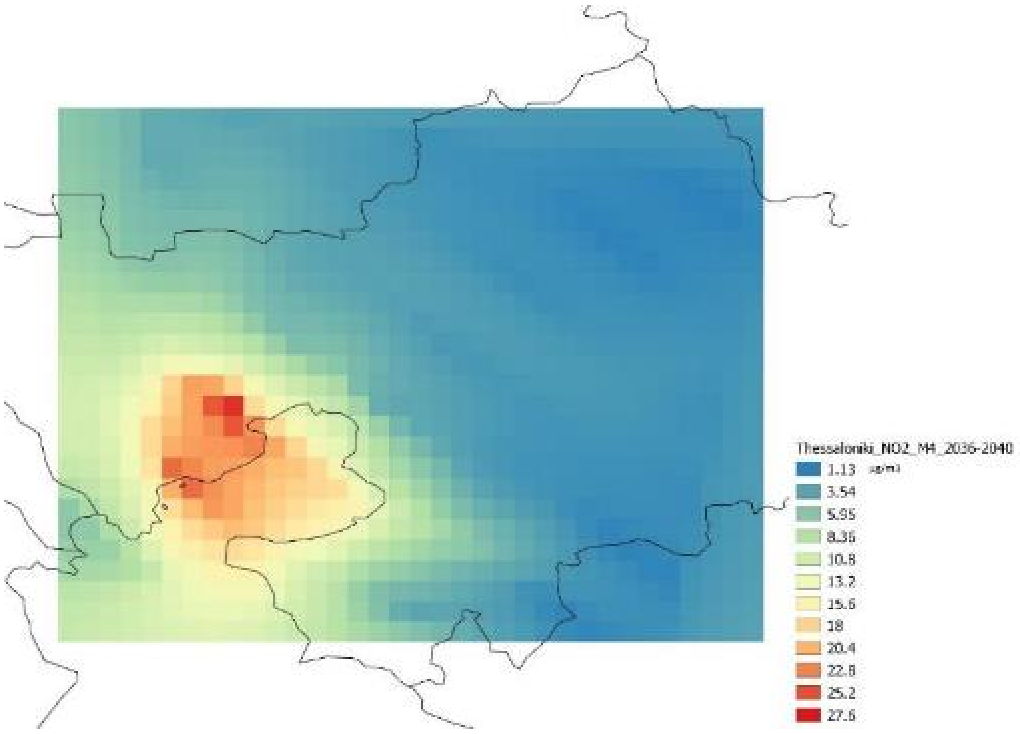


Figure 89: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M4 scenario

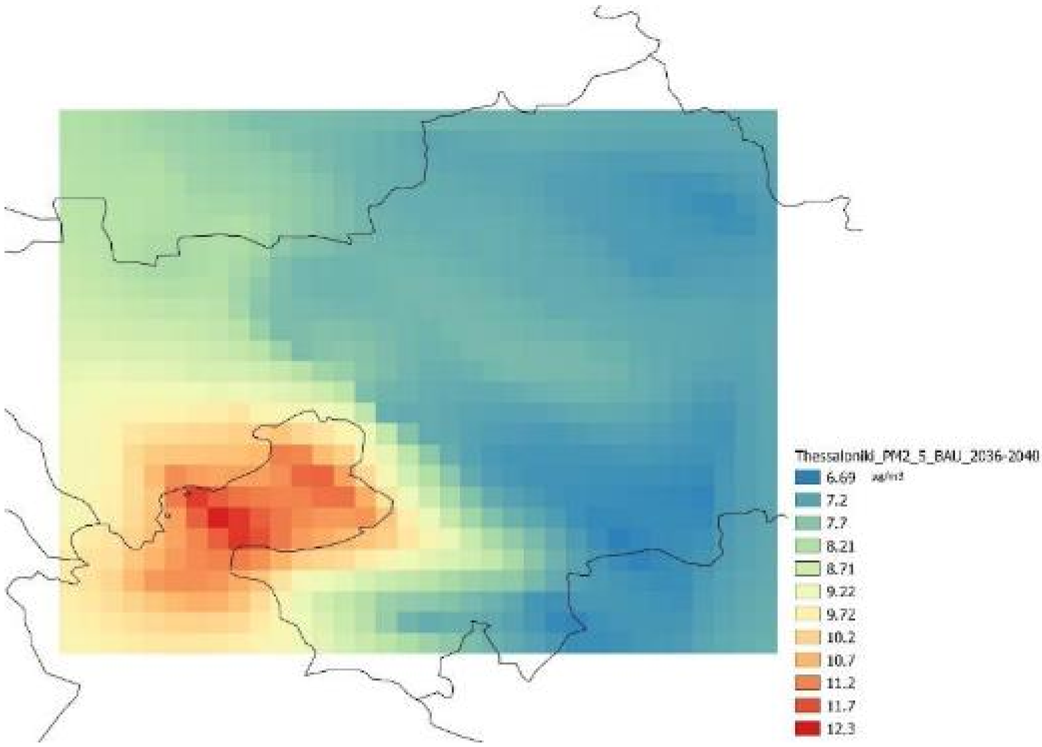


Figure 90: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – BAU scenario

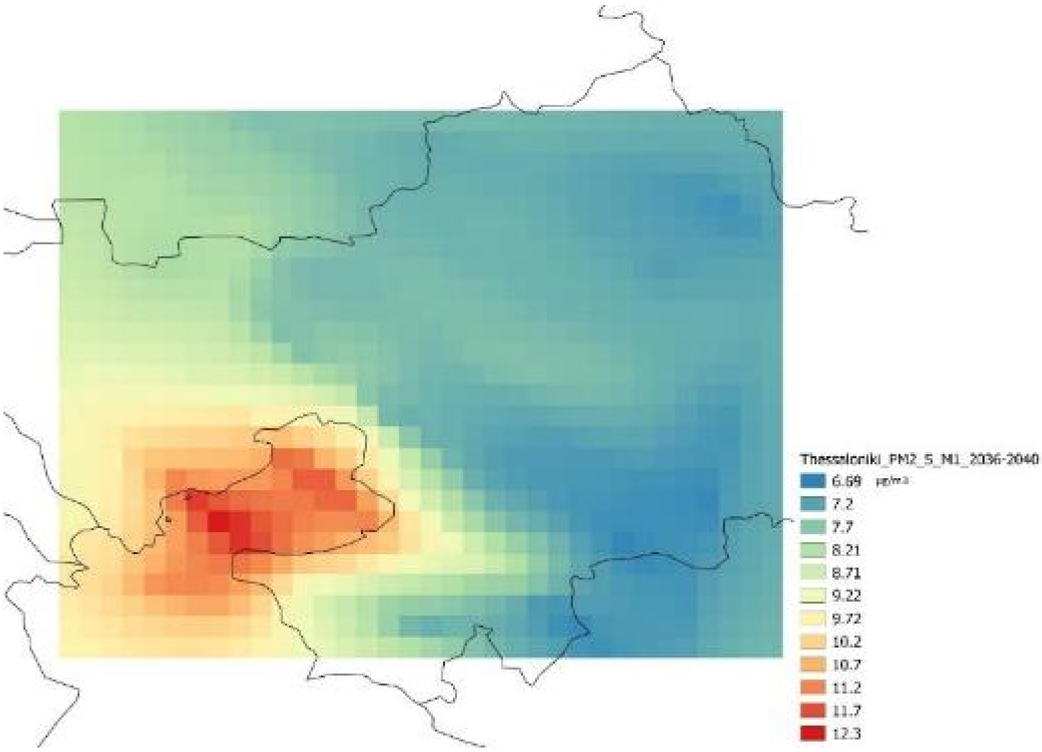


Figure 91: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M1 scenario

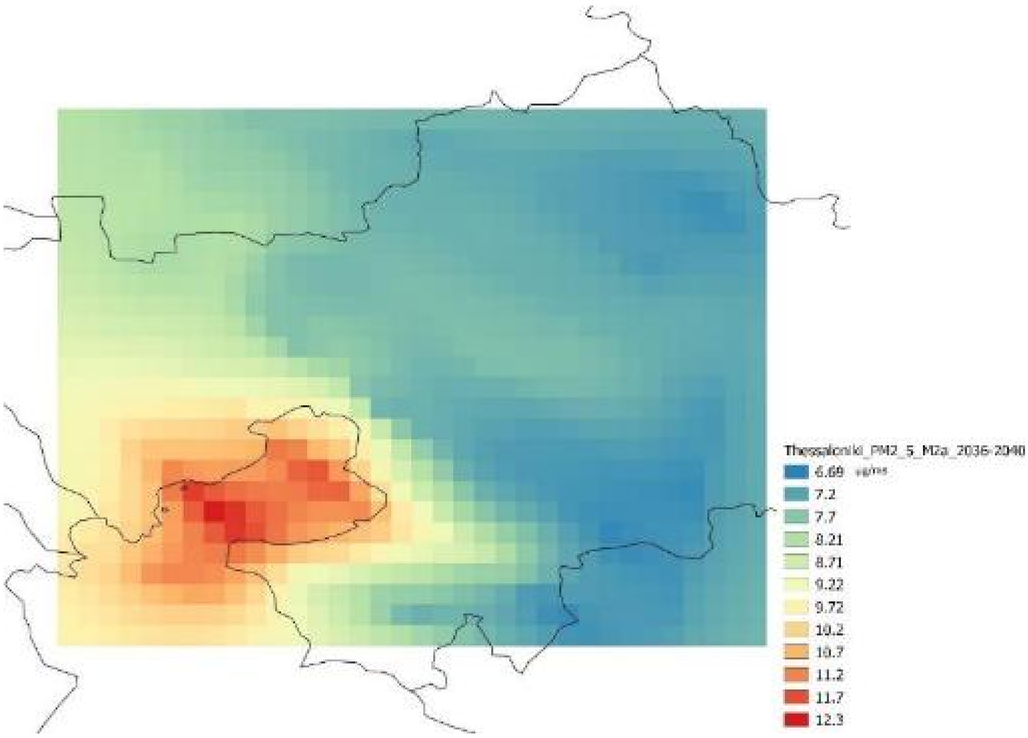


Figure 92: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M2a scenario

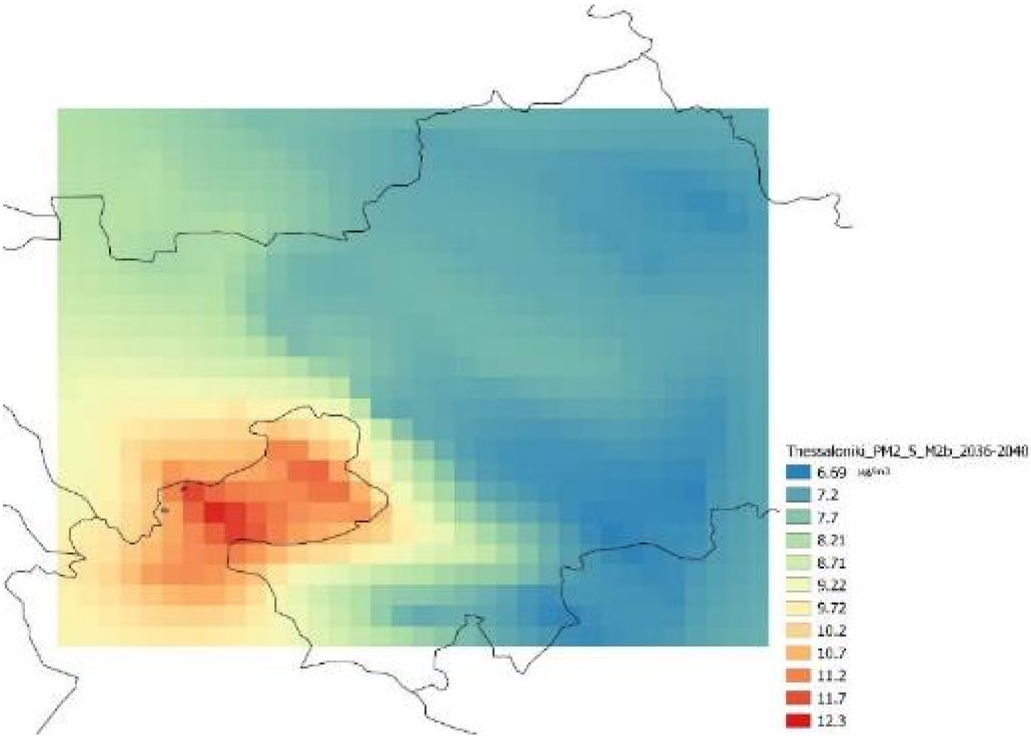


Figure 93: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M2b scenario

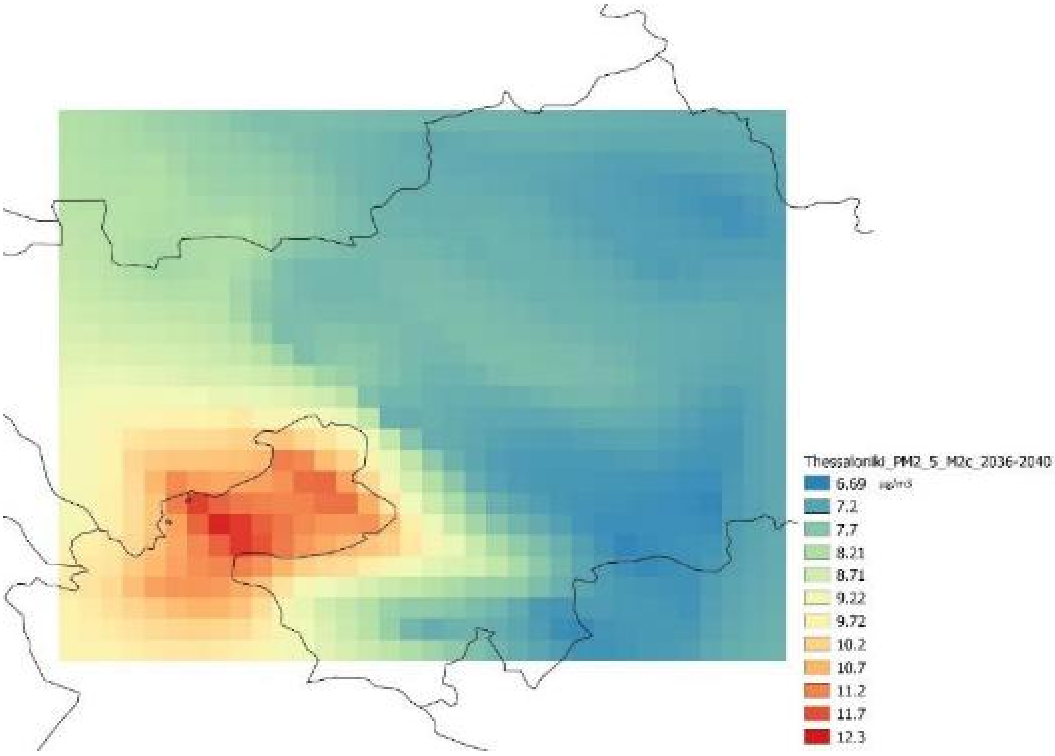


Figure 94: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M2c scenario

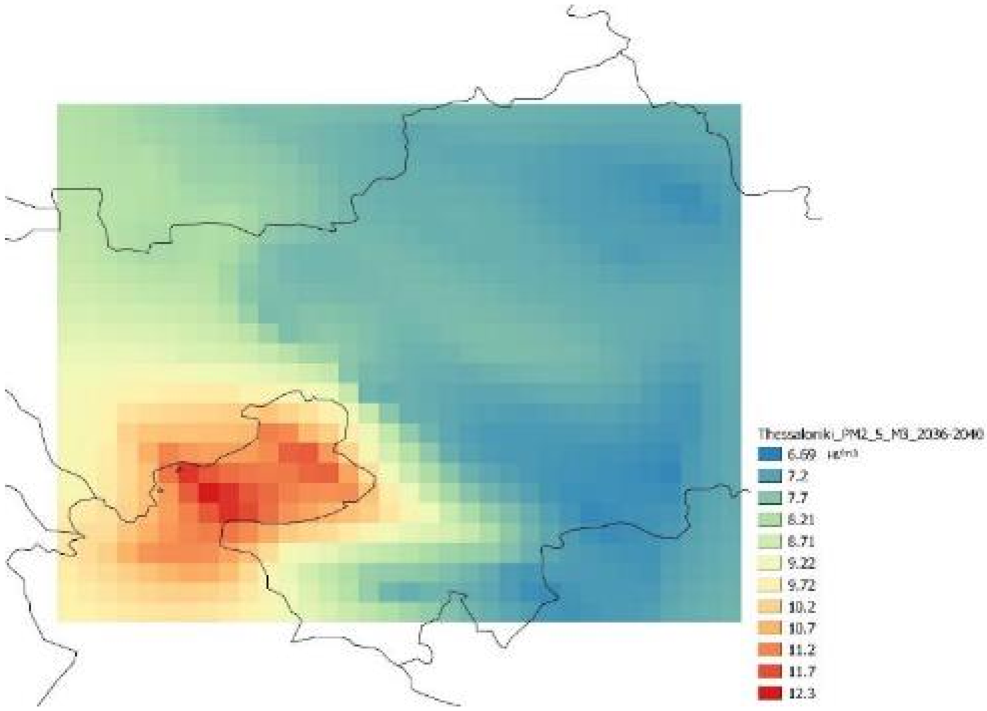


Figure 95: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M3 scenario

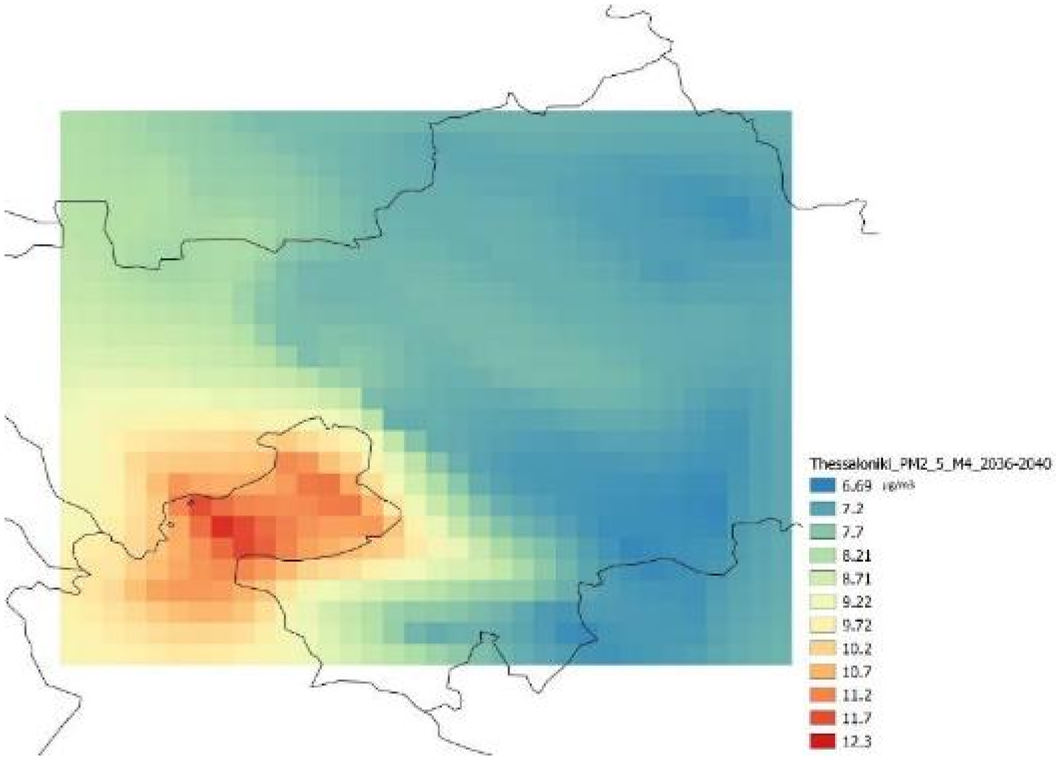


Figure 96: $PM_{2.5}$ Concentration map of the wider area of Thessaloniki – M4 scenario

ANNEX 3: HEALTH IMPACT ASSESSMENT RESULTS (TABLES)

Table 0-1: Health impact tables for ICARUS cities

Greater Athens Area

Health end point	Scenario	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
		Number of cases (min – max)			
PM2.5 mortality (all natural causes) >30 years old	**BAU**	411.84 (266.50 - 549.76)	273.14 (176.57 - 364.96)	972.96 (632.22 - 1293.69)	633.07 (410.32 - 43.76)
	SusMob	409.92 (265.26 - 547.21)	264.44 (170.93 - 353.36)	959.57 (623.46 - 1276.00)	622.92 (403.72 - 830.30)
	SusMobPuT	408.41 (264.28 - 545.20)	266.50 (172.27 - 356.11)	958.16 (622.53 - 1274.14)	615.31 (398.76 - 820.21)
	EnEff	408.97 (264.64 - 545.93)	262.84 (169.90 - 351.23)	966.68 (628.11 - 285.39)	630.61 (408.73 - 840.51)
	EnEffZEB	409.39 (264.91 - 546.50)	270.13 (174.62 - 360.95)	967.35 (628.55 - 1286.28)	519.09 (336.17 - 692.41)
	Waste	409.69 (265.11 - 546.90)	266.64 (172.36 - 356.30)	964.62 (626.76 - 1282.67)	631.55 (409.33 - 841.75)
PM10 infant mortality (0 - 1 year)	**BAU**	0.716 (0.359 - 1.246)	0.530 (0.266 - 0.924)	1.487 (0.749 - 2.572)	1.015 (0.510 - 1.762)
	SusMob	0.714 (0.358 - 1.243)	0.516 (0.259 - 0.899)	1.469 (0.740 - 2.542)	0.992 (0.499 - 1.723)
	SusMobPuT	0.712 (0.357 - 1.240)	0.518 (0.260 - 0.903)	1.466 (0.739 - 2.537)	0.981 (0.493 - 1.704)
	EnEff	0.713 (0.358 - 1.241)	0.514 (0.257 - 0.895)	1.479 (0.745 - 2.559)	1.003 (0.504 - 1.742)
	EnEffZEB	0.714 (0.358 - 1.242)	0.523 (0.262 - 0.911)	1.480 (0.745 - 2.560)	0.855 (0.429 - 1.487)

	Waste	0.715 (0.359 - 1.244)	0.519 (0.260 - 0.905)	1.478 (0.745 - 2.558)	1.006 (0.505 - 1.746)
PM10 Incidence of Chronic bronchitis (adults)	**BAU**	493.04 (170.94 - 786.16)	366.35 (126.55 - 586.12)	1008.60 (355.01 - 1585.93)	694.79 (242.29 - 101.86)
	SusMob	492.03 (170.58 - 784.56)	356.61 (123.15 - 570.69)	997.02 (350.81 - 1568.22)	679.63 (236.90 - 078.25)
	SusMobPuT	490.55 (170.06 - 782.23)	358.22 (123.71 - 573.23)	995.12 (350.12 - 1565.32)	672.21 (234.27- 1066.70)
	EnEff	491.04 (170.23 - 783.01)	355.13 (122.63 - 568.34)	1003.32 (353.09 - 1577.85)	686.82 (239.46- 1089.45)
	EnEffZEB	491.55 (170.41 - 783.81)	361.45 (124.84 - 578.35)	1003.94 (353.32 - 1578.81)	587.37 (204.19 - 934.19)
	Waste	492.20 (170.64 - 784.82)	358.81 (123.92 - 574.17)	1002.92 (352.95 - 1577.25)	688.73 (240.14 -1092.43)
PM10 Cardiac Hospital admissions	**BAU**	57.97 (29.00 - 86.91)	42.85 (21.43 - 64.25)	121.22 (60.68 - 181.62)	82.39 (41.23 - 123.49)
	SusMob	57.85 (28.94 - 86.73)	41.70 (20.86 - 62.52)	119.77 (59.95 - 179.45)	80.54 (40.30 - 120.72)
	SusMobPuT	57.67 (28.85 - 86.46)	41.89 (20.95 - 62.80)	119.53 (59.83 - 179.09)	79.64 (39.85 - 119.37)
	EnEff	57.73 (28.88 - 86.55)	41.52 (20.77 - 62.25)	120.56 (60.35 - 180.63)	81.42 (40.74 - 122.03)
	EnEffZEB	57.79 (28.91 - 86.64)	42.27 (21.14 - 63.38)	120.64 (60.39 - 180.75)	69.34 (34.69 - 103.94)
	Waste	57.87 (28.95 - 86.76)	41.96 (20.99 - 62.91)	120.51 (60.32 - 180.55)	81.65 (40.86 - 122.38)
PM10 Respiratory Hospital admissions	**BAU**	74.17 (57.71 - 82.40)	54.83 (42.66 - 60.91)	154.99 (120.64 - 172.15)	105.38 (82.01 - 117.06)
	SusMob	74.02 (57.59 - 82.22)	53.35 (41.51 - 59.27)	153.14 (119.20 - 170.09)	103.02 (80.17 - 114.44)
	SusMobPuT	73.79 (57.41 - 81.97)	53.60 (41.70 - 59.54)	152.84 (118.96 - 169.75)	101.87 (79.27 - 113.16)
	EnEff	73.86 (57.47 - 82.06)	53.13 (41.33 - 59.02)	154.15 (119.98 - 171.21)	104.14 (81.04 - 115.68)
	EnEffZEB	73.94 (57.53 - 82.14)	54.09 (42.08 - 60.09)	154.25 (120.06 - 171.32)	88.70 (69.02 - 98.53)
	Waste	74.04 (57.61 - 82.25)	53.69 (41.77 - 59.64)	154.08 (119.93 - 171.14)	104.44 (81.27 - 116.01)

PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU**	188.63 (-351.29 -3212.41)	139.46 (-259.33 - 2395.11)	394.03 (-738.33 - 6479.18)	267.98 (-500.23-4502.09)
	SusMob	188.23 (-350.54 - 3205.88)	135.70 (-252.31 - 2332.08)	389.33 (-729.41 - 6406.88)	261.97 (-488.93-4405.66)
	SusMobPuT	187.66 (-349.46 - 3196.34)	136.32 (-253.46 - 2342.44)	388.55 (-727.94 - 6395.03)	259.03 (-483.4 - 4358.46)
	EnEff	187.85 (-349.82 - 3199.52)	135.13 (-251.24 - 2322.46)	391.89 (-734.26 - 6446.20)	264.82 (-494.29-4451.41)
	EnEffZEB	188.05 (-350.19 - 3202.81)	137.56 (- 255.80 - 2363.39)	392.14 (- 734.74 - 6450.12)	225.57 (-420.53-3817.18)
	Waste	188.30 (-350.66 - 3206.94)	136.55 (- 253.89 - 2346.29)	391.72 (- 733.95 - 6443.73)	265.58 (-495.7- 4463.59)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) >30 years old	**BAU**	99.12 (55.92 - 144.06)	61.76 (34.83 - 89.78)	73.12 (41.24 - 106.29)	16.60 (9.36 - 24.14)
	SusMob	94.29 (53.19 - 137.04)	57.54 (32.45 - 83.65)	56.71 (31.98 - 82.44)	11.81 (6.66 - 17.18)
	SusMobPuT	92.83 (52.37 - 134.92)	56.82 (32.04 - 82.61)	51.20 (28.87 - 74.45)	10.19 (5.74 - 14.82)
	EnEff	97.62 (55.07 - 141.87)	60.32 (34.02 - 87.69)	70.23 (39.61 - 102.09)	16.19 (9.13 - 23.55)
	EnEffZEB	98.37 (55.49 - 142.96)	60.09 (33.89 - 87.36)	69.05 (38.94 - 100.38)	15.31 (8.63 - 22.27)
	Waste	99.06 (55.88 - 143.96)	61.24 (34.53 - 89.03)	71.78 (40.48 - 104.34)	16.12 (9.09 - 23.44)
NO2 Prevalence of	**BAU**	506.12 (24.17 - 742.31)	464.13 (22.14 - 681.09)	485.01 (23.15 - 711.55)	426.02 (20.30 - 625.47)
	SusMob	501.26 (23.94 - 735.23)	460.31 (21.96 - 675.52)	465.52 (22.21 - 683.12)	408.67 (19.47 - 600.14)

bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**SusMobPuT**	500.14 (23.88 - 733.60)	459.34 (21.91 - 674.11)	459.72 (21.93 - 674.66)	402.73 (19.18 - 591.46)
	EnEff	504.01 (24.07 - 739.24)	463.09 (22.09 - 679.58)	481.30 (22.97 - 706.14)	423.89 (20.20 - 622.37)
	EnEffZEB	504.80 (24.11 - 740.40)	462.47 (22.06 - 678.68)	480.37 (22.93 - 704.78)	423.14 (20.17 - 621.27)
	Waste	505.30 (24.13 - 741.11)	463.12 (22.09 - 679.62)	482.94 (23.05 - 708.52)	20.28 - 624.68)

Basel

Health end point	Scenarios	Time horizon			
		2021 - 2025	2026 - 2030	2031 - 2035	2036 - 2040
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**Basic**	99.70 (65.32 - 131.52)	76.52 (49.95 - 101.29)	64.55 (42.06 - 85.61)	75.22 (49.10 - 99.60)
	Not Heat	97.58 (63.92 - 128.77)	74.82 (48.83 - 99.07)	62.23 (40.53 - 82.55)	74.07 (48.34 - 98.09)
	Traffic10	97.71 (64.00 - 128.93)	75.86 (49.51 - 100.43)	63.37 (41.28 - 84.05)	74.34 (48.51 - 98.44)
	FirewoodBan			62.20 (40.52 - 82.52)	74.05 (48.32 - 98.06)
	NoHeatFirewood			59.36 (38.65 - 78.78)	74.06 (48.33 - 98.07)
	ZeroEmissionShips			63.70 (41.50 - 84.49)	74.74 (48.77 - 98.96)
PM10 infant mortality (0 - 1 year)	**Basic**	0.162 (0.083 - 0.277)	0.126 (0.064 - 0.216)	0.112 (0.057 - 0.192)	0.121 (0.061 - 0.208)
	Not Heat	0.160 (0.081 - 0.272)	0.124 (0.063 - 0.212)	0.108 (0.055 - 0.187)	0.119 (0.060 - 0.205)
	Traffic10	0.160 (0.081 - 0.273)	0.125 (0.063 - 0.214)	0.110 (0.056 - 0.190)	0.119 (0.060 - 0.205)
	FirewoodBan			0.108 (0.055 - 0.187)	0.119 (0.060 - 0.204)
	NoHeatFirewood			0.104 (0.053 - 0.180)	0.119 (0.060 - 0.205)
	ZeroEmissionShips			0.111 (0.056 - 0.191)	0.120 (0.061 - 0.207)
PM10 Incidence of Chronic	**Basic**	105.80 (38.56 - 161.17)	83.20 (29.89 - 128.42)	74.27 (26.53 - 115.21)	80.10 (28.72 - 123.85)
	Not Heat	104.01 (37.87 - 158.61)	81.70 (29.32 - 126.20)	72.14 (25.74 - 112.04)	78.88 (28.26 - 122.05)

bronchitis (adults)	**Traffic10**	104.05 (37.89 - 158.68)	82.54 (29.64 - 127.44)	73.26 (26.15 - 113.71)	79.09 (28.34 - 122.36)
	FirewoodBan			72.13 (25.73 - 112.04)	78.81 (28.23 - 121.94)
	NoHeatFirewood			69.47 (24.74 - 108.06)	78.86 (28.25 - 122.01)
	ZeroEmissionShips			73.86 (26.38 - 114.61)	79.65 (28.55 - 123.19)
PM10 Cardiac Hospital admissions	**Basic**	13.46 (6.75 - 20.14)	10.36 (5.19 - 15.51)	9.18 (4.60 - 13.74)	9.95 (4.98 - 14.89)
	Not Heat	13.21 (6.62 - 19.76)	10.16 (5.09 - 15.21)	8.90 (4.46 - 13.32)	9.79 (4.90 - 14.65)
	Traffic10	13.22 (6.62 - 19.77)	10.27 (5.15 - 15.38)	9.04 (4.53 - 13.54)	9.81 (4.92 - 14.69)
	FirewoodBan			8.89 (4.45 - 13.32)	9.78 (4.90 - 14.64)
	NoHeatFirewood			8.55 (4.28 - 12.80)	9.78 (4.90 - 14.65)
	ZeroEmissionShips			9.12 (4.57 - 13.66)	9.89 (4.95 - 14.81)
PM10 Respiratory Hospital admissions	**Basic**	17.19 (13.39 - 19.08)	13.24 (10.31 - 14.70)	11.73 (9.13 - 13.02)	12.71 (9.90 - 14.11)
	Not Heat	16.87 (13.14 - 18.73)	12.98 (10.11 - 14.42)	11.37 (8.85 - 12.62)	12.50 (9.74 - 13.88)
	Traffic10	16.87 (13.15 - 18.73)	13.13 (10.22 - 14.57)	11.56 (9.00 - 12.83)	12.54 (9.77 - 13.92)
	FirewoodBan			11.37 (8.85 - 12.62)	12.49 (9.73 - 13.87)
	NoHeatFirewood			10.92 (8.50 - 12.13)	12.50 (9.73 - 13.88)
	ZeroEmissionShips			11.66 (9.08 - 12.94)	12.64 (9.84 - 14.03)
PM10 Prevalence of Chronic bronchitis	**Basic**	42.25 (- 80.31 - 640.83)	32.56 (- 61.52 - 510.68)	28.84 (- 54.37 - 458.21)	31.26 (- 59.02 - 492.52)
	Not Heat	41.46 (- 78.79 - 630.66)	31.93 (- 60.31 - 501.88)	27.96 (- 52.68 - 445.60)	30.75 (- 58.04 - 485.37)
	Traffic10	41.48 (- 78.83 - 630.91)	32.28 (- 60.98 - 506.79)	28.42 (- 53.57 - 452.24)	30.84 (- 58.21 - 486.62)

(children aged between 6 and 12 years old)	**FirewoodBan**			27.96 (- 52.68 - 445.58)	30.72 (- 57.98 - 484.93)
	NoHeatFirewood			26.86 (- 50.58 - 429.78)	30.74 (- 58.02 - 485.24)
	ZeroEmissionShips			28.67 (- 54.04 - 455.80)	31.07 (- 58.66 - 489.91)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) >30 years old	**Basic**	186.15 (108.55-261.46)	103.87 (59.64 - 148.23)	94.47 (54.15 - 135.05)	29.13 (16.50 - 42.15)
	Not Heat	179.47 (104.52-252.41)	95.64 (54.83 - 136.70)	81.26 (46.47 - 116.46)	23.10 (13.07 - 33.46)
	Traffic10	177.38 (103.26-249.58)	94.15 (53.96 - 134.60)	84.81 (48.52 - 121.46)	24.15 (13.67 - 34.97)
	FirewoodBan			83.78 (47.93 - 120.01)	23.60 (13.36 - 34.18)
	NoHeatFirewood			76.79 (43.87 - 110.14)	24.12 (13.65 - 34.93)
	ZeroEmissionShips			87.25 (49.94 - 124.90)	25.92 (14.68 - 37.53)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and	**Basic**	275.29 (13.62 - 396.74)	202.82 (9.91 - 294.20)	194.89 (9.51 - 282.89)	136.55 (6.59 - 199.23)
	Not Heat	269.38 (13.32 - 388.44)	195.84 (9.55 - 284.24)	183.47 (8.93 - 266.58)	127.60 (6.15 - 186.32)
	Traffic10	267.51 (13.22 - 385.80)	194.56 (9.49 - 282.41)	186.51 (9.08 - 270.92)	128.86 (6.21 - 188.13)
	FirewoodBan			185.60 (9.04 - 269.63)	128.61 (6.20 - 187.77)
	NoHeatFirewood			179.50 (8.73 - 260.90)	128.92 (6.21 - 188.22)

14 years old)	**ZeroEmissionShips**			188.63 (9.19 - 273.95)	6.31 - 191.16)

Brno

Health end point	Scenarios	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
		Number of cases (min – max)			
PM2.5 mortality (all natural causes) >30 years old	**BAU**	146.68 (95.64 - 194.40)	63.87 (41.39 - 85.13)	195.41 (127.87 - 258.10)	115.08 (74.86 - 152.86)
	M1opti	146.49 (95.51 - 194.15)	59.34 (38.45 - 79.12)	194.01 (126.94 - 256.28)	114.57 (74.52 - 152.18)
	M2opti	146.99 (95.84 - 194.81)	59.86 (38.78 - 79.81)	196.04 (128.29 - 258.92)	114.10 (74.22 - 151.57)
	M2zero	147.19 (95.97 - 195.07)	59.08 (38.27 - 78.77)	194.73 (127.42 - 257.21)	115.21 (74.95 - 153.03)
	M3slow	146.61 (95.59 - 194.32)	60.35 (39.10 - 80.47)	193.67 (126.71 - 255.83)	114.49 (74.47 - 152.07)
	M4econ	146.54 (95.54 - 194.22)	60.61 (39.27 - 80.81)	194.36 (127.17 - 256.74)	114.38 (74.40 - 151.94)
PM10 infant mortality (0 - 1 year)	**BAU**	0.225 (0.114 - 0.388)	0.113 (0.057 - 0.196)	0.292 (0.148 - 0.500)	0.179 (0.090 - 0.310)
	M1opti	0.225 (0.114 - 0.387)	0.107 (0.054 - 0.185)	0.289 (0.147 - 0.496)	0.178 (0.090 - 0.307)
	M2opti	0.225 (0.114 - 0.388)	0.108 (0.054 - 0.187)	0.292 (0.148 - 0.501)	0.177 (0.089 - 0.306)
	M2zero	0.226 (0.114 - 0.389)	0.106 (0.053 - 0.184)	0.290 (0.147 - 0.497)	0.179 (0.090 - 0.309)
	M3slow	0.225 (0.114 - 0.388)	0.108 (0.054 - 0.188)	0.289 (0.146 - 0.495)	0.178 (0.090 - 0.307)
	M4econ	0.225 (0.114 - 0.387)	0.108 (0.054 - 0.187)	0.291 (0.147 - 0.498)	0.178 (0.090 - 0.307)

PM10 Incidence of Chronic bronchitis (adults)	**BAU**	148.92 (53.10 - 231.41)	76.46 (26.70 - 121.11)	190.74 (68.88 - 293.03)	119.63 (42.29 - 187.36)
	M1opti	148.79 (53.05 - 231.21)	72.10 (25.14 - 114.34)	189.13 (68.26 - 290.68)	118.81 (41.99 - 186.11)
	M2opti	149.08 (53.16 - 231.65)	72.85 (25.41 - 115.51)	190.95 (68.96 - 293.33)	118.30 (41.80 - 185.34)
	M2zero	149.30 (53.24 - 231.98)	71.75 (25.02 - 113.80)	189.70 (68.48 - 291.51)	119.39 (42.20 - 186.99)
	M3slow	148.95 (53.11 - 231.45)	73.22 (25.54 - 116.09)	188.76 (68.12 - 290.14)	118.73 (41.96 - 186.00)
	M4econ	148.79 (53.05 - 231.21)	72.96 (25.45 - 115.68)	189.88 (68.55 - 291.78)	118.57 (41.90 - 185.75)
PM10 Cardiac Hospital admissions	**BAU**	18.46 (9.25 - 27.65)	9.19 (4.60 - 13.78)	24.08 (12.07 - 36.05)	14.65 (7.33 - 21.94)
	M1opti	18.44 (9.24 - 27.62)	8.66 (4.3312.97)	23.86 (11.96 - 35.72)	14.54 (7.28 - 21.78)
	M2opti	18.48 (9.26 - 27.68)	8.75 (4.38 - 13.11)	24.11 (12.08 - 36.09)	14.48 (7.25 - 21.68)
	M2zero	18.51 (9.27 - 27.72)	8.61 (4.31 - 12.91)	23.94 (12.00 - 35.83)	14.62 (7.32 - 21.89)
	M3slow	18.46 (9.25 - 27.65)	8.79 (4.40 - 13.18)	23.81 (11.93 - 35.64)	14.53 (7.27 - 21.77)
	M4econ	18.44 (9.24 - 27.62)	8.76 (4.38 - 13.13)	23.97 (12.01 - 35.87)	14.51 (7.26 - 21.74)
PM10 Respiratory Hospital admissions	**BAU**	23.59 (18.37 - 26.20)	11.76 (9.15 - 13.06)	30.76 (23.96 - 34.15)	18.72 (14.58 - 20.80)
	M1opti	23.57 (18.35 - 26.18)	11.07 (8.61 - 12.30)	30.48 (23.74 - 33.84)	18.59 (14.47 - 20.65)
	M2opti	23.62 (18.39 - 26.23)	11.19 (8.71 - 12.43)	30.80 (23.99 - 34.19)	18.5114.41 - 20.55)
	M2zero	23.66 (18.42 - 26.27)	11.02 (8.57 - 12.24)	30.58 (23.82 - 33.95)	18.68 (14.54 - 20.75)
	M3slow	23.60 (18.37 - 26.20)	11.25 (8.75 - 12.49)	30.42 (23.69 - 33.77)	18.58 (14.46 - 20.63)
	M4econ	23.57 (18.35 - 26.17)	11.21 (8.72 - 12.45)	30.61 (23.84 - 33.99)	18.55 (14.44 - 20.60)
PM10	**BAU**	61.45 (-115.76 -980.65)	30.65 (-57.23 - 513.37)	80.10 (- 151.68 - 1241.56)	48.78 (- 91.57 - 794.07)

Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**M1opti**	61.39 (-115.65 - 979.80)	28.85 (- 53.86 - 484.69)	79.37 (- 150.26 - 1231.61)	48.43 (- 90.90 - 788.77)
	M2opti	61.52 (-115.90 - 981.66)	29.16 (- 54.43 - 489.61)	80.19 (- 151.86 - 1242.84)	48.21 (- 90.48 - 785.51)
	M2zero	61.62 (-116.08 - 983.06)	28.71 (- 53.59 - 482.40)	79.63 (- 150.77 - 1235.16)	48.68 (- 91.37 - 792.51)
	M3slow	61.46 (-115.78 - 980.80)	29.31 (- 54.73 - 492.09)	79.20 (- 149.94 - 1229.34)	48.40 (- 90.83 - 788.28)
	M4econ	61.39 (-115.65 - 979.80)	29.20 (- 54.52 - 490.35)	79.71 (- 150.93 - 1236.29)	48.33 (- 90.70 - 787.25)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) **>30 years BAU**	**BAU**	0.00	0.00	0.00	0.00
	M1opti	0.00	0.000016 (0.000009 - 0.000023)	0.00	0.00
	M2opti	0.00	0.00	0.00	0.00
	M2zero	0.00	0.00	0.00	0.00
	M3slow	0.00	0.000016 (0.000009 - 0.000023)	0.00	0.00
	M4econ	0.00	0.00	0.00	0.00
NO2 Prevalence of bronchitis symptoms in asthmatic	**BAU**	61.98 (2.97 - 90.83)	66.21 (3.17 - 96.97)	51.15 (2.44 - 75.05)	46.10 (2.20 - 67.68)
	M1opti	61.31 (2.93 - 89.85)	65.68 (3.15 - 96.20)	49.65 (2.37 - 72.87)	45.49 (2.17 - 66.79)
	M2opti	60.54 (2.90 - 88.73)	64.72 (3.10 - 94.81)	51.60 (2.46 - 75.71)	45.16 (2.15 - 66.31)

children (between 5 and 14 years old)	**M2zero**	60.79 (2.91 - 89.10)	65.37 (3.13 - 95.75)	50.53 (2.41 - 74.15)	45.56 (2.17 - 66.89)
	M3slow	61.86 (2.96 - 90.64)	66.16 (3.17 - 96.90)	49.73 (2.37 - 72.98)	45.60 (2.17 - 66.95)
	M4econ	61.48 (2.94 - 90.09)	65.75 (3.15 - 96.31)	51.14 (2.44 - 75.03)	(2.16 - 66.69)

Ljubljana

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU**			107.93 (70.36 - 143.06)	77.05 (50.08 - 102.42)
	M1			104.68 (68.22 - 138.80)	78.15 (50.80 - 103.88)
	M2			104.96 (68.41 - 139.16)	75.94 (49.35 - 100.96)
	M3			106.02 (69.10 - 140.55)	76.41 (49.66 - 101.57)
	M4			98.36 (64.06 - 130.49)	63.37 (41.14 - 84.35)
	M5			105.88 (69.01 - 140.37)	76.34 (49.62 - 101.49)
PM10 infant mortality (0 - 1 year)	**BAU**			0.173 (0.087 - 0.297)	0.136 (0.069 - 0.235)
	M1			0.168 (0.085 - 0.289)	0.137 (0.069 - 0.237)
	M2			0.168 (0.085 - 0.289)	0.134 (0.068 - 0.231)
	M3			0.170 (0.086 - 0.292)	0.135 (0.068 - 0.232)

	M4			0.157 (0.079 - 0.270)	0.111 (0.056 - 0.193)
	M5			0.174 (0.088 - 0.299)	0.135 (0.068 - 0.233)
PM10 Incidence of Chronic bronchitis (adults)	**BAU**			113.98 (40.73 - 176.75)	90.84 (32.16 - 142.08)
	M1			111.06 (39.64 - 172.42)	91.48 (32.39 - 143.04)
	M2			111.04 (39.63 - 172.38)	89.21 (31.56 - 139.62)
	M3			112.00 (39.99 - 173.81)	89.73 (31.75 - 140.41)
	M4			103.81 (36.94 - 161.59)	74.68 (26.27 - 117.49)
	M5			114.80 (41.04 - 177.98)	89.85 (31.80 - 140.59)
PM10 Cardiac Hospital admissions	**BAU**			14.17 (7.10 - 21.22)	11.14 (5.58 - 16.69)
	M1			13.79 (6.91 - 20.65)	11.23 (5.62 - 16.82)
	M2			13.79 (6.90 - 20.64)	10.93 (5.47 - 16.38)
	M3			13.91 (6.97 - 20.83)	11.00 (5.51 - 16.48)
	M4			12.83 (6.43 - 19.22)	9.08 (4.54 - 13.60)
	M5			14.28 (7.15 - 21.39)	11.02 (5.52 - 16.50)
PM10 Respiratory Hospital admissions	**BAU**			18.11 (14.10 - 20.11)	14.25 (11.09 - 15.82)
	M1			17.62 (13.72 - 19.57)	14.35 (11.17 - 15.94)
	M2			17.62 (13.72 - 19.56)	13.98 (10.88 - 15.52)
	M3			17.78 (13.84 - 19.74)	14.06 (10.95 - 15.62)
	M4			16.40 (12.77 - 18.21)	11.61 (9.03 - 12.89)

	M5			18.25 (14.21 - 20.27)	14.08 (10.96 - 15.64)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU**			45.03 (- 84.91 - 714.96)	35.43 (- 66.54 - 574.78)
	M1			43.81 (- 82.56 - 697.43)	35.69 (- 67.04 - 578.66)
	M2			43.80 (- 82.54 - 697.29)	34.76 (- 65.27 - 564.82)
	M3			44.20 (- 83.31 - 703.07)	34.97 (- 65.68 - 568.01)
	M4			40.78 (- 76.76 - 653.67)	28.87 (- 54.08 - 475.35)
	M5			45.38 (- 85.57 - 719.91)	35.02 (- 65.77 - 568.76)

Health end point	Scenarios	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) >30 years old	**BAU**			158.59 (90.98 - 226.47)	275.79 (160.43-388.32)
	M1			159.47 (92.68 - 227.74)	271.38 (157.87-382.10)
	M2			156.48 (89.77 - 223.46)	262.79 (152.87-370.01)
	M3			158.54 (90.96 - 226.40)	272.33 (158.42-383.44)
	M4			91.26 (45.43 - 115.15)	161.07 (80.73 - 201.77)
	M5			163.71 (93.93 - 233.80)	274.50 (159.68-386.49)
NO2 Prevalence	**BAU**			92.71 (4.51 - 134.68)	124.35 (6.12 - 179.65)

of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**M1**			92.84 (4.52 - 134.88)	123.09 (6.06 - 177.86)
	M2			91.97 (4.48 - 133.62)	120.66 (5.93 - 174.42)
	M3			92.17 (4.49 - 133.92)	123.00 (6.05 - 177.73)
	M4			71.57 (3.46 - 104.36)	89.00 (4.33 - 129.37)
	M5			93.62 (4.56 - 135.99)	124.026.11 - 179.18)

Madrid

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU_V2**	779.36 (506.111036.87)	1065.46 (693.59 - 1414.22)	846.84 (550.24 - 1126.04)	718.46 (466.32 - 956.32)
	Enef	774.35 (502.83 - 1030.25)	1066.27 (694.12 - 1415.29)	845.68 (549.48 - 1124.50)	713.54 (463.11 - 949.81)
	Log	776.42 (504.19 - 1032.99)	1061.03 (690.67 - 1408.38)	785.62 (510.20 - 1045.15)	714.41 (463.67 - 950.96)
	Park	788.60 (512.15 - 1049.09)	1054.42 (686.34 - 1399.69)	773.66 (502.38 - 1029.33)	719.60 (467.06 - 957.83)
	Put	765.33 (496.94 - 1018.32)	1067.95 (695.22 - 1417.50)	820.05 (532.71 - 1090.64)	715.95 (464.68 - 952.99)
	Zez	774.43 (502.88 - 1030.35)	1061.67 (691.10 - - 1409.23)	790.23 (513.21 - 1051.24)	714.27 (463.58 - 950.77)
PM10 infant mortality (0 - 1	**BAU_V2**	1.150 (0.579 - 1.992)	1.535 (0.775 - 2.651)	1.247 (0.628 - 2.158)	1.069 (0.538 - 1.853)
	Enef	1.143 (0.575 - 1.980)	1.537 (0.775 - 2.653)	1.242 (0.625 - 2.150)	1.059 (0.533 - 1.836)

year)	**Log**	1.147 (0.577 - 1.987)	1.530 (0.772 - 2.642)	1.165 (0.586 - 2.018)	1.064 (0.535 - 1.844)
	Park	1.163 (0.586 - 2.016)	1.521 (0.767 - 2.626)	1.149 (0.578 - 1.990)	1.071 (0.539 - 1.857)
	Put	1.131 (0.569 - 1.960)	1.540 (0.777 - 2.658)	1.210 (0.609 - 2.096)	1.065 (0.536 - 1.847)
	Zez	1.144 (0.576 - 1.983)	1.532 (0.773 - 2.645)	1.171 (0.590 - 2.029)	1.064 (0.536 - 1.845)
PM10 Incidence of Chronic bronchitis (adults)	**BAU_V2**	787.37 (276.19 - 1241.97)	1042.36 (368.82 - 1631.20)	851.87 (299.46 - 1341.04)	733.19 (256.72 - 1158.45)
	Enef	782.89 (274.57 - 1235.08)	1043.27 (369.15 - 1632.57)	848.65 (298.30 - 1336.10)	726.74 (254.40 - 1148.50)
	Log	785.45 (275.50 - 1239.02)	1038.83 (367.52 - 1625.84)	797.41 (279.81 - 1257.43)	729.92 (255.54 - 1153.40)
	Park	796.59 (279.51 - 1256.16)	1033.00 (365.39 - 1617.02)	786.85 (276.00 - 1241.17)	734.73 (257.27 - 1160.82)
	Put	774.93 (271.71 - 1222.82)	1045.17 (369.84 - 1635.44)	827.78 (290.76 - 1304.10)	730.90 (255.90 - 1154.92)
	Zez	783.91 (274.94 - 1236.65)	1040.01 (367.95 - 1627.63)	801.80 (281.39 - 1264.17)	730.37 (255.71 - 1154.10)
PM10 Cardiac Hospital admissions	**BAU_V2**	93.59 (46.84 - 140.25)	125.47 (62.82 - 187.95)	101.58 (50.85 - 152.20)	86.92 (43.50 - 130.27)
	Enef	93.04 (46.57 - 139.42)	125.58 (62.88 - 188.12)	101.18 (50.65 - 151.61)	86.13 (43.11 - 129.08)
	Log	93.36 (46.73 - 139.89)	125.02 (62.60 - 187.28)	94.83 (47.47 - 142.11)	86.52 (43.30 - 129.66)
	Park	94.73 (47.41 - 141.95)	124.28 (62.23 - 186.18)	93.53 (46.81 - 140.15)	87.11 (43.60 - 130.55)
	Put	92.06 (46.08 - 137.95)	125.82 (63.00 - 188.48)	98.59 (49.35 - 147.73)	86.64 (43.36 - 129.84)
	Zez	93.17 (46.63 - 139.61)	125.17 (62.67 - 187.50)	95.38 (47.74 - 142.92)	86.58 (43.33 - 129.75)
PM10 Respiratory Hospital	**BAU_V2**	119.69 (93.15 - 132.94)	160.39 (124.86 - 178.14)	129.89 (101.10 - 144.27)	111.17 (86.52 - 123.48)
	Enef	118.98 (92.60 - 132.16)	160.54 (124.98 - 178.30)	129.38 (100.70 - 143.70)	110.16 (85.73 - 122.36)
	Log	119.38 (92.92 - 132.60)	159.82 (124.42 - 177.50)	121.27 (94.39 - 134.70)	110.65 (86.12 - 122.91)

admissions	**Park**	121.14 (94.29 - 134.56)	158.88 (123.68 - 176.46)	119.60 (93.09 - 132.85)	111.41 (86.70 - 123.75)
	Put	117.73 (91.63 - 130.76)	160.85 (125.22 - 178.64)	126.07 (98.13 - 140.03)	110.81 (86.24 - 123.08)
	Zez	119.14 (92.73 - 132.34)	160.01 (124.57 - 177.71)	121.96 (94.93 - 135.47)	110.72 (86.17 - 122.99)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU_V2**	315.14 (- 589.68 - 5223.33)	422.24 (- 792.88 - 6859.52)	341.99 (- 640.48 - 5639.81)	292.72 (- 547.32 - 4872.18)
	Enef	313.28 (- 586.17 - 5194.33)	422.63 (- 793.62 - 6865.27)	340.64 (- 637.94 - 5619.06)	290.06 (- 542.30 - 4830.32)
	Log	314.35 (- 588.18 - 5210.91)	420.74 (- 790.02 - 6837.02)	319.31 (- 597.57 - 5288.32)	291.37 (- 544.77 - 4850.91)
	Park	318.97 (- 596.92 - 5282.98)	418.26 (- 785.31 - 6799.93)	314.93 (- 589.27 - 5219.96)	293.36 (- 548.52 - 4882.14)
	Put	309.98 (- 579.93 - 5142.80)	423.43 (- 795.15 - 6877.37)	331.95 (- 621.47 - 5484.50)	291.78 (- 545.54 - 4857.33)
	Zez	313.71 (- 586.97 - 5200.95)	421.24 (- 790.98 - 6844.52)	321.14 (- 601.01 - 5316.66)	291.56 (- 545.12 - 4853.87)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) **>30 years old**	**BAU_V2**	2376.41 (1371.17 - 3373.98)	3060.40 (1778.41-4313.67)	3532.14 (2062.84 - 4953.32)	2845.26 (1649.67 - 4019.65)
	Enef	2344.21 (1352.14 - 3329.39)	3053.67 (1774.38 - 4304.50)	3506.41 (2047.25 - 4918.61)	2773.72 (1607.00 - 3921.57)
	Log	2354.27 (1358.08 - 3343.32)	3023.81 (1756.48 - 4263.77)	3394.61 (1979.61 - 4767.56)	2799.61 (1622.43 - 3957.09)
	Park	2379.04 (1372.72 - 3377.62)	3013.30 (1750.18 - 4249.42)	3380.27 (1970.95 - 4748.15)	2842.36 (1647.94 - 4015.68)
	Put	2329.72 (1343.58 - 3309.31)	3060.27 (1778.33 - 4313.49)	3486.48 (2035.18 - 4891.72)	2811.14 (1629.31 - 3972.90)

	Zez	2374.94 (1370.30 - 3371.95)	3064.92 (1781.12 - 4319.83)	3418.22 (1993.88 - 4799.49)	2842.46 (1648.00 - 4015.82)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU_V2**	4209.54 (206.40 - 6094.47)	4859.46 (239.78 - 7013.71)	5300.49 (262.67 - 7634.15)	4675.05 (230.26 - 6753.48)
	Enef	4176.17 (204.70 - 6047.10)	4860.55 (239.83 - 7015.25)	5270.52 (261.11 - 7592.08)	4607.49 (226.79 - 6658.03)
	Log	4186.56 (205.23 - 6061.85)	4829.01 (238.20 - 6970.78)	5159.49 (255.33 - 7436.09)	4631.22 (228.01 - 6691.57)
	Park	4210.46 (206.45 - 6095.76)	4811.10 (237.28 - 6945.51)	5145.81 (254.62 - 7416.85)	4670.85 (230.05 - 6747.56)
	Put	4161.10 (203.93 - 6025.71)	4850.54 (239.32 - 7001.14)	5247.87 (259.93 - 7560.27)	4641.67 (228.55 - 6706.33)
	Zez	4205.08 (206.17 - 6088.13)	4868.25 (240.23 - 7026.10)	5184.30 (256.62 - 7470.96)	4671.23 (230.07 - 6748.09)

Milan

Health end point	**Scenarios**	**Time horizon**			
		2021-2025	**2026-2030**	**2031-2035**	**2036-2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU_V2**	122.32 (79.12 - 163.33)	292.86 (190.11 - 389.75)	430.28 (280.14 - 571.03)	440.06 (286.57- 583.89)
	AREA B	117.84 (76.21 - 157.38)	272.25 (176.66 - 362.47)	412.30 (268.34 - 547.37)	431.07 (280.67- 572.06)
	ELECTRIC BUS	121.69 (78.71 - 162.52)	291.71 (189.36 - 388.22)	425.34 (276.90 - 564.52)	436.70 (284.37- 579.46)
	BUILDINGS	121.67 (78.70 - 162.49)	289.44 (187.88 - 385.22)	425.39 (276.94 - 564.59)	438.78 (285.74- 582.20)
	ENERGY	119.01 (76.97 - 158.93)	301.11 (195.51 - 400.66)	426.95 (277.97 - 566.65)	441.77 (287.71- 586.14)
	TREES	118.25 (76.48 - 157.93)	290.13 (188.33 - 386.14)	429.41 (279.58 - 569.88)	440.47 (286.85- 584.42)

PM10 infant mortality (0 - 1 year)	**BAU_V2**	0.363 (0.183 - 0.631)	0.564 (0.285 - 0.975)	0.724 (0.366 - 1.246)	0.752 (0.381 - 1.295)
	AREA B	0.356 (0.179 - 0.618)	0.535 (0.269 - 0.924)	0.693 (0.350 - 1.193)	0.734 (0.371 - 1.264)
	ELECTRIC BUS	0.362 (0.182 - 0.628)	0.563 (0.284 - 0.972)	0.717 (0.362 - 1.235)	0.747 (0.378 - 1.285)
	BUILDINGS	0.362 (0.182 - 0.629)	0.559 (0.282 - 0.967)	0.717 (0.362 - 1.234)	0.751 (0.380 - 1.292)
	ENERGY	0.359 (0.180 - 0.623)	0.575 (0.290 - 0.993)	0.718 (0.363 - 1.237)	0.754 (0.381 - 1.297)
	TREES	0.358 (0.180 - 0.621)	0.559 (0.282 - 0.966)	0.723 (0.365 - 1.244)	0.752 (0.380 - 1.294)
PM10 Incidence of Chronic bronchitis (adults)	**BAU_V2**	253.02 (88.33 - 400.85)	388.50 (137.22 - 608.94)	493.62 (175.98 - 767.18)	512.32 (182.95- 795.04)
	AREA B	247.89 (86.51 - 392.89)	368.62 (129.98 - 578.69)	473.25 (168.41 - 736.74)	500.51 (178.54 -777.45)
	ELECTRIC BUS	251.92 (87.94 - 399.15)	387.31 (136.79 - 607.12)	489.17 (174.32 - 760.54)	508.79 (181.63- 789.79)
	BUILDINGS	252.27 (88.07 - 399.68)	385.23 (136.03 - 603.97)	488.97 (174.25 - 760.25)	511.16 (182.52- 793.32)
	ENERGY	249.98 (87.25 - 396.13)	395.59 (139.81 - 619.69)	490.12 (174.68 - 761.96)	513.38 (183.35- 796.61)
	TREES	249.24 (86.99 - 394.98)	384.85 (135.89 - 603.38)	492.79 (175.67 - 765.95)	512.14 (182.88- 794.78)
PM10 Cardiac Hospital admissions	**BAU_V2**	29.52 (14.77 - 44.24)	46.09 (23.08 - 69.05)	59.35 (29.73 - 88.88)	61.75 (30.93 - 92.47)
	AREA B	28.90 (14.46 - 43.31)	43.62 (21.84 - 65.36)	56.76 (28.42 - 85.00)	60.24 (30.17 - 90.20)
	ELECTRIC BUS	29.38 (14.70 - 44.04)	45.94 (23.00 - 68.83)	58.79 (29.44 - 88.03)	61.30 (30.70 - 91.79)
	BUILDINGS	29.42 (14.72 - 44.10)	45.68 (22.87 - 68.44)	58.76 (29.43 - 88.00)	61.60 (30.86 - 92.25)
	ENERGY	29.15 (14.59 - 43.69)	46.97 (23.52 - 70.37)	58.91 (29.50 - 88.22)	61.89 (31.00 - 92.67)
	TREES	29.06 (14.54 - 43.56)	45.64 (22.85 - 68.37)	59.25 (29.67 - 88.73)	61.73 (30.92 - 92.44)
PM10	**BAU_V2**	37.75 (29.38 - 41.93)	58.92 (45.87 - 65.44)	75.85 (59.06 - 84.24)	78.91 (61.45 - 87.63)

Respiratory Hospital admissions	**AREA B**	36.96 (28.76 - 41.06)	55.77 (43.41 - 61.95)	72.54 (56.48 - 80.56)	76.98 (59.94 - 85.48)
	ELECTRIC BUS	37.58 (29.25 - 41.75)	58.73 (45.72 - 65.23)	75.13 (58.50 - 83.43)	78.33 (61.00 - 86.99)
	BUILDINGS	37.64 (29.29 - 41.81)	58.41 (45.46 - 64.87)	75.10 (58.47 - 83.39)	78.72 (61.30 - 87.42)
	ENERGY	37.28 (29.01 - 41.41)	60.05 (46.75 - 66.69)	75.28 (58.62 - 83.60)	79.09 (61.58 - 87.82)
	TREES	37.17 (28.93 - 41.29)	58.34 (45.42 - 64.80)	75.72 (58.96 - 84.09)	78.88 (61.42 - 87.60)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU_V2**	89.75 (-167.61 - 1503.91)	140.04 (-262.79 - 2284.26)	180.24 (-339.50 - 2877.53)	187.50 (-353.42-2981.95)
	AREA B	87.87 (-164.08 - 1474.02)	132.56 (-248.57 - 2170.85)	172.37 (-324.43 - 2763.41)	182.91 (-344.62 - 2916.02)
	ELECTRIC BUS	89.35 (-166.85 - 1497.51)	139.59 (-261.93 - 2277.45)	178.52 (-336.20 - 2852.64)	186.13 (-350.79 - 2962.27)
	BUILDINGS	89.47 (-167.09 - 1499.53)	138.81 (-260.44 - 2265.63)	178.44 (-336.05 - 2851.53)	187.05 (-352.56 - 2975.50)
	ENERGY	88.64 (-165.51 - 1486.18)	142.72 (-267.88 - 2324.58)	178.88 (-336.91 - 2857.97)	187.91 (-354.22 - 2987.86)
	TREES	88.37 (-165.01 - 1481.87)	138.67 (-260.16 - 2263.43)	179.92 (-338.89 - 2872.90)	187.43 (-353.29 - 2980.97)

Health end point	**Scenarios**	**Time horizon**			
		2021-2025	**2026-2030**	**2031-2035**	**2036-2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) >30	**BAU_V2**	980.28 (566.19-1390.32)	865.94 (498.67- 1231.88)	1021.51 (590.64- 1447.20)	989.84 (571.86- 1403.53)
	AREA B	936.36 (540.21-1329.58)	649.19 (371.79 - 928.80)	626.14 (358.38 - 896.36)	665.65(381.38- 951.94)
	ELECTRIC BUS	980.90 (566.56-1391.18)	831.81 (478.60 - 1184.40)	961.91 (555.32 - 1364.94)	944.44 (544.98-1340.76)

years old	**BUILDINGS**	986.89 (570.11 - 1399.45)	834.57 (480.22 - 1188.24)	996.05 (575.54 - 1412.10)	973.70 (562.30 - 1381.23)
	ENERGY	985.08 (569.03 - 1396.95)	846.66 (487.33 - 1205.06)	995.52 (575.22 - 1411.36)	971.47 (560.98 - 1378.15)
	TREES	983.81 (568.28 - 1395.20)	849.07 (488.75 - 1208.43)	1029.86 (595.60 - 1458.70)	992.38 (573.36 - 1407.03)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU_V2**	1516.48 (74.45 - 2194.18)	1432.05 (70.14 - 2074.39)	1549.34 (76.13 - 2240.72)	1524.32 (74.85 - 2205.28)
	AREA B	1478.20 (72.49 - 2139.90)	1252.09 (61.02 - 1818.10)	1233.47 (60.09 - 1791.52)	1264.15 (61.63 - 1835.32)
	ELECTRIC BUS	1514.14 (74.33 - 2190.87)	1396.37 (68.33 - 2023.67)	1498.80 (73.54 - 2169.11)	1484.93 (72.84 - 2149.45)
	BUILDINGS	1518.92 (74.57 - 2197.63)	1398.68 (68.44 - 2026.96)	1526.30 (74.95 - 2208.09)	1508.51 (74.04 - 2182.88)
	ENERGY	1517.46 (74.50 - 2195.56)	1408.07 (68.92 - 2040.31)	1525.67 (74.92 - 2207.20)	1506.71 (73.95 -2180.32)
	TREES	1516.59 (74.45 - 2194.33)	1410.54 (69.05 - 2043.82)	1553.45 (76.34 - 2246.54)	(74.81 - 2204.15)

Stuttgart

Health end point	Scenarios	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
		Number of cases (min – max)			
PM2.5 mortality (all natural causes) >30 years old	**BAU_V2**	205.54 (133.89- 272.65)	220.68 (143.86 - 292.53)	97.13 (62.95 - 129.47)	179.22 (116.60- 238.02)
	FVH	219.12 (142.83- 290.48)	94.92 (61.51 - 126.54)	181.02 (117.78 - 240.39)	
	Sc1	220.99 (144.06- 292.94)	98.45 (63.81 - 131.23)	180.18 (117.23 - 239.29)	
	Scel			180.11 (117.18 - 239.20)	

	Scuv			178.66 (116.23 - 237.27)	
PM10 infant mortality (0 - 1 year)	**BAU_V2**	0.031 (0.016 - 0.055)	0.034 (0.017 - 0.059)	0.017 (0.009 - 0.030)	0.028 (0.014 - 0.049)
	FVH	0.033 (0.017 - 0.058)	0.017 (0.008 - 0.029)	0.029 (0.014 - 0.050)	
	Sc1	0.034 (0.017 - 0.059)	0.017 (0.009 - 0.030)	0.028 (0.014 - 0.050)	
	Scel			0.028 (0.014 - 0.050)	
	Scuv			0.028 (0.014 - 0.049)	
PM10 Incidence of Chronic bronchitis (adults)	**BAU_V2**	206.70 (75.64 - 332.15)	221.08 (81.12 - 354.34)	115.62 (41.58 - 188.71)	187.60 (68.39 - 302.46)
	FVH	219.97 (80.70 - 352.64)	113.48 (40.80 - 185.33)	189.06 (68.94 - 304.72)	
	Sc1	221.39 (81.24 - 354.81)	116.79 (42.02 - 190.62)	187.99 (68.54 - 303.07)	
	Scel			188.32 (68.67 - 303.58)	
	Scuv			186.85 (68.11 - 301.28)	
PM10 Cardiac Hospital admissions	**BAU_V2**	25.17 (12.60 - 37.69)	27.03 (13.53 - 40.47)	13.74 (6.87 - 20.58)	22.72 (11.38 - 34.03)
	FVH	26.89 (13.46 - 40.26)	13.47 (6.74 - 20.19)	22.91 (11.47 - 34.31)	
	Sc1	27.07 (13.55 - 40.53)	13.88 (6.94 - 20.80)	22.77 (11.40 - 34.11)	
	Scel			22.82 (11.42 - 34.17)	
	Scuv			22.63 (11.33 - 33.89)	
PM10 Respiratory Hospital	**BAU_V2**	32.17 (25.04 - 35.72)	34.54 (26.89 - 38.36)	17.56 (13.67 - 19.51)	29.04 (22.61 - 32.26)
	FVH	34.36 (26.75 - 38.15)	17.23 (13.41 - 19.14)	29.28 (22.79 - 32.52)	
	Sc1	34.59 (26.93 - 38.41)	17.75 (13.81 - 19.71)	29.11 (22.66 - 32.33)	

admissions	**Scel**			29.16 (22.70 - 32.39)	
	Scuv			28.92 (22.52 - 32.12)	
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU_V2**	71.68 (-134.81-1154.53)	76.96 (- 144.90 - 1231.61)	39.15 (- 73.10 - 656.10)	64.73 (-121.54-1051.37)
	FVH	76.55 (-144.12-1225.71)	38.41 (- 71.72 - 644.34)	65.25 (- 122.55 - 1059.25)	
	Sc1	77.07 (-145.12-1233.27)	39.56 (- 73.89 - 662.72)	64.87 (- 121.82 - 1053.50)	
	Scel			64.99 (- 122.04 - 1055.28)	
	Scuv			64.45 (- 121.03 - 1047.30)	

Health end point	Scenarios	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
		Number of cases (min – max)			
NO2 mortality (all natural causes) >30 years old	**BAU_V2**	50.05 (28.29 - 72.60)	24.58 (13.87 - 35.71)	80.80 (45.74 - 117.01)	1.44 (0.81 - 2.10)
	FVH	23.28 (13.14 - 33.81)	61.44 (34.74 - 89.06)	1.23 (0.69 - 1.78)	
	Sc1	24.26 (13.69 - 35.23)	80.79 (45.73 - 116.98)	1.20 (0.68 - 1.75)	
	Scel			0.95 (0.54 - 1.38)	
	Scuv			1.38 (0.79 - 2.03)	
NO2 Prevalence of bronchitis	**BAU_V2**	364.98 (17.59 - 532.94)	327.76 (15.76 - 479.13)	384.03 (18.53 - 560.43)	294.91 (14.15-431.54)
	FVH	322.77 (15.51 - 471.91)	365.53 (17.61 - 533.73)	292.28 (14.02 - 427.72)	

symptoms in asthmatic children (between 5 and 14 years old)	**Sc1**	326.56 (15.70 - 477.39)	382.91 (18.47 - 558.82)	291.98 (14.01 - 427.29)	
	Scel			291.97 (14.01 - 427.28)	
	Scuv			292.51 (14.03 - 428.06)	

Greater Thessaloniki Area

Health end point	Scenarios	Time horizon			
		2021-2025	**2026-2030**	**2031-2035**	**2036-2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU**	95.19 (61.56 - 127.14)	155.96 (101.01 - 208.01)	432.99 (282.42 - 573.66)	162.41 (105.21 - 216.59)
	M1	95.19 (61.56 - 127.14)	154 (99.74 - 205.41)	432.45 (282.06 - 572.95)	163.9 (106.17 - 218.56)
	M2A	94.34 (61.01 - 126.01)	150.92 (97.74 - 201.32)	432.23 (281.91 - 572.66)	163.59 (105.97 - 218.15)
	M2B	91.34 (59.06 - 122.02)	148.24 (95.99 - 197.76)	423.12 (275.91 - 560.72)	159.61 (103.38 - 212.86)
	M2C	92.48 (59.8 - 123.53)	153.13 (99.17 - 204.25)	426.29 (278 - 564.87)	159.77 (103.49 - 213.08)
	M3	92.57 (59.86 - 123.65)	156.85 (101.59 - 209.19)	433.01 (282.43 - 573.69)	162.86 (105.5 - 217.19)
	M4	95.77 (61.93 - 127.92)	155.52 (100.73 - 207.43)	424.33 (276.7 - 562.3)	158.25 (102.5 - 211.05)
PM10 infant mortality (0 - 1	**BAU**	0.16 (0.08 - 0.28)	0.24 (0.12 - 0.41)	0.62 (0.31 - 1.06)	0.26 (0.13 - 0.45)
	M1	0.16 (0.08 - 0.28)	0.23 (0.12 - 0.41)	0.62 (0.31 - 1.07)	0.26 (0.13 - 0.46)

year)	**M2A**	0.16 (0.08 - 0.28)	0.23 (0.11 - 0.4)	0.62 (0.31 - 1.07)	0.26 (0.13 - 0.46)
	M2B	0.15 (0.08 - 0.26)	0.22 (0.11 - 0.38)	0.6 (0.3 - 1.03)	0.25 (0.13 - 0.43)
	M2C	0.16 (0.08 - 0.27)	0.23 (0.12 - 0.4)	0.61 (0.31 - 1.05)	0.26 (0.13 - 0.45)
	M3	0.16 (0.08 - 0.28)	0.24 (0.12 - 0.41)	0.62 (0.31 - 1.07)	0.26 (0.13 - 0.46)
	M4	0.16 (0.08 - 0.28)	0.23 (0.12 - 0.4)	0.6 (0.3 - 1.04)	0.25 (0.13 - 0.44)
PM10 Incidence of Chronic bronchitis (adults)	**BAU**	111.38 (38.49 - 178.14)	161.79 (56.19 - 257.57)	413.51 (147.33 - 643.03)	177.21 (61.64 - 281.72)
	M1	112.38 (38.84 - 179.72)	160.31 (55.67 - 255.25)	415.35 (148.01 - 645.78)	181.08 (63.01 - 287.77)
	M2A	110.98 (38.35 - 177.5)	156.88 (54.46 - 249.87)	414.93 (147.86 - 645.14)	180.46 (62.79 - 286.8)
	M2B	104.53 (36.1 - 167.28)	151.59 (52.59 - 241.55)	401.58 (142.9 - 625.18)	171.51 (59.62 - 272.8)
	M2C	109.02 (37.67 - 174.4)	158.97 (55.19 - 253.14)	409.65 (145.89 - 637.25)	176.8 (61.49 - 281.08)
	M3	109.97 (38 - 175.9)	162.71 (56.51 - 259.01)	416.01 (148.26 - 646.75)	180.01 (62.63 - 286.09)
	M4	111.66 (38.59 - 178.58)	160.12 (55.6 - 254.94)	404.84 (144.11 - 630.07)	172.05 (59.81 - 273.65)
PM10 Cardiac Hospital admissions	**BAU**	13.04 (6.52 - 19.54)	19.07 (9.54 - 28.59)	50.58 (25.33 - 75.75)	20.93 (10.47 - 31.38)
	M1	13.15 (6.58 - 19.72)	18.89 (9.45 - 28.32)	50.82 (25.45 - 76.11)	21.4 (10.71 - 32.08)
	M2A	12.99 (6.5 - 19.47)	18.48 (9.24 - 27.7)	50.77 (25.42 - 76.02)	21.33 (10.67 - 31.97)
	M2B	12.22 (6.11 - 18.32)	17.84 (8.93 - 26.75)	49.03 (24.56 - 73.43)	20.24 (10.13 - 30.35)
	M2C	12.76 (6.38 - 19.12)	18.73 (9.37 - 28.08)	50.08 (25.08 - 75)	20.88 (10.45 - 31.31)
	M3	12.87 (6.44 - 19.29)	19.18 (9.6 - 28.75)	50.91 (25.5 - 76.23)	21.27 (10.64 - 31.89)
	M4	13.07 (6.54 - 19.59)	18.87 (9.44 - 28.29)	49.46 (24.77 - 74.07)	20.31 (10.16 - 30.45)

PM10 Respiratory Hospital admissions	**BAU**	16.68 (12.98 - 18.53)	24.4 (18.98 - 27.1)	64.64 (50.33 - 71.79)	26.78 (20.84 - 29.75)
	M1	16.83 (13.09 - 18.7)	24.17 (18.81 - 26.85)	64.95 (50.57 - 72.13)	27.38 (21.3 - 30.41)
	M2A	16.62 (12.93 - 18.46)	23.64 (18.39 - 26.26)	64.88 (50.52 - 72.05)	27.28 (21.23 - 30.31)
	M2B	15.64 (12.17 - 17.37)	22.83 (17.76 - 25.36)	62.67 (48.79 - 69.59)	25.9 (20.15 - 28.77)
	M2C	16.32 (12.7 - 18.13)	23.96 (18.64 - 26.62)	64 (49.83 - 71.08)	26.72 (20.79 - 29.68)
	M3	16.47 (12.81 - 18.29)	24.54 (19.09 - 27.26)	65.06 (50.66 - 72.25)	27.21 (21.17 - 30.23)
	M4	16.72 (13.01 - 18.58)	24.14 (18.78 - 26.82)	63.21 (49.21 - 70.19)	25.98 (20.22 - 28.86)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years oldyears old)	**BAU**	42.42 (-78.9 - 727.94)	62.04 (-115.62 - 1052.47)	164.3 (-309.4 - 2626.65)	68.1 (-126.99 - 1151.13)
	M1	42.81 (-79.62 - 734.39)	61.46 (-114.54 - 1043)	165.07 (-310.88 - 2637.87)	69.62 (-129.85 - 1175.84)
	M2A	42.27 (-78.61 - 725.32)	60.12 (-112.02 - 1021)	164.89 (-310.54 - 2635.25)	69.38 (-129.39 - 1171.88)
	M2B	39.77 (-73.95 - 683.56)	58.05 (-108.13 - 987.01)	159.28 (-299.79 - 2553.77)	65.86 (-122.78 - 1114.69)
	M2C	41.51 (-77.2 - 712.67)	60.94 (-113.55 - 1034.38)	162.67 (-306.28 - 2603.05)	67.94 (-126.68 - 1148.49)
	M3	41.88 (-77.88 - 718.81)	62.4 (-116.3 - 1058.34)	165.35 (-311.41 - 2641.84)	69.2 (-129.05 - 1168.99)
	M4	42.53 (-79.1 - 729.75)	61.39 (-114.39 - 1041.73)	160.65 (-302.41 - 2573.73)	66.07 (-123.18 - 1118.17)

Health end point	Scenarios	Time horizon			
		2021-2025	**2026-2030**	**2031-2035**	**2036-2040**
		Number of cases (min – max)			

NO2 mortality (all natural causes) >30 years old	**BAU**			3.43 (1.93 - 4.99)	0.84 (0.47 - 1.22)
	M1			3.24 (1.83 - 4.72)	0.6 (0.34 - 0.88)
	M2A			3.16 (1.78 - 4.59)	0.6 (0.34 - 0.87)
	M2B			2.99 (1.69 - 4.35)	0.47 (0.26 - 0.68)
	M2C			2.96 (1.67 - 4.31)	0.46 (0.26 - 0.66)
	M3			3.19 (1.8 - 4.64)	0.58 (0.33 - 0.85)
	M4			2.75 (1.55 - 4)	0.39 (0.22 - 0.56)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU**	84.14 (4 - 123.75)	61.73 (2.93 - 90.88)	114.72 (5.46 - 168.51)	93.51 (4.44 - 137.48)
	M1	84.21 (4 - 123.86)	61.62 (2.92 - 90.71)	114.93 (5.47 - 168.82)	93.73 (4.45 - 137.8)
	M2A	81.96 (3.89 - 120.56)	59.22 (2.81 - 87.2)	114.13 (5.43 - 167.65)	92.64 (4.4 - 136.2)
	M2B	74.51 (3.54 - 109.64)	56.49 (2.68 - 83.19)	110.92 (5.28 - 162.95)	91.01 (4.32 - 133.82)
	M2C	77.3 (3.67 - 113.72)	57.9 (2.74 - 85.26)	110.29 (5.25 - 162.03)	89.33 (4.24 - 131.36)
	M3	83.99 (3.99 - 123.54)	61.72 (2.93 - 90.87)	115 (5.48 - 168.91)	92.82 (4.41 - 136.47)
	M4	83.33 (3.96 - 122.57)	60.04 (2.85 - 88.4)	110.72 (5.27 - 162.65)	88.53 (4.21 - 130.18)

Table 2: Health impact tables for the whole simulated domains of the ICARUS cities

Basel

Health end point	Scenarios	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
		Number of cases (min – max)			
PM2.5 mortality (all natural causes) >30 years old	**Basic**	482.39 (314.98 - 638.46)	450.36 (293.82 - 596.53)	313.44 (203.79 - 416.53)	421.74 (274.95 - 559)
	Not Heat	473.17 (308.88 - 626.4)	443.05 (289 - 586.94)	309.44 (201.17 - 411.26)	414.17 (269.96 - 549.07)
	Traffic10	474.23 (309.58 - 627.78)	446.14 (291.04 - 591)	310.68 (201.98 - 412.89)	415.42 (270.79 - 550.71)
	FirewoodBan			309.77 (201.39 - 411.69)	415.06 (270.55 - 550.24)
	NoHeatFirewood			303.87 (197.52 - 403.91)	414.17 (269.96 - 549.06)
	ZeroEmissionShips			313 (203.5 - 415.95)	417.79 (272.35 - 553.81)
PM10 infant mortality (0 - 1 year)	**Basic**	0.75 (0.38 - 1.29)	0.71 (0.36 - 1.22)	0.52 (0.26 - 0.9)	0.65 (0.33 - 1.12)
	Not Heat	0.74 (0.37 - 1.27)	0.7 (0.35 - 1.2)	0.51 (0.26 - 0.88)	0.64 (0.32 - 1.11)
	Traffic10	0.74 (0.37 - 1.27)	0.7 (0.35 - 1.21)	0.51 (0.26 - 0.89)	0.64 (0.33 - 1.11)
	FirewoodBan			0.51 (0.26 - 0.88)	0.64 (0.32 - 1.11)
	NoHeatFirewood			0.5 (0.25 - 0.87)	0.64 (0.32 - 1.1)
	ZeroEmissionShips			0.52 (0.26 - 0.89)	0.65 (0.33 - 1.12)
PM10 Incidence	**Basic**	496.58 (178.05 - 767.78)	469.05 (167.71 - 727.04)	348.25 (123.03 - 545.73)	434.31 (154.75 - 675.34)

of Chronic bronchitis (adults)	**Not Heat**	488.52 (175.02 - 755.87)	462.49 (165.26 - 717.3)	343.18 (121.18 - 538.03)	427.72 (152.3 - 665.48)
	Traffic10	489.3 (175.31 - 757.03)	465.27 (166.3 - 721.43)	344.25 (121.57 - 539.67)	428.81 (152.71 - 667.12)
	FirewoodBan			343.43 (121.27 - 538.42)	428.25 (152.5 - 666.27)
	NoHeatFirewood			337.94 (119.27 - 530.07)	427.4 (152.18 - 665.01)
	ZeroEmissionShips			346.93 (122.55 - 543.74)	431.44 (153.68 - 671.05)
PM10 Cardiac Hospital admissions	**Basic**	61.68 (30.9 - 92.34)	58.02 (29.06 - 86.88)	42.34 (21.2 - 63.42)	53.46 (26.77 - 80.05)
	Not Heat	60.6 (30.36 - 90.74)	57.16 (28.63 - 85.59)	41.69 (20.87 - 62.46)	52.59 (26.34 - 78.76)
	Traffic10	60.71 (30.41 - 90.9)	57.52 (28.81 - 86.13)	41.83 (20.94 - 62.66)	52.74 (26.41 - 78.98)
	FirewoodBan			41.72 (20.89 - 62.5)	52.66 (26.37 - 78.87)
	NoHeatFirewood			41.02 (20.54 - 61.46)	52.55 (26.32 - 78.7)
	ZeroEmissionShips			42.17 (21.11 - 63.17)	53.08 (26.58 - 79.49)
PM10 Respiratory Hospital admissions	**Basic**	78.81 (61.37 - 87.51)	74.14 (57.74 - 82.33)	54.12 (42.13 - 60.11)	68.32 (53.19 - 75.86)
	Not Heat	77.44 (60.3 - 85.99)	73.04 (56.87 - 81.11)	53.3 (41.49 - 59.2)	67.22 (52.34 - 74.64)
	Traffic10	77.57 (60.41 - 86.13)	73.51 (57.24 - 81.63)	53.47 (41.63 - 59.39)	67.4 (52.48 - 74.85)
	FirewoodBan			53.34 (41.52 - 59.24)	67.3 (52.4 - 74.74)
	NoHeatFirewood			52.45 (40.83 - 58.25)	67.16 (52.29 - 74.59)
	ZeroEmissionShips			53.91 (41.97 - 59.87)	67.84 (52.82 - 75.33)
PM10 Prevalence of	**Basic**	193.8 (-365.91 - 3053.39)	182.35 (-343.89 - 2891.46)	133.15 (-249.87 - 2170.72)	168.03 (-316.43 - 2685.95)
	Not Heat	190.44 (-359.44 - 3006.03)	179.63 (-338.68 - 2852.76)	131.12 (-246.01 - 2140.11)	165.33 (-311.26 - 2646.79)

Chronic bronchitis (children aged between 6 and 12 years old)	**Traffic10**	190.76 (-360.07 - 3010.65)	180.78 (-340.89 - 2869.17)	131.55 (-246.83 - 2146.6)	165.77 (-312.11 - 2653.27)
	FirewoodBan			131.22 (-246.21 - 2141.65)	165.54 (-311.67 - 2649.91)
	NoHeatFirewood			129.03 (-242.03 - 2108.44)	165.2 (-311.01 - 2644.89)
	ZeroEmissionShips			132.62 (-248.87 - 2162.8)	166.85 (-314.18 - 2668.91)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) **>30 years old**	**Basic**	415.58 (237.01 - 597.13)	266.16 (151.14 - 384.14)	203.08 (115.12 - 293.65)	76.51 (43.22 - 111.04)
	Not Heat	383.55 (218.54 - 551.63)	236.19 (134.01 - 341.18)	173.63 (98.34 - 251.28)	66.45 (37.53 - 96.47)
	Traffic10	380.29 (216.66 - 547)	233.22 (132.32 - 336.93)	178.47 (101.1 - 258.25)	68.46 (38.66 - 99.38)
	FirewoodBan			179.39 (101.62 - 259.57)	67.78 (38.28 - 98.4)
	NoHeatFirewood			166.83 (94.47 - 241.49)	68.51 (38.69 - 99.45)
	ZeroEmissionShips			181.18 (102.64 - 262.15)	71.8 (40.55 - 104.22)
NO2 Prevalence of bronchitis symptoms in asthmatic children	**Basic**	936.05 (45.3 - 1363.96)	825.27 (39.81 - 1204.41)	695.46 (33.43 - 1016.81)	575.27 (27.56 - 842.5)
	Not Heat	904.07 (43.71 - 1317.95)	790.73 (38.11 - 1154.56)	654.11 (31.4 - 956.9)	540.65 (25.87 - 792.17)
	Traffic10	901.71 (43.59 - 1314.55)	789.02 (38.02 - 1152.09)	658.68 (31.62 - 963.53)	545.04 (26.09 - 798.56)
	FirewoodBan			662.36 (31.81 - 968.86)	545.38 (26.1 - 799.05)

(between 5 and 14 years old)	**NoHeatFirewood**			649.37 (31.17 - 950.04)	543.31 (26 - 796.05)
	ZeroEmissionShips			662.66 (31.82 - 969.3)	549.89 (26.32 - 805.61)

Brno

Health end point	Scenarios	Time horizon			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU**	297.09 (193.59 - 393.97)	138.8 (89.96 - 185)	393.13 (257.02 - 519.7)	246.97 (160.66 - 328.04)
	M1opti	296.7 (193.33 - 393.45)	128.96 (83.55 - 171.93)	390.33 (255.16 - 516.04)	245.86 (159.93 - 326.58)
	M2opti	297.72 (194.01 - 394.8)	130.08 (84.29 - 173.43)	394.41 (257.87 - 521.36)	244.87 (159.28 - 325.26)
	M2zero	298.12 (194.27 - 395.32)	128.37 (83.18 - 171.16)	391.77 (256.12 - 517.92)	247.25 (160.84 - 328.4)
	M3slow	296.96 (193.5 - 393.8)	131.15 (84.98 - 174.85)	389.64 (254.7 - 515.13)	245.69 (159.82 - 326.35)
	M4econ	296.9 (193.46 - 393.72)	131.67 (85.32 - 175.53)	391.95 (256.23 - 518.15)	245.72 (159.83 - 326.38)
PM10 infant mortality (0 - 1 year)	**BAU**	0.44 (0.22 - 0.76)	0.23 (0.11 - 0.39)	0.57 (0.29 - 0.98)	0.37 (0.19 - 0.64)
	M1opti	0.44 (0.22 - 0.76)	0.21 (0.11 - 0.37)	0.56 (0.29 - 0.97)	0.36 (0.18 - 0.63)
	M2opti	0.44 (0.22 - 0.76)	0.21 (0.11 - 0.37)	0.57 (0.29 - 0.98)	0.36 (0.18 - 0.63)
	M2zero	0.44 (0.22 - 0.76)	0.21 (0.11 - 0.37)	0.56 (0.29 - 0.97)	0.37 (0.18 - 0.63)

	M3slow	0.44 (0.22 - 0.76)	0.22 (0.11 - 0.38)	0.56 (0.28 - 0.96)	0.36 (0.18 - 0.63)
	M4econ	0.44 (0.22 - 0.76)	0.22 (0.11 - 0.38)	0.56 (0.28 - 0.96)	0.36 (0.18 - 0.63)
PM10 Incidence of Chronic bronchitis (adults)	**BAU**	292.3 (103.84 - 455.74)	152.67 (53.23 - 242.18)	373.97 (134.38 - 577.09)	245.89 (86.8 - 385.6)
	M1opti	292.04 (103.74 - 455.35)	143.98 (50.14 - 228.62)	369.94 (132.85 - 571.17)	243.44 (85.91 - 381.88)
	M2opti	292.62 (103.96 - 456.22)	145.47 (50.67 - 230.95)	373.51 (134.2 - 576.4)	242.4 (85.53 - 380.29)
	M2zero	293.05 (104.12 - 456.87)	143.29 (49.89 - 227.54)	371.07 (133.28 - 572.82)	244.63 (86.34 - 383.69)
	M3slow	292.35 (103.86 - 455.81)	146.22 (50.94 - 232.12)	369.23 (132.58 - 570.11)	243.29 (85.85 - 381.64)
	M4econ	292.17 (103.79 - 455.54)	146.19 (50.93 - 232.08)	371.57 (133.47 - 573.56)	243.24 (85.84 - 381.58)
PM10 Cardiac Hospital admissions	**BAU**	36.04 (18.05 - 53.98)	18.32 (9.17 - 27.46)	46.88 (23.49 - 70.18)	30.04 (15.04 - 45.01)
	M1opti	36.01 (18.03 - 53.93)	17.25 (8.63 - 25.85)	46.34 (23.21 - 69.37)	29.73 (14.88 - 44.54)
	M2opti	36.08 (18.07 - 54.04)	17.43 (8.72 - 26.13)	46.82 (23.45 - 70.09)	29.6 (14.82 - 44.34)
	M2zero	36.14 (18.1 - 54.13)	17.16 (8.59 - 25.73)	46.49 (23.29 - 69.6)	29.88 (14.96 - 44.77)
	M3slow	36.05 (18.05 - 53.99)	17.52 (8.77 - 26.27)	46.24 (23.17 - 69.23)	29.71 (14.87 - 44.51)
	M4econ	36.02 (18.04 - 53.96)	17.52 (8.77 - 26.26)	46.56 (23.32 - 69.7)	29.7 (14.87 - 44.5)
PM10 Respiratory Hospital admissions	**BAU**	46.07 (35.87 - 51.16)	23.43 (18.24 - 26.03)	59.89 (46.64 - 66.5)	38.41 (29.9 - 42.66)
	M1opti	46.02 (35.83 - 51.11)	22.06 (17.17 - 24.51)	59.2 (46.1 - 65.74)	38.01 (29.59 - 42.21)
	M2opti	46.12 (35.91 - 51.22)	22.3 (17.35 - 24.77)	59.81 (46.58 - 66.42)	37.84 (29.45 - 42.02)
	M2zero	46.19 (35.96 - 51.3)	21.95 (17.08 - 24.39)	59.39 (46.26 - 65.95)	38.2 (29.74 - 42.43)
	M3slow	46.07 (35.87 - 51.17)	22.42 (17.44 - 24.9)	59.08 (46.01 - 65.6)	37.98 (29.57 - 42.19)

	M4econ	46.04 (35.85 - 51.14)	22.41 (17.44 - 24.9)	59.48 (46.32 - 66.05)	37.98 (29.56 - 42.18)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU**	120 (-225.71 - 1931.37)	61.07 (-113.99 - 1026.55)	155.97 (-294.75 - 2445.28)	100.06 (-187.72 - 1634.25)
	M1opti	119.89 (-225.49 - 1929.72)	57.5 (-107.28 - 969.12)	154.17 (-291.28 - 2420.21)	99.02 (-185.74 - 1618.48)
	M2opti	120.14 (-225.97 - 1933.39)	58.11 (-108.43 - 978.98)	155.76 (-294.35 - 2442.39)	98.58 (-184.9 - 1611.77)
	M2zero	120.33 (-226.33 - 1936.15)	57.22 (-106.74 - 964.54)	154.67 (-292.25 - 2427.22)	99.53 (-186.71 - 1626.16)
	M3slow	120.02 (-225.75 - 1931.68)	58.42 (-109.01 - 983.93)	153.85 (-290.66 - 2415.74)	98.96 (-185.62 - 1617.49)
	M4econ	119.94 (-225.6 - 1930.54)	58.41 (-108.99 - 983.77)	154.9 (-292.69 - 2430.36)	98.94 (-185.59 - 1617.23)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) **>30 years BAU**	**BAU**	0.1459 (0.0821 - 0.212)	0.1337 (0.0752 - 0.1941)	0 (0 - 0)	0 (0 - 0)
	M1opti	0.0254 (0.0144 - 0.0371)	0.2204 (0.1242 - 0.3205)	0 (0 - 0)	0 (0 - 0)
	M2opti	0.0008 (0.0005 - 0.0014)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)
	M2zero	0.0342 (0.0192 - 0.0496)	0.003 (0.0016 - 0.0042)	0 (0 - 0)	0 (0 - 0)
	M3slow	0.1701 (0.0958 - 0.2472)	0.2205 (0.1244 - 0.3209)	0 (0 - 0)	0 (0 - 0)
	M4econ	0.1366 (0.0769 - 0.1985)	0.1052 (0.0593 - 0.1531)	0 (0 - 0)	0 (0 - 0)
NO2 Prevalence	**BAU**	104.83 (5 - 153.85)	114.86 (5.49 - 168.48)	84.22 (4.01 - 123.74)	79.79 (3.8 - 117.26)

of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**M1opti**	103.41 (4.94 - 151.78)	113.79 (5.44 - 166.91)	81.58 (3.89 - 119.88)	78.67 (3.75 - 115.63)
	M2opti	102.08 (4.87 - 149.83)	112.19 (5.36 - 164.59)	84.67 (4.03 - 124.4)	77.83 (3.71 - 114.39)
	M2zero	102.74 (4.9 - 150.8)	113.19 (5.41 - 166.05)	83.15 (3.96 - 122.18)	78.63 (3.74 - 115.56)
	M3slow	104.39 (4.98 - 153.2)	114.58 (5.48 - 168.07)	81.96 (3.9 - 120.45)	78.95 (3.76 - 116.03)
	M4econ	104.04 (4.97 - 152.7)	113.8 (5.44 - 166.93)	84.22 (4.01 - 123.74)	78.66 (3.75 - 115.61)

Ljubljana

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU**			179.5 (116.9 - 238.17)	120.42 (78.18 - 160.26)
	M1			174.25 (113.45 - 231.26)	119.28 (77.43 - 158.74)
	M2			174.07 (113.32 - 231.02)	118.94 (77.21 - 158.29)
	M3			175.48 (114.26 - 232.89)	118.72 (77.07 - 158)
	M4			166.16 (108.13 - 220.62)	104.51 (67.79 - 139.18)
	M5			177.29 (115.45 - 235.27)	120.06 (77.94 - 159.78)
PM10 infant mortality (0 - 1	**BAU**			0.28 (0.14 - 0.48)	0.2 (0.1 - 0.35)
	M1			0.27 (0.14 - 0.47)	0.2 (0.1 - 0.35)

year)	**M2**			0.27 (0.14 - 0.47)	0.2 (0.1 - 0.35)
	M3			0.28 (0.14 - 0.47)	0.2 (0.1 - 0.35)
	M4			0.26 (0.13 - 0.45)	0.18 (0.09 - 0.31)
	M5			0.28 (0.14 - 0.49)	0.2 (0.1 - 0.35)
PM10 Incidence of Chronic bronchitis (adults)	**BAU**			186.52 (66.3 - 290.67)	136.05 (47.83 - 214.13)
	M1			181.79 (64.55 - 283.57)	134.93 (47.43 - 212.42)
	M2			181.65 (64.5 - 283.35)	134.08 (47.12 - 211.12)
	M3			182.98 (64.99 - 285.35)	134.11 (47.13 - 211.16)
	M4			172.92 (61.28 - 270.2)	118.77 (41.61 - 187.57)
	M5			188.51 (67.04 - 293.65)	135.4 (47.6 - 213.14)
PM10 Cardiac Hospital admissions	**BAU**			23.02 (11.53 - 34.47)	16.53 (8.27 - 24.76)
	M1			22.4 (11.22 - 33.55)	16.38 (8.2 - 24.55)
	M2			22.38 (11.21 - 33.52)	16.28 (8.15 - 24.39)
	M3			22.55 (11.29 - 33.78)	16.28 (8.15 - 24.39)
	M4			21.25 (10.64 - 31.83)	14.35 (7.18 - 21.51)
	M5			23.28 (11.66 - 34.86)	16.44 (8.23 - 24.64)
PM10 Respiratory Hospital	**BAU**			29.42 (22.9 - 32.67)	21.13 (16.45 - 23.47)
	M1			28.63 (22.29 - 31.8)	20.95 (16.31 - 23.27)
	M2			28.61 (22.27 - 31.77)	20.81 (16.2 - 23.12)

admissions	**M3**			28.83 (22.44 - 32.02)	20.82 (16.2 - 23.12)
	M4			27.16 (21.14 - 30.16)	18.35 (14.28 - 20.39)
	M5			29.75 (23.16 - 33.04)	21.03 (16.37 - 23.35)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU**			73.15 (-137.62 - 1175.81)	52.56 (-98.43 - 866.34)
	M1			71.19 (-133.88 - 1147.1)	52.11 (-97.58 - 859.42)
	M2			71.13 (-133.77 - 1146.22)	51.76 (-96.94 - 854.13)
	M3			71.68 (-134.82 - 1154.31)	51.78 (-96.96 - 854.3)
	M4			67.54 (-126.9 - 1093.05)	45.65 (-85.37 - 758.91)
	M5			73.97 (-139.19 - 1187.88)	52.29 (-97.94 - 862.3)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) **>30 years old**	**BAU**			212.77 (121.47 - 305.42)	370.03 (213.32 - 525.82)
	M1			213.96 (122.16 - 307.11)	364.11 (209.83 - 517.61)
	M2			209.94 (119.83 - 301.41)	352.59 (203.04 - 501.6)
	M3			212.71 (121.43 - 305.33)	365.38 (210.58 - 519.38)
	M4			122.45 (69.52 - 176.77)	216.11 (123.4 - 310.15)

	M5			219.65 (125.45 - 315.16)	368.29 (212.29 - 523.41)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU**			124.39 (6 - 181.51)	166.84 (8.12 - 242.49)
	M1			124.57 (6.01 - 181.77)	165.15 (8.03 - 240.07)
	M2			123.39 (5.95 - 180.08)	161.89 (7.87 - 235.4)
	M3			123.67 (5.97 - 180.47)	165.02 (8.02 - 239.88)
	M4			96.02 (4.61 - 140.5)	119.4 (5.76 - 174.32)
	M5			125.61 (6.06 - 183.27)	166.4 (8.09 - 241.86)

Madrid

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU_V2**	1450.58 (941.89 - 1930.07)	1921.8 (1250.51 - 2551.89)	1464.41 (950.93 - 1948.35)	1321.36 (857.49 - 1759.1)
	Enef	1438.33 (933.88 - 1913.86)	1923.76 (1251.8 - 2554.48)	1467.63 (953.03 - 1952.6)	1313.78 (852.54 - 1749.06)
	Log	1439.18 (934.44 - 1914.99)	1915.04 (1246.07 - 2542.99)	1406.71 (913.22 - 1872.04)	1316.16 (854.09 - 1752.22)
	Park	1461.83 (949.24 - 1944.94)	1908.31 (1241.66 - 2534.13)	1394.73 (905.4 - 1856.2)	1323.67 (858.99 - 1762.16)
	Put	1427.62 (926.88 - 1899.69)	1925.15 (1252.71 - 2556.3)	1445.73 (938.72 - 1923.65)	1318.32 (855.5 - 1755.07)

	Zez	1441.04 (935.65 - 1917.45)	1915.24 (1246.21 - 2543.26)	1412.73 (917.15 - 1880)	1315.39 (853.59 - 1751.2)
PM10 infant mortality (0 - 1 year)	**BAU_V2**	2.13 (1.07 - 3.69)	2.77 (1.4 - 4.79)	2.17 (1.09 - 3.76)	1.96 (0.99 - 3.4)
	Enef	2.11 (1.06 - 3.66)	2.77 (1.4 - 4.79)	2.17 (1.09 - 3.76)	1.94 (0.98 - 3.37)
	Log	2.12 (1.06 - 3.67)	2.76 (1.39 - 4.77)	2.09 (1.05 - 3.63)	1.95 (0.98 - 3.39)
	Park	2.15 (1.08 - 3.72)	2.75 (1.39 - 4.75)	2.08 (1.05 - 3.6)	1.96 (0.99 - 3.4)
	Put	2.1 (1.06 - 3.64)	2.77 (1.4 - 4.79)	2.15 (1.08 - 3.72)	1.95 (0.98 - 3.39)
	Zez	2.12 (1.07 - 3.67)	2.76 (1.39 - 4.77)	2.1 (1.06 - 3.64)	1.95 (0.98 - 3.39)
PM10 Incidence of Chronic bronchitis (adults)	**BAU_V2**	1460.88 (512.18 - 2305.44)	1884.71 (665.81 - 2953.65)	1487.47 (521.75 - 2346.37)	1346.27 (471.04 - 2128.53)
	Enef	1447.45 (507.35 - 2284.73)	1884.55 (665.75 - 2953.39)	1484.64 (520.73 - 2342.02)	1333.91 (466.61 - 2109.42)
	Log	1449.66 (508.14 - 2288.15)	1876.63 (662.86 - 2941.37)	1435.07 (502.9 - 2265.66)	1340.61 (469.01 - 2119.78)
	Park	1470.42 (515.61 - 2320.13)	1871.44 (660.96 - 2933.49)	1424.74 (499.19 - 2249.72)	1347.16 (471.36 - 2129.92)
	Put	1438.86 (504.26 - 2271.5)	1886.68 (666.53 - 2956.63)	1469.78 (515.38 - 2319.14)	1341.4 (469.3 - 2121.01)
	Zez	1451.96 (508.97 - 2291.69)	1878.27 (663.46 - 2943.87)	1440.66 (504.91 - 2274.28)	1712.21 (468.96 - 2119.55)
PM10 Cardiac Hospital admissions	**BAU_V2**	173.53 (86.85 - 260.03)	226.35 (113.32 - 339.08)	176.81 (88.49 - 264.94)	159.44 (79.79 - 238.95)
	Enef	171.87 (86.02 - 257.55)	226.32 (113.31 - 339.05)	176.46 (88.32 - 264.42)	157.93 (79.04 - 236.68)
	Log	172.14 (86.16 - 257.96)	225.33 (112.81 - 337.56)	170.35 (85.26 - 255.27)	158.75 (79.45 - 237.91)
	Park	174.7 (87.44 - 261.79)	224.67 (112.48 - 336.58)	169.08 (84.62 - 253.37)	159.55 (79.85 - 239.11)
	Put	170.81 (85.49 - 255.97)	226.59 (113.44 - 339.45)	174.62 (87.4 - 261.67)	158.85 (79.5 - 238.06)
	Zez	172.43 (86.3 - 258.39)	225.53 (112.91 - 337.87)	171.04 (85.6 - 256.3)	158.73 (79.44 - 237.88)

PM10 Respiratory Hospital admissions	**BAU_V2**	221.91 (172.71 - 246.48)	289.37 (225.26 - 321.38)	226.1 (175.97 - 251.13)	203.92 (158.7 - 226.5)
	Enef	219.79 (171.06 - 244.14)	289.34 (225.24 - 321.35)	225.65 (175.62 - 250.64)	201.98 (157.19 - 224.36)
	Log	220.14 (171.33 - 244.52)	288.07 (224.24 - 319.94)	217.85 (169.55 - 241.97)	203.03 (158.01 - 225.52)
	Park	223.41 (173.88 - 248.15)	287.23 (223.59 - 319.01)	216.22 (168.28 - 240.17)	204.06 (158.81 - 226.66)
	Put	218.44 (170.01 - 242.64)	289.68 (225.5 - 321.73)	223.31 (173.8 - 248.04)	203.15 (158.1 - 225.66)
	Zez	220.5 (171.62 - 244.92)	288.33 (224.45 - 320.23)	218.73 (170.23 - 242.95)	203.01 (157.99 - 225.49)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU_V2**	584.31 (-1093.1 - 9695.96)	761.8 (-1429.57 - 12420.94)	595.33 (-1113.94 - 9868.06)	536.96 (-1003.69 - 8952.19)
	Enef	578.74 (-1082.59 - 9608.91)	761.73 (-1429.44 - 12419.88)	594.16 (-1111.72 - 9849.75)	531.87 (-994.09 - 8871.82)
	Log	579.66 (-1084.32 - 9623.27)	758.37 (-1423.07 - 12369.34)	573.62 (-1072.91 - 9528.71)	534.62 (-999.29 - 8915.39)
	Park	588.26 (-1100.57 - 9757.72)	756.18 (-1418.89 - 12336.22)	569.35 (-1064.83 - 9461.71)	537.32 (-1004.38 - 8958.03)
	Put	575.19 (-1075.87 - 9553.3)	762.63 (-1431.15 - 12433.49)	588 (-1100.07 - 9753.58)	534.95 (-999.91 - 8920.57)
	Zez	580.61 (-1086.12 - 9638.17)	759.07 (-1424.39 - 12379.83)	575.94 (-1077.28 - 9564.97)	534.56 (-999.17 - 8914.42)

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural	**BAU_V2**	3190.89 (1828.29 - 4562.99)	4240.57 (2443.4 - 6029.18)	4686.94 (2707.14 - 6647.32)	3567.21 (2048 - 5090.66)
	Enef	3124.2 (1789.45 - 4469.26)	4217.34 (2429.71 - 5996.92)	4602.52 (2657.16 - 6530.67)	3447.16 (1977.81 - 4922.57)

causes) >30 years old	**Log**	3136.4 (1796.55 - 4486.41)	4181.62 (2408.67 - 5947.31)	4550.28 (2626.25 - 6458.41)	3511.18 (2015.23 - 5012.23)
	Park	3182.18 (1823.22 - 4550.76)	4185.08 (2410.7 - 5952.11)	4531.99 (2615.44 - 6433.11)	3561.01 (2044.37 - 5081.98)
	Put	3120.91 (1787.53 - 4464.63)	4234.91 (2440.06 - 6021.33)	4623.18 (2669.38 - 6559.22)	3518.87 (2019.72 - 5023)
	Zez	3180.25 (1822.09 - 4548.04)	4245.15 (2446.1 - 6035.54)	4554.41 (2628.7 - 6464.13)	3180.25 (1822.09 - 4548.04)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU_V2**	6307.13 (306.66 - 9168.99)	7277.24 (355.57 - 10553.84)	7638.36 (373.9 - 11067.59)	6721.02 (327.47 - 9760.67)
	Enef	6245.89 (303.59 - 9081.34)	7277.25 (355.57 - 10553.85)	7559.24 (369.88 - 10955.1)	6609.6 (321.86 - 9601.51)
	Log	6256.04 (304.1 - 9095.87)	7243.25 (353.85 - 10505.43)	7505.18 (367.14 - 10878.23)	6665.94 (324.7 - 9682)
	Park	6306.84 (306.65 - 9168.58)	7223.62 (352.86 - 10477.47)	7486.69 (366.2 - 10851.93)	6714.6 (327.15 - 9751.49)
	Put	6242.34 (303.42 - 9076.26)	7266.96 (355.05 - 10539.2)	7573.15 (370.59 - 10974.89)	6673.81 (325.09 - 9693.24)
	Zez	6301.89 (306.4 - 9161.49)	7299.52 (356.7 - 10585.56)	7508.44 (367.3 - 10882.87)	6716.86 (327.26 - 9754.72)

Milan

Health end point	Scenarios	Time horizon			
		2021-2025	**2026-2030**	**2031-2035**	**2036-2040**
Number of cases (min – max)					
PM2.5 mortality (all natural causes) >30 years old	**BAU_V2**	498.37 (322.32 - 664.87)	903.95 (586.12 - 1203.63)	1384.14 (900.1 - 1838.3)	1517.28 (987.48 - 2013.65)
	AREA B	491.37 (317.92 - 656.02)	854.78 (554.22 - 1138.87)	1340.02 (871.35 - 1780.52)	1486.65 (967.54 - 1973.71)
	ELECTRIC BUS	496.6 (321.31 - 662.97)	895.01 (580.45 - 1192.21)	1370.6 (891.4 - 1820.84)	1508.09 (981.63 - 2001.94)

	BUILDINGS	496.27 (321.1 - 662.54)	892.88 (579.06 - 1189.39)	1370.59 (891.4 - 1820.83)	1513.13 (984.94 - 2008.56)
	ENERGY	488.83 (316.27 - 652.64)	903.04 (585.69 - 1202.86)	1375.44 (894.58 - 1827.22)	1518.8 (988.66 - 2016.03)
	TREES	485.64 (314.2 - 648.38)	898.77 (582.9 - 1197.2)	1382.62 (899.28 - 1836.68)	1525.04 (992.76 - 2024.24)
PM10 infant mortality (0 - 1 year)	**BAU_V2**	1.19 (0.6 - 2.07)	1.67 (0.84 - 2.9)	2.29 (1.16 - 3.95)	2.5 (1.26 - 4.3)
	AREA B	1.18 (0.59 - 2.05)	1.6 (0.81 - 2.78)	2.22 (1.12 - 3.83)	2.44 (1.23 - 4.21)
	ELECTRIC BUS	1.19 (0.6 - 2.07)	1.66 (0.84 - 2.88)	2.27 (1.15 - 3.92)	2.48 (1.25 - 4.28)
	BUILDINGS	1.19 (0.6 - 2.07)	1.66 (0.84 - 2.88)	2.27 (1.15 - 3.92)	2.49 (1.26 - 4.29)
	ENERGY	1.18 (0.59 - 2.06)	1.67 (0.84 - 2.9)	2.28 (1.15 - 3.93)	2.5 (1.26 - 4.31)
	TREES	1.18 (0.59 - 2.05)	1.67 (0.84 - 2.89)	2.29 (1.15 - 3.95)	2.51 (1.27 - 4.32)
PM10 Incidence of Chronic bronchitis (adults)	**BAU_V2**	832.53 (290.09 - 1321.31)	1159.11 (407 - 1826.61)	1569.2 (556.47 - 2450.63)	1705.72 (606.91 - 2655.74)
	AREA B	824.34 (287.18 - 1308.54)	1112.51 (390.21 - 1754.97)	1522.26 (539.21 - 2379.79)	1671.68 (594.3 - 2604.71)
	ELECTRIC BUS	831.59 (289.76 - 1319.84)	1151.93 (404.42 - 1815.59)	1557.07 (552.01 - 2432.34)	1697.56 (603.88 - 2643.52)
	BUILDINGS	831.1 (289.58 - 1319.07)	1150.3 (403.83 - 1813.08)	1557.54 (552.18 - 2433.05)	1703.16 (605.96 - 2651.9)
	ENERGY	825.98 (287.76 - 1311.09)	1158.71 (406.86 - 1826.01)	1561.66 (553.69 - 2439.26)	1707.81 (607.68 - 2658.87)
	TREES	822.2 (286.42 - 1305.2)	1154.67 (405.4 - 1819.8)	1568.09 (556.06 - 2448.94)	1712.21 (609.31 - 2665.44)
PM10 Cardiac Hospital admissions	**BAU_V2**	96.85 (48.46 - 145.16)	136.35 (68.24 - 204.3)	187.24 (93.76 - 280.46)	204.52 (102.42 - 306.3)
	AREA B	95.87 (47.97 - 143.69)	130.66 (65.39 - 195.79)	181.34 (90.8 - 271.63)	200.2 (100.25 - 299.83)
	ELECTRIC BUS	96.73 (48.4 - 144.99)	135.47 (67.8 - 202.99)	185.72 (92.99 - 278.18)	203.48 (101.9 - 304.75)
	BUILDINGS	96.67 (48.37 - 144.9)	135.27 (67.7 - 202.69)	185.78 (93.02 - 278.27)	204.2 (102.26 - 305.81)

	ENERGY	96.06 (48.07 - 143.99)	136.3 (68.22 - 204.23)	186.29 (93.28 - 279.04)	204.79 (102.56 - 306.7)
	TREES	95.61 (47.84 - 143.31)	135.8 (67.97 - 203.49)	187.1 (93.69 - 280.25)	205.35 (102.84 - 307.53)
PM10 Respiratory Hospital admissions	**BAU_V2**	123.88 (96.4 - 137.61)	174.35 (135.7 - 193.65)	239.34 (186.33 - 265.81)	261.39 (203.52 - 290.28)
	AREA B	122.63 (95.42 - 136.22)	167.08 (130.04 - 185.58)	231.81 (180.46 - 257.44)	255.87 (199.22 - 284.16)
	ELECTRIC BUS	123.73 (96.29 - 137.45)	173.23 (134.83 - 192.41)	237.39 (184.82 - 263.64)	260.07 (202.49 - 288.81)
	BUILDINGS	123.66 (96.23 - 137.36)	172.97 (134.63 - 192.13)	237.47 (184.87 - 263.73)	260.98 (203.19 - 289.82)
	ENERGY	122.88 (95.62 - 136.5)	174.29 (135.65 - 193.59)	238.13 (185.39 - 264.46)	261.73 (203.78 - 290.66)
	TREES	122.3 (95.17 - 135.86)	173.66 (135.16 - 192.89)	239.16 (186.19 - 265.61)	262.45 (204.34 - 291.45)
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)	**BAU_V2**	294.51 (-549.59 - 4957.36)	414.43 (-775.79 - 6852.54)	568.78 (-1069.04 - 9192.38)	621.13 (-1169.04 - 9961.33)
	AREA B	291.54 (-543.99 - 4909.48)	397.16 (-743.13 - 6583.86)	550.89 (-1034.93 - 8926.79)	608.03 (-1143.99 - 9770.03)
	ELECTRIC BUS	294.17 (-548.94 - 4951.86)	411.77 (-770.75 - 6811.21)	564.15 (-1060.21 - 9123.82)	617.99 (-1163.03 - 9915.53)
	BUILDINGS	293.99 (-548.6 - 4948.97)	411.16 (-769.6 - 6801.77)	564.33 (-1060.55 - 9126.48)	620.15 (-1167.15 - 9946.94)
	ENERGY	292.13 (-545.11 - 4919.05)	414.28 (-775.51 - 6850.26)	565.9 (-1063.55 - 9149.75)	621.94 (-1170.58 - 9973.07)
	TREES	290.76 (-542.53 - 4896.95)	412.78 (-772.67 - 6826.99)	568.36 (-1068.22 - 9186.07)	623.63 (-1173.82 - 9997.73)

Health end point	**Scenarios**	**Time horizon**			
		2021-2025	**2026-2030**	**2031-2035**	**2036-2040**
Number of cases (min – max)					

NO2 mortality (all natural causes) >30 years old	**BAU_V2**	2369.4 (1357.16 - 3389.37)	1922.14 (1097.56 - 2758.41)	2523.6 (1447.05 - 3605.95)	2562.59 (1469.81 - 3660.62)
	AREA B	2263.51 (1295.55 - 3240.36)	1534.42 (873.83 - 2208.08)	1777.71 (1014.08 - 2553.76)	1866.62 (1065.45 - 2679.8)
	ELECTRIC BUS	2355.86 (1349.28 - 3370.33)	1762.05 (1005.04 - 2531.55)	2414.63 (1383.51 - 3452.96)	2474.64 (1418.49 - 3537.24)
	BUILDINGS	2368.51 (1356.64 - 3388.12)	1901.2 (1085.45 - 2728.76)	2476.06 (1419.32 - 3539.23)	2538.65 (1455.83 - 3627.05)
	ENERGY	2373.45 (1359.52 - 3395.07)	1909 (1089.96 - 2739.81)	2475.66 (1419.08 - 3538.66)	2531.7 (1451.78 - 3617.31)
	TREES	2372.27 (1358.84 - 3393.41)	1915.18 (1093.54 - 2748.56)	2530.21 (1450.91 - 3615.22)	2576.08 (1477.69 - 3679.54)
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU_V2**	4514.87 (220.02 - 6556.18)	4165.36 (202.45 - 6056.49)	4698.73 (229.3 - 6818.51)	4672.9 (227.99 - 6781.68)
	AREA B	4415.97 (215.04 - 6414.92)	3847.01 (186.53 - 5600.2)	4059.48 (197.15 - 5904.86)	4082.14 (198.28 - 5937.31)
	ELECTRIC BUS	4489.91 (218.76 - 6520.54)	4135.95 (200.98 - 6014.37)	4593.84 (224 - 6668.89)	4582.77 (223.44 - 6653.1)
	BUILDINGS	4501.92 (219.37 - 6537.68)	4142.03 (201.28 -6023.09)	4648.88 (226.78 - 6747.41)	4638.77 (226.27 - 6733)
	ENERGY	4506.09 (219.58 - 6543.64)	4146.32 (201.5 - 6029.23)	4646.55 (226.66 - 6744.08)	4631.76 (225.92 -6722.99)
	TREES	4504.7 (219.51 - 6541.65)	4157.67 (202.07 - 6045.48)	4696.3 (229.18 - 6815.04)	4667.36 (227.71 -6773.76)

Stuttgart

Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
		Number of cases (min – max)			
PM2.5 mortality	**BAU_V2**	871.9 (568.07 - 1156.37)	951.3 (620.37 - 1260.58)	454.54 (294.74 - 605.56)	734.53 (477.81 - 975.63)

(all natural causes) >30 years old	**FVH**	943.95 (615.52 - 1250.93)	449.53 (291.48 - 598.92)	740.3 (481.6 - 983.24)	
	Sc1	949.07 (618.9 - 1257.65)	455.69 (295.5 - 607.1)	739.2 (480.88 - 981.78)	
	Scel			737.25 (479.6 - 979.21)	
	Scuv			729.42 (474.46 - 968.89)	
PM10 infant mortality (0 - 1 year)	**BAU_V2**	0.13 (0.06 - 0.23)	0.14 (0.07 - 0.25)	0.07 (0.04 - 0.13)	0.11 (0.06 - 0.19)
	FVH	0.14 (0.07 - 0.24)	0.07 (0.04 - 0.13)	0.11 (0.06 - 0.19)	
	Sc1	0.14 (0.07 - 0.25)	0.07 (0.04 - 0.13)	0.11 (0.06 - 0.19)	
	Scel			0.11 (0.06 - 0.19)	
	Scuv			0.11 (0.05 - 0.19)	
PM10 Incidence of Chronic bronchitis (adults)	**BAU_V2**	852.85 (302.79 - 1330.5)	923.55 (328.97 - 1436.49)	491.61 (171.7 - 778.56)	734.32 (259.29 - 1151.31)
	FVH	917.38 (326.68 - 1427.27)	486.87 (170.01 - 771.22)	739.32 (261.12 - 1158.92)	
	Sc1	921.67 (328.27 - 1433.68)	492.52 (172.02 - 779.97)	737.58 (260.48 - 1156.25)	
	Scel			736.67 (260.14 - 1154.87)	
	Scuv			729.11 (257.39 - 1143.38)	
PM10 Cardiac Hospital admissions	**BAU_V2**	103.86 (51.97 - 155.45)	113.03 (56.56 - 169.12)	58.51 (29.24 - 87.56)	88.72 (44.39 - 132.82)
	FVH	112.25 (56.15 - 167.92)	57.93 (28.95 - 86.69)	89.35 (44.71 - 133.77)	
	Sc1	112.8 (56.43 - 168.76)	58.62 (29.29 - 87.73)	89.12 (44.59 - 133.44)	
	Scel			89.01 (44.54 - 133.27)	
	Scuv			88.06 (44.06 - 131.84)	

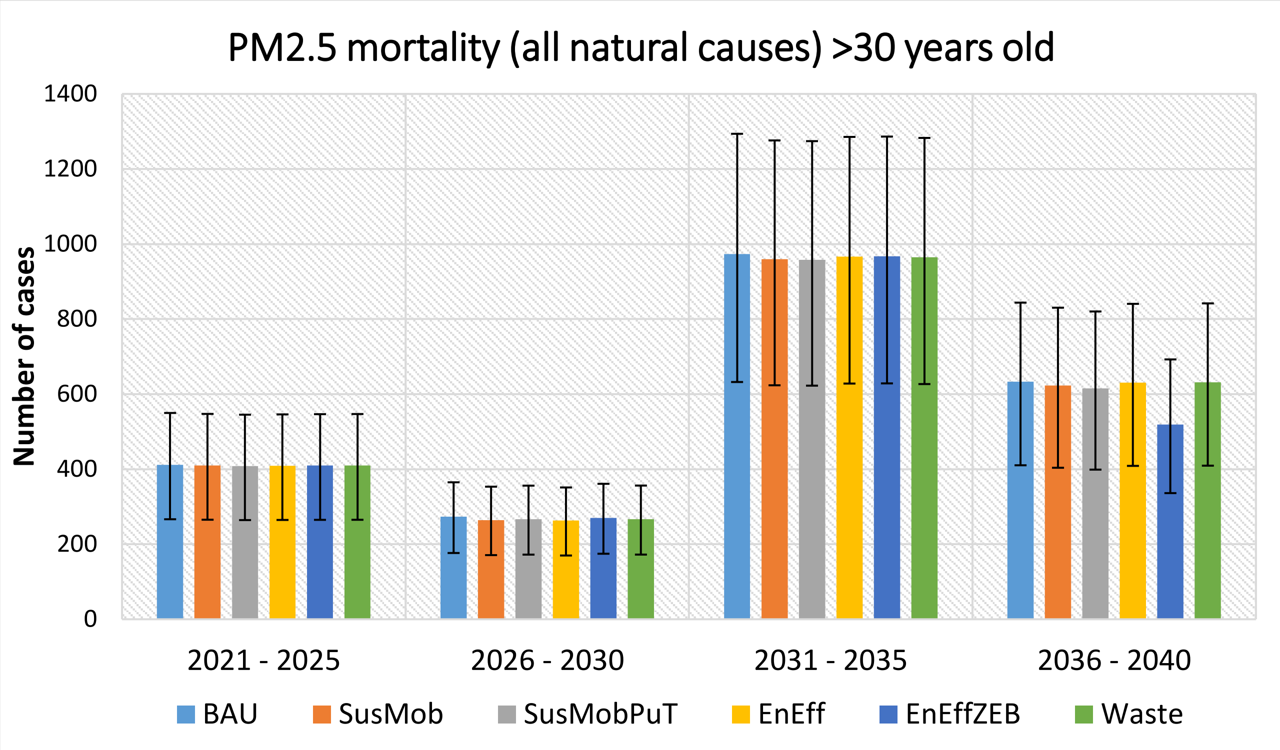
PM10 Respiratory Hospital admissions	**BAU_V2**	132.66 (103.28 - 147.33)	144.33 (112.37 - 160.28)	74.72 (58.15 - 83)	113.35 (88.24 - 125.89)
	FVH	143.3 (111.58 - 159.14)	73.98 (57.57 - 82.18)	114.16 (88.87 - 126.79)	
	Sc1	144.01 (112.13 - 159.93)	74.87 (58.26 - 83.16)	113.88 (88.65 - 126.48)	
	Scel			113.73 (88.53 - 126.31)	
	Scuv			112.51 (87.58 - 124.96)	
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old years old)	**BAU_V2**	295.62 (-555.88 - 4764.91)	321.58 (-605.53 - 5144.28)	166.58 (-311.14 - 2788.81)	252.62 (-473.96 - 4123.46)
	FVH	319.31 (-601.17 - 5111.29)	164.92 (-308.03 - 2762.52)	254.42 (-477.39 - 4150.69)	319.31 (-601.17 - 5111.29)
	Sc1	320.89 (-604.2 - 5134.2)	166.89 (-311.74 - 2793.88)	253.79 (-476.19 - 4141.15)	320.89 (-604.2 - 5134.2)
	Scel			253.46 (-475.56 - 4136.18)	
	Scuv			250.74 (-470.39 - 4095.07)	

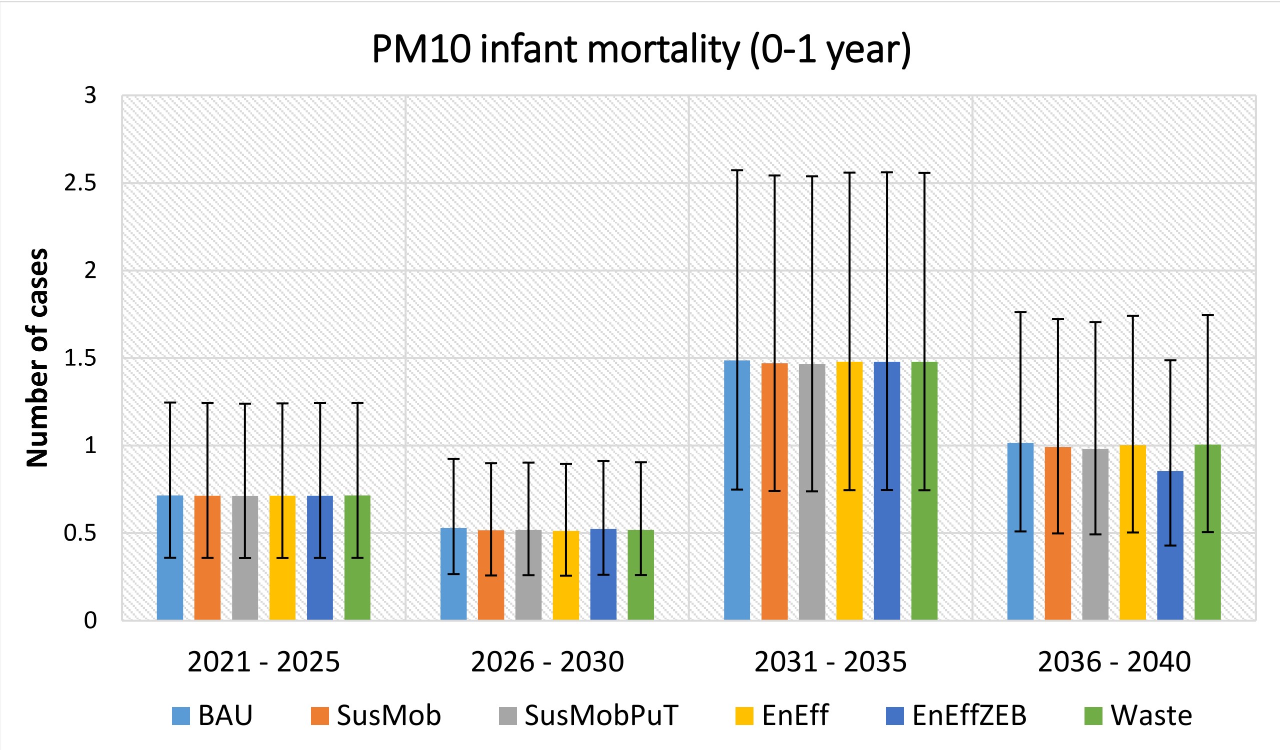
Health end point	**Scenarios**	**Time horizon**			
		2021 - 2025	**2026 - 2030**	**2031 - 2035**	**2036 - 2040**
Number of cases (min – max)					
NO2 mortality (all natural causes) >30	**BAU_V2**	98.72 (55.71 - 143.41)	54.06 (30.49 - 78.58)	143.67 (81.13 - 208.58)	4.13 (2.33 - 6)
	FVH	49.42 (27.87 - 71.83)	115.05 (64.94 - 167.09)	3.98 (2.24 - 5.79)	
	Sc1	52.05 (29.36 - 75.65)	141.95 (80.15 - 206.08)	4.23 (2.39 - 6.16)	

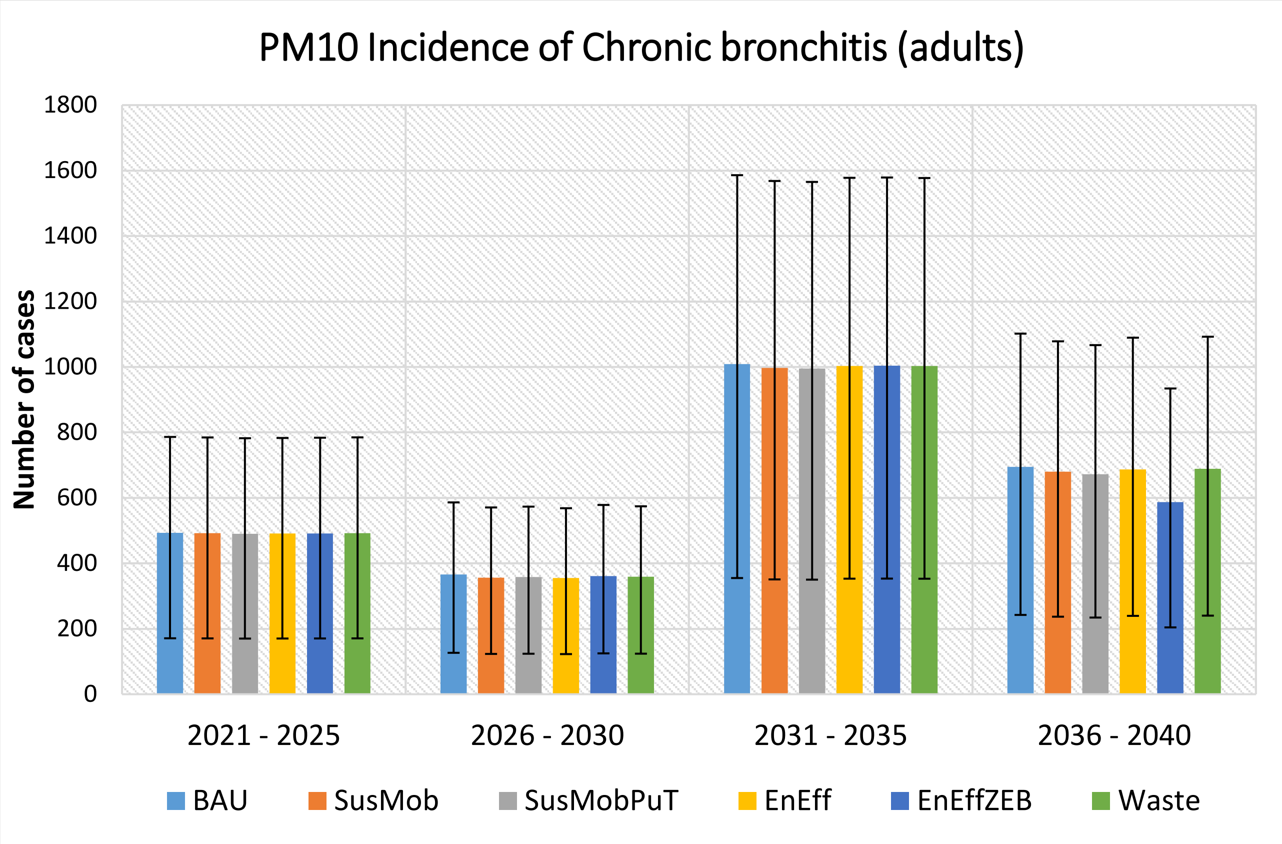
years old	**Scel**			3.59 (2.02 - 5.23)	
	Scuv			4.16 (2.34 - 6.04)	
NO2 Prevalence of bronchitis symptoms in asthmatic children (between 5 and 14 years old)	**BAU_V2**	1292.04 (62.05 - 1889.73)	1162.98 (55.75 - 1702.56)	1218.84 (58.48 - 1783.61)	967.86 (46.27 - 1418.91)
	FVH	1176.06 (56.39 - 1721.54)	1032.42 (49.4 - 1512.85)	1035.57 (49.55 - 1517.43)	854.7 (40.79 - 1254.03)
	Sc1	1144.36 (54.84 - 1675.52)	1180.7 (56.61 - 1728.28)	961.56 (45.96 - 1409.73)	
	Scel	1158.72 (55.54 - 1696.38)	1213.65 (58.22 - 1776.08)	961.25 (45.94 - 1409.28)	
	Scuv			958.74 (45.82 - 1405.63)	

ANNEX 4: HEALTH IMPACT ASSESSMENT RESULTS (CHARTS)

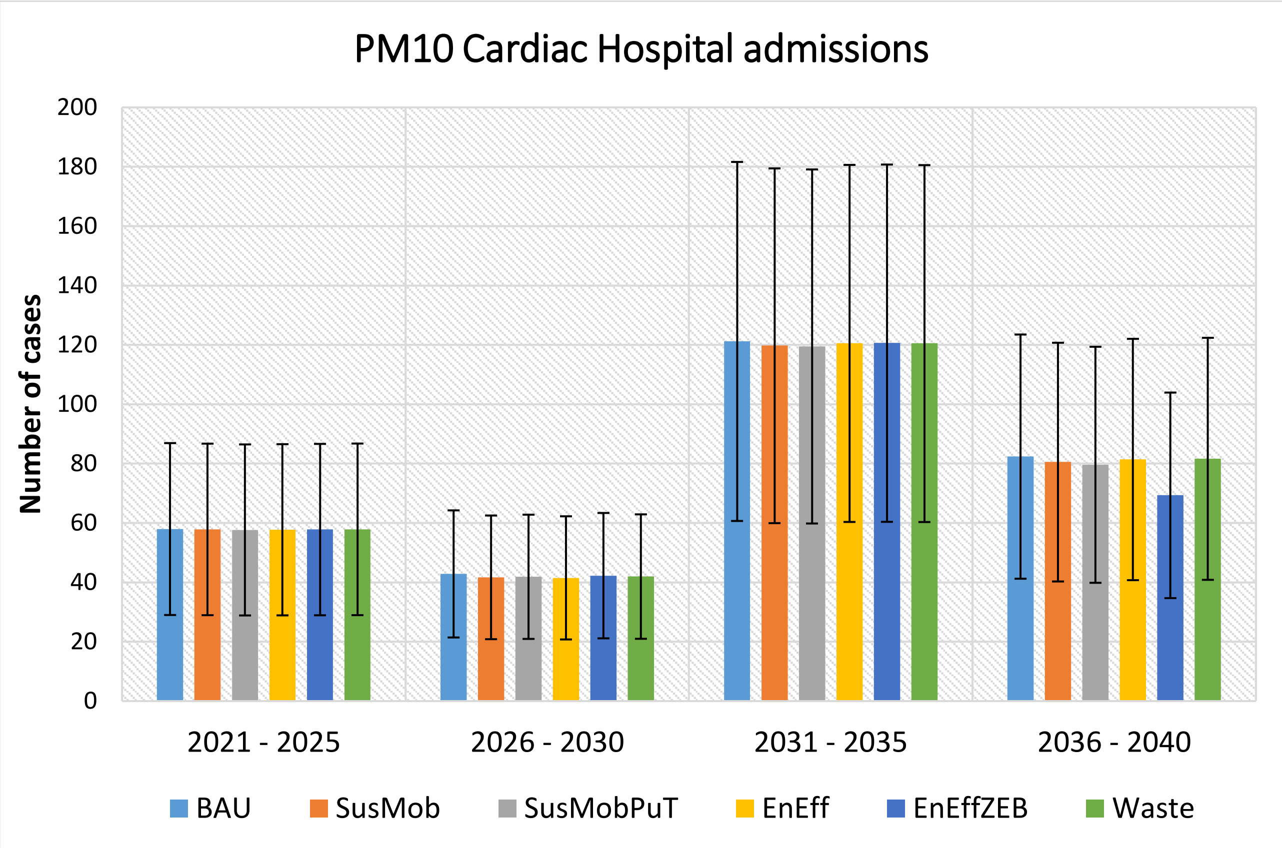
Greater Athens Area



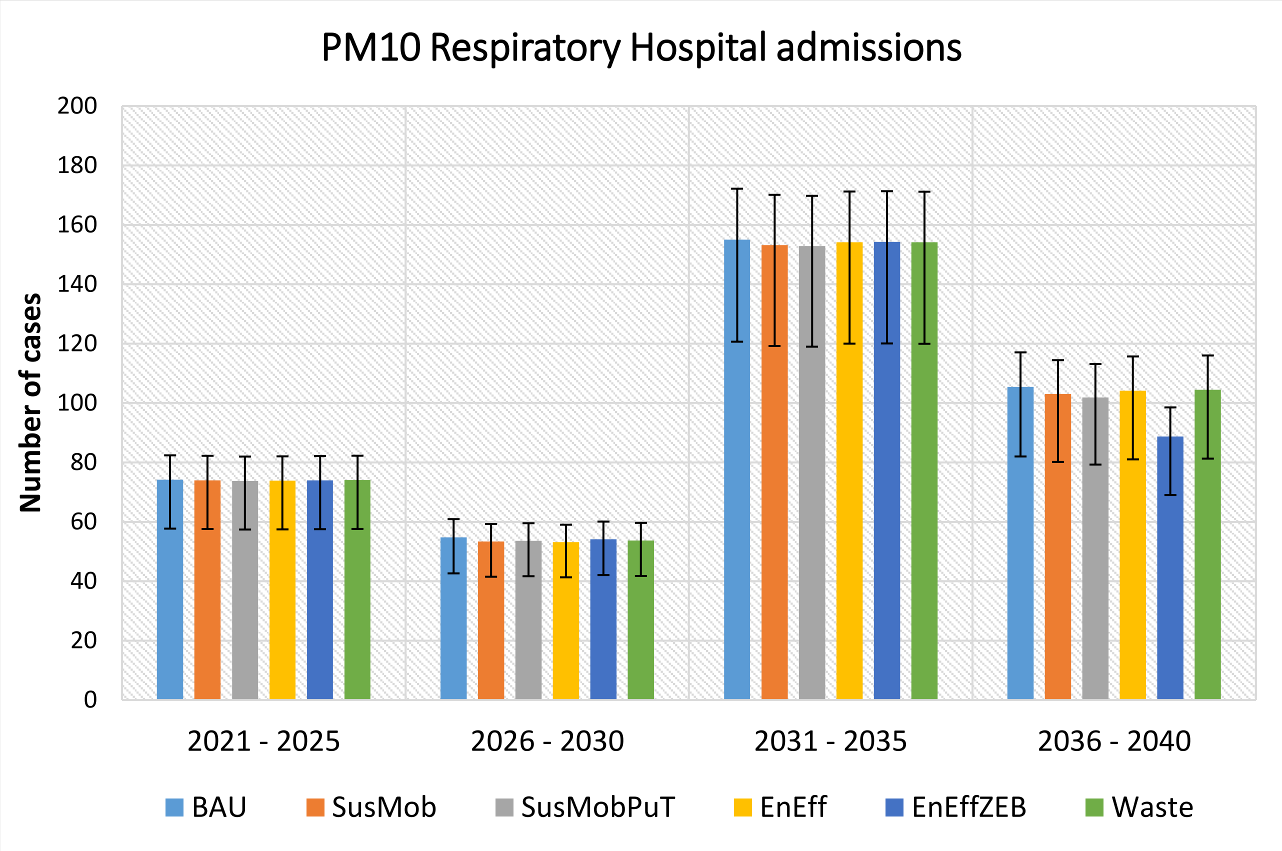




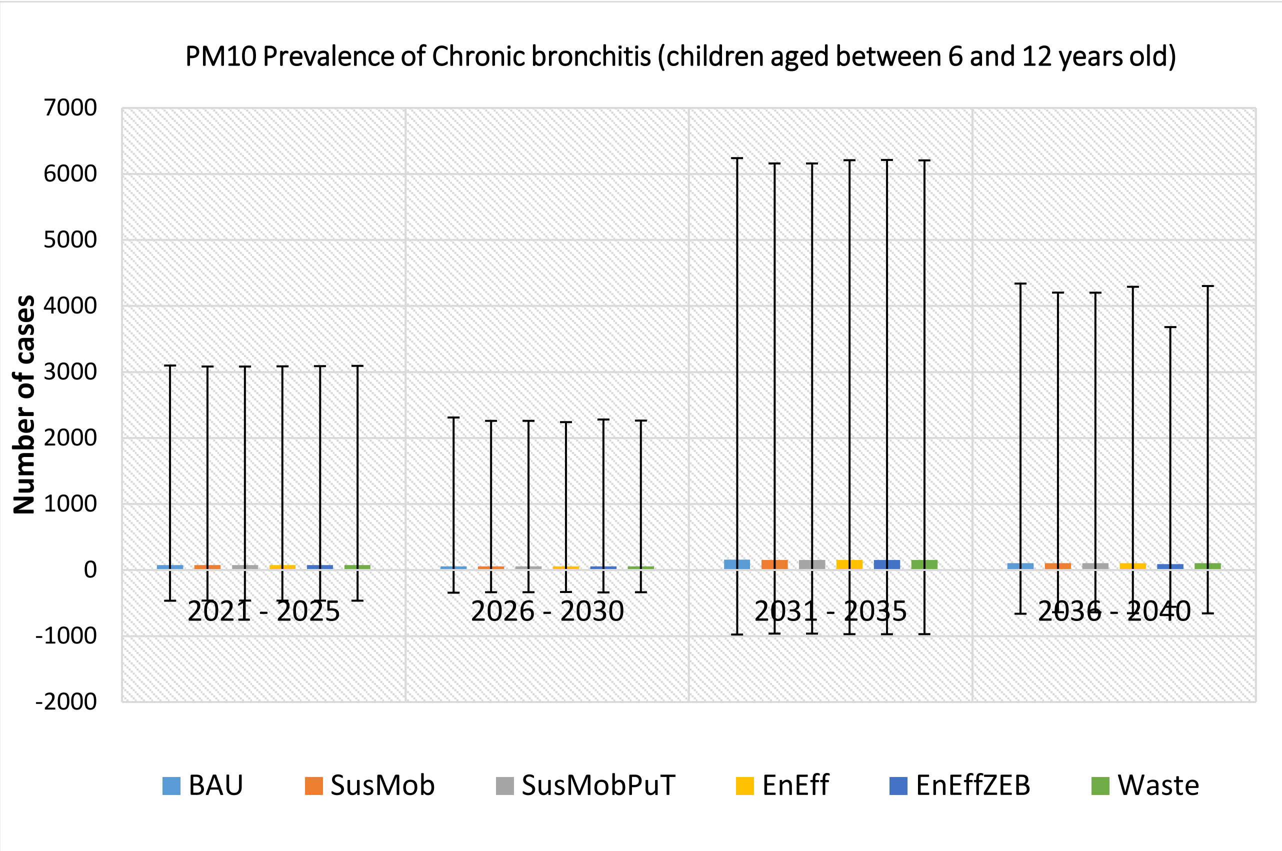
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
0
200
400
600
800
1000
1200
1400
1600
1800
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
SusMob
SusMobPuT
EnEff
EnEffZEB
Waste



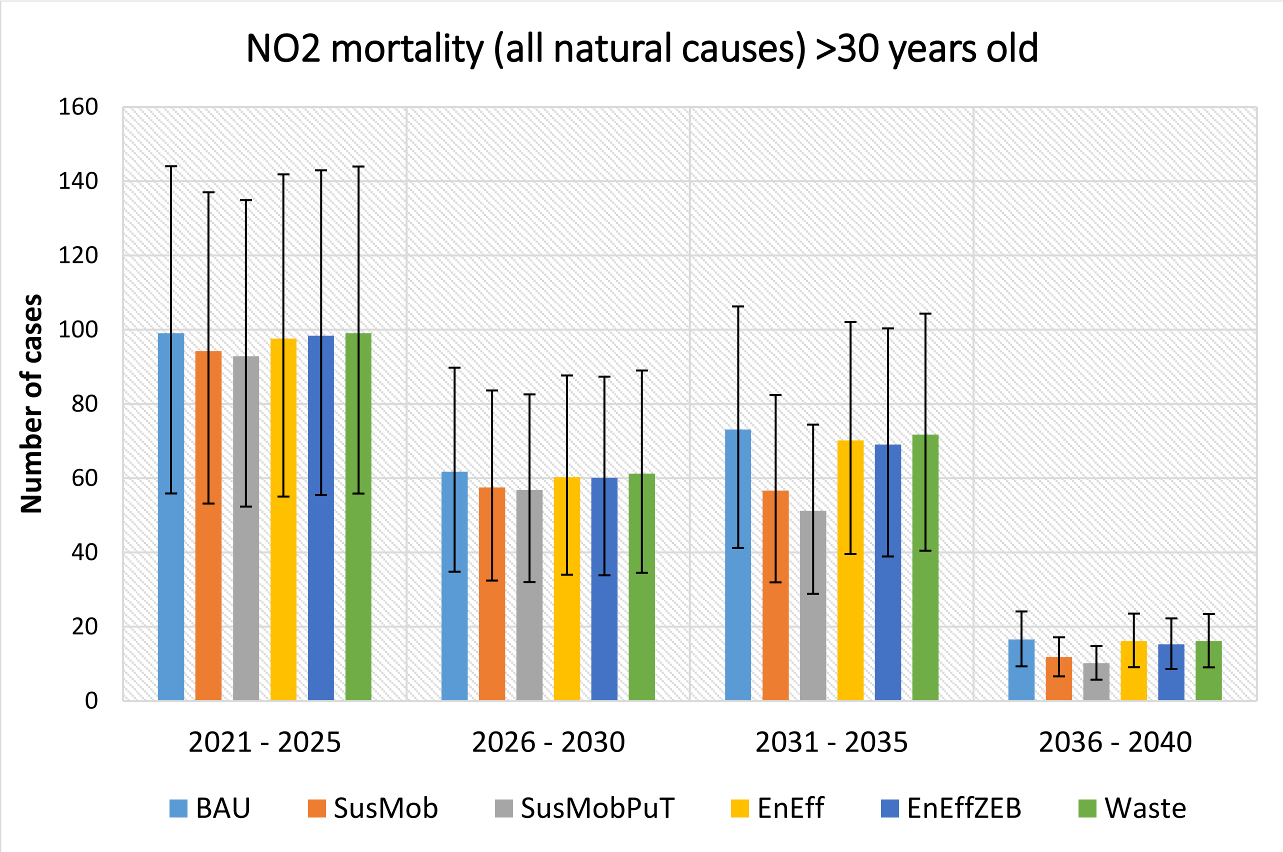
PM10 Cardiac Hospital admissions
Number of cases
0
20
40
60
80
100
120
140
160
180
200
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
SusMob
SusMobPuT
EnEff
EnEffZEB
Waste



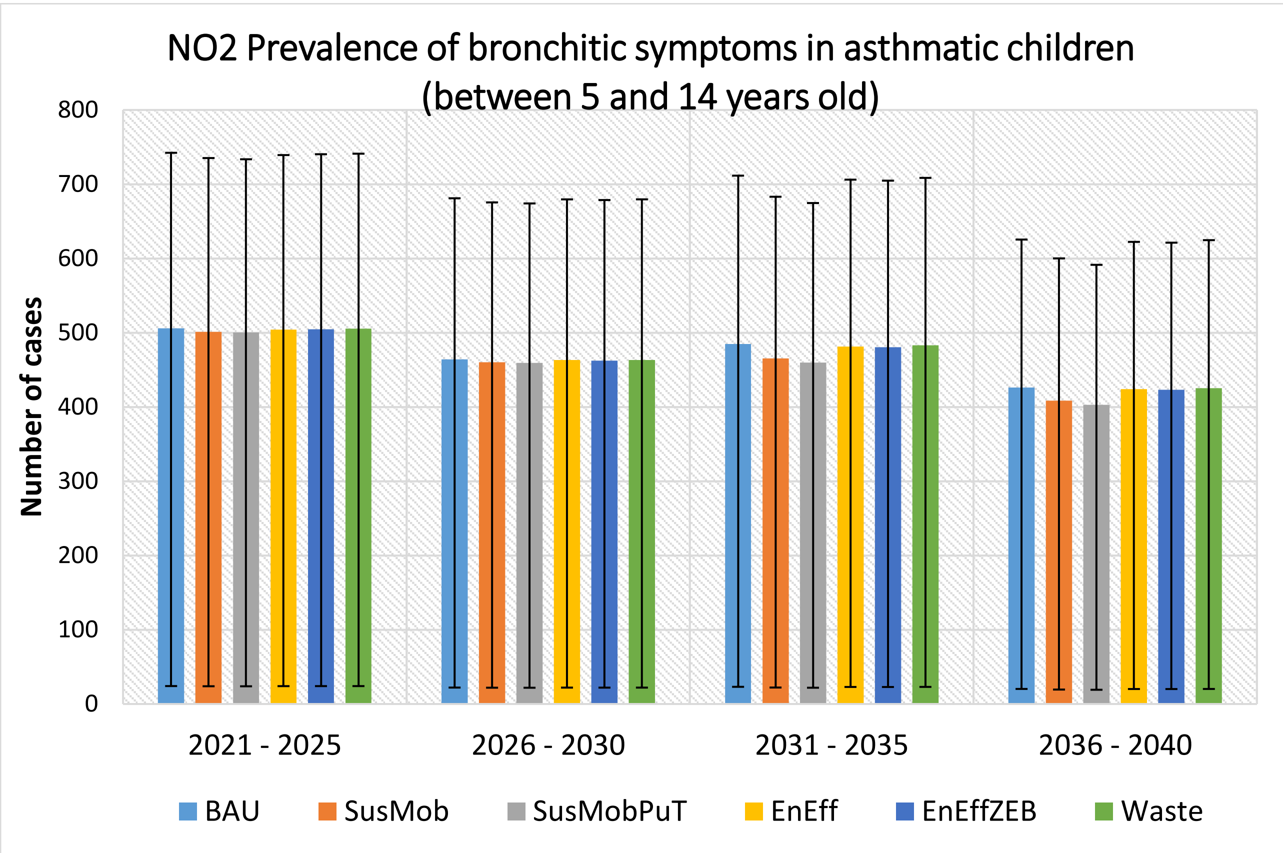
PM10 Respiratory Hospital admissions
Number of cases
200
180
160
140
120
100
80
60
40
20
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
SusMob
SusMobPuT
EnEff
EnEffZEB
Waste



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
SusMob
SusMobPuT
EnEff
EnEffZEB
Waste

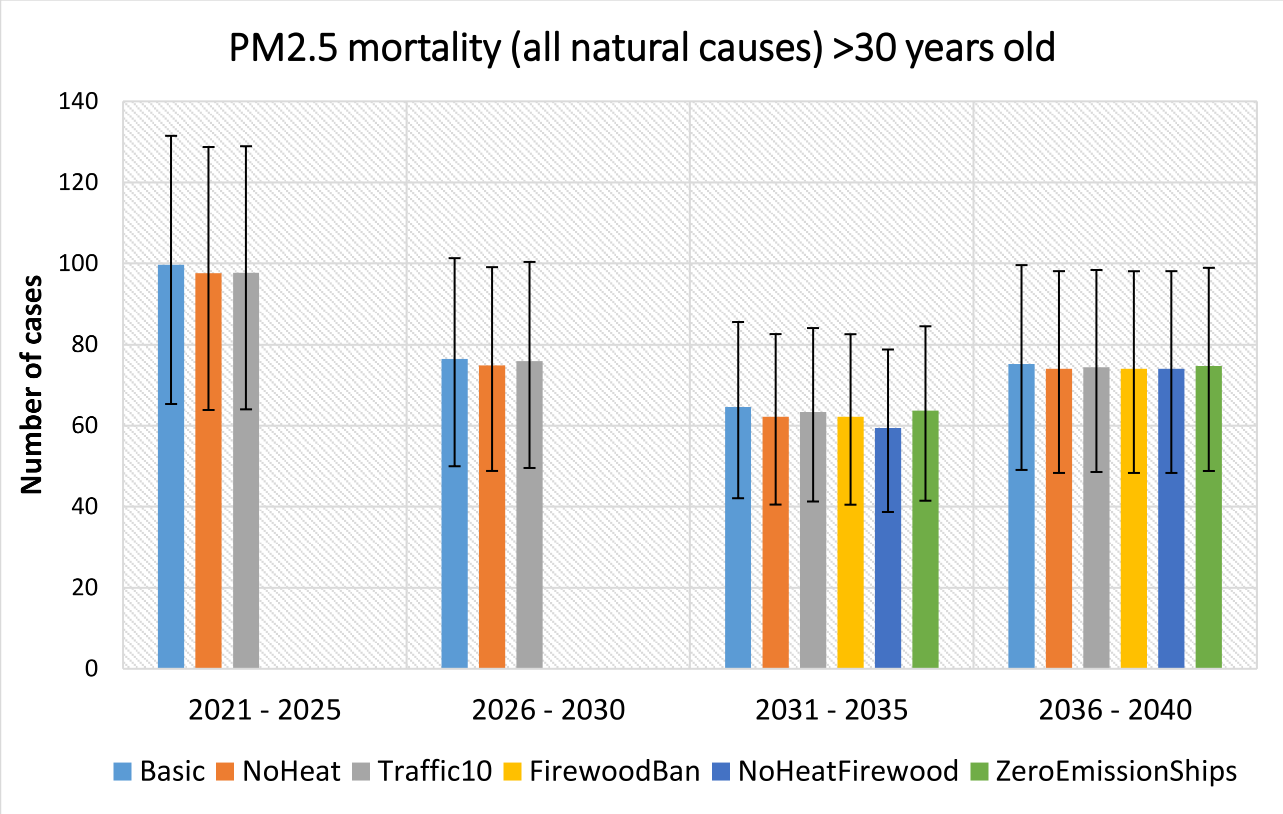


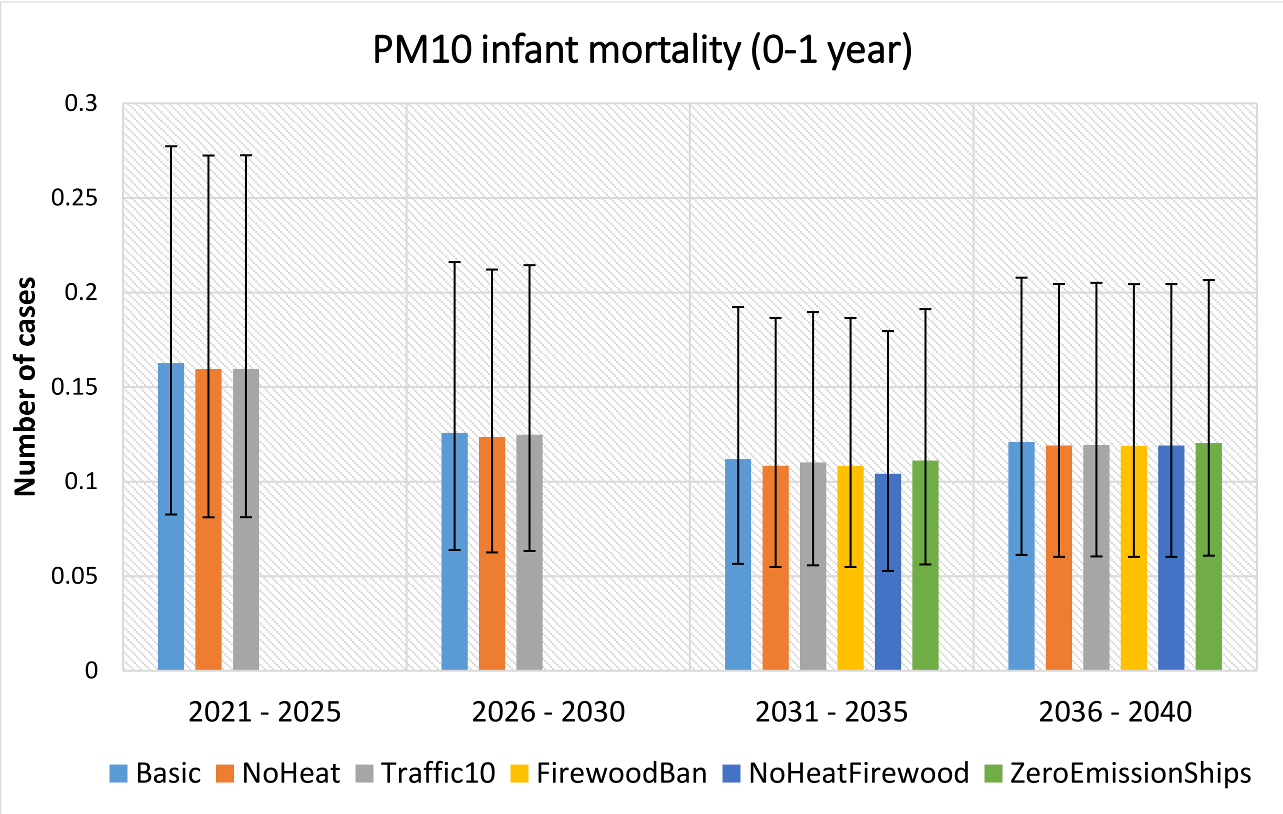
NO2 mortality (all natural causes) >30 years old
Number of cases
0
20
40
60
80
100
120
140
160
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
SusMob
SusMobPuT
EnEff
EnEffZEB
Waste

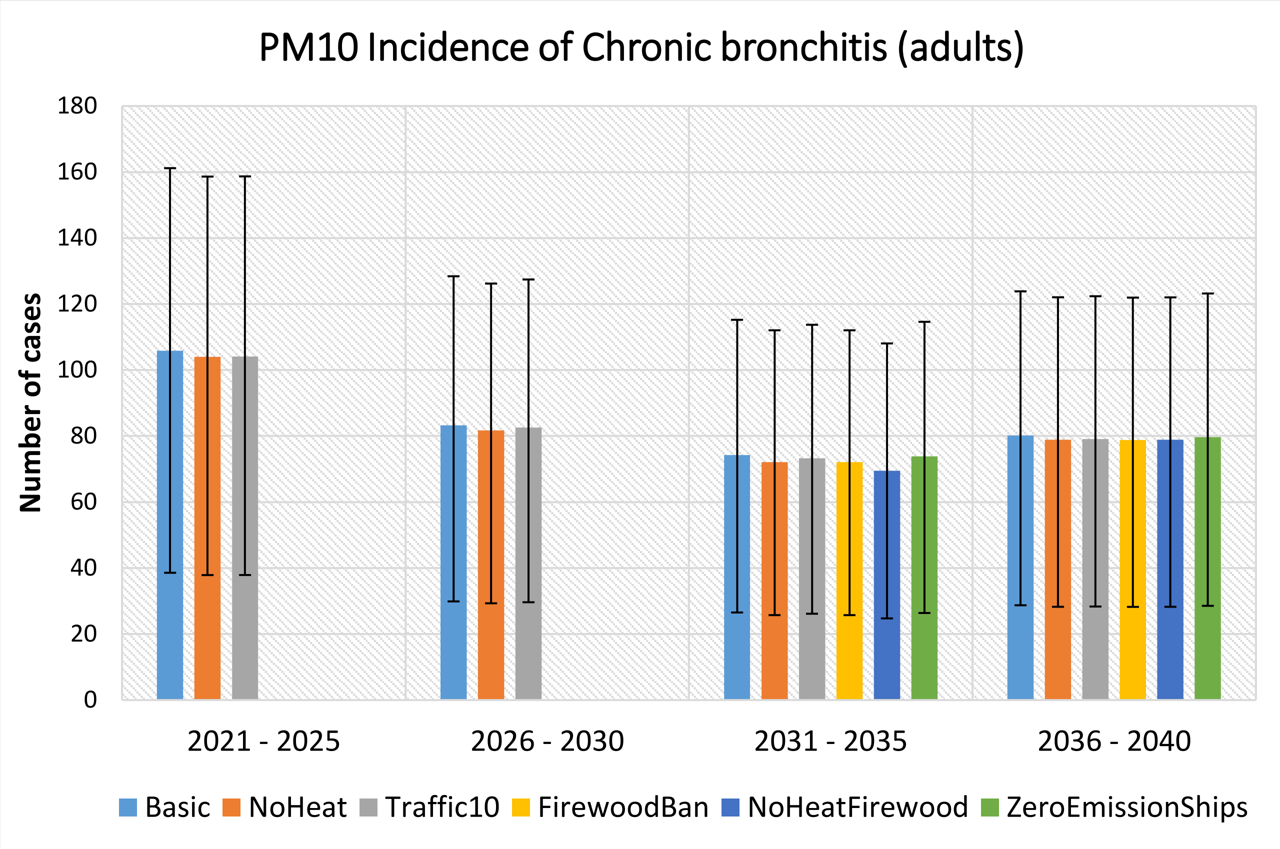


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
0
100
200
300
400
500
600
700
800
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
SusMob
SusMobPuT
EnEff
EnEffZEB
Waste

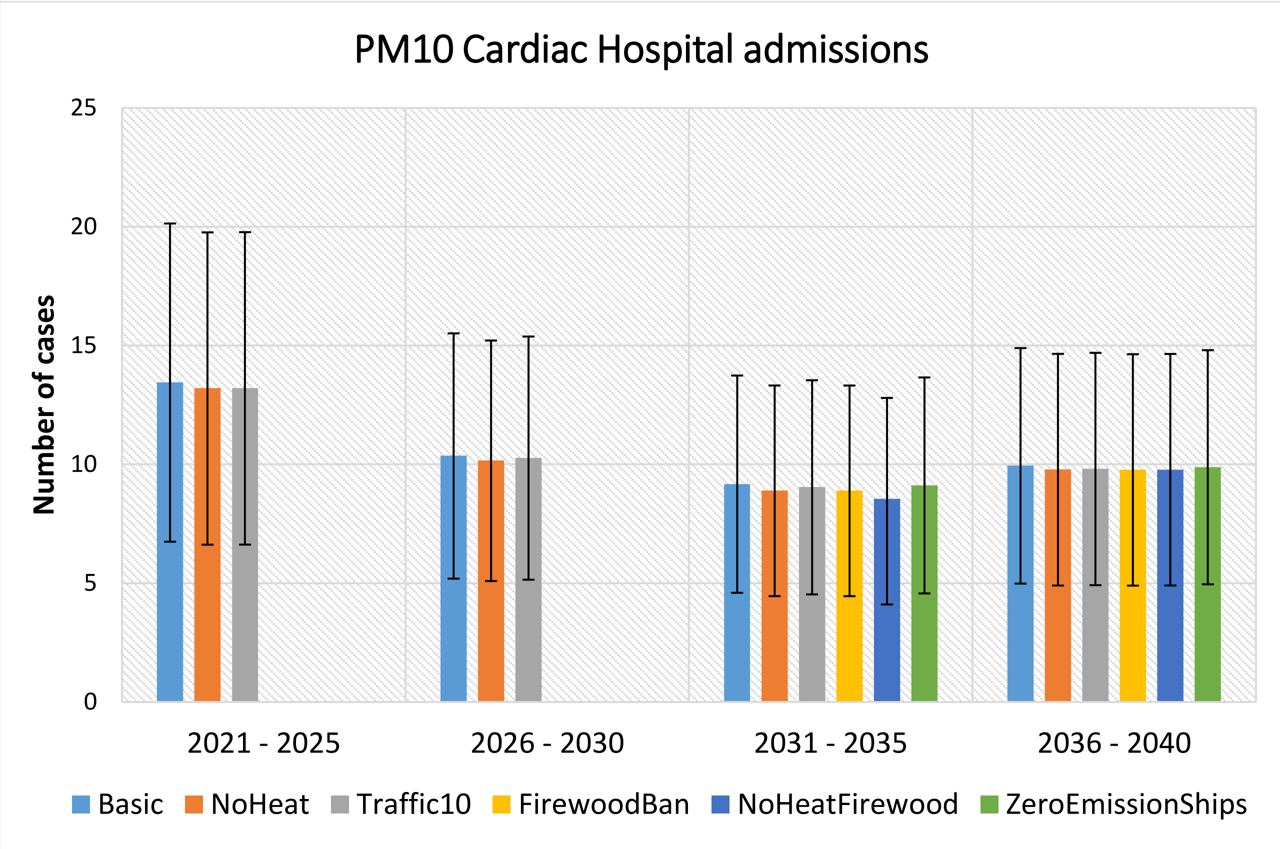
Basel


PM2.5 mortality (all natural causes) >30 years old
140
120
100
80
60
40
20
0
Number of cases
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

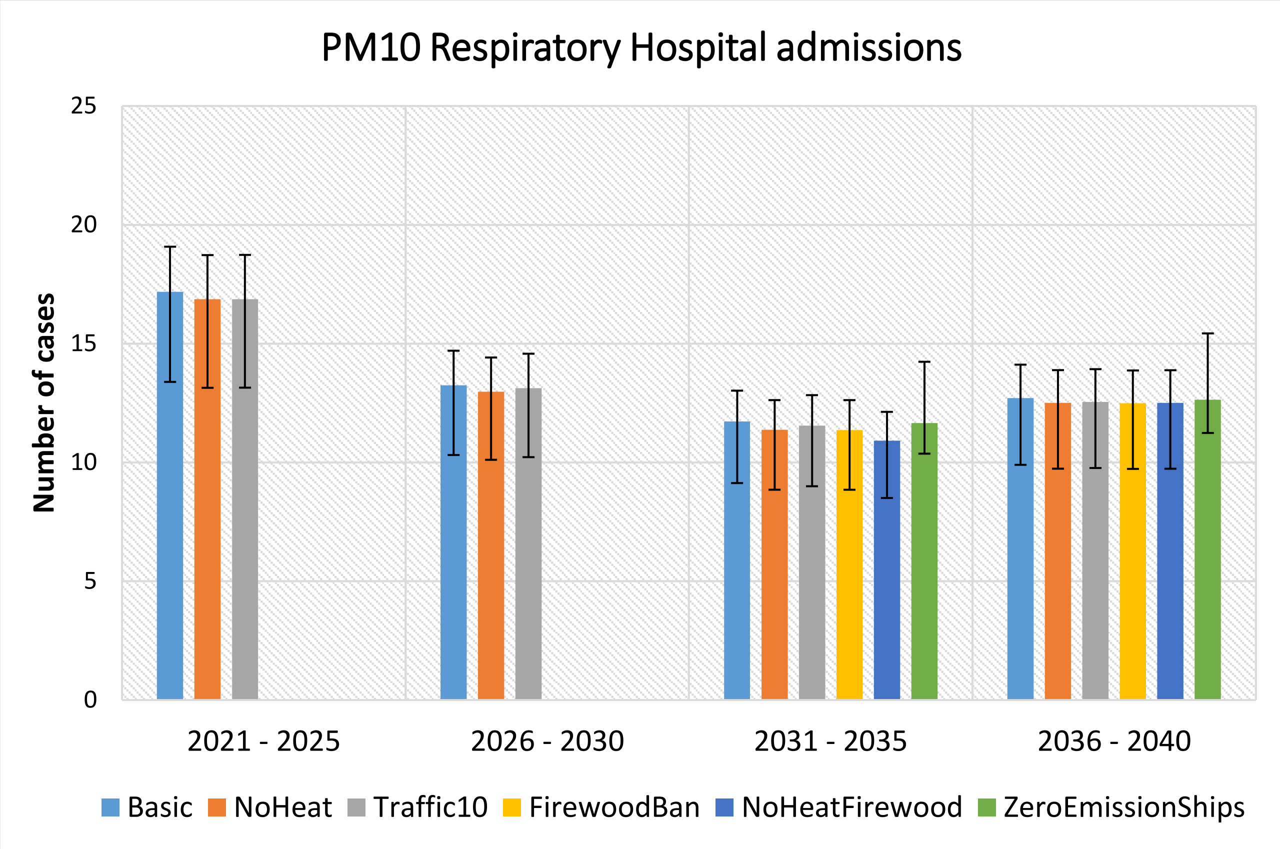

PM10 infant mortality (0-1 year)
0.3
0.25
0.2
0.15
0.1
0.05
0
Number of cases
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips



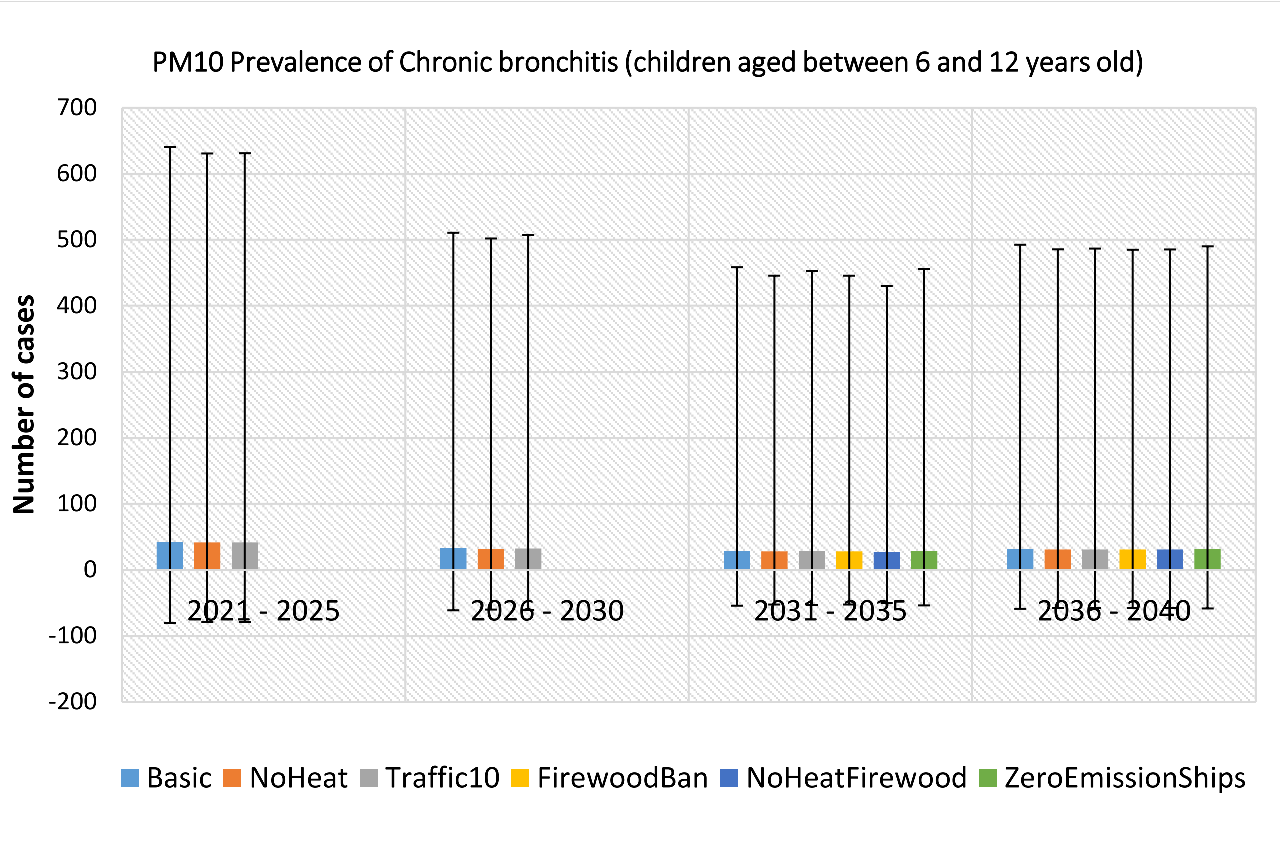
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
0
20
40
60
80
100
120
140
160
180
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips



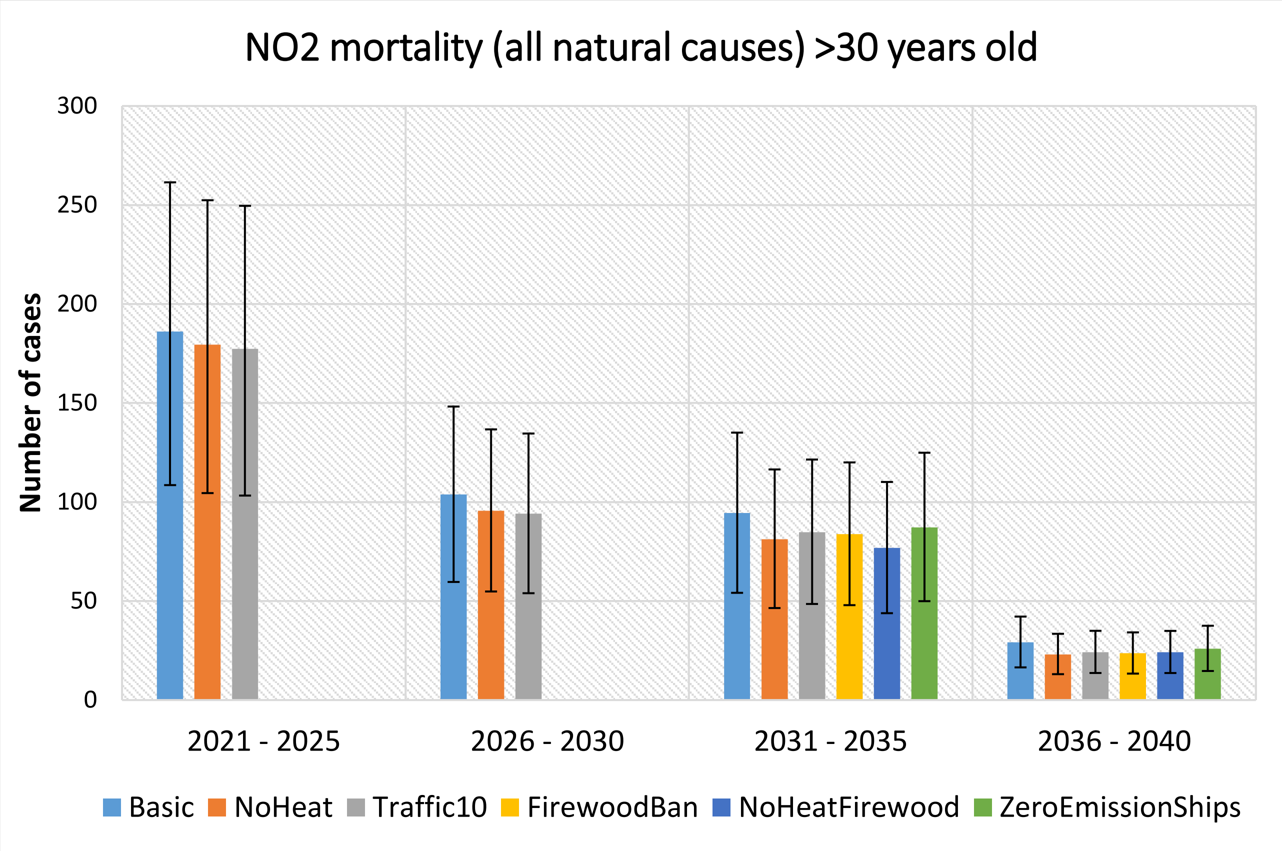
PM10 Cardiac Hospital admissions
Number of cases
0
5
10
15
20
25
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

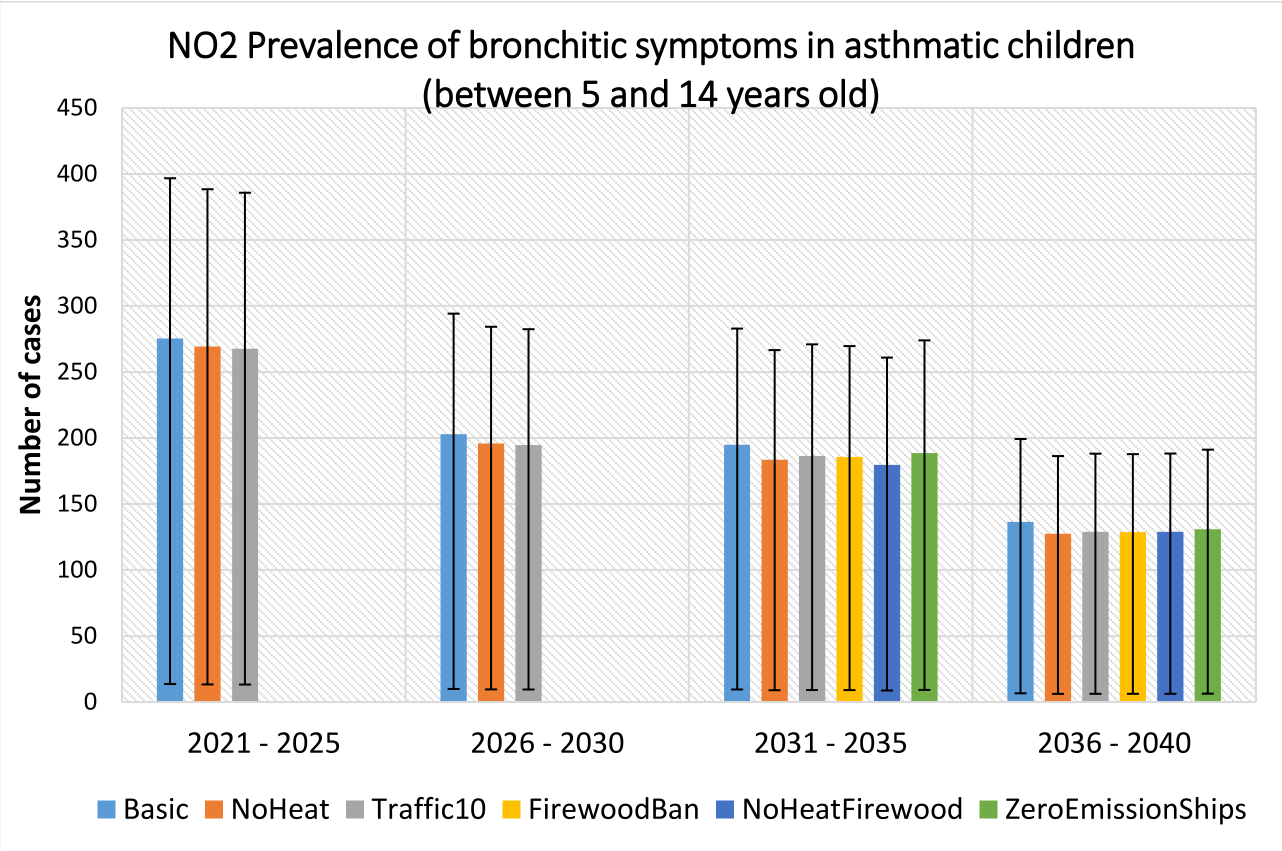


PM10 Respiratory Hospital admissions
Number of cases
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

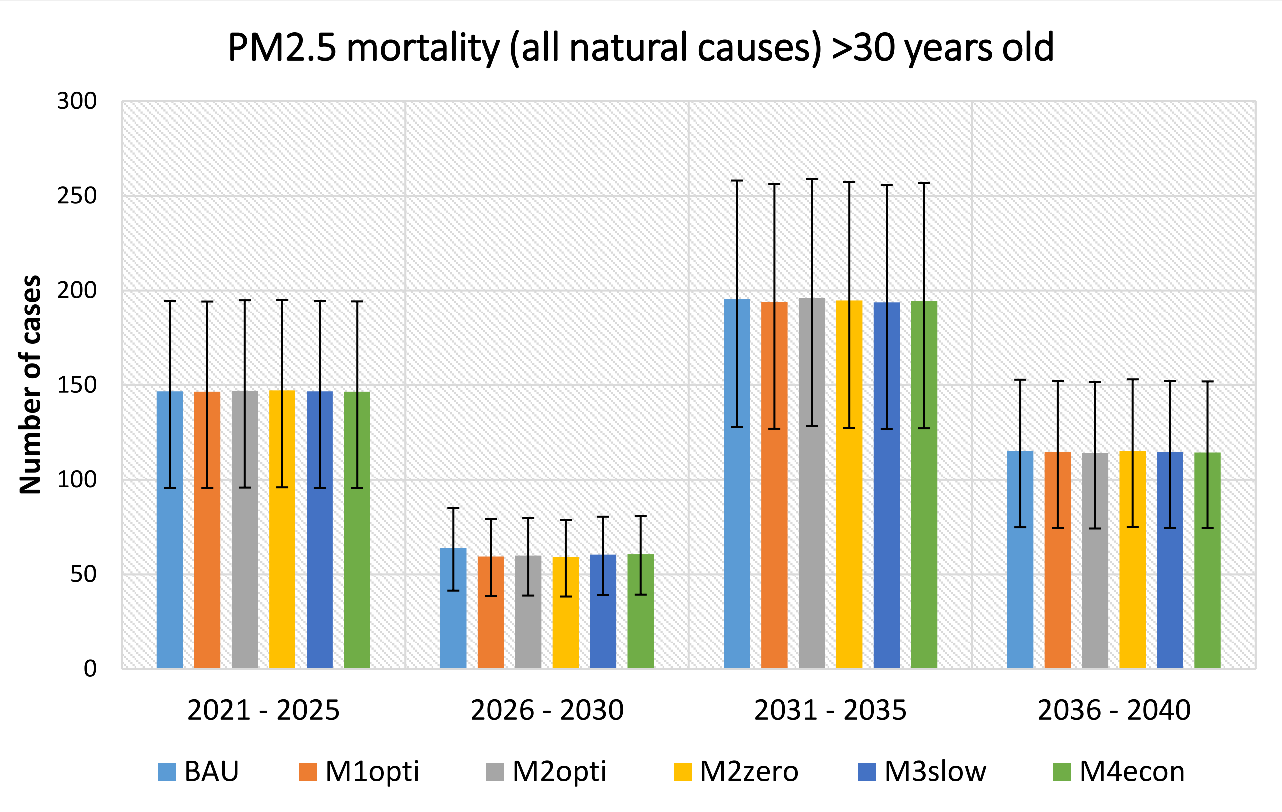


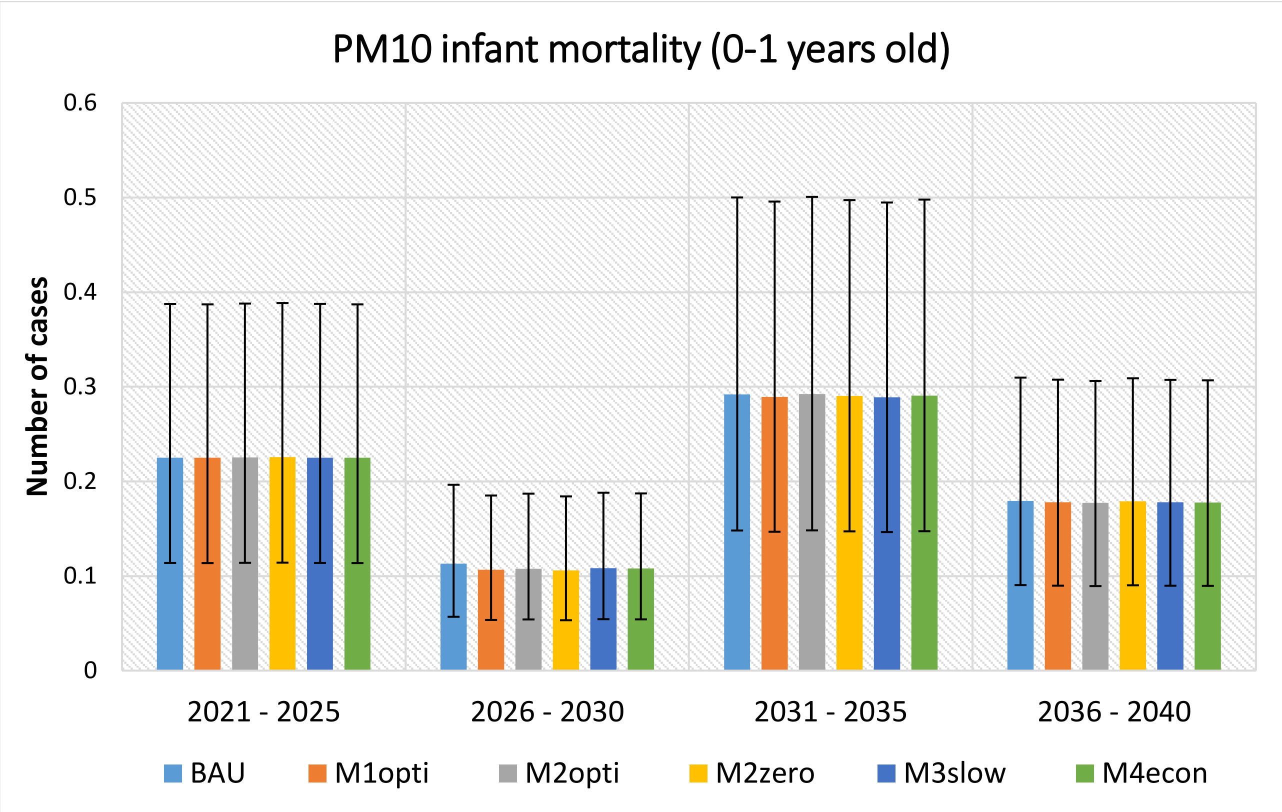
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
700
600
500
400
300
200
100
0
-100
-200
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

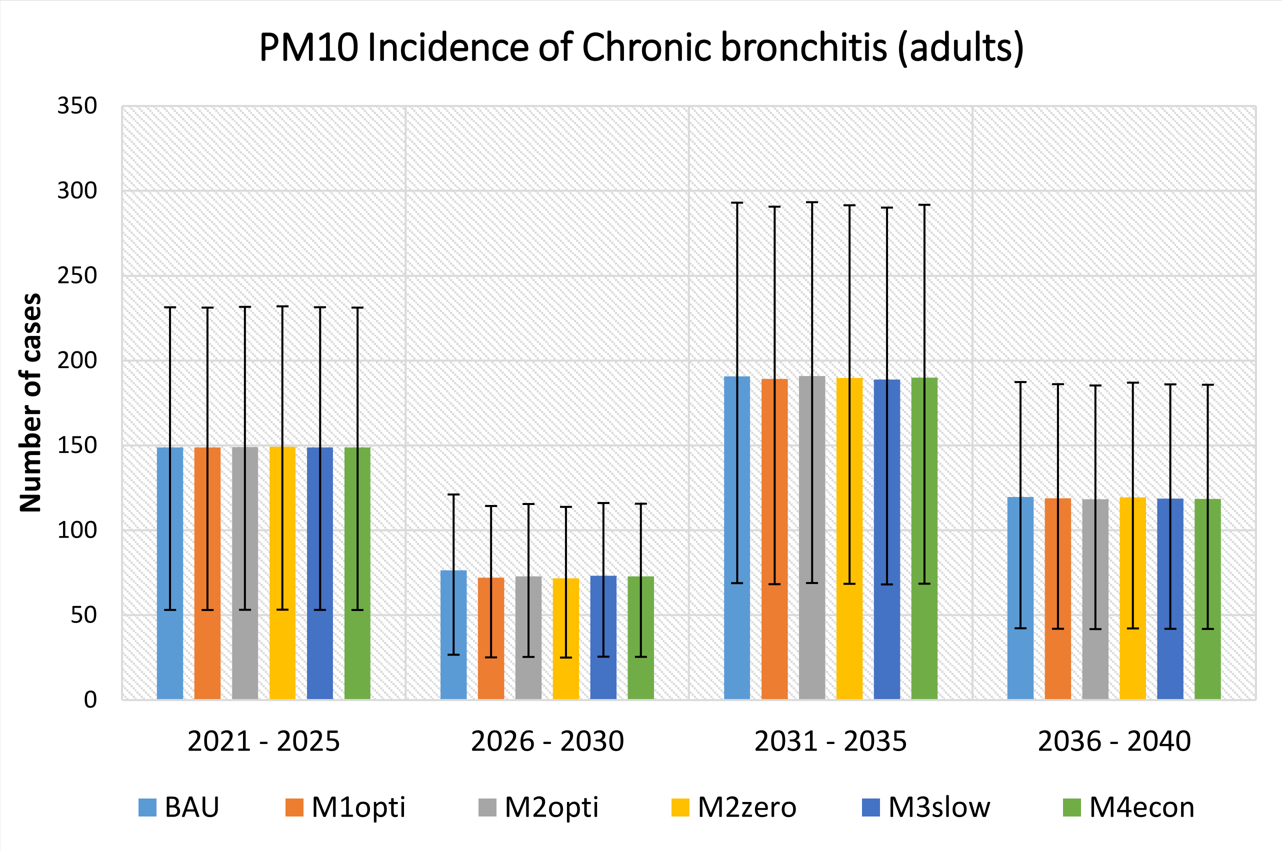

NO2 mortality (all natural causes) >30 years old
Number of cases
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
450
400
350
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

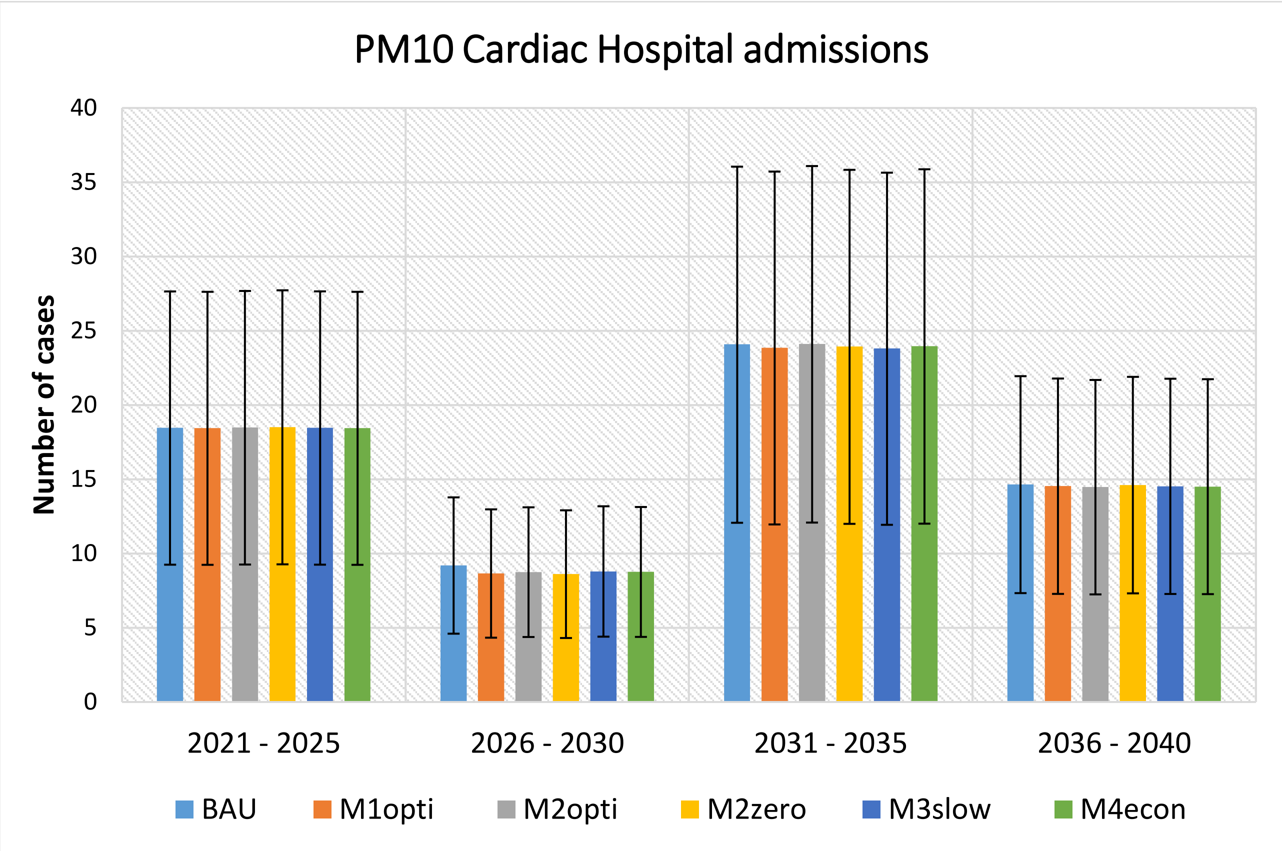
Brno


PM2.5 mortality (all natural causes) >30 years old
Number of cases
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

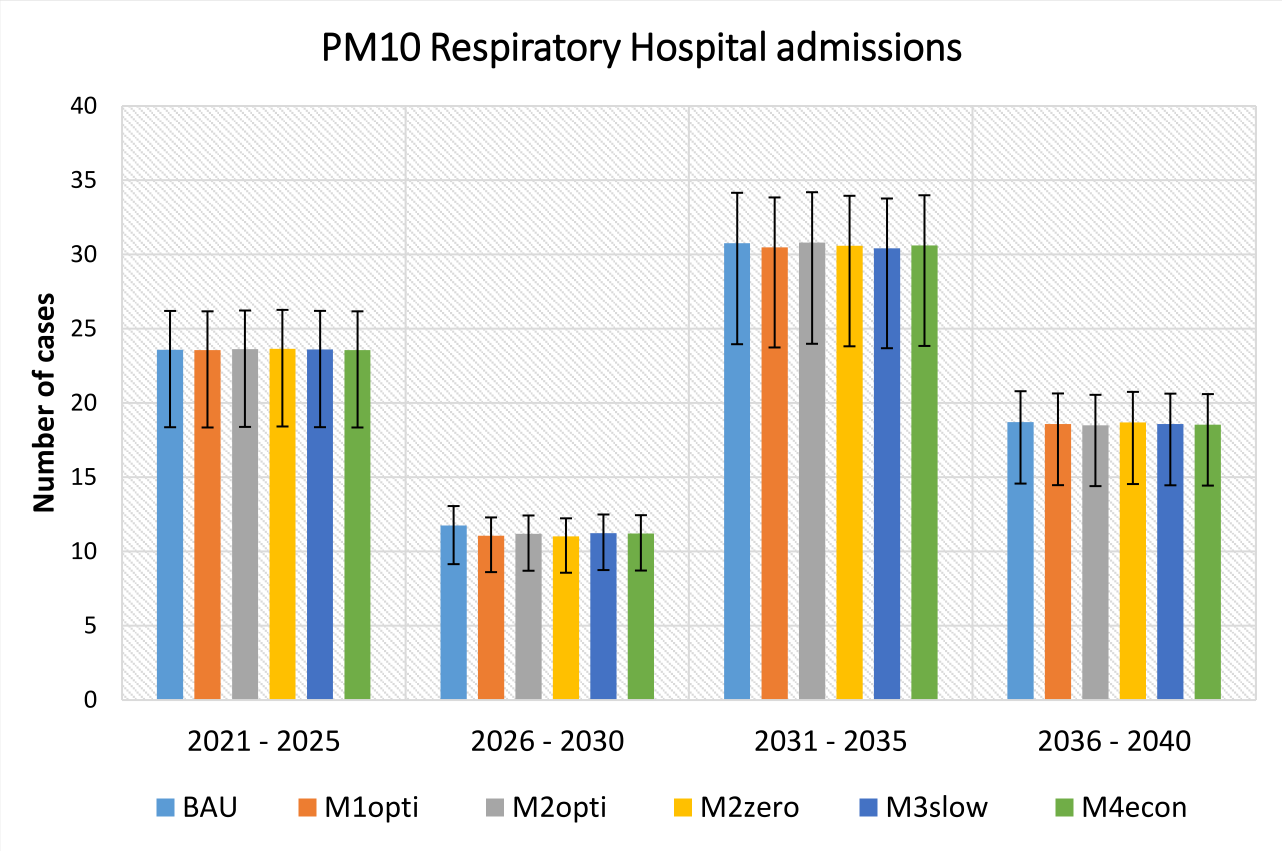

PM10 infant mortality (0-1 years old)
Number of cases
0.6
0.5
0.4
0.3
0.2
0.1
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

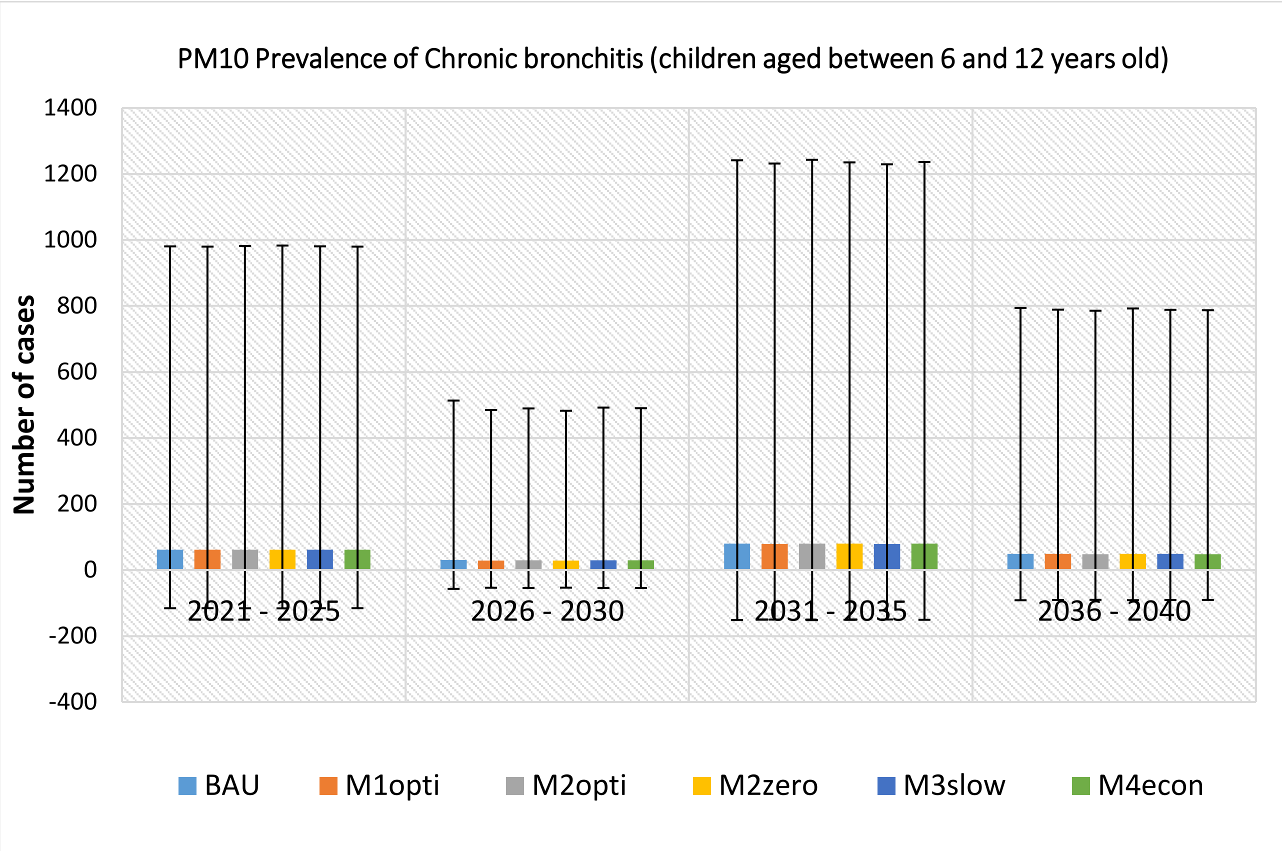


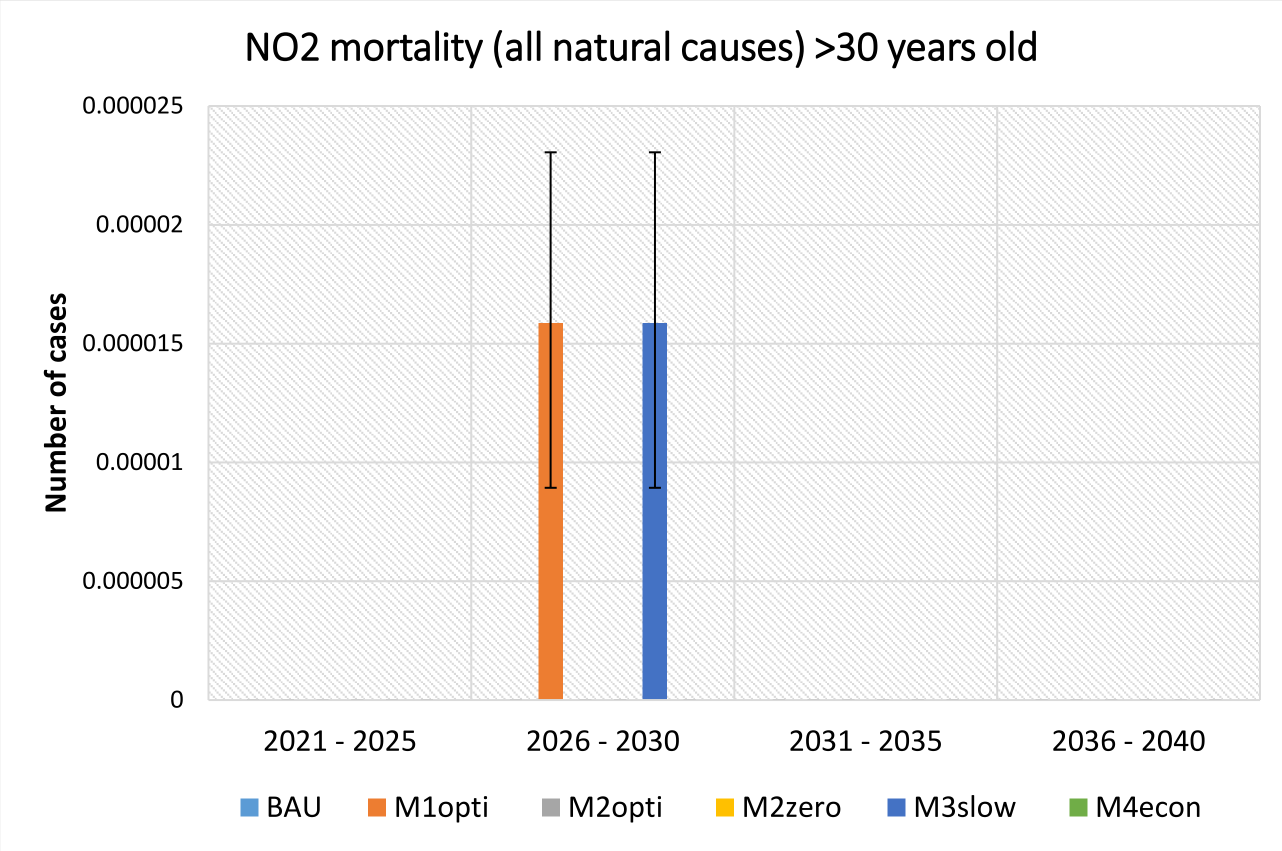
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
350
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ



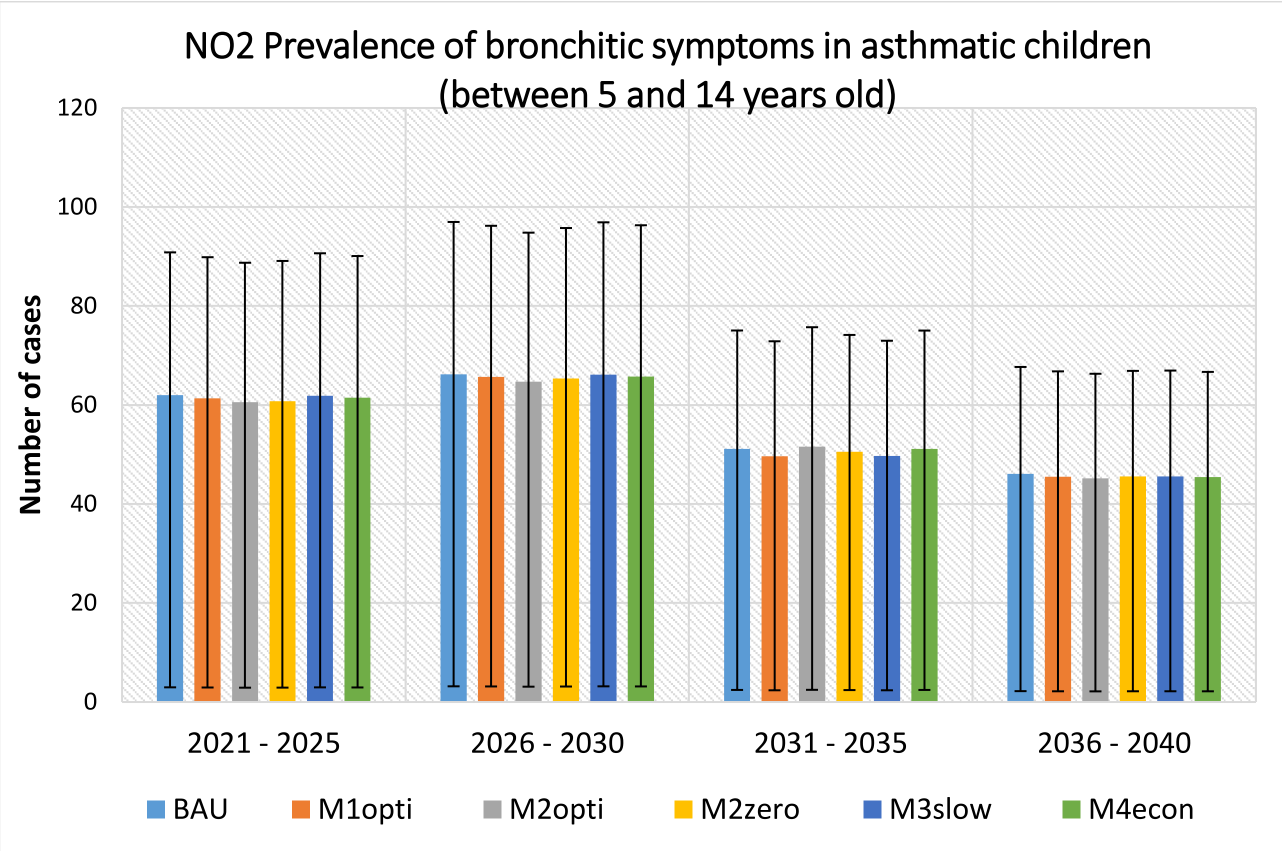
PM10 Cardiac Hospital admissions
Number of cases
40
35
30
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ


PM10 Respiratory Hospital admissions
Number of cases
40
35
30
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ


PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
1400
1200
1000
800
600
400
200
0
-200
-400
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

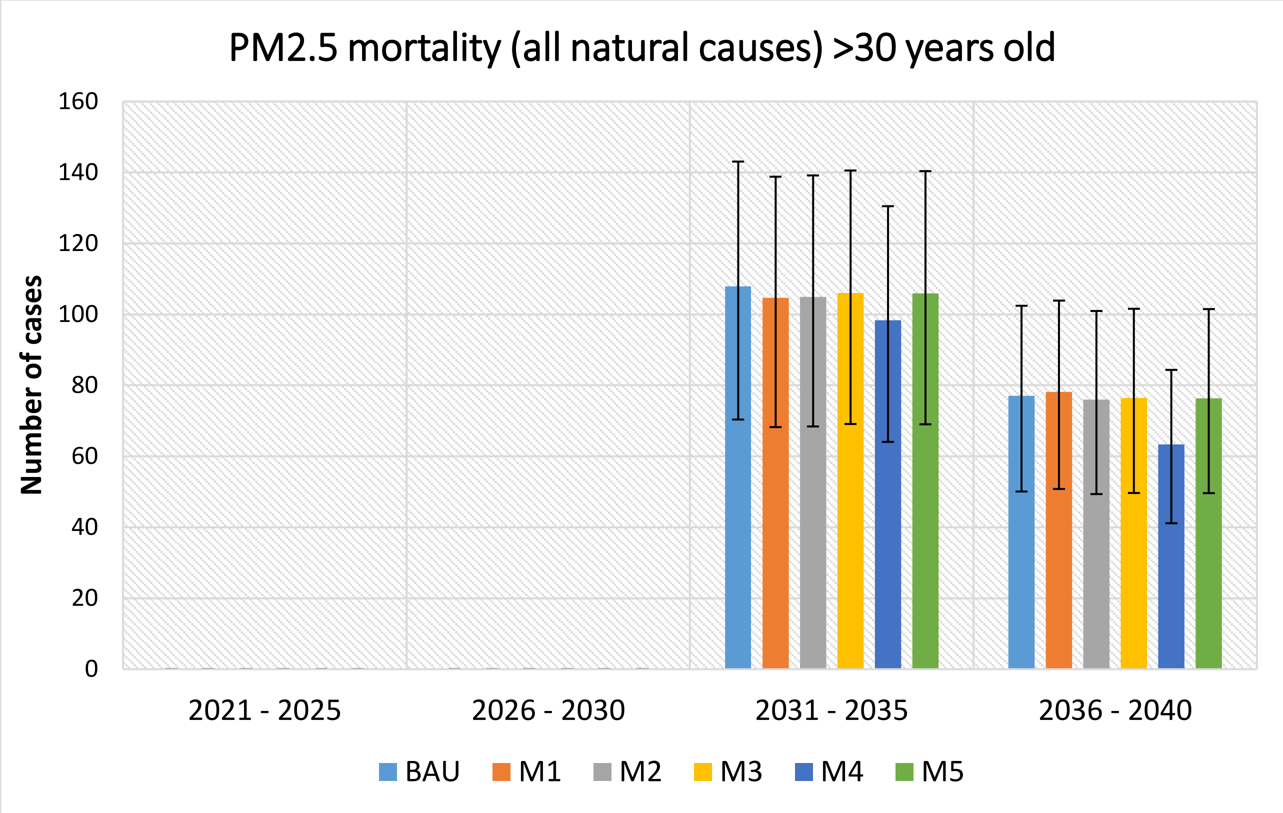


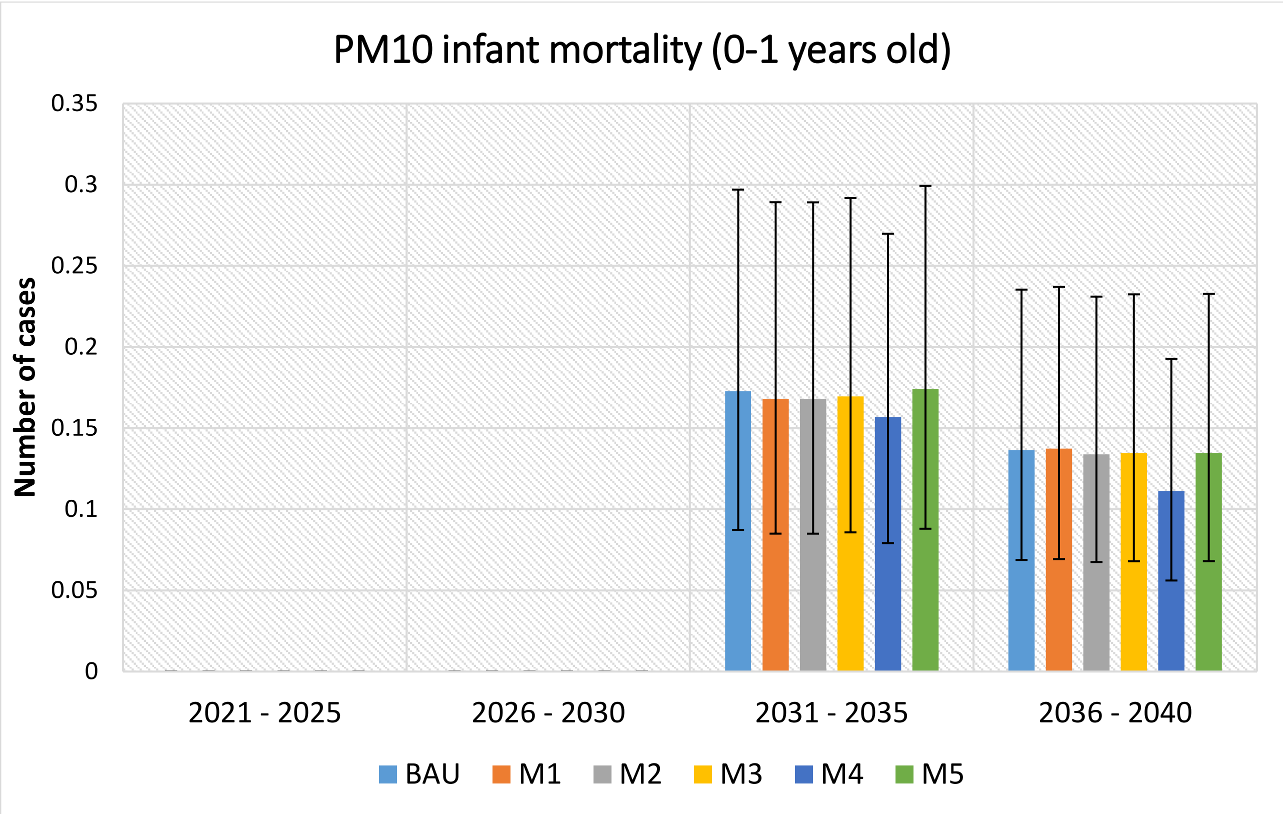
NO2 mortality (all natural causes) >30 years old
Number of cases
0.000025
0.00002
0.000015
0.00001
0.000005
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

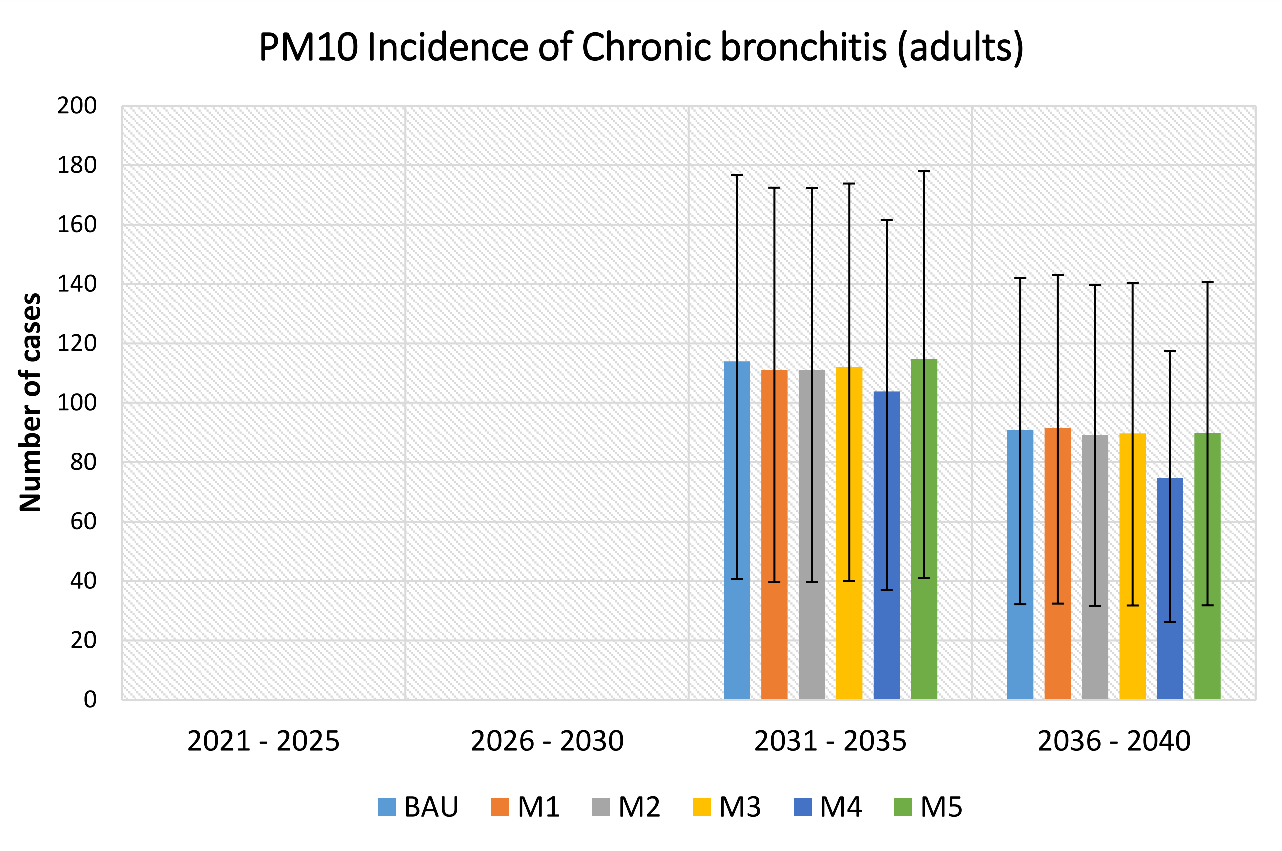


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
120
100
80
60
40
20
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

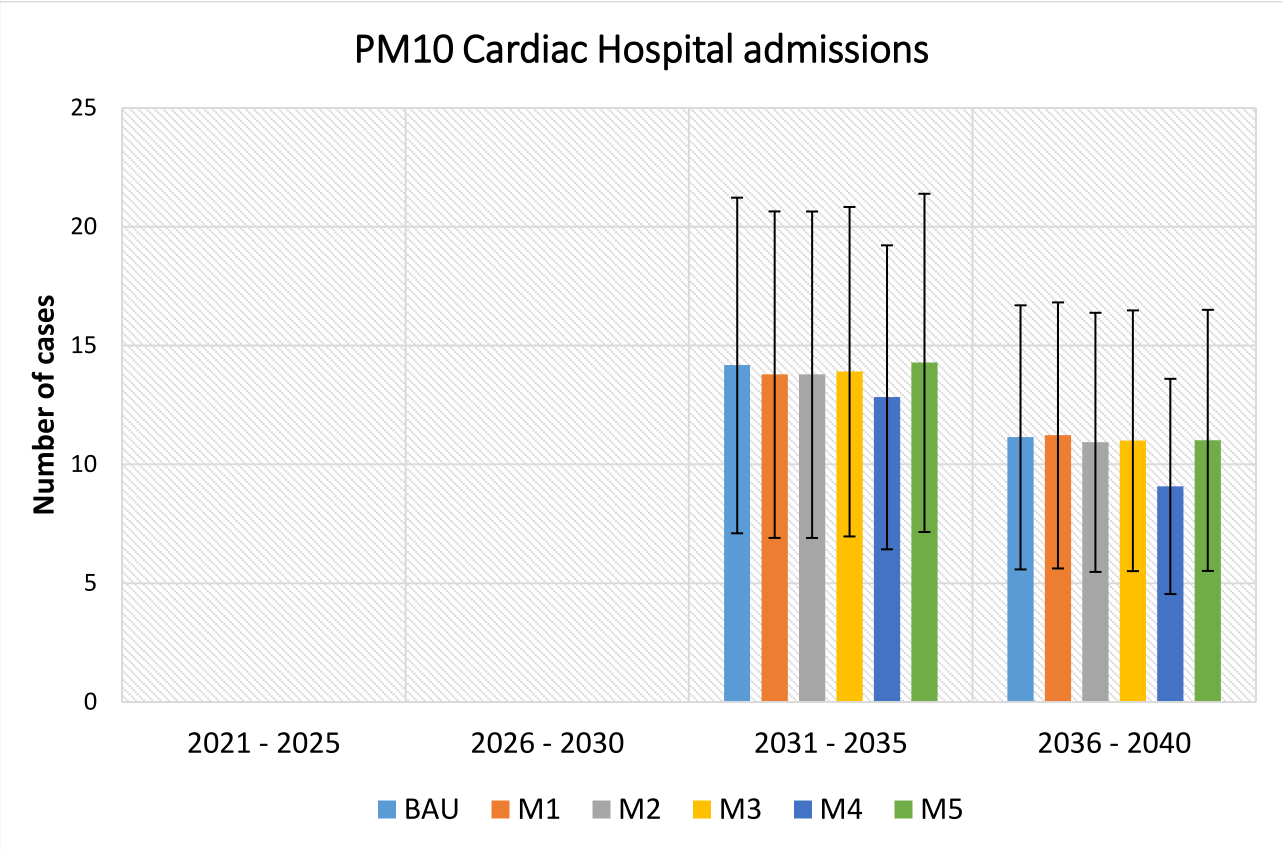
Ljubljana


PM2.5 mortality (all natural causes) >30 years old
Number of cases
160
140
120
100
80
60
40
20
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

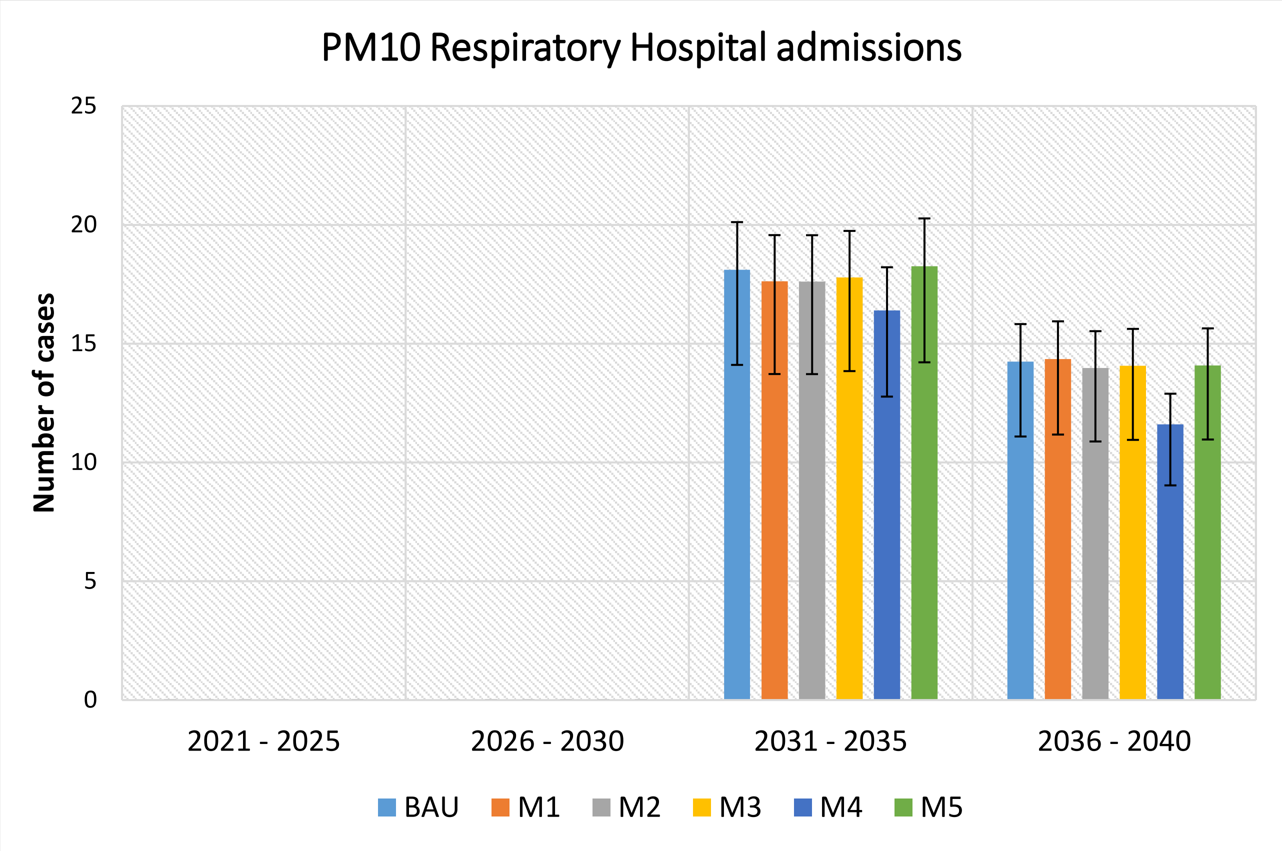

PM10 infant mortality (0-1 years old)
Number of cases
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5



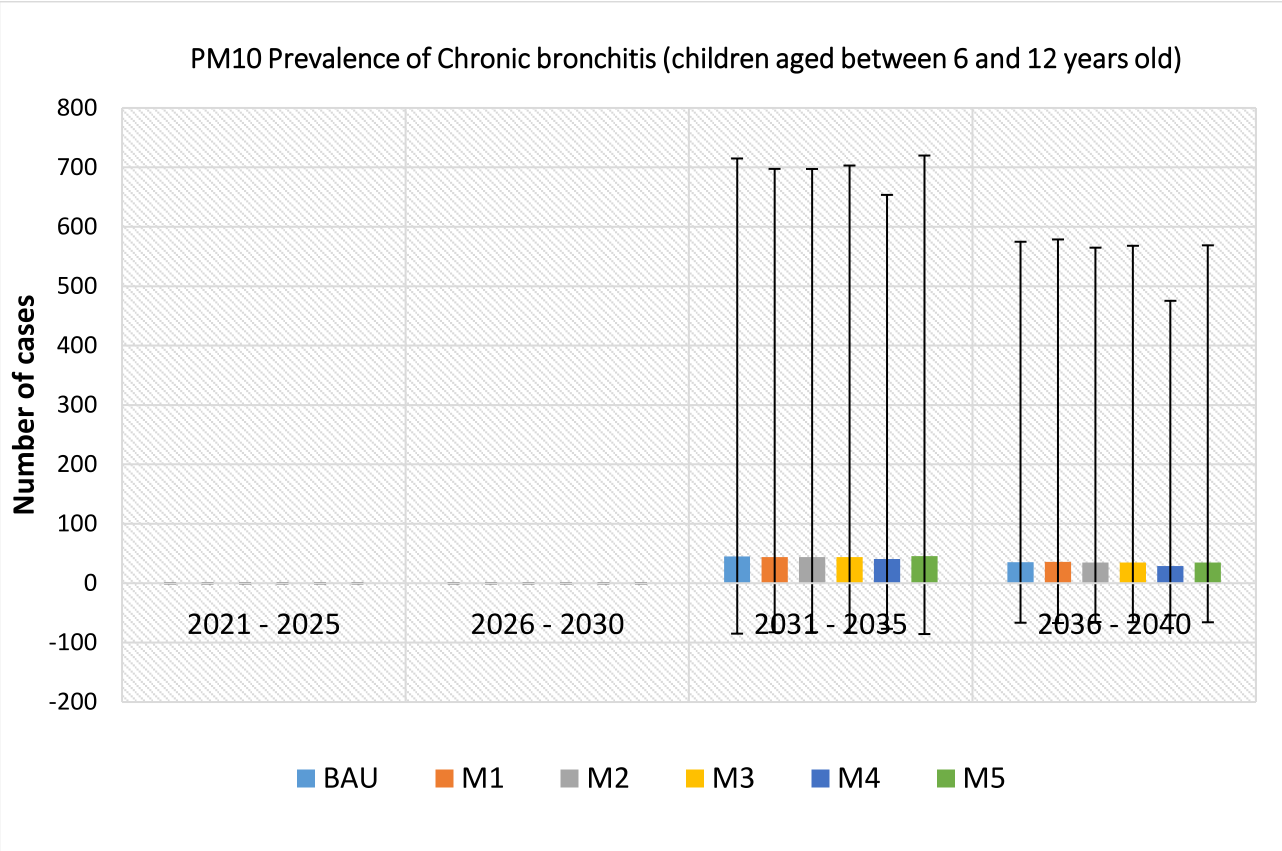
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
200
180
160
140
120
100
80
60
40
20
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5



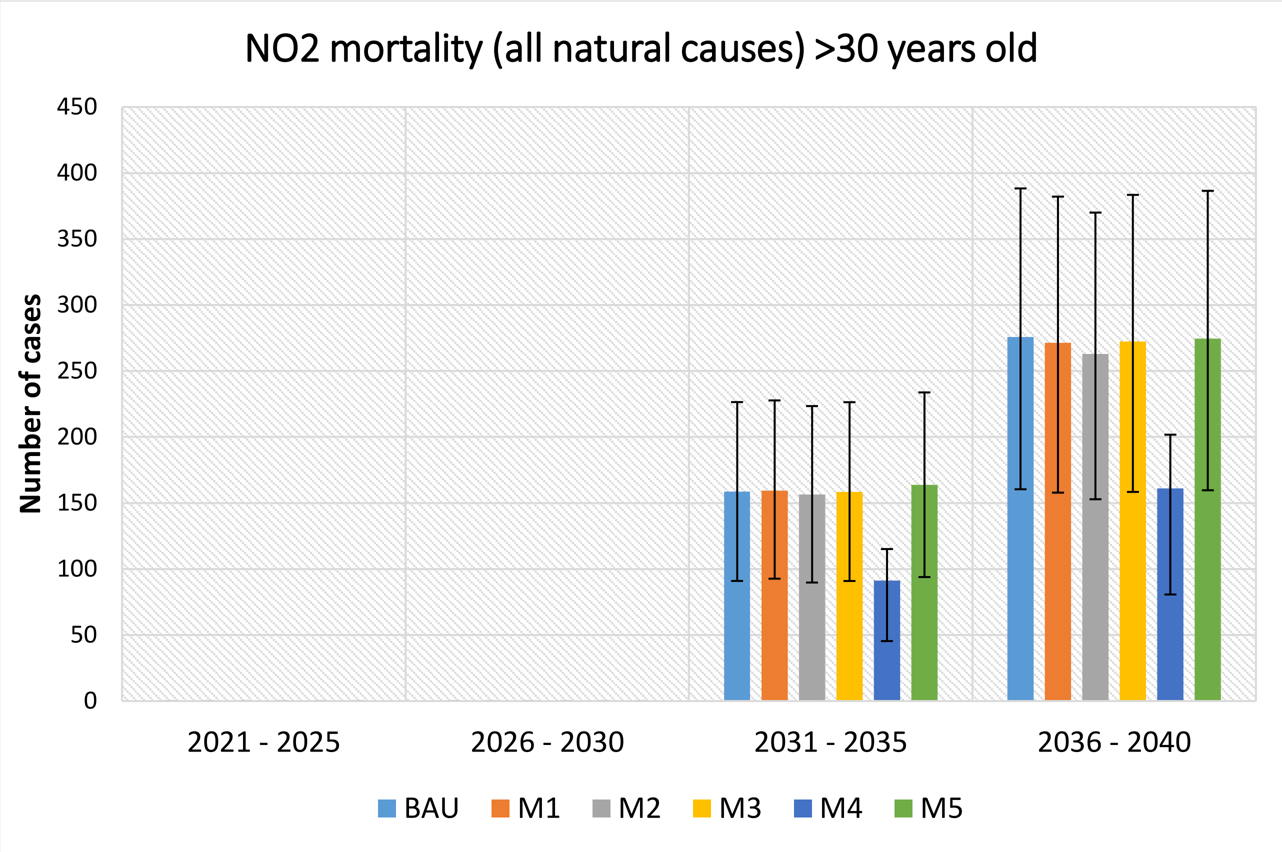
PM10 Cardiac Hospital admissions
Number of cases
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5



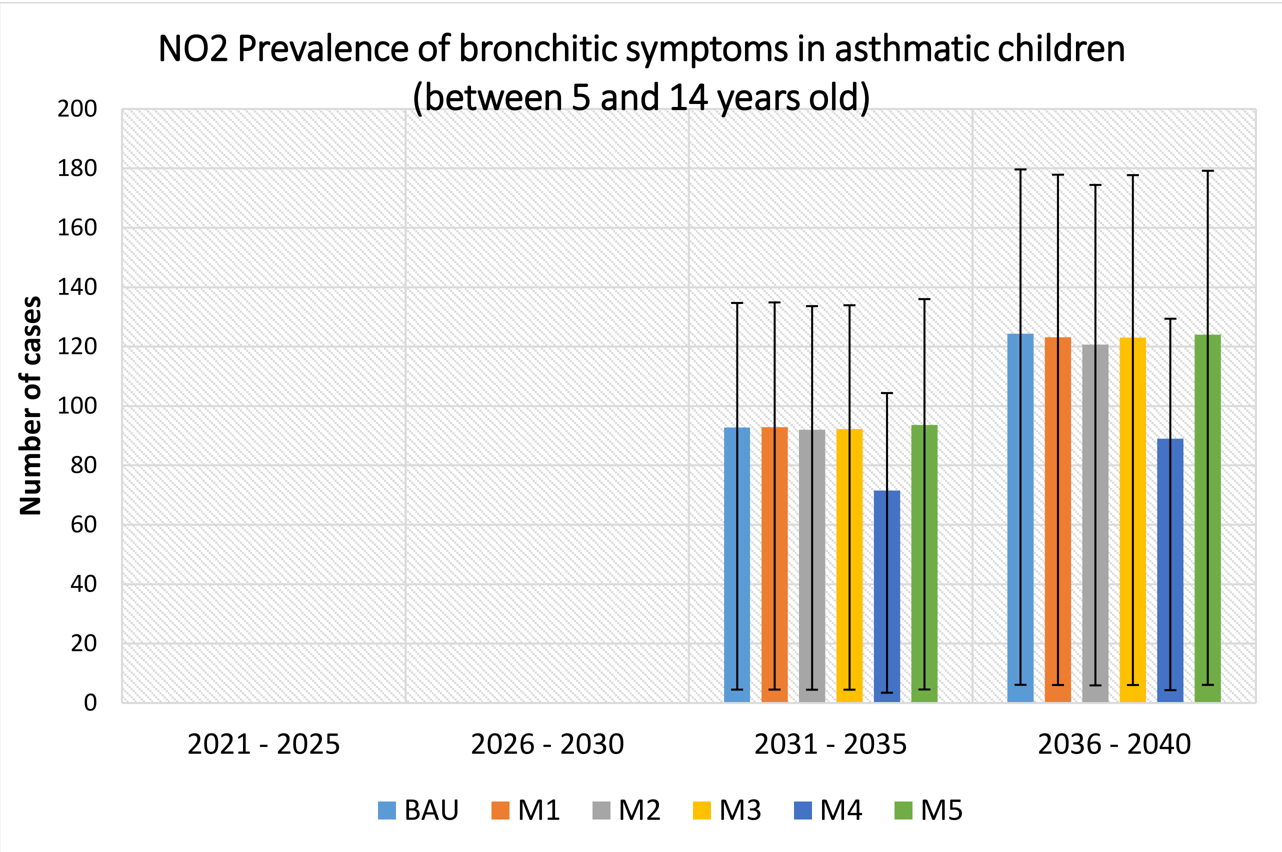
PM10 Respiratory Hospital admissions
Number of cases
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
800
700
600
500
400
300
200
100
0
-100
-200
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

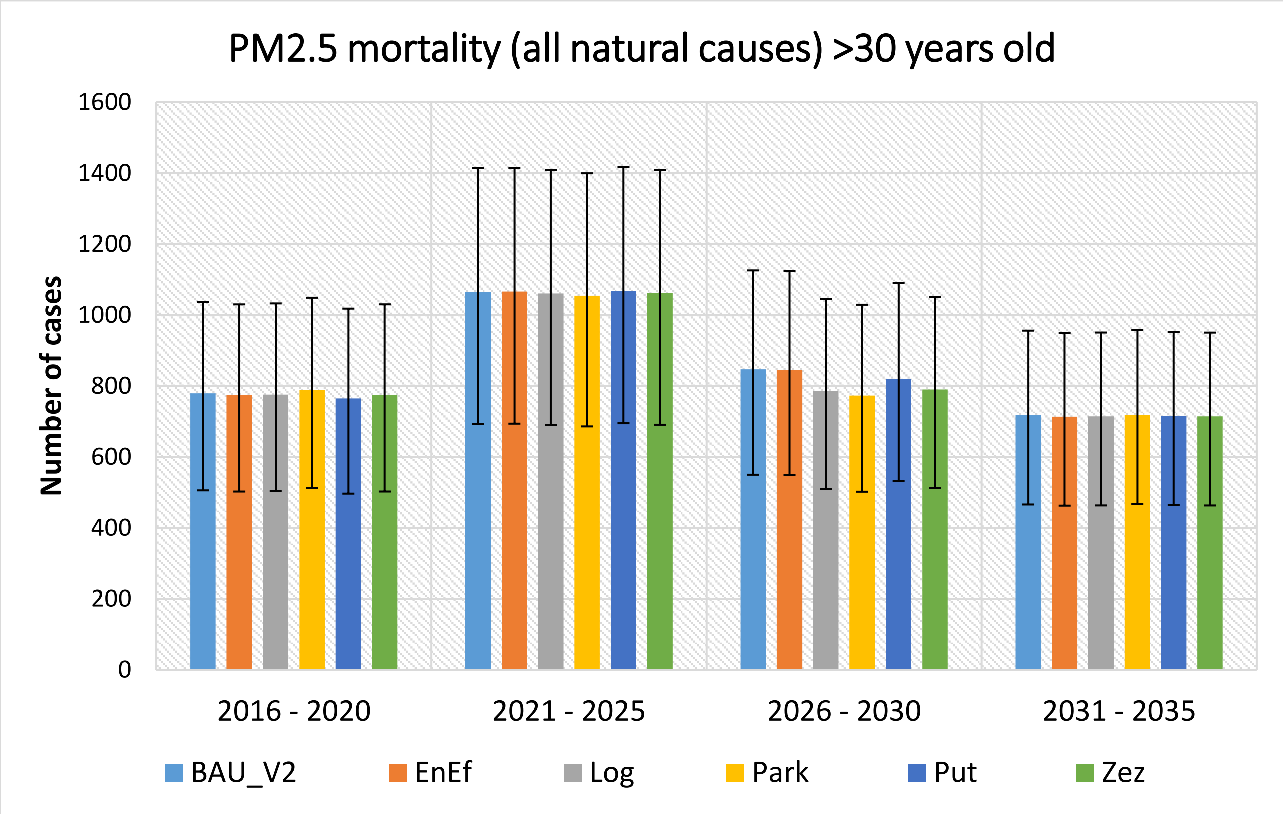


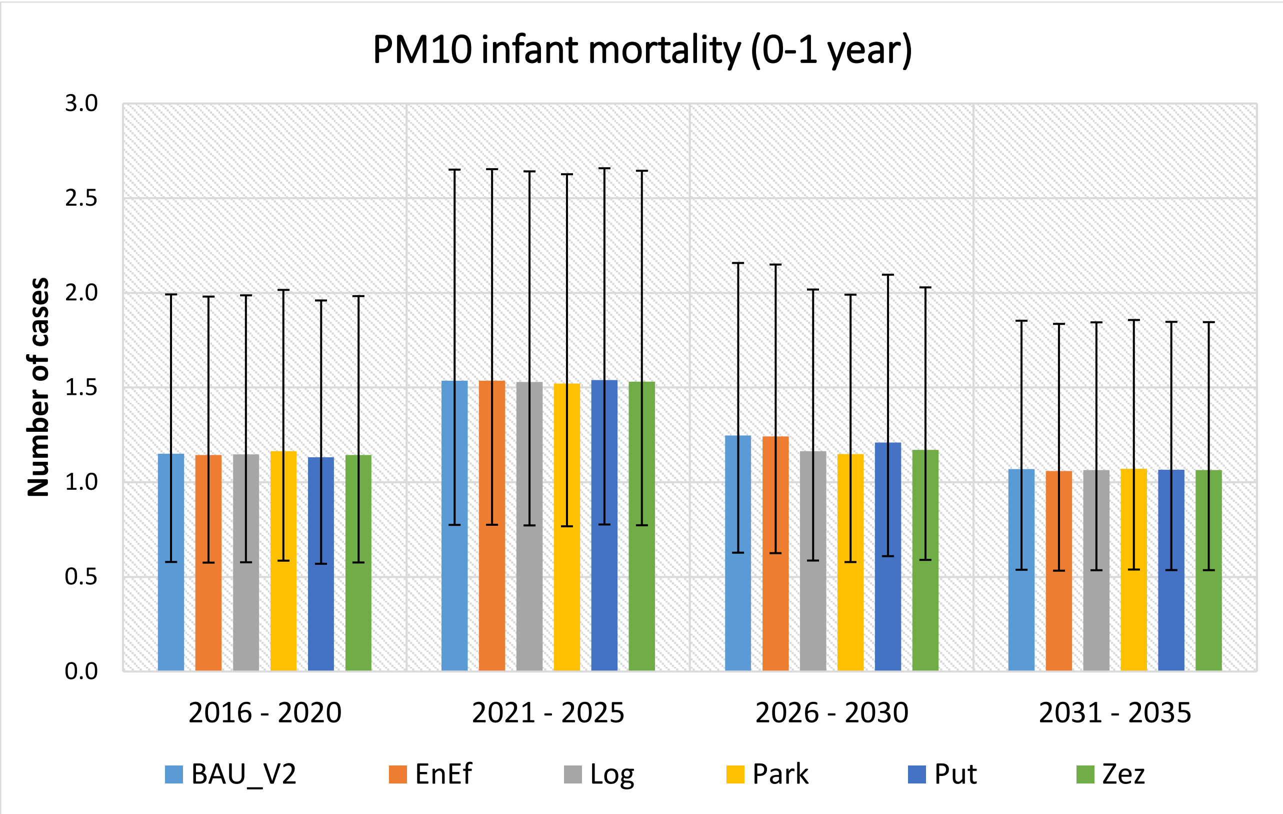
NO2 mortality (all natural causes) >30 years old
Number of cases
450
400
350
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

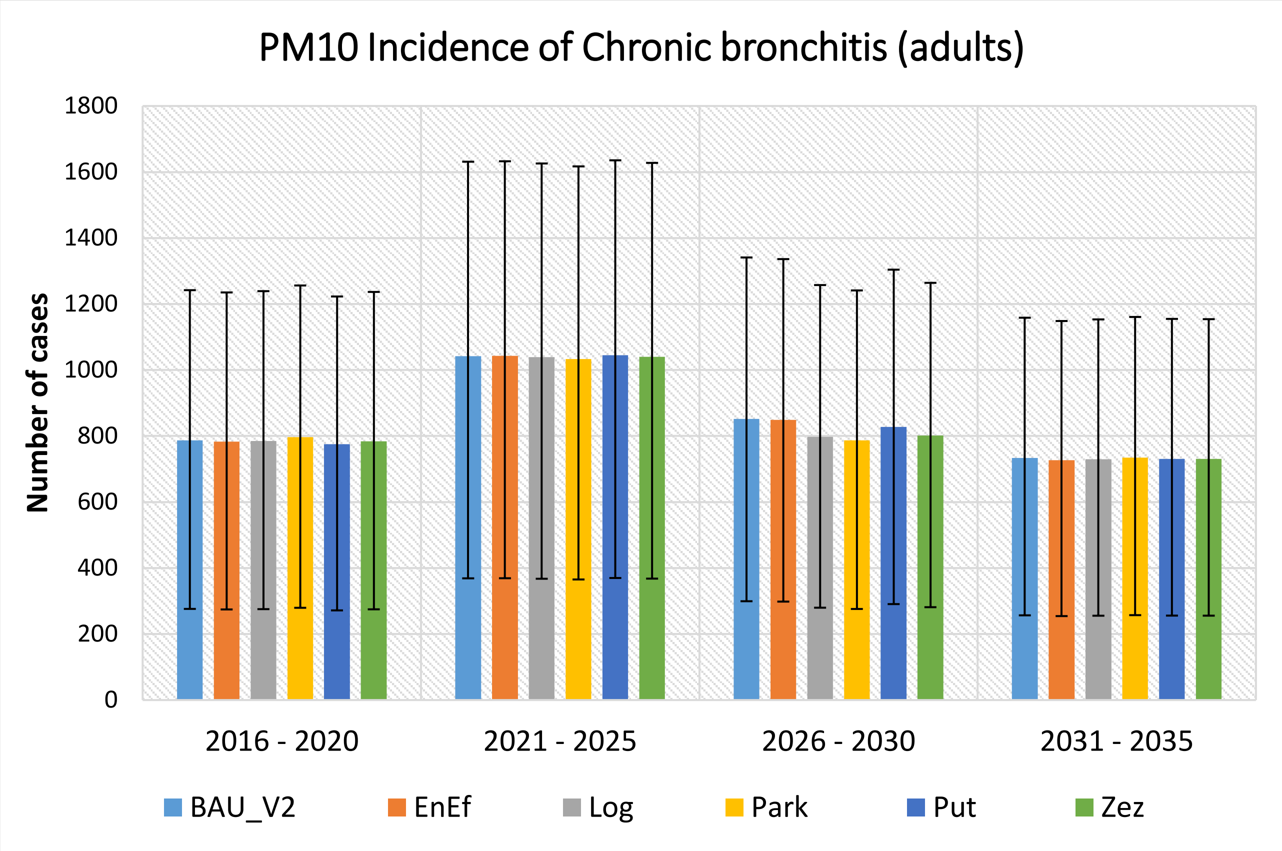


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
200
180
160
140
120
100
80
60
40
20
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

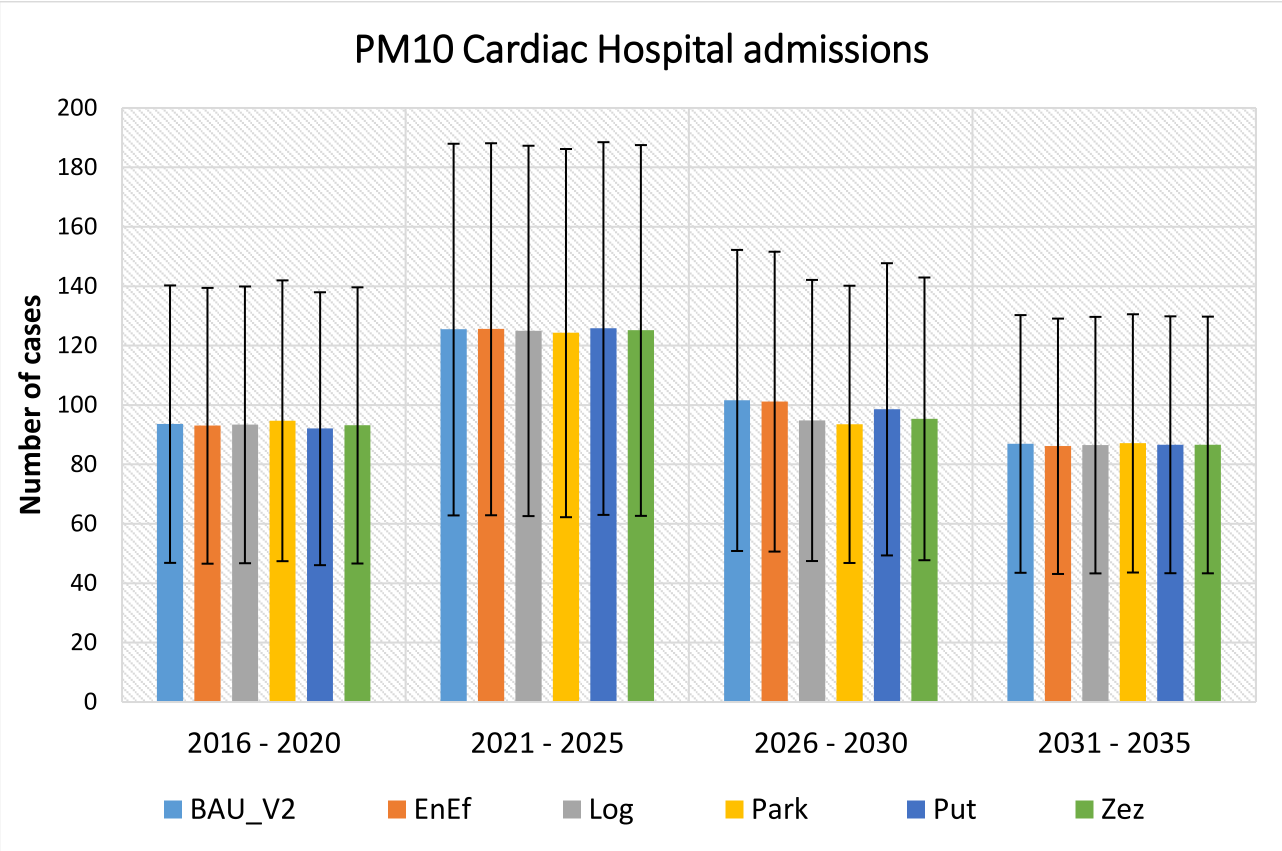
Madrid


PM2.5 mortality (all natural causes) >30 years old
Number of cases
1600
1400
1200
1000
800
600
400
200
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

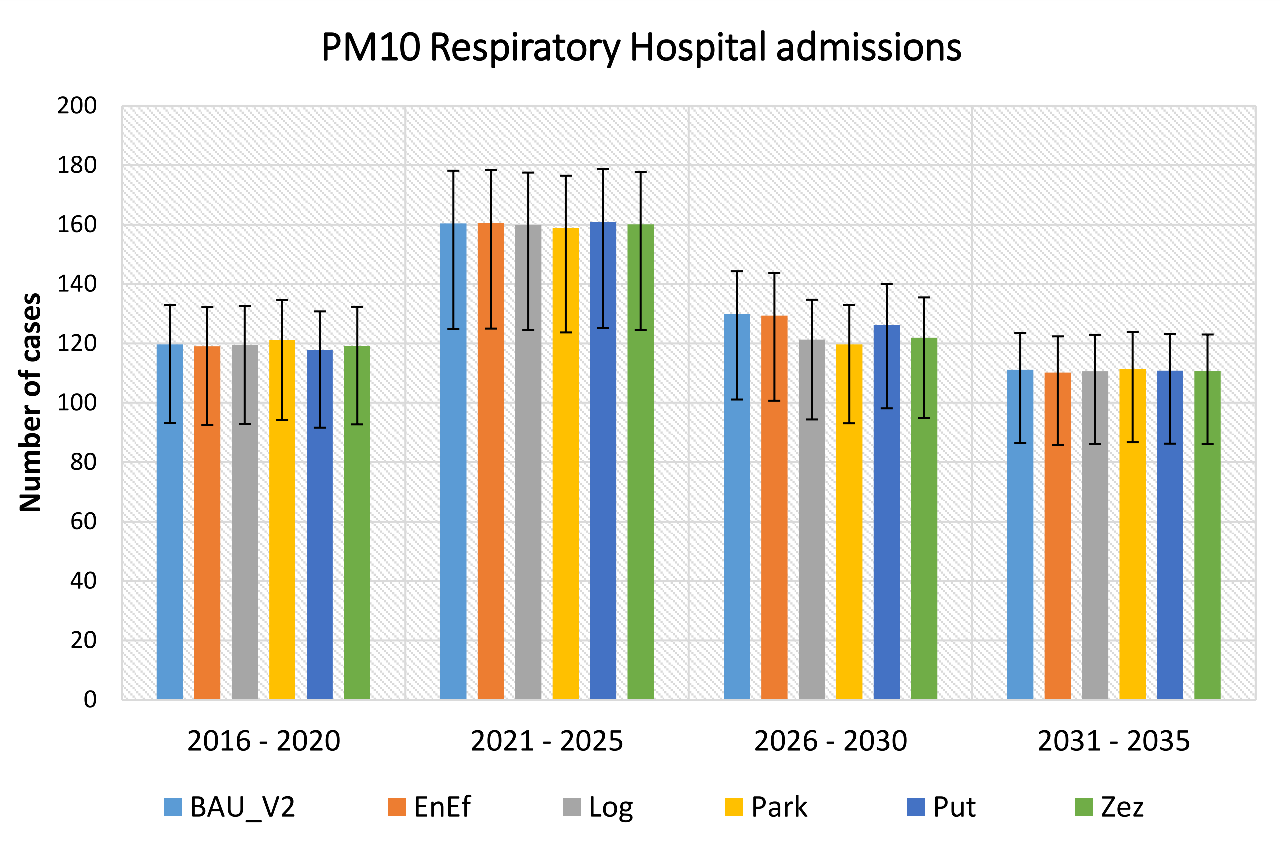

PM10 infant mortality (0-1 year)
Number of cases
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



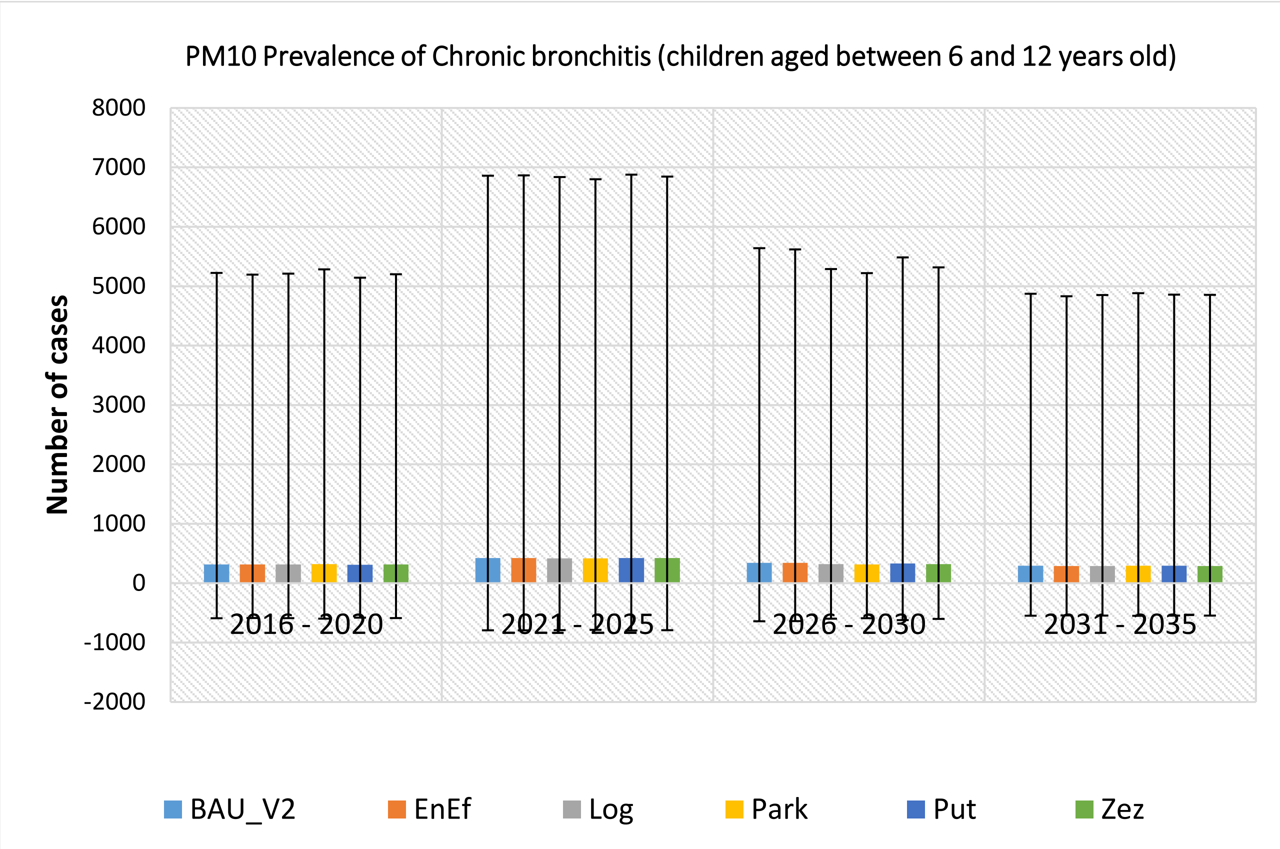
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
1800
1600
1400
1200
1000
800
600
400
200
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



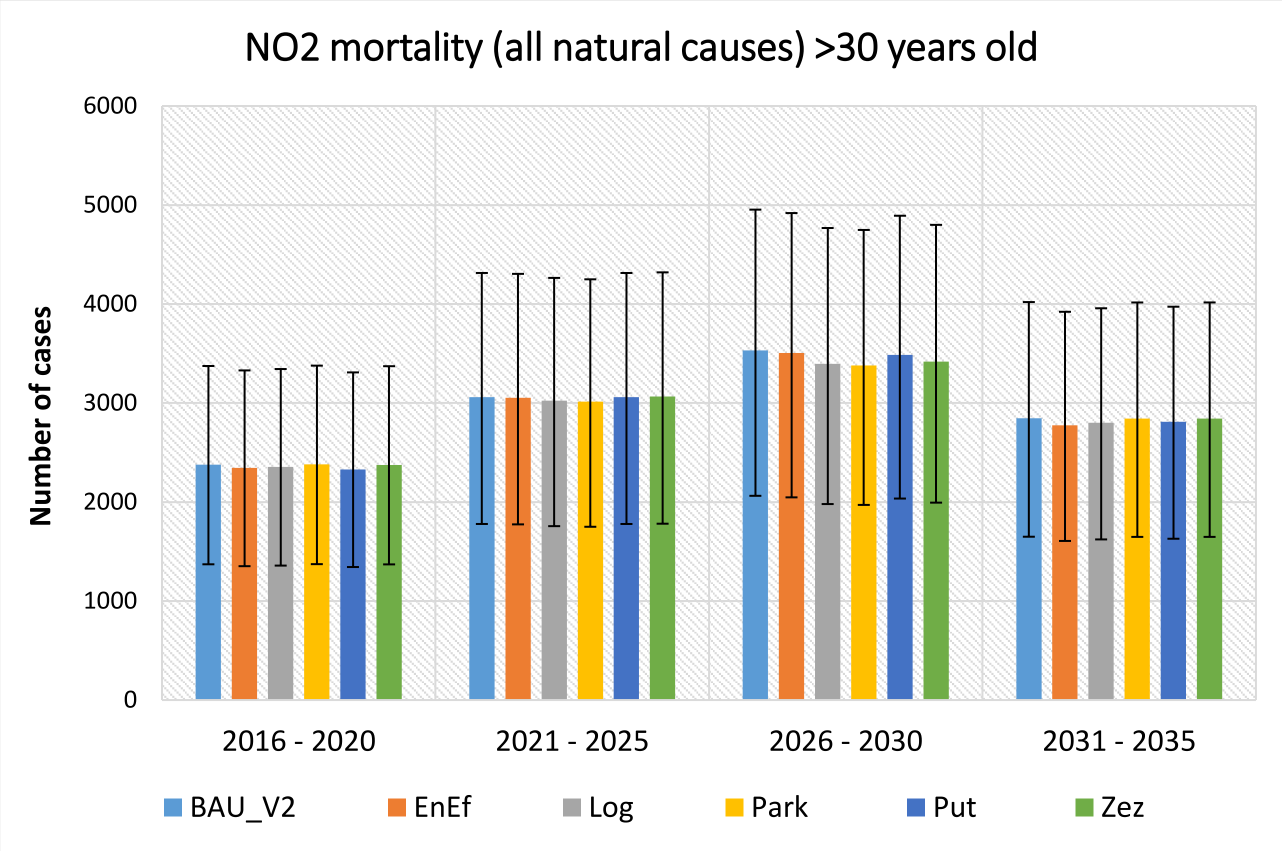
PM10 Cardiac Hospital admissions
Number of cases
200
180
160
140
120
100
80
60
40
20
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



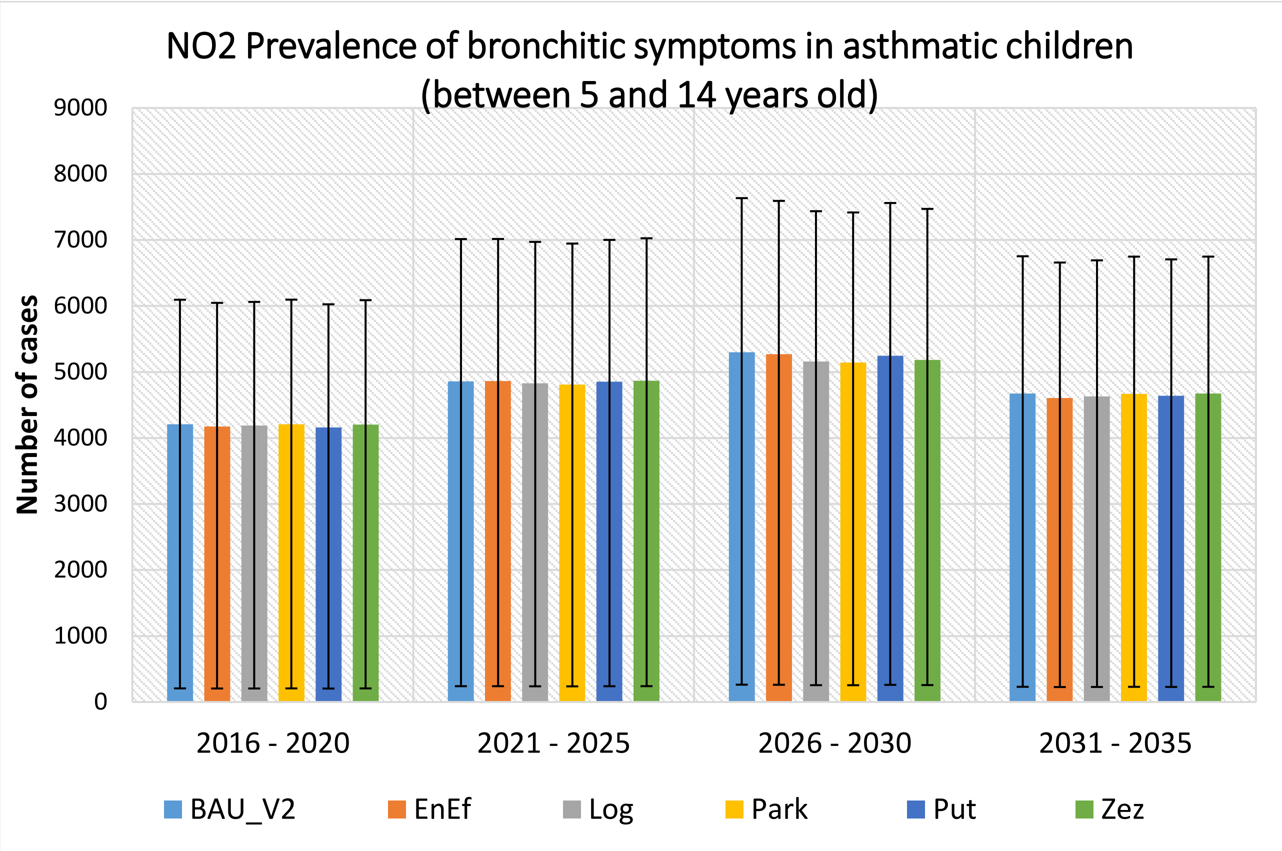
PM10 Respiratory Hospital admissions
Number of cases
200
180
160
140
120
100
80
60
40
20
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

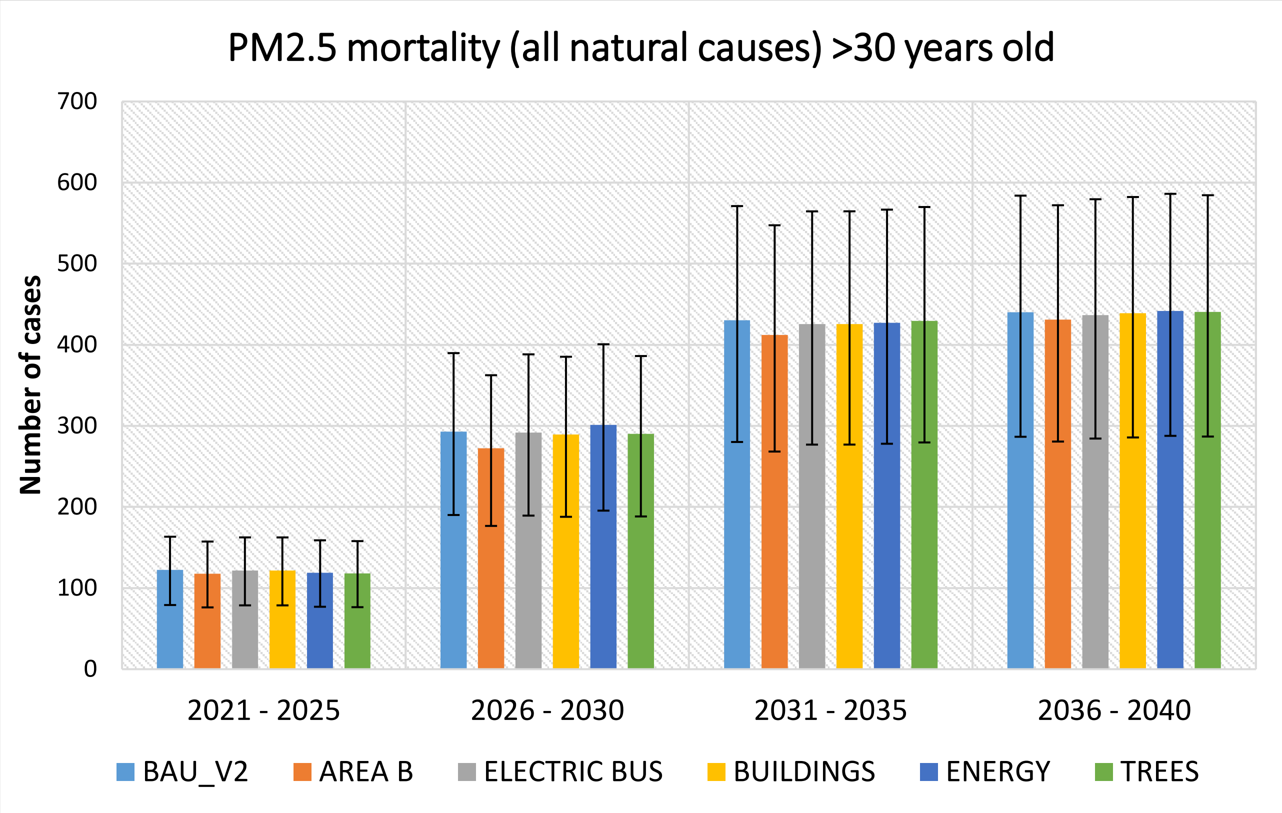


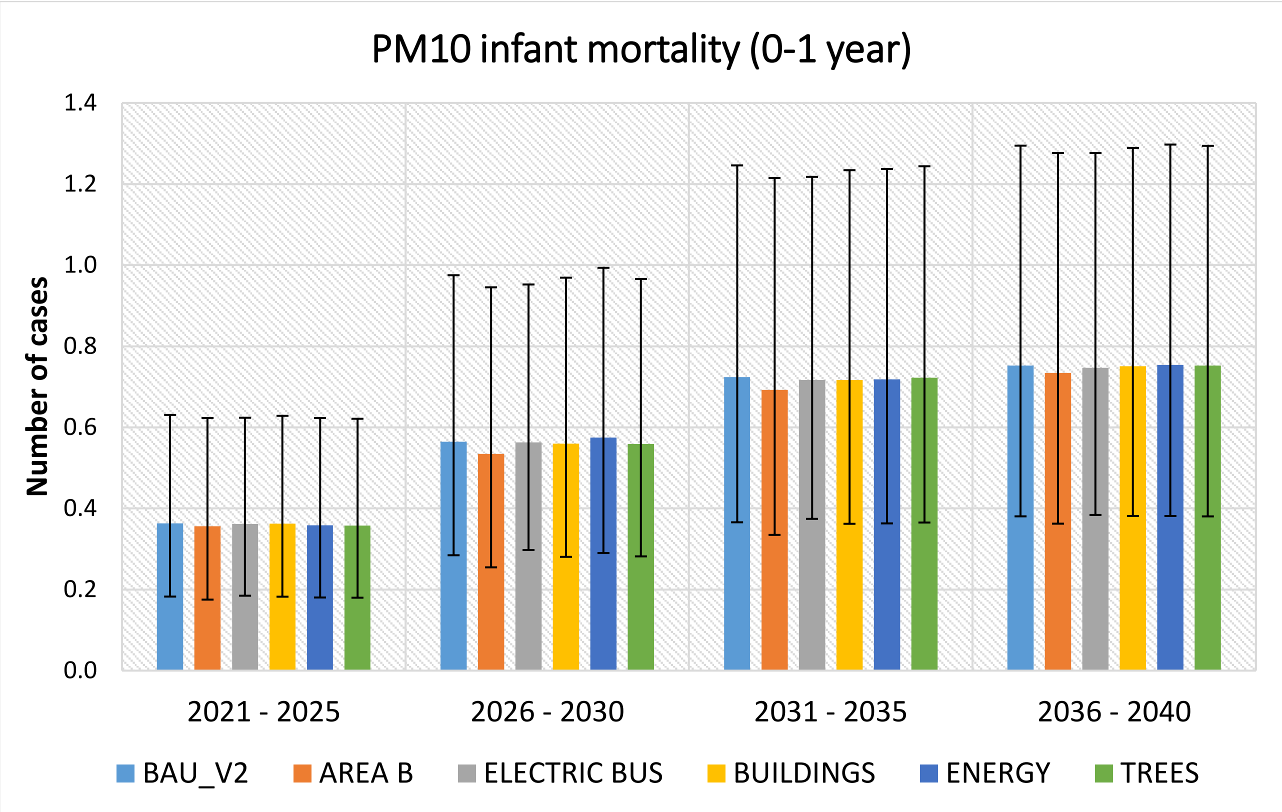
NO2 mortality (all natural causes) >30 years old
Number of cases
6000
5000
4000
3000
2000
1000
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

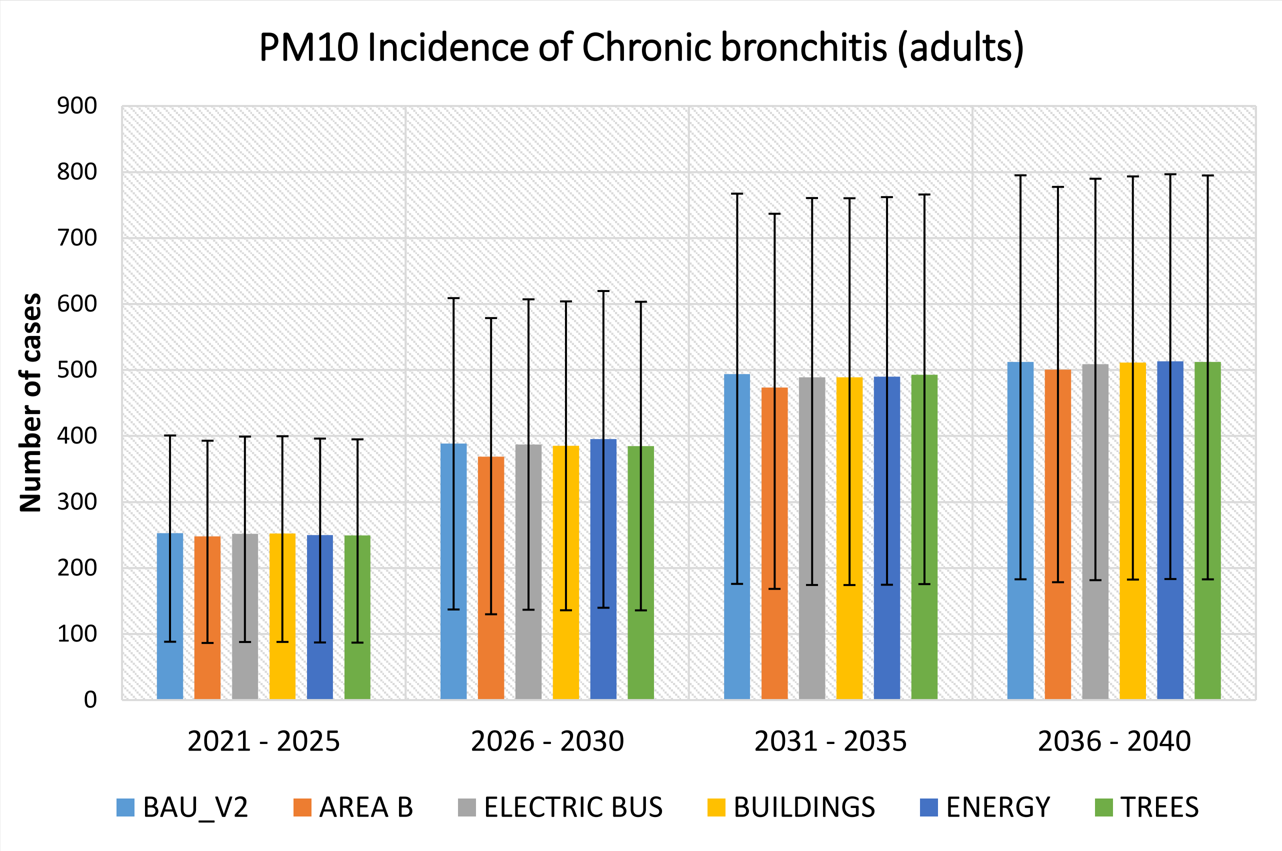


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

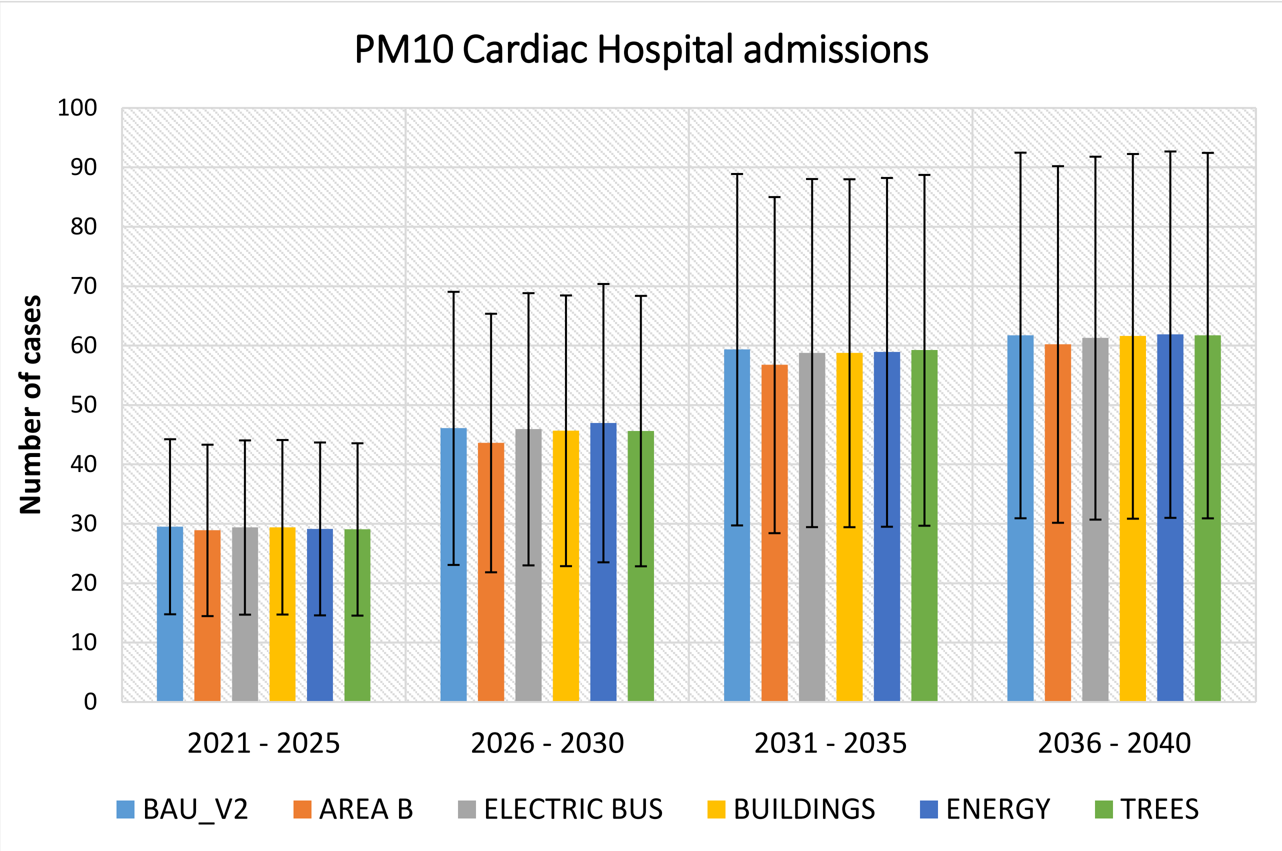
Milan


PM2.5 mortality (all natural causes) >30 years old
Number of cases
700
600
500
400
300
200
100
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

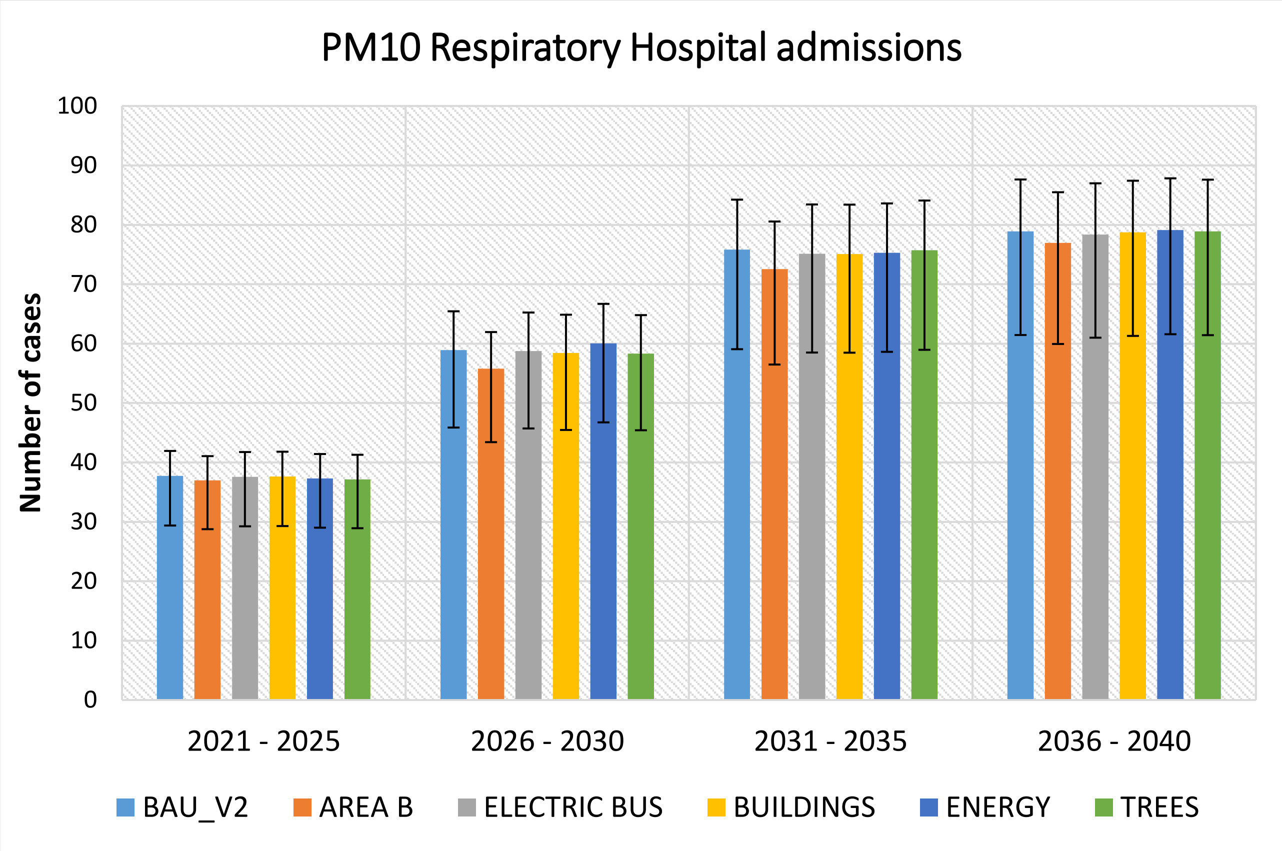

PM10 infant mortality (0-1 year)
Number of cases
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES



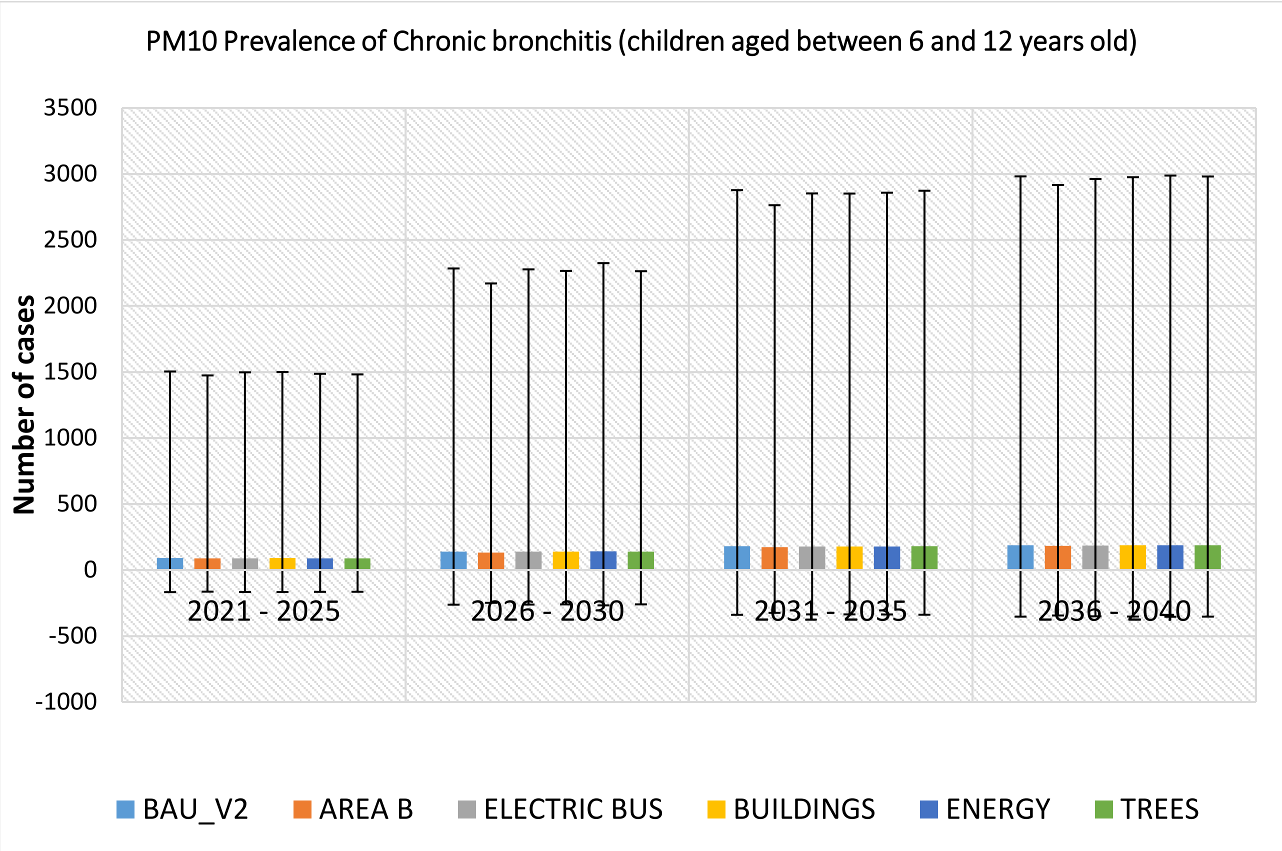
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
900
800
700
600
500
400
300
200
100
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES



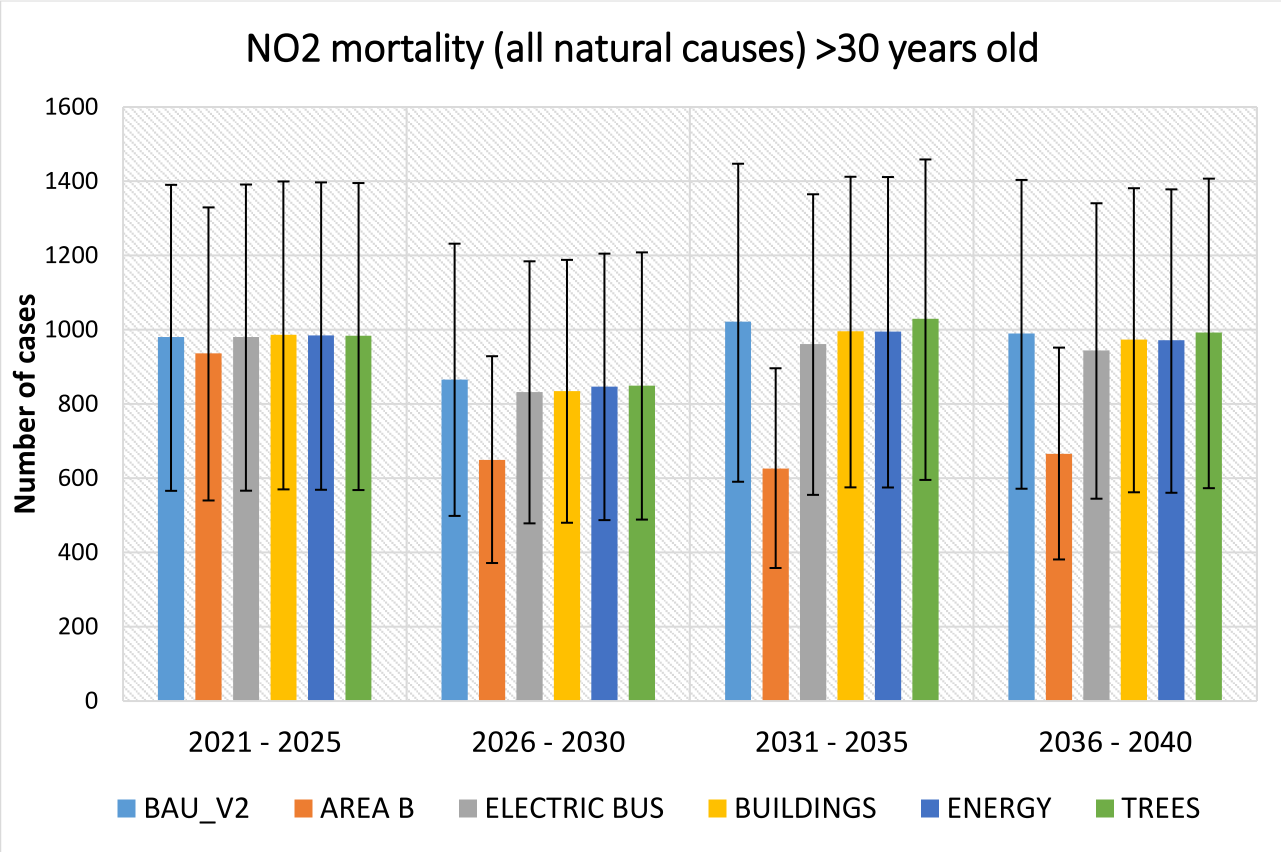
PM10 Cardiac Hospital admissions
Number of cases
100
90
80
70
60
50
40
30
20
10
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES



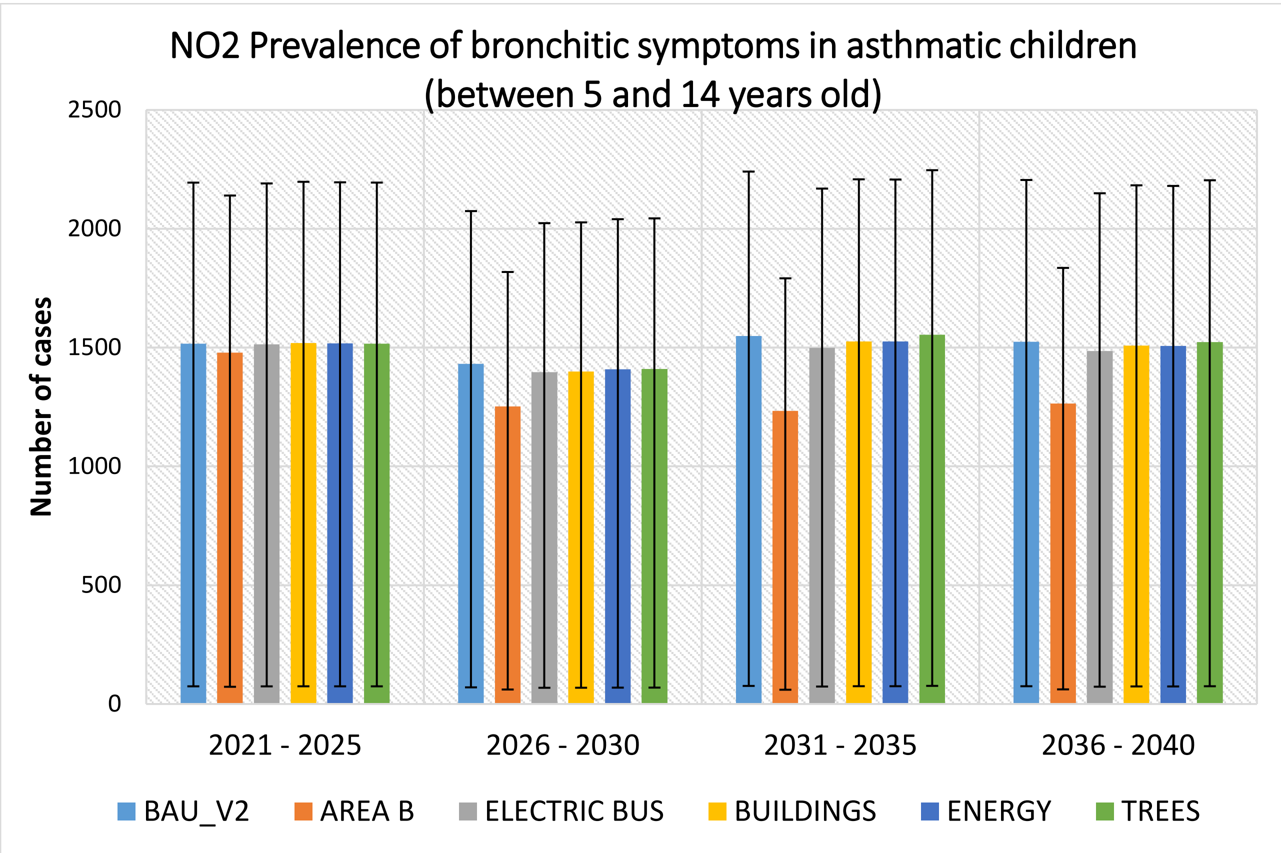
PM10 Respiratory Hospital admissions
Number of cases
100
90
80
70
60
50
40
30
20
10
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

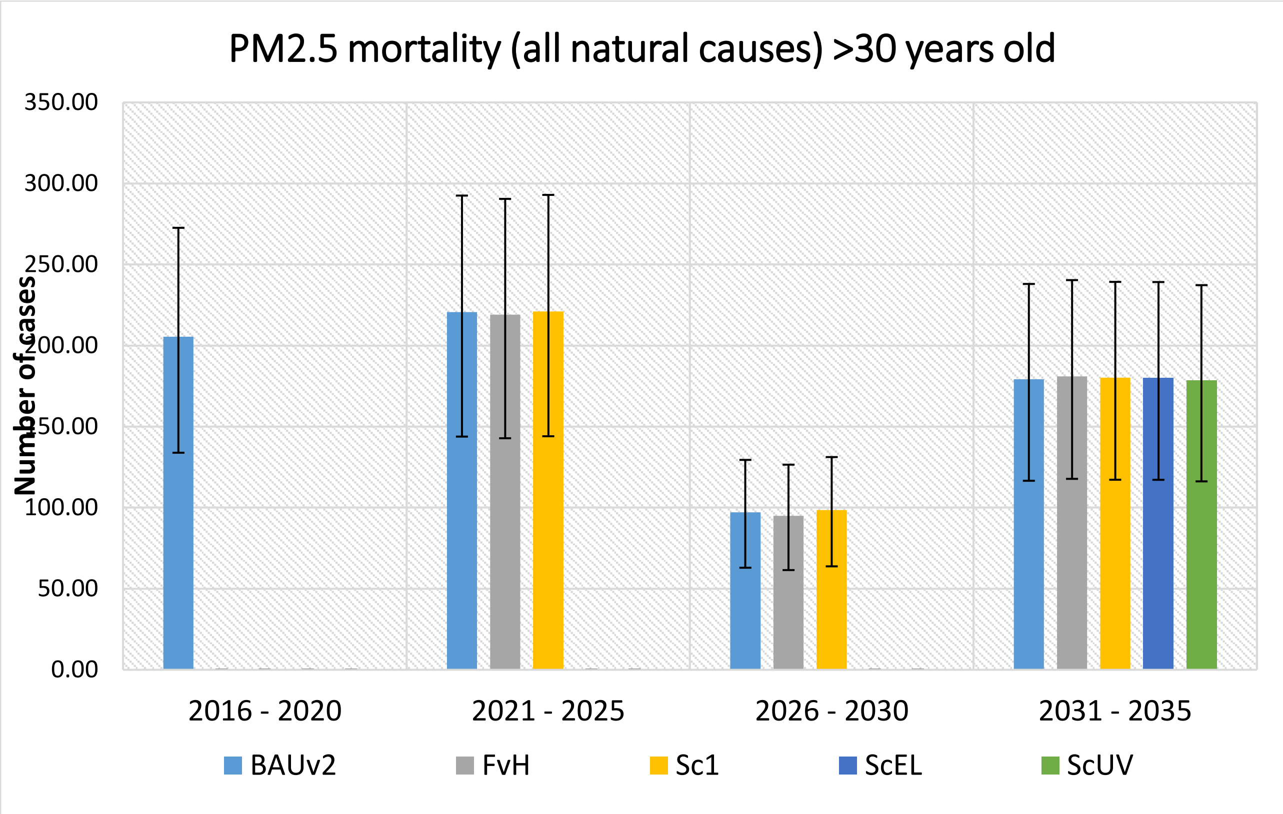


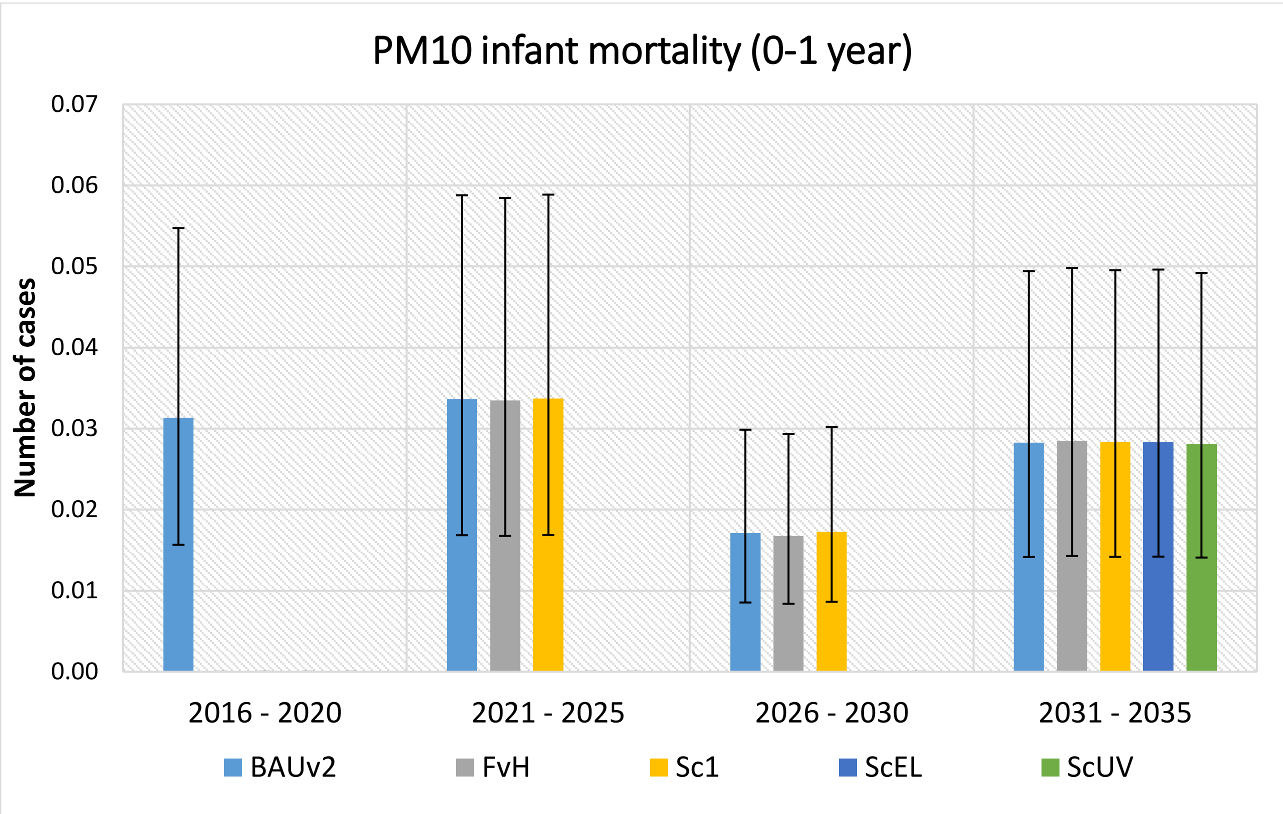
NO2 mortality (all natural causes) >30 years old
1600
1400
1200
1000
800
600
400
200
0
Number of cases
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

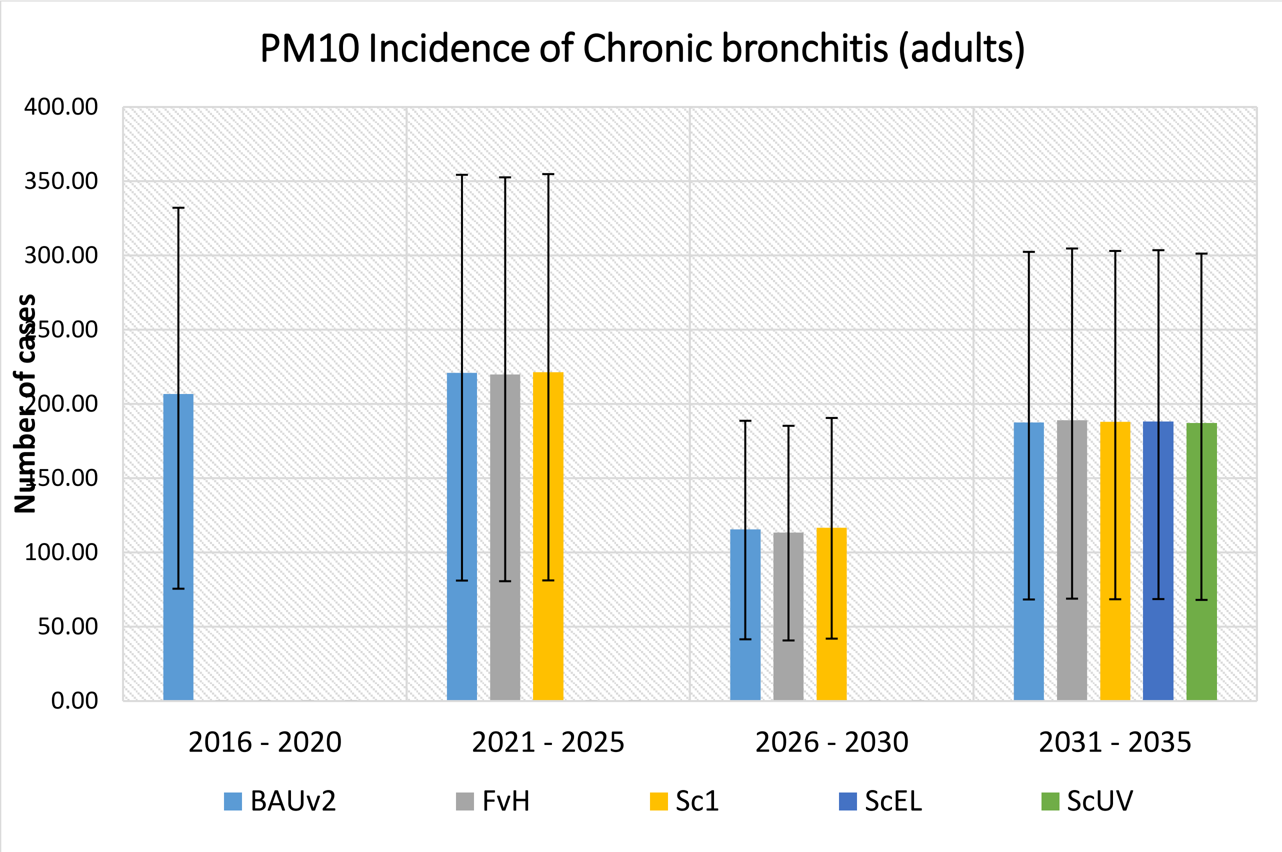


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
2500
2000
1500
1000
500
0
Number of cases
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

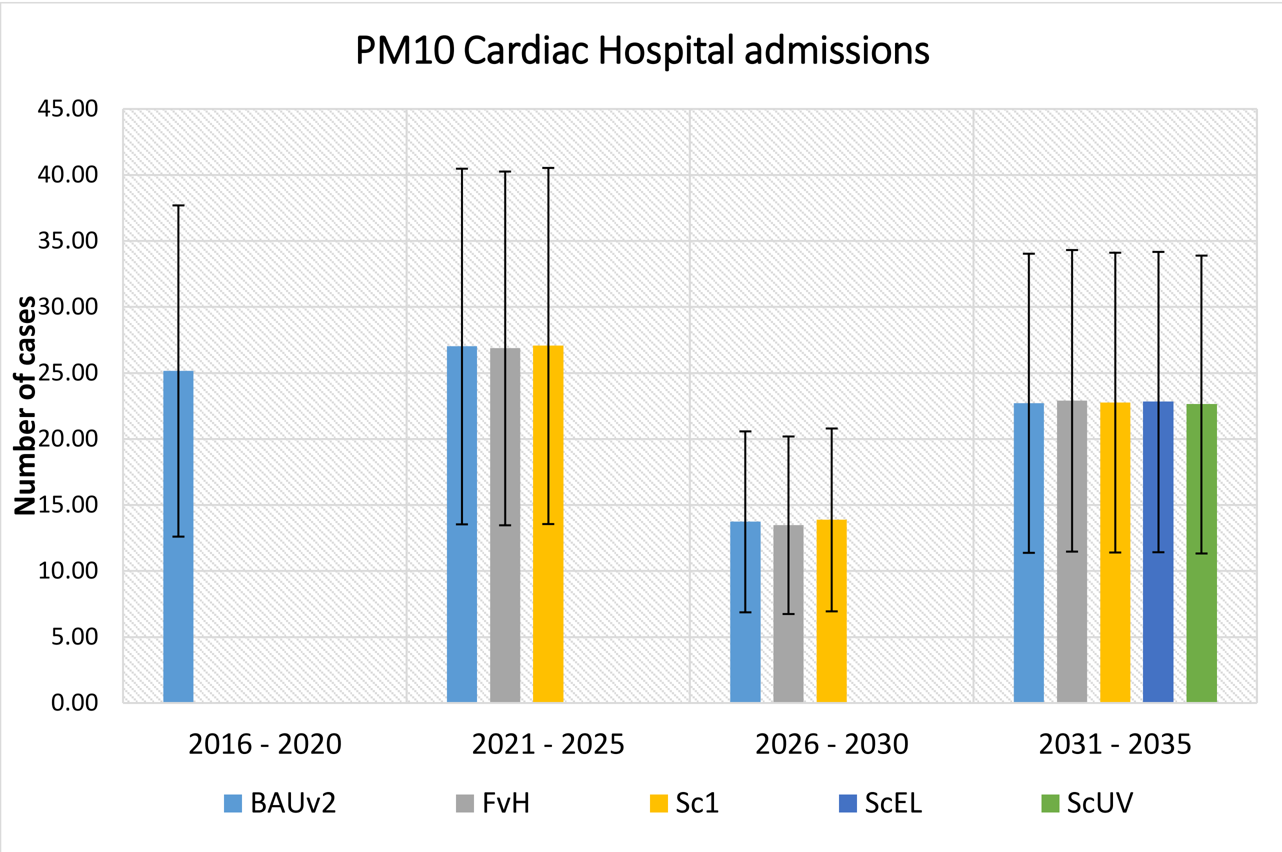
Stuttgart


PM2.5 mortality (all natural causes) >30 years old
Number of cases
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

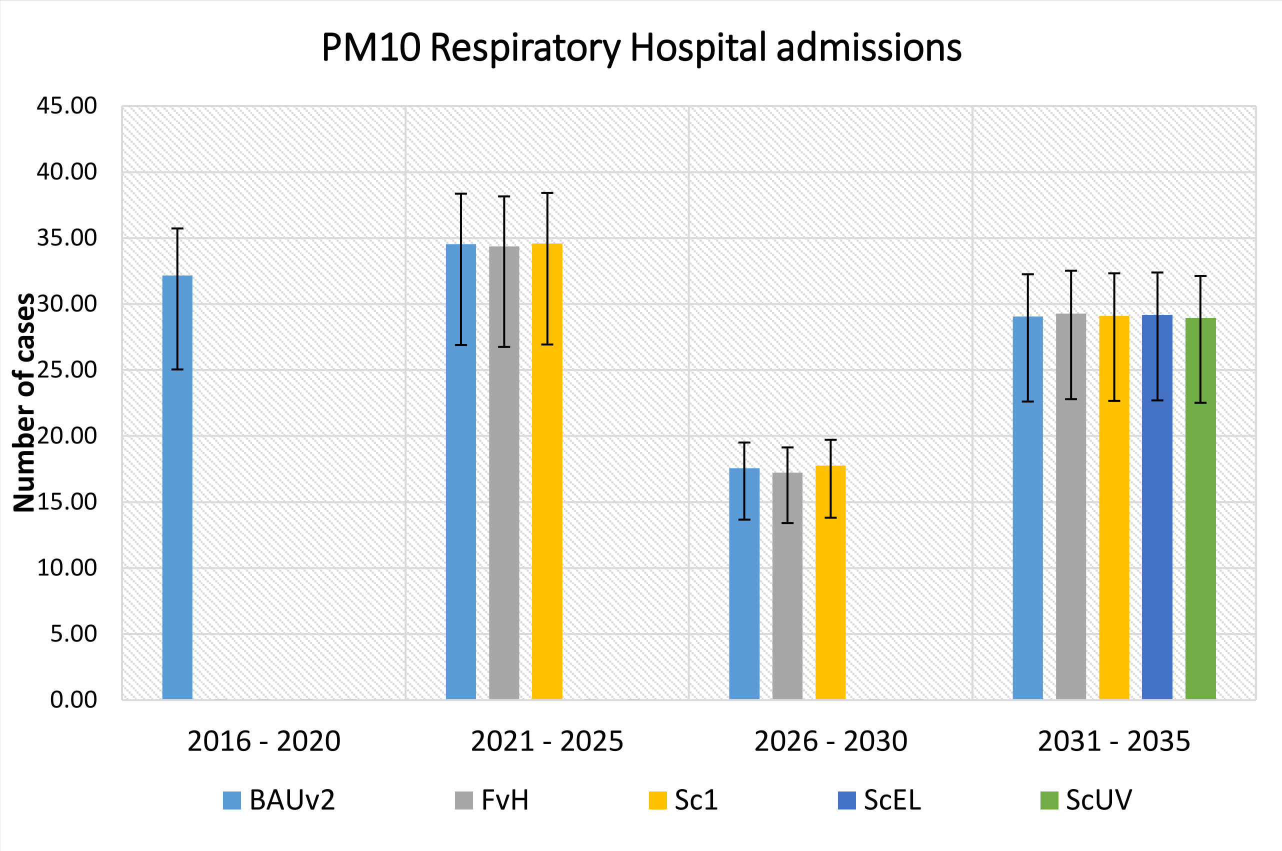

PM10 infant mortality (0-1 year)
Number of cases
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



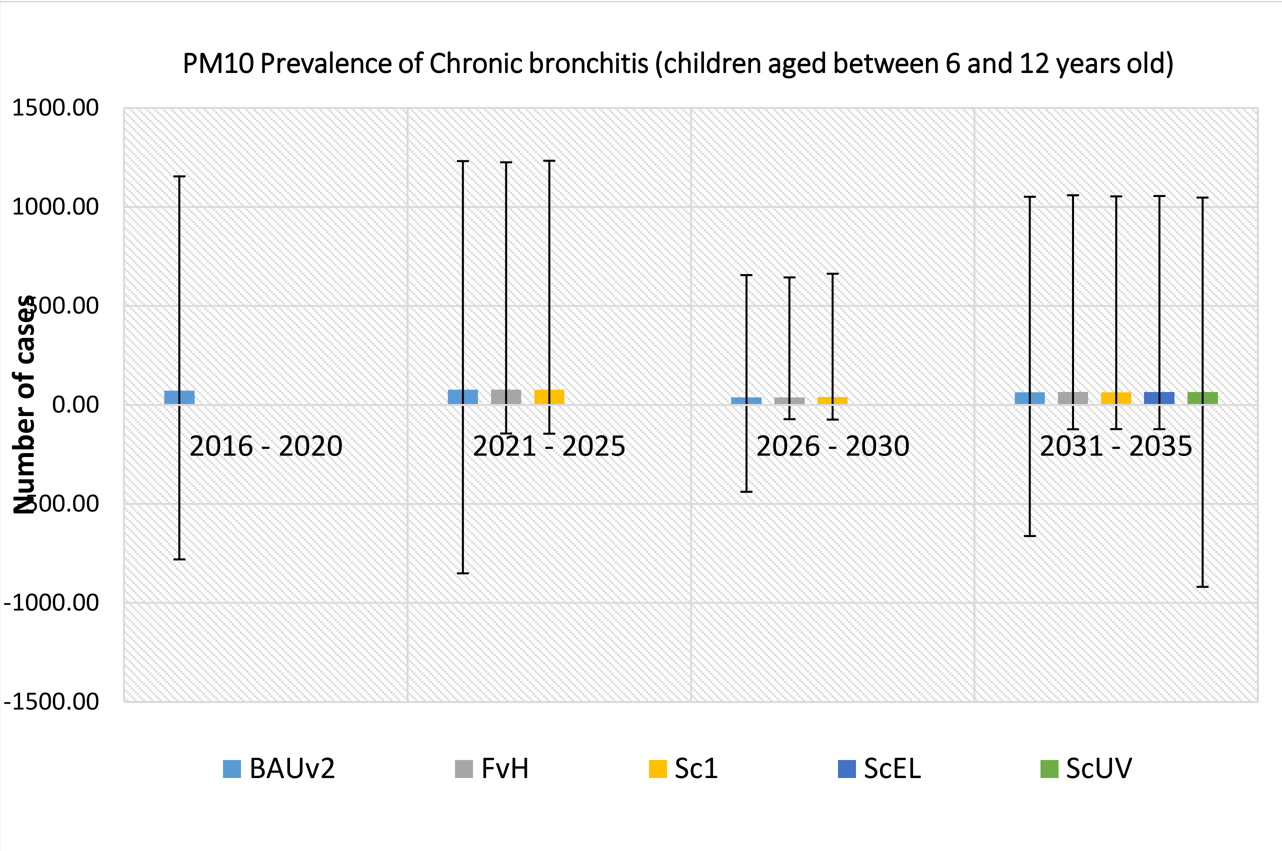
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



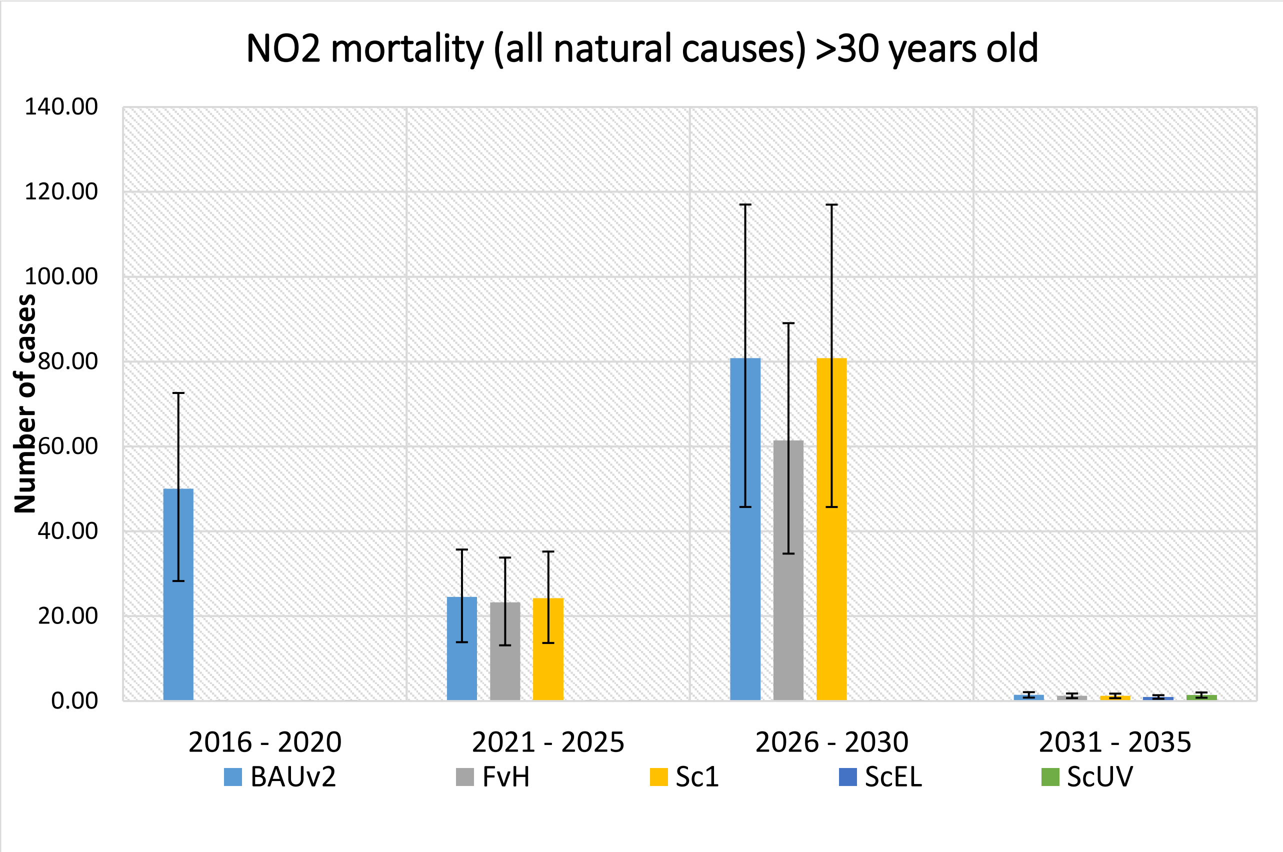
PM10 Cardiac Hospital admissions
Number of cases
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



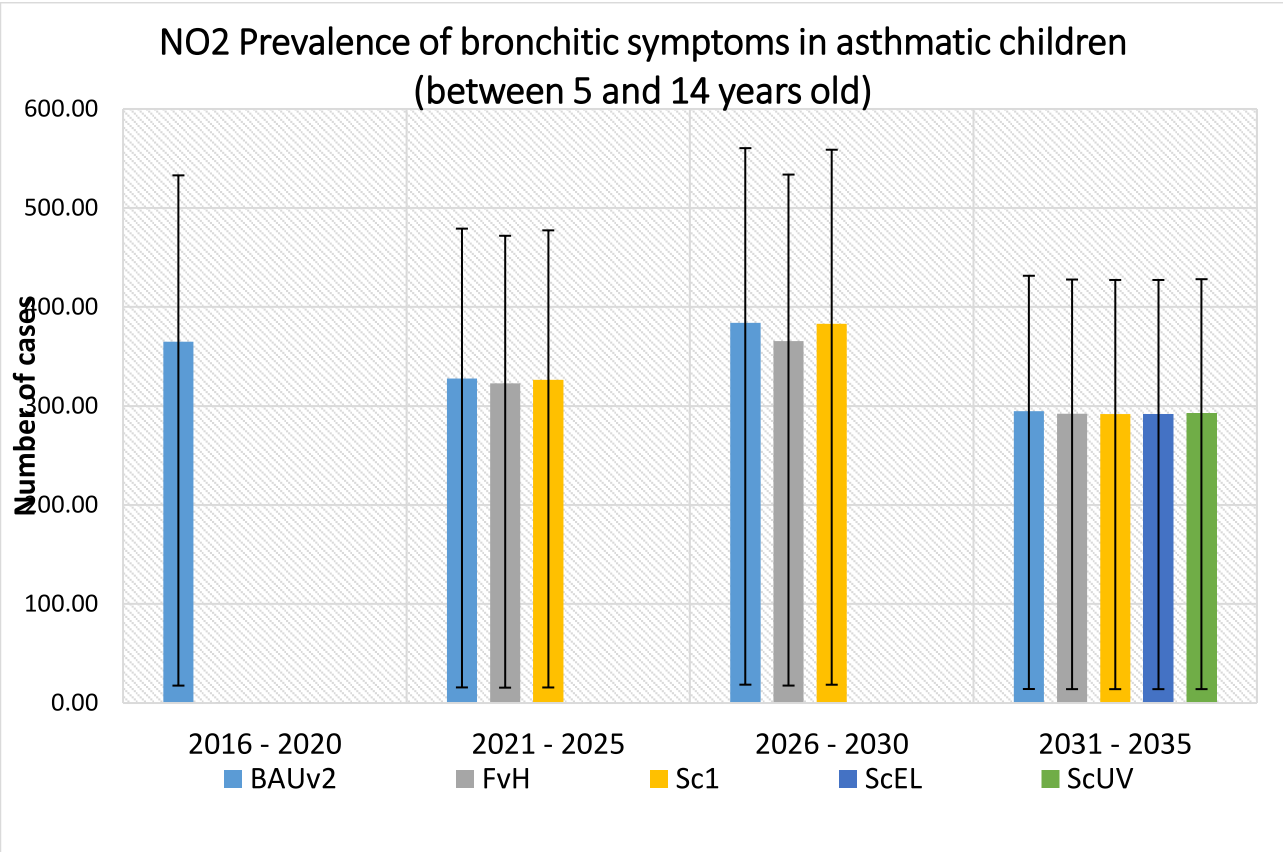
PM10 Respiratory Hospital admissions
Number of cases
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
1500.00
1000.00
500.00
0.00
-500.00
-1000.00
-1500.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

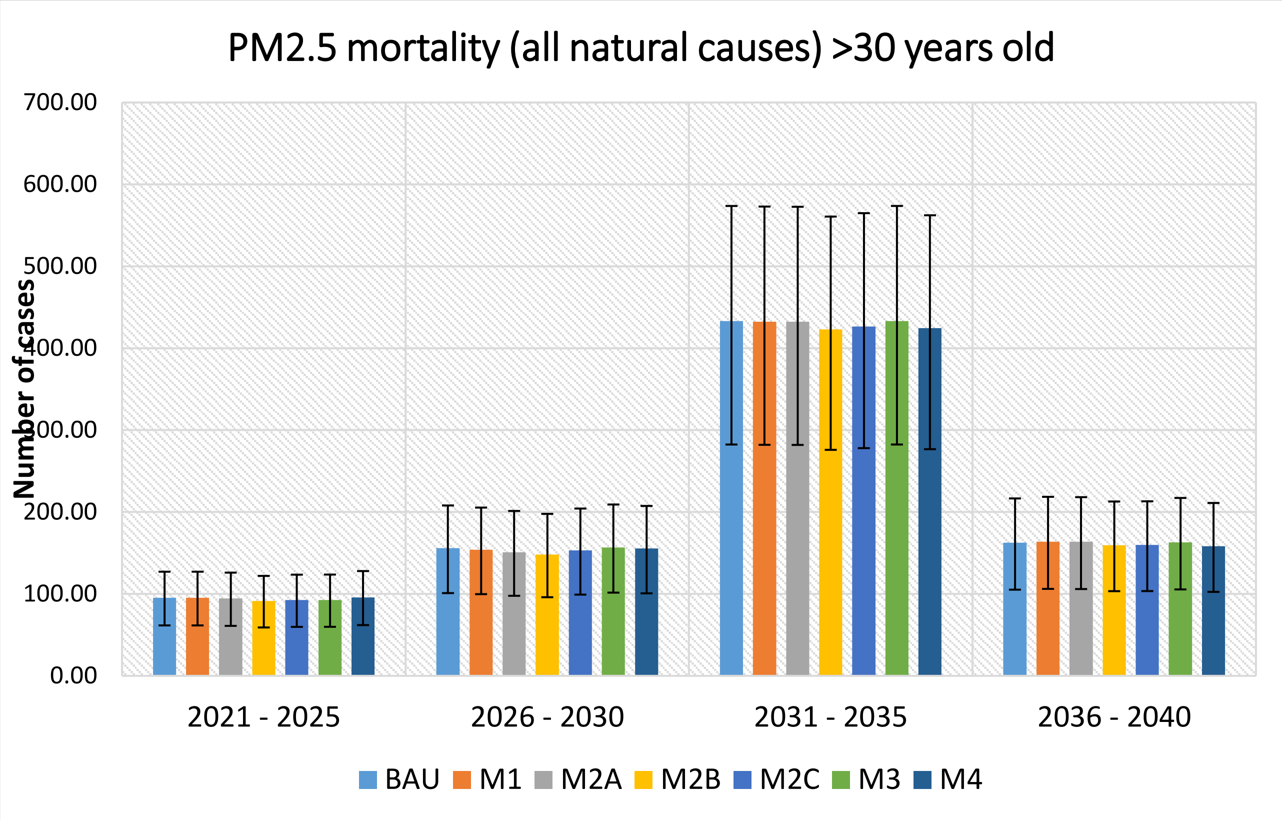


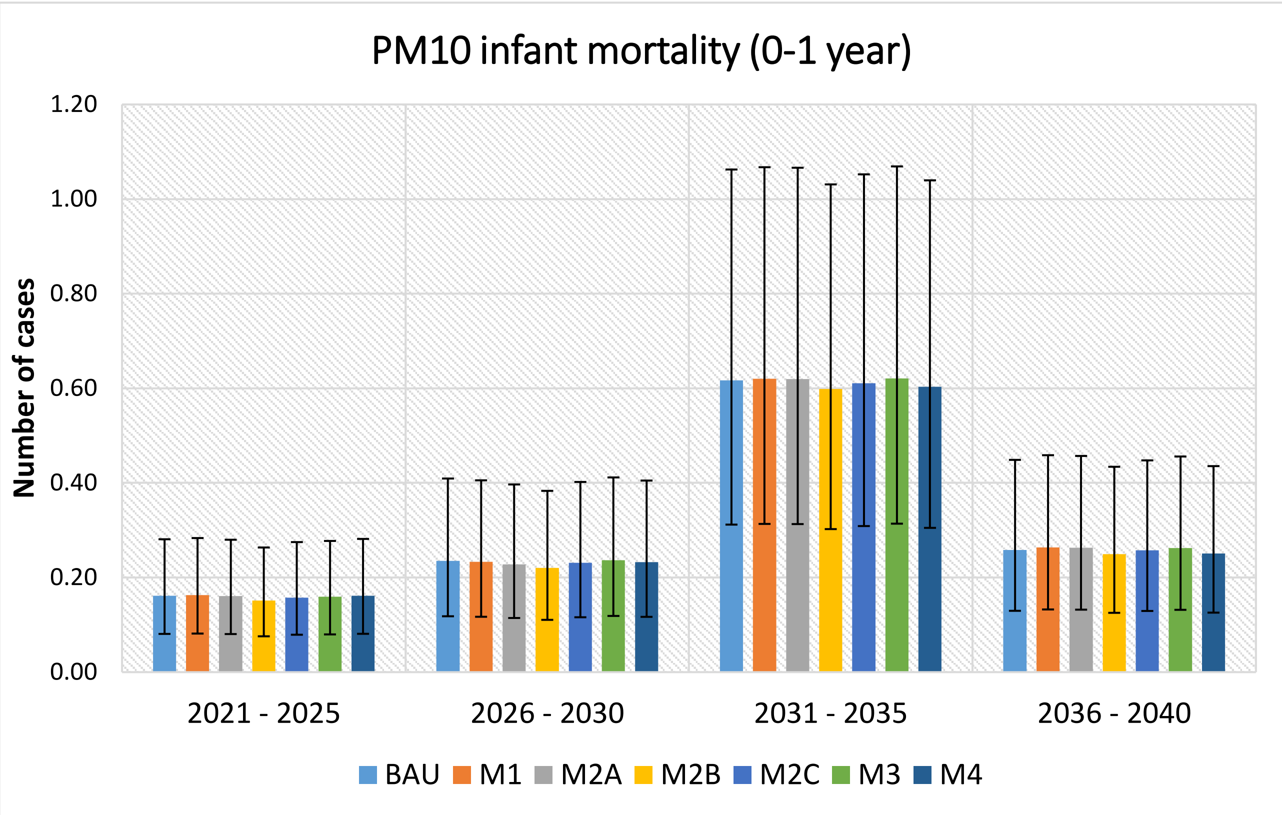
NO2 mortality (all natural causes) >30 years old
Number of cases
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

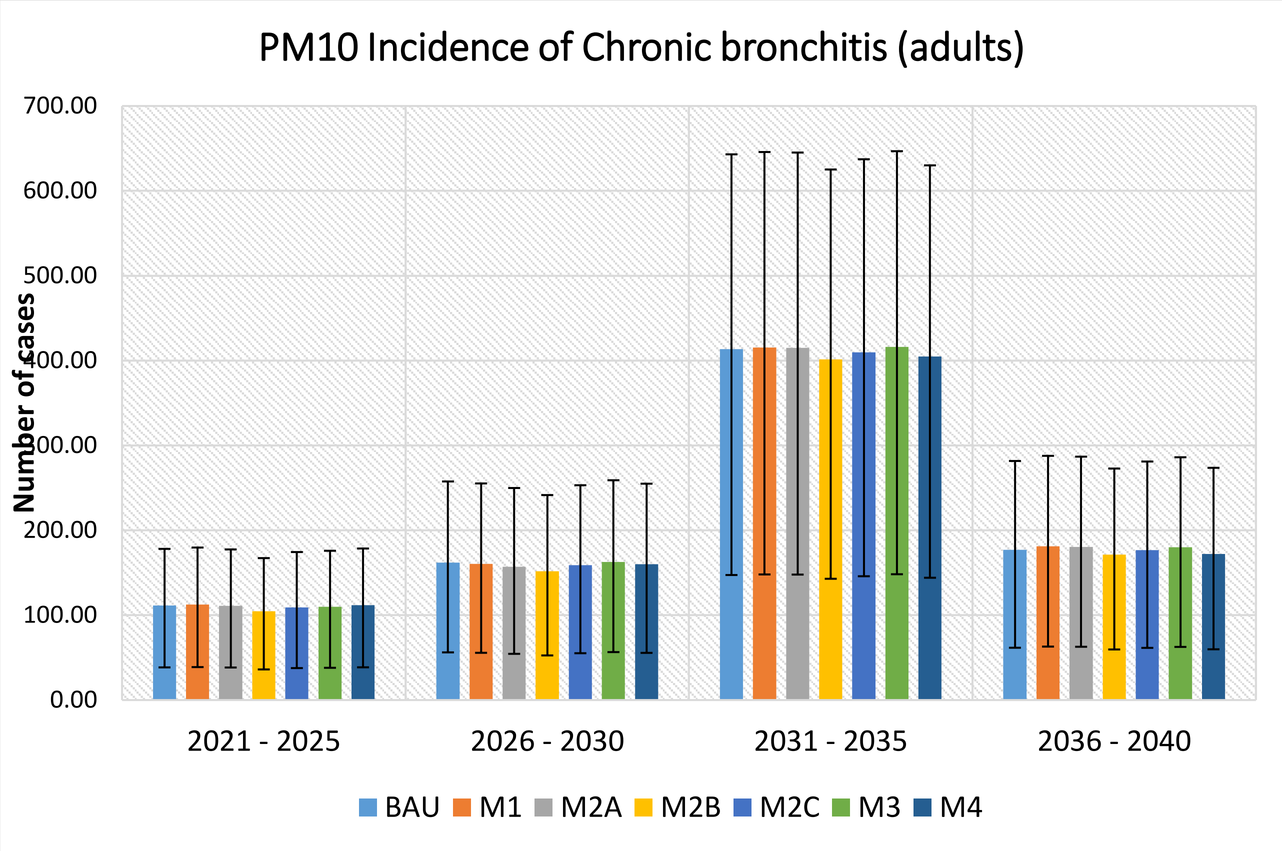


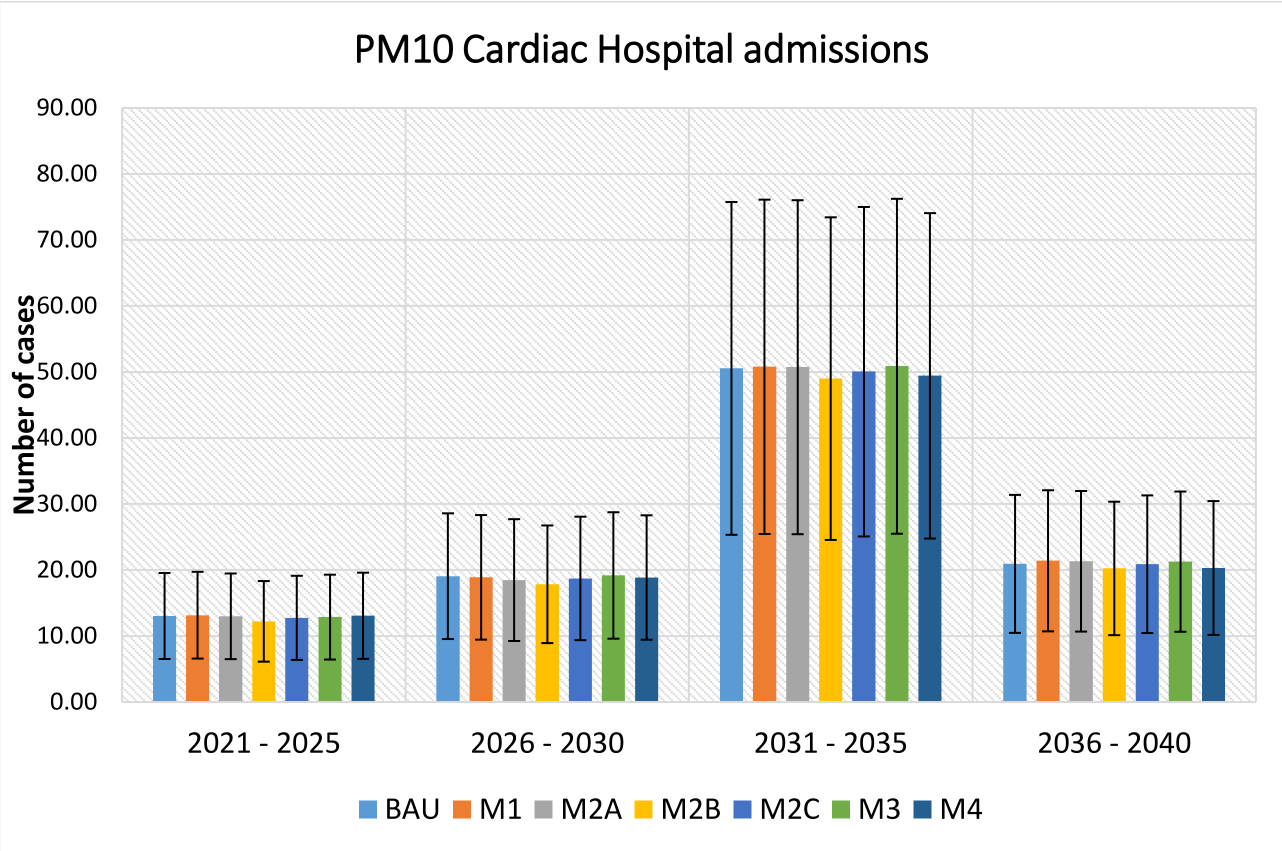
NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
600.00
500.00
400.00
300.00
200.00
100.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

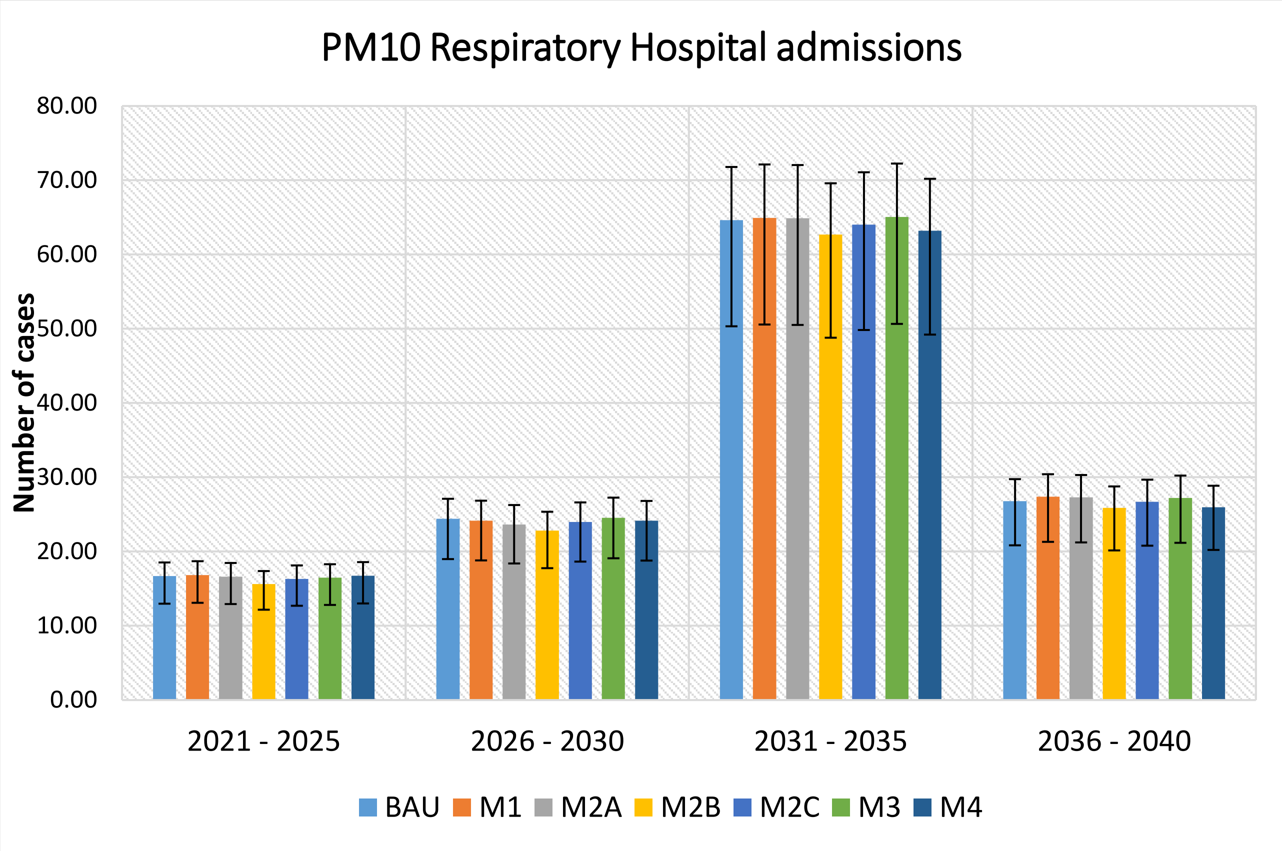
Greater Thessaloniki Area



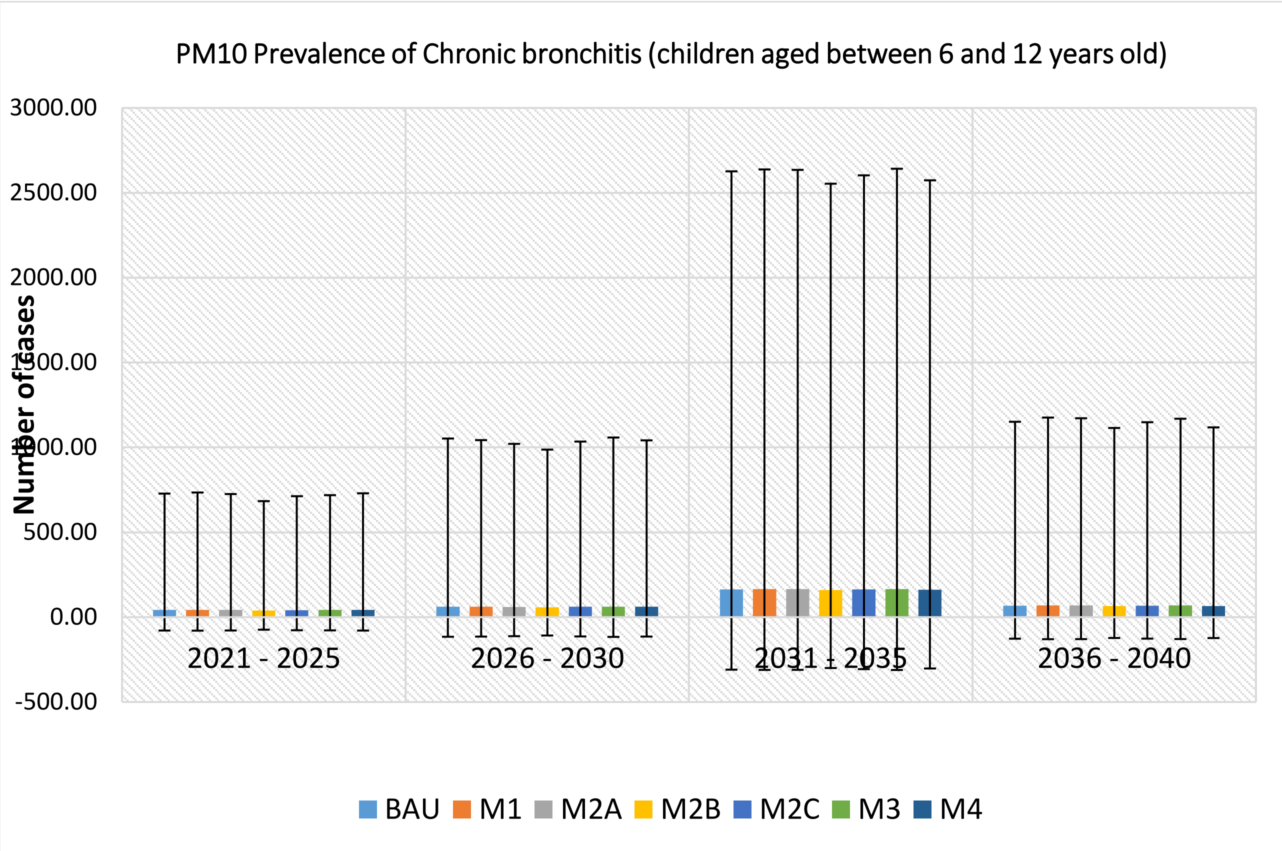



PM10 Incidence of Chronic bronchitis (adults)
Number of cases
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2A
M2B
M2C
M3
M4

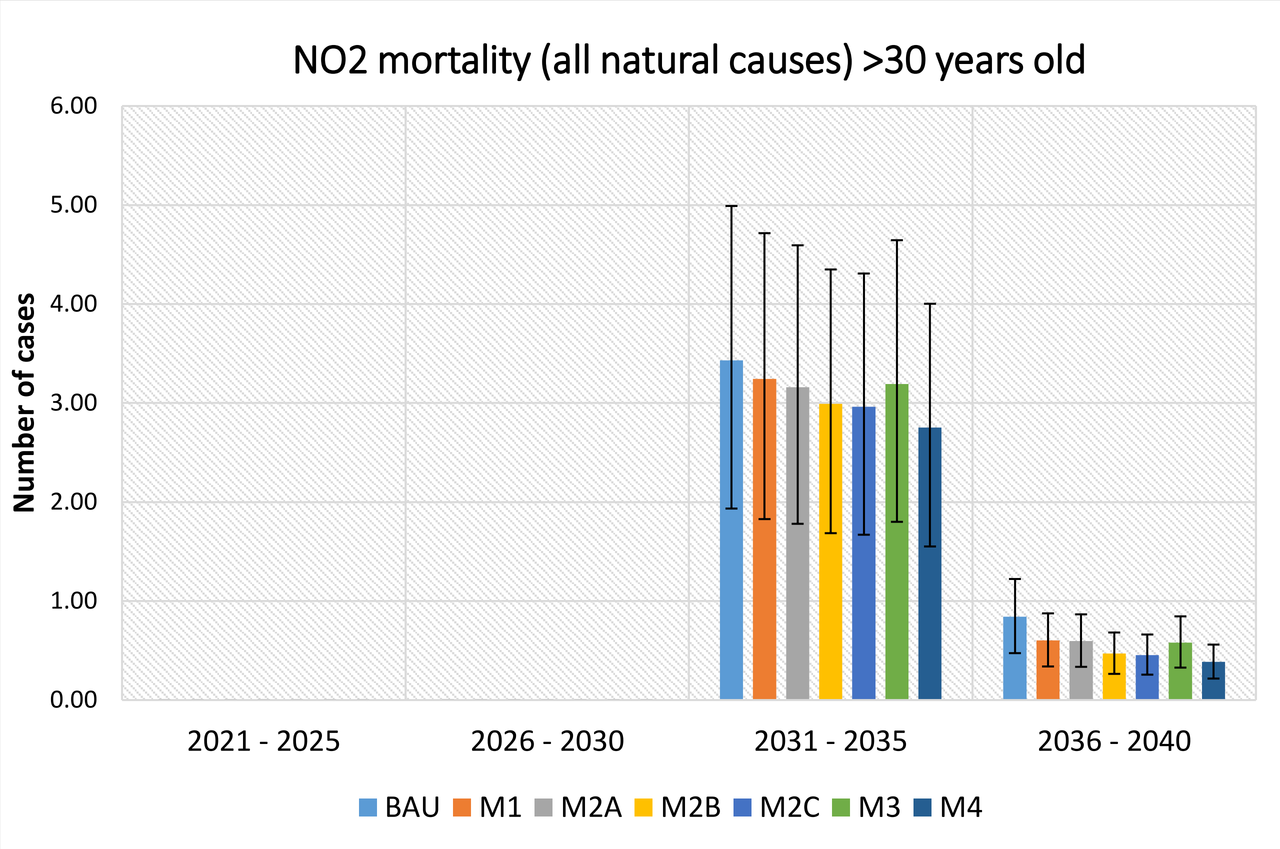

PM10 Cardiac Hospital admissions
Number of cases
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2A
M2B
M2C
M3
M4



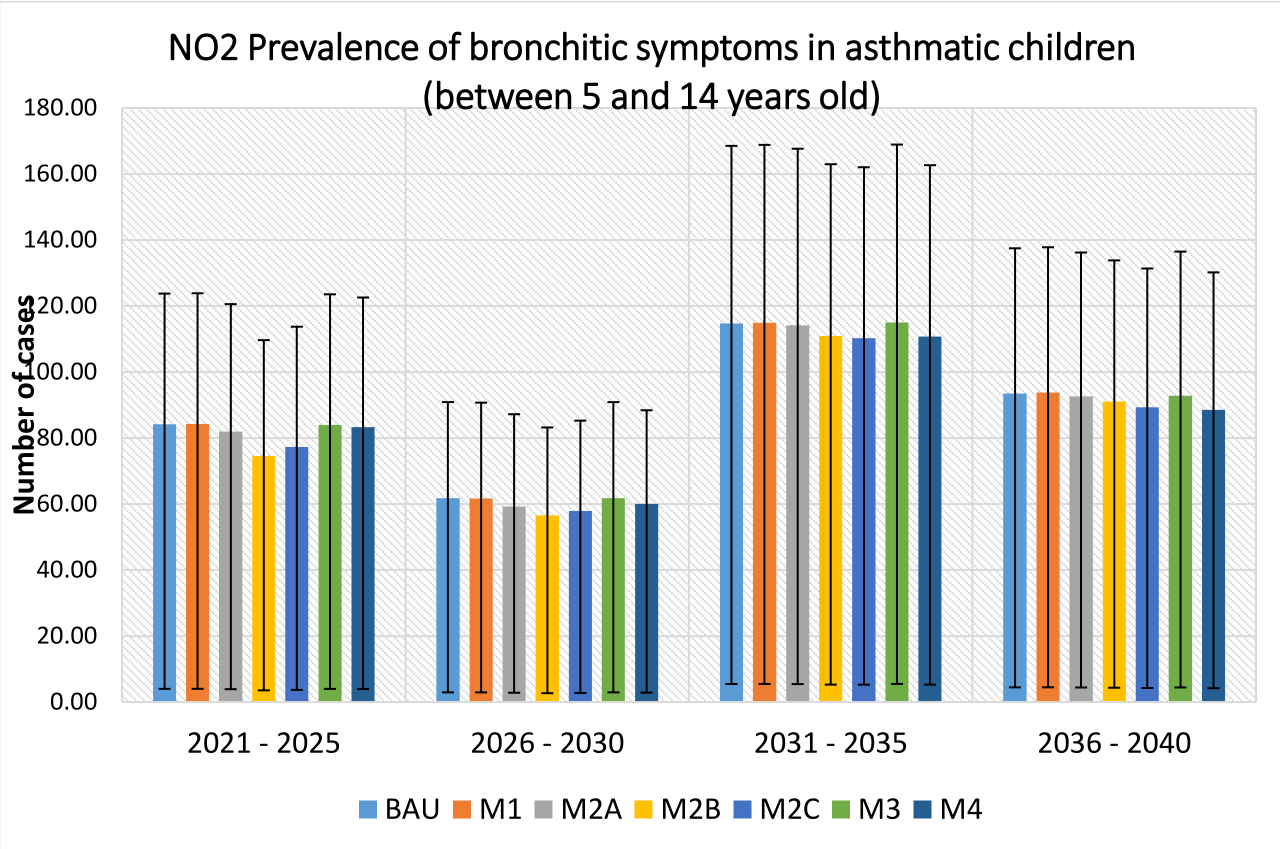
PM10 Respiratory Hospital admissions
Number of cases
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU M1 M2A M2B M2C M3 M4



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
-500.00
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU M1 M2A M2B M2C M3 M4



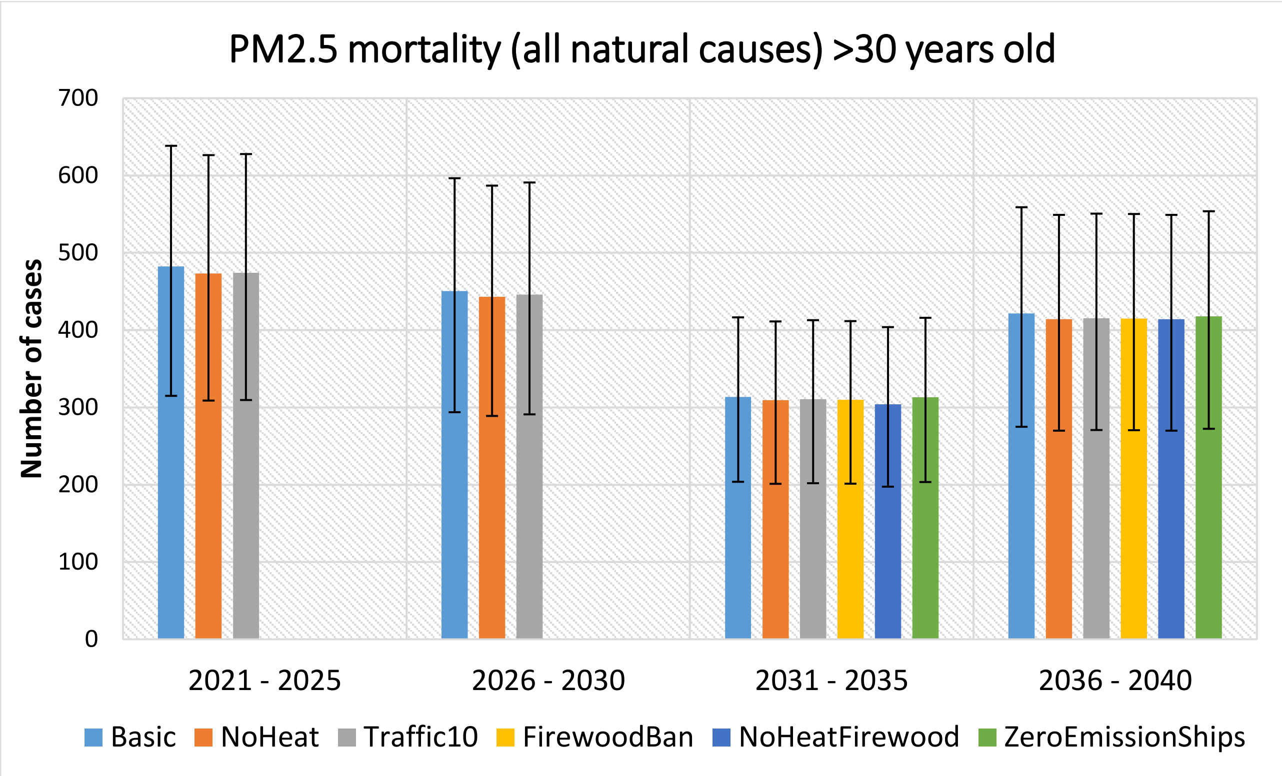
NO2 mortality (all natural causes) >30 years old
Number of cases
6.00
5.00
4.00
3.00
2.00
1.00
0.00
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2A
M2B
M2C
M3
M4

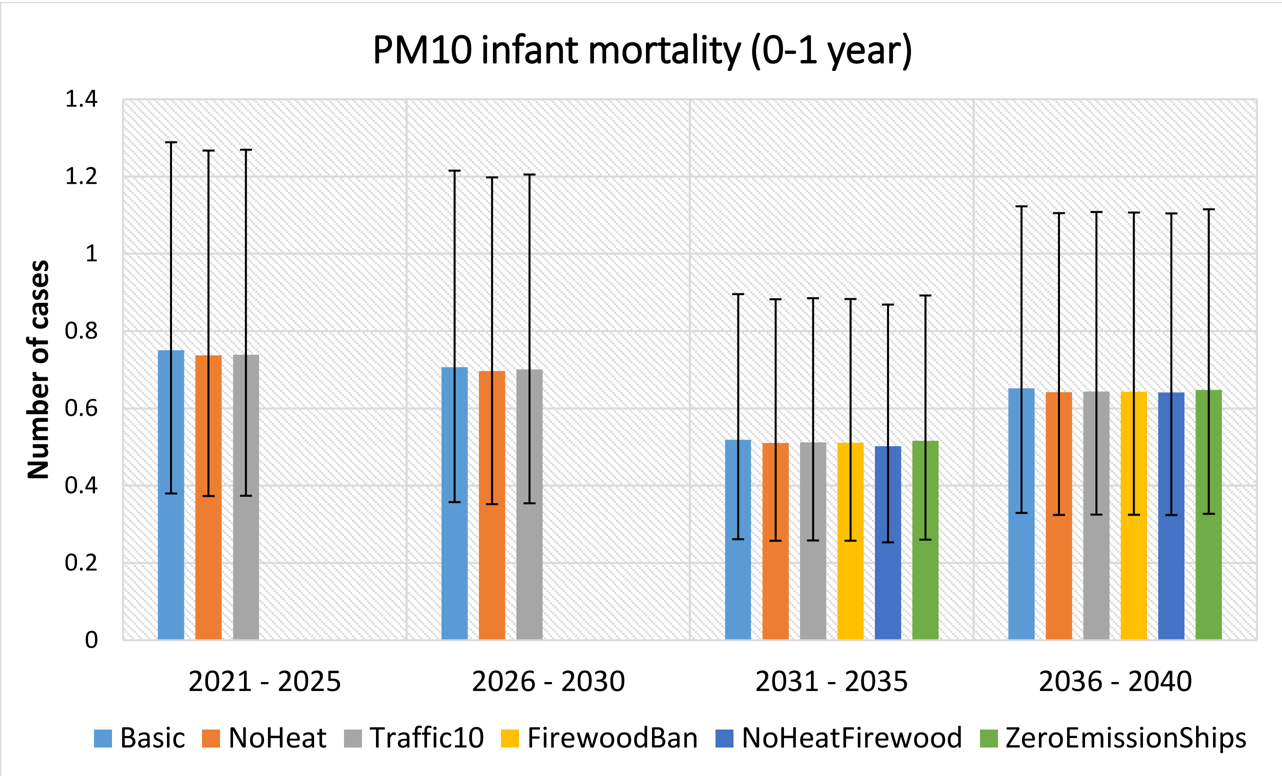


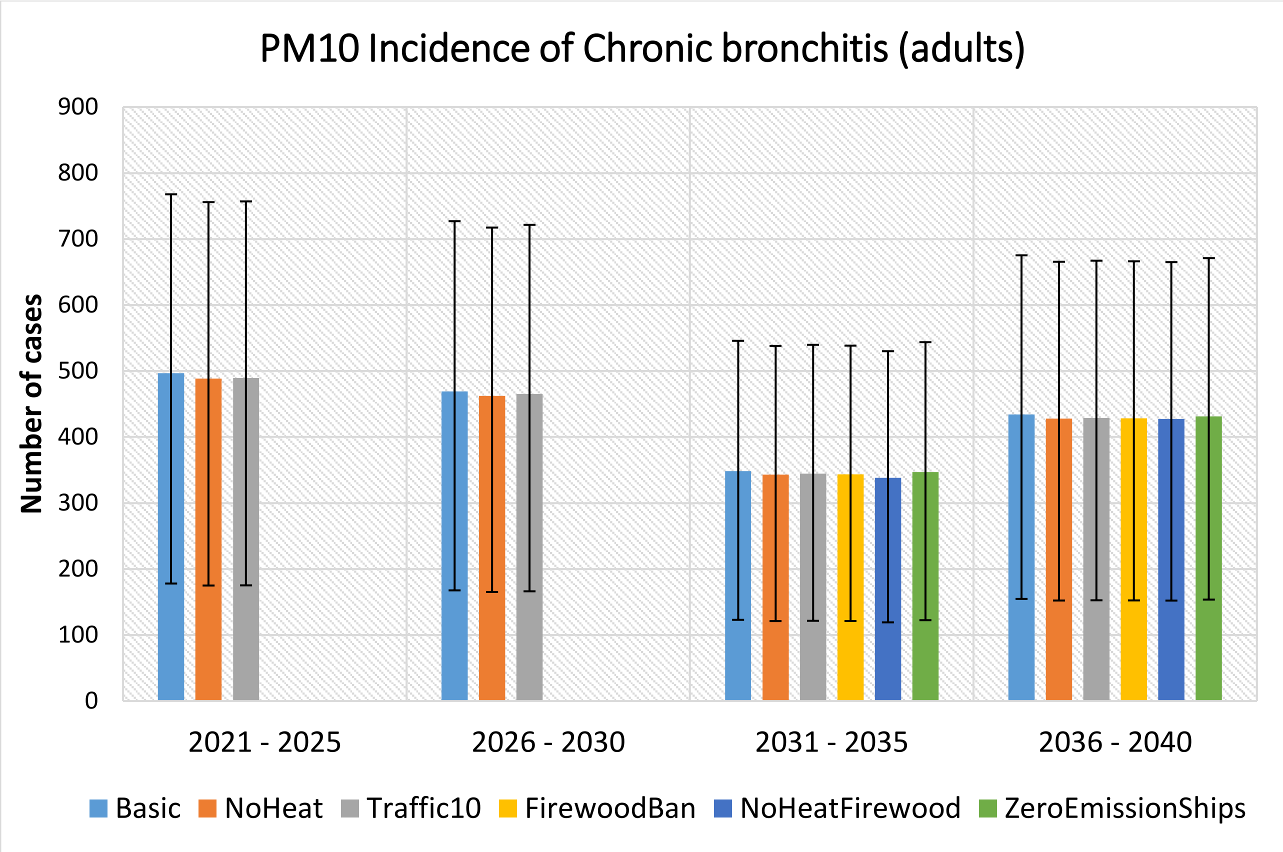
NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2A
M2B
M2C
M3
M4

Health impact charts for the whole simulated domains of the ICARUS cities

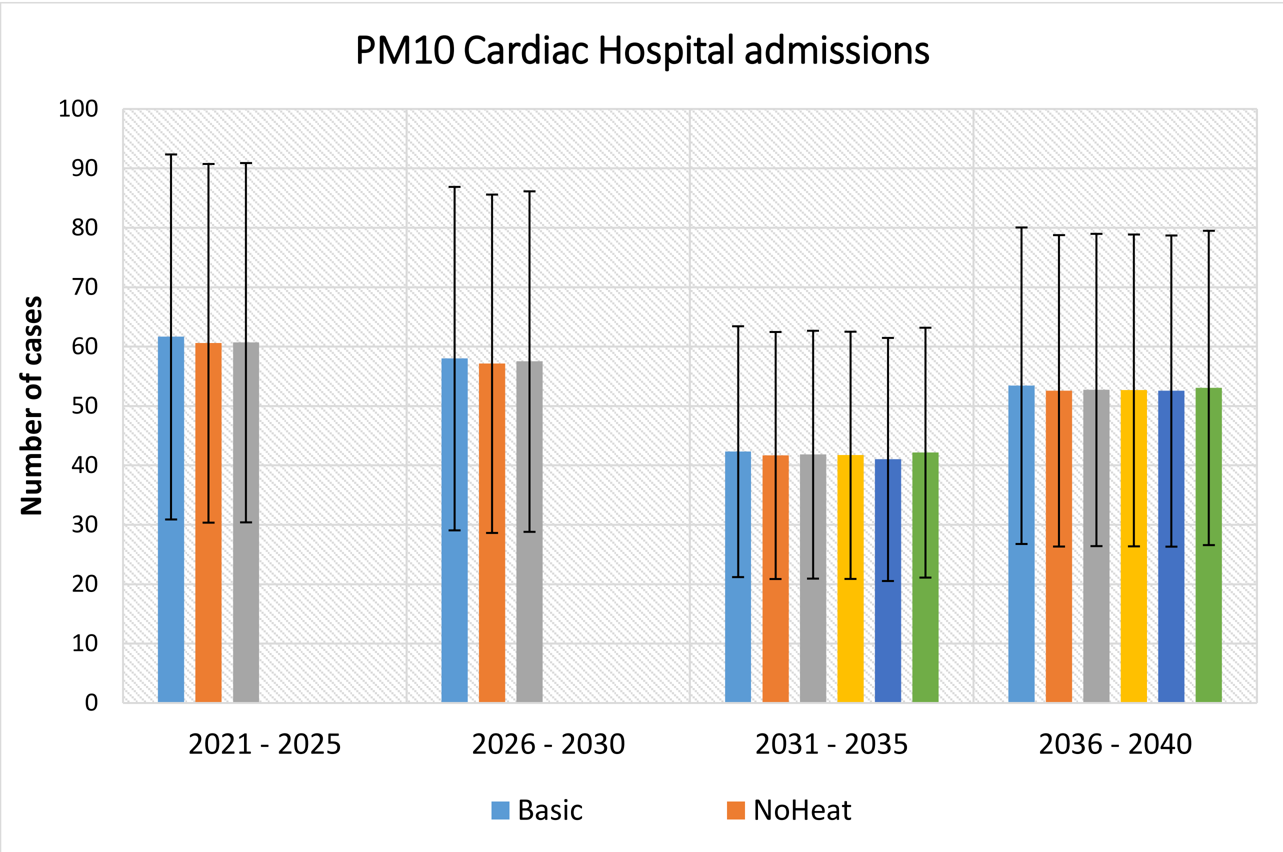
Basel



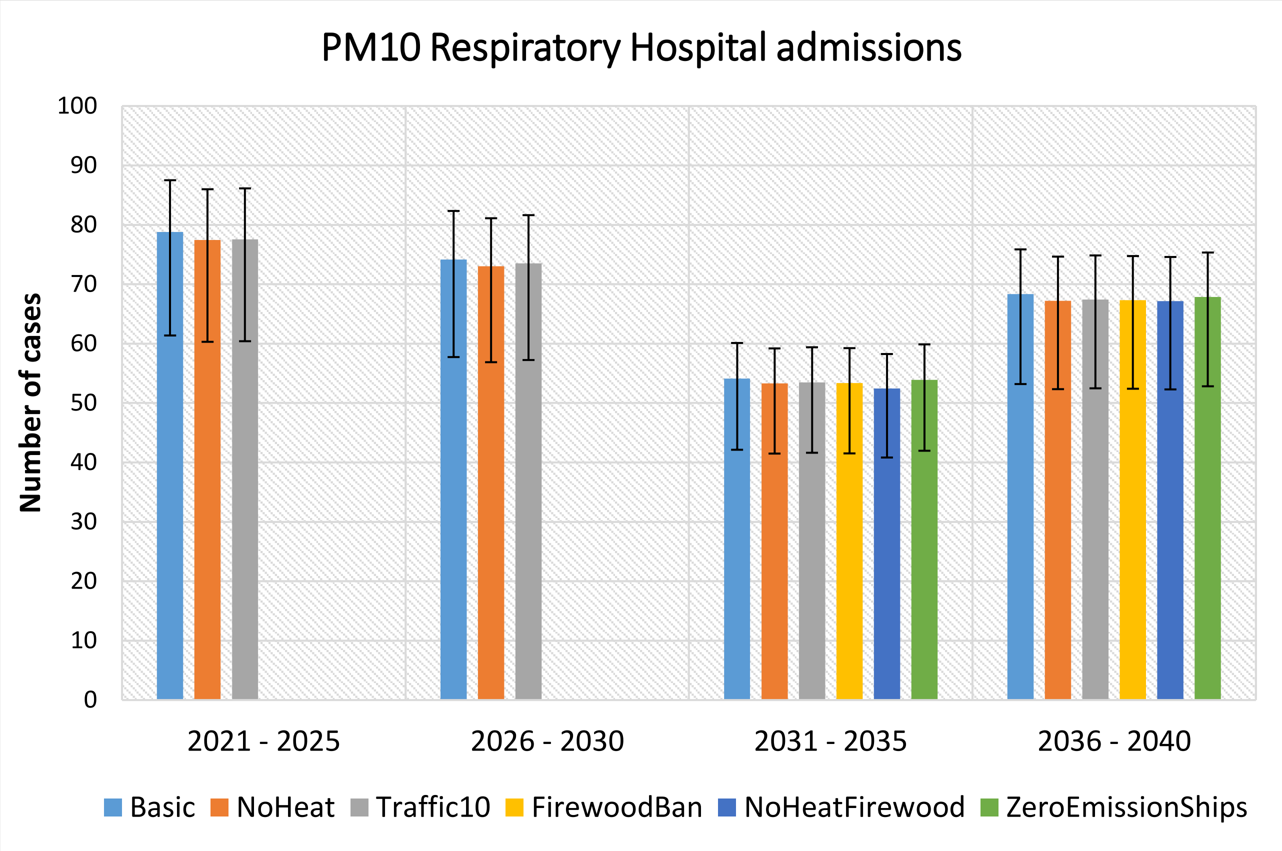


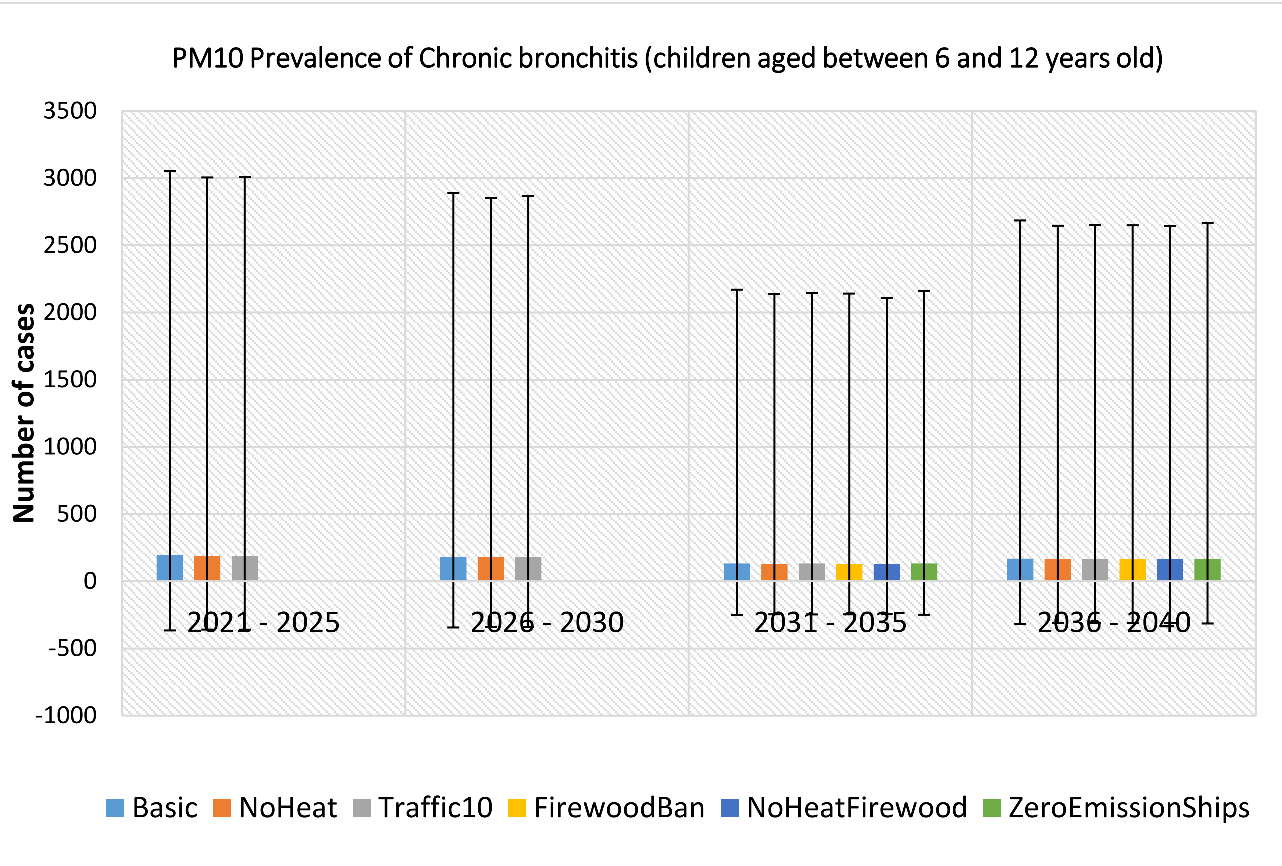


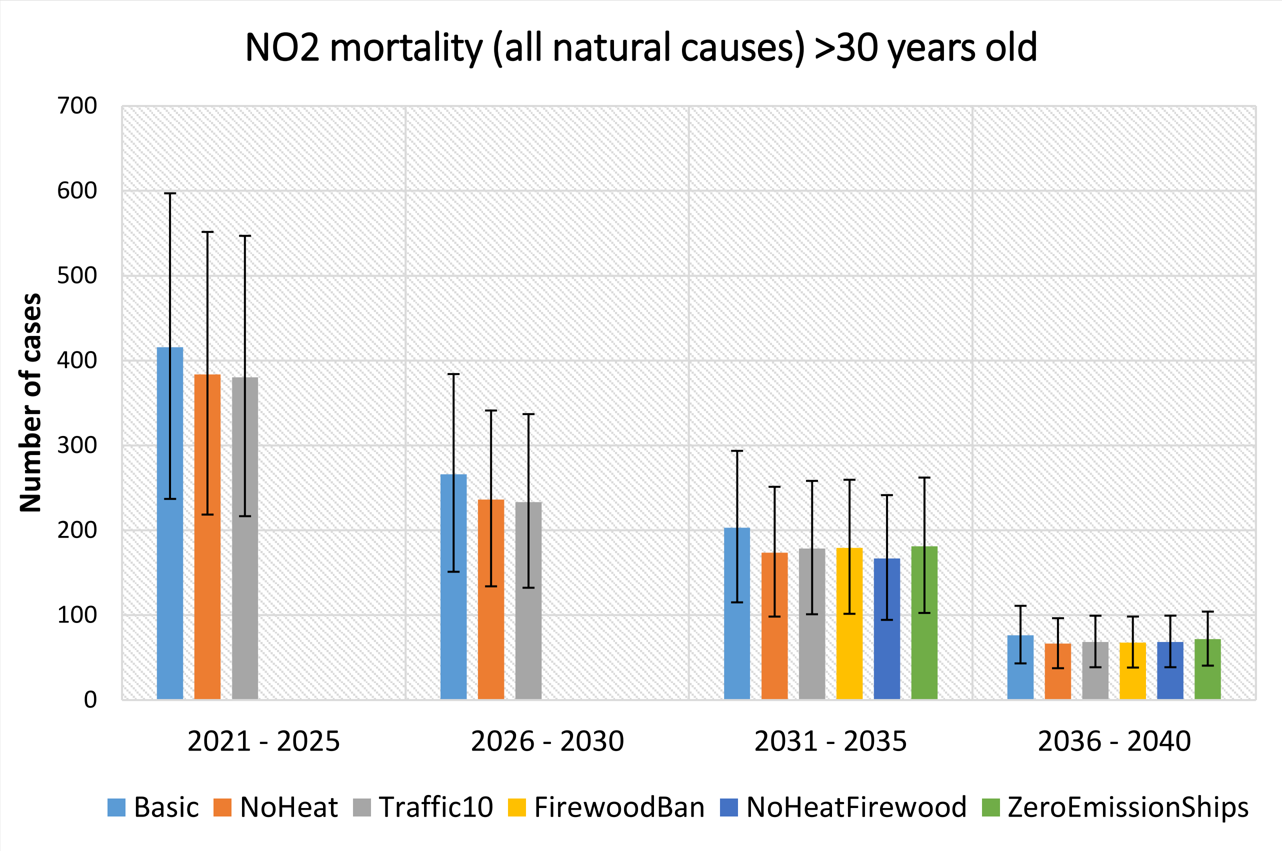
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
900
800
700
600
500
400
300
200
100
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips



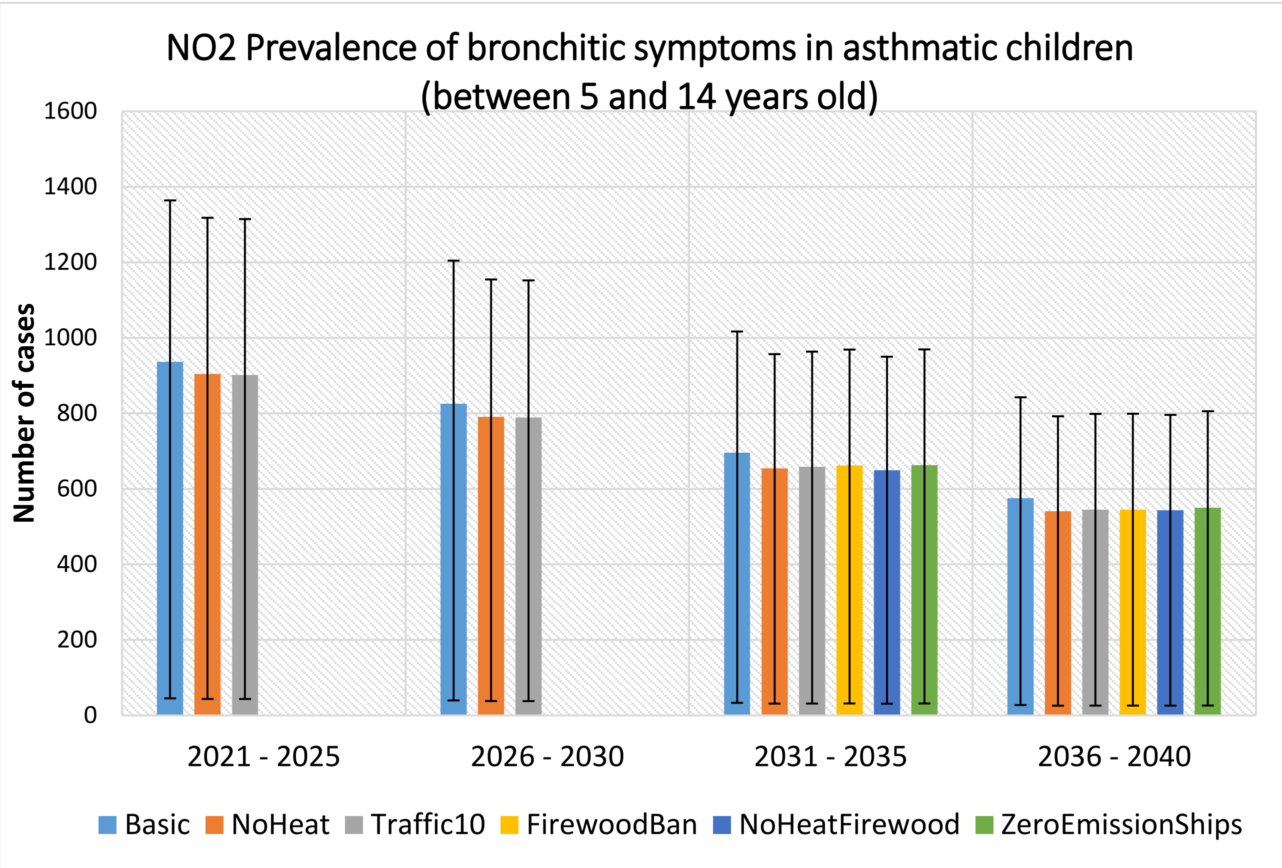
PM10 Cardiac Hospital admissions
Number of cases
100
90
80
70
60
50
40
30
20
10
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat


PM10 Respiratory Hospital admissions
Number of cases
100
90
80
70
60
50
40
30
20
10
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips


PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
3500
3000
2500
2000
1500
1000
500
0
-500
-1000
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

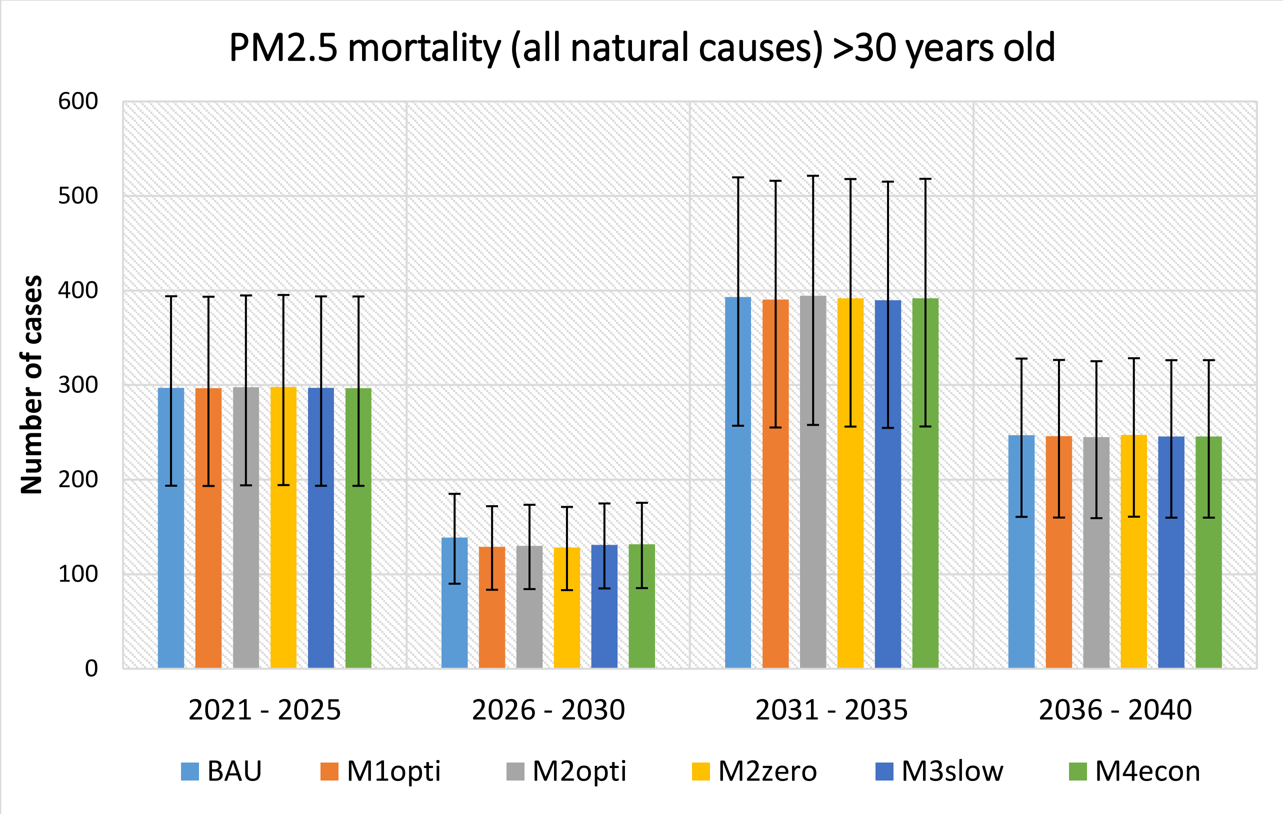


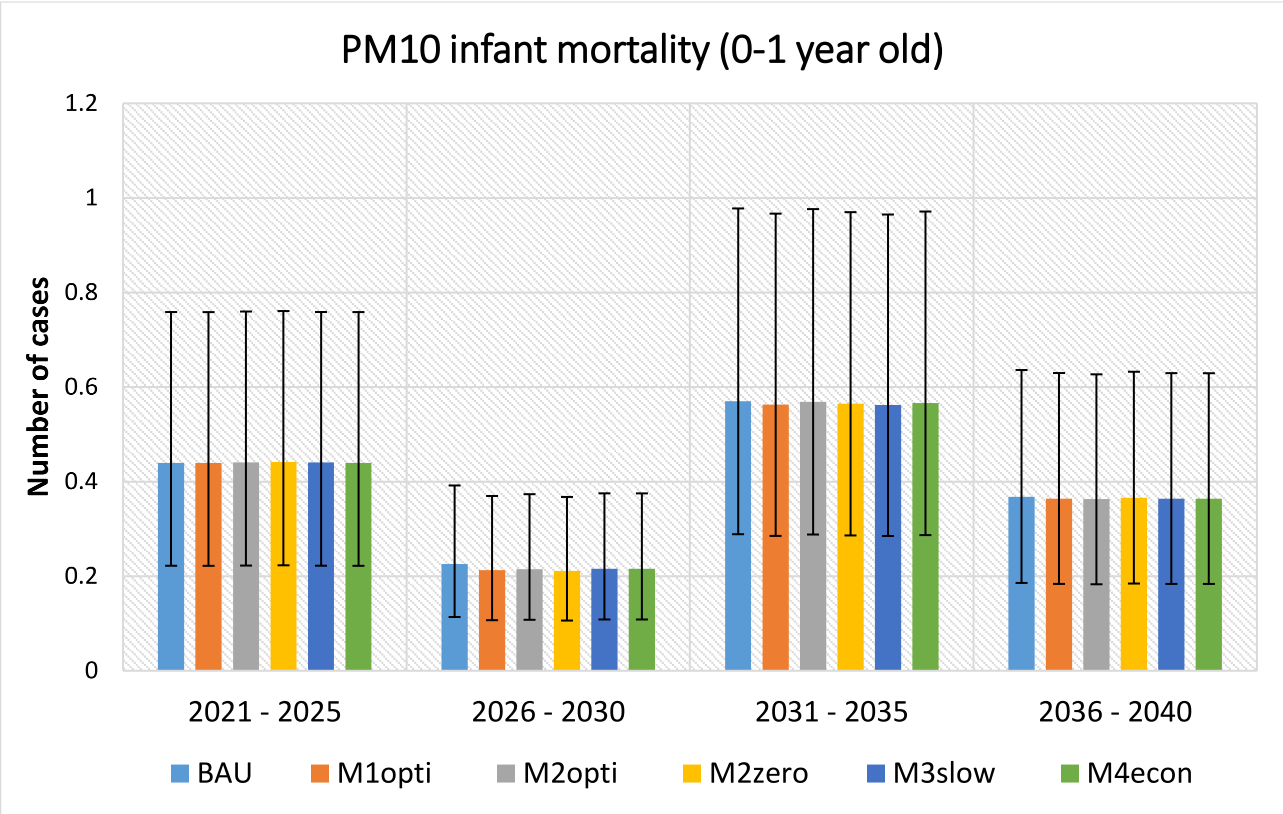
NO2 mortality (all natural causes) >30 years old
Number of cases
700
600
500
400
300
200
100
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

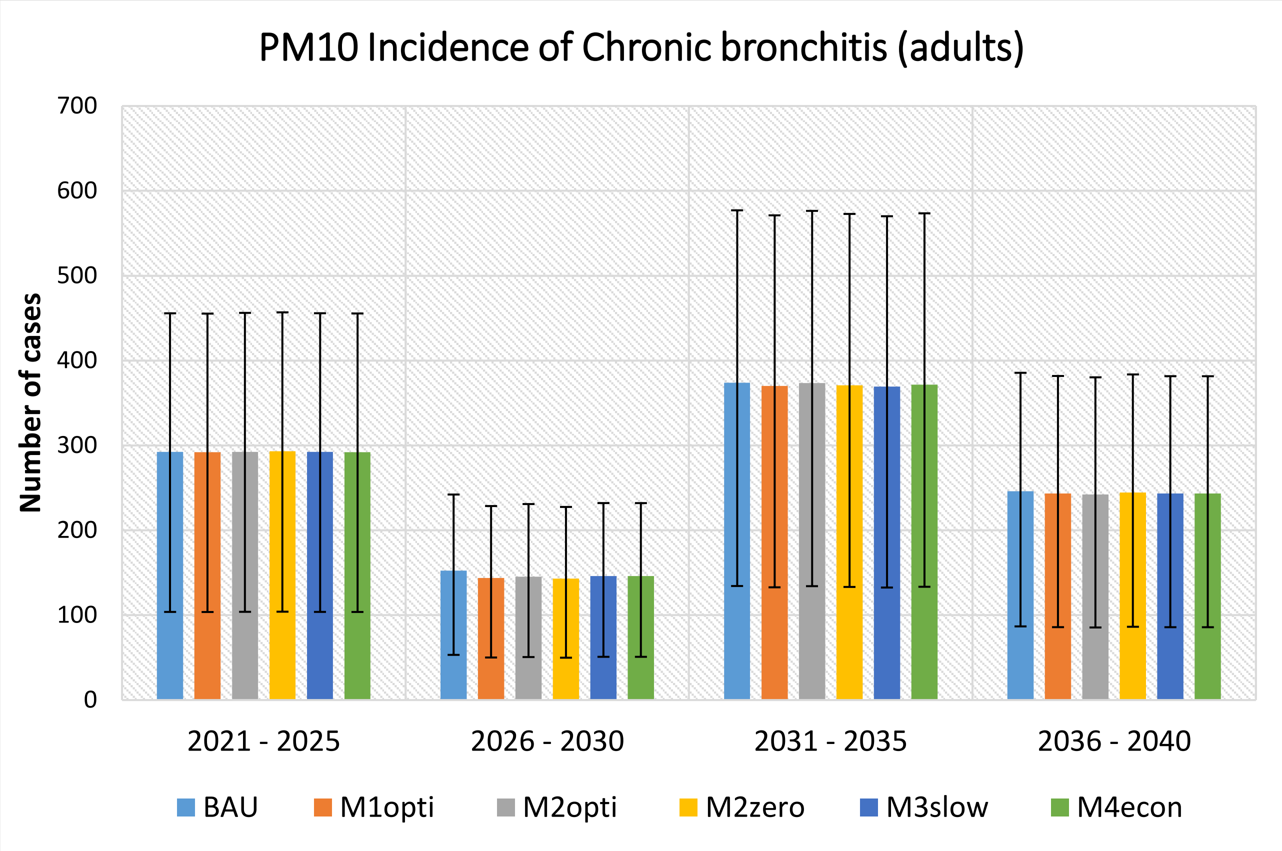


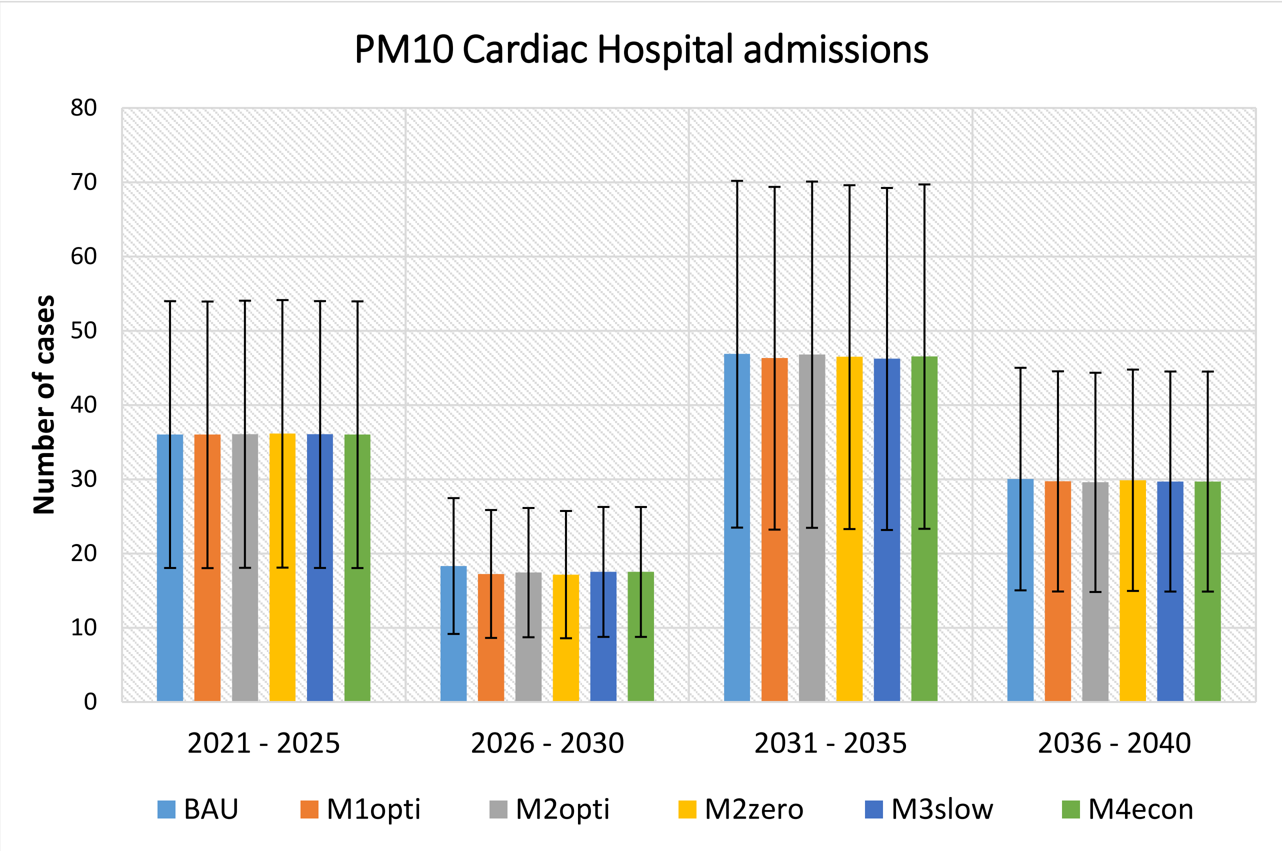
NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
1600
1400
1200
1000
800
600
400
200
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
Basic
NoHeat
Traffic10
FirewoodBan
NoHeatFirewood
ZeroEmissionShips

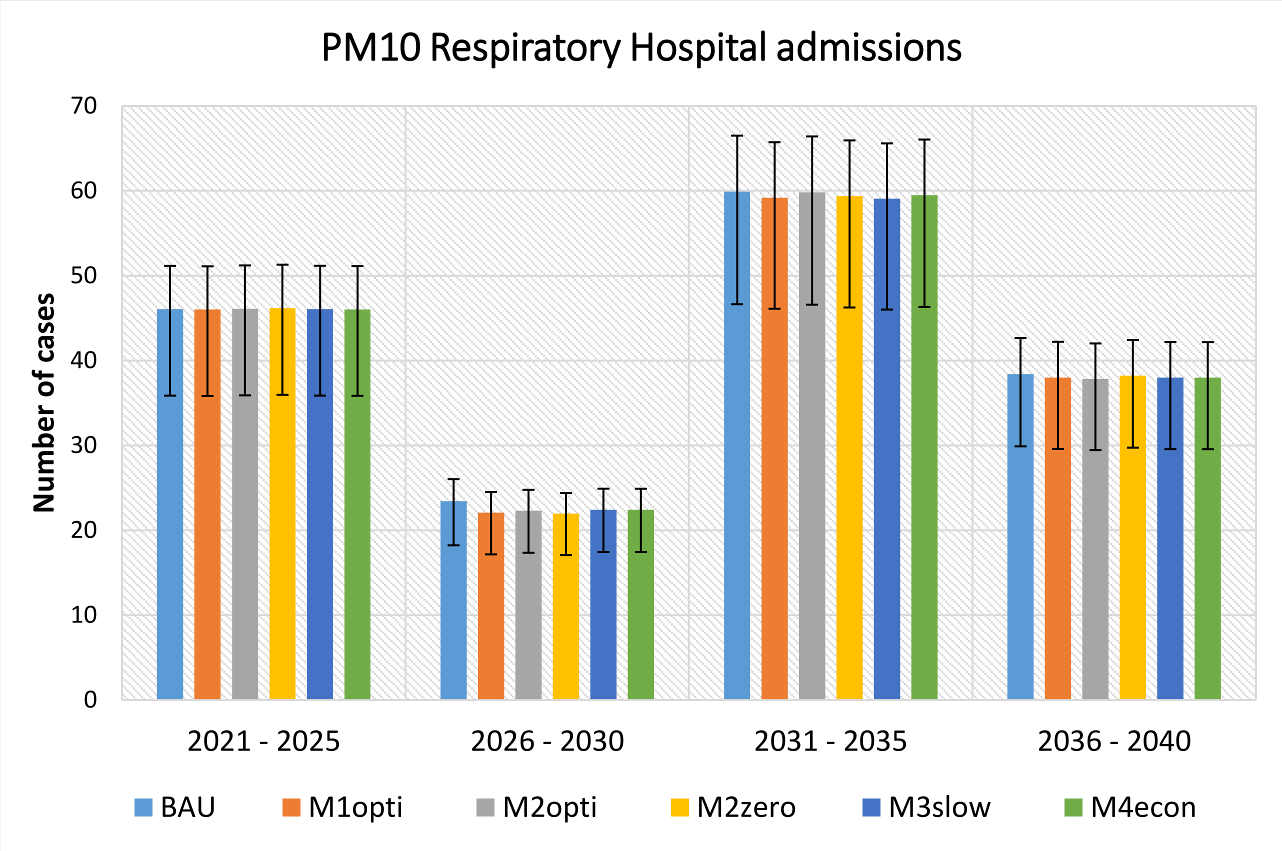
Brno

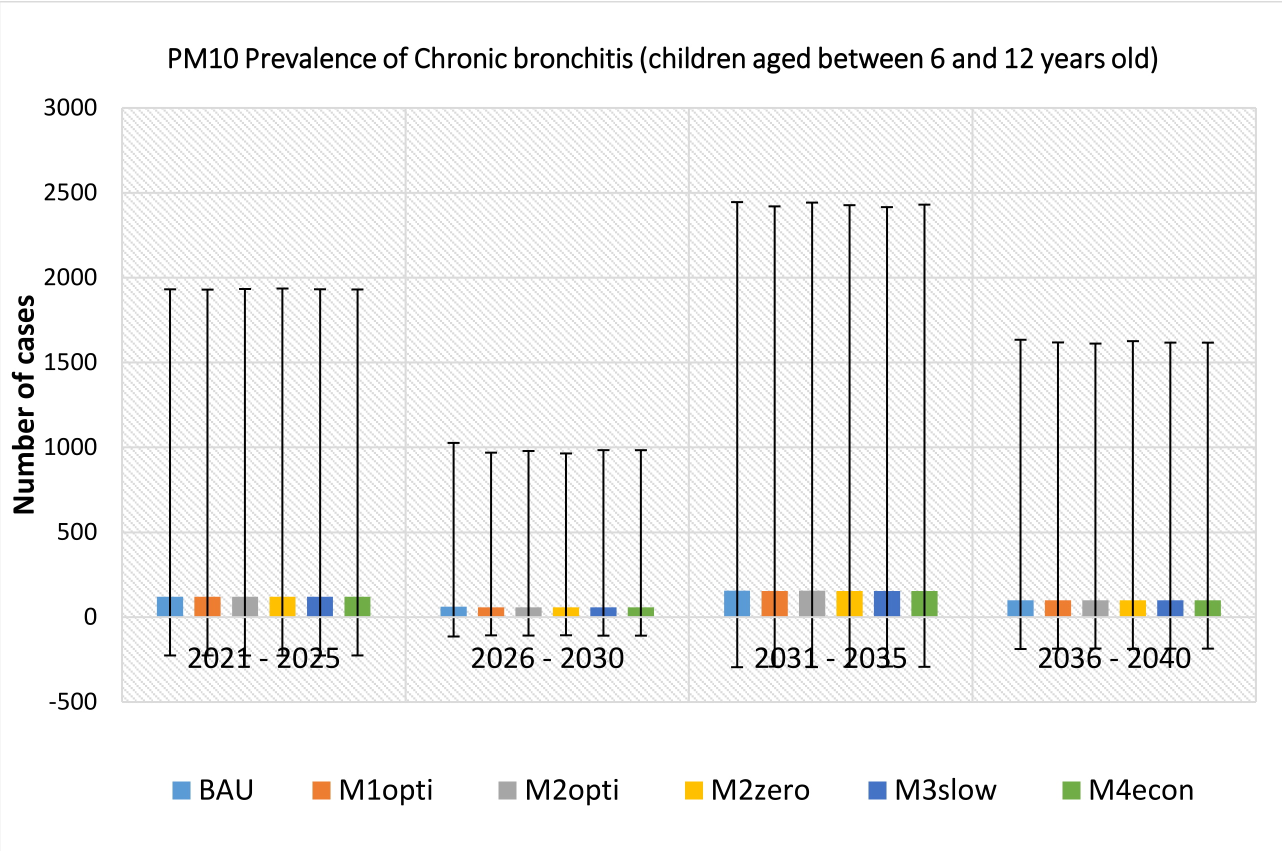

PM2.5 mortality (all natural causes) >30 years old
Number of cases
600
500
400
300
200
100
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

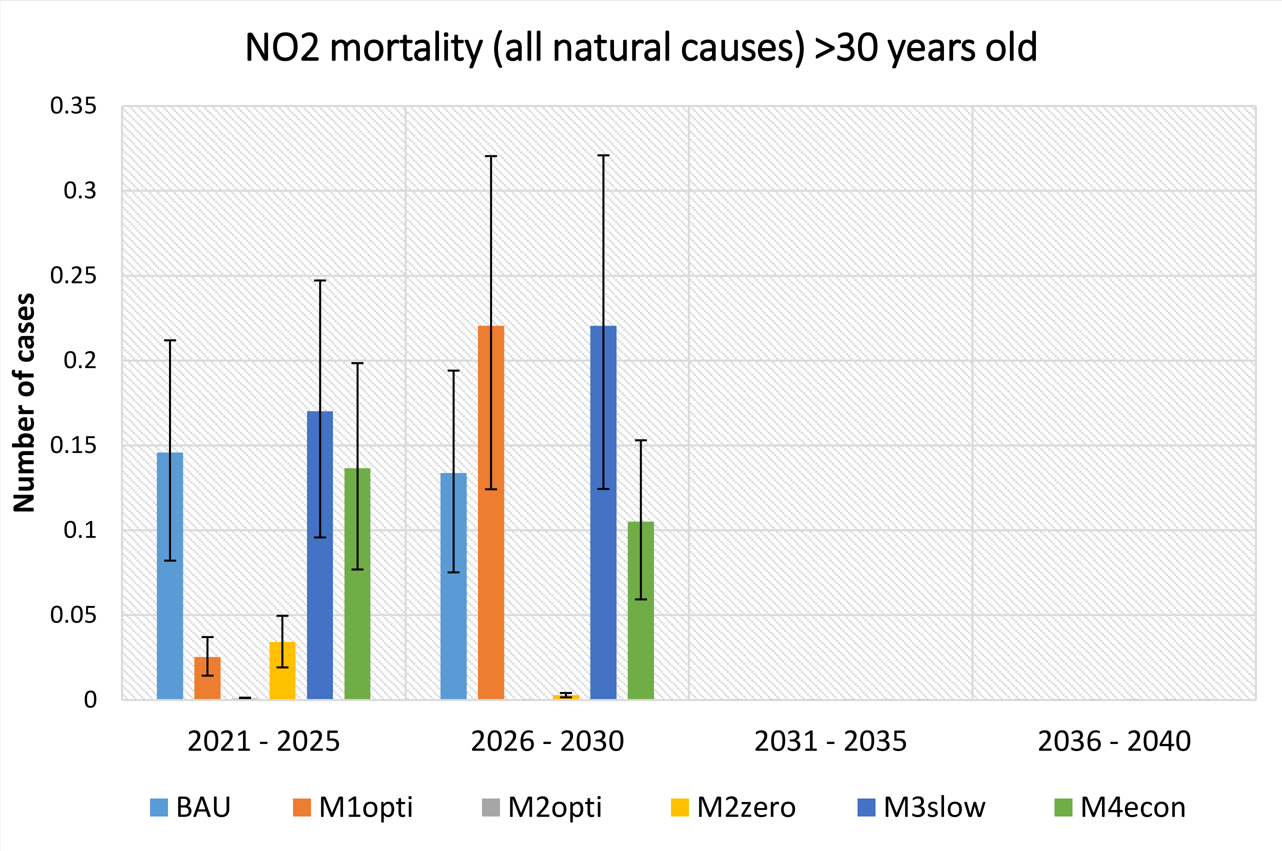

PM10 infant mortality (0-1 year old)
Number of cases
1.2
1
0.8
0.6
0.4
0.2
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ


PM10 Incidence of Chronic bronchitis (adults)
Number of cases
0
100
200
300
400
500
600
700
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

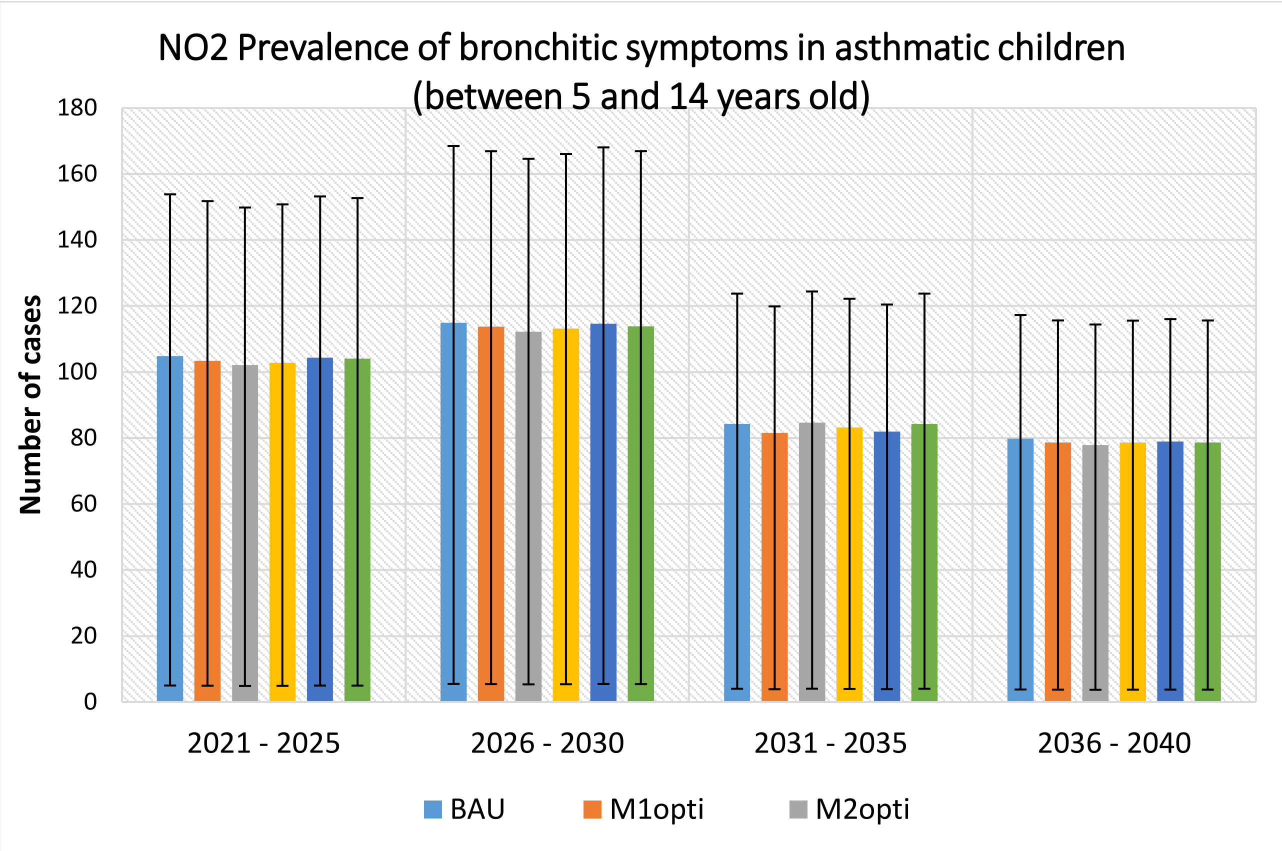

PM10 Cardiac Hospital admissions
Number of cases
0
10
20
30
40
50
60
70
80
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ


PM10 Respiratory Hospital admissions
Number of cases
70
60
50
40
30
20
10
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ


PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
3000
2500
2000
1500
1000
500
0
-500
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

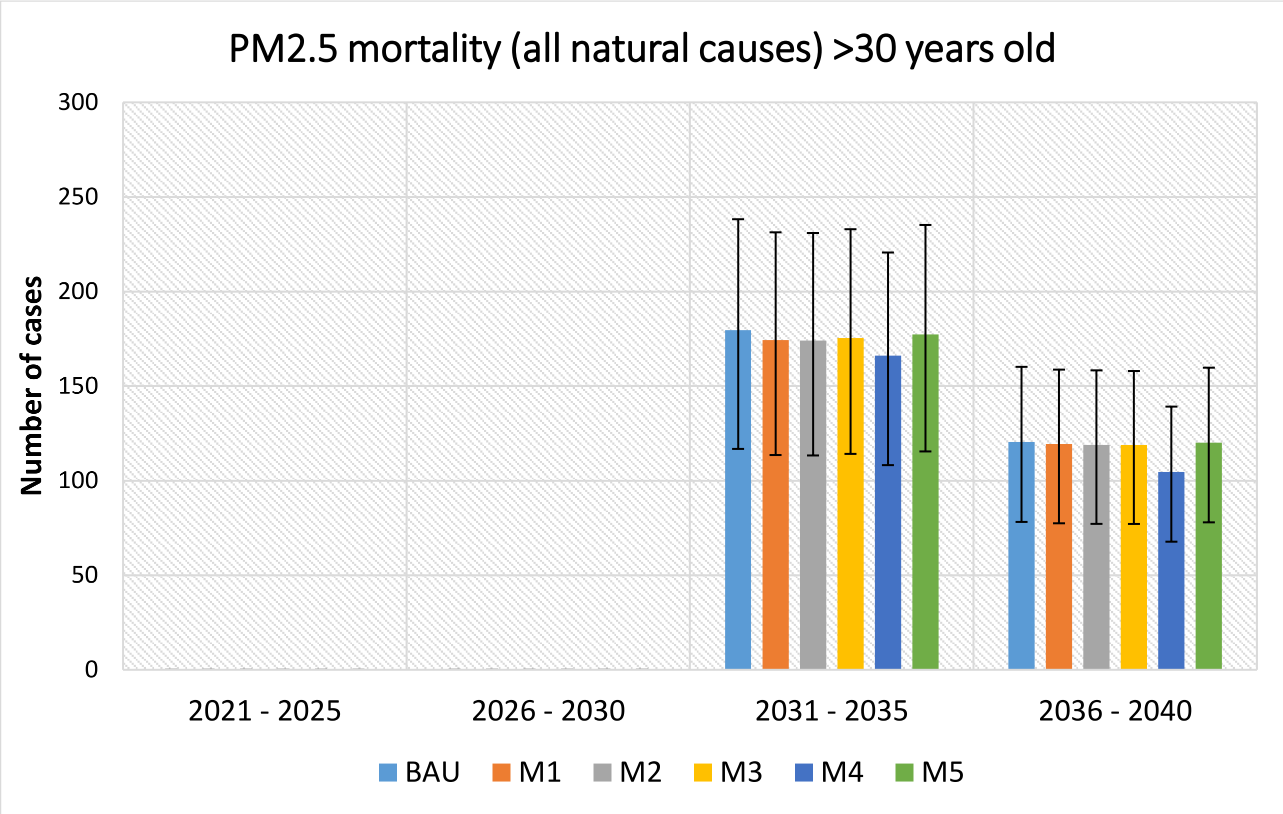


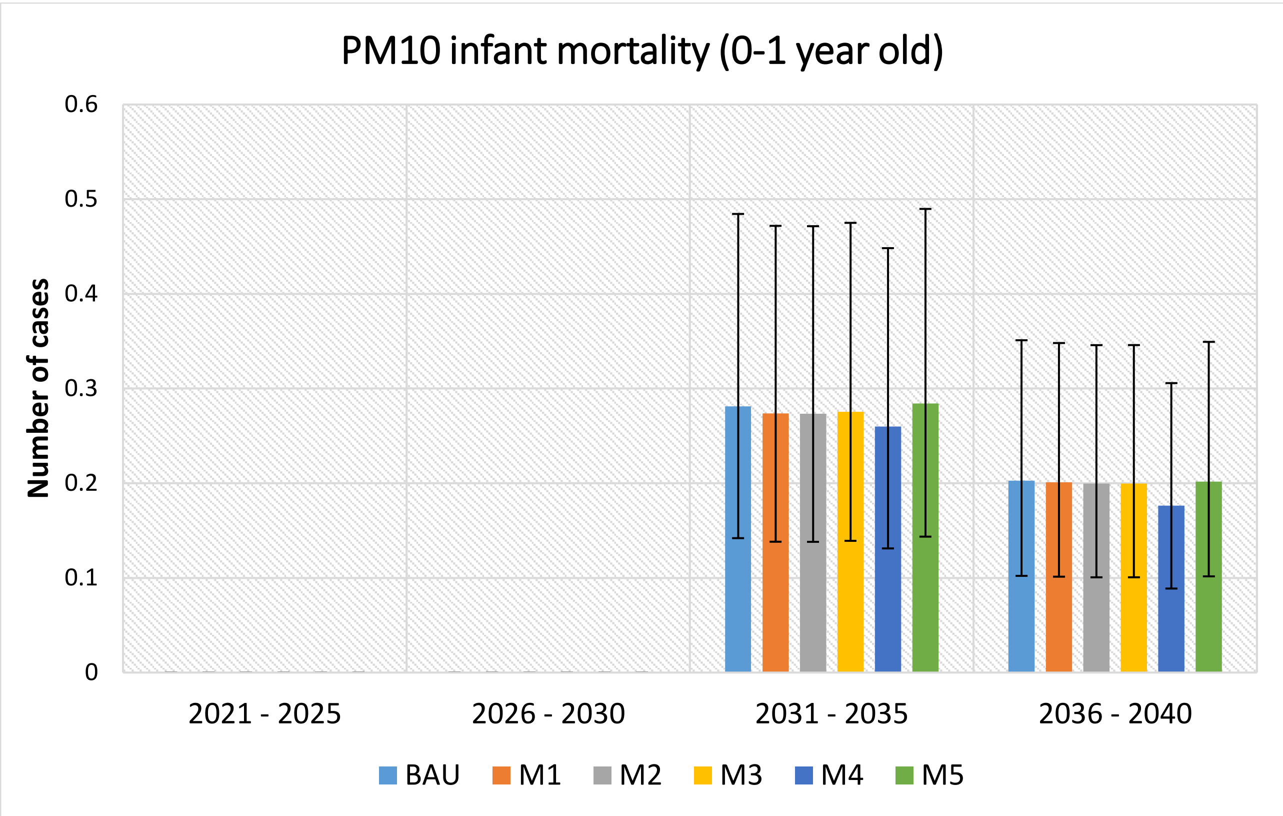
NO2 mortality (all natural causes) >30 years old
Number of cases
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti
M2zero
M3slow
M4econ

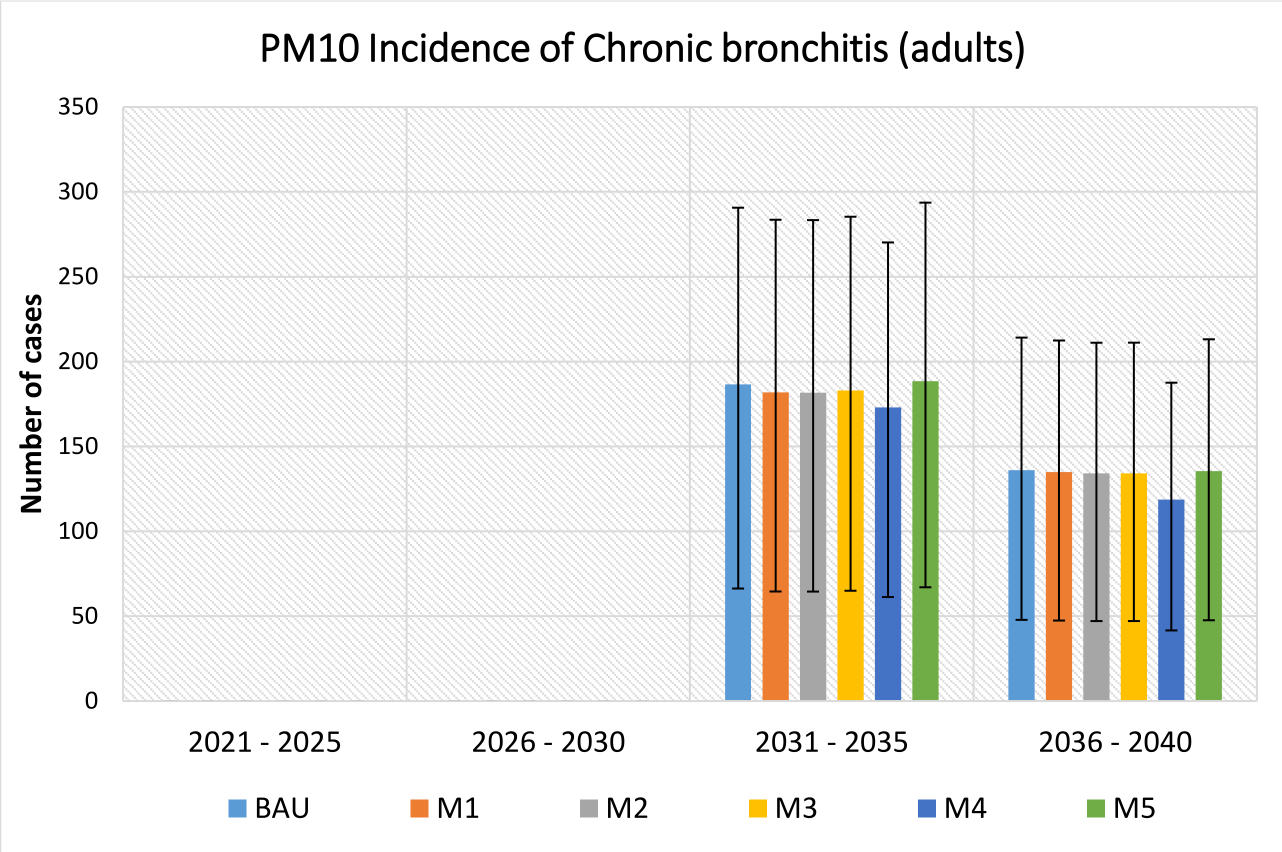


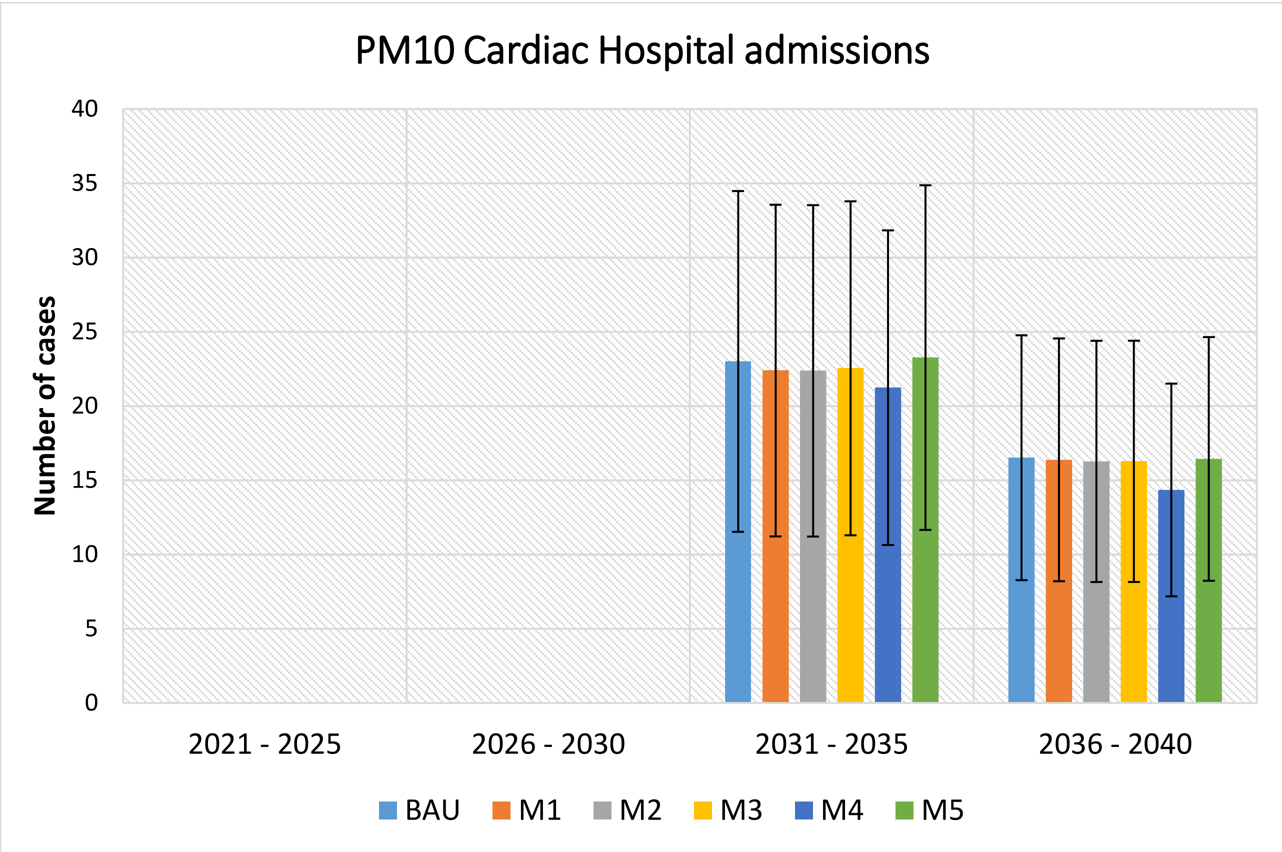
NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
180
160
140
120
100
80
60
40
20
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1opti
M2opti

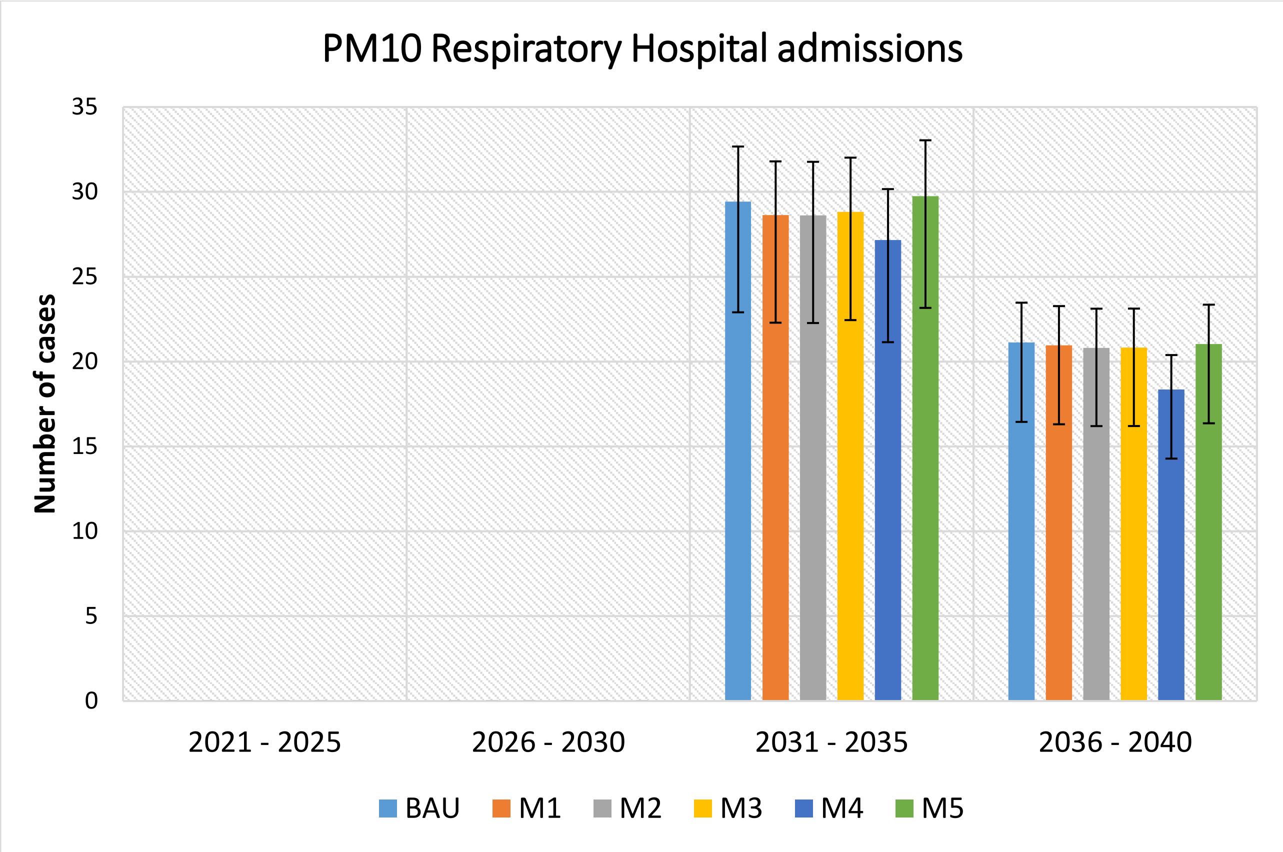
Ljubljana


PM2.5 mortality (all natural causes) >30 years old
Number of cases
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

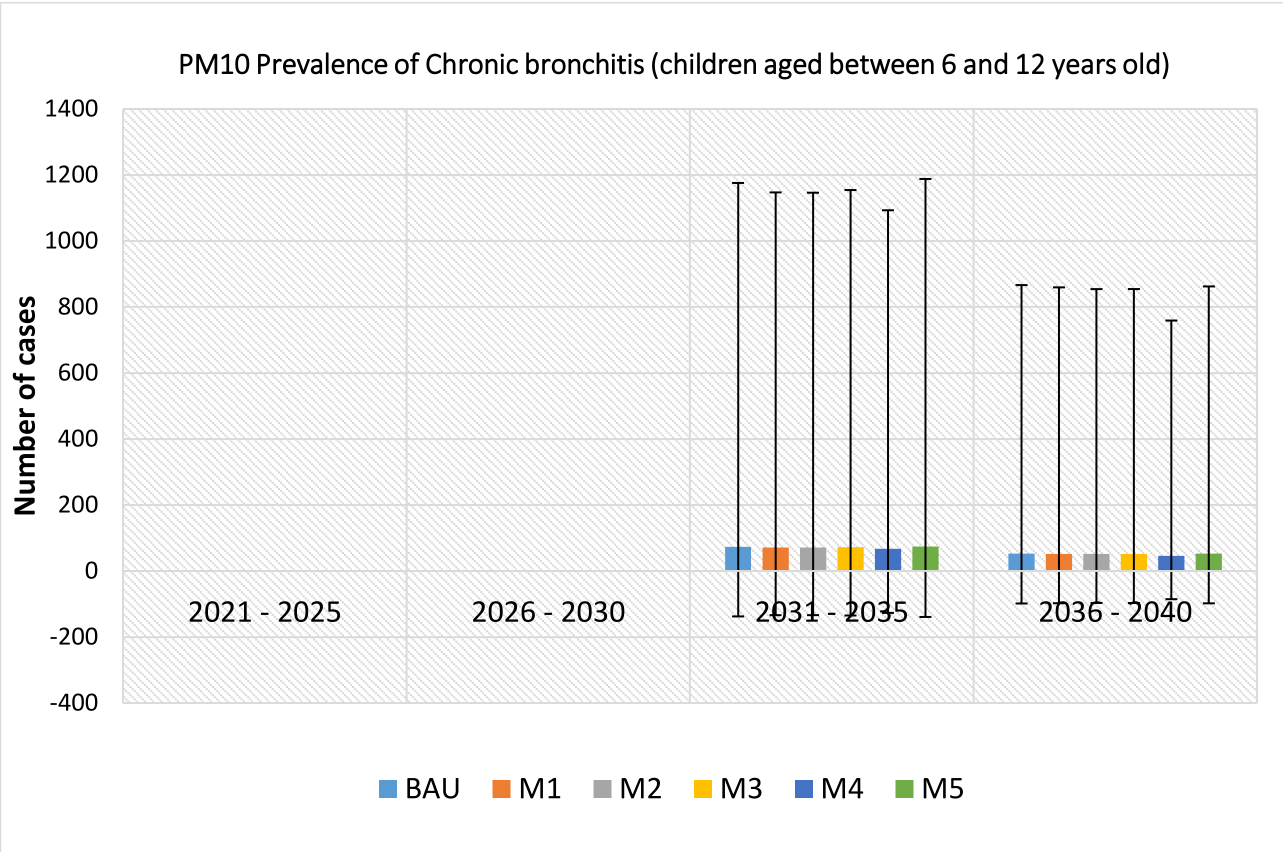

PM10 infant mortality (0-1 year old)
Number of cases
0.6
0.5
0.4
0.3
0.2
0.1
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5


PM10 Incidence of Chronic bronchitis (adults)
Number of cases
350
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

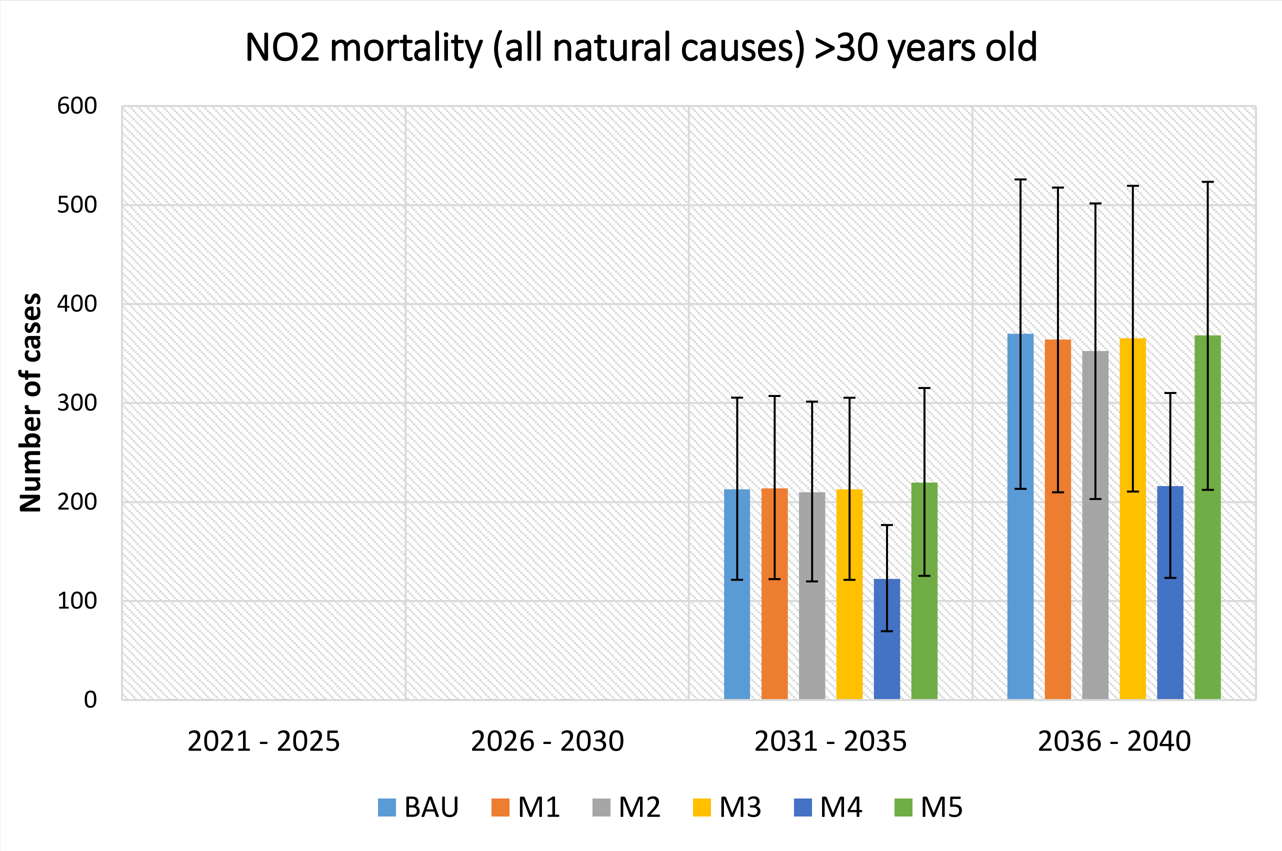

PM10 Cardiac Hospital admissions
Number of cases
40
35
30
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

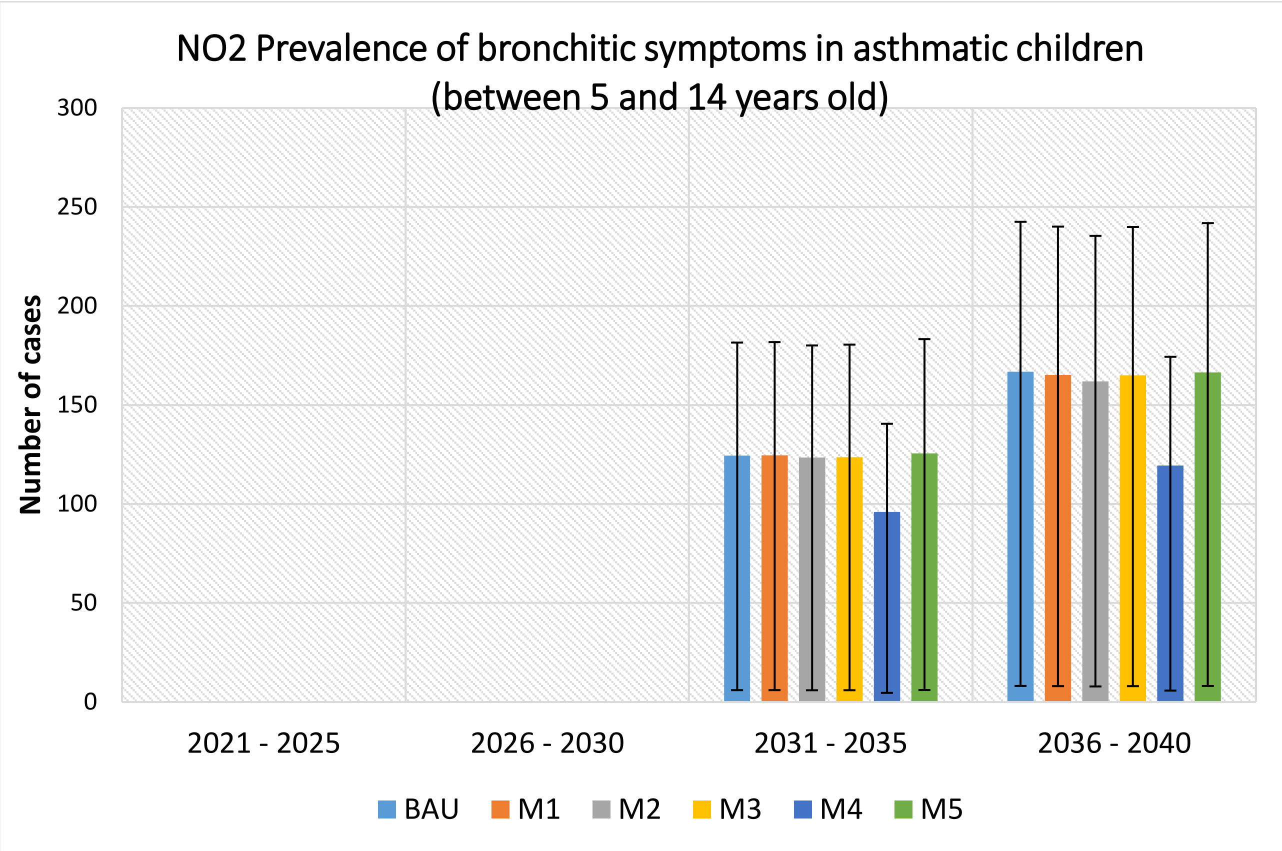


PM10 Respiratory Hospital admissions
Number of cases
35
30
25
20
15
10
5
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

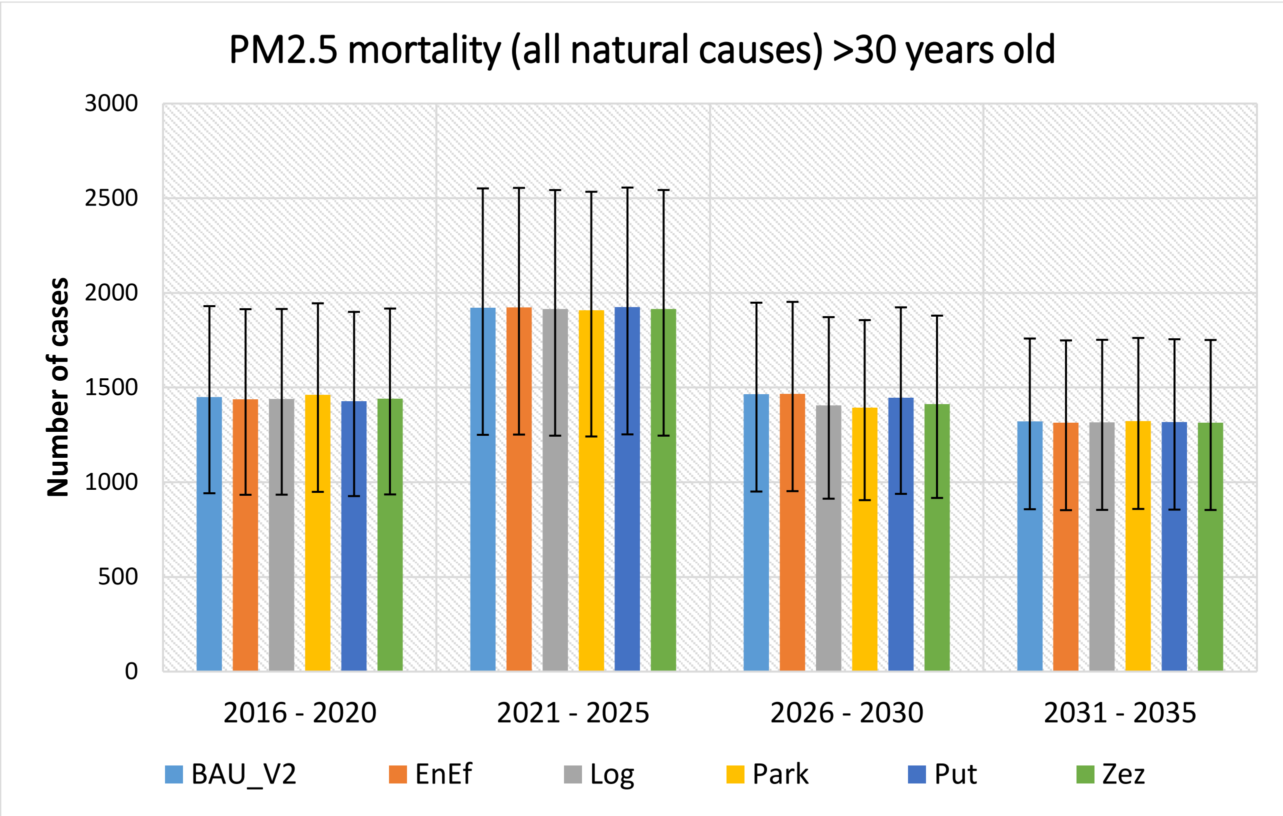


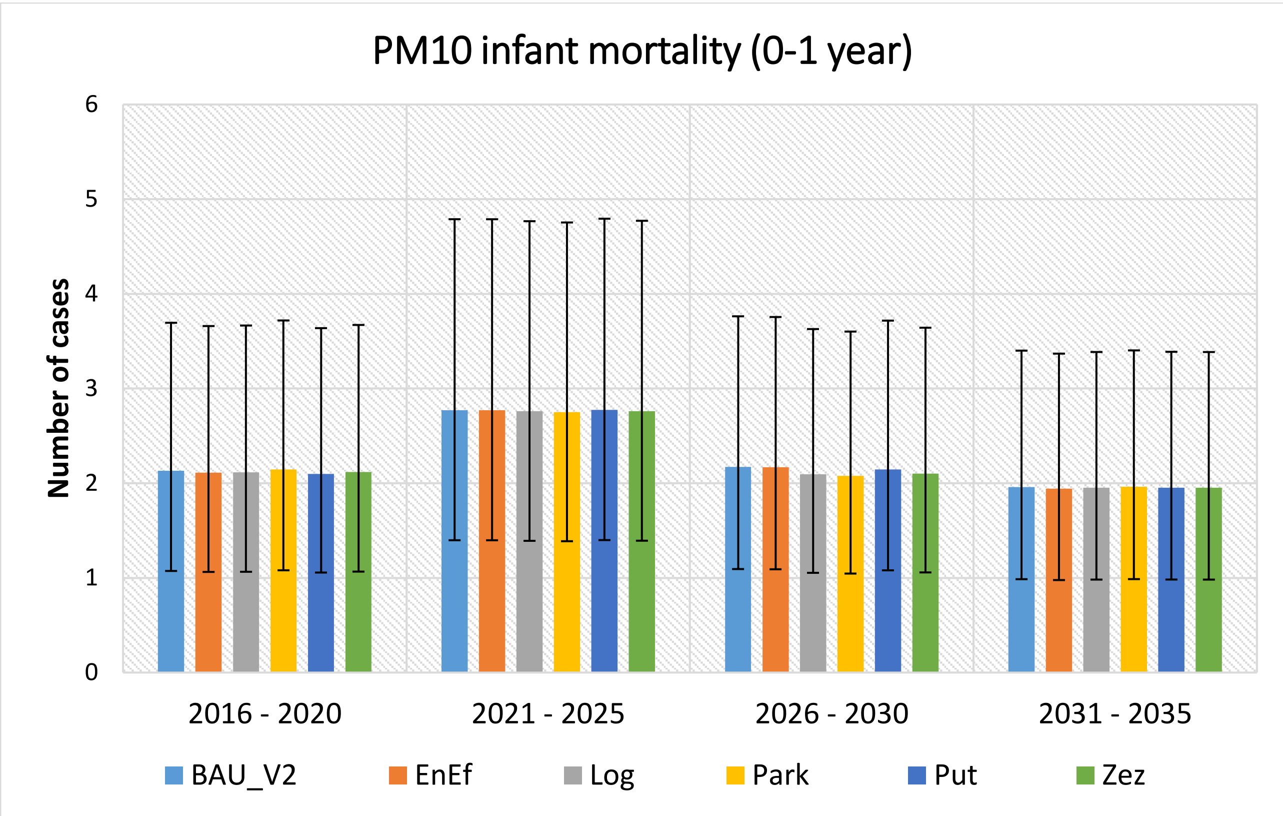
PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
1400
1200
1000
800
600
400
200
0
-200
-400
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

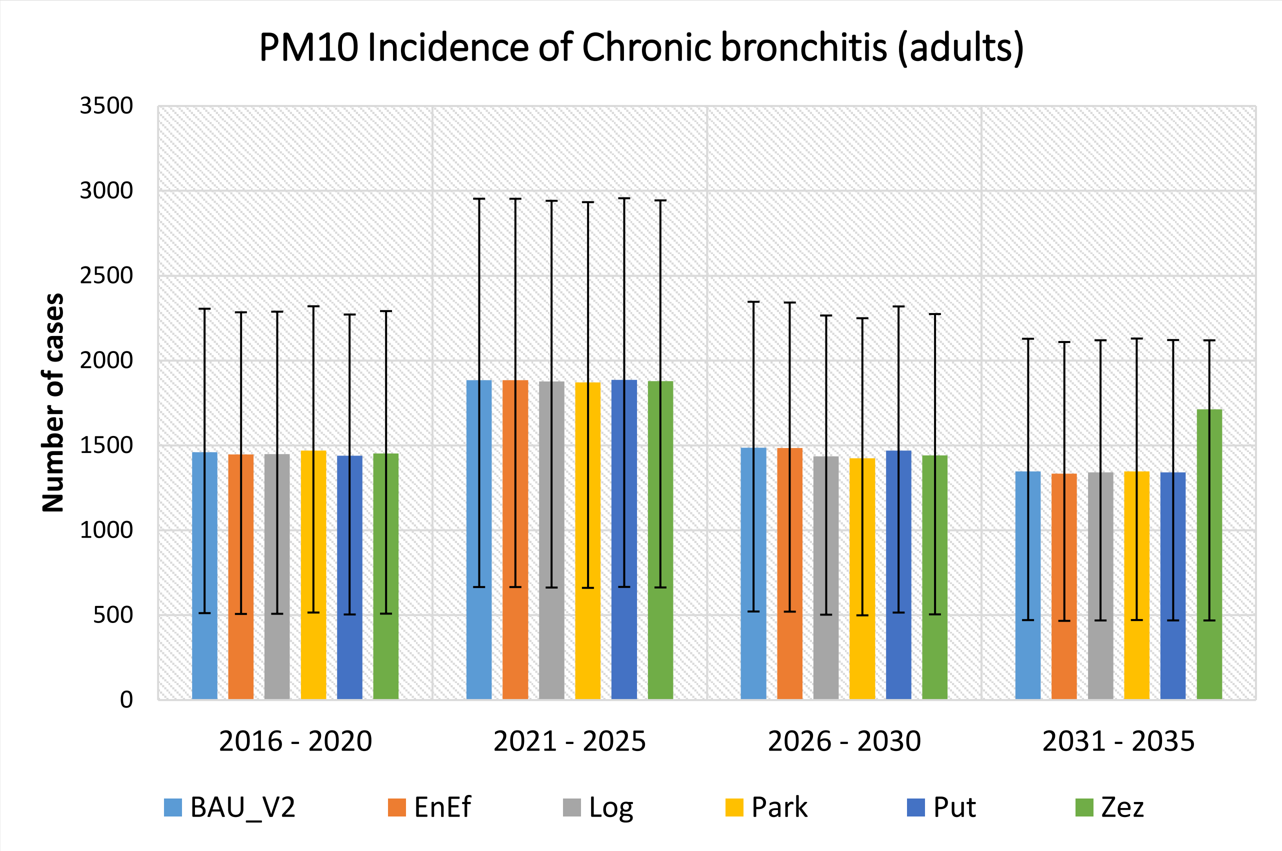

NO2 mortality (all natural causes) >30 years old
Number of cases
600
500
400
300
200
100
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU
M1
M2
M3
M4
M5

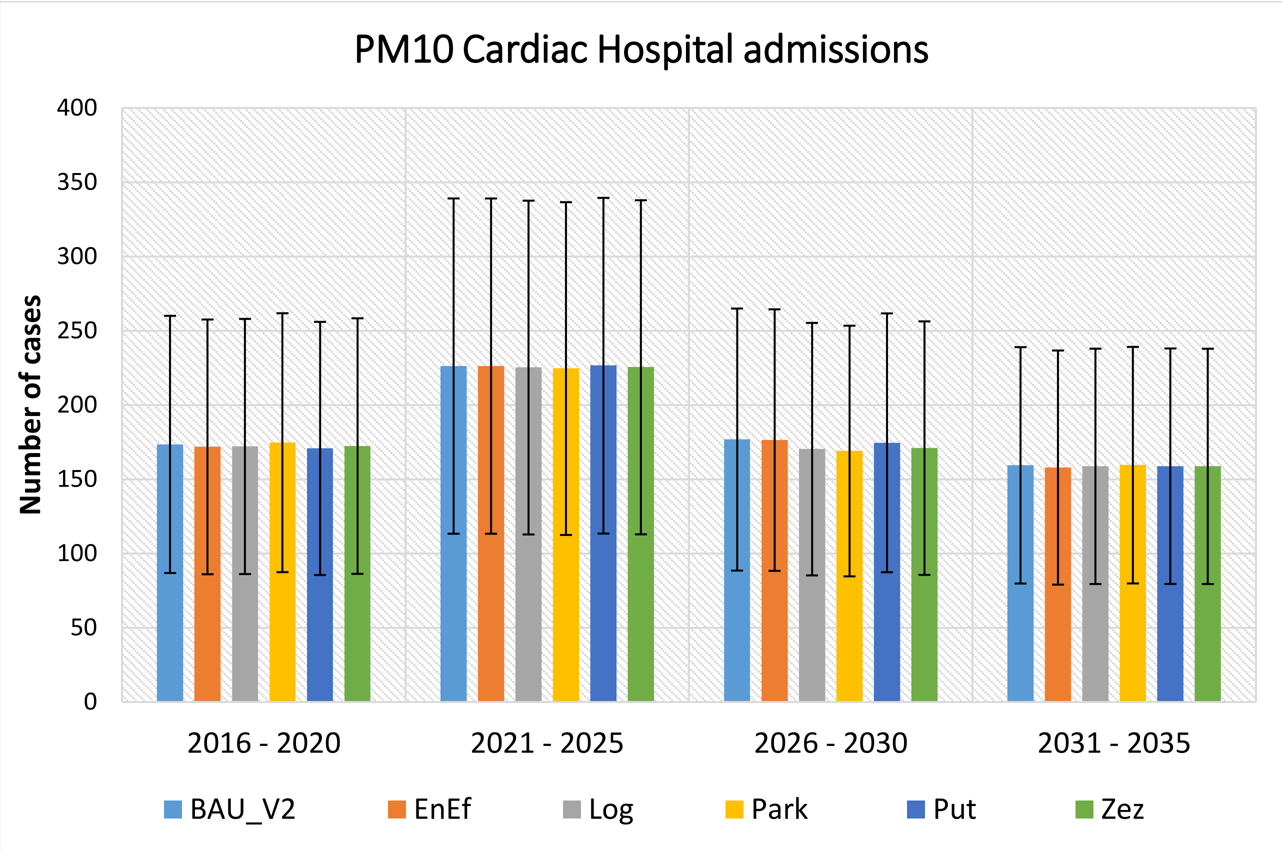
Madrid


PM2.5 mortality (all natural causes) >30 years old
Number of cases
3000
2500
2000
1500
1000
500
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

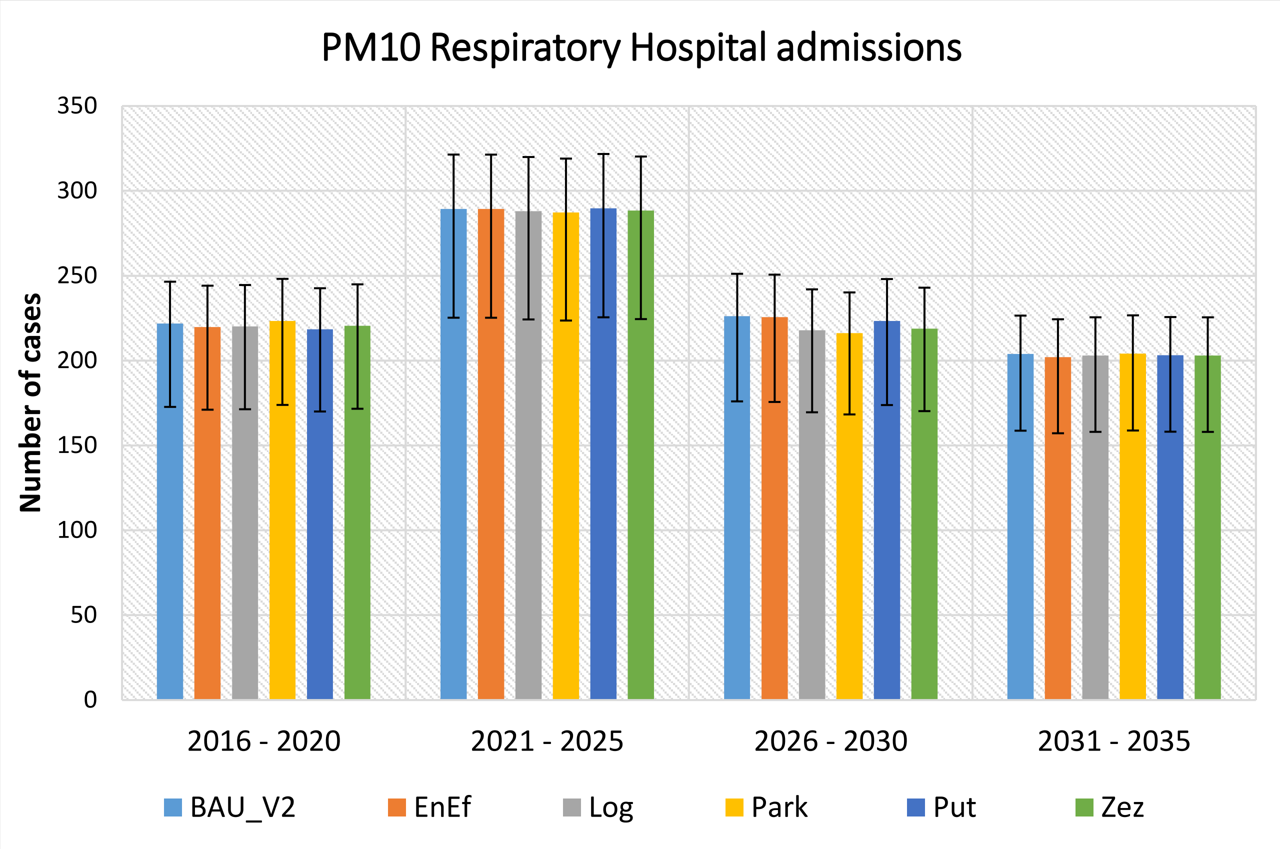

PM10 infant mortality (0-1 year)
Number of cases
6
5
4
3
2
1
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



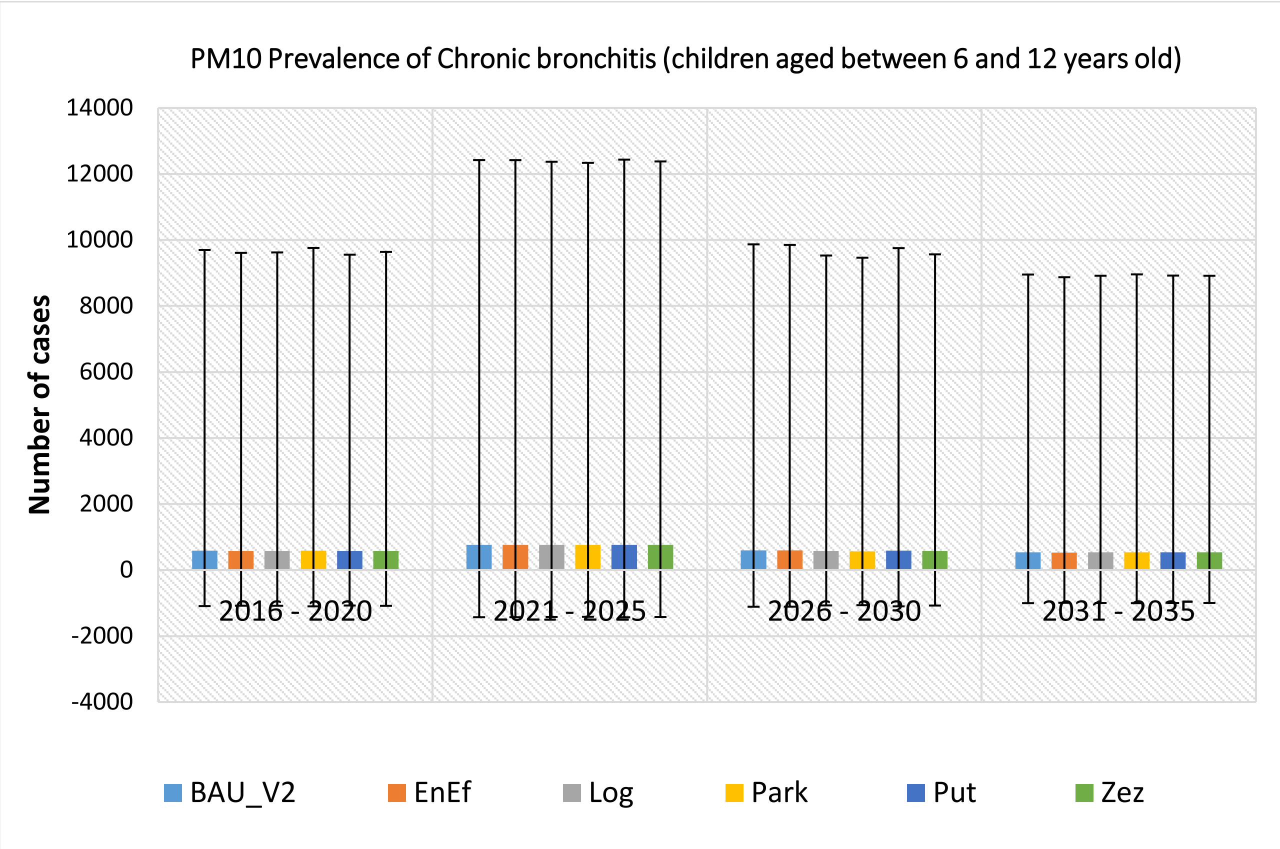
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
3500
3000
2500
2000
1500
1000
500
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



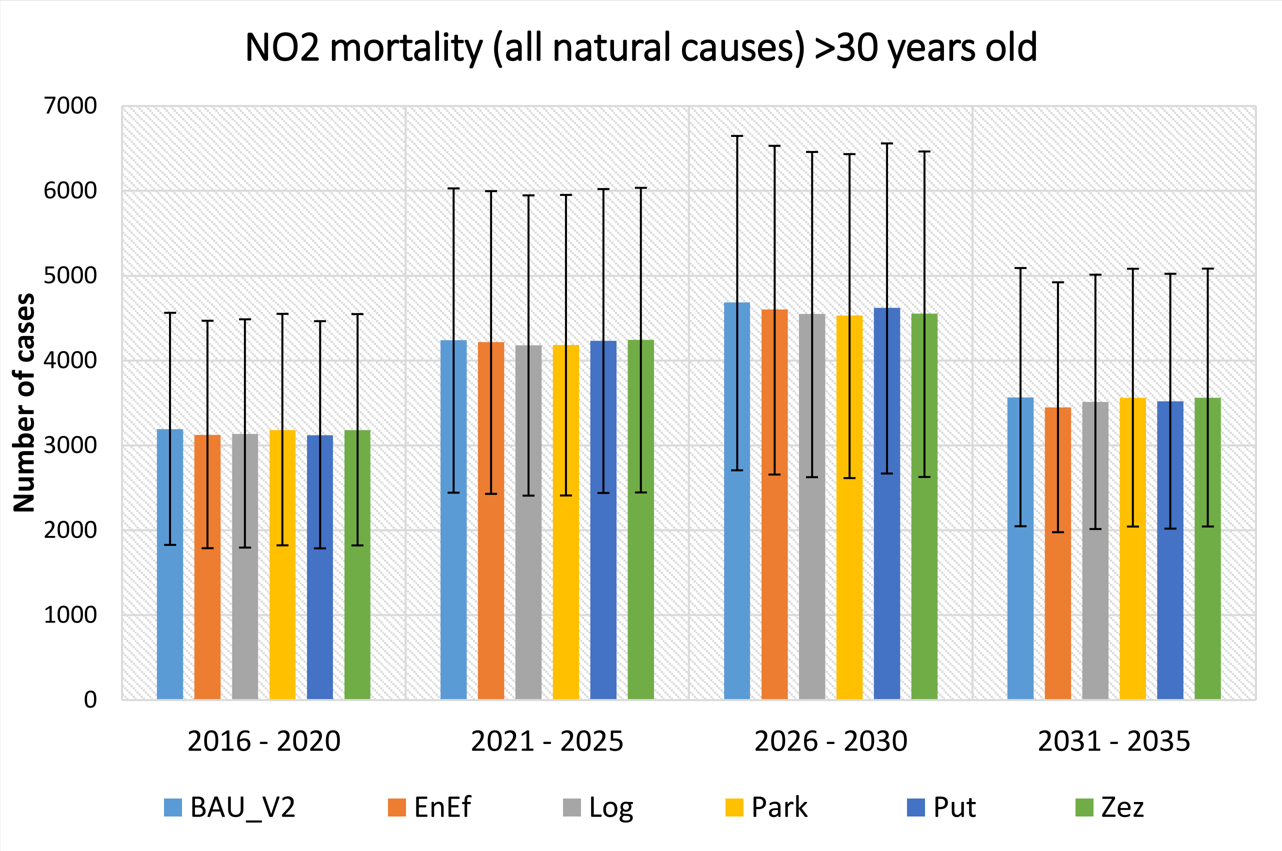
PM10 Cardiac Hospital admissions
Number of cases
400
350
300
250
200
150
100
50
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



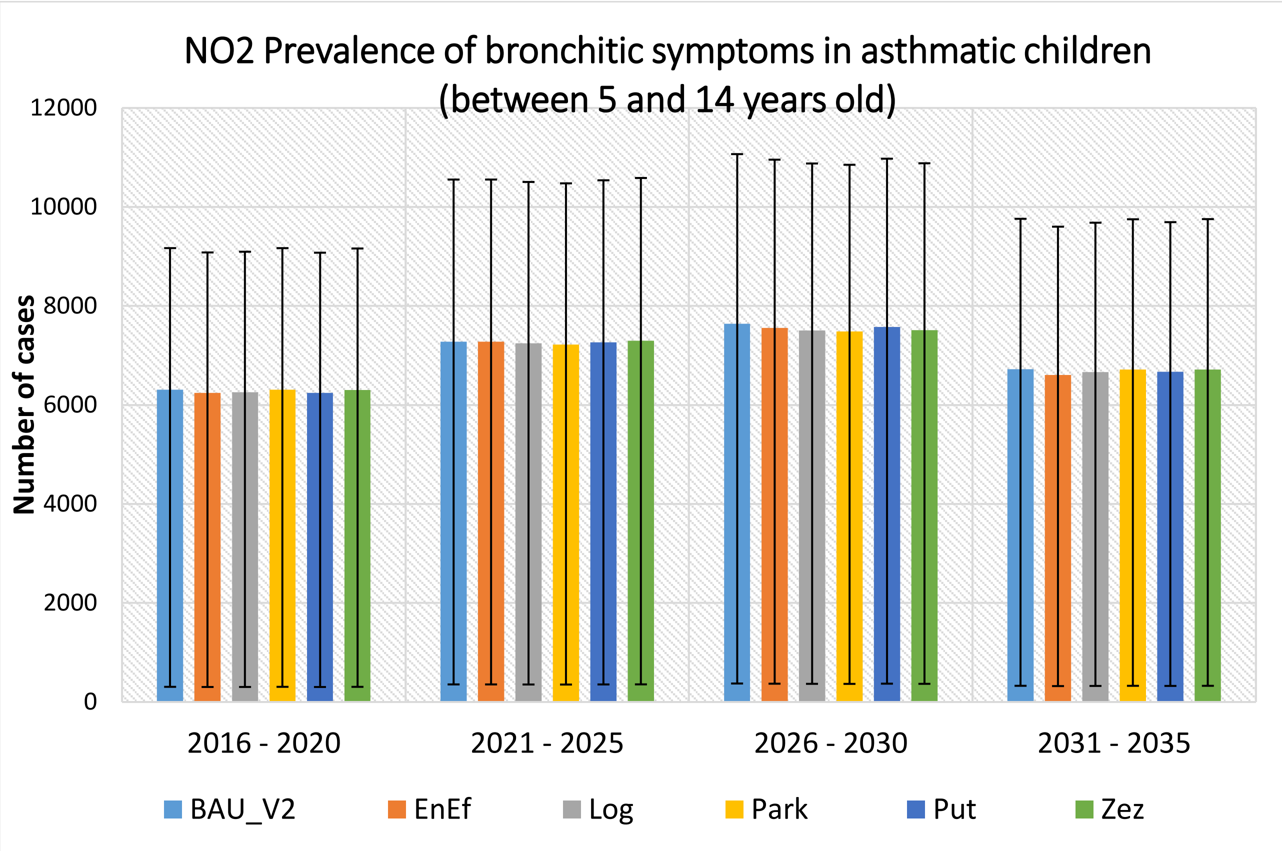
PM10 Respiratory Hospital admissions
Number of cases
350
300
250
200
150
100
50
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

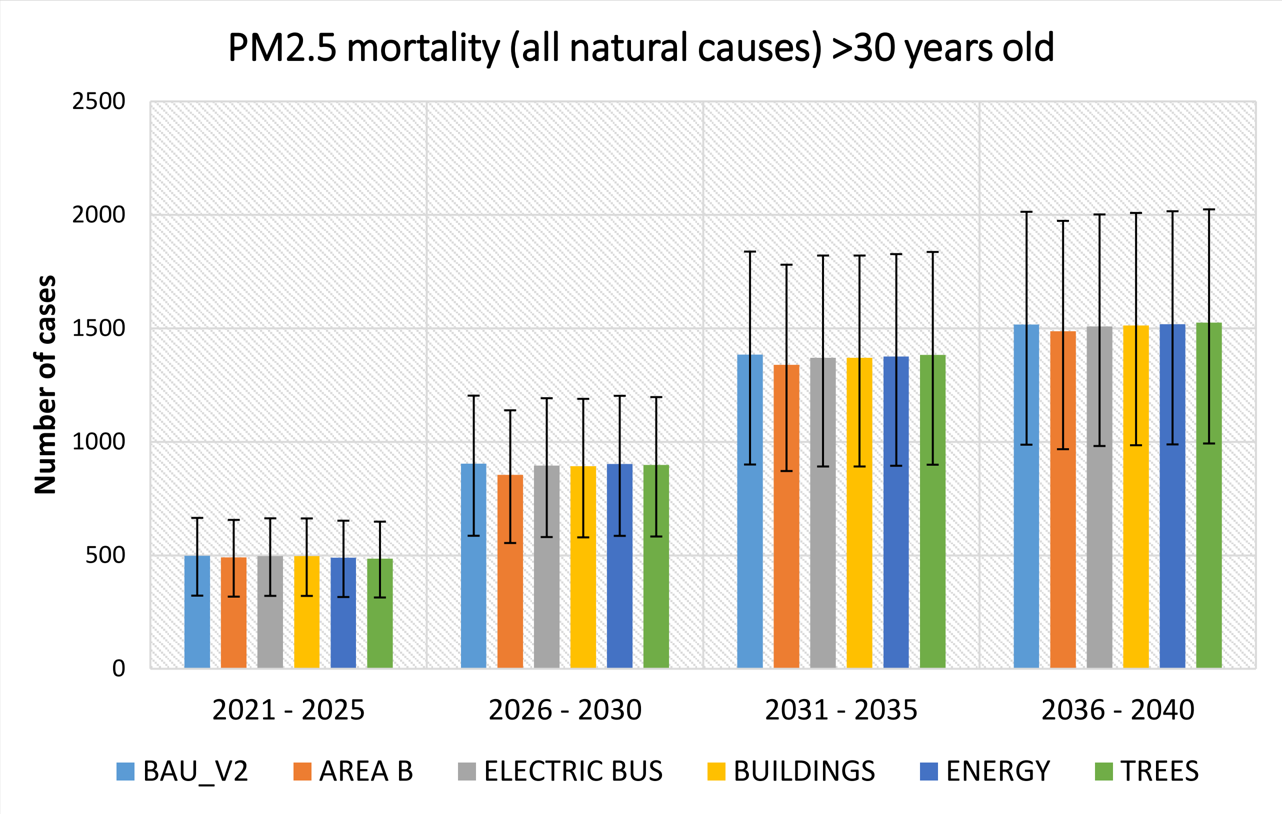


NO2 mortality (all natural causes) >30 years old
Number of cases
7000
6000
5000
4000
3000
2000
1000
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

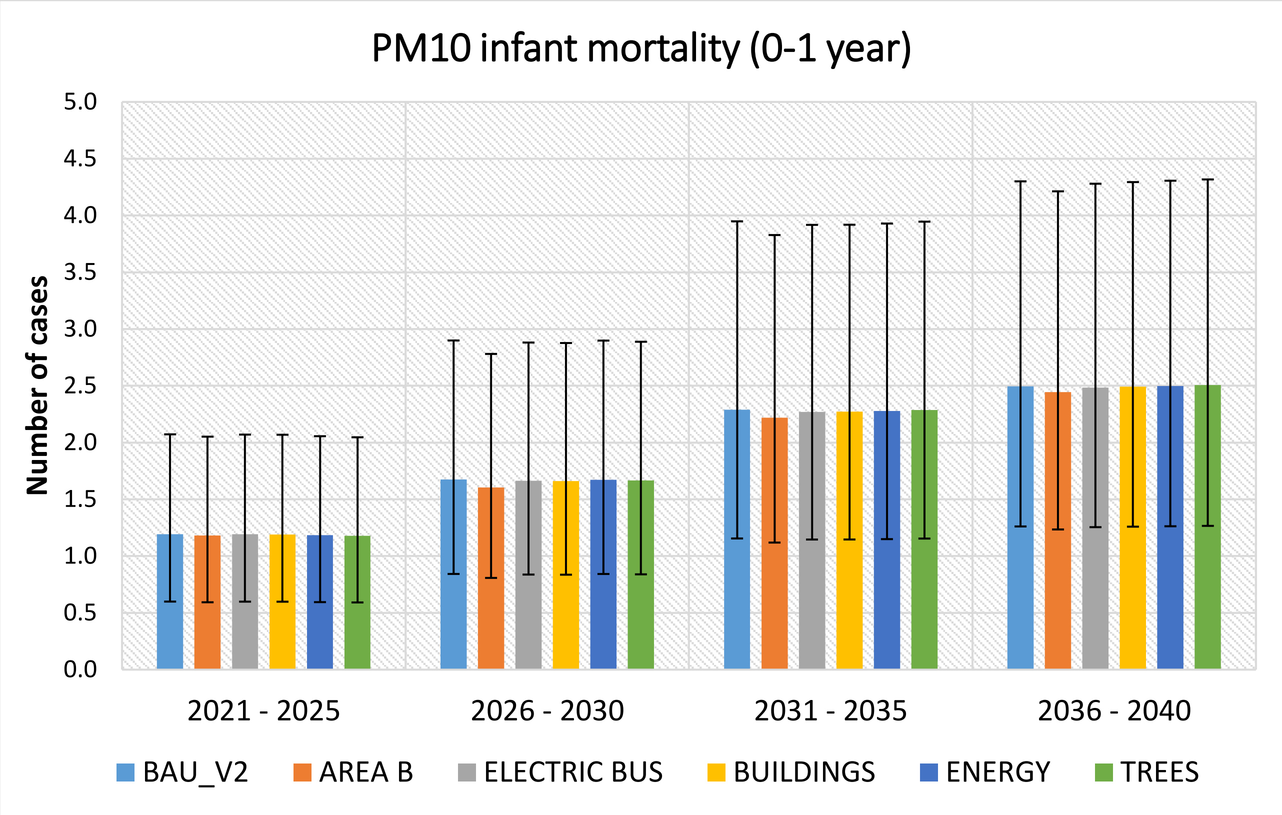


NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
12000
10000
8000
6000
4000
2000
0
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAU_V2
EnEf
Log
Park
Put
Zez

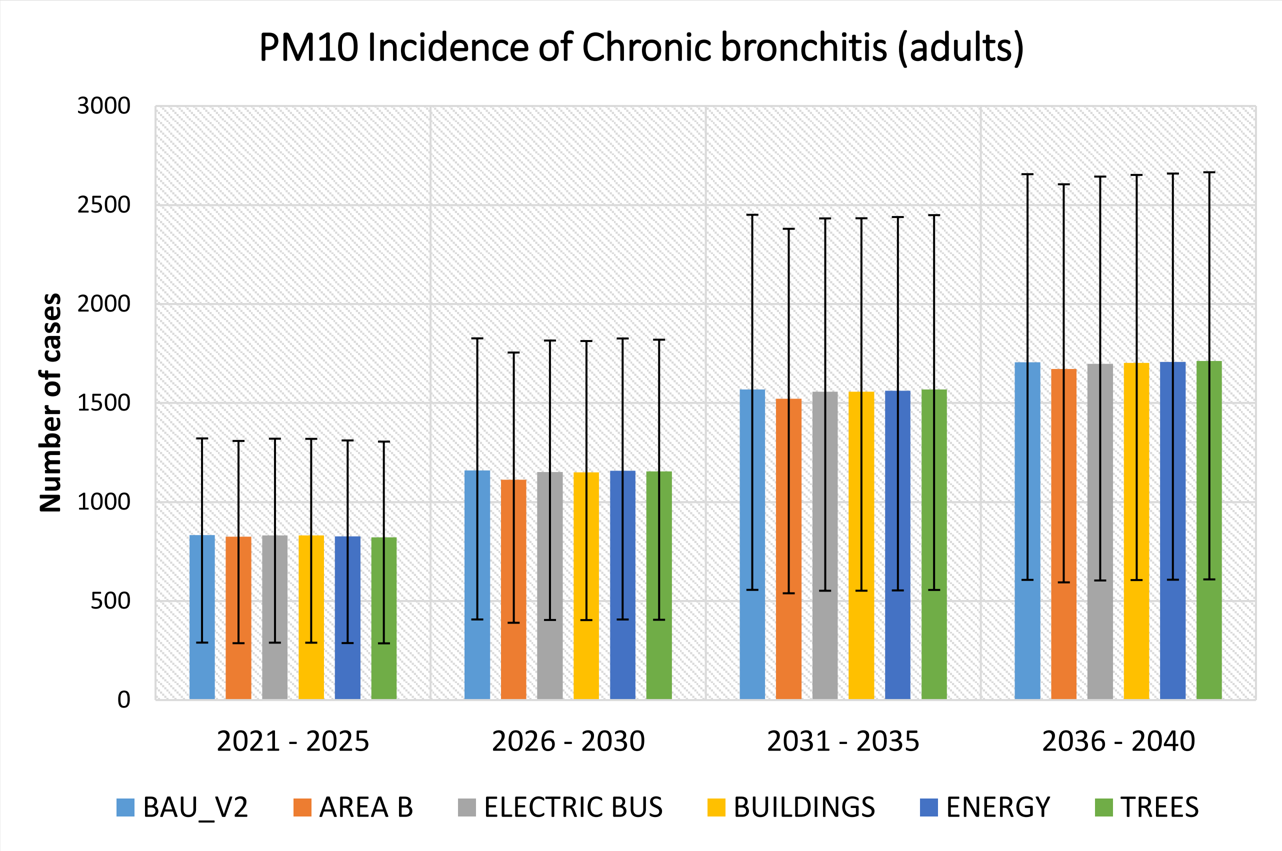
Milan



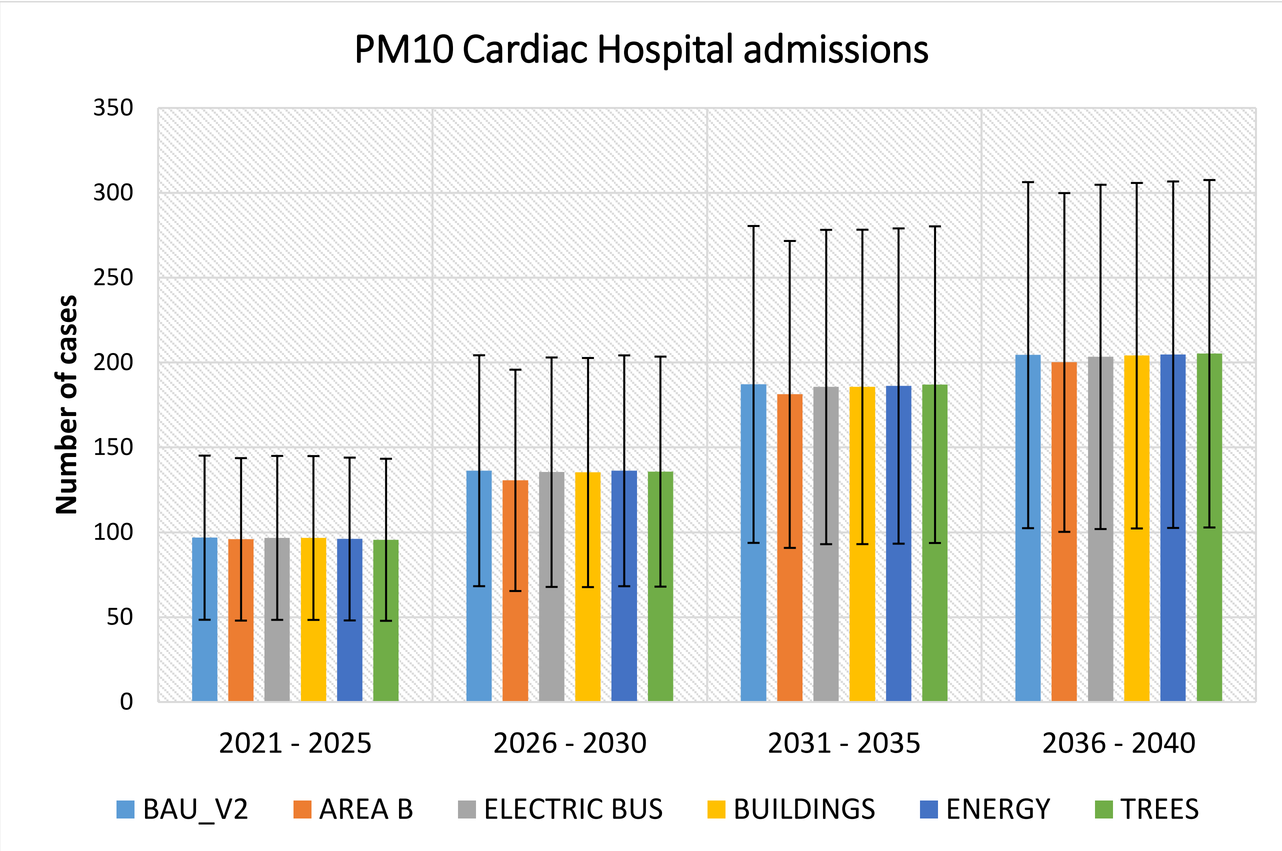
PM2.5 mortality (all natural causes) >30 years old
Number of cases
2500
2000
1500
1000
500
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES



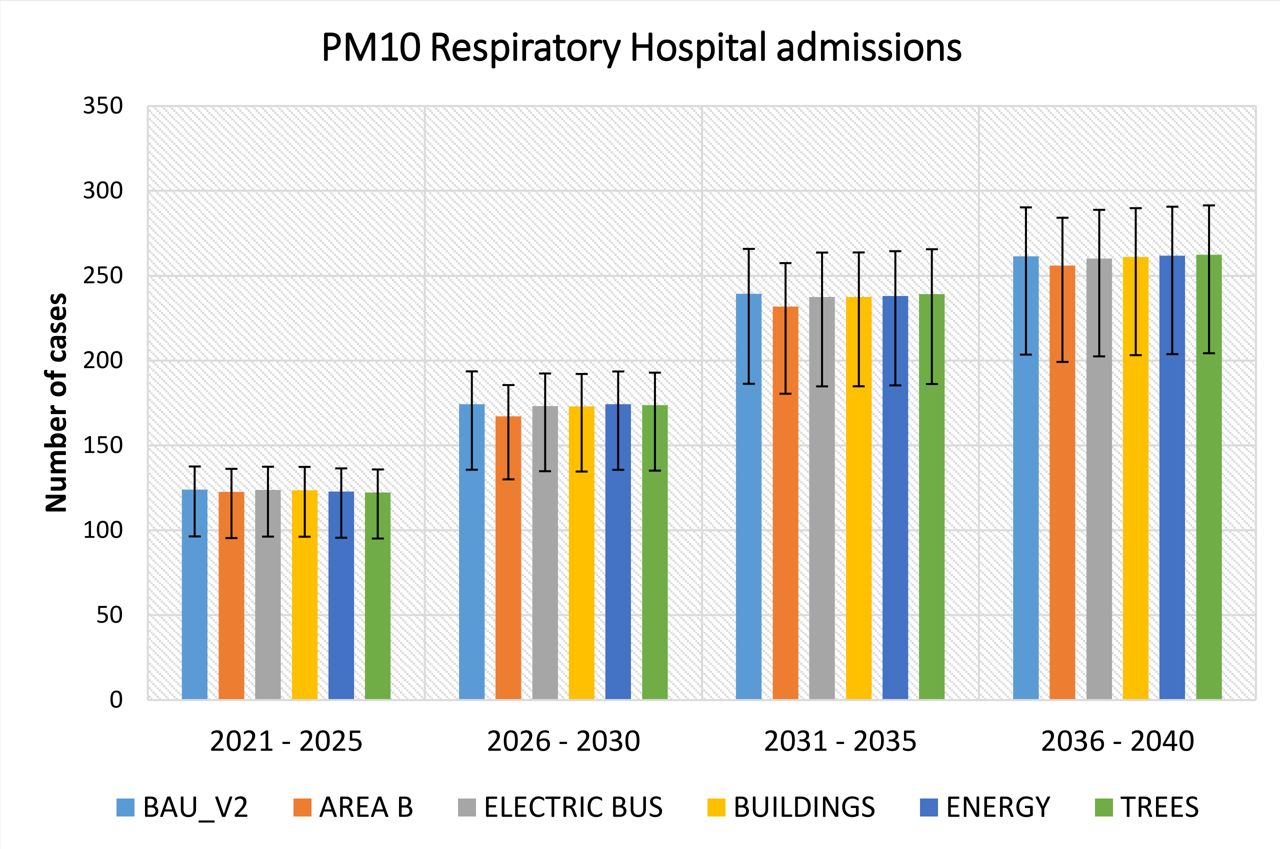
PM10 infant mortality (0-1 year)
Number of cases
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

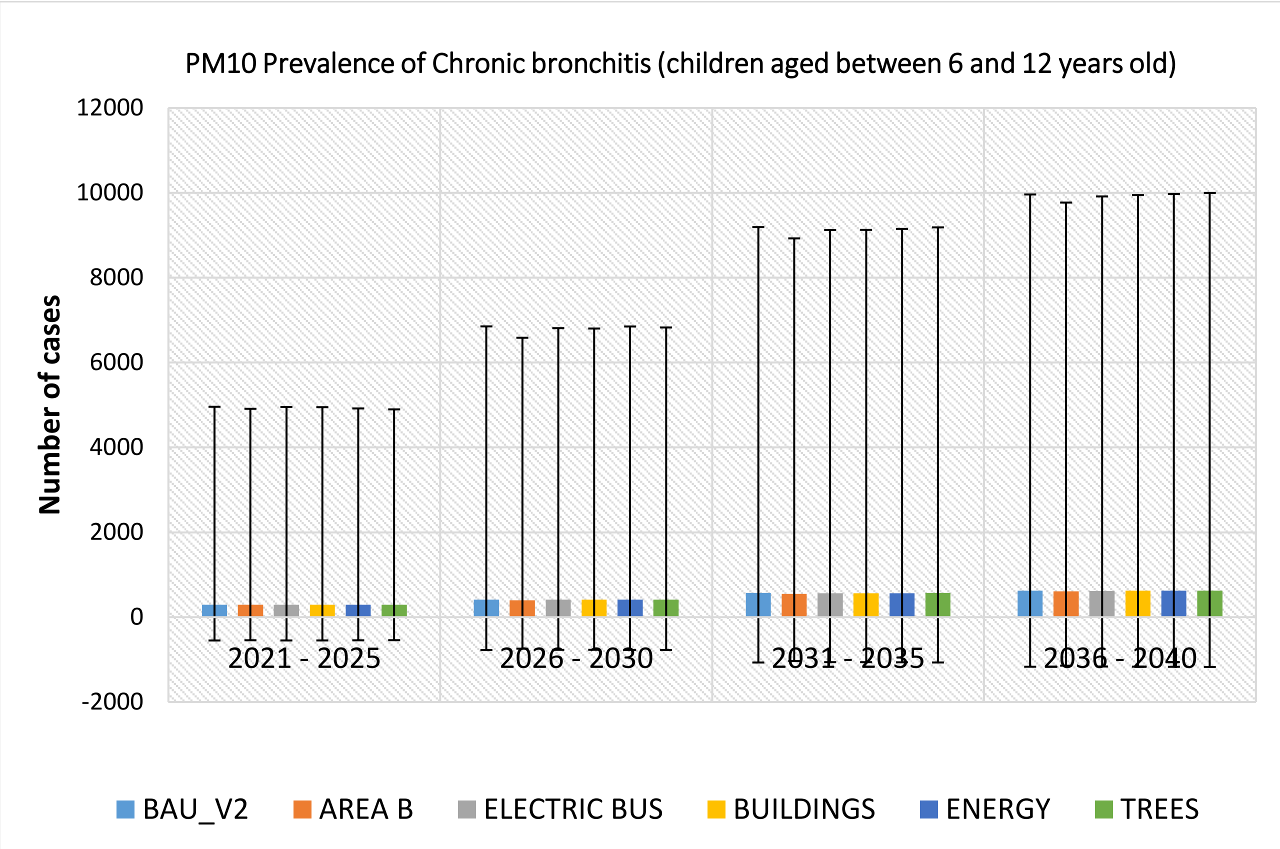


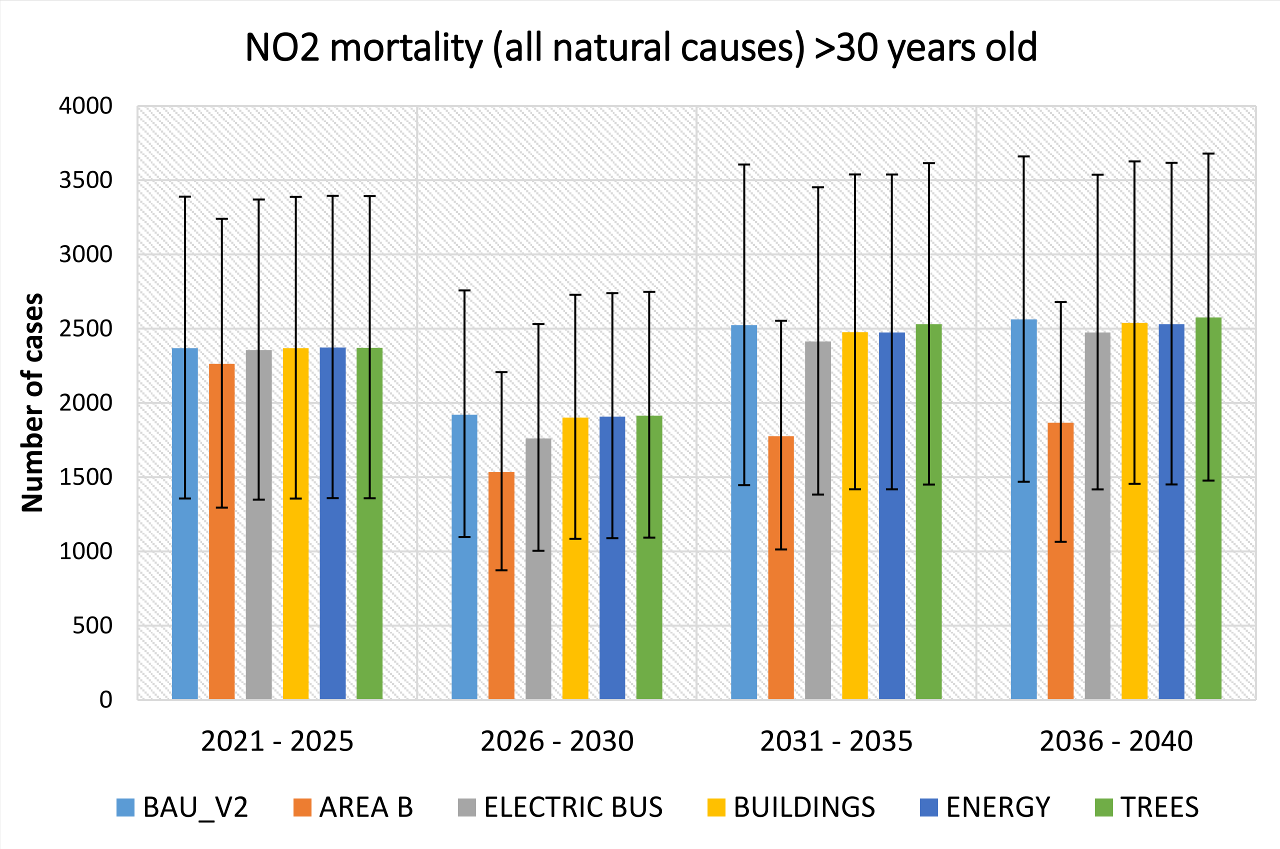
PM10 Incidence of Chronic bronchitis (adults)
Number of cases
3000
2500
2000
1500
1000
500
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES



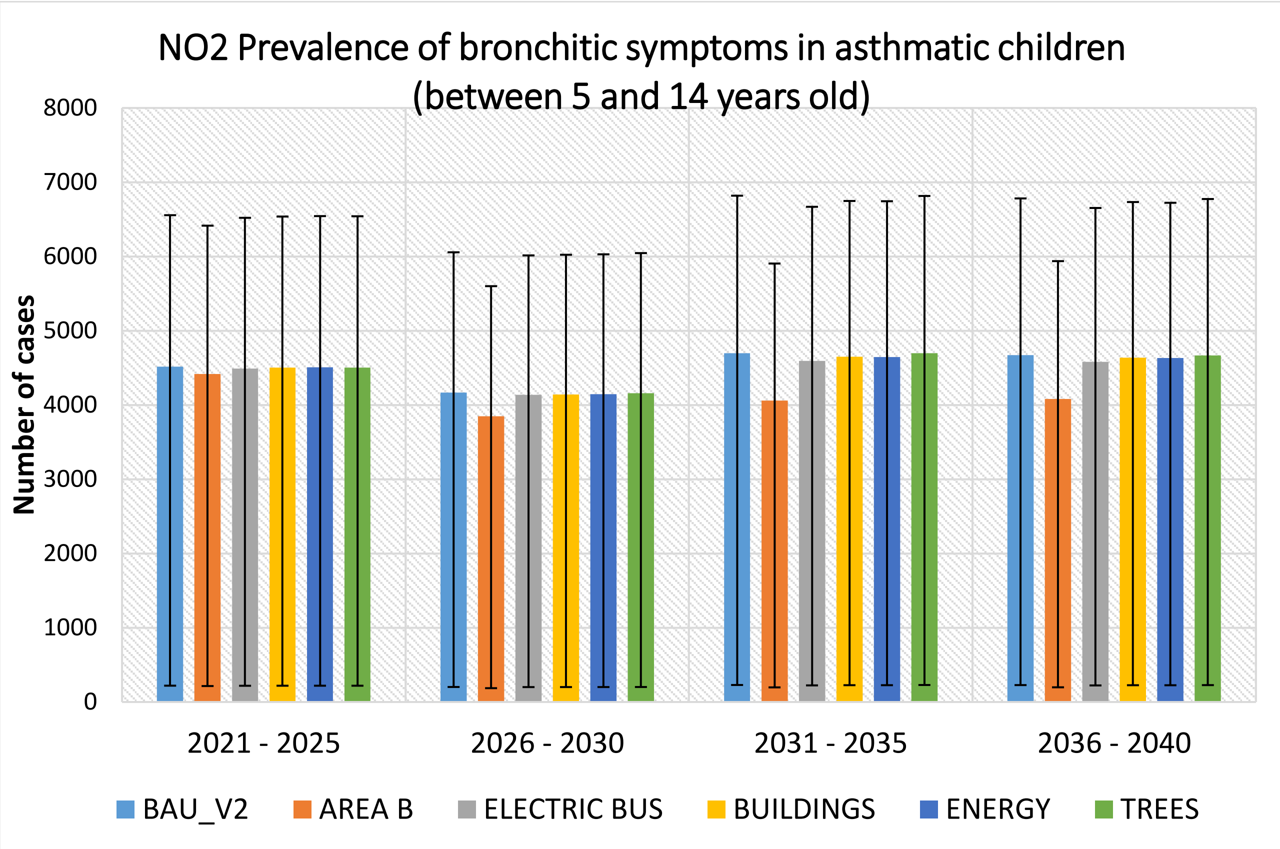
PM10 Cardiac Hospital admissions
Number of cases
350
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES


PM10 Respiratory Hospital admissions
Number of cases
350
300
250
200
150
100
50
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES


PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
12000
10000
8000
6000
4000
2000
0
-2000
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

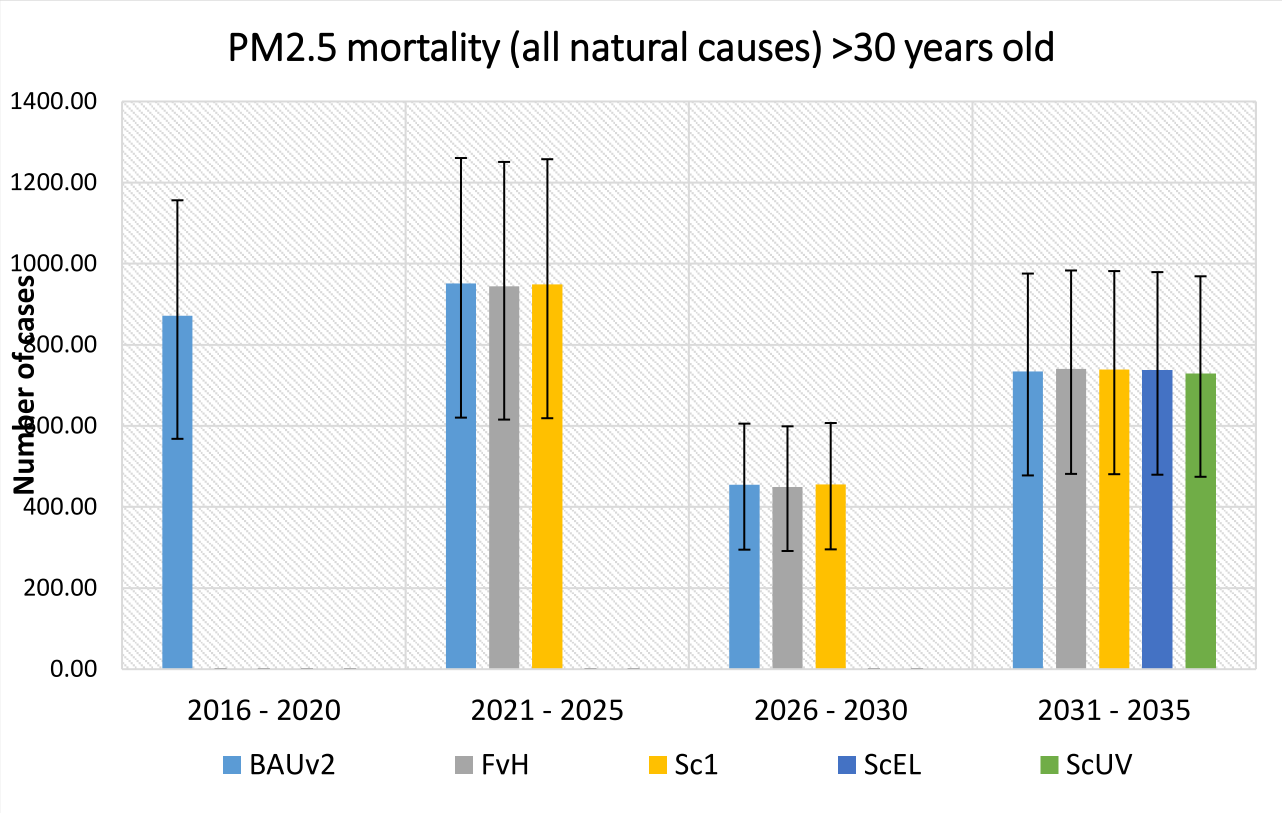


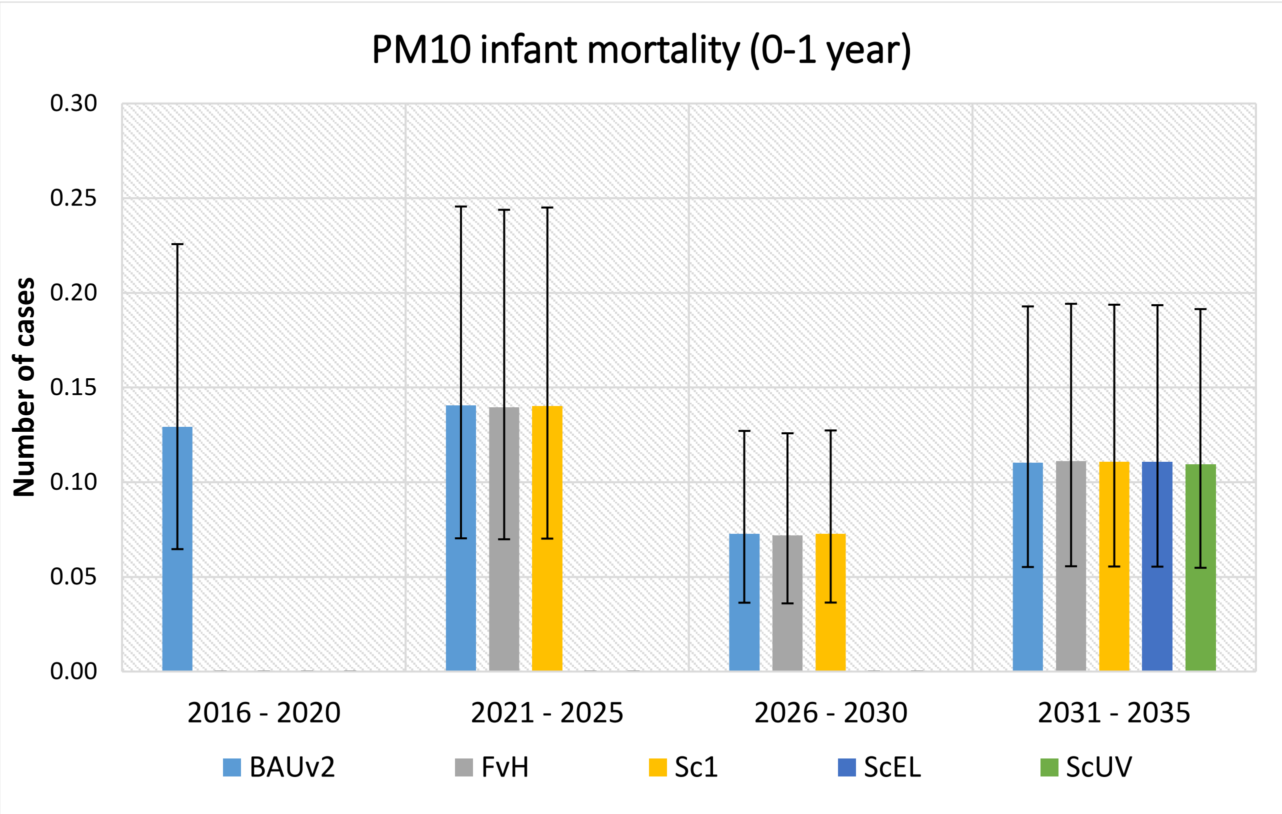
NO2 mortality (all natural causes) >30 years old
Number of cases
4000
3500
3000
2500
2000
1500
1000
500
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

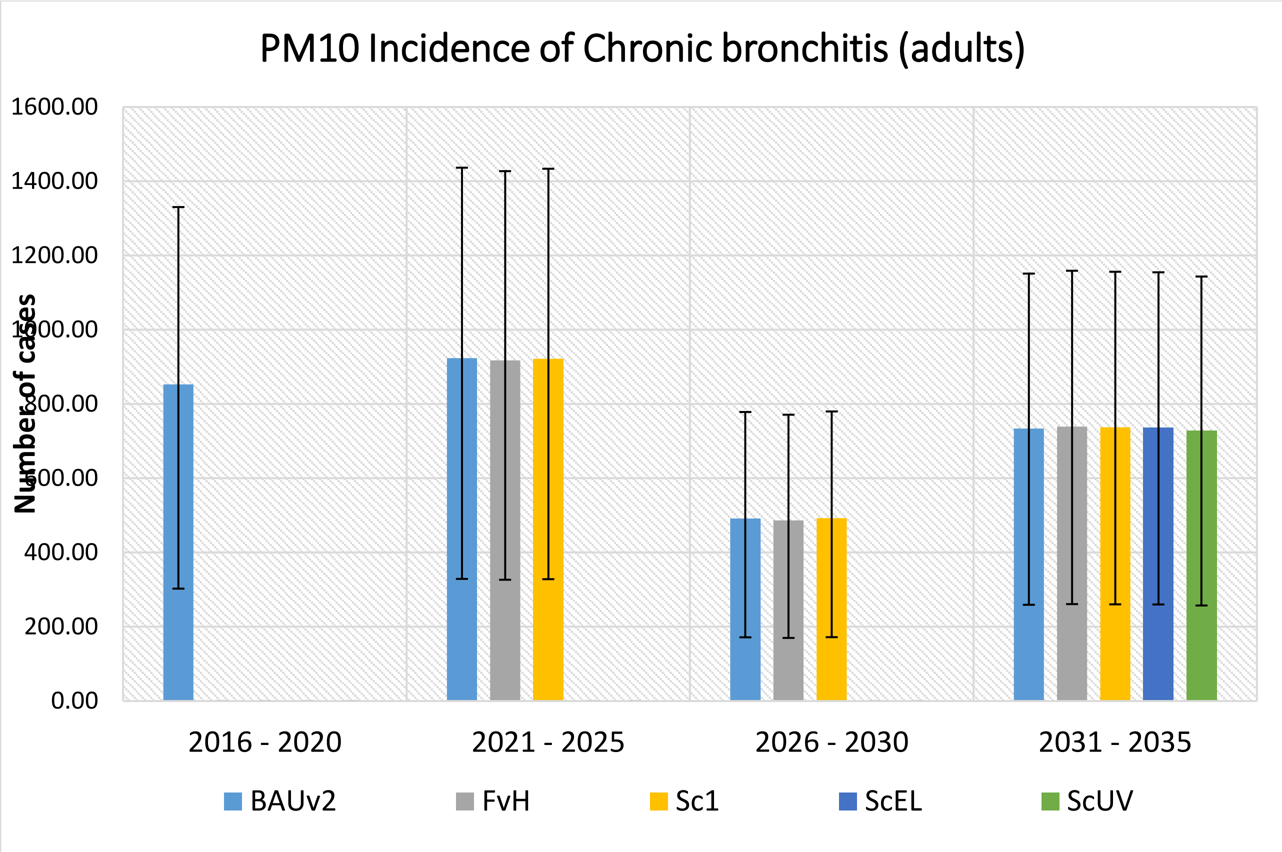


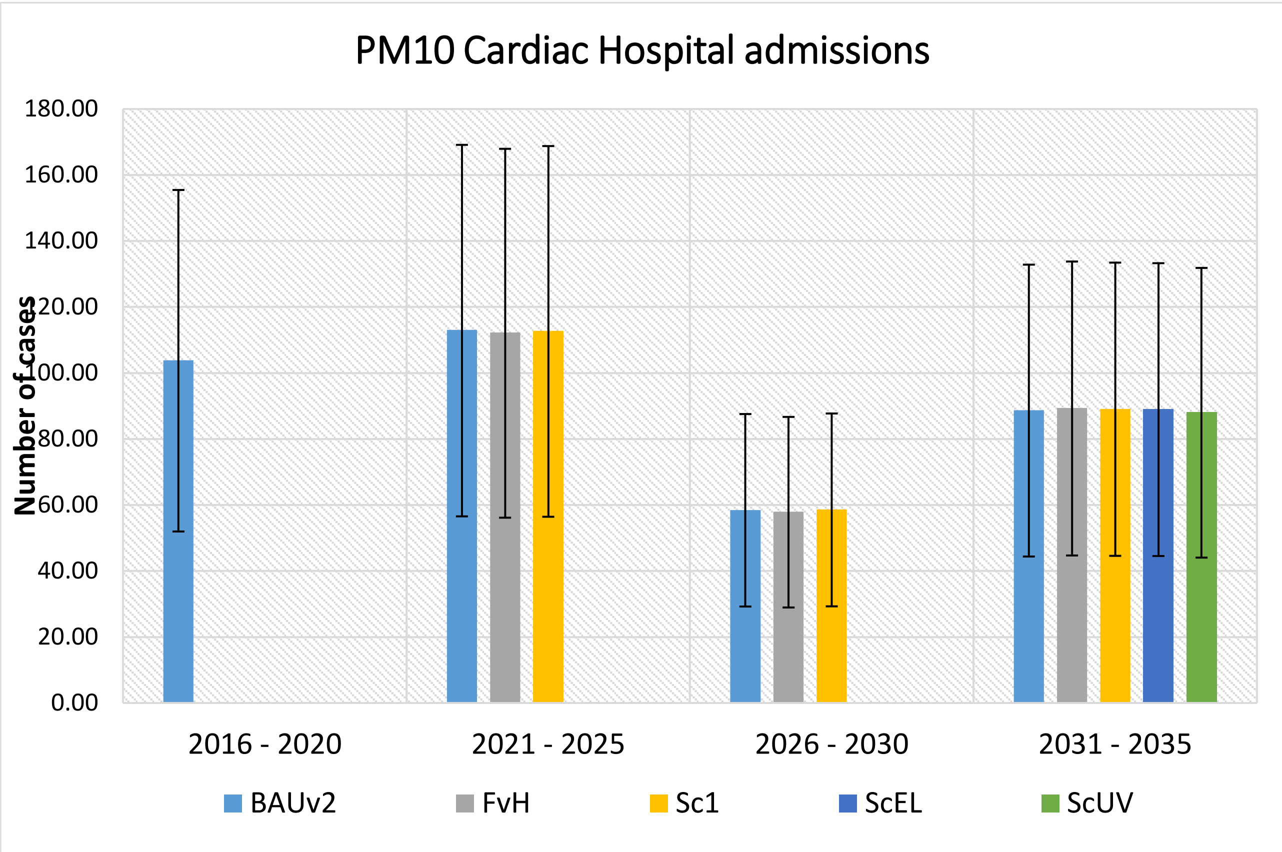
NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
8000
7000
6000
5000
4000
3000
2000
1000
0
2021 - 2025
2026 - 2030
2031 - 2035
2036 - 2040
BAU_V2
AREA B
ELECTRIC BUS
BUILDINGS
ENERGY
TREES

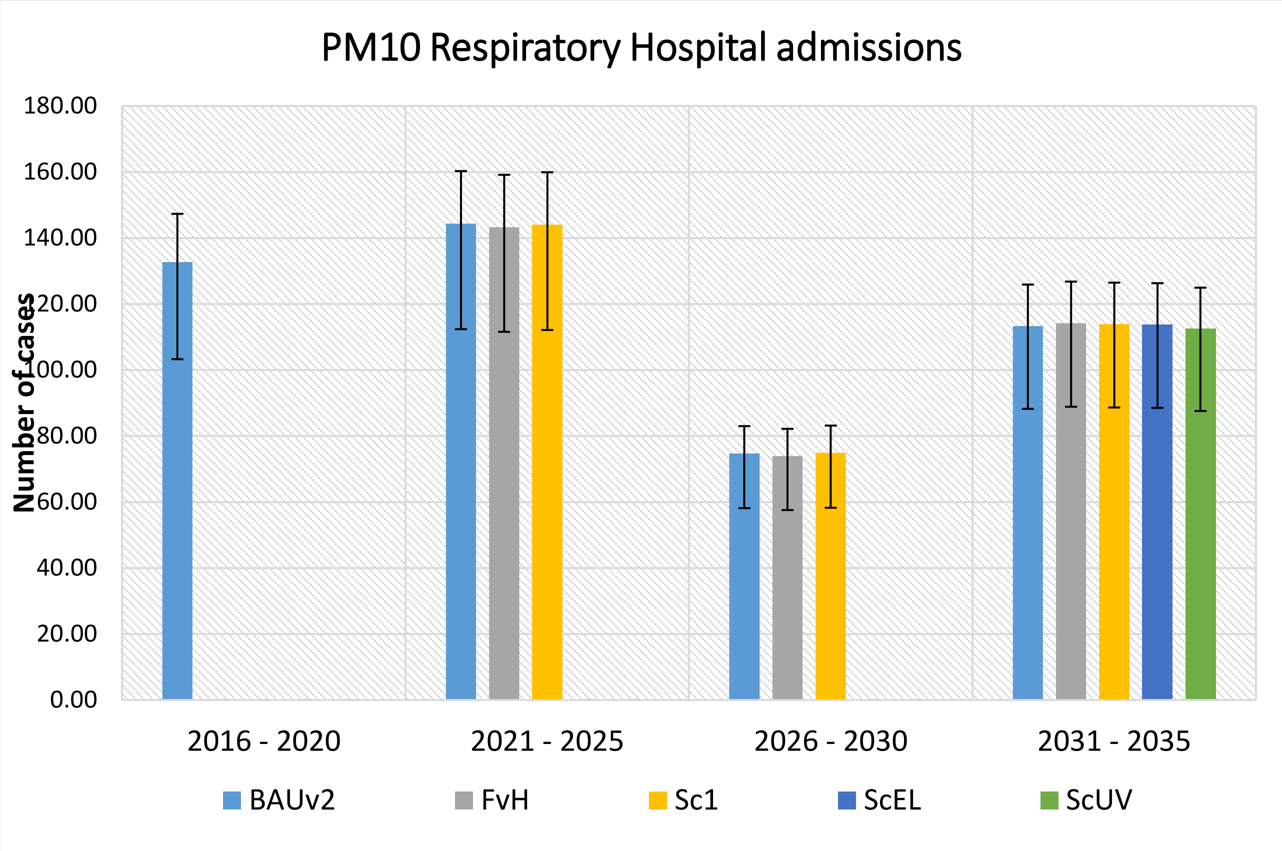
Stuttgart


PM2.5 mortality (all natural causes) >30 years old
Number of cases
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

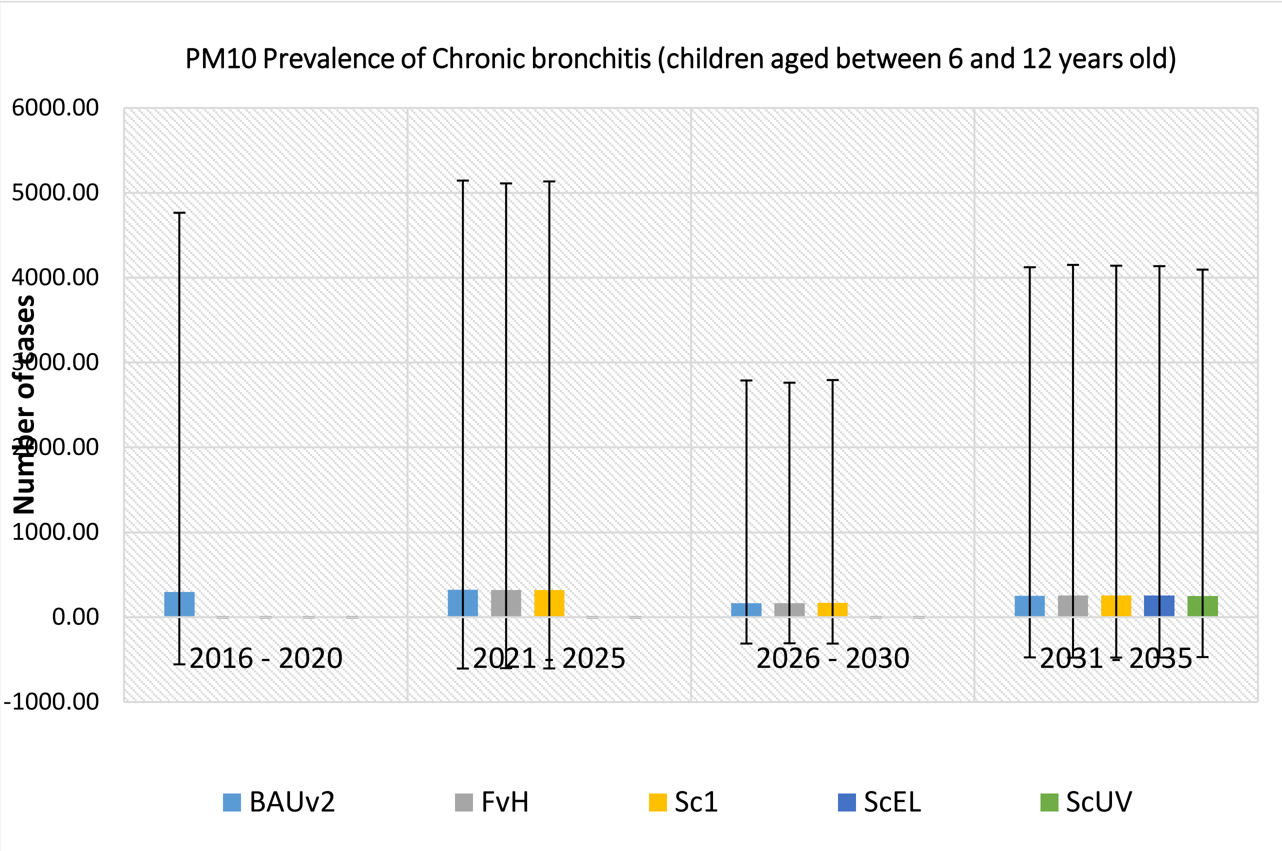

PM10 infant mortality (0-1 year)
Number of cases
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV


PM10 Incidence of Chronic bronchitis (adults)
Number of cases
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

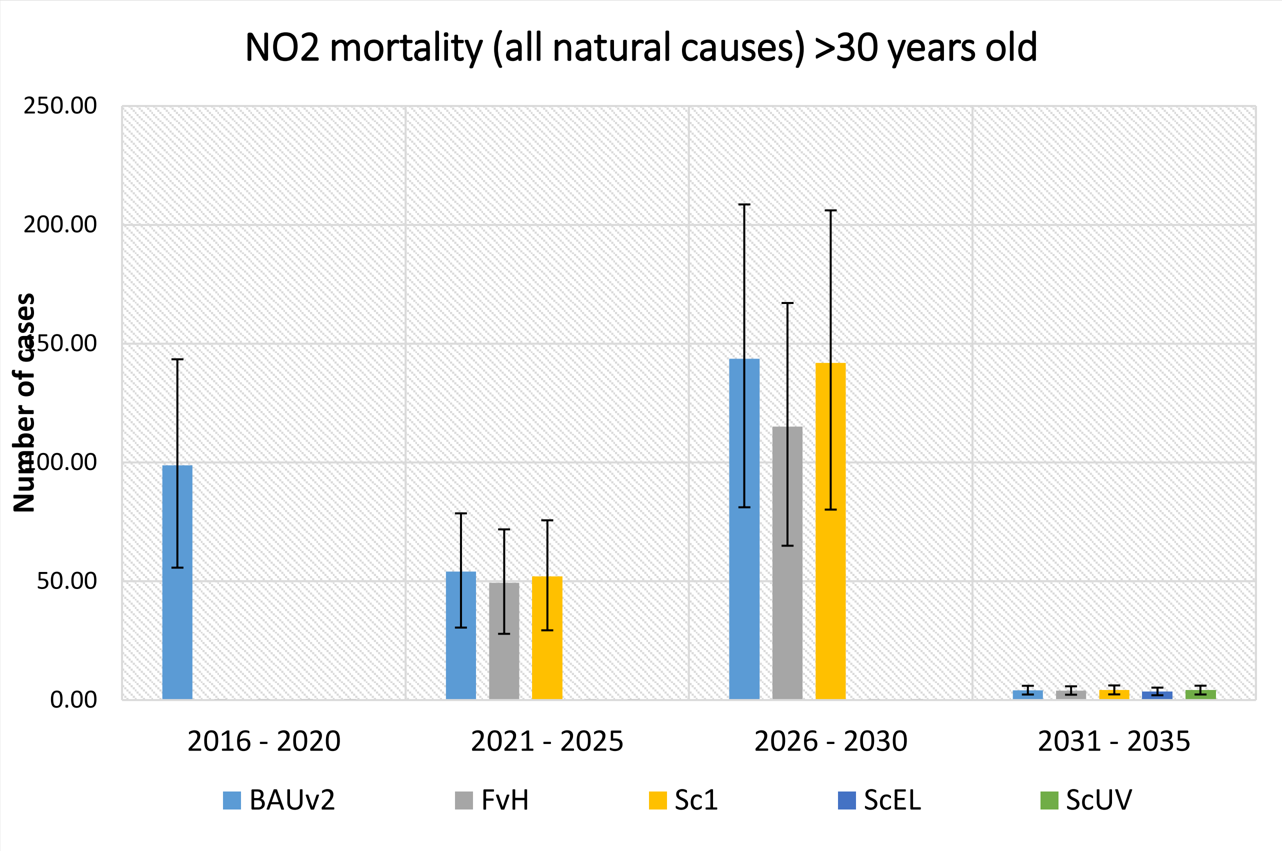

PM10 Cardiac Hospital admissions
Number of cases
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



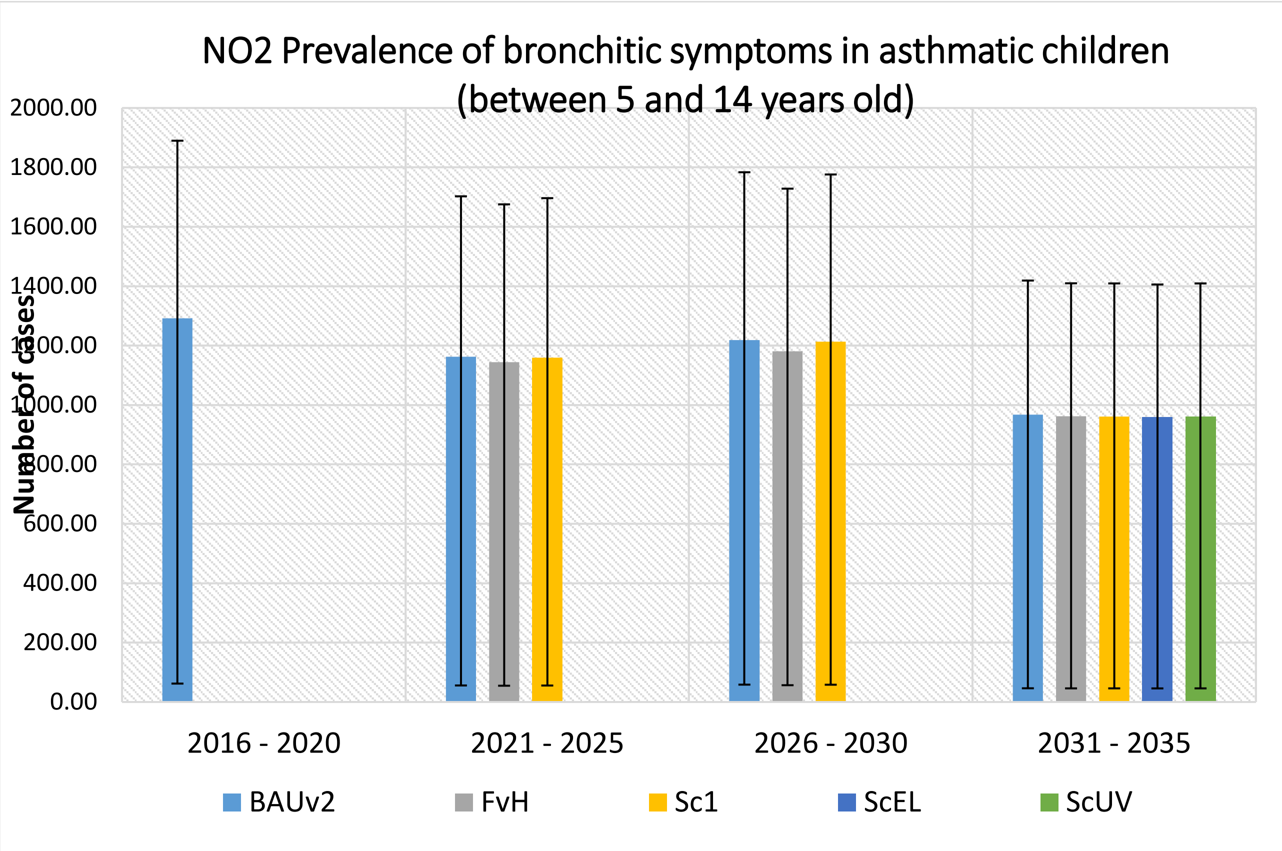
PM10 Respiratory Hospital admissions
Number of cases
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



PM10 Prevalence of Chronic bronchitis (children aged between 6 and 12 years old)
Number of cases
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
-1000.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



NO2 mortality (all natural causes) >30 years old
Number of cases
250.00
200.00
150.00
100.00
50.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV



NO2 Prevalence of bronchitic symptoms in asthmatic children (between 5 and 14 years old)
Number of cases
2000.00
1800.00
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
2016 - 2020
2021 - 2025
2026 - 2030
2031 - 2035
BAUv2
FvH
Sc1
ScEL
ScUV

ANNEX 5: Targeted WRF and WRF/Chem Validation Present Studies

Since the WRF and WRF/Chem models are well established and widely used in regional/urban scale wind and air quality studies, the aim of the present evaluation exercise has the meaning of proper model implementation rather than model evaluation as such. It is well understood that the good air quality predictions depend not only the good model but also on a fairly accurate emission inventory which is not always the case. We select the following two test cases that the emission inventories can be trusted to a certain degree.:

- Stuttgart Greater Area Meteorology and Air Quality
- PM10 Levels in the Western Macedonia region.

A.1. Stuttgart Greater Area Meteorology and Air Quality

<u>The Meteorology Example</u>

For the area of Stuttgart, a meteorological simulation using WRF model has been performed for the month of June 2015. The meteorological data observed in Echterdingen station (48.68, 9.22) are compared with the modeled data in terms of average daily values on temperature (Fig A.1), humidity (Fig A.2) , wind speed (Fig A.3) and wind direction (Fig A.4).

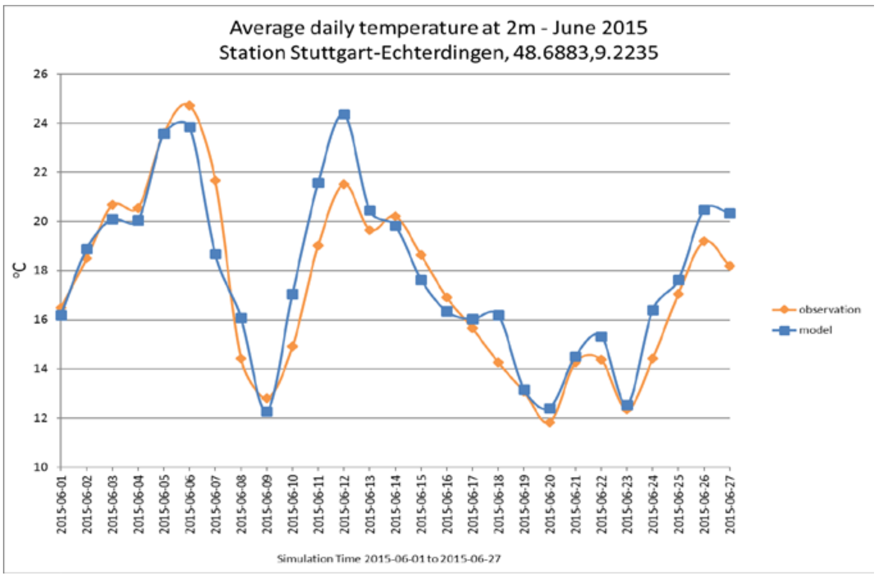


Figure A.1: Average daily temperature

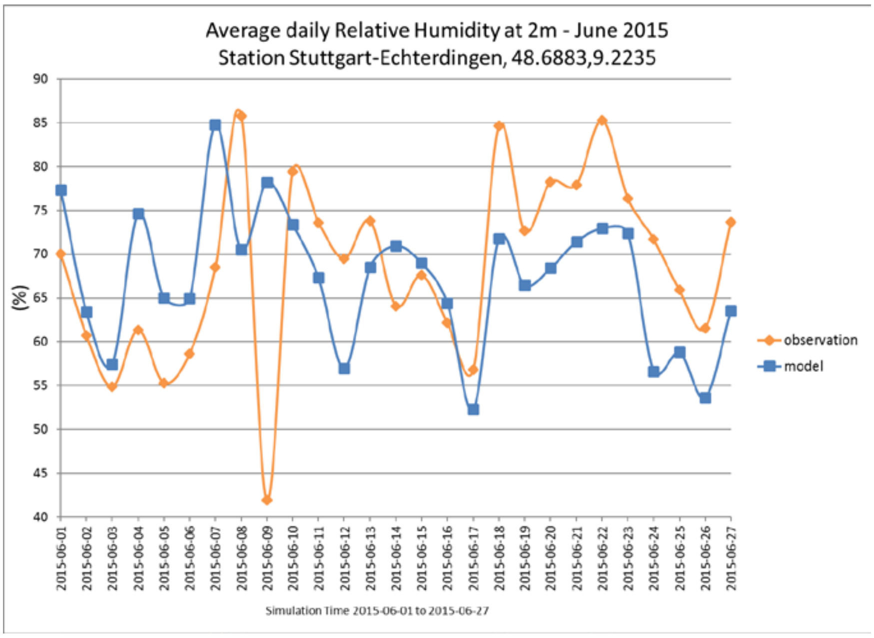


Figure A.2: Average daily relative humidity

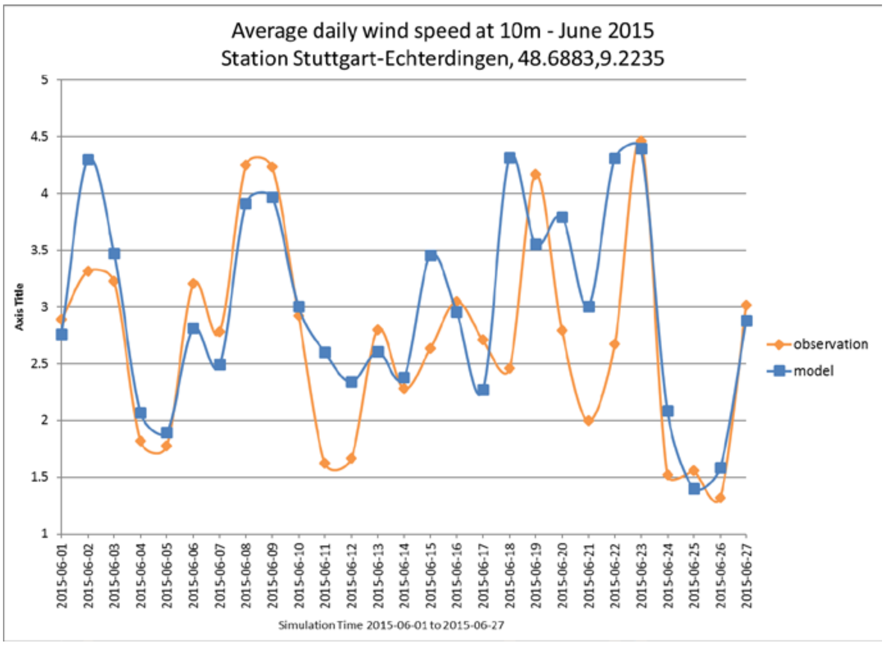


Figure A.3: Average daily wind speed

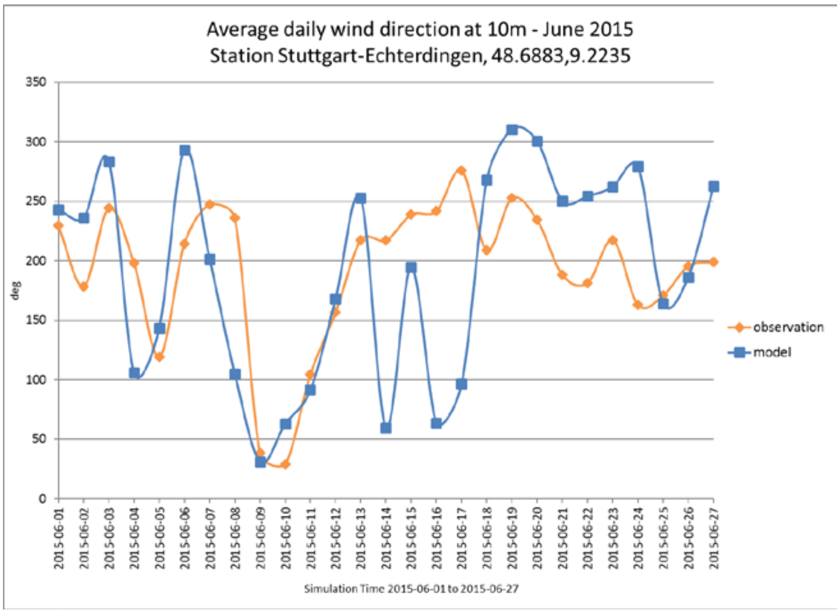


Figure A.4: Average daily wind direction

The obtained results are more or less as expected with relatively small discrepancies compared against observations.

<u>The examples of NO_2 and O3 Levels</u>

The hourly NO_2 and O_3 data observed in DEBW011 station (9.17, 48.82) are compared with the modeled data for the cluster selected dates 14.06.2014 and 5.09.2005 are shown in Figures A.5-A.8.

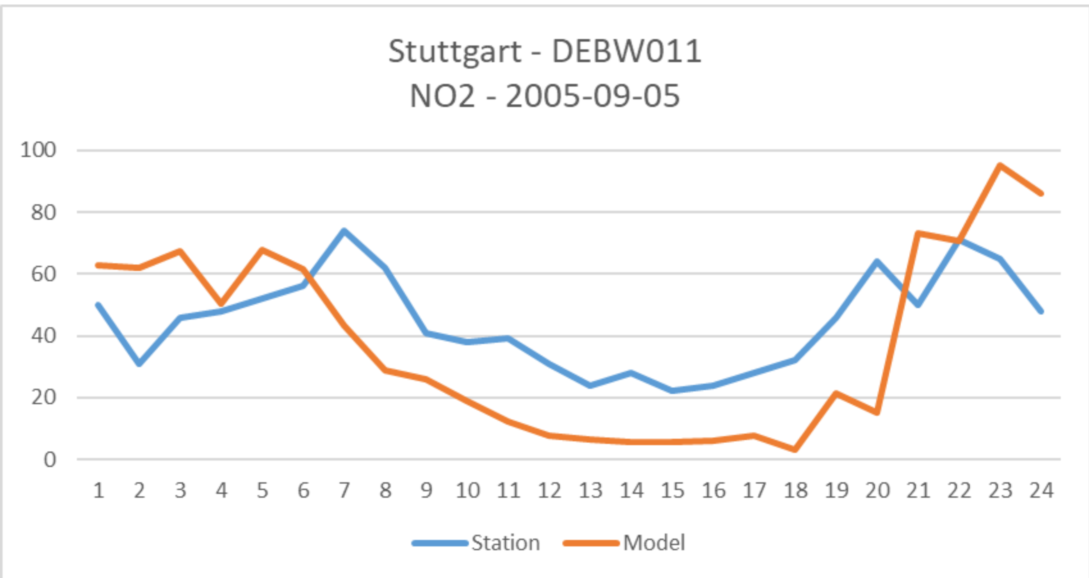


Figure A.5: Hourly NO_2 concentrations

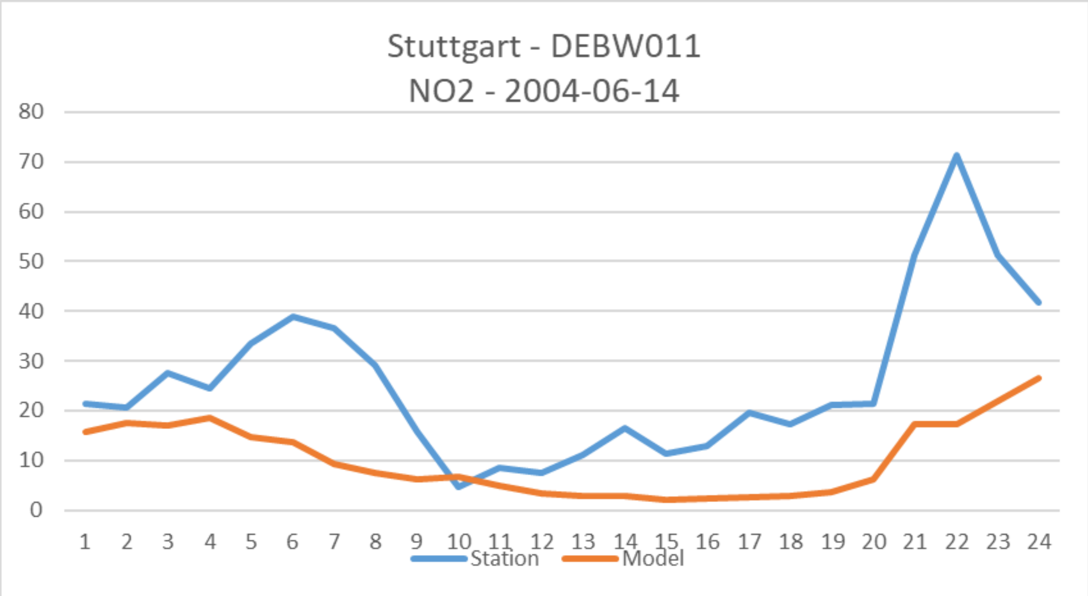


Figure A.6: Hourly NO_2 concentrations

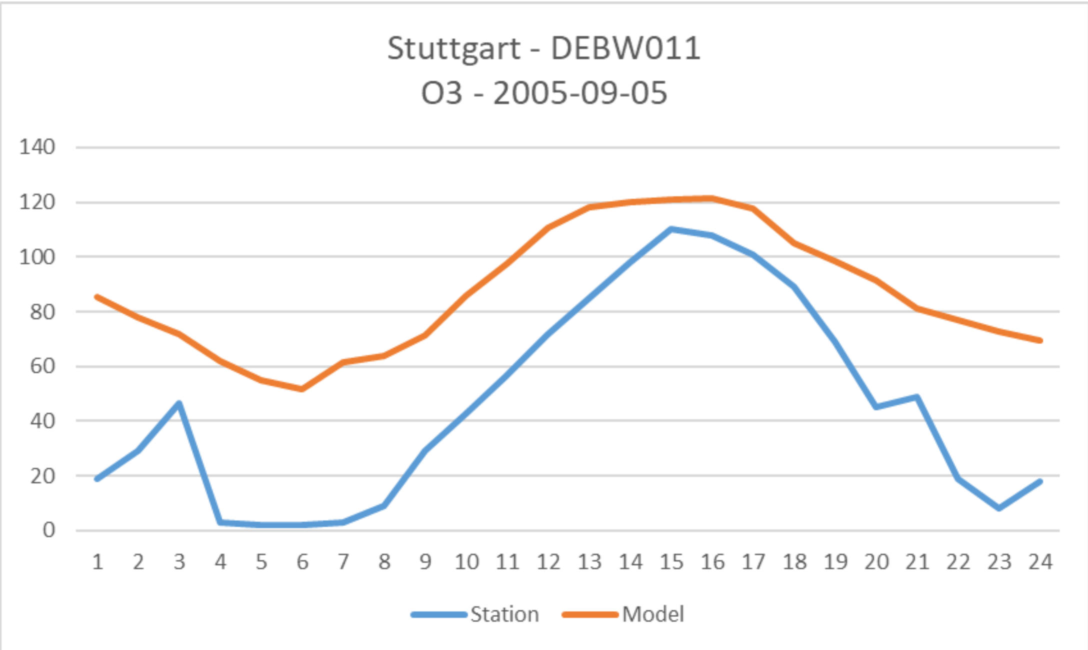


Figure A.7: Hourly O_3 concentrations

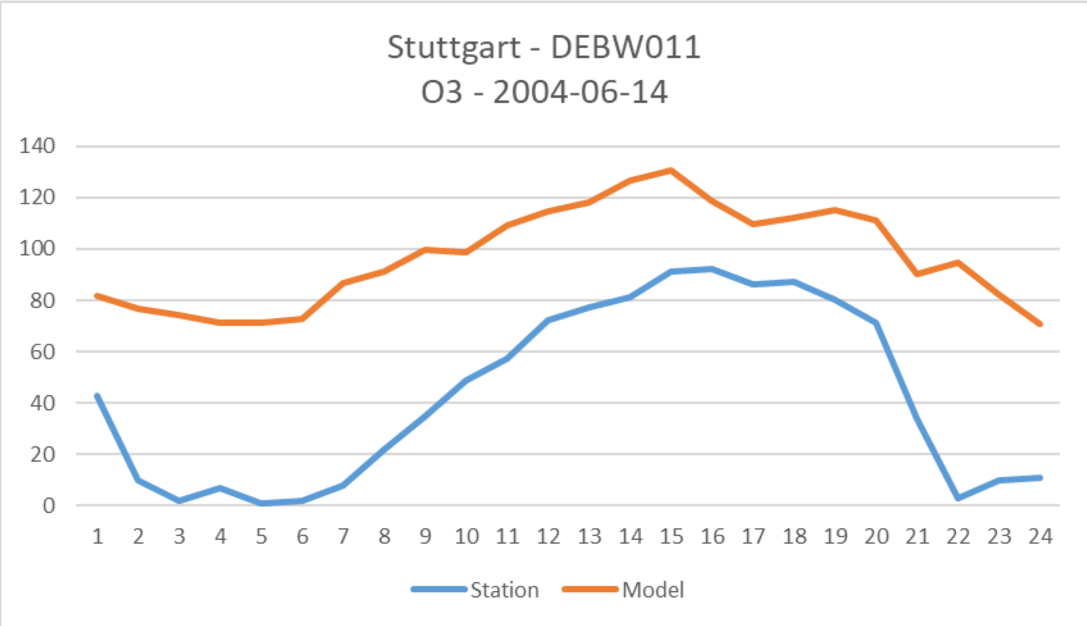


Figure A.8: Hourly O_3 concentrations

From the above figures it is clear that model trends follow to a large extend the observation ones. Some degree of under prediction is observed that can be justified by the fact that the model values are averages over 2km x 2km, filtering out any 'local peak' occurring at a specific location such as the observation point. Subgrid variation of the emissions also can cause model vs observation discrepancies.

Based on the above remarks the model performance with respect to observation data can be considered rather satisfactory.

A.2. PM_{10} Levels in The Western Macedonia Region

The region of Western Macedonia is characterized by relatively high PM levels, due to the operation of lignite mines and power stations in the region. A three month simulation has been performed from 1.1.2017 to 31.3.2017. A PM monitoring network of seven(7) stations operated by Public Power Corporation (Figure A.9) has been used for the model evaluation.

Figure A.9: Monitoring stations in Western Macedonia Region

For the comparisons the daily average values were used by applying the following statistical indicators (COST ES1006) : Mean Bias (MB), Fractional Bias (FB), Root Mean Square Error (RMSE), Normalised Mean Square Error (NMSE), Fraction of predictions within a factor of two of observations (FAC2), Correlation coefficient (R2).

It was recommended, as typical performance measures (COST ES1006: Model evaluation protocol (2015)): FAC2 > 0.3, $|FB|$ < 0.67 and NMSE < 6.

Table A.1 summarizes the statistical results of the modeled vs observation comparisons for all stations

Table A.2: Statistical results per monitoring station

	Station	MB	FB	RMSE	NMSE	FAC2	R	R2	Fitted curve
1	OIKISMOS DEH	-13.8	-0.34	27.79	0.5	0.625	0.649	0.4215	y = 0.305x + 18.601
2	PONTOKOMI	-4.68	-0.17	16.43	0.37	0.75	0.466	0.217	y = 0.2989x + 15.833
3	BEYH	-12.98	-0.56	18.16	0.65	0.682	0.767	0.588	y = 0.4018x + 4.8344

4	FLORINA	-22.05	-0.58	31.29	0.75	0.671	0.725	0.525	y = 0.3758x + 8.3271
5	FILOTAS	-6.3	-0.26	13.3	0.31	0.693	0.571	0.326	y = 0.4839x + 7.6047
6	KATO KOMI	-10.86	-0.52	16.3	0.65	0.571	0.404	0.163	y = 0.2915x + 7.9863
7	AMYNTAIO	-7.37	-0.37	13.06	0.45	0.648	0.52	0.27	y = 0.4727x + 4.9385
	All stations	-5.57	-0.2	20.61	0.56	0.667	0.643	0.261	y = 0.7858x + 10.89

The minimum FAC2 is 0.57 i.e. above the acceptable lower limit of 0.3
The maximum value of |FB| is 0.58 i.e. below the acceptable upper value of 0.67
The maximum value of NMSE is 0.75 i.e. well below the acceptable upper value of 6.0.
A typical example is given in Figure A.10 where the modeled vs observed daily concentrations of PM_{10} in Florina station are shown.

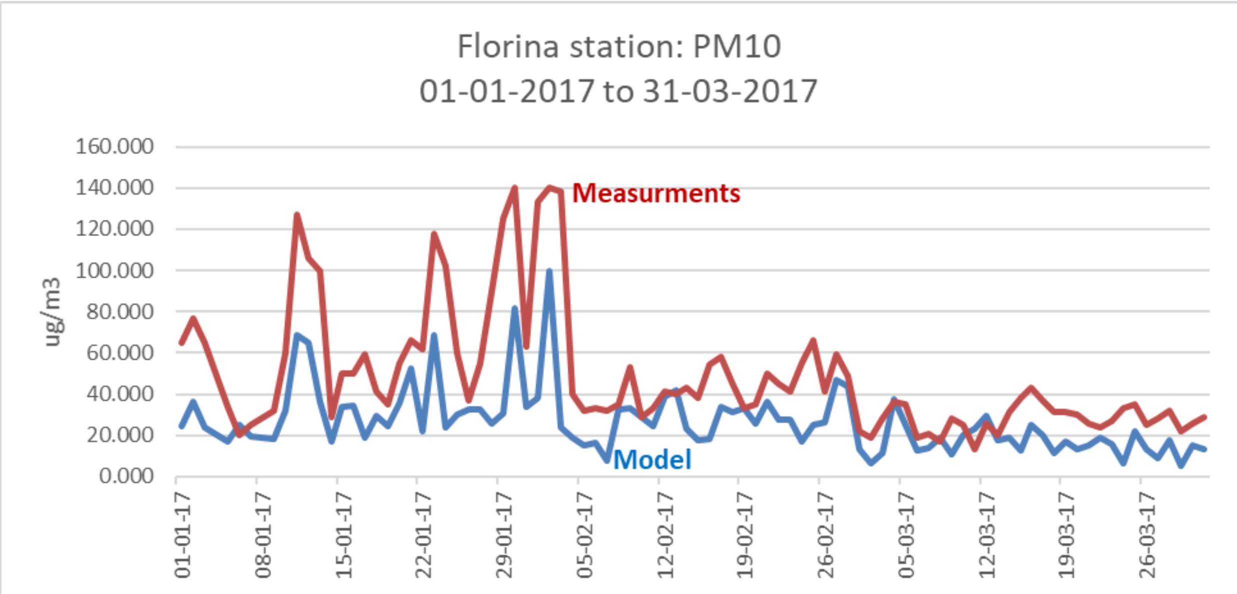


Figure A.10: Daily concentrations of PM_{10} in Florina station

Again here, we can see the consistency in concentration trends within some degree of under prediction probably due the model spatial filtering.

In general terms, the above modeling results are quite satisfactory compared with observation data.