ClairCity: Citizen-led air pollution reduction in cities

Deliverable 5.7: City Impact Analysis Report – Amsterdam

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Document Details

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Description	The Deliverable 5.7 collects all results of the full impact analysis, methodological approach and data sources. This report describes the full impact analysis for Amsterdam.

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Version	Updated By	Date	Changes / Comments
V1.0	Kris Vanherle	08/05/2019	Outline
V1.1	Kris Vanherle	12/11/2019	Added content by Peter (TML) and An (DTU)
V2.0	Kris Vanherle	13/01/2020	Incorporation of inputs from TECHNE, DTU, PBL
V2.1	Kris Vanherle	18/02/2020	Updated inputs from UAVR and NILU and updated as stand-alone document
V2.2	Kris Vanherle	10/03/2020	Completed for Amsterdam
V2.3	Vera Rodrigues	31/03/2020	Revised for Amsterdam

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Quality Assurance	Enda Hayes (UWE)
Native Language Check	Enda Hayes (UWE)
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Table of Content

In this document, we elaborate into the methodology and results of the modelling for the Amsterdam case. We first elaborate on any methodological particularity [1] and then report on the specific assumptions, translating the scenarios to model input [2] and report on the results of the modelling [3]. The impact assessment data illustrating the work undertaken can be found on the ClairCity Data Portal, as follow: https://claircitydata.cbs.nl/dataset/d5-5a-assessment-of-impacts-amsterdam. Access can be arranged upon request. Furthermore, it was created a ClairCity community on Zenodo.org, where the full dataset was uploaded from the ClairCity Data Portal to Zenodo. The comunity is available on the link: https://zenodo.org/communities/claircity.

1 Methodological particularities

The source for the transport volume in Amsterdam is data from the traffic model of the Amsterdam municipality. This data holds traffic intensity at link level, by mode. As indicated in the chapter on the general methodology, we use this data as input for transport emission estimates. We added 2 key links manually where road transport emissions are expected to have an effect on air quality in the municipality.

1.1 Transport: Mode choice model

The Netherlands, similarly to the UK, also conducts travel surveys on a regular basis, and these surveys – the Onderzoek Verplaatsingen in Nederland (OViN) – are also easily accessible[1]. Therefore, due to Amsterdam being a very special place thanks to the present very high share of active modes (which is far beyond the share of these modes in any of the other five cities/regions), initially we wanted to build a mode choice model specific to the urban Netherlands.

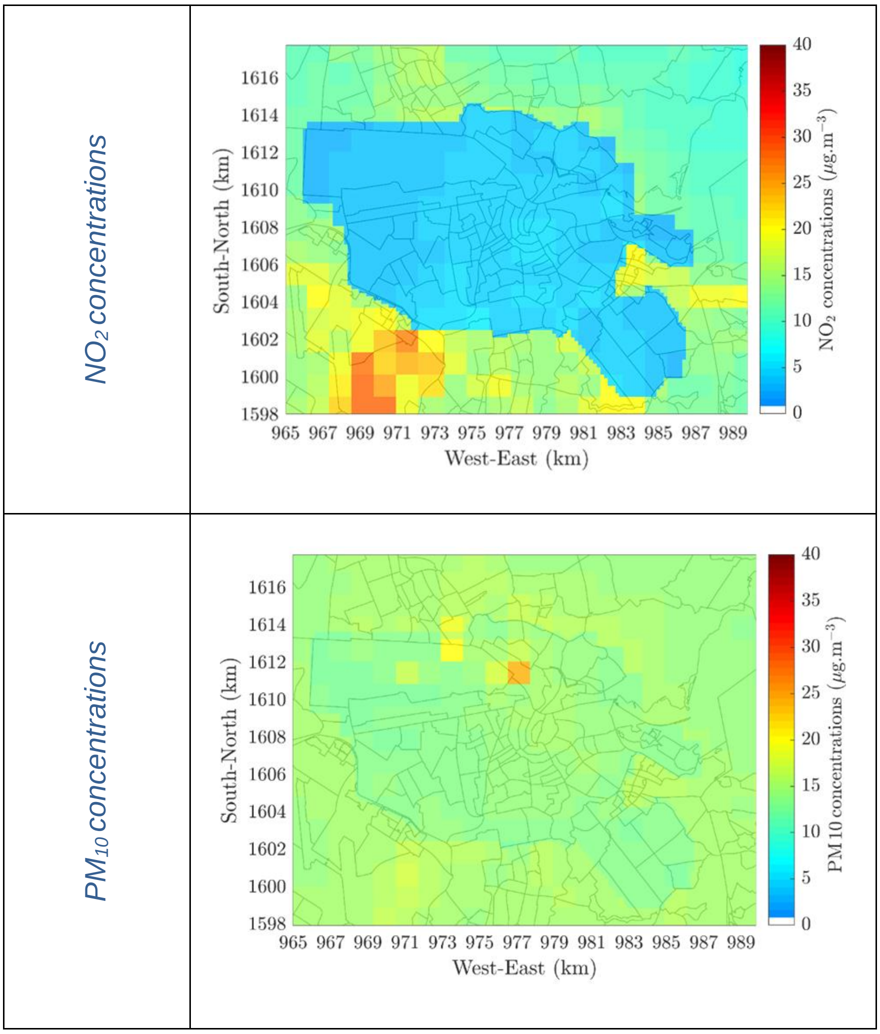
After some early tests we abandoned the idea as the resulting model parameters were nonsensical (e.g., negative value of time) even when only looking at the time and cost variable. As a fall-back option, we used the mode choice model built for Bristol for Amsterdam, and we only looked at changes in mode mileages and not at the absolute values of trip shares. This implies similar behaviour with respect to incentives that influence mode choices of citizen (i.e. cost, quality, speed,…).

[1] https://www.cbs.nl/nl-nl/onze-diensten/methoden/onderzoeksomschrijvingen/korte-onderzoeksbeschrijvingen/onderzoek-verplaatsingen-in-nederland--ovin--

1.2 Air quality modelling

1.2.1 Background concentrations

Based on the source apportionment analysis obtained from the WRF-CAMx and the PSAT tool, it was expected an underestimation of the URBAIR concentrations comparing to measured data results due to the lack of other emission sources contributing to the concentrations within the area, as well as the background concentrations. Therefore, a procedure was defined to account for the background concentrations, considering the transboundary contribution and other remaining sources, based on the background concentration maps for 2015 published by the National Institute for Public Health and the Environment of the Netherlands (RIVM). The background air pollution maps made available by RIVM are the total annual mean concentrations based on modelled data on 1 km x 1 km grid squares. Figure 1-1 shows the contour maps of the background concentrations estimated for Amsterdam to be added to the URBAIR outputs.



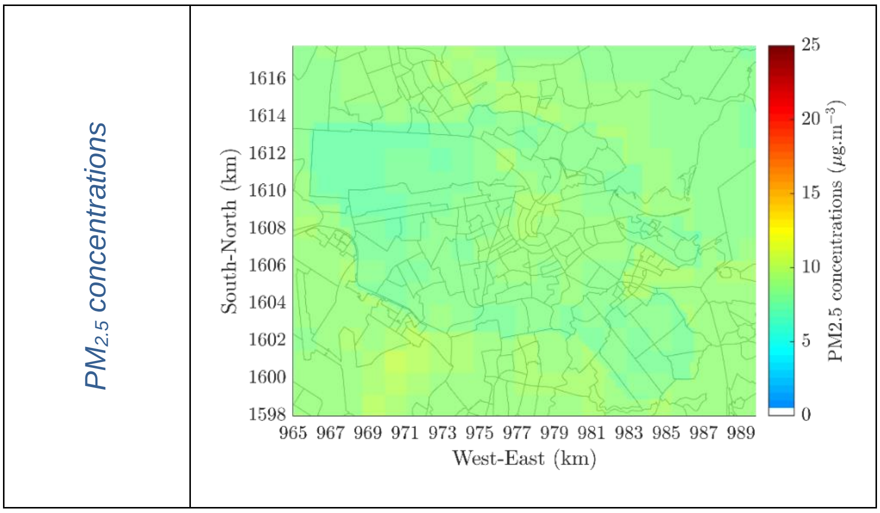


Figure 1-1: Summary data of the background concentrations estimated for Amsterdam in µg.m^{-3}.

1.2.2 Summary of measuring data

In order to compare and calibrate the modelling results for the year of 2015, for NO_2 a total of 100 diffuse tubes (44 background sites, 51 street sites, 3 waterway sites and 2 highway sites) were used combined with 16 monitoring stations (5 road traffic sites, 7 urban background sites, 3 rural sites and 1 industrial site). For PM_{10} concentrations, the modelling results could be compared with 12 monitoring stations (3 urban background, 4 urban traffic, 1 rural background, 2 urban industrial and 2 suburban background). For $PM_{2.5}$, the modelling results could be compared with 4 monitoring stations (3 urban background and 1 rural background station). Figure 1-2 shows the location of the equipment providing continuous measurements, with the NO_2 concentrations in µg.m^{-3} measured in 2015, a) by the diffusion tubes and b) by the continuous monitoring equipment. Figure 1-2-b is a zoomed area of the city center where the continuous sites are located.

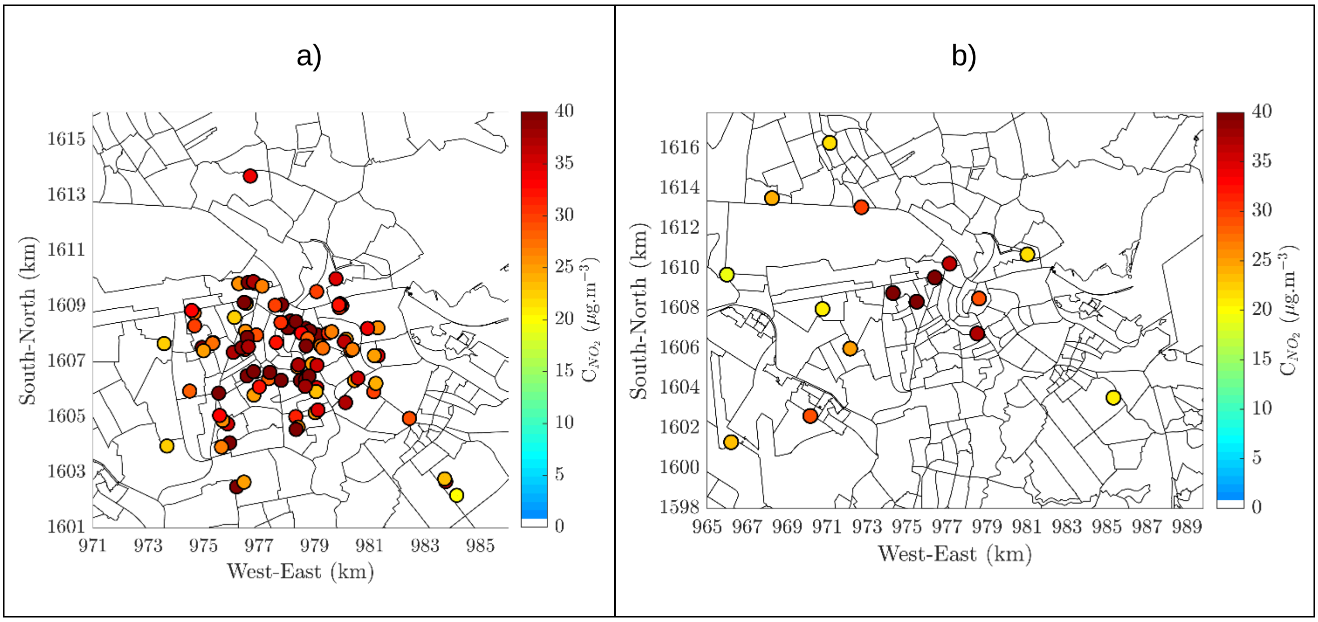


Figure 1-2: Summary data for 2015 with the location of the measurement points: a) zoomed area of the diffusion tubes with information about the annual average of the NO_2

concentrations in µg.m $^{-3}$; b) the monitoring stations with information about the annual average of the NO_2 concentrations in µg.m $^{-3}$.

The majority of the diffusion tubes are located within the city center, providing a good overview of the NO_2 concentrations in areas most influenced by road traffic The maximum value monitored in 2015 by the diffusion tubes is 56.8 µg.m^{-3}, while for the monitoring stations is 49 µg.m^{-3}. Figure 1-3 shows the location of the monitoring stations and the annual mean concentration for 2015 for PM_{10} and $PM_{2.5}$.

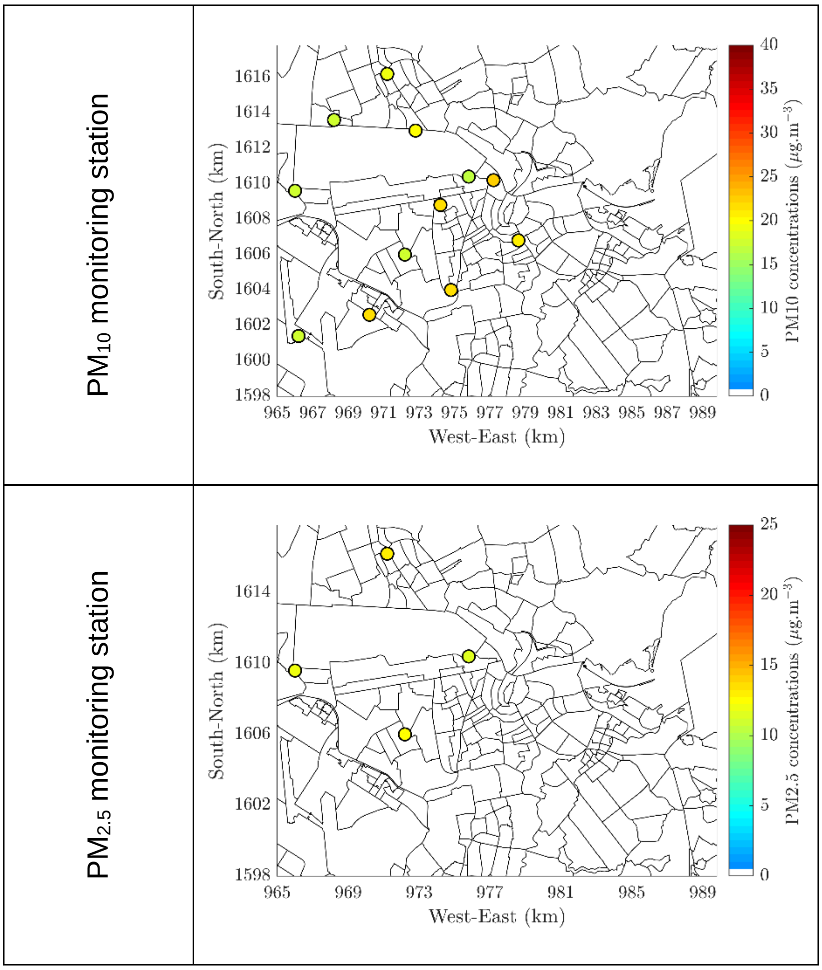


Figure 1-3: Summary data for 2015 with the location of the monitoring stations and respective measured annual mean concentration for each pollutant (PM_{10} and $PM_{2.5}$), in µg.m^{-3}.

1.2.3 Adjustment procedure

The adjustment procedure is based on the linear regression between the measurements and the simulated concentrations obtained within the cells corresponding to the location of the measurement points. The slope from the linear regression is applied as an adjustment factor over the entire domain. For NO_2 concentrations, due to the large availability of measured data, a separation by AQ station type was applied, originating different factors to be applied to the accounted sectors. From the background stations the factor is 1.2, for the traffic stations the factor is 1.6 and for industrial stations the factor is 1.3.

For PM_{10} two factors were applied, for the transport sector a factor of 3.0 was applied and for the commercial and residential sector a factor of 2.9.For $PM_{2.5}$ no distinction were made between AQ stations type resulting in a factor of 4.3.

2 Description and modelling of the scenario's

In ClairCity, we do the quantification of the emissions and air quality in 4 sequential steps:

- **The baseline**: the emissions, air quality and carbon footprint in our reference year: 2015. These results can be verified with observations and serve as a calibration of the tools.
- **The business as usual scenario (BAU)**: the emissions, air quality and carbon footprint are estimated for selected future years: 2025, 2035, 2050. This takes into account the effect of existing measures (e.g. natural fleet renewal in transport)
- **The Stakeholder Dialogue Workshop scenario's (SDW)**: the emissions, air quality and carbon footprint in future years, compared to BAU, including the measures in the scenario's established in the stakeholder workshops.
- **The final unified scenario (UPS)**: the emissions, air quality and carbon footprint in future years, compared to BAU, in the single selected scenario, established in the policy workshop

This section mainly describes the assumption made in the modelling to estimate the scenarios

The SDW resulted in two proposed scenarios (a High and a Low version) which differ mainly in the ambition level and timeline in the selected policies. Afterwards a final scenario was developed from selected ingredients of these initial proposed scenarios. Learning from the case of Bristol, starting from Amsterdam the policies were formulated already in the first phase in a way that they were easier to interpret from a modellers' point of view. Each of these scenarios are explained sector-by-sector and scenario-by-scenario in the following subsections. An overview of the initial definition of the individual policies and their timelines are given in the table below.

Table 2-1: Overview of the measures in the Amsterdam SDW and final Unified Scenario.

Policy	Low Scenario	High Scenario	Final Scenario
Cleaner buses	Half of the busses emission-free (100% electric or hydro-powered) by 2025	All busses emission-free (100% electric or hydro-powered) by 2022	Low option
Better public transport	Increase network density from the net and increase frequency by 2030	Increase network density from the net and increase frequency by 2030	High option

More bike paths and bike parkings	40 000 new bike parking spots by 2030. Improving current bike pats and fast bike routes (bike highways) by 2025	60 000 new bike parking spots by 2025. Improving current bike pats and fast bike routes (bike highways) by 2022	High option
Cheaper public transport	Price of public transport remains the same until 2030	Price of public transport becomes 50% cheaper for everyone by 2025	Low option
Environmental zone for polluting cars	Maintain current environmental zones	Adding an environmental zone for private cars and making current environmental zones more stringent	High option
Less parking for cars	Maintain the current number of parking spots	Remove 7.000-10.000 parking spots (approx. 10% of the current parking spaces in the city centre) and charge € 7.5 per hour everywhere in the city by 2020	High option
Reducing car traffic in the centre	Maintain current legislation for cars (i.e. reducing car traffic by one-way roads and splitting up traffic routes)	Cars in the city centre are only allowed for people living there	High option
Accelerate energy efficient renovations	All houses belonging to housing associations reach an energy label B or C by 2050	All houses belonging to housing associations reach an energy label A by 2050	Low option
Ban wood stoves and fireplaces in houses and bars & restaurants (terraces)	Ban wood stoves and fireplaces in both new buildings and existing buildings from 2025	Ban wood stoves and fireplaces in both new buildings and existing buildings from 2025	High option
Accelerate the uptake of solar panels in the built environment	Maintain current regulation. No incentives from the Municipality of Amsterdam to promote solar energy (except for housing associations)	Mandatory solar panels in all suitable roofs and provide subsidies for it	High option
Amsterdam (natural) gas-free	€ 2.500 subsidy per household in order to facilitate renovation to become gas-free. No obligations for the building sector.	€ 10.000 subsidy per household in order to facilitate renovation to become gas-free. Mandatory gas-free building sector by 2030.	High option

2.1 Transport

2.1.1 Baseline and BAU

The modal split (trip and mileage) in the BAU is the following (from the OViN data, filtered to urban regions with 50000+ inhabitants):

- Car: 38% - 69%
- Train: 2.7% - 12.3%
- Bus/tram/metro: 5.1% – 3.6%
- Moped/fast e-bike: 1.1% - 0.7%
- Bike: 26.1% - 8.9%
- Walk: 25.6% - 3.1%
- Motor and others: 1.4% - 2.5%

The baseline fleet and vehicle kilometre demand is according to our original MOVEET model. In the BAU there is no change assumed in the modal split, and the fleet evolves in agreement with the Under 100 scenario from McKinsey&Company: *Boost! Transforming the powertrain value chain – a portfolio challenge*.

2.1.2 Proposed SDW scenario's

In the Low Scenario we keep the fleet evolution scenario from the Baseline, and only mode-choice related changes are simulated.

Environmental zone for polluting cars: In the High Scenario we accelerate the uptake of EVs and implement a stepwise scrappage scheme exactly as we did when modelling Bristol's low emission zone in the Final Scenario, and there are mode choice changes made on top of that.

Better public transport: we are assuming a strong decrease in waiting and travel times (as a result of better network organisation, higher frequencies, higher average speed thanks to bus lanes, etc.) and model this by using a 0.8 multiplier on stage times. This is the same in both Low and High Scenarios.

- In model:
    - StageTime_4 = data['StageTime_4'] * 0.8

Cheaper public transport: only takes effect in the High Scenario. We model it simply by setting PT prices to 50% of the observed.

- In model:
    - StageCost_4 = data['StageCost_4'] * 0.5

Less parking for cars: only takes effect in the High Scenario. We model this by adding 5 minutes per trip for parking space search, plus an estimated 0.4 EUR extra parking price which was calculated as follows: this policy is estimated to bring 30 million EUR extra income for the city[2], calculating with 0.5 trips per person per day[3], gives ~400000 trips, half of these needs paying parking (as the other half is parked at home), that is 200000 parking ticket purchases per day, 73 million per year, which combined with the 30 million estimated income gives 0.4 EUR extra per parking ticket. (Then since we input this to the Bristol mode choice model we translate this to GBP and use an estimated 0.3 GBP extra.)

- In model:
  - StageTime_3 = data['StageTime_3'] + 5 #Since times are in minutes in data
  - StageCost_3 = data['StageCost_3'] + 0.3

Reducing car traffic in city centre: this again only applies in the High scenario, and we model its effect with a final scaling factor applied at the very end on the total car mileages.

2.1.3 Final Scenario

The final scenario is simply a mix of already discussed modelling elements from the Low and High scenario according to the policy overview in Table 2-1, without any further changes.

2.2 Industrial, Residential, Commercial & Institutional (IRCI)

2.2.1 Baseline

In the following the data collection and evaluation procedures in the baseline are detailed for Amsterdam. The following tables document the methodology and data used for:

- Industrial sources (Table 2-2);
- Residential and commercial sources (
- Table 2-3);
- Wood statistics (Table 2-4);
- BUURT disaggregation variables (Table 2-5).

[2] https://www.parkeer24.nl/nieuws/240518/coalitieakkoord-amsterdam-duurder-en-minder-parkeren
[3] https://www.ois.amsterdam.nl/downloads/pdf/2018%20jaarboek%20amsterdam%20in%20cijfers.pdf

Table 2-2: Methodology and source of data for Amsterdam emissions evaluation - Industrial sources.

Activity	Data availability	Source	Publication	Reference
Industrial sector	Single facility	Emissieregistratie		https://emissieregistratie.nl

Table 2-3: Methodology and source of data for Amsterdam fuel consumptions evaluation - Residential and services sources.

Activity	Energy vector	Data availability	Source	Publication	Reference	Field	Disaggregation variable
Residential sector	Natural Gas	Level 3 (Buurt)	CBS	Wijk - en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	G_GAS_TOT*WONINGEN where: [G_GAS_TOT]: Average total natural gas consumption [WONINGEN]: Housing stock	None

	Wood	Level 2 (Gemeente)	RIVM	Klimaatmonitor	https://klimaatmonitor.databank.nl/dashboard/	Wood burning stoves dwellings hern. heat [TJ] (see Share of wood on biomass in Table 2-4 for technology spit)	Population (Table 2-5)
	LPG	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: households Period: 2015 Energy commodities: LPG	Population (Table 2-5)
	Gasoil	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: households Period: 2015 Energy commodities: Heating and other gas oil	Population (Table 2-5)
Service sector	Natural gas	Level 2 (Gemeente)	RIVM	Klimaatmonitor	https://klimaatmonitor.databank.nl/dashboard/	Gas use commercial Services [m3] + Gas use Public Services [m3]	Services Companies number (Table 2-5)

	Wood	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: services waste and repairs Period: 2015 Energy commodities: Solid and liquid biomass	Services Companies number (Table 2-5)
	LPG	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: services waste and repairs Period: 2015 Energy commodities: LPG	Services Companies number (Table 2-5)
	Gasoil	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: services waste and repairs Period: 2015 Energy commodities: Heating and other gas oil	Services Companies number (Table 2-5)
Residential sector	Natural Gas	Level 3 (Buurt)	CBS	Wijk - en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	G_GAS_TOT*WONINGEN where: [G_GAS_TOT]: Average total natural gas consumption	None

						[WONINGEN]: Housing stock	
	Wood	Level 2 (Gemeente)	RIVM	Klimaatmonitor	https://klimaatmonitor.databank.nl/dashboard/	Wood burning stoves dwellings hern. heat [TJ] (see Share of wood on biomass in Table 2-4 for technology spit)	Population (Table 2-5)

(°) if MSOA data are used to evaluate LSOA a bias is introduced due to different distribution industry/services in different MSOA

Table 2-4: Methodology and source of data for Amsterdam fuel consumptions evaluation – Wood statistics.

Variable	Data availability	Sources	Publication	Reference	Note
Technologies split	Level 3 (National)	CBS	Houtverbruik bij huishouden (Wood consumption in households)	https://www.cbs.nl/-/media/imported/documents/2010/18/2010-houtverbruik-bij-huishoudens-art.pdf?la=nl-nl	On the basis of available data, the following shares are evaluated: stoves 55% fireplaces 45%. Using national EMEP PM_{10} data the following shares are derived: traditional 30% advanced 70%.) Service sector allocated to boilers.

Table 2-5: Methodology and source of data for Amsterdam fuel consumptions evaluation – BUURT disaggregation variables.

Variable	Data availability	Sources	Publication	Reference	Fields
Population	Level 3 (Buurt)	CBS	Wijk-en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	AANT_INW (Number of inhabitants)
Services Companies number	Level 3 (Buurt)	CBS	Wijk-en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	[A_BED_GI]+[A_BED_HJ]+[A_BED_KL]+[A_BED_MN]+[A_BED_RU] where: [A_BED_GI]: Number of companies and catering trade [A_BED_HJ]: Number of companies in transport, information, communication [A_BED_KL]: Number of firms financially property [A_BED_MN]: Number of companies in business services [A_BED_RU]: Number of companies in culture, recreation, other
Industry Companies number	Level 3 (Buurt)	CBS	Wijk-en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	[A_BED_BF]: Number of companies in industry and energy

2.2.2 BAU

Business as Usual (BAU) scenario takes into consideration national and city level measures already defined/decided.

National BAU scenario evaluates national emission reduction starting from Netherland official projections.

The scenario was built in different steps using:

- the projections of greenhouse gas emissions and energy demand from the 7th national communication to UNFCCC[4] using scenario with additional measures (WAM)
- the projections of greenhouse gas emissions and energy demand over 2030 from Ministry of Economic Affairs and Climate *Energy Policy*[5];
- the national measures defined in the 'with measures' (adopted measures) projection in the frame of NECD[6];
- the coal power plants ban by Dutch government in 2018[7].

In the first step the fuel consumption was varied following the energy demand projection with socioeconomic drivers, in the second step the emissions were varied to meet the NECD emissions considering technological drivers.

Regarding coal ban, the government prohibits electricity production in the Netherlands with coal as fuel from 2030 onwards[8]. The two oldest power plants - the Hemweg and the Amer power station - have to stop electricity production by the end of 2024 by means of coal. In consequence in the BAU scenario we close Hemweg 8 coal fired power plant by 2025.

The **Amsterdam** BAU projections consider:

- *Demographic evolution*. The city population will grow[9] with time (7% by 2020, 13% by 2025, 18% by 2030, 23% by 2035, and 27% by 2040 on 2015 levels for Amsterdam and 6% by 2020, 11% by 2025, 16% by 2030, 19% by 2035, and 23% by 2040 on 2015 levels for Greater Amsterdam). Also, private households will grow in future (3% by 2020, 7% by 2025, 11% by 2030, 15% by 2035, and 19% by 2040 on 2015 levels for Amsterdam and Greater Amsterdam)[10].
- *Sustainable Amsterdam: Agenda for renewable energy, clear air, a circular economy and a climate-resilient city*[11]

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[4] Ministry of Economic Affairs and Climate Policy, Seventh Netherlands National Communication under the United Nations Framework Convention on Climate Change
[5] Ministry of Economic Affairs and Climate Policy, Energy Report, Transition to sustainable energy
[6] EEA Eionet, Reporting Obligations Database (ROD), Deliveries for National Emission Ceiling Directive (NECD) - Projected emissions by aggregated NFR sectors
[7] Rijksoverheid , Kabinet verbiedt elektriciteitsproductie met kolen
[8] Rijksoverheid , Kabinet verbiedt elektriciteitsproductie met kolen
[9] CBS, Regionale prognose 2017-2040; bevolking, intervallen, regio-indeling 2015
[10] CBS, Regionale prognose 2017-2040; huishoudens, intervallen, regio-indeling 2015
[11] Sustainable Amsterdam, Agenda for renewable energy, clear air, a circular economy and a climate-resilient city. Adopted by the Municipal Council of Amsterdam, March 2015

The Municipality of Amsterdam is working with numerous partners to create a more renewable energy-based economy, which in time should be entirely fossil fuel-free – thus not dependent on coal, oil or gas.

Since Amsterdam is likely to continue its strong growth rate over the coming years, we aim to improve our renewable energy performance per capita. The city has set the following main targets:

- By 2020, they will generate 20 per cent more renewable energy per capita compared to 2013. They will achieve this in the following ways:
  - Producing more wind and solar energy;
  - Making more use of renewable heating.
- By 2020, they will use 20 per cent less energy per capita compared to 2013. They will achieve this in the following ways:
  - Making existing housing stock more sustainable;
  - Reducing energy consumption by corporate real estate and social real estate;
  - Encouraging energy-neutral construction.
  - Reducing the use of (fossil-based) energy and increasing renewable energy production will result in a lowering of Amsterdam's CO_2 emissions. This effort will thus contribute to building an economy that will emit 40 and 75 per cent less CO_2 by 2025 and 2040 respectively, compared to 1990.

The Agenda doesn't report specific measures to insert in the model but only general goals.

- *'Grand Design' for a regional heating network*[12]

In December 2016, 32 public and private parties in the Amsterdam Metropolitan Area (MRA) voted to go ahead with the 'Grand Design' for a regional heating network stretching from IJmuiden to Almere and from Zaanstad to Aalsmeer. This move will prepare the area for a gas-free future with heating networks as an attractive alternative for the built environment. Research carried out by independent research organization CE Delft has shown that the planned collective heating network ('district heating') would be much cheaper than an approach involving individual measures in each home, and it would generate considerable energy savings too. The Roadmap to Sustainable Heating in the Amsterdam Metropolitan Area (Routekaart Duurzame Warmte in de MRA), which includes agreements on how district heating can be established, has also been determined. The district heating grid will need to provide homes, greenhouses and businesses with the equivalent amount of sustainable energy that would be required to heat 500,000 homes.

For drivers coming from EU NEC "with measures" data, as it's impossible to derive from available information the split between socio-economic measures, such as for example fuel consumptions reductions, and technological measures, such as for example advanced combustion technologies, all the measures are inserted as technological ones. The NEC measures are evaluated net of BEIS ones.

[12] Press: Amsterdam Metropolitan Area prepares for a gas-free future

Table 2-6: Socio-economic drivers used to project emissions in industrial, residential and commercial sector for Amsterdam.

Code	Name	Domain
AMS_BAS_CFF	Amsterdam 7NC WAM: Commercial - Fossil fuels	All Buurts
AMS_BAS_RFF	Amsterdam 7NC WAM: Residential - Fossil fuels	All Buurts
AMS_BAU_CFF	Amsterdam NEC: Residential & Commercial - Fossil fuels	All Buurts
AMS_HOUSE	Amsterdam Private Households Growth	All Buurts

Table 2-7: Technological drivers used to project emissions in industrial, residential and commercial sector for Amsterdam.

Code	Name	Domain
AMS_NEC_B_PM	AMS NEC Building PM	All Buurts
AMS_NEC_I_PM	AMS NEC Industry PM	All Buurts
AMS_NEC_I_NOx	AMS NEC Industry NOx	All Buurts
AMS_NEC_B_NOx	AMS NEC Building NOx	All Buurts

Table 2-8: Point sources drivers used to project emissions for point sources for Amsterdam.

Code	Name	Domain
AMS_Coal	AMS Coal ban	Nuon Hemweg Coal unit

2.2.3 SDW scenarios

Scenarios from the Stakeholder dialog workshop (SWD) includes the measures summarized in table below, relating to the IRCI sector (the codes are defined in this report).

Table 2-9: Measures coming from the Stakeholder dialog workshop in Amsterdam.

Code	Description	Scenario
AMS_LblBC	Amsterdam house label B&C	Low
AMS_LblA	Amsterdam house label A	High
AMS_Wood	Amsterdam ban wood stoves and fireplaces	Low & High
AMS_SunMand	Amsterdam Solar Panel mandatory	High
AMS_GFNMand	Amsterdam Gas free no mandatory	Low
AMS_GFMand	Amsterdam Gas free mandatory Natgas	High

AMS_GFMandBg	Amsterdam Gas free mandatory Biogas	High
AMS_GFMandGg	Amsterdam Gas free mandatory Greengas	High

We assume that:

- Regarding the measures on the acceleration of energy efficiency renovations for all houses belonging to housing associations (*Amsterdam house label*):
    - The house association own about 42% of the total amount of dwellings in Amsterdam[13];
    - Less than 10 percent of dwellings in the municipalities Amsterdam have an energy label as of 2009 and one in three of the nearly one million homes in the Netherlands with an energy label fall in energy category E, F or G[14] reach an energy label B or C by 2050;
    - for the measure *Amsterdam house label B&C* (*AMS_LblBC*), we assume that the 42% of house reduce the energy consumptions of 50%;
    - for the measure *Amsterdam house label A* (*AMS_LblA*), we assume that the 42% of house reduce the energy consumptions of 80%;
- with the measure *Amsterdam ban wood stoves and fireplaces* (*AMS_Wood*), wood combustion is set to 0 from 2025;
- for the measure *Amsterdam Solar Panel mandatory* (*AMS_SunMand*), that prescribes mandatory solar panels in all suitable roofs and provide subsidies for it, we assume that[15]:
    - Amsterdam actually generate solar energy on about 2% of total number of households
    - Amsterdam will generate in 2020 solar energy on about 12% of total number of households in Amsterdam;
    - Amsterdam will generate in 2050 solar energy on about 60% of total number of households in Amsterdam;
- for the measure *Amsterdam Gas free no mandatory* (*AMS_GFNMand*) we assume a reduction of 20% of gas consumptions at 2030;
- for the measures *Amsterdam Gas free mandatory Natural gas* (*AMS_GFMand*), *Amsterdam Gas free mandatory Biogas* (*AMS_GFMandBg*), *Amsterdam Gas free mandatory Greengas AMS_GFMandGg* we assume in the city of Amsterdam at *2030*[16]:
    - no fossil fuel for 100% of buildings;
    - residual use of gas allocated to biogas (45%) and greengas (55%).

[13] Amsterdam Federation of Housing Associations, Information in english
[14] CBS, One third of homes with an energy label can use a lot less energy

[15] Gemeente Amsterdam, Zonvisie Amsterdam - Burgers en bedrijven gaan voor de zon!', juni 2013

[16] CE Delft, Towards a climate-neutral built environment in 2050, update 2016

2.2.4 Unified Policy Scenario

The final Unified Policy Scenario includes the measures summarized in table below, relating to the IRCI sector (the codes are defined in this report). The scenario postpones at 2040 the measures "*Gas green*" with the measures *Amsterdam Gas free mandatory Natural gas in 2040* (*AMS_GFM40*), *Amsterdam Gas free mandatory Biogas in 2040* (*AMS_GFM40Bg*), *Amsterdam Gas free mandatory Greengas in 2040* (*AMS_GFMandGg*) that assume in the city of Amsterdam at *2040*[17]:

- no fossil fuel for 100% of buildings;
- residual use of gas allocated to biogas (45%) and greengas (55%).

Table 2-10: Measures for the Unified Policy Scenario in Amsterdam.

Code	Description
AMS_LblBC	Amsterdam house label B&C
AMS_Wood	Amsterdam ban wood stoves and fireplaces
AMS_SunMand	Amsterdam Solar Panel mandatory
AMS_GFMand40	Amsterdam Gas free mandatory in 2040
AMS_GFM40	Amsterdam Gas Free Mandatory in 2040 Natgas
AMS_GFM40Bg	Amsterdam Gas free mandatory 2040 Biogas
AMS_GFM40Gg	Amsterdam Gas free mandatory 2040 Greengas

2.3 Carbon footprint

2.3.1 Baseline

The following tables document the methodology and data used for:

- Industrial sources (Table 2-11)
- Residential and commercial sources (Table 2-12)
- Buurt disaggregation variables (Table 2-13).

[17] CE Delft, Towards a climate-neutral built environment in 2050, update 2016

Table 2-11: Methodology and source of data for Amsterdam fuel consumptions evaluation - Industrial sources.

Activity	Energy vector	Data availability	Source	Publication	Reference	Field	Disaggregation variable
Industrial sector	Natural Gas	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: Industry (Total_26) Period: 2015 Energy commodities: Natural gas	Industry Companies number (Table 2-13)
	Gasoil	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: Industry (Total_26) Period: 2015 Energy commodities: heating and other gasoil	Industry Companies number (Table 2-13)
	Coal	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: Industry (Total_26) Period: 2015 Energy commodities: Total Coal Product	Industry Companies number (Table 2-13)
	Electricity	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: Industry (Total_26) Period: 2015 Energy commodities: Electricity	Industry Companies number (Table 2-13)

(°) if MSOA data are used to evaluate LSOA a bias is introduced due to different distribution industry/services in different MSOA

Table 2-12: Methodology and source of data for Amsterdam fuel consumptions evaluation - Residential and services sources.

Activity	Energy vector	Data availability	Source	Publication	Reference	Field	Disaggregation variable
Residential sector	Natural Gas	Level 3 (Buurt)	CBS	Wijk - en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	G_GAS_TOT*WONINGEN where: [G_GAS_TOT]: Average total natural gas consumption [WONINGEN]: Housing stock	None
	Wood	Level 2 (Gemeente)	RIVM	Klimaatmonitor	https://klimaatmonitor.databank.nl/dashboard/	Wood burning stoves dwellings hern. heat [TJ]	Population (Table 2-13)
	LPG	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: households Period: 2015 Energy commodities: LPG	Population (Table 2-13)
	Gasoil	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Selection: Topic: households Period: 2015 Energy commodities: Heating and other gas oil	Population (Table 2-13)

Table 2-12: Methodology and source of data for Amsterdam fuel consumptions evaluation - Residential and services sources.

Activity	Energy vector	Data availability	Source	Publication	Reference	Field	Disaggregation variable
	Electricity	Level 3 (Buurt)	CBS	Wijk - en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	G_ELEK_TOT*WONINGEN where: [G_ELEK_TOT]: Average total Electricity consumption [WONINGEN]: Housing stock	None
Service sector	Natural gas	Level 2 (Gemeente)	RIVM	Klimaatmonitor	https://klimaatmonitor.databank.nl/dashboard/	Gas use commercial Services [m3] + Gas use Public Services [m3]	Services Companies number (Table 2-13)
	Wood	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: services waste and repairs Period: 2015 Energy commodities: Solid and liquid biomass	Services Companies number (Table 2-13)
	LPG	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: services waste and repairs Period: 2015 Energy commodities: LPG	Services Companies number (Table 2-13)

Table 2-12: Methodology and source of data for Amsterdam fuel consumptions evaluation - Residential and services sources.

Activity	Energy vector	Data availability	Source	Publication	Reference	Field	Disaggregation variable
	Gasoil	Level 1 (National)	CBS	Energy balance sheet supply consumption	https://opendata.cbs.nl/statline/portal.html?_la=en&_catalog=CBS&tableId=83140ENG&_theme=1028	Topic: services waste and repairs Period: 2015 Energy commodities: Heating and other gas oil	Services Companies number (Table 2-13)
	Electricity	Level 2 (Gemeente)	RIVM	Klimaatmonitor	https://klimaatmonitor.databank.nl/dashboard/	Electricity use commercial Services [kWh] + Electricity use Public Services [kWh]	Services Companies number (Table 2-13)

(°) if MSOA data are used to evaluate LSOA a bias is introduced due to different distribution industry/services in different MSOA

Table 2-13: Methodology and source of data for Amsterdam fuel consumptions evaluation – aggregate fuel consumptions data subdivision.

Energy vector	Data availability	Source	Publication	Reference	Note
Population	Level 3 (Buurt)	CBS	Wijk-en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	AANT_INW (Number of inhabitants)

Services Companies number	Level 3 (Buurt)	CBS	Wijk-en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	[A_BED_GI]+[A_BED_HJ]+[A_BED_KL]+[A_BED_MN]+[A_BED_RU] where: [A_BED_GI]: Number of companies and catering trade [A_BED_HJ]: Number of companies in transport, information, communication [A_BED_KL]: Number of firms financially property [A_BED_MN]: Number of companies in business services [A_BED_RU]: Number of companies in culture, recreation, other
Industry Companies number	Level 3 (Buurt)	CBS	Wijk-en buurtkaart 2015	https://www.cbs.nl/nl-nl/dossier/nederland-regionaal/geografische%20data/wijk-en-buurtkaart-2015	[A_BED_BF]: Number of companies in industry and energy

2.3.2 BAU

Business as Usual (BAU) scenario takes into consideration national and city level measures already defined/decided. As a general input to the projection model, data from IRCI and Traffic model results have been assumed for fuel consumptions.

For electricity emission factors an additional driver was introduced to take into consideration the evolution of carbon footprint from electricity generation. The driver is defined using official Netherland projection data up to 2030[18,19]. For 2050 we assume zero emissions for electricity according to Dutch Ministerie van Economische Zaken[20] that has fixed as a policy requirement that the power sector should be zero-carbon by 2050. In the same document are also hypotheses of near-zero emissions for all the energy system. Also, in this case, as for UK, some more cautious consideration has been adopted for the other sectors, so in the projections the near-zero emissions hypothesis has been inserted only for the power sector and not for industry sector where we maintain the more conservative 2030 projection in Seventh UNFCC Netherland National Communication, also considering that PBL not issued a National Energy Survey (NEV) after 2018. The management of the PBL has decided this in connection with the ongoing discussions about the Climate Agreement[21]. For the commercial and domestic sectors, we take the same assumptions as in the IRCI projections. Following the UNFCCC National communication[22], CO_2 emissions from the industry are expected to remain stable in the coming decade and no other information is available after 2030.

2.3.3 SDW Scenarios

Scenario projections take into consideration city level additional measures from Stakeholder dialog workshop (SWD). Also, in this case as a general input to the projection model, results from IRCI and Traffic models have been assumed for fuel consumptions.

2.3.4 Final Unified Policy Scenario

Also, for the final Unified Policy Scenario as a general input to the projection model, results from IRCI and Traffic models have been assumed for fuel consumptions.

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[18] PBL, Nationale Energieverkenning 2017
[19] Netherland Ministry of Economic Affairs and Climate Policy, Seventh Netherlands National Communication under the United Nations Framework Convention on Climate Change
[20] Ministerie van Economische Zaken, Energieagenda: naar een CO_2-arme energievoorziening, 2016
[21] PBL, Vanwege werk aan Klimaatakkoord geen Nationale Energieverkenning in 2018
[22] Netherland Ministry of Economic Affairs and Climate Policy, Seventh Netherlands National Communication under the United Nations Framework Convention on Climate Change

3 Results

In this section, we elaborate on the results of the simulations. We report on a sector by sector basis, first reporting on transport, as most of the policy measures focus on transport and secondly on the other sectors (IRCI) combined.

In transport, we first report the (passenger) mode choice changes and secondly on the fleet/emissions impact.

Emissions for other sectors are reported in the section on the IRCI-module results.

Carbon footprint, air quality and consequent health impacts are reported in separate sections as well.

3.1 Transport

3.1.1 Mode choice changes

We present here the tables containing the relative mileage changes (compared to the Baseline) for various reporting years in each scenario. (As noted earlier – due to methodological reasons – modal split is not reported for Amsterdam. For similar reasons, absolute mileage changes for other than cars and vans can be exaggerated or underestimated, even though the direction of change is correct).

Mode	Mileage change
1|Walk	0.978
2|Bicycle	0.958
3|Car/van	0.982
4|Bus/metro	▲ 1.308
5|Train/surface rail	0.989
6|Taxi	▼ 0.936
7|Other (incl. motorbike)	0.960

Figure 3-1: Low Scenario (2035-2050).

Mode	Mileage change
1|Walk	▲ 1.089
2|Bicycle	▲ 1.094
3|Car/van	▼ 0.935
4|Bus/metro	▲ 1.526
5|Train/surface rail	▲ 1.099
6|Taxi	▬ 1.028
7|Other (incl. motorbike)	▲ 1.120

Figure 3-2: High Scenario (2025).

Mode	Mileage change
1|Walk	▲ 1.058
2|Bicycle	▬ 0.980
3|Car/van	▼ 0.909
4|Bus/metro	▲ 2.073
5|Train/surface rail	▬ 1.022
6|Taxi	▬ 1.002
7|Other (incl. motorbike)	▬ 1.049

Figure 3-3: High Scenario (2035-2050).

Mode	Mileage change
1|Walk	▲ 1.113
2|Bicycle	▲ 1.172
3|Car/van	▬ 0.957
4|Bus/metro	▲ 1.115
5|Train/surface rail	▲ 1.138
6|Taxi	▲ 1.162
7|Other (incl. motorbike)	▲ 1.155

Figure 3-4: Final Scenario(2025).

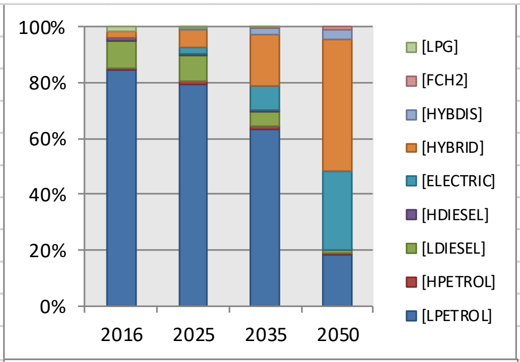
Mode	Mileage change
1|Walk	▲ 1.086
2|Bicycle	▲ 1.098
3|Car/van	▼ 0.940
4|Bus/metro	▲ 1.470
5|Train/surface rail	▲ 1.093
6|Taxi	▲ 1.084
7|Other (incl. motorbike)	▲ 1.114

Figure 3-5: Final Scenario (2035-2050).

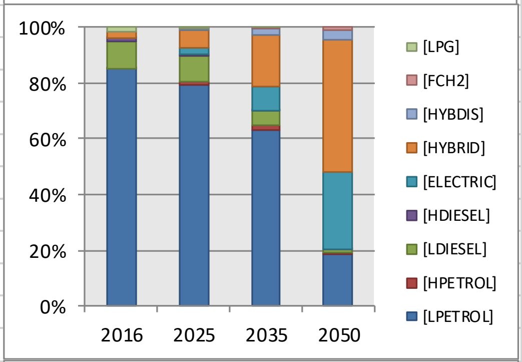
3.1.2 Fleet and Emissions

We present here the fleet compositions for each reporting year within each scenario, and the final emission calculation tables.

	VENSIM model in percentage of total fleet per reporting year			
BAU	2016	2025	2035	2050
[LPETROL]	84.90%	79.46%	63.29%	18.39%
[HPETROL]	0.41%	0.92%	1.29%	0.78%
[LDIESEL]	9.42%	9.31%	5.29%	1.08%
[HDIESEL]	1.28%	0.80%	0.41%	0.10%
[ELECTRIC]	0.30%	1.93%	8.58%	27.71%
[HYBRID]	2.25%	6.35%	18.58%	47.76%
[HYBDIS]	0.00%	0.75%	2.22%	3.47%
[FCH2]	0.00%	0.06%	0.30%	0.72%
[LPG]	1.45%	0.43%	0.05%	0.00%



	VENSIM model in percentage of total fleet per reporting year			
LOW	2016	2025	2035	2050
[LPETROL]	84.90%	79.46%	63.29%	18.39%
[HPETROL]	0.41%	0.92%	1.29%	0.78%
[LDIESEL]	9.42%	9.31%	5.29%	1.08%
[HDIESEL]	1.28%	0.80%	0.41%	0.10%
[ELECTRIC]	0.30%	1.93%	8.58%	27.71%
[HYBRID]	2.25%	6.35%	18.58%	47.76%
[HYBDIS]	0.00%	0.75%	2.22%	3.47%
[FCH2]	0.00%	0.06%	0.30%	0.72%
[LPG]	1.45%	0.43%	0.05%	0.00%



	VENSIM model in percentage of total fleet per reporting year			
HIGH	2016	2025	2035	2050
[LPETROL]	84.90%	69.88%	0.00%	0.00%
[HPETROL]	0.41%	1.03%	0.00%	0.00%
[LDIESEL]	9.42%	8.88%	0.00%	0.00%
[HDIESEL]	1.28%	0.62%	0.00%	0.00%
[ELECTRIC]	0.30%	2.88%	28.24%	77.07%
[HYBRID]	2.25%	14.40%	65.57%	16.33%
[HYBDIS]	0.00%	1.68%	4.55%	1.48%
[FCH2]	0.00%	0.12%	1.57%	5.13%
[LPG]	1.45%	0.50%	0.07%	0.00%

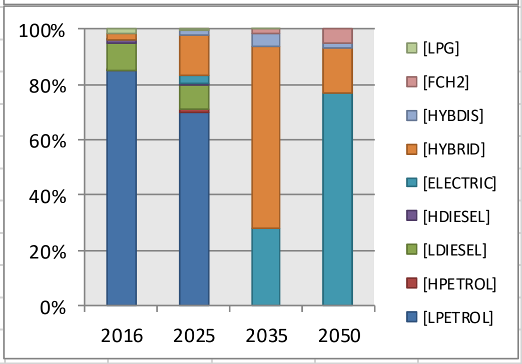
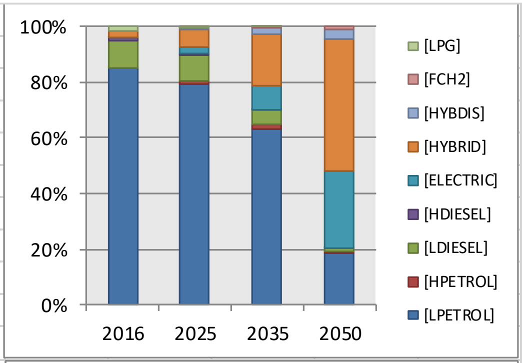


Figure 3-6: Passenger car fleet composition in the BAU and in the Low and High (and Final) Scenario. Since the fleet component of the Final Scenario is the same as the oen of the High Scenario, the bottom row also corresponds to the Final Scenario.

BAU	*VENSIM model in percentage of total fleet per reporting year*			
	2016	2025	2035	2050
[LPETROL]	84.90%	79.46%	63.29%	18.39%
[HPETROL]	0.41%	0.92%	1.29%	0.78%
[LDIESEL]	9.42%	9.31%	5.29%	1.08%
[HDIESEL]	1.28%	0.80%	0.41%	0.10%
[ELECTRIC]	0.30%	1.93%	8.58%	27.71%
[HYBRID]	2.25%	6.35%	18.58%	47.76%
[HYBDIS]	0.00%	0.75%	2.22%	3.47%
[FCH2]	0.00%	0.06%	0.30%	0.72%
[LPG]	1.45%	0.43%	0.05%	0.00%



FINAL	*VENSIM model in percentage of total fleet per reporting year*			
	2016	2025	2035	2050
[LPETROL]	84.90%	69.88%	0.00%	0.00%
[HPETROL]	0.41%	1.03%	0.00%	0.00%
[LDIESEL]	9.42%	8.88%	0.00%	0.00%
[HDIESEL]	1.28%	0.62%	0.00%	0.00%
[ELECTRIC]	0.30%	2.88%	28.24%	77.07%
[HYBRID]	2.25%	14.40%	65.57%	16.33%
[HYBDIS]	0.00%	1.68%	4.55%	1.48%
[FCH2]	0.00%	0.12%	1.57%	5.13%
[LPG]	1.45%	0.50%	0.07%	0.00%

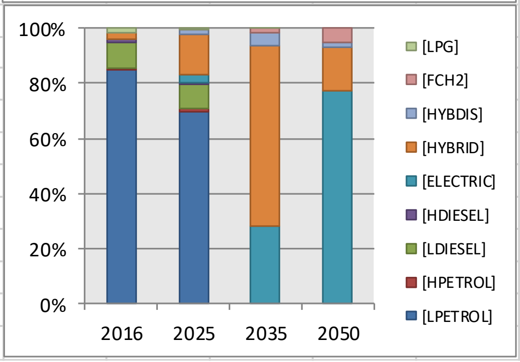


Figure 3-7: Passenger car fleet composition in the BAU and in the Final Scenario.

Table 3-1: Relative emissions in the BAU and SDW scenario (top) and the final scenario (bottom).

MIDZWVR

Nox

Year	2015	2025	2035	2050
BAU	100.00%	24.20%	17.78%	19.97%
Scenario 1		24.20%	17.78%	19.97%
Scenario 2		14.74%	17.20%	19.97%

PM

Year	2015	2025	2035	2050
BAU	100.00%	16.88%	9.64%	10.69%
Scenario 1		16.88%	9.64%	10.69%
Scenario 2		8.20%	9.21%	10.69%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	108.55%	126.72%	147.12%
Scenario 1		108.55%	126.72%	147.12%
Scenario 2		108.55%	126.72%	147.12%

MOTO

Nox

Year	2015	2025	2035	2050
BAU	100.00%	25.35%	23.77%	25.12%
Scenario 1		25.35%	23.77%	25.12%
Scenario 2		22.40%	24.63%	25.12%

PM

Year	2015	2025	2035	2050
BAU	100.00%	10.45%	6.35%	6.98%
Scenario 1		10.45%	6.35%	6.98%
Scenario 2		6.22%	6.84%	6.98%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	112.53%	123.72%	126.22%
Scenario 1		112.53%	123.72%	126.22%
Scenario 2		112.53%	123.72%	126.22%

ZWVR

Nox

Year	2015	2025	2035	2050
BAU	100.00%	15.79%	13.79%	16.04%
Scenario 1		15.79%	13.79%	16.04%
Scenario 2		12.30%	13.81%	16.04%

PM

Year	2015	2025	2035	2050
BAU	100.00%	14.29%	13.38%	15.81%
Scenario 1		14.29%	13.38%	15.81%
Scenario 2		12.12%	13.62%	15.81%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	108.83%	122.24%	141.92%
Scenario 1		108.83%	122.24%	141.92%
Scenario 2		108.83%	122.24%	141.92%

CAR

Nox

Year	2015	2025	2035	2050
BAU	100.00%	54.90%	39.98%	48.22%
Scenario 1		54.90%	39.25%	47.34%
Scenario 2		45.80%	43.40%	12.43%

PM

Year	2015	2025	2035	2050
BAU	100.00%	47.10%	40.65%	44.52%
Scenario 1		47.10%	39.90%	43.70%
Scenario 2		35.56%	36.67%	10.97%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	114.84%	129.27%	148.70%
Scenario 1		114.84%	126.91%	145.99%
Scenario 2		107.41%	117.44%	135.10%

BUS

Nox

Year	2015	2025	2035	2050
BAU	100.00%	18.31%	13.09%	13.28%
Scenario 1		9.15%	5.14%	0.00%
Scenario 2		0.00%	0.00%	0.00%

PM

Year	2015	2025	2035	2050
BAU	100.00%	17.49%	13.39%	13.61%
Scenario 1		8.75%	5.26%	0.00%
Scenario 2		0.00%	0.00%	0.00%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	120.00%	122.42%	124.89%
Scenario 1		120.00%	160.18%	163.41%
Scenario 2		183.10%	253.83%	258.96%

VAN

Nox

Year	2015	2025	2035	2050
BAU	100.00%	39.55%	28.88%	34.10%
Scenario 1		39.55%	28.52%	33.66%
Scenario 2		30.27%	30.30%	16.20%

PM

Year	2015	2025	2035	2050
BAU	100.00%	31.99%	25.14%	27.60%
Scenario 1		31.99%	24.77%	27.20%
Scenario 2		21.88%	22.94%	10.83%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	111.69%	127.99%	147.91%
Scenario 1		111.69%	126.82%	146.56%
Scenario 2		107.98%	122.08%	141.11%

MIDZWVR

Nox

Year	2015	2025	2035	2050
BAU	100.00%	24.20%	17.78%	19.97%
UPS		14.74%	17.20%	19.97%

PM

Year	2015	2025	2035	2050
BAU	100.00%	16.88%	9.64%	10.69%
UPS		8.20%	9.21%	10.69%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	108.55%	126.72%	147.12%
UPS		108.55%	126.72%	147.12%

MOTO

Nox

Year	2015	2025	2035	2050
BAU	100.00%	25.35%	23.77%	25.12%
UPS		22.40%	24.63%	25.12%

PM

Year	2015	2025	2035	2050
BAU	100.00%	10.45%	6.35%	6.98%
UPS		6.22%	6.84%	6.98%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	112.53%	123.72%	126.22%
UPS		112.53%	123.72%	126.22%

ZWVR

Nox

Year	2015	2025	2035	2050
BAU	100.00%	15.79%	13.79%	16.04%
UPS		12.30%	13.81%	16.04%

PM

Year	2015	2025	2035	2050
BAU	100.00%	14.29%	13.38%	15.81%
UPS		12.12%	13.62%	15.81%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	108.83%	122.24%	141.92%
UPS		108.83%	122.24%	141.92%

CAR

Nox

Year	2015	2025	2035	2050
BAU	100.00%	54.90%	39.98%	48.22%
UPS		46.86%	44.90%	12.86%

PM

Year	2015	2025	2035	2050
BAU	100.00%	47.10%	40.65%	44.52%
UPS		36.38%	37.94%	11.35%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	114.84%	129.27%	148.70%
UPS		109.89%	121.51%	139.78%

BUS

Nox

Year	2015	2025	2035	2050
BAU	100.00%	18.31%	13.09%	13.28%
UPS		10.20%	5.77%	0.00%

PM

Year	2015	2025	2035	2050
BAU	100.00%	17.49%	13.39%	13.61%
UPS		9.75%	5.91%	0.00%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	120.00%	122.42%	124.89%
UPS		133.75%	179.98%	183.61%

VAN

Nox

Year	2015	2025	2035	2050
BAU	100.00%	39.55%	28.88%	34.10%
UPS		30.80%	31.05%	16.42%

PM

Year	2015	2025	2035	2050
BAU	100.00%	31.99%	25.14%	27.60%
UPS		22.29%	23.57%	11.02%

PM_NE

Year	2015	2025	2035	2050
BAU	100.00%	111.69%	127.99%	147.91%
UPS		109.22%	124.12%	143.45%

3.2 Spatial-temporal

The temperature dataset is retrieved from The Royal Netherlands Meteorological Institute (KNMI), the official Dutch national weather service. Specifically, we selected the data from the Schiphol weather station (ID: 240), the nearest station to Amsterdam and in the same region of Noord-Holland. The data source for daily temperatures is provided in a .txt file that consists of four variables: station code, date and temperature. The temperature value is in 0.1 degrees where Celsius is the unit. In this dataset cleaning was not required, as it contained no missing, noisy or inconsistent data.

Reduction was carried out in this case, since the station code variable is not required by the modelling tool. Furthermore, due to the different standards between the data source and the modelling tool, we transformed the dataset from .txt to .csv by reducing the first variable, the station code, and normalizing the temperature value. The aim of this is to transform the value of the data source into a format, scale or unit that is required by the tool that was used. Finally, this new dataset is compatible with the modelling tool we used and thus suitable to be the one of the inputs of our model.

Table 3-2: resulting intra-day profiles.

Typical days (TD)	Pattern (%)		
	Commercial	Residential	
	NO_x and PM_{10}	NO_x	PM_{10}
11-02-2015	0.350919243	0.352070939	0.410206934
15-02-2015	0.356458608	0.357628484	0.416682173
12-08-2015	0.157580773	0.156845628	0.119736499
16-08-2015	0.168351761	0.167566366	0.127920748

3.3 IRCI

3.3.1 Baseline

In the following maps the main results for NO_x and PM_{10} emissions are reported by Buurt. In detail are reported:

- Amsterdam Buurt Residential, Commercial & Institutional NO_x emissions for all sectors and fuel (Figure 3-8),
- Amsterdam Buurt Residential, Commercial & Institutional PM_{10} emissions for all sectors and fuels (Figure 3-9),
- Amsterdam Buurt Residential, Commercial & Institutional PM_{10} emissions from biomass use (Figure 3-10),
- Amsterdam Industry NO_x emissions (Figure 3-11),
- Amsterdam Industry PM_{10} emissions (Figure 3-12).

Figure 3-8: Amsterdam Buurt Residential, Commercial & Institutional NO_x emissions – all sectors and fuels.

Figure 3-9: Amsterdam Buurt Residential, Commercial & Institutional PM_{10} emissions – all sectors and fuels.

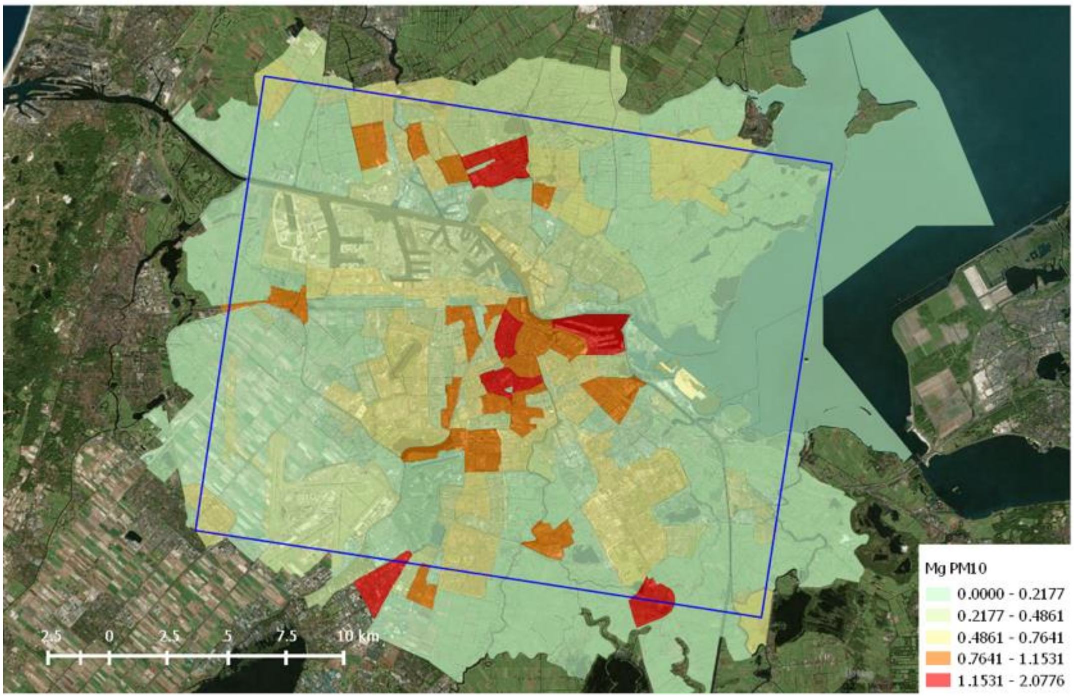


Figure 3-10: Amsterdam Buurt Residential, Commercial & Institutional PM_{10} emissions – biomass.

Figure 3-11: Amsterdam Industry NO_x emissions.

Figure 3-12: Amsterdam Industry PM_{10} emissions.

Finally, in the following Figure 3-13 and Figure 3-14 the emissions for the different activities & fuels only in the gemeente of Amsterdam are reported.

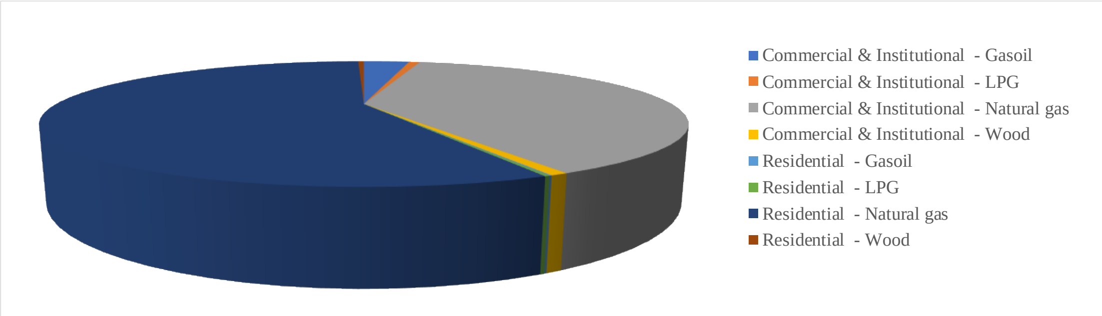


Figure 3-13: Amsterdam Gemeente Residential, Commercial & Institutional NO_x emissions.

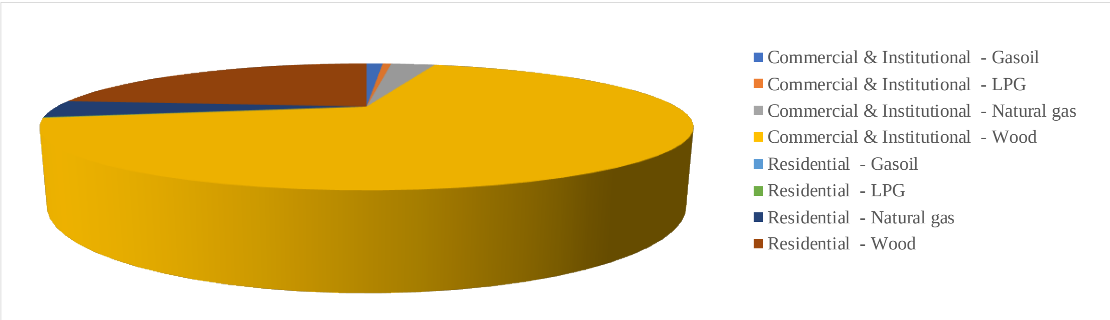


Figure 3-14: Amsterdam Gemeente Residential, Commercial & Institutional PM_{10} emissions.

3.3.2 BAU

The evolutions of industrial area emissions are reported in Figure 3-15 for nitrogen oxides (NO_x) and in Figure 3-16 for suspended particles with diameter less than 10µ (PM_{10}). The variation is evaluated as the average variation of industrial emissions in national projection.

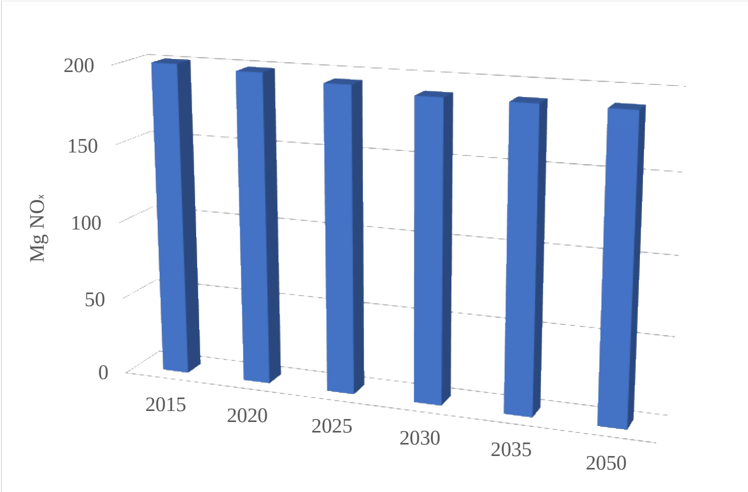


Figure 3-15: Amsterdam BAU NO_x Industrial area emissions.

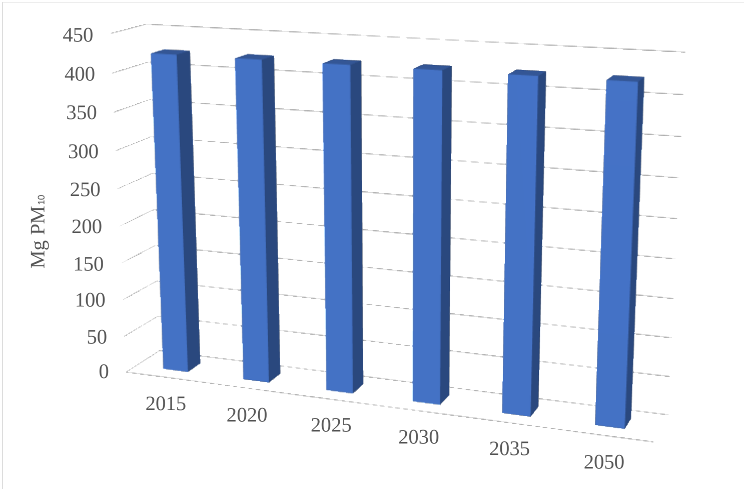


Figure 3-16: Amsterdam BAU PM_{10} Industrial area emissions.

In Figure 3-17 the evolution of NOx emissions from main point sources is reported. It is worth mentioning the strong reduction of nitrogen oxide emissions for the Nuweg plant at Hemweg due to the planned closure of the coal unit as for the coal power plants ban by Dutch government in 2018.

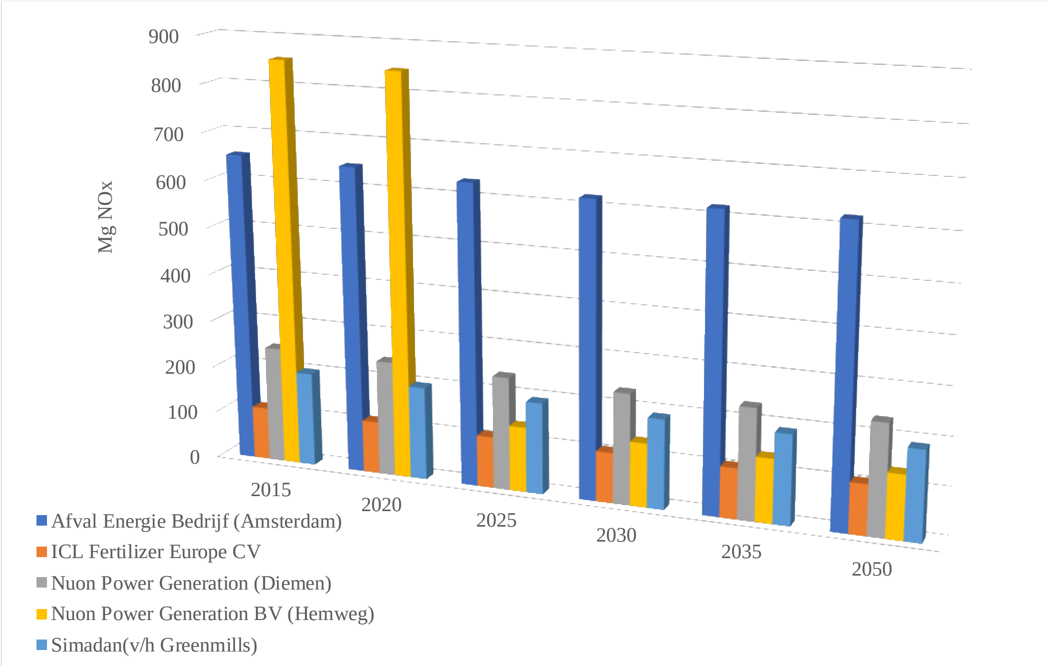


Figure 3-17: Amsterdam BAU Industrial NO_x emissions: main point sources.

In Figure 3-18 for nitrogen oxides (NO_x) and in Figure 3-19 for suspended particles with diameter less than 10μ (PM_{10}) the evolutions of emissions are reported.

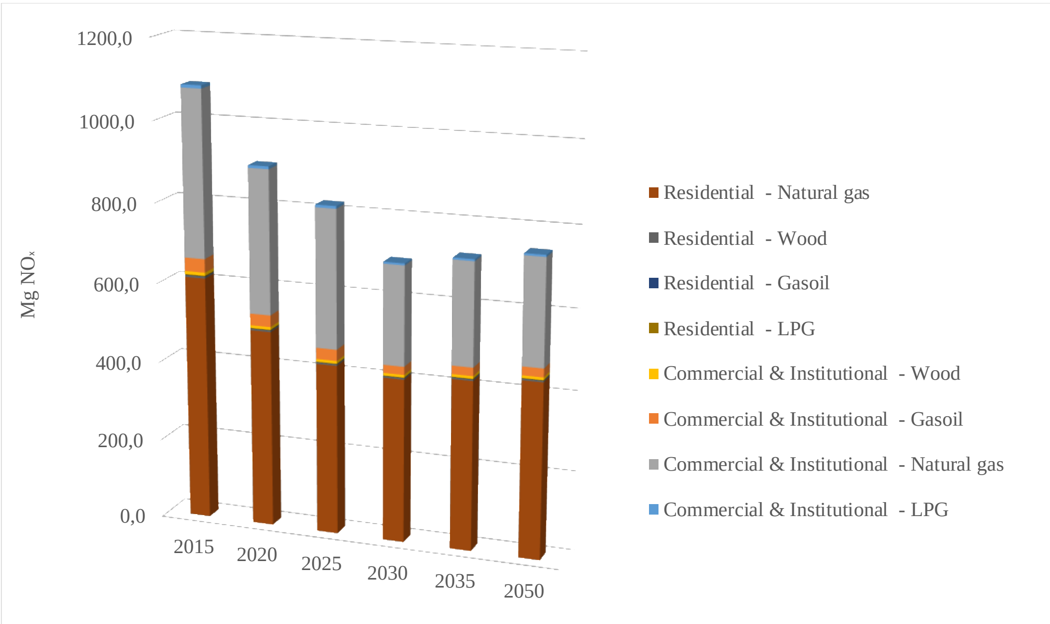


Figure 3-18: Amsterdam BAU total Residential, Commercial & Institutional NO_x emissions.

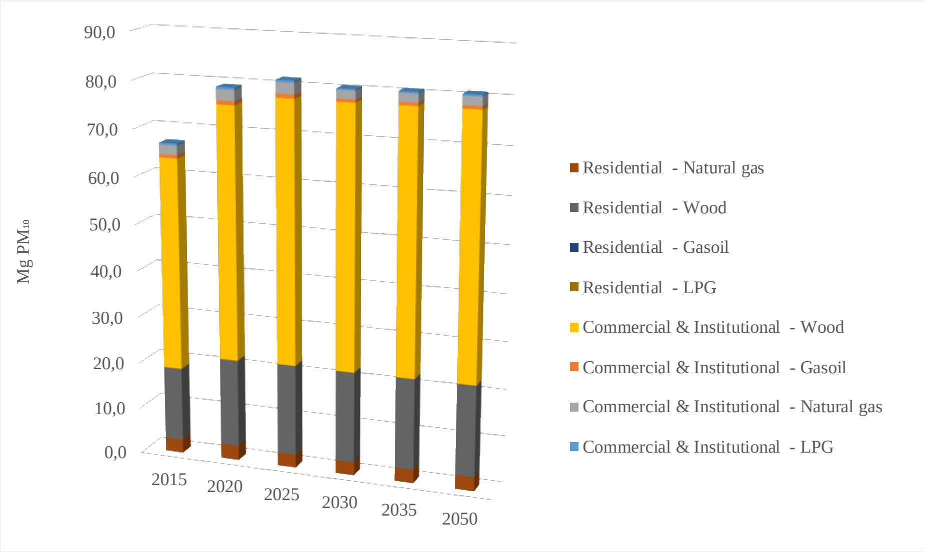


Figure 3-19: Amsterdam BAU Residential, Commercial & Institutional PM_{10} emissions.

3.3.3 Stakeholder dialog workshop Scenarios

In Figure 3-20 for nitrogen oxides (NO_x) and Figure 3-21 for suspended particles with diameter less than 10μ (PM_{10}) the trends of emissions are reported for scenario 1 (“low”); in Figure 3-22 for nitrogen oxides (NO_x) and Figure 3-23 for suspended particles with diameter less than 10μ (PM_{10}) the trends of emissions are reported for scenario 2 (“high”). The Scenario include only the Amsterdam Gemeente while the emissions from surrounding Gemeente are kept constant.

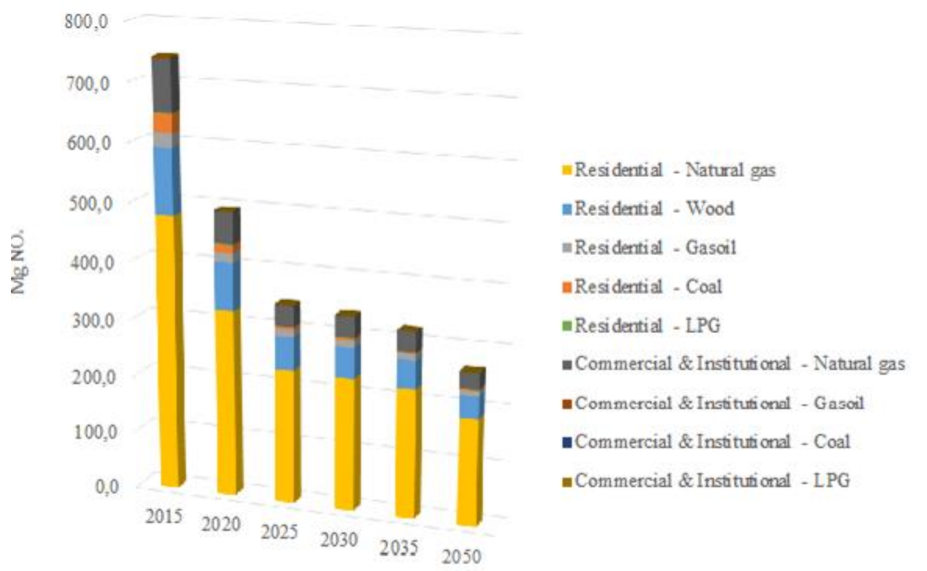


Figure 3-20: Amsterdam Scenario 1 (low): Residential, Commercial & Institutional NO_x emissions – all sectors and fuels.

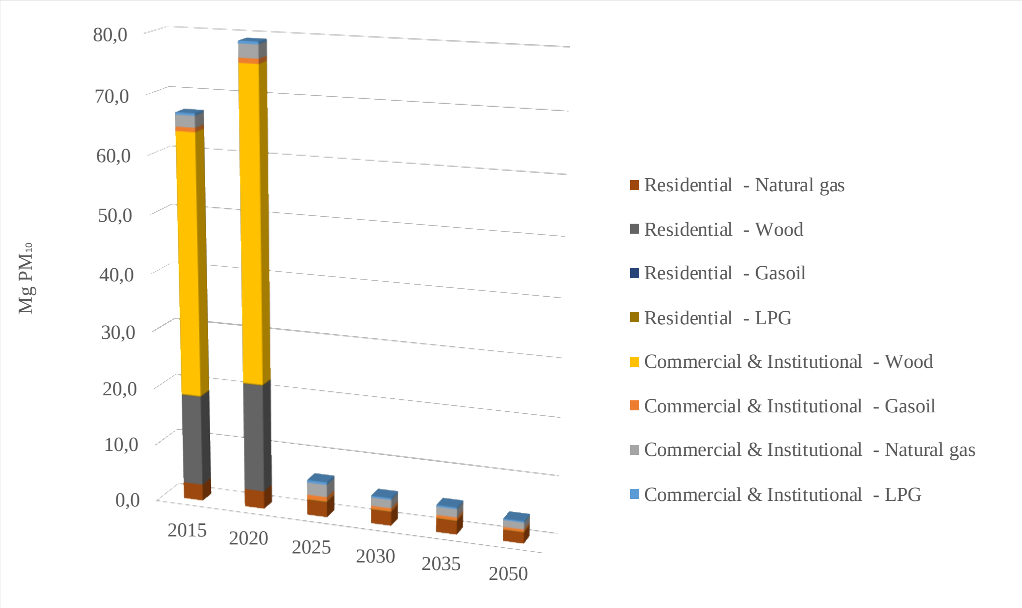


Figure 3-21: Amsterdam Scenario 1 (low): (renewables & efficiency): Residential, Commercial & Institutional PM_{10} emissions – all sectors and fuels.

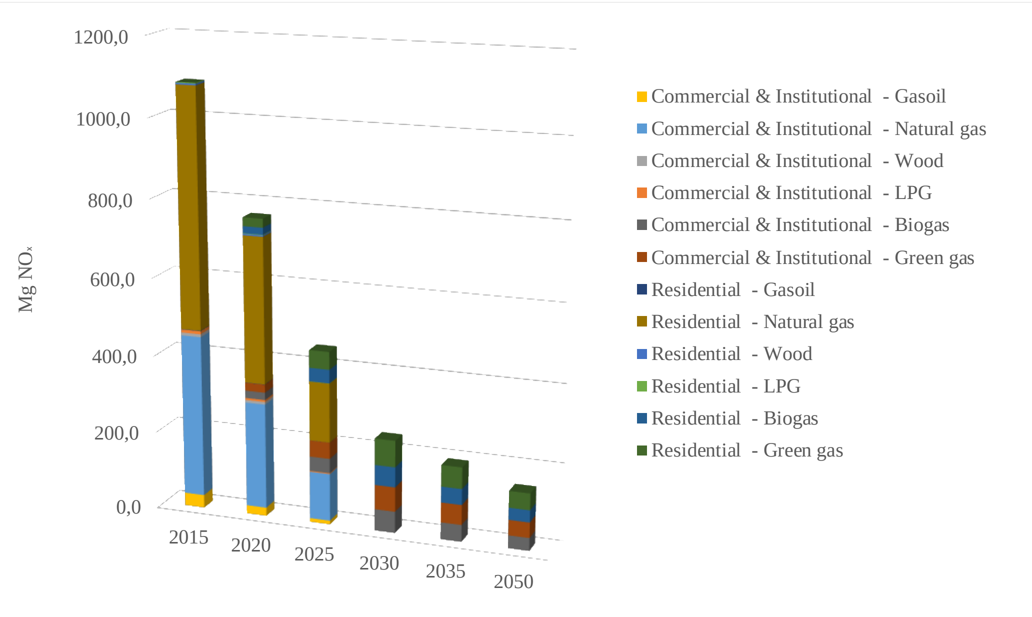


Figure 3-22: Amsterdam Scenario 2 (high): Residential, Commercial & Institutional NOx emissions – all sectors and fuels.

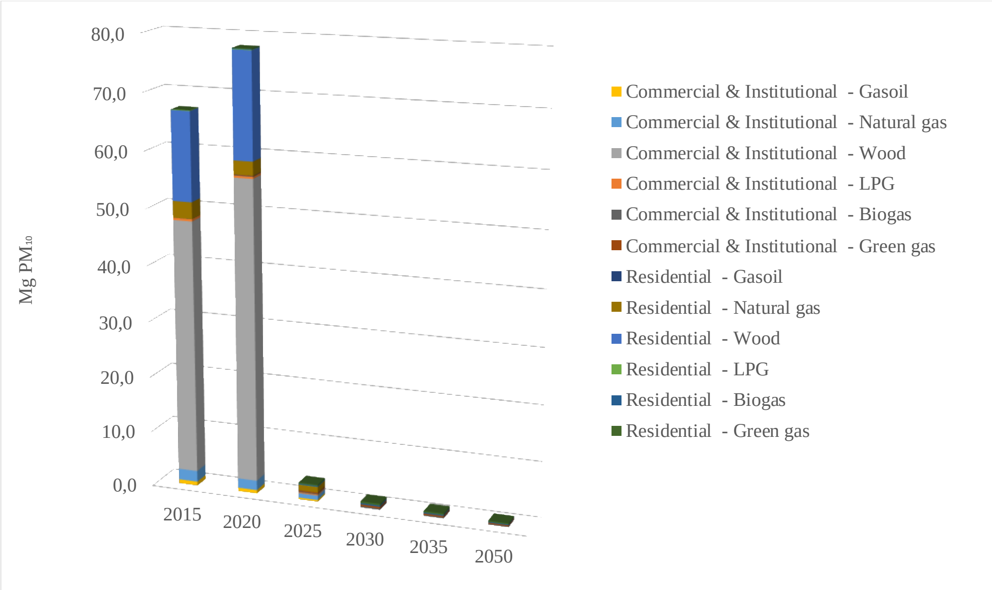


Figure 3-23: Amsterdam Scenario 2 (high): (renewables & efficiency): Residential, Commercial & Institutional PM10 emissions – all sectors and fuels.

In Figure 3-24 for nitrogen oxides (NO_x) and in Figure 3-25 for suspended particles with diameter less than 10µ (PM_{10}) the comparison of the trends of emissions are reported for the different scenarios.

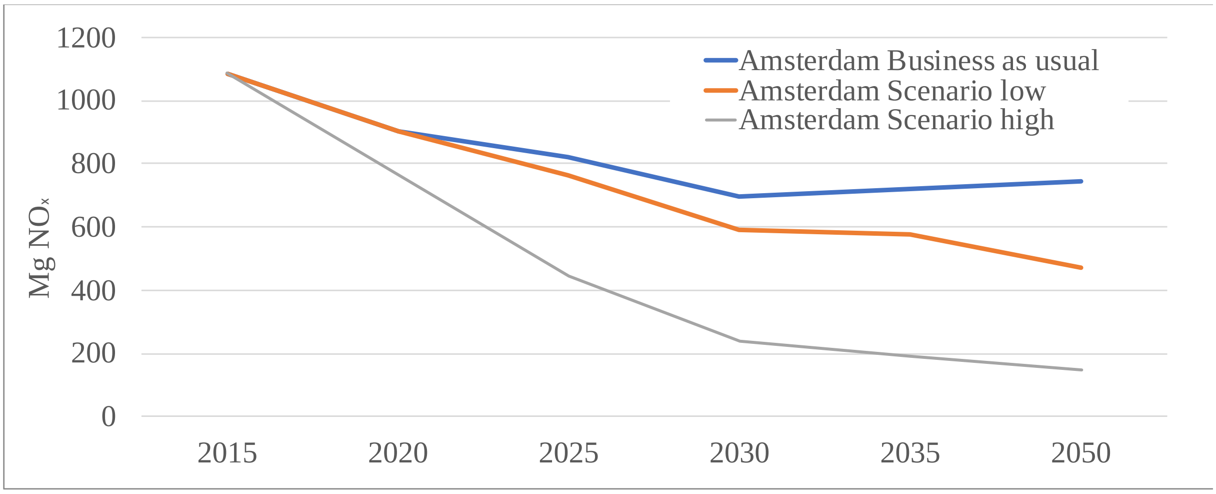


Figure 3-24: Amsterdam BAU & Scenarios comparison: Residential, Commercial & Institutional NO_x emissions – all sectors and fuels.

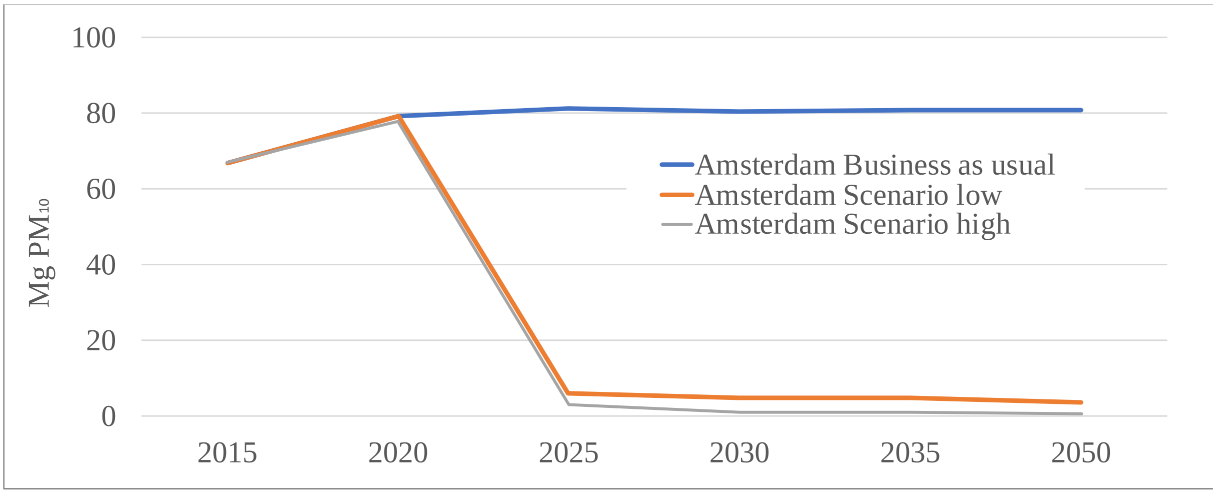


Figure 3-25: Amsterdam BAU & Scenarios comparison: Residential, Commercial & Institutional PM_{10} emissions – all sectors and fuels.

3.3.4 Unified Policy Scenario

In Figure 3-26 for nitrogen oxides (NO_x) and Figure 3-27 for suspended particles with diameter less than 10μ (PM_{10}) the trends of emissions are reported for Unified Policy Scenario.

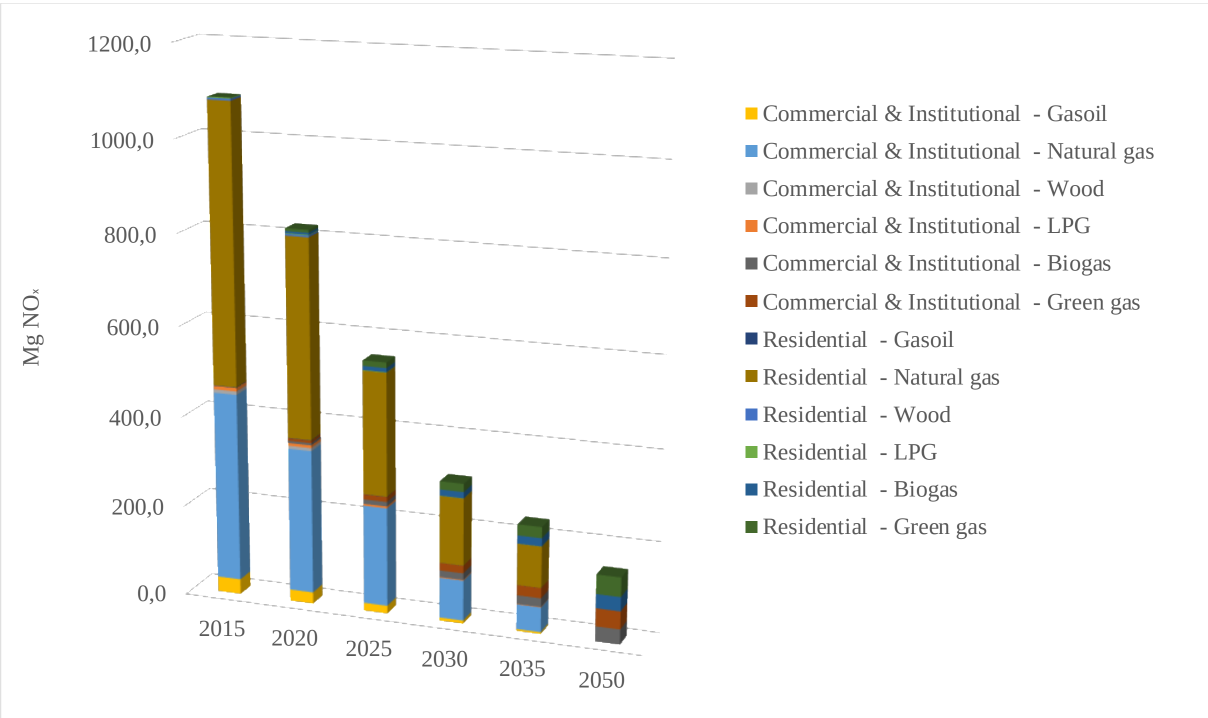


Figure 3-26: Amsterdam Unified Policy Scenario: Residential, Commercial & Institutional NO_x emissions – all sectors and fuels.

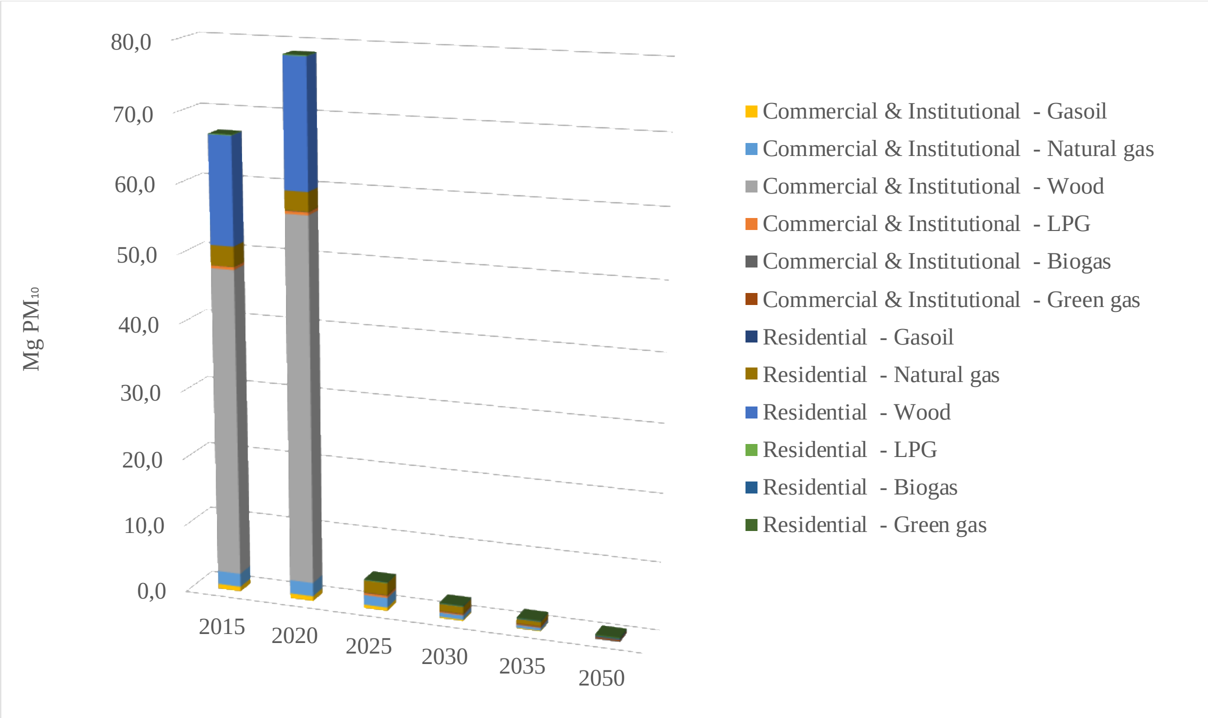


Figure 3-27: Amsterdam Unified Policy Scenario: Residential, Commercial & Institutional PM_{10} emissions – all sectors and fuels.

In Figure 3-28 for nitrogen oxides (NO_x) and in Figure 3-29 for suspended particles with diameter less than 10μ (PM_{10}) the comparison of the trends of emissions are reported for Business As Usual (BAU) and Unified Policy Scenarios (UPS).

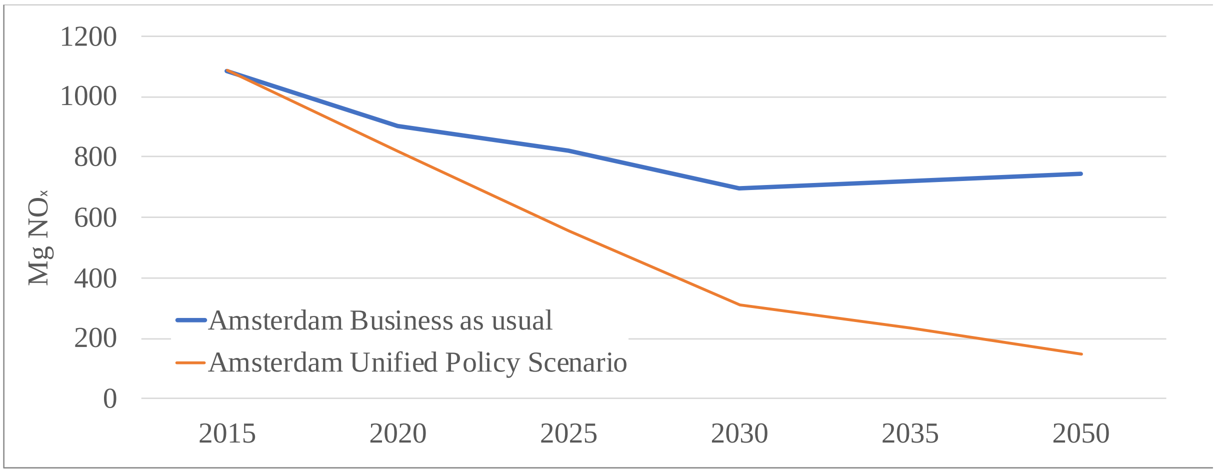


Figure 3-28: Amsterdam BAU & Unified Policy Scenario comparison: Residential, Commercial & Institutional NO_x emissions – all sectors and fuels.

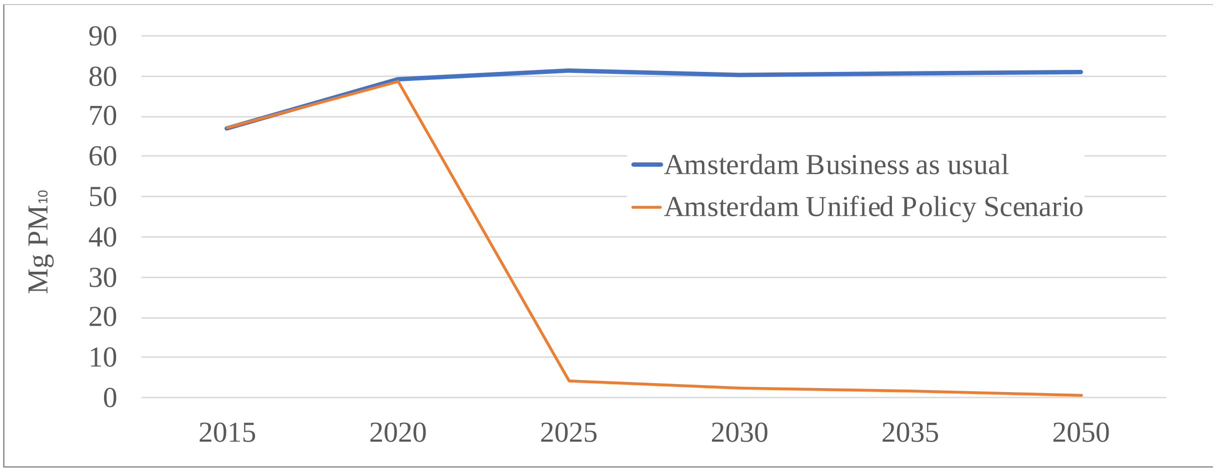


Figure 3-29 – Amsterdam BAU & Unified Policy Scenario comparison: Residential, Commercial & Institutional PM_{10} emissions – all sectors and fuel.

3.4 Carbon footprint

3.4.1 Baseline

In Table 3-3, the Carbon Footprint by fuel is reported for Amsterdam expressed as CO_2, CO_2 equivalent and CO_2 equivalent on Life Cycle.

Table 3-3: Amsterdam Carbon Footprint by Fuel (Mg).

Energy Vector	CO_2	CO_{2eq}	$CO_{2eq,LCA}$
Biomass	-	97	240
Gasoil/diesel	362.400	363.376	415.148
Gasoline	559.240	560.856	704.707
Hard Coal	67.044	67.462	70.323
LPG	19.970	19.970	24.718
Natural gas	1.737.363	1.737.363	2.065.635
Electricity	2.389.257	2.393.265	2.705.953
Total	**5.135.273**	**5.142.391**	**5.986.723**

In figure below, the Carbon Footprint expressed as CO_2 equivalent on Life Cycle is reported by fuel and sector.

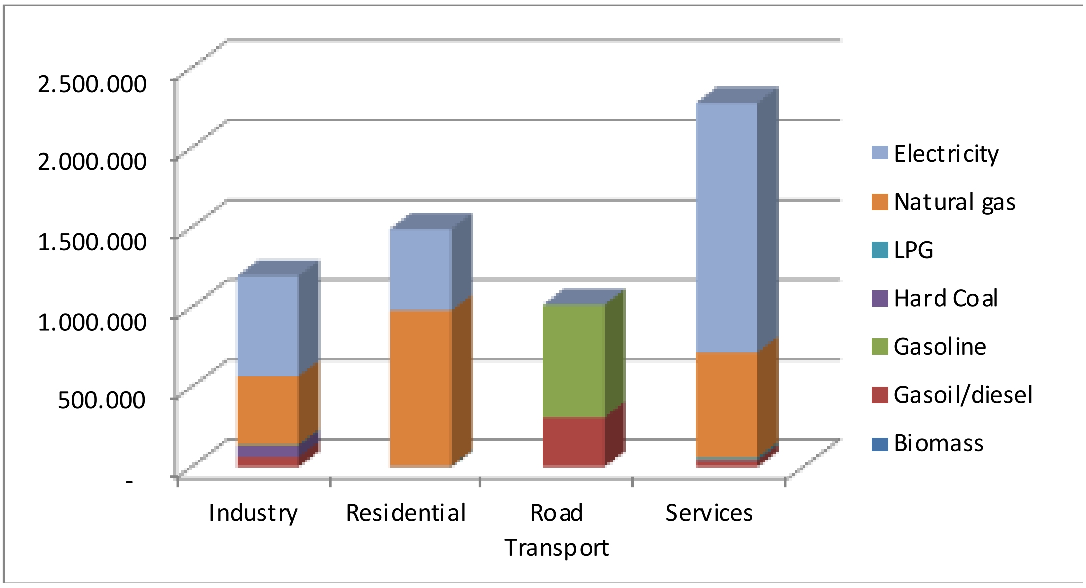


Figure 3-30: Amsterdam Carbon Footprint (Mg CO_2 equivalent on Life Cycle).

3.4.2 BAU

In Table 3-4 Carbon Footprint by sector is reported for Amsterdam BAU expressed as CO_2, CO_2 equivalent and CO_2 equivalent on Life Cycle. In Table 3-5 CO_2 equivalent on Life Cycle reductions on 2015 are reported.

Table 3-4: Amsterdam BAU Carbon Footprint by Sector (Gg).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide (CO_2)						
Residential	1.275,9	1.035,9	941,6	802,8	713,1	695,8
Services	1.984,8	1.468,7	1.452,6	892,0	562,2	453,2
Transport	832,3	823,7	814,2	750,7	681,0	407,3
Industry	1.042,3	842,5	842,5	675,9	537,1	487,2
Total	***5.135,3***	***4.170,7***	***4.050,9***	***3.121,5***	***2.493,4***	***2.043,5***
Carbon dioxide equivalent (CO_{2eq})						
Residential	1.276,7	1.036,5	942,2	803,2	713,3	695,9
Services	1.987,2	1.470,2	1.454,2	892,9	562,5	453,3
Transport	834,7	826,0	816,5	752,9	682,9	408,5

Industry	1.043,8	843,6	843,6	676,8	537,8	487,7
Total	***5.142,4***	***4.176,4***	***4.056,5***	***3.125,7***	***2.496,4***	***2.045,4***
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	1.491,8	1.215,7	1.103,5	946,2	845,9	827,6
Services	2.281,0	1.695,4	1.676,3	1.033,4	660,7	538,1
Transport	1.017,5	1.007,0	995,6	919,4	836,0	500,0
Industry	1.196,4	970,1	970,1	781,5	624,3	567,7
Total	***5.986,7***	***4.888,3***	***4.745,5***	***3.680,5***	***2.967,0***	***2.433,4***

Table 3-5: Amsterdam BAU Carbon Footprint by Sector: index (2015=100).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	100	81	74	63	57	55
Services	100	74	73	45	29	24
Transport	100	99	98	90	82	49
Industry	100	81	81	65	52	47
Total	100	82	79	61	50	41

Carbon Footprint, expressed as CO_2 equivalent on Life Cycle, is reported in Figure 3-31 by sector and in Figure 3-32 by fuel. The graphs highlight the largely dominant contribution of the residential and service sectors as described above, from the point of view of energy carriers, natural gas and electricity.

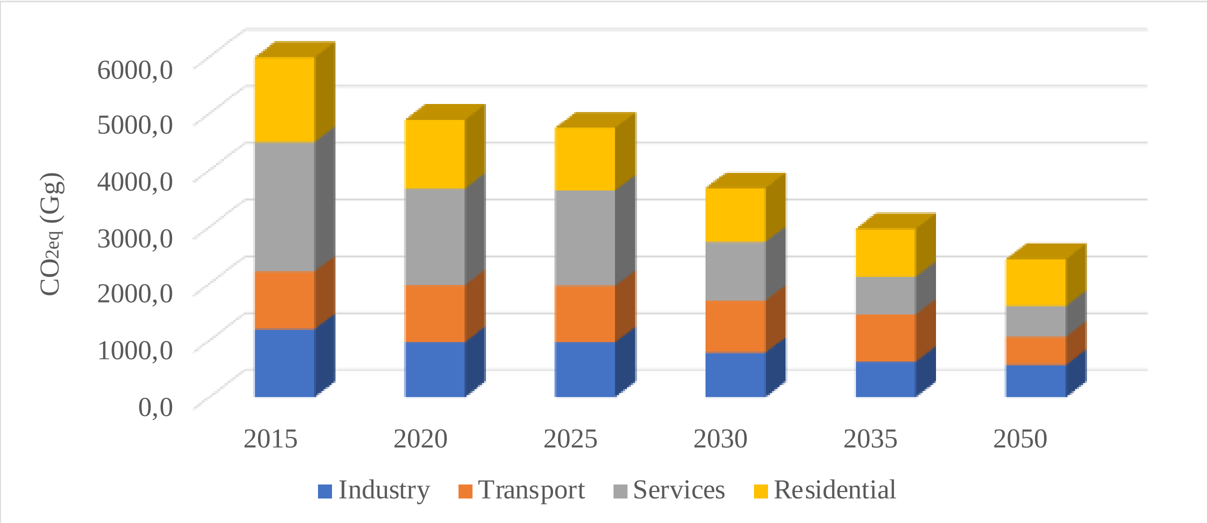


Figure 3-31: Amsterdam BAU Carbon Footprint by sector (Gg CO_2 equivalent on Life Cycle).

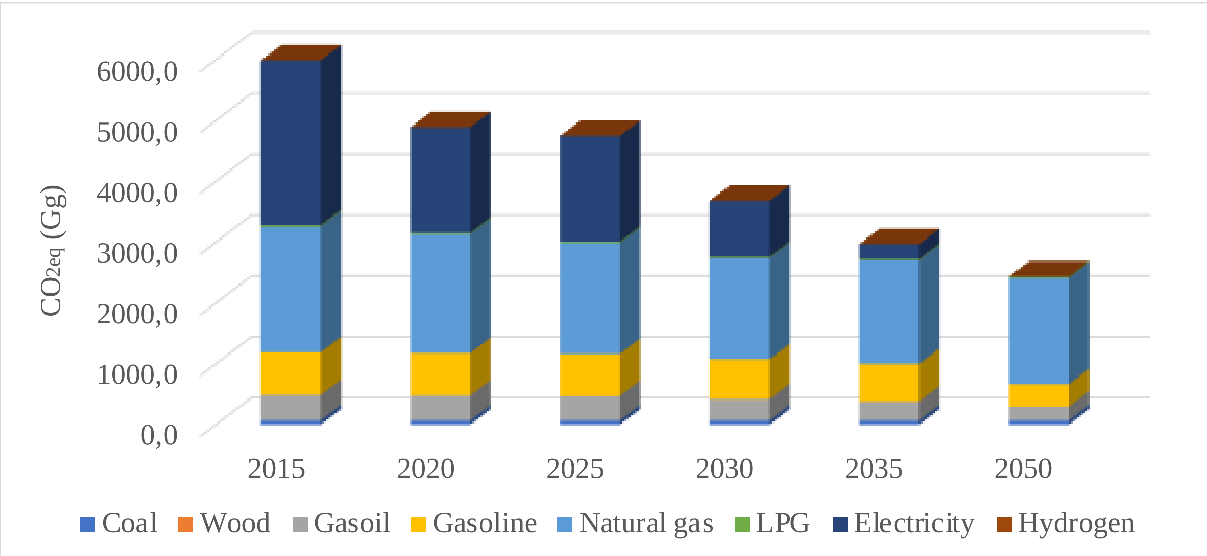


Figure 3-32 – Amsterdam BAU Carbon Footprint by fuel (Gg CO_2 equivalent on Life Cycle).

3.4.3 Stakeholder dialog workshop Scenarios

Scenario projections take into consideration city level additional measures from Stakeholder dialog workshop (SWD). Also, in this case as a general input to the projection model, results from IRCI and Traffic models have been assumed for fuel consumptions.

In Table 3-6 Carbon Footprint by sector is reported for Amsterdam Scenario low expressed as CO_2, CO_2 equivalent and CO_2 equivalent on Life Cycle. In Table 3-7 CO_2 equivalent on Life Cycle reductions on 2015 are reported.

For the Scenario 1, Carbon Footprint, expressed as CO_2 equivalent on Life Cycle, is reported in Figure 3-33 by sector and in Figure 3-34 by fuel.

Table 3-6: Amsterdam Scenario low Carbon Footprint by Sector (Gg).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide (CO_2)						
Residential	1.275,9	1.035,9	903,0	715,1	585,4	445,3
Services	1.984,8	1.468,7	1.418,9	834,9	479,0	290,0
Transport	832,3	818,9	804,6	733,6	658,2	385,2
Industry	1.042,3	842,5	842,5	675,9	537,1	487,2
Total	***5.135,3***	***4.166,0***	***3.969,0***	***2.959,5***	***2.259,7***	***1.607,7***
Carbon dioxide equivalent (CO_{2eq})						
Residential	1.276,7	1.036,5	903,5	715,4	585,4	445,3
Services	1.987,2	1.470,2	1.420,5	835,8	479,2	290,1
Transport	834,7	821,3	806,8	735,6	660,1	386,3
Industry	1.043,8	843,6	843,6	676,8	537,8	487,7
Total	***5.142,4***	***4.171,7***	***3.974,5***	***2.963,6***	***2.262,5***	***1.609,4***
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	1.491,8	1.215,7	1.057,4	841,7	693,8	529,5
Services	2.281,0	1.695,4	1.636,4	965,6	561,9	344,4
Transport	1.017,5	1.020,8	1.013,5	927,7	835,2	502,5
Industry	1.196,4	970,1	970,1	781,5	624,3	567,7
Total	***5.986,7***	***4.902,0***	***4.677,4***	***3.516,5***	***2.715,2***	***1.944,2***

Table 3-7: Amsterdam Scenario low Carbon Footprint by Sector: index (2015=100).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	100	81	71	56	47	35
Services	100	74	72	42	25	15
Transport	100	100	100	91	82	49
Industry	100	81	81	65	52	47
Total	***100***	***82***	***78***	***59***	***45***	***32***

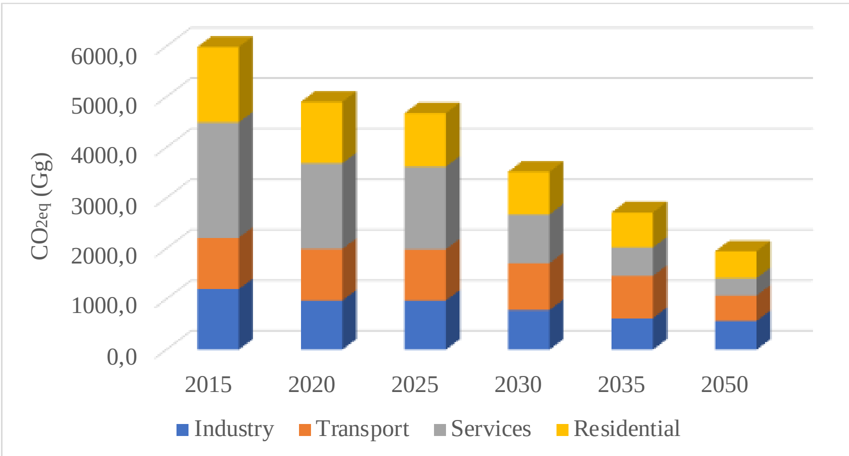


Figure 3-33: Amsterdam Scenario *low* Carbon Footprint by sector (Gg CO_2 equivalent on Life Cycle).

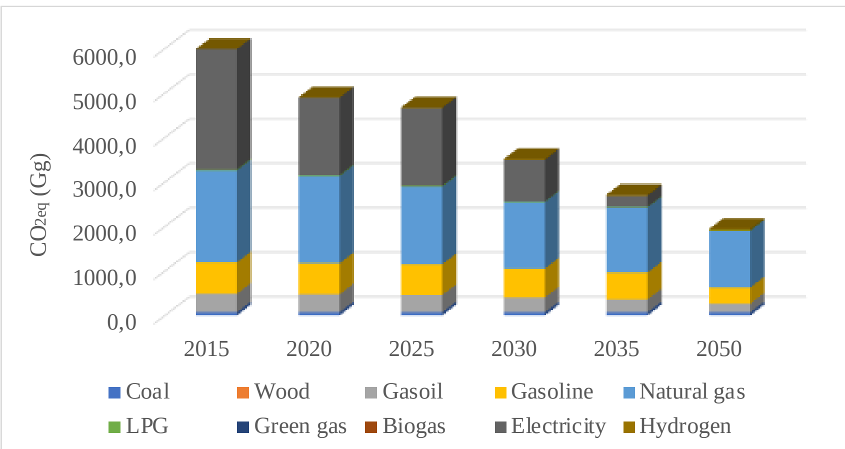


Figure 3-34: Amsterdam Scenario *low* Carbon Footprint by fuel (Gg CO_2 equivalent on Life Cycle).

In Table 3-8 Carbon Footprint by sector is reported for Amsterdam Scenario high expressed as CO_2, CO_2 equivalent and CO_2 equivalent on Life Cycle. In Table 3-9 CO_2 equivalent on Life Cycle reductions on 2015 are reported.

Table 3-8: Amsterdam Scenario high Carbon Footprint by Sector (Gg).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide (CO_2)						
Residential	1.275,9	854,2	520,9	153,8	40,7	0,0
Services	1.984,8	1.326,1	1.085,4	469,3	124,2	0,0
Transport	832,3	771,0	702,0	500,7	288,5	119,9
Industry	1.042,3	842,5	842,5	675,9	537,1	487,2
Total	***5.135,3***	***3.793,8***	***3.150,7***	***1.799,7***	***990,6***	***607,1***
Carbon dioxide equivalent (CO_{2eq})						
Residential	1.276,7	854,8	521,4	154,0	40,8	0,0
Services	1.987,2	1.327,7	1.086,9	470,1	124,4	0,0
Transport	834,7	773,2	704,0	502,1	289,3	120,3
Industry	1.043,8	843,6	843,6	676,8	537,8	487,7
Total	***5.142,4***	***3.799,3***	***3.155,9***	***1.803,0***	***992,3***	***608,0***
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	1.491,8	1.021,7	647,2	240,5	99,3	40,8
Services	2.281,0	1.550,0	1.288,0	603,0	198,0	43,9
Transport	1.017,5	988,7	941,0	683,0	412,9	189,9
Industry	1.196,4	970,1	970,1	781,5	624,3	567,7
Total	***5.986,7***	***4.530,4***	***3.846,3***	***2.308,0***	***1.334,5***	***842,3***

Table 3-9: Amsterdam Scenario high Carbon Footprint by Sector: index (2015=100).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	100	68	43	16	7	3
Services	100	68	56	26	9	2
Transport	100	97	92	67	41	19
Industry	100	81	81	65	52	47
Total	100	76	64	39	22	14

For the Scenario high, Carbon Footprint, expressed as CO_2 equivalent on Life Cycle, is reported in Figure 3-35 by sector and in Figure 3-36 by fuel.

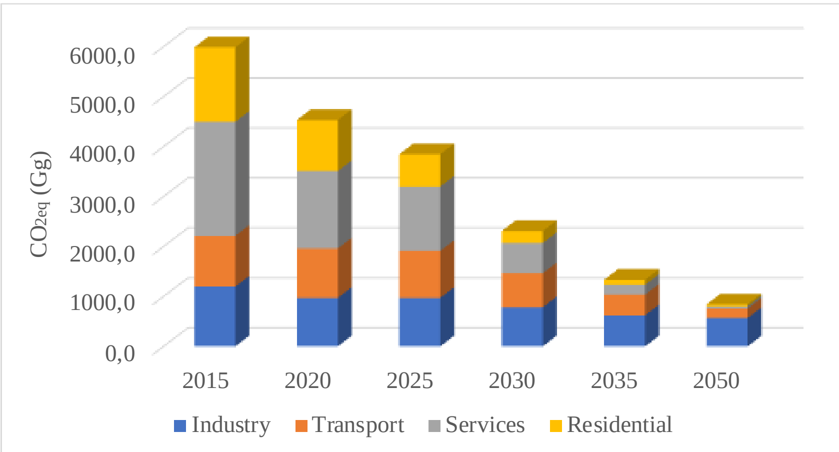


Figure 3-35: Amsterdam Scenario *high* Carbon Footprint by sector (Gg CO_2 equivalent on Life Cycle).

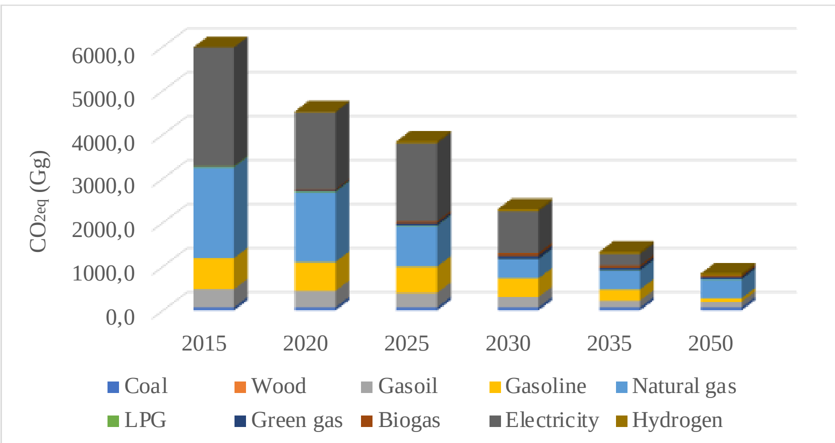


Figure 3-36: Amsterdam Scenario *high* Carbon Footprint by fuel (Gg CO_2 equivalent on Life Cycle).

3.4.4 Unified Policy Scenario

In Table 3-10 Carbon Footprint by sector is reported for Amsterdam Unified Policy Scenario expressed as CO_2, CO_2 equivalent and CO_2 equivalent on Life Cycle. In Table 3-11 CO_2 equivalent on Life Cycle reductions on 2015 are reported.

Table 3-10: Amsterdam Unified Policy Scenario Carbon Footprint by Sector (Gg).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide (CO_2)						
Residential	1.275,9	950,3	701,9	387,0	183,8	0,0
Services	1.984,8	1.401,5	1.243,3	621,2	217,4	0,0
Transport	832,3	783,3	726,6	524,2	303,2	125,0
Industry	1.042,3	842,5	842,5	675,9	537,1	487,2
Total	***5.135,3***	***3.977,6***	***3.514,2***	***2.208,3***	***1.241,7***	***612,1***
Carbon dioxide equivalent (CO_{2eq})						
Residential	1.276,7	950,9	702,3	387,3	183,9	0,0
Services	1.987,2	1.403,1	1.244,9	622,0	217,7	0,0
Transport	834,7	785,5	728,6	525,6	304,1	125,3
Industry	1.043,8	843,6	843,6	676,8	537,8	487,7
Total	***5.142,4***	***3.983,1***	***3.519,5***	***2.211,7***	***1.243,4***	***613,0***
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	1.491,8	1.119,7	829,8	469,0	239,6	40,8
Services	2.281,0	1.622,0	1.440,4	730,7	276,5	43,9
Transport	1.017,5	978,1	919,8	672,4	401,2	184,4
Industry	1.196,4	970,1	970,1	781,5	624,3	567,7
Total	***5.986,7***	***4.689,9***	***4.160,2***	***2.653,6***	***1.541,6***	***836,8***

Table 3-11: Amsterdam Unified Policy Scenario Carbon Footprint by Sector: index (2015=100).

Year	2015	2020	2025	2030	2035	2050
Carbon dioxide equivalent on life cycle (CO_{2eq})						
Residential	100	75	56	31	16	3
Services	100	71	63	32	12	2
Transport	100	96	90	66	39	18
Industry	100	81	81	65	52	47
Total	***100***	***78***	***69***	***44***	***26***	***14***

For the Unified Policy Scenario, Carbon Footprint, expressed as CO_2 equivalent on Life Cycle, is reported in Figure 3-37 by sector and in Figure 3-38 by fuel.

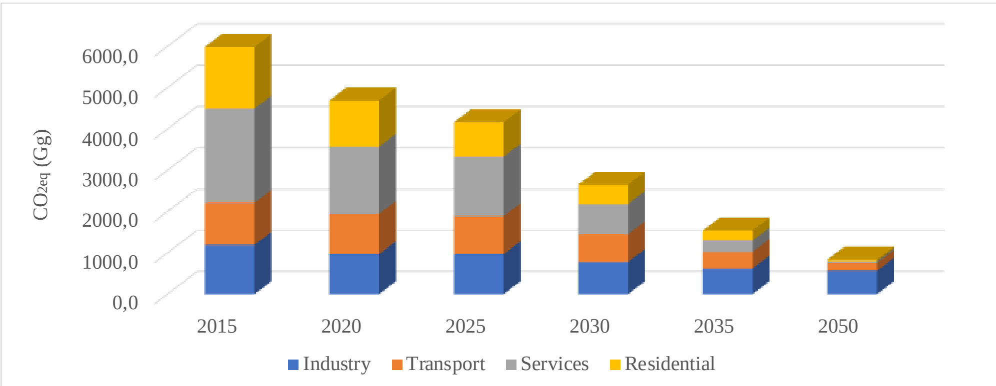


Figure 3-37: Amsterdam Unified Policy Scenario Carbon Footprint by sector (Gg CO_2 equivalent on Life Cycle).

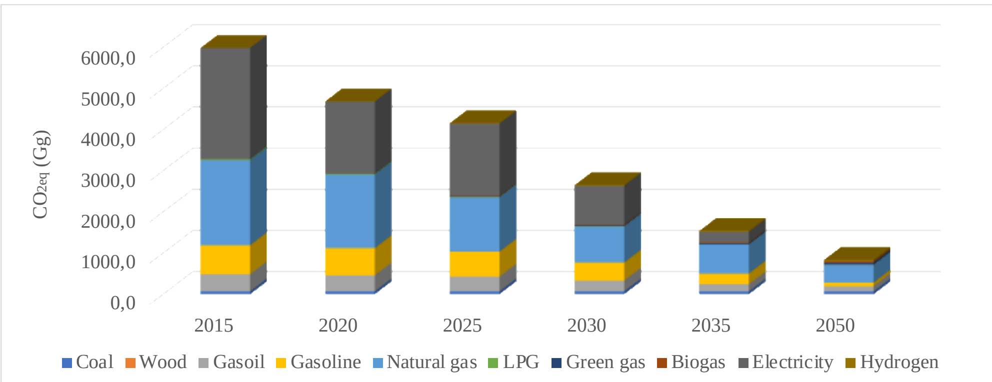


Figure 3-38: Amsterdam Unified Policy Scenario Carbon Footprint by fuel (Gg CO_2 equivalent on Life Cycle).

Total Carbon Footprint in the different scenarios is compared in Figure 3-39 expressed as CO_2 equivalent on Life Cycle.

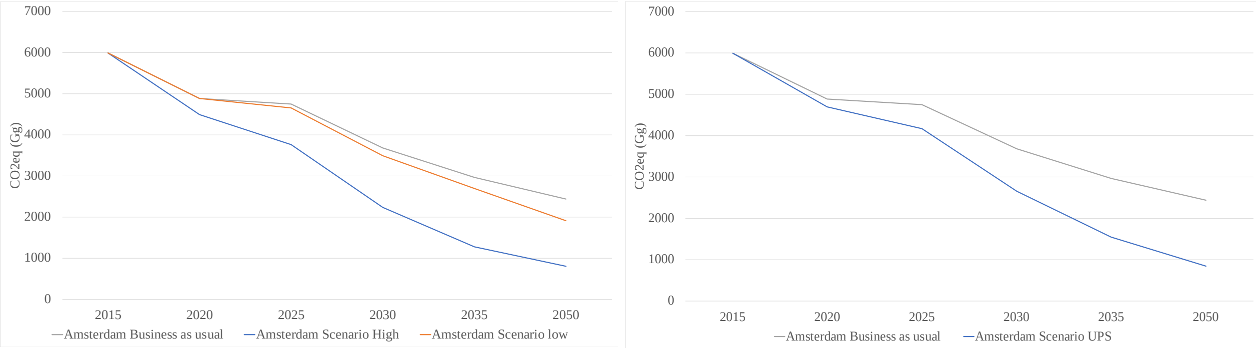


Figure 3-39: Amsterdam Carbon Footprint (Mg CO_2 equivalent on Life Cycle) by SDW scenario (left) and final unified scenario (right).

In Figure 3-40 results are reported by sector and in Figure 3-41 by sector and fuel. Finally, in Figure 3-42 Amsterdam Carbon Footprint on life cycle generated by citizens' activities is reported in BAU and UPS scenario.

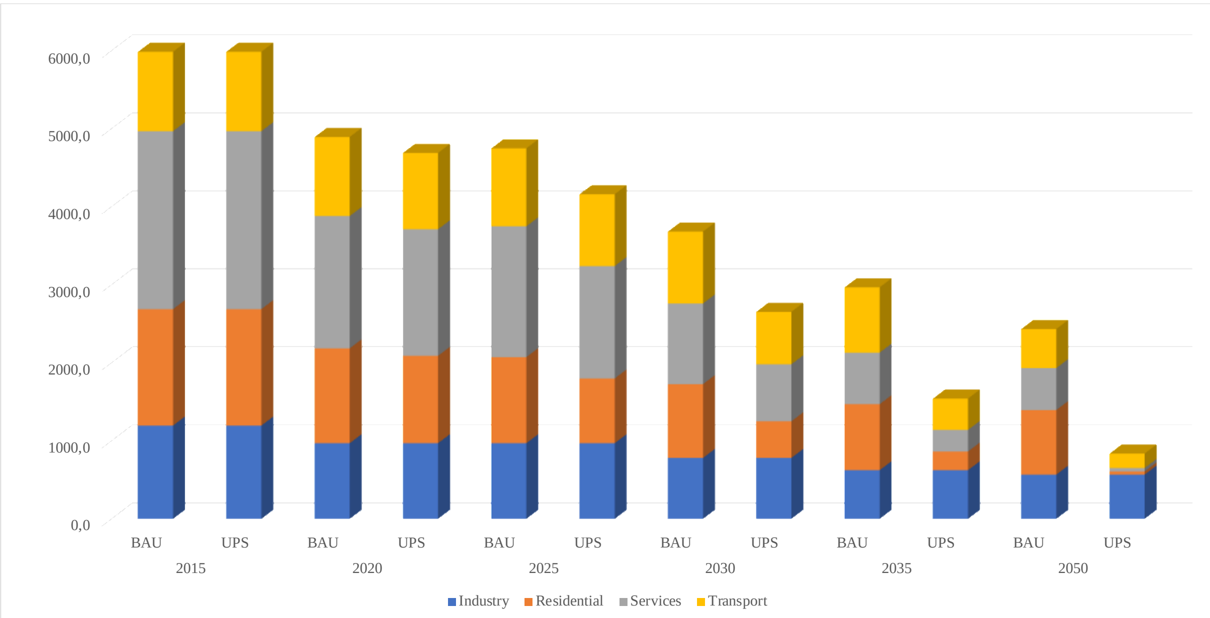


Figure 3-40: Amsterdam Carbon Footprint BAU and UPS comparison by sector (Mg CO_2 equivalent on Life Cycle).

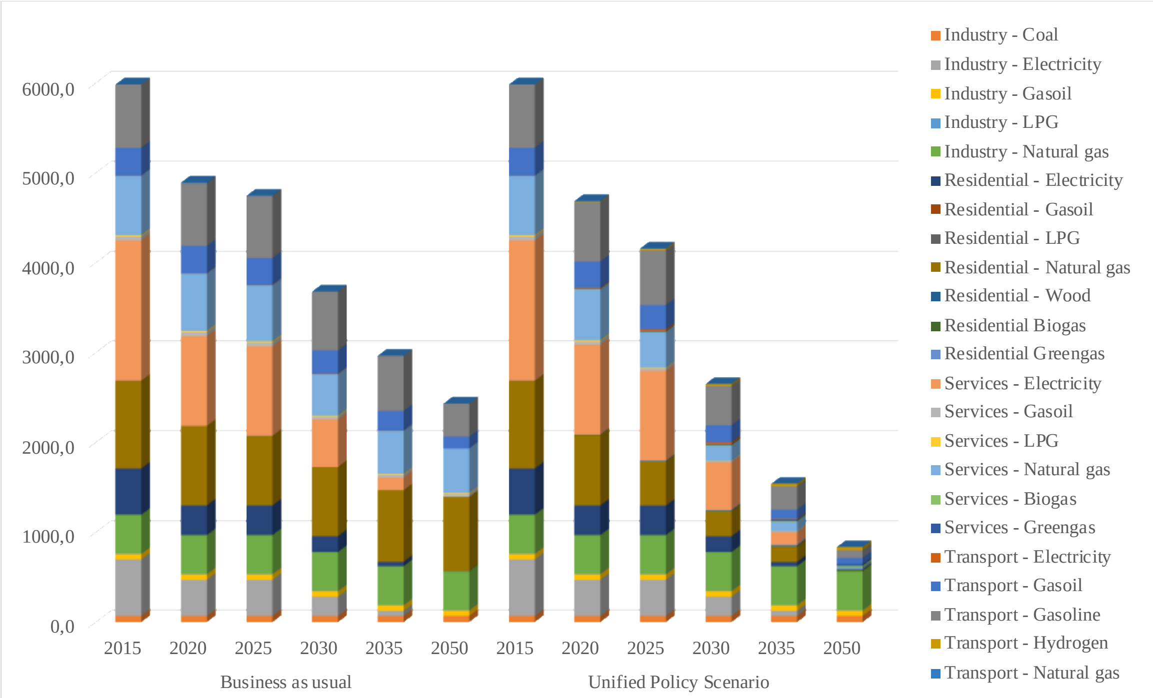


Figure 3-41: Amsterdam Carbon Footprint BAU and UPS comparison by sector and fuel ($Mg\ CO_2$ equivalent on Life Cycle).

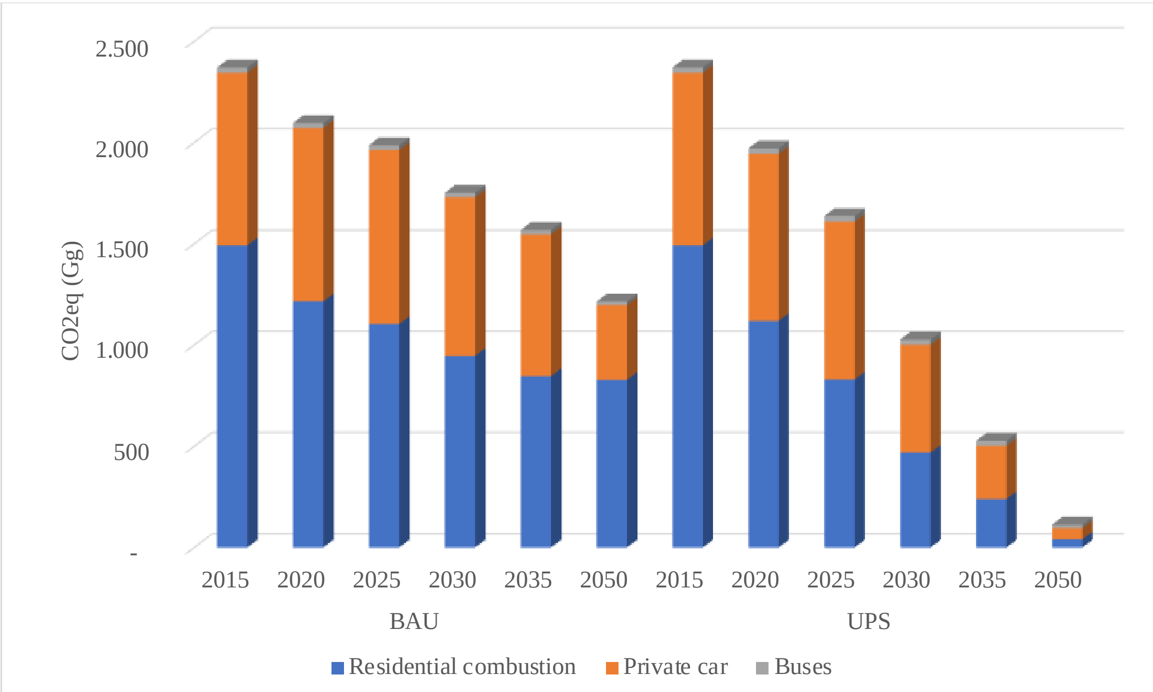
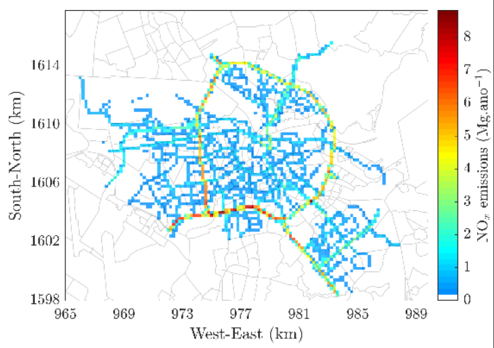
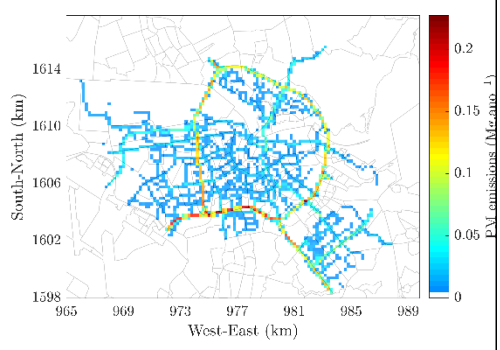
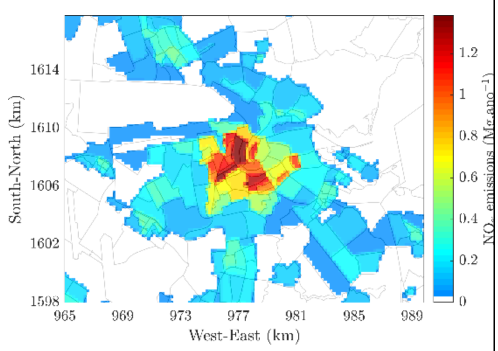
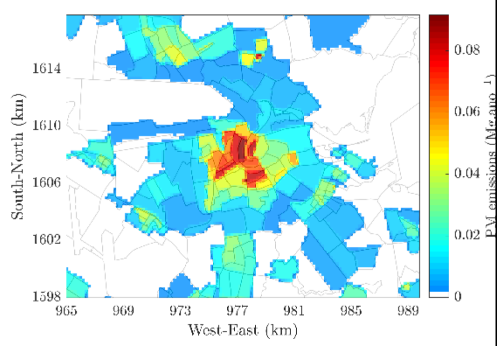
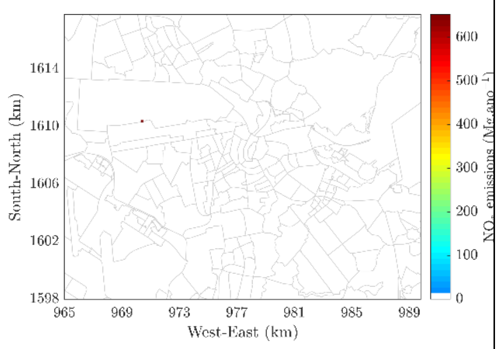


Figure 3-42: Amsterdam Carbon Footprint generated by citizens' activities in BAU and UPS scenario (Mg CO2 equivalent on Life Cycle).

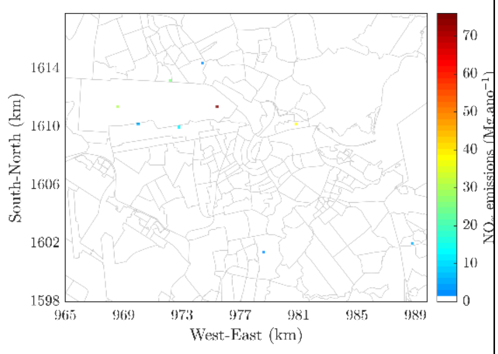
3.5 Air quality impacts

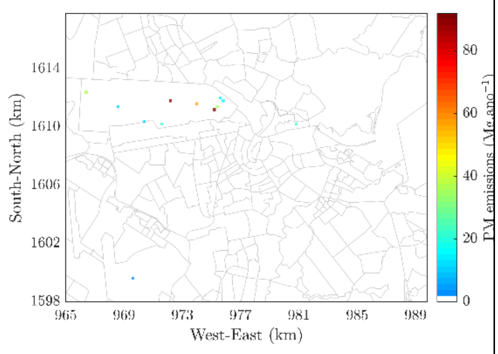
3.5.1 Annual emissions input

Air quality emissions estimates, start from the spatiotemporally distributed emissions from all the sources described in the previous section. Figure 3-43 shows the emission values for NO_x and PM in $Mg.year^{-1}$ for each sector.

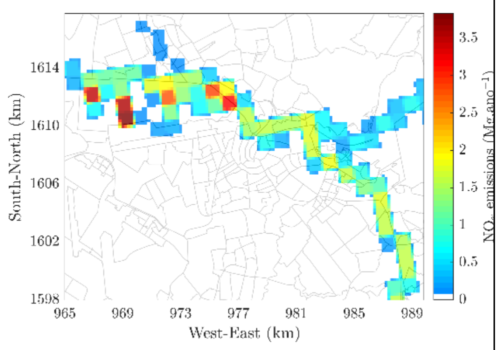
	NOx	PM
Transport		
Commercial and Residential		
Industrial Point		

Industrial Area





Shipping



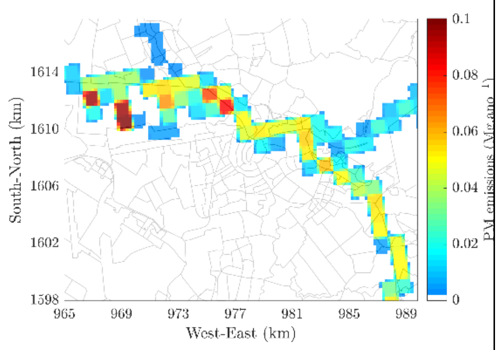


Figure 3-43: Emission values for NOx and PM by sector, in Mg.year^{-1}.

The absence of PM industrial point sources indicates that the industrial sources were all assumed as area sources due to the annual emission rate being lower than 100 Mg.year^{-1}, as established by ClairCity.

3.5.2 Assessment of air quality at mesoscale: baseline year

The meteorological characterization in Amsterdam, at the mesoscale, was based on the analysis of the spatial average of the following variables: temperature, precipitation and wind speed and direction. The mean air temperatures and accumulated temperature, for each month, are presented in Figure 3-44.

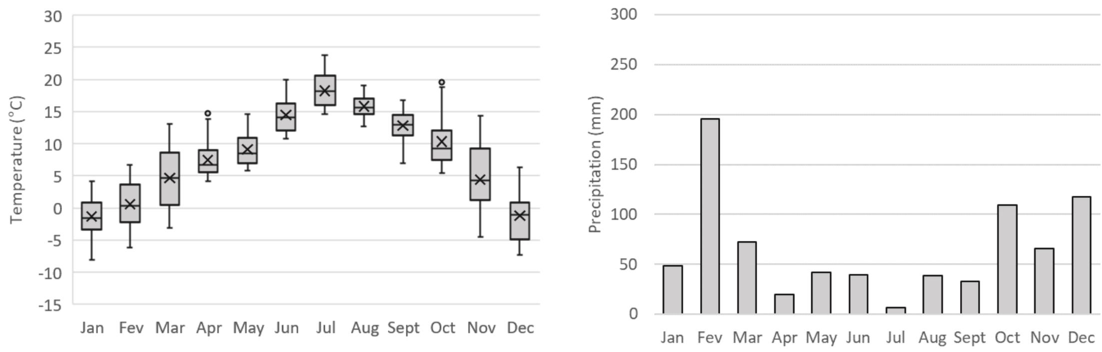
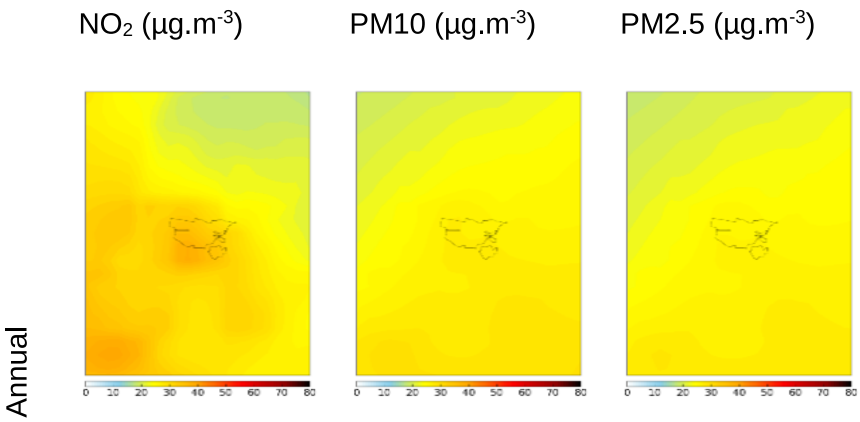


Figure 3-44: (Left) Box and whisker plot of temperature by month; boxes indicate the lower and upper quartile; horizontal line in each box represents the median temperature; the mean temperature for each month is indicated by a x; vertical lines extending from each box represent the minimum and maximum temperature recorded for that month. (Right) Column graph of total precipitation by month.

According to Figure 3-44, in Amsterdam, the minimum mean temperatures are obtained in January, December and February, with -1.4°C, -1.2°C and 0.6°C, respectively. The month where the highest mean temperature is recorded is July, with 18.3°C, followed by August, with 15.8°C. Regarding precipitation, the months with the highest accumulated precipitation go from October to March (with values from 50 to 195 mm), while the driest month is July with 6 mm. During almost the whole year, the wind blows predominantly from the 3rd quadrant (SW), with a wind speed between 2 and 10 $m.s^{-1}$.

The air quality characterization in Bristol, at mesoscale, was based on spatial maps of concentrations and on a source contribution analysis. The spatial analysis was done for the average concentrations of NO_2, PM10 and PM2.5 for the following periods: (i) annual; (ii) a typical winter month (February); and (iii) a typical summer month (August) (Figure 3-45).



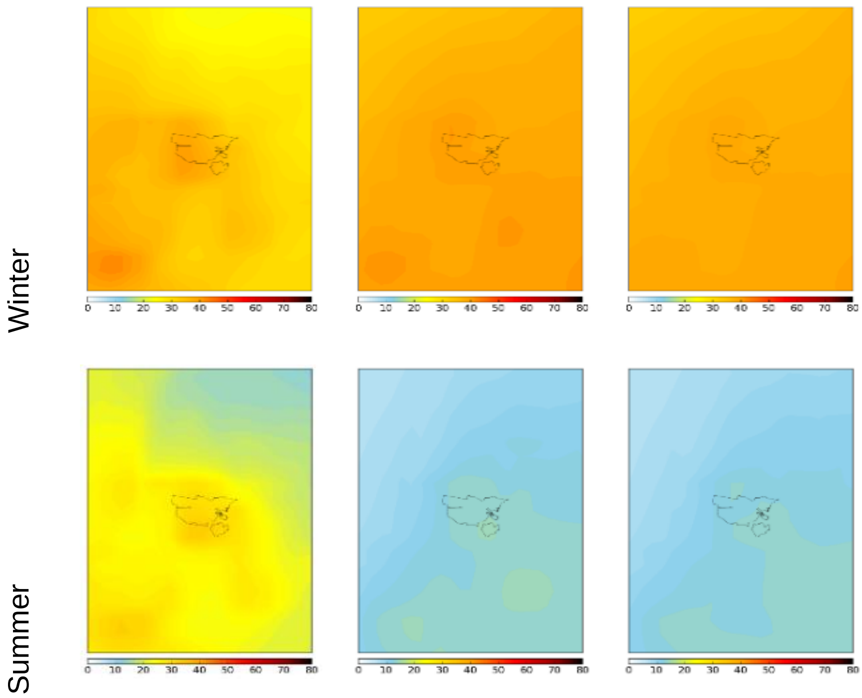


Figure 3-45: Spatial distribution of NO_2, PM10 and PM2.5 concentrations, for the different periods analysed (annual, winter and summer) in Amsterdam.

For each pollutant, NO_2, PM10 and PM2.5, results presented in Figure 3-45 show similar spatial patterns for the different periods analysed. For NO_2, the concentration fields show a gradient decreasing from southwest to northeast. However, for PM10 and PM2.5, de concentration fields shows a gradient decreasing from southeast to northwest of the domain.

Regarding the analysis of seasonal concentration fields, results show that, for all pollutants, the maximum values are found in winter, while the minimum values are recorded in summer. For NO_2, the highest concentration values, for annual, winter and summer periods are 40 $\mu g.m^{-3}$, 43 $\mu g.m^{-3}$ and 33 $\mu g.m^{-3}$, respectively. For PM10, the maximum concentration values are close to 30 $\mu g.m^{-3}$, for the annual average, 41 $\mu g.m^{-3}$ in winter and 19 $\mu g.m^{-3}$ in summer. For PM2.5, the highest concentration values are 28 $\mu g.m^{-3}$, 40 $\mu g.m^{-3}$ and 14 $\mu g.m^{-3}$ for annual, winter and summer periods, respectively.

The source contribution analysis was provided to estimate the contribution to the modelled NO_2, PM10 and PM2.5 concentrations, from transboundary transport (TBD) and from specific source groups previously defined – residential and commercial combustion (RES), industrial combustion and processes (IND), road transport (TRP) and all the remaining sources (OTH). The results were analysed in terms of the relative contribution of those groups to the NO_2, PM10 and PM2.5 concentration simulated for the urban area of Amsterdam, which was the receptor area defined in the PSAT application.

The contribution of each source group for NO_2, PM10 and PM2.5 concentrations, in the urban area of Amsterdam for the three periods previously defined, are analysed in Figure 3-46.

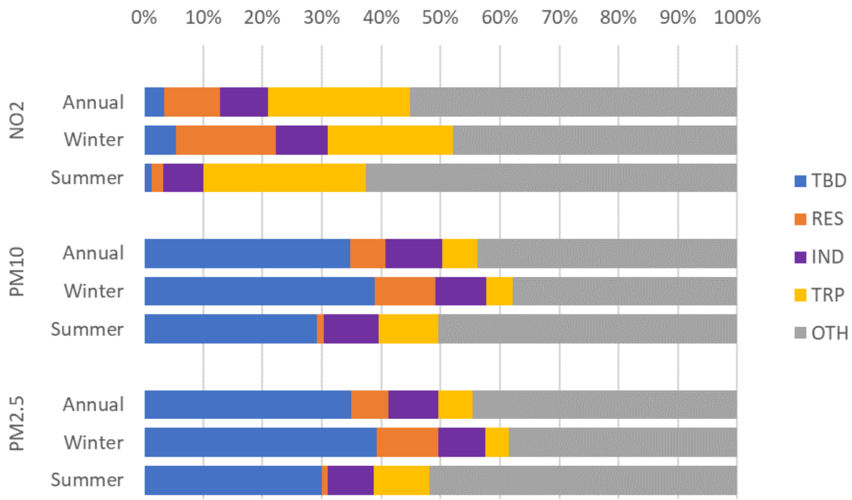


Figure 3-46: Annual, winter and summer averages contribution for each source group for NO_2, PM10 and PM2.5 concentrations, for Amsterdam urban area; (TBD- transboundary transport, RES - residential and commercial combustion, IND - industrial combustion and processes, TRP - road transport and OTH - all the remaining sources).

The average annual contributions of each source group reveal that, for NO_2, the largest contribution is from TRP, followed by RES, with IND in third place. While RES presents higher values in the winter, TRP and IND remains almost unchanged in the three analysed periods.

For PM10, the annual average contributions of each source group reveal that one of the major contributions is from TBD (35%), highlighting the importance of transboundary transport for the PM10 pollution in the study region. This long-range transport effect is even more notorious in the winter period, with values of 39%. Source contribution results also point to a great influence of the contribution of different human activities, such as residential combustion and traffic emissions, to the PM10 levels, with the residential combustion being higher in the winter period and the traffic in the summer period. For PM2.5, the analysis is similar to that of PM10.

Although the other sources (OTH) have a significant contribution for NO_2, PM10 and PM2.5 concentrations, in this analysis it is neglected, as it represents several groups, rather than a specific source group.

3.5.3 Assessment of air quality at urban scale: baseline year

Figure 3-47 shows, for the baseline year, the annual average of NO_2, PM_{10} and $PM_{2.5}$ concentrations simulated by the urban scale model URBAIR, including the background concentrations and the adjustment factor. For each pollutant two color scheme are presented, a) the standard ClairCity color scheme and b) a customized color scheme based on the EC assessment thresholds, which the EC directive EU/50/2008 establishes for each pollutant an upper and a lower assessment threshold. For NO_2 the lower assessment threshold (LAT) is 26 and the upper assessment threshold (UAT) is 32. For PM_{10} the LAT value is 20 and the UAT value is 28, and for $PM_{2.5}$ the LAT value is 12 and the UAT value is 17.

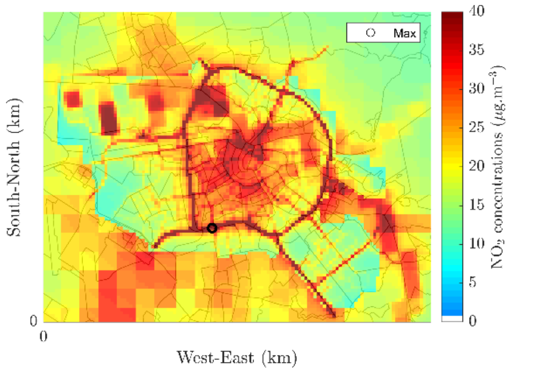
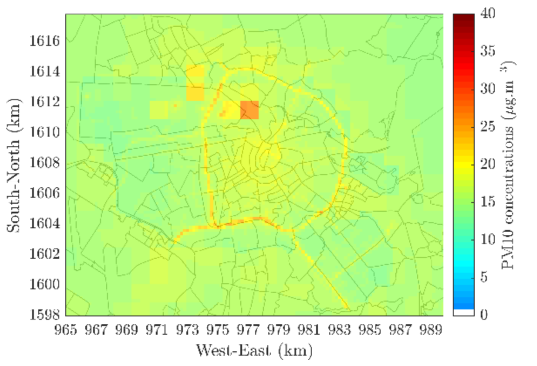
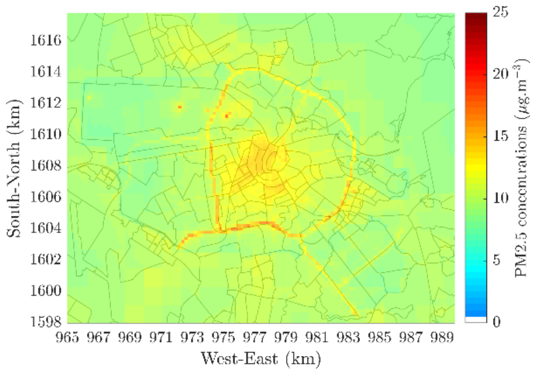
	a) Standard colour scheme	b) EC assessment thresholds
NO_2 concentrations		
PM_{10} concentrations		
$PM_{2.5}$ concentrations		

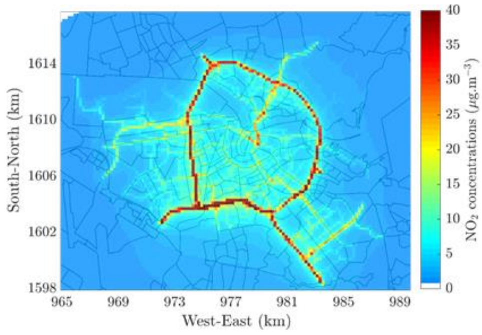
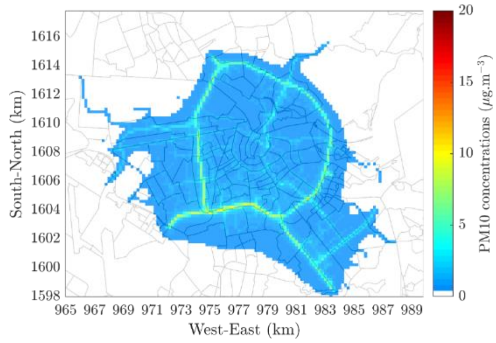
Figure 3-47: Annual average of the NO_2, PM_{10} and $PM_{2.5}$ concentrations, including the background concentrations and the adjustment factor. a) using a standard color scheme, and b) using a customized color scheme based on the EC assessment thresholds.

The maximum value of the annual NO_2 concentrations in 2015 is equal to 82.7 µg.m^{-3} and is located within the urban area (as indicated on the map). The main sector contributing to that maximum value is the transport sector, with a contribution of 89.8%, followed by the commercial and residential sector with 6.8%, the shipping sector with a contribution of 2.3%, and the industrial sector with a contribution of 1.1 %. These contributions are obtained from the source apportionment analysis. The average value of the NO_2 concentrations over the entire domain is equal to 21.7 µg.m^{-3} and the source apportionment analysis indicates that transport is contributing with 37.6%, shipping sector with 29.2%, industrial sector with 9.0% and the residential and commercial sector with 24.2% to the simulated concentrations.

The maximum value of the annual PM_{10} concentrations in 2015 is equal to 26.4 µg.m^{-3}. The main sector contributing to that maximum value is the transport sector, with a contribution of 54.7%, followed by the commercial and residential sector with 19.6%, the industrial sector with a contribution of 16.2%, and the shipping sector with a contribution of 9.6 %.The average value over the entire domain is equal to 15.8 µg.m^{-3}. For PM_{10} concentrations average over all the domain a source apportionment analysis indicates that transport is contributing with 46.2%, shipping sector with 7.9%, industrial sector with 14.5% and the residential and commercial sector with 31.4% to the simulated concentrations.

The maximum value of the annual $PM_{2.5}$ concentrations in 2015 is equal to 17.4 µg.m^{-3}. A source apportionment analysis to the cell where the maximum annual value is simulated presents a major contribution from the industrial sector (87.1%). The average value over the entire domain is equal to 9.9 µg.m^{-3}. For $PM_{2.5}$ concentrations average over all the domain a source apportionment analysis indicates that transport is contributing with 32.7%, shipping sector with 7.7%, industrial sector with 14.1% and the residential and commercial sector with 45.4% to the simulated concentrations.

In order to assess the impact of each sector on air quality, the concentration maps for each pollutant and for each sector are presented. Figure 3-48 shows the final adjusted concentration maps for each emission sector for NO_2 and PM_{10}, without adding the background.

<table>
<tr><th></th><th>NO_2 concentrations</th><th>PM_{10} concentrations</th></tr>
<tr><td>Transport sector</td><td>
</td><td>
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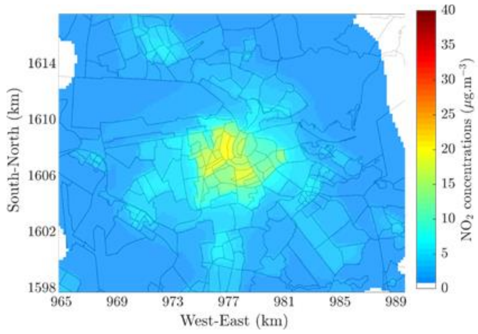
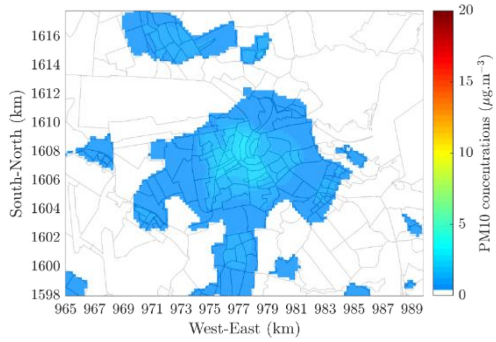
<tr><td>Commercial and Residential sector</td><td>
</td><td>
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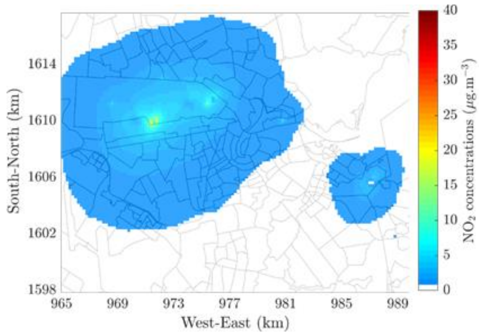
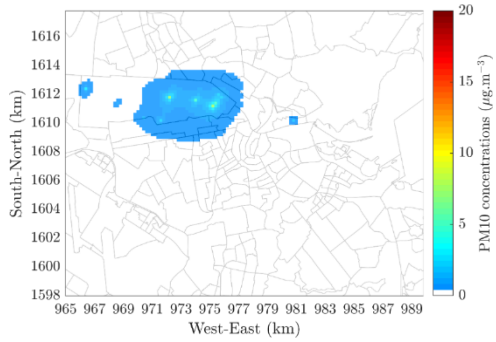
<tr><td>Industrial sector</td><td>
</td><td>
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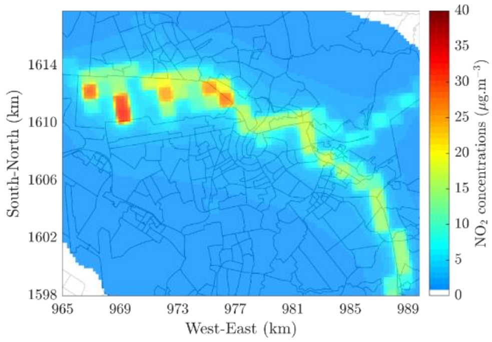
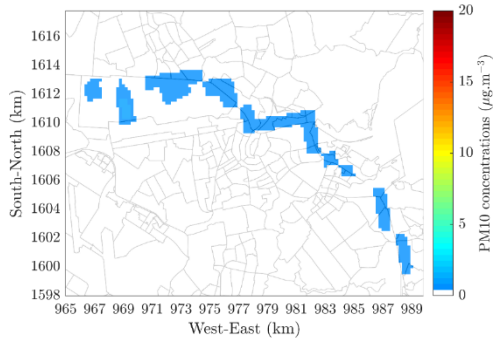
<tr><td>Shipping sector</td><td>
</td><td>
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Figure 3-48: Air quality maps for NO_2 and PM adjusted concentrations by sector without the added background.

For the emission sectors considered, the emissions of particulate matter are assumed to be equal except for the transport sector, therefore, for industrial and commercial and residential sector the $PM_{2.5}$ concentrations maps will be the same as PM_{10} concentration maps. For transport, the emission are different due to different $PM_{10}/PM_{2.5}$ contribution from exhaust and non-exhaust emissions, as explained before at the transport methodology. In terms of concentrations, for the transport sector the spatial distribution is roughly the same although smaller concentration of $PM_{2.5}$ are simulated. For transport, the maximum value simulated for PM_{10} is 10.0 $\mu g.m^{-3}$ and for $PM_{2.5}$ is 7.2 $\mu g.m^{-3}$.

The final air quality results are then compared with the measuring data. Table 3-12 presents the comparison between the measurements and the simulated NO_2 concentrations (with the background concentrations and the adjustment factor) and the sector contribution for all the monitoring sites. The final simulated NO_2 concentrations present a good agreement with the measurements.

Table 3-12: Comparison between the measurements and the simulated NO_2 concentrations (with the background concentrations and the adjustment factor) and contribution of each sector to the simulated values.

Station		**NO_2 concentrations**		**Sector contribution for the location of the station (%)**			
ID	Type	Measured	Simulated	Transport	Shipping	Industrial	Commercial and residential
NL00002	Urban Traffic	49.0	33.9	28.7	13.4	5.8	52.1
NL00003	Urban Background	21.9	23.7	21.4	47.7	5.9	25.1
NL00007	Urban Traffic	45.7	60.9	79.6	4.5	3.7	12.2
NL00012	Urban Traffic	36.4	36.6	27.3	40.2	4.8	27.6
NL00014	Urban Background	24.5	18.8	55.1	9.0	5.1	30.8
NL00017	Urban Traffic	37.1	38.3	37.1	6.4	2.5	54
NL00019	Urban Background	29.1	51.4	55.7	17.9	2.2	24.2

NL00020	Urban Traffic	42.9	28.1	28.8	10.2	6.5	54.5
NL00021	Urban Background	21.1	13.1	35.9	26	9.8	28.3
NL00022	Urban Background	21.2	16.6	36.4	16.7	20.4	26.5
NL00546	Urban Industrial	29.8	26.6	8.8	73.2	10.9	7.1
NL00561	Suburban	28.9	26.3	32.1	19.4	14	34.4
NL00565	Suburban Background	23.5	21.4	29.1	26.2	18.8	25.9
NL00701	Urban Traffic	21.7	24.3	11.6	26.2	9.7	52.5
NL00703	Rural Background	19.2	8.8	24.2	37.4	19.7	18.7
NL00704	Urban Industrial	24.4	18.9	7.7	77.8	7.7	6.8

Table 3-13 presents the comparison between the measurements and the simulated PM_{10} concentrations (with the background concentrations and the adjustment factor) and the sector contribution for all the monitoring sites.

Table 3-13: Comparison between the measurements and the simulated PM_{10} concentrations (with the background concentrations and the adjustment factor) and contribution of each sector to the simulated values.

Station		**PM_{10} concentrations**		**Sector contribution for the location of the station (%)**			
ID	Type	Measured	Simulated	Transport	Shipping	Industrial	Commercial and residential
NL00007	Urban Traffic	21.4	21.1	81.3	1.0	5.8	11.9
NL00012	Urban Traffic	22.7	17.5	37.3	13.0	11.4	38.3

NL00014	Rural Background	17.2	14.9	40.6	2.9	14.5	42.0
NL00016	Rural Background	17.0	17.7	44.8	4.2	23.7	27.3
NL00017	Urban Traffic	21.0	18.5	40.8	1.4	3.6	54.2
NL00545	Urban Traffic	21.4	23.1	90.5	0.4	1.7	7.4
NL00546	Urban Industrial	20.3	15.1	15.3	32.4	37.9	14.4
NL00561	Suburban	21.6	15.7	35.5	4.7	18.3	41.5
NL00565	Suburban Background	17.2	14.8	34.4	7.0	25.6	33.0
NL00701	Urban Traffic	19.5	16.3	10.5	3.9	12.8	72.8
NL00703	Rural Background	17.2	13.9	29.8	10.7	31.3	28.2
NL00704	Urban Industrial	17.4	14.9	16	41.5	26.5	16.0

presents the comparison between the measurements and the simulated PM2.5 concentrations (with the background concentrations and the adjustment factor) and the sector contribution for all the monitoring sites.

presents the comparison between the measurements and the simulated $PM_{2.5}$ concentrations (with the background concentrations and the adjustment factor) and the sector contribution for all the monitoring sites.

Table 3-14: Comparison between the measurements and the simulated $PM_{2.5}$ concentrations (with the background concentrations and the adjustment factor) and contribution of each sector to the simulated values.

Station		**$PM_{2.5}$ concentration**		**Sector contribution for the location of the station (%)**			
ID	Type	Measured	Modelled	Transport	Shipping	Industrial	Commercial and residential
NL00014	Urban Background	12.4	9.7	27	2.7	13.3	57.0
NL00016	Urban Background	11.5	11.1	32.3	4.2	23.5	40.0
NL00701	Urban Traffic	12.8	10.6	5.8	2.9	9.7	81.6
NL00703	Rural Background	12.0	8.5	20.5	10.1	29.7	39.7

3.5.4 Assessment of population exposure: baseline year

The population potentially exposed to harmful concentration levels portray the amount of people on each grid cell where simulated values are exceeding the EU/WHO guideline limits. Figure 3-49 shows the population exposure to NO_2, PM_{10} and $PM_{2.5}$ baseline concentration values.

	EU annual limit value	WHO guideline value

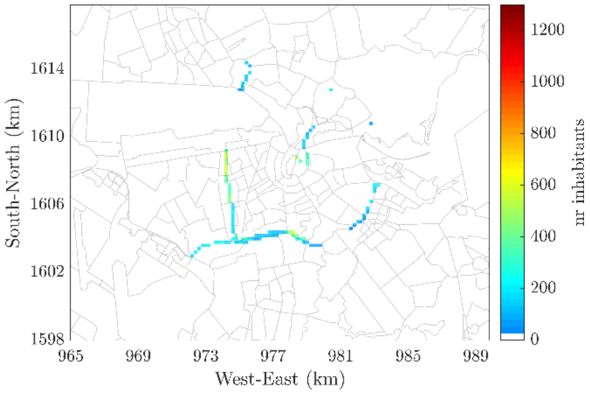
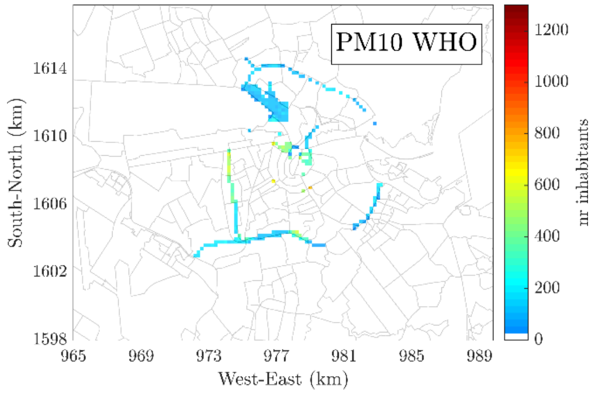
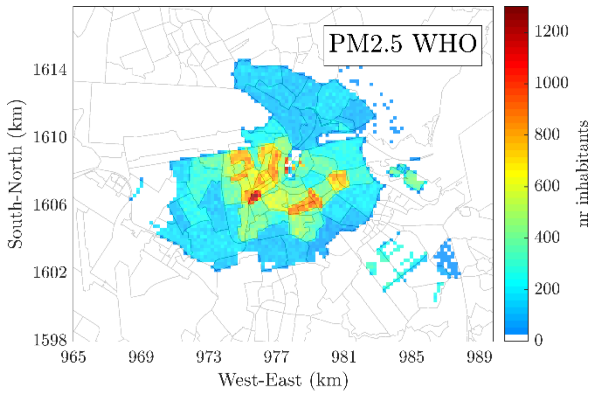
<table>
<tr>
<td>NO_2 concentrations</td>
<td colspan="2">
</td>
</tr>
<tr>
<td>PM_{10} concentrations</td>
<td>There are no exceedances to the EU limits</td>
<td>
</td>
</tr>
<tr>
<td>$PM_{2.5}$ concentrations</td>
<td>There are no exceedances to the EU limits</td>
<td>
</td>
</tr>
</table>

Figure 3-49: Population potentially exposed to values above the EU limits and WHO guideline values for NO_2, PM_{10} and $PM_{2.5}$ baseline concentrations.

For NO_2 the limits established by the EU and the WHO are equivalent, being 40 µg.m^{-3} for the annual mean. In Amsterdam, the NO_2 annual limits are exceeded in 155 cells corresponding to 3% of the total population within the urban area potentially exposed to those concentrations.

As for particulate matter, the limits diverge between both standards, with WHO showing stricter limits. PM_{10} values under the EU annual mean limits are 40 µg.m^{-3} and under WHO guidelines are 20 µg.m^{-3}, for $PM_{2.5}$ the EU established for the annual mean limit value of 25 µg.m^{-3} and for the WHO limits it is established at 10 µg.m^{-3}. For PM_{10} and $PM_{2.5}$ concentration maps for the baseline point out no exceedances to the EU legal limit values, although for the WHO guidelines the annual concentrations indicate exceedances to the limit values. For PM_{10}, 102 cells are exceeding the guideline, which represents less than 1% of the population within the simulation area potentially affected. For $PM_{2.5}$, 62% of the population within the simulation area are potentially exposed to those concentrations.

3.5.5 Assessment of air quality impacts at urban scale

3.5.5.1 BAU scenarios

The substantial reductions of NO_x emissions in the BAU scenario will lead to significant reductions of the NO_2 concentrations. Figure 3-50 presents the NO_2 annual averaged concentrations considering the impacts of BAU scenario in 2025 and 2050. The maximum annual averaged NO_2 concentrations will be equal to 52.2 µg.m^{-3} in 2025 and to 49.8 µg.m^{-3} in 2050, corresponding to an overall reduction of the maximum concentration of 52.9% and 57.4%, when compared to the baseline.

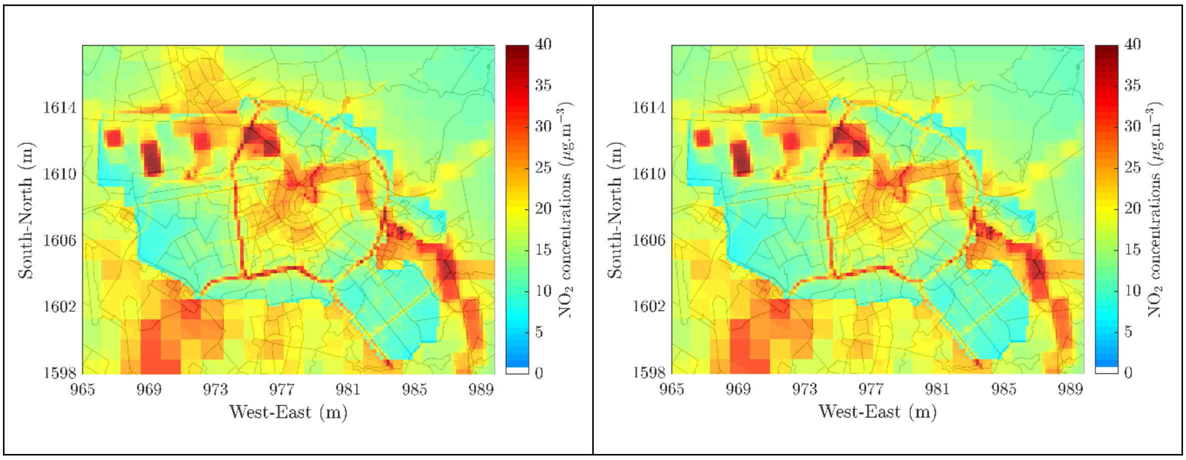


Figure 3-50: NO_2 annual average concentrations in the BAU scenario a) in 2025 and b) in 2050.

Figure 3-51 presents the differences of the NO_2 concentrations between the baseline year and the BAU scenarios in 2025 and 2050. These differences are absolute concentrations obtained from the relationship $NO_{2\ \text{baseline year}} - NO_{2\ \text{scenarios}}$ in µg.m^{-3}. The BAU scenario will lead to a maximum reduction of 43.7 µg.m^{-3} of the NO_2 concentrations in 2025, corresponding to a reduction of 52.9%, while the spatial average over the entire the domain will reduce 3.6 µg.m^{-3} of NO_2 concentrations, which corresponds to a reduction of 15.2%. In 2050 the BAU scenario will lead to a maximum reduction of the NO_2 concentrations of 47.4 µg.m^{-3} which corresponds to a reduction of 57.4%, while the average over the entire domain will reduce 3.9 µg.m^{-3} (16.8%).

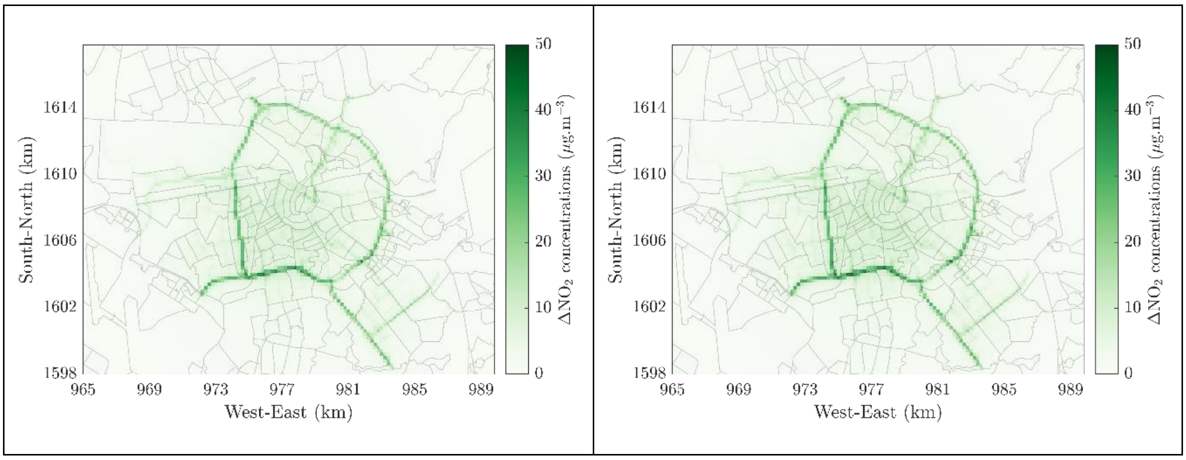


Figure 3-51: Differences of the NO_2 annual averaged concentrations in the BAU scenario a) in 2025 and b) in 2050.

Table 3-15 summarizes the overall impacts of BAU scenarios on air quality and population exposure. The population within the urban area of Amsterdam potentially exposed to NO_2 concentrations will diminish from 3.4% in the baseline year to no inhabitants in risk of exposure with the implementation of the BAU scenarios. Therefore, the simulation results indicate almost fully compliance with the EU limits already with the BAU scenario in 2025 (except within 14 grid cells, 3 of them with inhabitants living there).

Table 3-15: Summary of results including the annual averages of NO_2 concentrations, together with the number of exceedances to the EU legal limit value (Exc.), as well as the number of exceedances to the EU legal limit value with inhabitants allocated to those grid cells (Exc. Inhabit.), the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit (Inhabit.), and the corresponding % of population (Pop.).

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	8.6	82.7	21.7	302	214	36837	3.40%
BAU 2025	7.2	52.2	18.1	14	3	124	0.01%
BAU 2035	6.8	47.2	17.4	6	0	0	0.00%
BAU 2050	7.0	49.8	17.8	10	2	21	0.00%

The reductions of PM emissions in the BAU scenario will also lead to reductions of the PM concentrations. Figure 3-52 presents the PM_{10} annual averaged concentrations considering the impacts of BAU scenario in 2025 and 2050. The maximum annual averaged PM_{10} concentrations will be equal to 24.8 $\mu g.m^{-3}$ in 2025 and to 23.4 $\mu g.m^{-3}$ in 2050, corresponding to an overall reduction of the maximum concentration of 29.8% and 30.5%, when compared to the baseline.

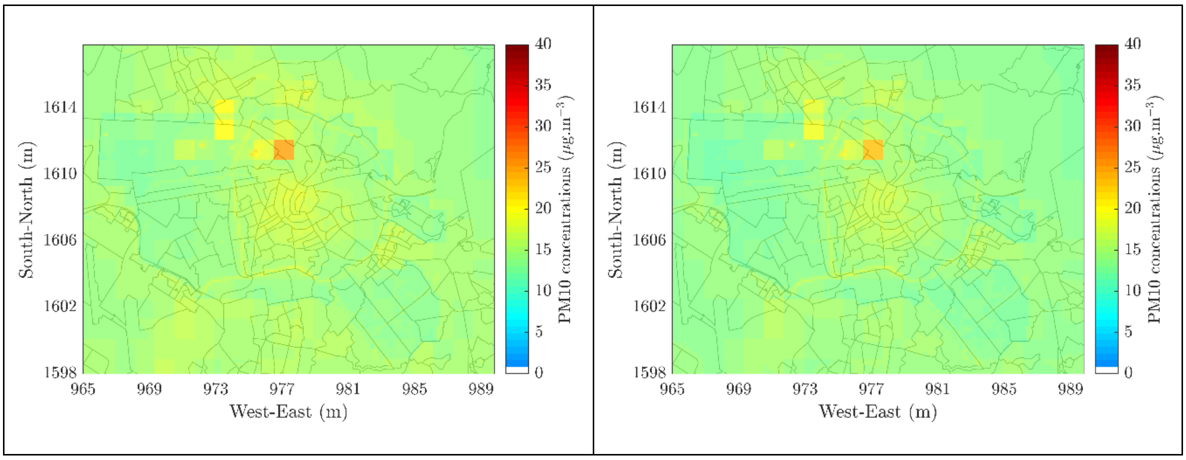


Figure 3-52: PM10 annual average concentrations in the BAU scenario a) in 2025 and b) in 2050.

Figure 3-53 presents the differences of the PM_{10} concentrations between the baseline year and the BAU scenarios in 2025 and 2050. The BAU scenario will lead to a maximum reduction of 7.4 µg.m^{-3} of the PM_{10} concentrations in 2025, corresponding to a reduction of 29.8%, while the spatial average over the entire the domain will reduce 0.9 µg.m^{-3} of PM_{10} concentrations, which corresponds to a reduction of 5.3%. In 2050 the BAU scenario will lead to a maximum reduction of the PM10 concentrations of 7.5 µg.m^{-3} which corresponds to a reduction of 30.5%, while the average over the entire domain will reduce 1.7 µg.m^{-3} (10.6%).

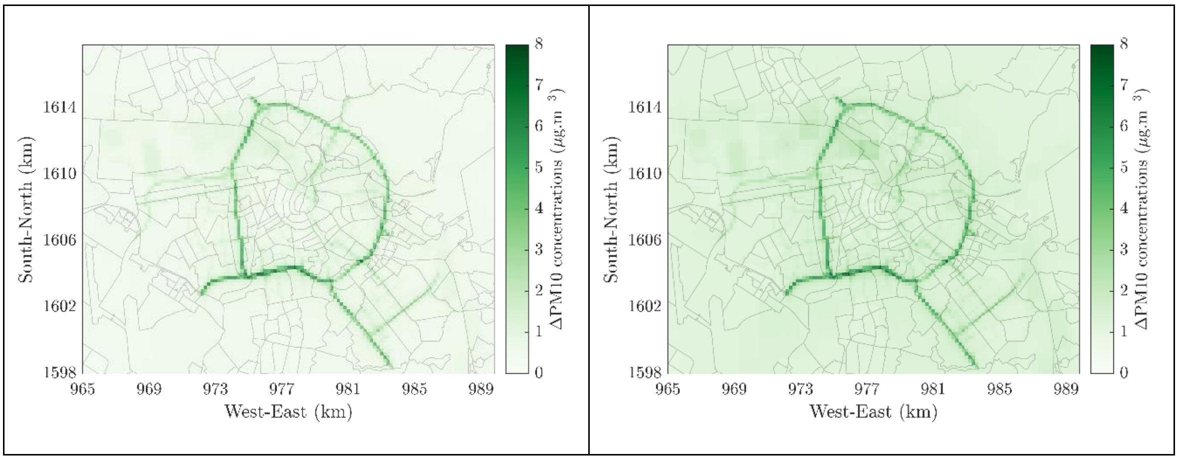


Figure 3-53: Differences of the PM_{10} annual averaged concentrations in the BAU scenario a) in 2025 and b) in 2050.

Table 3-16 summarizes the overall impacts of BAU scenarios on PM10 concentrations and population exposure to those concentrations. The population within the urban area of Amsterdam potentially exposed to PM10 concentrations considering the WHO guideline values will diminish from 1.8% in the baseline year to 0.1% in 2050 with the implementation of the BAU scenarios. The simulation results indicate compliance with the EU limits already in 2015.

Table 3-16: Summary of results including the annual averages of PM_{10} concentrations, together with the number of exceedances to the WHO guideline values, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	13.3	26.4	15.8	241	179	19991	1.84%
BAU 2025	12.8	24.8	15.0	66	37	1782	0.16%
BAU 2035	12.4	24.0	14.5	39	35	1136	0.10%
BAU 2050	12.0	23.4	14.1	39	35	1136	0.10%

Figure 3-54 shows the $PM_{2.5}$ annual averaged concentrations considering the impacts of BAU scenario in 2025 and 2050. The maximum annual averaged $PM_{2.5}$ concentrations will be equal to 16.7 µg.m^{-3} in 2025 and to 16.0 µg.m^{-3} in 2050, corresponding to an overall reduction of the maximum concentration of 31.8% and 32.2%, when compared to the baseline.

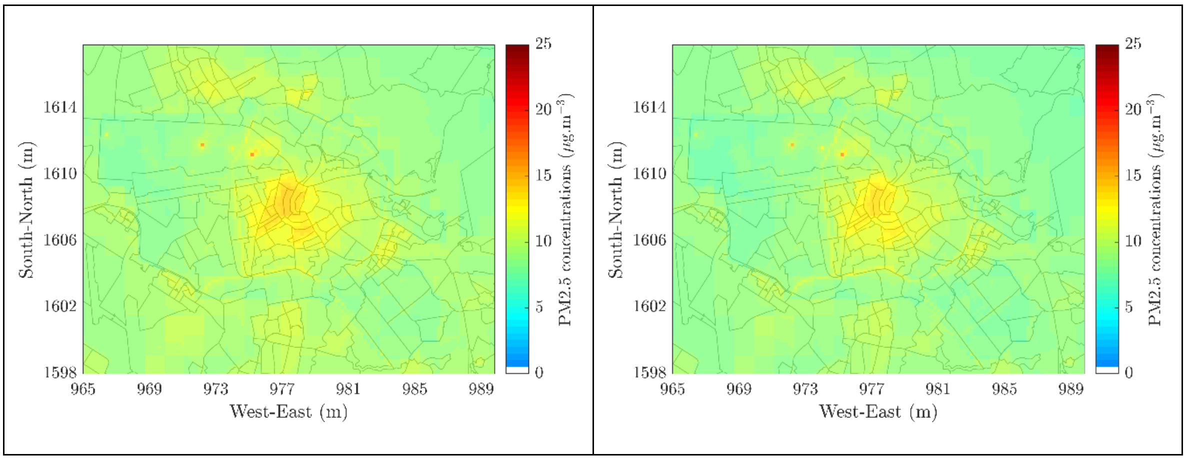


Figure 3-54: $PM_{2.5}$ annual average concentrations in the BAU scenario a) in 2025 and b) in 2050.

Figure 3-55 presents the differences of the $PM_{2.5}$ concentrations between the baseline year and the BAU scenarios in 2025 and 2050. The BAU scenario will lead to a maximum reduction of 5.3 µg.m^{-3} of the $PM_{2.5}$ concentrations in 2025, corresponding to a reduction of 31.8%, while the spatial average over the entire the domain will reduce 0.4 µg.m^{-3} of $PM_{2.5}$ concentrations, which corresponds to a reduction of 4.2%. In 2050 the BAU scenario will lead to a maximum reduction of the $PM_{2.5}$ concentrations of 5.4 µg.m^{-3} which corresponds to a reduction of 32.2%, while the average over the entire domain will reduce 0.9 µg.m^{-3} (9.4%).

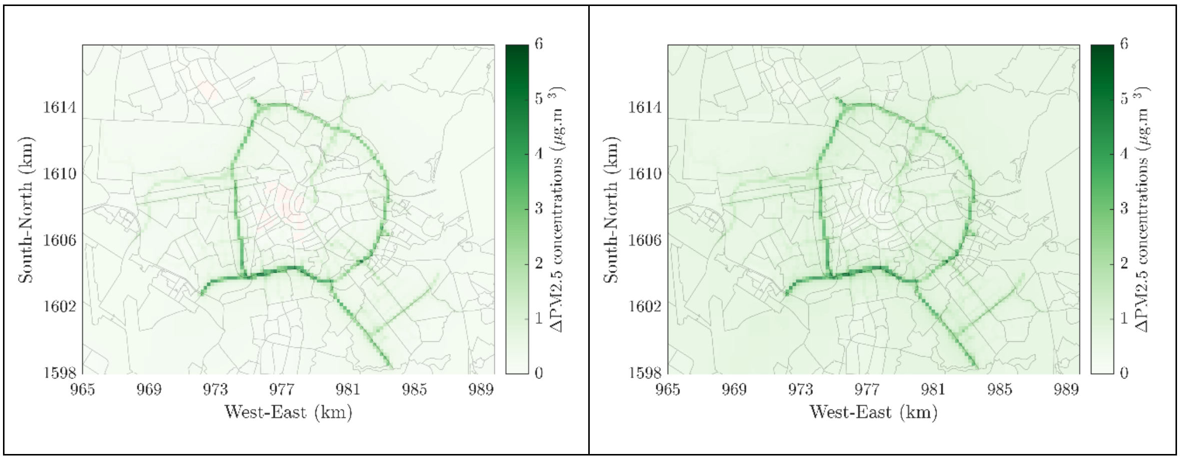


Figure 3-55: Differences of the $PM_{2.5}$ annual averaged concentrations in the BAU scenario a) in 2025 and b) in 2050.

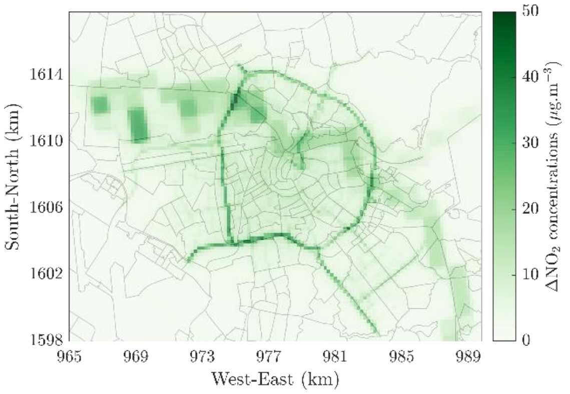
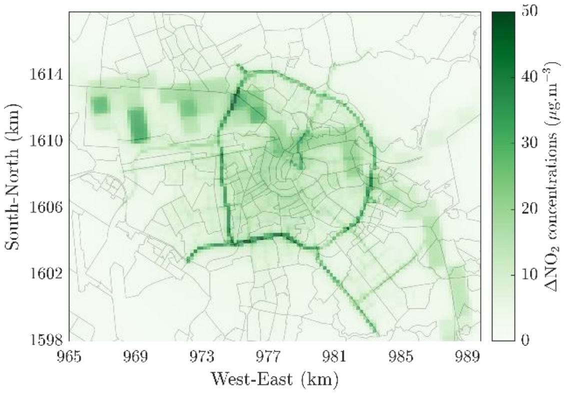
Table 3-17 summarizes the overall impacts of BAU scenarios on $PM_{2.5}$ concentrations and population exposure to those concentrations. The population within the urban area of Amsterdam potentially exposed to $PM_{2.5}$ concentrations considering the WHO guideline values will diminish from 71.2% in the baseline year to 46.6% in 2050 with the implementation of the BAU scenarios. The simulation results indicate compliance with the EU limits already in 2015.

Table 3-17: Summary of results including the annual averages of $PM_{2.5}$ concentrations, together with the number of exceedances to the WHO guideline values, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	8.0	17.4	9.9	4251	3609	772276	71.2%
BAU 2025	7.7	16.7	9.4	2553	2261	635411	58.6%
BAU 2035	7.3	15.9	9.1	1700	1616	544358	50.2%
BAU 2050	7.3	16.0	8.9	1465	1394	505121	46.6%

3.5.5.2 SDW scenarios

The two proposed scenarios from the SDW – low and high ambition scenarios – will distinctly impact the air quality over the urban area of Amsterdam. Figure 3-56 shows the differences of the NO_2 annual concentrations with the implementation of the SDW scenarios compared to the baseline year. The maximum NO_2 concentrations will range from 37.2 µg.m^{-3} to 34.2 µg.m^{-3} between 2025 and 2050 with the implementation of the low ambition scenario, while with the implementation of the high ambition scenario the maximum NO_2 concentrations will range from 33.2 µg.m^{-3} to 28.7 µg.m^{-3}. Figure 3-56 also points out that the maximum reductions of the NO_2 concentrations are simulated over the city centre and over the main roads and motorways, denoting a relevant link between the reduction of NO_x emissions in the transport sector and the reductions of NO_2 concentrations achieved with the implementation of those scenarios.

	2025	2050
Low ambition scenario		

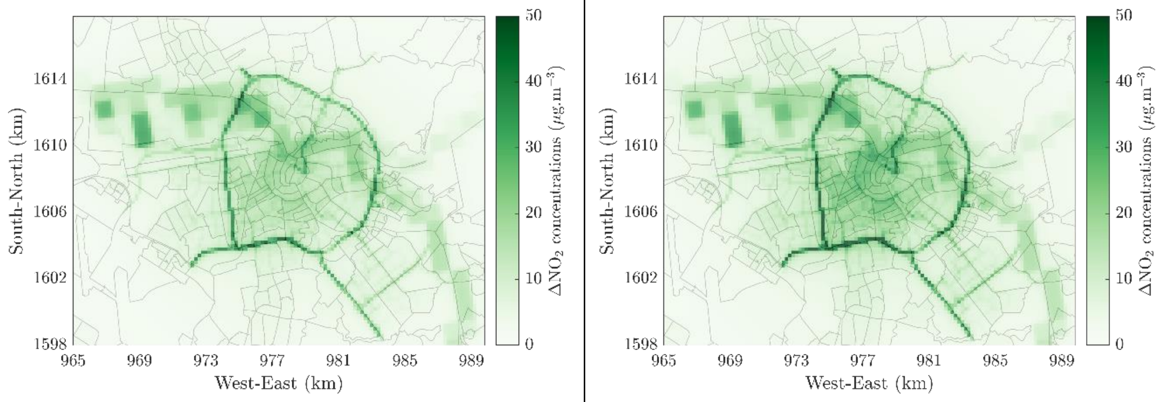
High ambition scenario		

Figure 3-56: Differences of the NO_2 annual averaged concentrations in the SDW scenarios a) in 2025 and b) in 2050.

Table 3-18 presents an overview of the overall impact of the SDW scenarios on the NO_2 concentrations, indicating that independently on the level of ambition of the scenarios all of them will lead to no risk of population exposure to those concentrations already in 2025, in comparison with 3.4% of the population within Amsterdam computational domain, which are potentially exposed to NO_2 concentrations above the EU annual legal limit value.

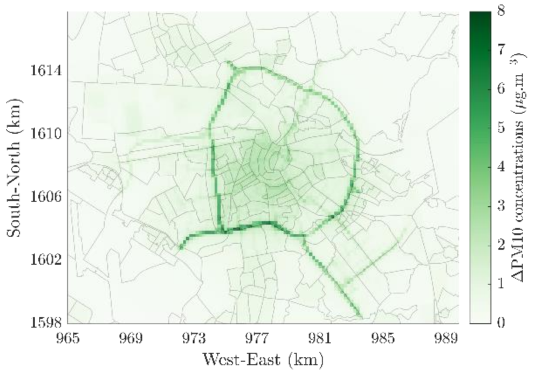
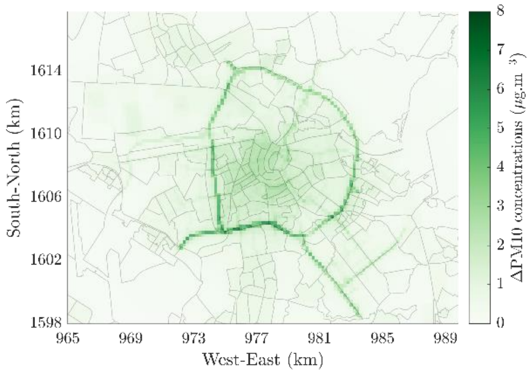
The low ambition scenario will lead to an overall reduction of the NO_2 concentrations of 30.4% over the entire computational domain in 2025, and of 35.3% in 2050. While the high ambition scenario will lead to an averaged reduction over the entire area of the NO_2 concentrations of 36.4% in 2025, and of 44.1% in 2050.

Table 3-18: Summary of the SDW impacts including the annual averages of NO_2 concentrations, together with the number of exceedances to the EU legal limit value, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	8.6	82.7	21.7	302	214	36837	3.4
Low 2025	4.8	37.2	14.6	0	0	0	0%
Low 2035	4.5	32.7	13.7	0	0	0	0%

Low 2050	4.5	34.2	13.5	0	0	0	0%
High 2025	4.4	33.2	13.3	0	0	0	0%
High 2035	4.0	32.5	12.2	0	0	0	0%
High 2050	3.7	28.7	11.5	0	0	0	0%

The overall measures impacting the transport sector will also promote important reductions of PM_{10} concentrations over the city centre and over the ring road of Amsterdam as indicated in Figure 3-57. The differences contour maps of the annual PM10 concentrations point out a maximum concentration ranging from 25.1 µg.m^{-3} to 25.0 µg.m^{-3} between 2025 and 2050 with the implementation of the low ambition scenario, while the high ambition scenario will lead to a maximum concentration of PM10 concentrations from 25.0 µg.m^{-3} in 2050.

<table>
<tr><td></td><td>2025</td><td>2050</td></tr>
<tr><td>Low ambition scenario</td><td>
</td><td>
</td></tr>
</table>

High ambition scenario

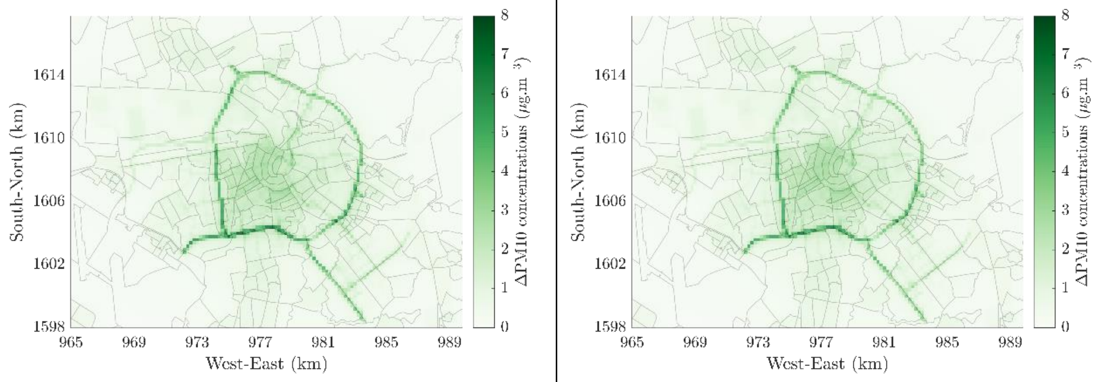


Figure 3-57: Differences of the PM_{10} annual averaged concentrations in the SDW scenario a) in 2025 and b) in 2050.

Table 3-19 presents an overview of the overall impact of the SDW scenarios on the PM_{10} concentrations. The low ambition scenario will lead to an overall reduction of 5.1% over the entire computational domain in 2025, and of 5.0% in 2050. While the high ambition scenario will lead to the same reduction of 5.2% in 2025 and in 2050. The results indicate no risk of population exposure to PM_{10} concentrations to the EU annual limit value already in the baseline year. However, there are some risks of population exposure over the urban area of Amsterdam to the stricter limits recommended by the WHO in the baseline year and even with the high ambition scenario.

Table 3-19: Summary of results including the annual averages of PM_{10} concentrations, together with the number of exceedances to the WHO legal limit value, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	13.3	26.4	15.8	241	179	19991	1.84%
Low 2025	13.0	25.0	15.0	76	41	1198	0.11%

Low 2035	12.9	25.0	15.0	76	41	1198	0.11%
Low 2050	13.0	25.1	15.0	76	41	1198	0.11%
High 2025	12.9	25.0	15.0	76	41	1198	0.11%
High 2035	12.9	25.0	14.9	76	41	1198	0.11%
High 2050	12.9	25.0	15.0	76	41	1198	0.11%

Figure 3-58 shows the contour maps with the differences between the proposed scenarios and the baseline of the annual $PM_{2.5}$ concentrations. These contour maps point out a maximum concentration ranging from 16.2 $\mu g.m^{-3}$ to 15.5 $\mu g.m^{-3}$ between 2025 and 2050 with the implementation of both the low and high ambition scenarios.

	2025	2050

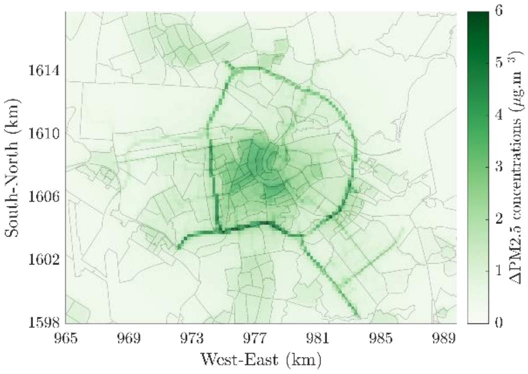
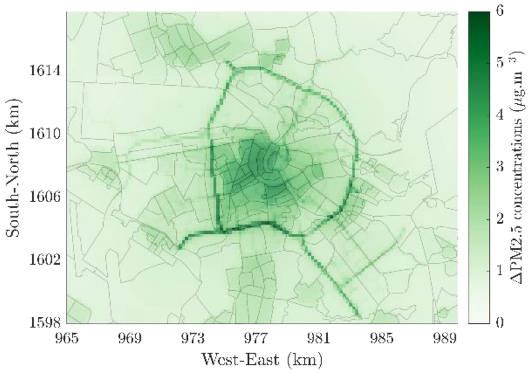
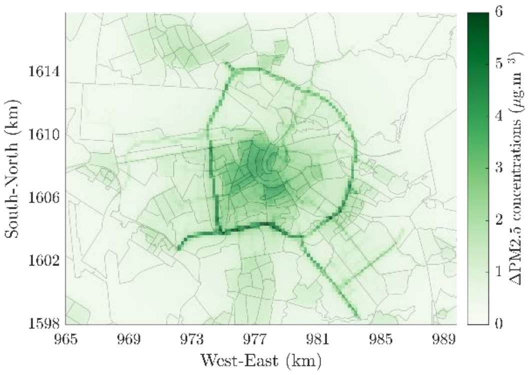
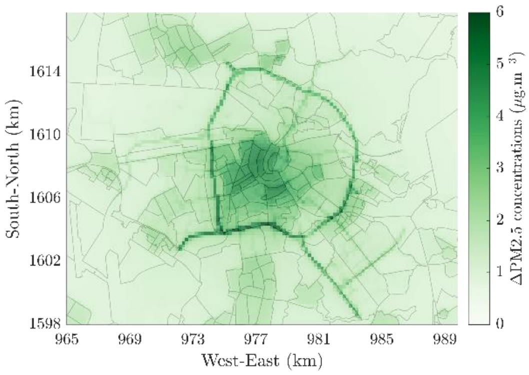
<table>
<tr><td>Low ambition scenario</td><td></td><td></td></tr>
<tr><td>High ambition scenario</td><td></td><td></td></tr>
</table>

Figure 3-58: Differences of the $PM_{2.5}$ annual averaged concentrations in the FUPS scenario a) in 2025 and b) in 2050.

Table 3-20 presents an overview of the overall impact of the SDW scenarios on the $PM_{2.5}$ concentrations. The low ambition scenario will lead to an overall reduction of 10.2% over the entire computational domain in 2025, and of 15.6% in 2050. While the high ambition scenario will lead to a reduction of 10.5% in 2025, and of 16.0% in 2050. The results indicate no risk of population exposure to $PM_{2.5}$ concentrations to the EU annual limit value already in the baseline year. However, some risks of population exposure may still occur over the urban area of Amsterdam to the stricter limits recommended by the WHO with the proposed scenario from the SDW.

Table 3-20: Summary of results including the annual averages of $PM_{2.5}$ concentrations, together with the number of exceedances to the WHO guideline value, the number of

inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	8.0	17.4	9.9	4251	3609	772276	71.2%
Low 2025	7.5	16.2	8.8	180	76	15830	1.46%
Low 2035	7.3	15.7	8.5	86	26	1588	0.15%
Low 2050	7.0	15.5	8.3	52	16	1291	0.12%
High 2025	7.5	16.2	8.8	158	55	8798	0.81%
High 2035	7.2	15.7	8.5	71	23	1372	0.13%
High 2050	7.0	15.5	8.2	46	13	1198	0.11%

3.5.5.3 FUPS scenarios

The substantial reductions of NO_x emissions in the FUPS scenario will lead to significant reductions of the NO_2 concentrations. Figure 3-59 presents the NO_2 annual averaged concentrations considering the impacts of FUPS scenario in 2025 and 2050. The maximum annual averaged NO2 concentrations will be equal to 48.0 $\mu g.m^{-3}$ in 2025 and to 38.8 $\mu g.m^{-3}$ in 2050, corresponding to an overall reduction of the maximum concentration of 61.7% and 80.2%, when compared to the baseline.

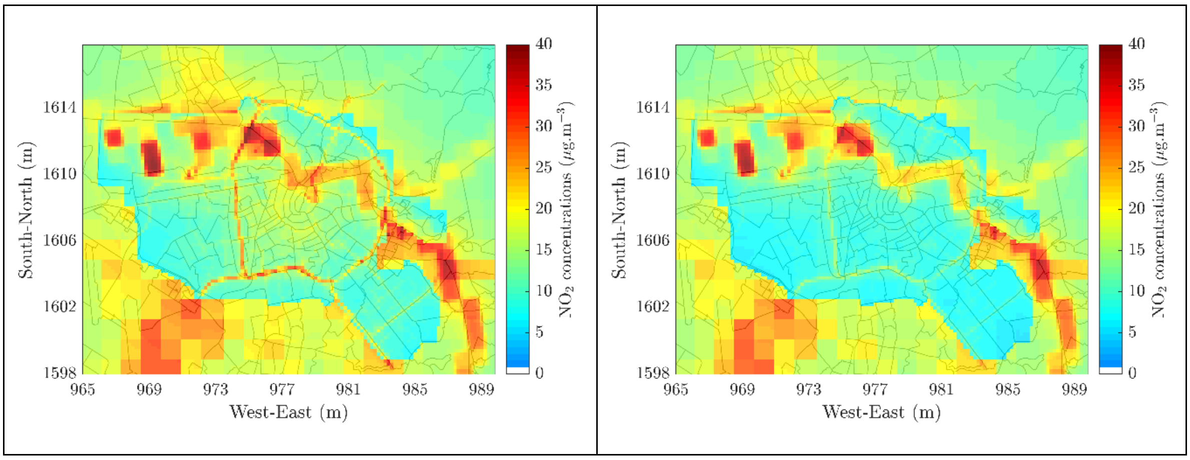


Figure 3-59: NO_2 annual average concentrations in the FUPS scenario a) in 2025 and b) in 2050.

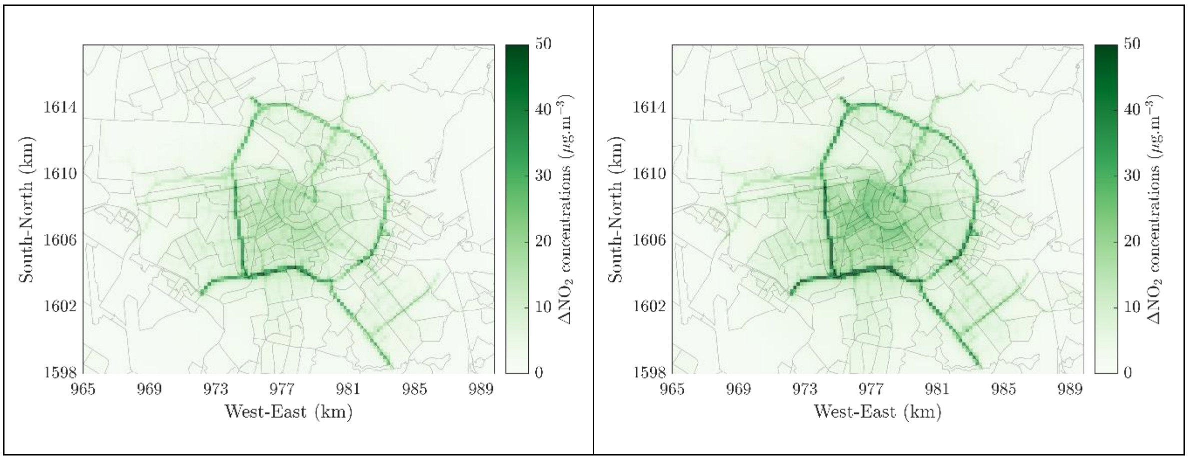


Figure 3-60: Differences of the NO_2 annual averaged concentrations in the FUPS scenario a) in 2025 and b) in 2050.

Table 3-21 shows the summary of the overall impact of the FUPS scenario on the NO_2 concentrations, indicating no risk of population exposure to those concentrations already in 2025. The FUPS scenario will lead to an overall reduction of 21.4% over the entire computational domain in 2025, and of 29.3% in 2050.

Table 3-21: Summary of the FUPS impacts including the annual averages of NO_2 concentrations, together with the number of exceedances to the EU legal limit value, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	8.6	82.7	21.7	302	214	36837	3.4%
FUPS 2025	6.4	48.0	16.7	5	0	0	0
FUPS 2035	5.7	46.9	15.7	5	0	0	0
FUPS 2050	5.3	38.8	14.9	0	0	0	0

Figure 3-61 and Figure 3-62 present the impact of the FUPS scenario on PM_{10} concentrations. The contour maps with the differences of the annual PM_{10} concentrations (Figure 3-61) point out a maximum concentration ranging from 24.3 µg.m^{-3} to 22.8 µg.m^{-3} between 2025 and 2050 with the implementation of the FUPS scenario.

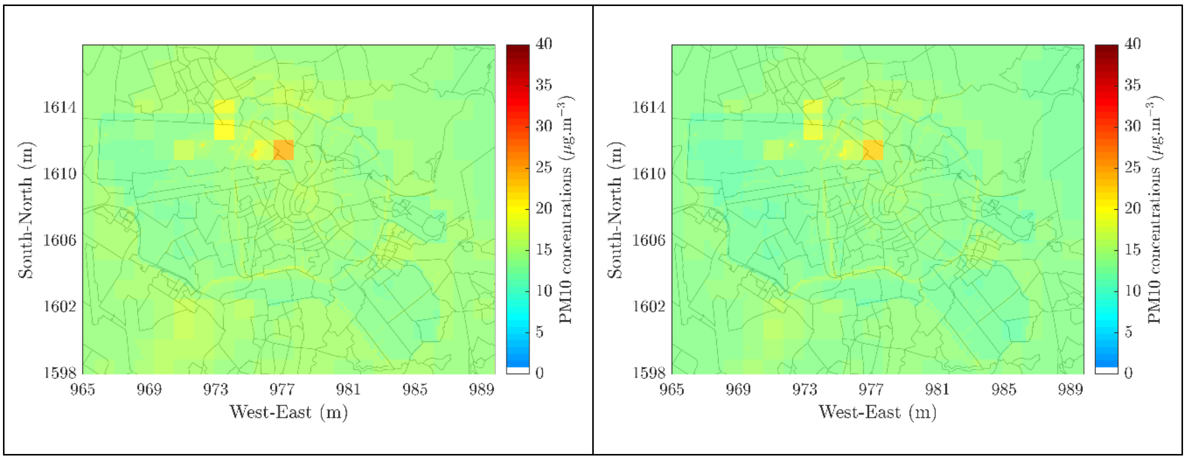


Figure 3-61: PM10 annual average concentrations in the FUPS scenario a) in 2025 and b) in 2050.

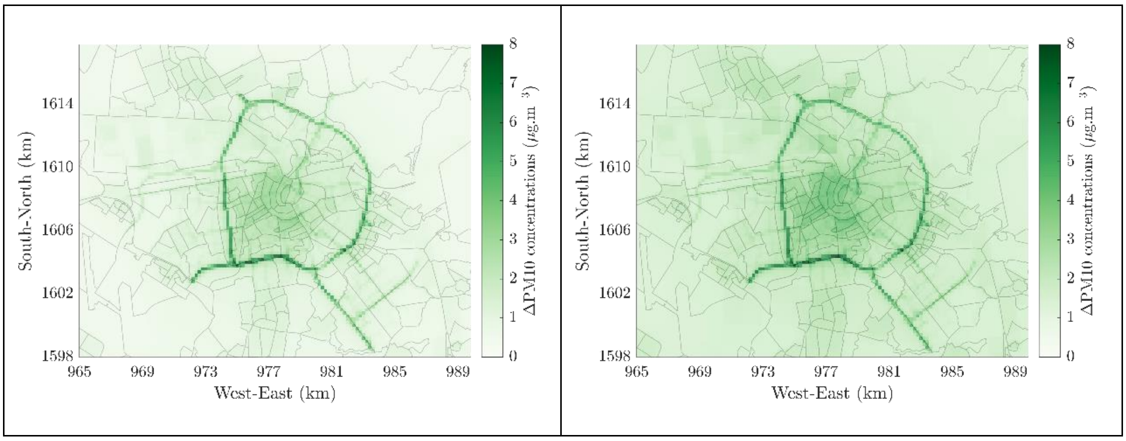


Figure 3-62: Differences of the PM_{10} annual averaged concentrations in the FUPS scenario a) in 2025 and b) in 2050.

Table 3-22 summarizes the overall impact of the FUPS scenario on the PM_{10} concentrations. This scenario will lead to an overall reduction of 8.0% over the entire computational domain in 2025, and of 13.5% in 2050. The results indicate no risk of population exposure to PM_{10} concentrations above the EU annual limit value already in 2025. However, there will still be some exceedances to the stricter limits recommended by the WHO with the FUPS in 2050.

Table 3-22: Summary of results including the annual averages of PM_{10} concentrations, together with the number of exceedances to the WHO guideline value, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	13.3	26.4	15.8	241	179	19991	1.84%
FUPS 2025	12.6	24.3	14.5	41	35	1136	0.10%
FUPS 2035	12.2	23.5	14.1	39	35	1136	0.10%
FUPS 2050	11.8	22.8	13.6	38	35	1136	0.10%

Figure 3-63 shows the $PM_{2.5}$ annual averaged concentrations considering the impacts of FUPS scenario in 2025 and 2050. The maximum annual averaged $PM_{2.5}$ concentrations will be equal to 16.2 µg.m^{-3} in 2025 and to 15.5 µg.m^{-3} in 2050, corresponding to an overall reduction of the maximum concentration of 38.3% and 39.4%, when compared to the baseline.

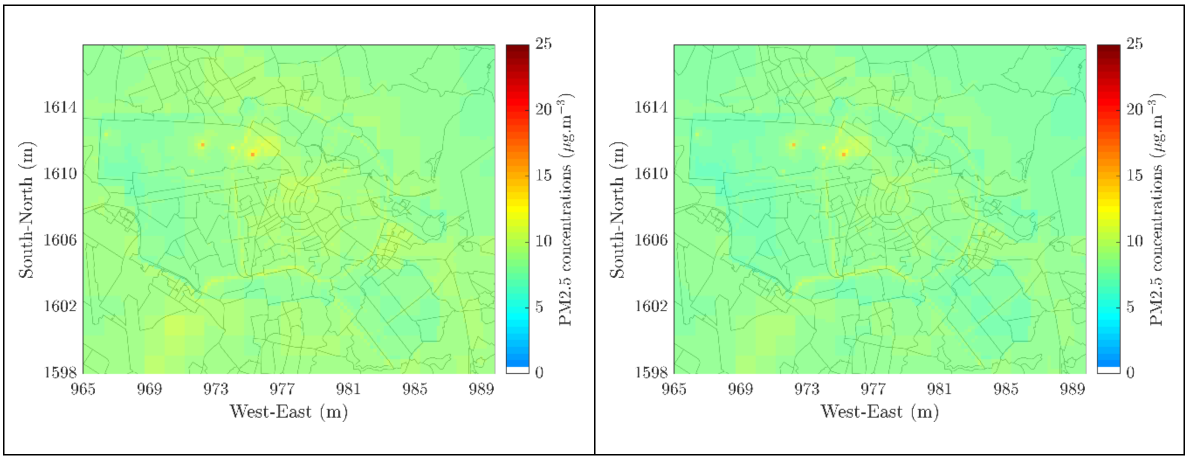


Figure 3-63: PM2.5 annual average concentrations in the FUPS scenario a) in 2025 and b) in 2050.

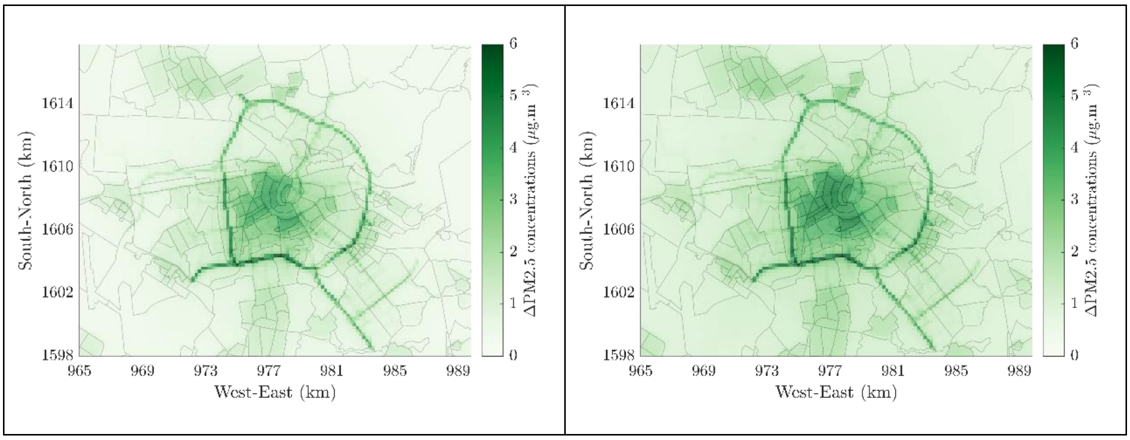


Figure 3-64: Differences of the $PM_{2.5}$ annual averaged concentrations in the FUPS scenario a) in 2025 and b) in 2050.

Table 3-23 presents the overall impact of the FUPS scenario on the $PM_{2.5}$ concentrations. The FUPS scenario will lead to an overall reduction of 10.5% over the entire computational domain in 2025, and of 16.0% in 2050. The results indicate no risk of population exposure to $PM_{2.5}$ concentrations above the EU annual limit value already in the baseline year. However, there are still some residual risks of population exposure over the urban area of Amsterdam to the stricter limits recommended by the WHO even with the FUPS scenario, with 0.8% of the population within the urban area of Amsterdam potentially exposed to those levels in 2025, and reducing to 0.1% of the population in 2050.

Table 3-23: Summary of results including the annual averages of $PM_{2.5}$ concentrations, together with the number of exceedances to the WHO legal limit value, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.

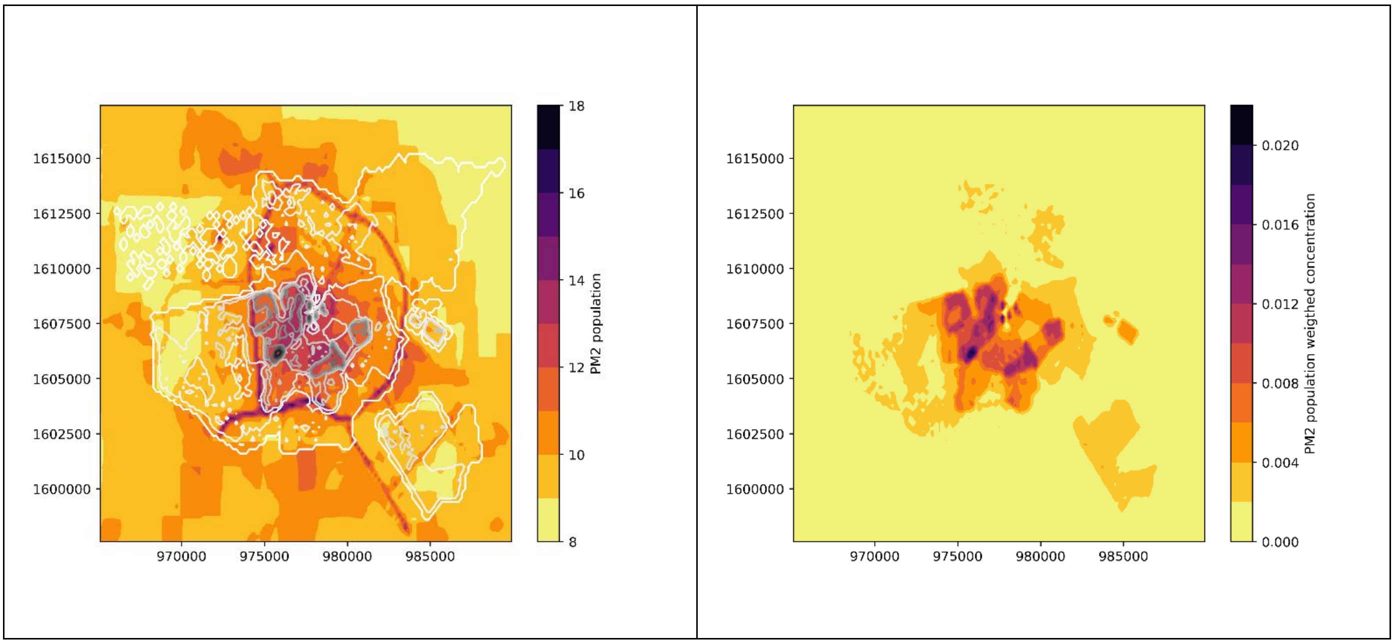
	Min.	Max.	Aver.	Exc.	Exc. Inhabit.	Inhabit.	Pop.
2015	8.0	17.4	9.9	4251	3609	772276	71.2%
FUPS 2025	7.5	16.2	8.8	158	55	8798	0.8%
FUPS 2035	7.1	15.4	8.4	29	11	1187	0.1%
FUPS 2050	7.0	15.5	8.2	46	13	1198	0.1%

3.6 Health impacts

3.6.1 Baseline

The health impacts related to exposure to NO_2, PM_{10}, and $PM_{2.5}$ were calculated based on the baseline emissions scenario. The figures below show maps to illustrate the areas of highest concern regarding human exposure to the individual pollutants. The left panels show the concentration maps overlaid with the population density distribution within the study area. The concentration levels are shown in a colour scale from yellow to dark purple (the same concentrations as presented before) and population density with contours from light to dark grey (no colour bar), the darker the grey, the denser the population is. On the right panels, the concentration weighted population maps indicating where the population is mostly affected by the air concentration levels in Amsterdam, for individual pollutants. The population weighted concentration maps indicate that exposure is the highest closer to the city centre.

The assessment includes the estimation of premature deaths and year potentially lost due to air pollution exposure. The results for the baseline scenario indicate there has been 444, 433, and 557 premature deaths, and 4639, 4526, and 5813 years of life potentially lost attributed to $PM_{2.5}$, PM_{10}, and NO_2 pollution levels in Amsterdam in 2015, respectively.



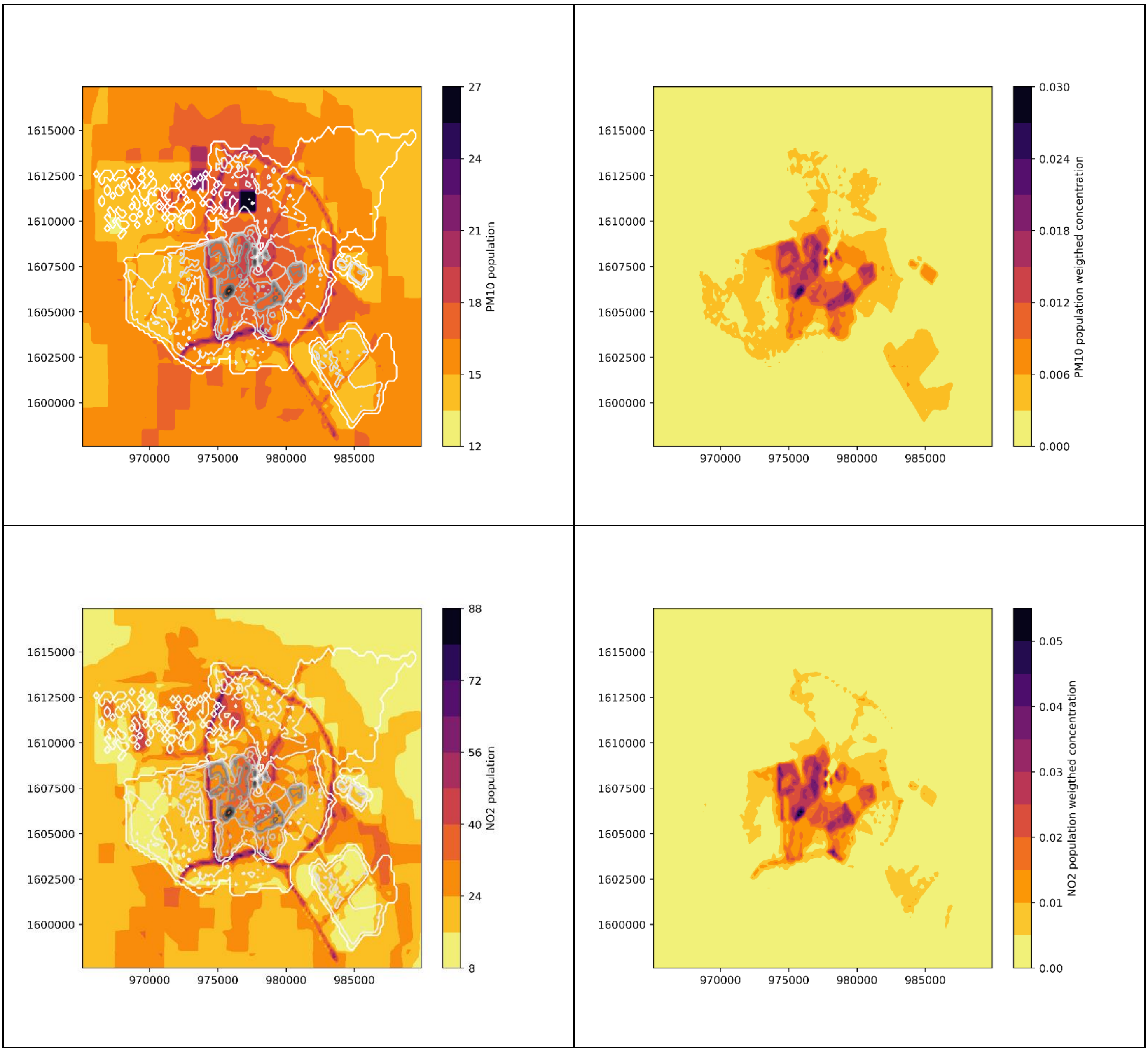


Figure 3-65: Concentration maps overlaid with population density contours (left), population weighted concentration maps (right) for $PM_{2.5}$ (top), PM_{10} (centre), and NO_2 (bottom) based on the baseline emission scenario (2015), for Amsterdam.

3.6.2 BAU and UPS

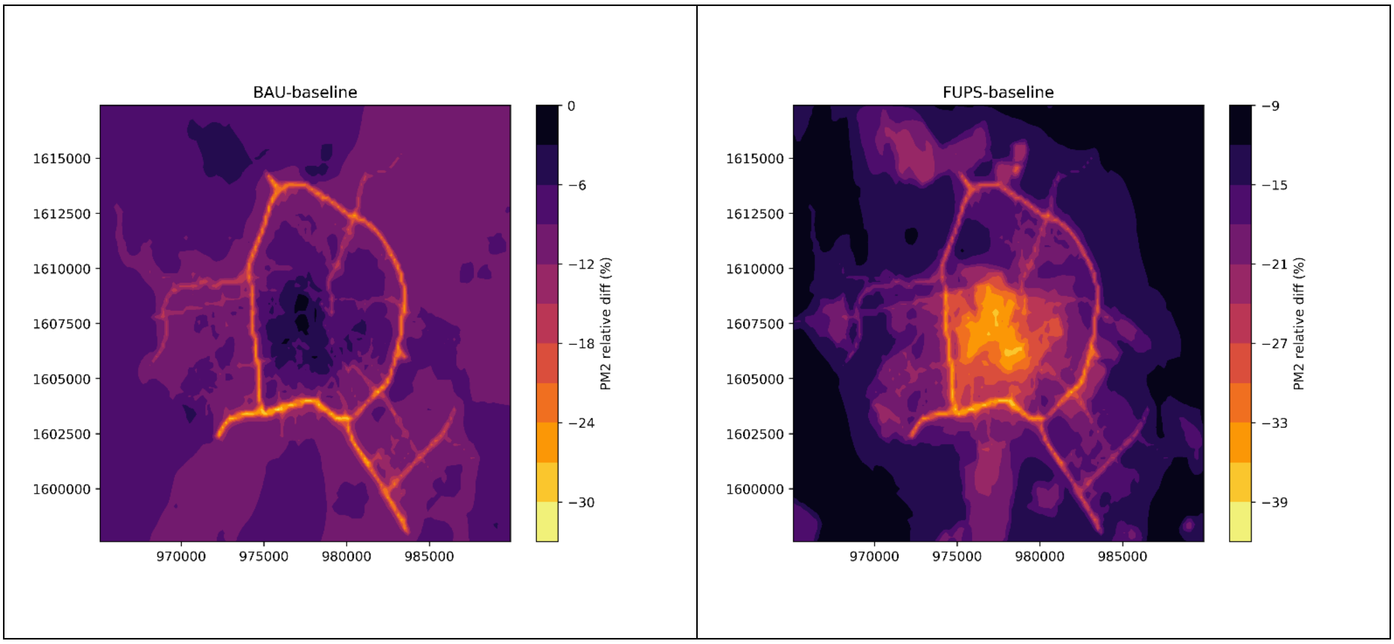
The analysis of the health impact benefits of implementing emission control measures can be quantified by benchmarking the health indicators estimated based on the BAU and UPS emission scenarios. The results in relative terms (%) are described in the table below. Note that independently of the indicators, the impact is the same since the indicators are related.

Table 3-24: Health impact benefits of implementing emission control measures in Amsterdam (%).

	PM2.5			PM10			NO2		
	2025	2035	2050	2025	2035	2050	2025	2035	2050
BAU	-4	-7	-8	-6	-8	-10	-42	-51	-46
UPS	-18	-22	-23	-12	-15	-17	-63	-79	-84

The results show that both future emission scenarios will contribute to the improvement on human health, reducing the health impact indicators for all air pollutants. UPS scenario seems to be the most efficient on reducing the numbers on premature deaths and years of life lost. According to these results, both future scenarios will be more efficient on reducing the impact of NO_2 on human health and less on PM_{10} for UPS, and $PM_{2.5}$ for BAU; the reduction on the impact will be larger at later years, with NO_2 showing a high rate of reduction already in 2015.

The mapping of the air quality impact benefits of implementing emission control measures is a good proxy to support the analysis on the impact of the emission scenario. The maps for the year 2050 are shown in Figure 3-66 shows the comparison between future and current emission scenario. Note that the maps have different scales and they show the reduction, thus the higher the negative values, the larger the reduction is. For particulate matter, the figures show a similar reduction in concentration levels reduction but with considerably different magnitude in the city centre, with larger benefits on health when the assessment is based on the UPS emission scenario. However, the PM2.5 emission reduction measures are more effective on reducing the impact on human health than PM_{10}. NO_2 concentration levels have a larger reduction across the city, impacting to a higher degree the people living in Amsterdam, especially in the city centre.



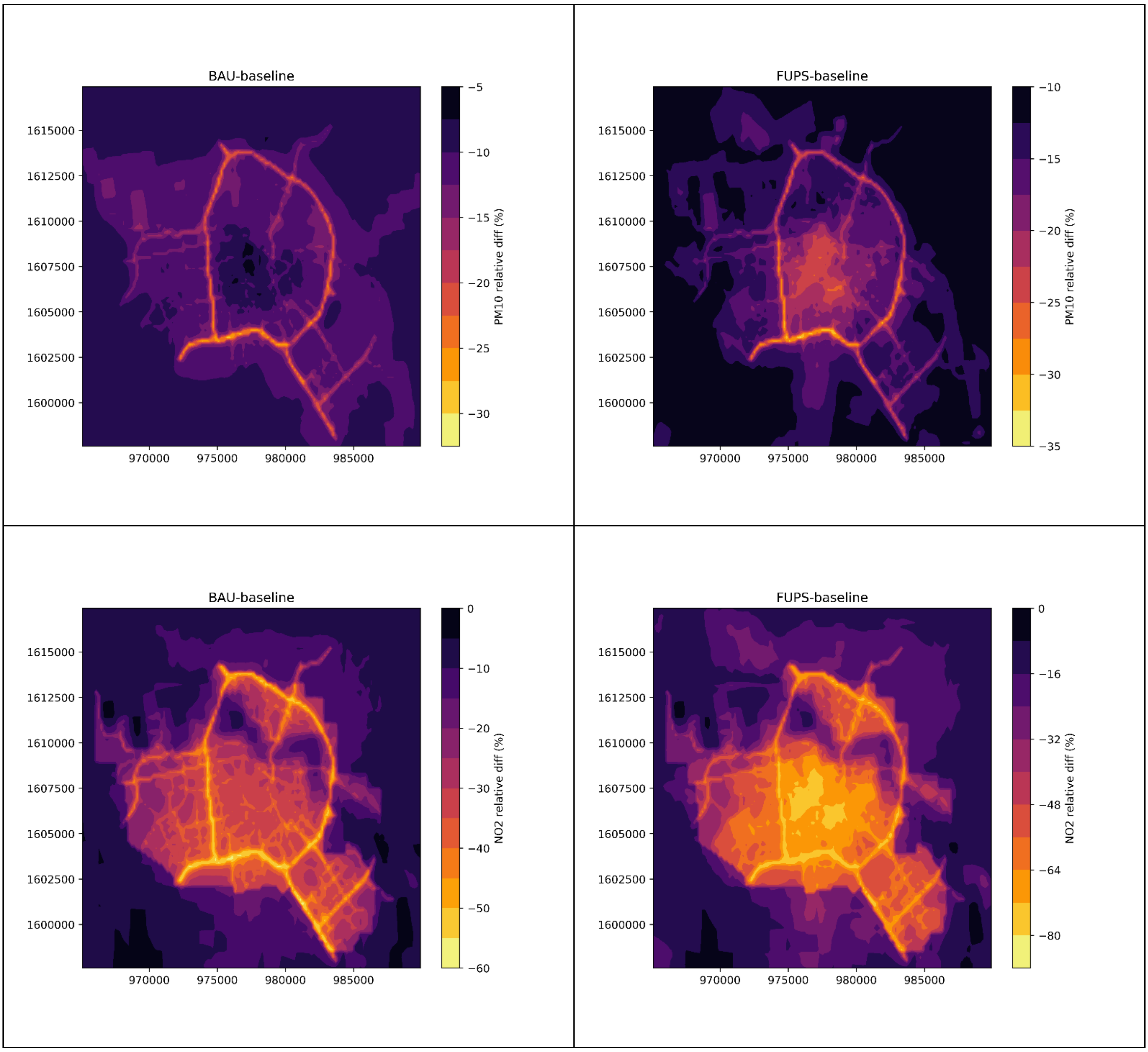


Figure 3-66: Air quality impact benefits of implementing emission control measures in 2050 for Amsterdam, BAU vs baseline on the left and UPS vs baseline on the right for $PM_{2.5}$ (top), PM_{10} (centre), and NO_2 (bottom).

4 Conclusions

This report presents the overall results on the impact assessment approach to consider the impacts on emissions (air pollution and carbon), air quality concentrations, exposure and health of the ClairCity baseline and future scenarios for Amsterdam. The baseline and all the scenarios are quantified as input to the ClairCity Policy Report to be delivered at the end of the process. The ClairCity framework contributes to assess air pollution through the source apportionment of air pollutant emissions and concentrations, as well as, carbon emissions, not only by technology, but by citizens' behaviour.

The impact assessment data illustrating the work undertaken can be found on the ClairCity Data Portal, as follow: https://claircitydata.cbs.nl/dataset/d5-5a-assessment-of-impacts-amsterdam. Access can be arranged upon request. Furthermore, it was created a ClairCity community on Zenodo.org, where the full dataset was uploaded from the ClairCity Data Portal to Zenodo. The comunity is available on the link: https://zenodo.org/communities/claircity.