



ClairCity: Citizen-led air pollution reduction in cities

# **Deliverable 5.7: City Impact Analysis Report - Sosnowiec**

March 2020

## Document Details

|                              |   |
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| <b>Authors</b>               | Vera Rodrigues, Myriam Lopes, Sandra Rafael, Sílvia Coelho, Kevin Oliveira (UAVR)<br>Kris Vanherle, Peter Papics (TML)<br>Iason Daifas (PBL)<br>Angreine Kewo (DTU)<br>Carlo Trozzi, Enzo Piscitello (Techne Consulting)<br>Joana Soares (NILU) |
| <b>Contact</b>               | Kris Vanherle, TML ( <a href="mailto:kris.vanherle@tmleuven.be">kris.vanherle@tmleuven.be</a> )<br>Vera Rodrigues, UAVR ( <a href="mailto:vera.rodrigues@ua.pt">vera.rodrigues@ua.pt</a> )  |
| <b>Creation Date</b>         | 08/05/2019  |
| <b>Date of Last Revision</b> | 25/05/2020  |
| <b>Description</b>           | 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 Sosnowiec  |

## Version History

| 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 TECHNE, DTU, PBL                  |
| V2.1    | Kris Vanherle  | 18/02/2020 | Updated inputs Aveiro and updated as stand-alone document |
| V2.2    | Vera Rodrigues | 25/05/2020 | Completed for Sosnowiec                                   |

## Contributions and Acknowledgements

The authors would like to thank the following people for their important contributions used in the preparation of this final document.

|                                  |  |
|----------------------------------|--|
| <b>Quality Assurance</b>         | Enda Hayes (UWE)                             |
| <b>Native Language Check</b>     | Enda Hayes (UWE)                             |
| <b>Project internal comments</b> | Enda Hayes (UWE)<br>Irati Artola (Trinomics) |

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In this document, we elaborate into the methodology and results of the modelling for the Sosnowiec 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/d5-5c-assessment-of-impacts-sosnowiec>. 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 community is available on the link: <https://zenodo.org/communities/claircity>.

# 1 Methodological particularities

## 1.1 Transport: activity data

Detailed transport activity data was lacking for the Sosnowiec area and/or a transport model estimating transport volumes was unavailable. As such, we use a different approach to estimate the transport volumes in following steps:

- Road network generation
- Production & Attraction for demand generation
- Mode choice
- Assignment
- Post-processing

### Road network generation

We use OpenStreetMaps<sup>1</sup> to generate a noded network.

### Demand generation

Production factors define the generation of demand for a zone. The factors feed into a function that describes the total amount of trips being generated in a zone. In most cases the trip generation function is a multi-variable regression model based on socio-economic variables such as population density, age distribution, income levels, etc...

The attractiveness of a zone as a trip end is mostly defined by infrastructural/spatial characteristics. The total amount of trips that dissipate in a zone is also described by multi-variable regression model based on number of available workplaces, schools, quantity and quality of shopping locations, availability of leisure activities, etc...

We use the land-use data from the integrated model for demand generation.

### Mode choice

We rely on local data as well as EU-data from the TRANSPHORM city database for the modal shares (walk/bike/car/PT/freight)

### Assignment

The main idea of assigning demand to the network is based on equilibrium principles. These state that drivers will keep on looking for shorter routes until all drivers unilateral perceive the least resistance. We incorporate a first calibration, scaling the generated demand in such a way the traffic volumes on key roads matches the data. In Sosnowiec, only for a few key roads, traffic volume data could be used.

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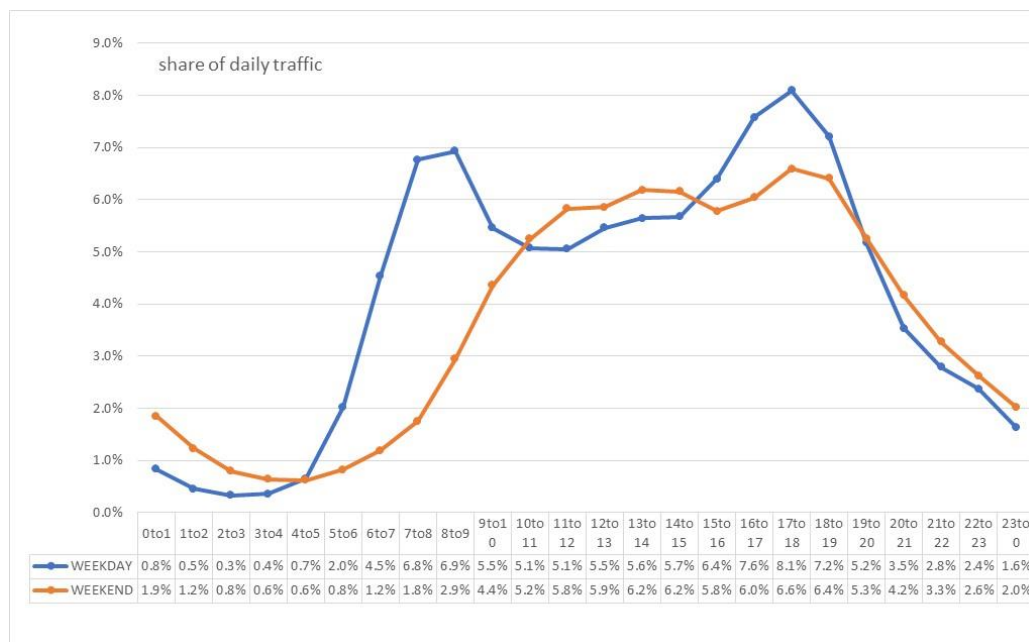
<sup>1</sup> <https://www.openstreetmap.org/#map=13/50.2741/19.1064&layers=T>

The assignment is for a full day. Capacities are adjusted accordingly. It is assumed that the maximum hourly road capacity is adjust to a full day and that this factor is a parameter to control for responsiveness of drivers with respect to busy roads. The factor is set to 10 which introduces mild responsiveness and a quick convergence of the algorithm.

### Post-processing

The initial demand generation and assignment need further refinement. This includes, for Sosnowiec: **OD corrections and local road attractiveness**: For some of the origin or destinations in the network a straightforward correction can be applied to be in line with counting data. All the highest OSM class roads that cut the cordon around the case-study area are origins and destinations in the final trip matrix. This means that a single factor per origin row or destination column can be applied to match the total sum of a row / column with observed averages volumes per day.

Finally, as volumes are estimated for daily totals, a final step is needed to distribute intensity by time of day. This is fairly trivial and can be done using various data that is specific for the local situation. In Figure 1-1, the estimates we've used, based on observed highway traffic intensity (a good proxy for all roads), making a distinction between weekday and weekend. Note that the sum over all hours is 1 for weekday, but lower for weekend, as traffic generation an assignment is assumed for a weekday with typical peak-profiles.



**Figure 1-1: Share of daily traffic by type of day, compared to a typical weekday**

The approach chosen in Sosnowiec, Ljubljana, Aveiro and Liguria is the backbone of the transport module in the generic model. For more information on the methodology, we refer to *Deliverable 5.4: Generic city model*

## 1.2 Transport: Mode choice model

Since the present time modal split in Sosnowiec and Bristol is very similar (with all modes within a few percent's margin), we used the mode choice model built for Bristol as is for Sosnowiec. In the Final Scenario and the remaining three cities we went a step further and manually calibrated the model using the ASC values to create an even better match with the current observed modal split.

## 1.3 Air quality modelling

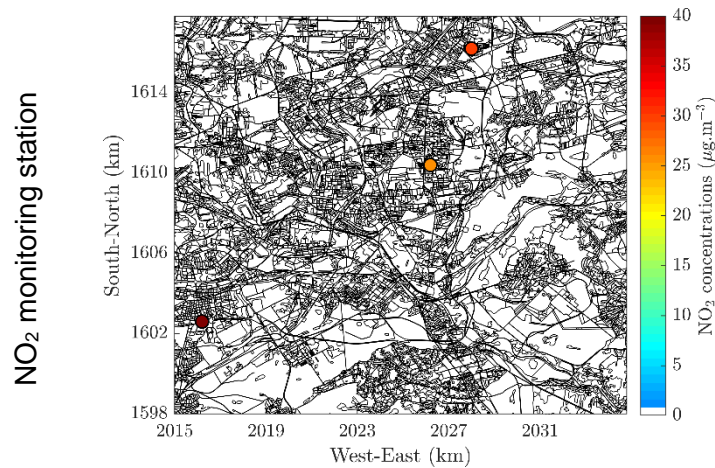
### 1.3.1 Background concentrations

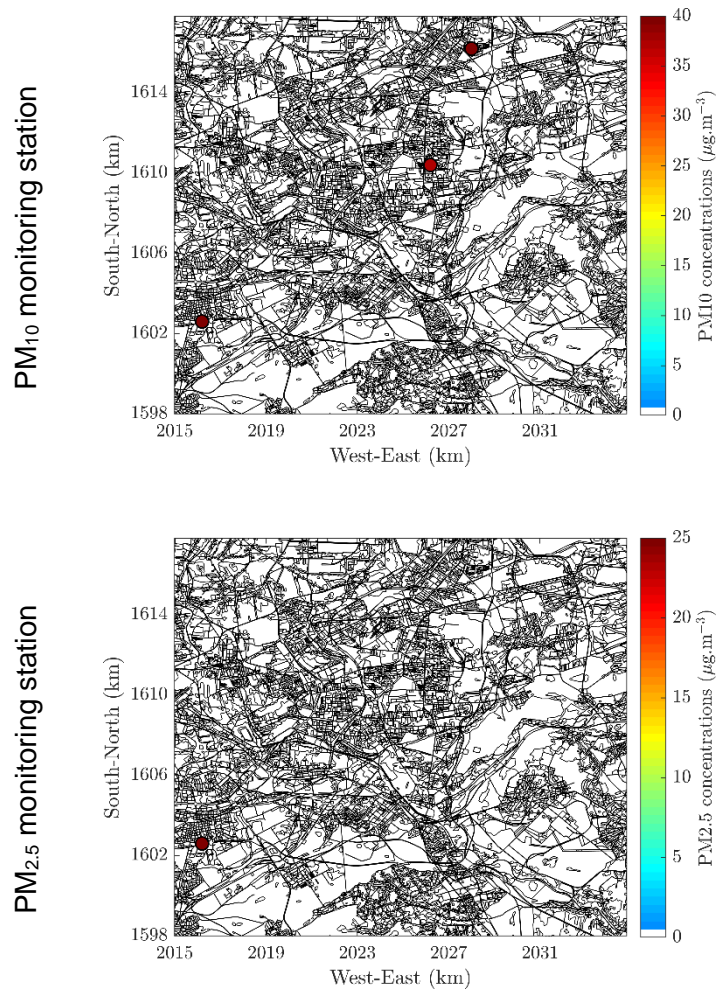
Based on the source apportionment analysis obtained from the WRF-CAMx and the PSAT tool, it is expected an underestimation of the URBAIR concentrations comparing to measured data results due to the lack of other emission sources contributing to the concentrations within the area, as well as the background concentrations. Therefore, based on the SA, a concentration value for the background concentrations and other sources was used to add on the whole domain. For  $\text{NO}_2$  the background added was  $0.2 \mu\text{g.m}^{-3}$ , for  $\text{PM}_{10}$  was  $16.5 \mu\text{g.m}^{-3}$  and for  $\text{PM}_{2.5}$  was  $15.9 \mu\text{g.m}^{-3}$ .

### 1.3.2 Summary of measuring data

In order to compare and calibrate the modelling results for the year of 2015, for  $\text{NO}_2$  and  $\text{PM}_{10}$  concentrations the modelling results could be compared with 2 urban background and 1 urban traffic monitoring station. For  $\text{PM}_{2.5}$ , the modelling results could only be compared with 1 urban traffic station.

Figure 1-2 shows the location of the monitoring stations and the annual mean concentration for 2015 for  $\text{NO}_2$ ,  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ .





**Figure 1-2: Summary data for 2015 with the location of the monitoring stations and respective annual mean concentration for each pollutant in  $\mu\text{g.m}^{-3}$ .**

The maximum value monitored in 2015 was measured by the urban traffic monitoring station. For  $\text{NO}_2$  it measured  $58.3 \mu\text{g.m}^{-3}$  and for  $\text{PM}_{10}$  it measured  $46.4 \mu\text{g.m}^{-3}$ .

### 1.3.3 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  $\text{NO}_2$  concentrations, the slope obtained from the linear regression is equal to 2.18. For  $\text{PM}_{10}$  concentrations the resulting slope is equal 1.1 and for  $\text{PM}_{2.5}$  the slope is 0.86.

## 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

Sosnowiec (the region of Sosnowiec and Katowice) is special in a sense that some policies only come into effect on days with high air pollution levels. This is easy to understand given the climate, the industry, and the socio-economical background of the population in this corner of Poland. As a consequence, we actually modelled the clean and polluted days separately, and at the end the results were merged to account for a general average.

In a few cases policies (especially the ones targeting modal shift) were overly ambitious (meaning: definitely impossible to reach), so – after consultation with the city correspondents – we proposed and modelled modified policy targets.

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. 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 Sosnowiec SDW and final scenario**

| Policy                                 | Low Scenario   | High Scenario  | Final Scenario |
|--|--|--|----------------|
| Make public transport free/cheaper     | Free public transport on days with high level of air pollution by 2020 | Free public transport by 2025  | Low option     |
| Reduce emissions from public transport | Replace 10% public transport fleet with zero-emission vehicles by 2030 | Replace 50% public transport fleet with zero-emission vehicles by 2022 | Low option     |

|  |   |   |  |
|--|---|---|--|
| <b>Improve the public transport service/connectivity</b>                       | 90% public transport journeys on schedule and most areas catered for by 2020                        | 100% public transport journeys on schedule and most areas catered for by 2020                       | Low option   |
| <b>Create/increase cycle lanes and infrastructure (storage, security)</b>      | 20 km of new cycle lanes and 15 new cycle parking spaces by 2020                                    | 20 km of new cycle lanes and 15 new cycle parking spaces by 2020                                    | High option (High and Low here were the same)  |
| <b>Encourage/incentivise electric vehicles</b>                                 | Replace 10% cars with EVs and 100 EV charging points installed by 2025                              | Replace 50% cars with EVs and 500 EV charging points installed by 2030                              | Low option   |
| <b>Restrict (polluting) vehicles</b>   | Ban diesel cars from the city centre on days with level of air pollution by 2050 (in model by 2030) | 100% ban on fossil fuelled vehicles by 2025 (only diesel in model)                                  | Low option, but ban diesel cars from the city centre on days with level of air pollution in a faster perspective – by 2025 |
| <b>Raise public awareness of health/environmental impacts of air pollution</b> | 10% modal shift from private to public transport or active travel by 2030                           | 80% in modal shift from private to public transport or active travel by 2025 (In model 40% by 2030) | High option  |
| <b>Reduce emissions from domestic heating</b>                                  | Ban on domestic coal heating in districts with the highest concentration of air pollution by 2025   | 100% ban on domestic coal heating by 2020   | Low option   |
| <b>Replace old domestic heating systems</b>                                    | Replace 75% heating systems > 10 years old by 2025  | Replace 100% heating systems > 10 years old by 2021   | High option  |
| <b>Reduce industrial emissions</b>   | Reduce industrial emissions by 25% by 2025  | Reduce industrial emissions by 50% by 2025  | Low option   |

## 2.1 Transport

### 2.1.1 Baseline and BAU

The baseline modal split (trip share) is as follows:

- Walk 23%
- Bike 2%
- Car/van 60%
- Public transport 15%

(In comparison, in Bristol this was ~29%, ~2%, ~57%, ~11%)

To match the mode choice model of Bristol with these shares we derived the following changes in the ASC values:

$$ASC\_1 = ASC\_1 - 0.4$$

$$ASC\_2 = ASC\_2 + 0.1$$

$$ASC\_4 = ASC\_4 + 0.24$$

$$ASC\_5 = ASC\_5 + 0.3$$

The baseline passenger vehicle stock and its fleet evolution is according to our modified and updated MOVEET model. We adapt the input assumptions for the annual market share forecast from the ePURE report (Europe's Clean Mobility Outlook: Scenarios for the EU light-duty vehicle fleet, associated energy needs and emissions, 2020-2050) of Ricardo Energy & Environment (Ricardo 2018), namely the High xEV Scenario (see A5 in Ricardo 2018). We use this approach in each of the following regions too. The uptake of xEV (electric and hybrid) is different country by country (mostly for socio-economic, infrastructural, and policy reasons), and we model this by calibrating the general (global) xEV uptake curves to the actual observed registration numbers of xEV vehicles, resulting in a technology time shift parameter. For example, in the BAU for Poland this technology time shift is 5 years, meaning that Poland is 5 years behind the general, average uptake curve. This parameter is important, because we can easily model different uptake scenarios by modifying this number on the model, advancing (or delaying) the uptake.

To scale the number of cars from Poland to the region in question we simply scaled the numbers according to the population of the region relative to the population of Poland (assuming that the car ownership rate in Poland and the region is the same).

### 2.1.2 *Proposed SDW scenario's*

For the Low scenarios we have modelled two versions, one with policies active on clean air days, and another one with policies active when air pollution levels are above a critical limit. These are referred to Low Clean and Low Polluted, respectively.

**Encourage/incentivise electric vehicles and Restrict (polluting) vehicles:** this policy guides us in making changes in the fleet evolution. In the Low Scenario people are aware that on days with bad air pollution they cannot drive their diesel cars anymore in the future, which will make them consider shifting towards new technologies earlier compared to the BAU. We model this by setting the technology shift parameter from 5 to -3 (basically accelerating the growth of xEV sale shares by 8 years). This results in the Low Clean Scenario. To calculate the Low Polluted scenario we simply assume that on polluted days (starting from 2030) diesel cars do not drive, so we a) turn off their emissions in the fleet model, and also b) note down the vehicle kilometre demand they would normally fulfil, and redistribute these kilometres over other modes in the mode choice calculation phase.

The High Scenario is very different, because while in the LOW Scenario people still keep their diesel cars (they simply do not use them on specific days), here we really scrap all diesel vehicles using the usual stepwise approach (similar to the Final Scenario of Bristol). The final ban is implemented by 2025 (with bans of Euro 3-4-5 by 2019-2021-2023). As people are also made aware in time that such a strict ban is coming, we accelerate the uptake of xEV technologies even more by using a technology shift parameter of -10 (which is admittedly very extreme, similar to the observed uptake rate of Norway). Leading up to the ban the sale shares of diesel cars are gradually cut back (according to the actual drop in diesel sales) to model that suddenly less diesels are going to be sold, while the sale shares

of the remaining technologies are boosted to fill the formed gap<sup>2</sup>. This overall means that as diesel is getting phased out, less diesel cars are bought than in the model without scrappage, while the deficit is distributed over the other propulsion types.

During the calculation of the modal shifts in the Low Polluted scenario for 2035 and 2050 we made a small mistake which was only noticed during the calculation of the Final scenario. The final effect of this mistake was not too significant (it did not influence the definition of the Final scenario in any way), but to be fully transparent we still publish both the initial and the corrected result tables in the next sections. (The actual mistake we made during the calculation of the proposed scenarios was that while we redistributed the mentioned potential diesel kilometres, we forgot to remove them from the mileage of cars, therefore the resulting car mileage shares were higher than they should have been, and the mileage shares of the other modes were consequently lower. The relative mileage changes that we used for scaling emission calculations were only affected for cars.) The Final scenario was calculated using the correct equations.

**Make public transport free/cheaper:** We model this by making public transport (including surface rail too as there are many tram lines in this region) free on polluted days in the Low Polluted Scenario, and always in the High Scenario.

- In model:
  - $\text{StageCost\_4} = \text{data}['\text{StageCost\_4}'] * 0$
  - $\text{StageCost\_5} = \text{data}['\text{StageCost\_5}'] * 0$

**Raise public awareness of health/environmental impacts of air pollution and Create/increase cycle lanes and infrastructure (storage, security):** we model these together as their aimed goals are very similar and complement each other well. We modify the alternative specific constants to match the aimed modal splits for each Scenario. (Modifying ASC values is always a last resort, so if other policies are also active in a given reporting year, then we make the calculations first without modifying the ASCs, see what the outcome is, and then only if necessary do we modify the ASCs in the final step.)

In the Low Scenario we model a doubling in bike trips by 2025 (as a result of the infrastructure policy), then by 2035 we meet the goals outlined in the scenario overview table. For the latter we assume that the 10% drop in car shares shifts to slow modes and public transport in a 50-50 split.

- In Clean model 2025:
  - $\text{ASC\_2} = \text{ASC\_2} + 0.8$

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<sup>2</sup> In Poland the passenger car market is dominated by used car sales, so “new” registrations have a wide age distribution. When growth rates are set to zero for years and vintages that are after the corresponding scrappage years then the sum of the remaining growth rates for diesel in a given year (that is after the scrappage) is not 1 anymore, but – in this specific example – between 0.63 to 0.29; we note these values down. To make sure that there is no unrealistic boost caused by this in sales for these younger still not-banned diesel vintages, the sale percentages of diesel are multiplied with these (smaller than one values), and the sale percentages of the other types are boosted slightly to have a total of 100% in sale shares. Finally the remaining growth rates of diesel (which summed up to between 0.63 and 0.29 until this step) are boosted to sum up to 1, which is required by how the growth rates are defined. A reminder: sale shares decide what percentage of cars are sold as diesel (and they sum up to 100% over the propulsion technologies for a given year), while growth rates decide the age distribution of these cars (and they always sum up to 1 for each propulsion type for any given each year).

- In Polluted model 2025:
  - $ASC\_2 = ASC\_2 + 0.9$  #Stronger change needed compared to Clean as free PT takes a bigger share (away from not only cars but potential cyclist)
- In Clean model 2035:
  - $ASC\_1 = ASC\_1 + 0.2$
  - $ASC\_2 = ASC\_2 + 1$
  - $ASC\_4 = ASC\_4 + 0.70$
  - $ASC\_5 = ASC\_5 + 0.70$
- In Polluted model 2035:
  - $ASC\_1 = ASC\_1 + 0.1$
  - $ASC\_2 = ASC\_2 + 1$
  - $ASC\_4 = ASC\_4 + 0.2$  #Weaker change needed compared to Clean since being free these PT modes already have a higher utility
  - $ASC\_5 = ASC\_5 + 0.2$

### 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.

**Encourage/incentivise electric vehicles:** the modelling of this is the same as the modelling of the Low Scenarios, except that in the Final Polluted Scenario the air-pollution-based diesel ban start already in 2025. (There is now scrappage like there was in the High Scenario.)

The rest of the policies were picked as a mix of the Low and High Scenarios, as such were already discussed above.

We made some refinements to the modelling workflow for the calculation of this scenario, meaning:

As mentioned before, for the final scenario we also calibrated the mode choice model to the observed modal split using the ASC values. This resulted in a slightly modified mileage distribution for the modes, which serve as the baseline for our relative mileage change calculations for the reporting years. The calibrated ASC parameters were:

- Baseline:
  - $ASC\_1 = ASC\_1 - 0.4$
  - $ASC\_2 = ASC\_2 + 0.1$
  - $ASC\_4 = ASC\_4 + 0.24$
  - $ASC\_5 = ASC\_5 + 0.3$

For the modelling of the policy which had fixed modal shift goals for 2030 we already calculated results for 2025 too, assuming a linear change in the modal split from the 2015 observed to 2030. We model the redistribution of the 40% of car trips that go towards other modes as follows: 40% of cars go to slow and PT (30% to slow (20% bike, 10% walk), rest to PT (keeping the existing relative share of the two sub-modes). Past the 2030 horizon we keep the 2030 values constant. The final ASC values per scenario are:

- Clean 2025:
  - $ASC\_1 = ASC\_1 - 0.4$
  - $ASC\_2 = ASC\_2 + 1.45$
  - $ASC\_3 = ASC\_3 - 0.8$
  - $ASC\_4 = ASC\_4 + 0.22$
  - $ASC\_5 = ASC\_5 + 0.18$
- Clean 2035:
  - $ASC\_1 = ASC\_1 - 0.05$
  - $ASC\_2 = ASC\_2 + 2$
  - $ASC\_3 = ASC\_3 - 0.9$
  - $ASC\_4 = ASC\_4 + 0.6$
  - $ASC\_5 = ASC\_5 + 0.7$
- Polluted 2025:
  - $ASC\_1 = ASC\_1 - 0.45$
  - $ASC\_2 = ASC\_2 + 1.45$
  - $ASC\_3 = ASC\_3 - 0.7$
  - $ASC\_4 = ASC\_4 - 0.2$
  - $ASC\_5 = ASC\_5 - 0.1$
- Polluted 2035:
  - $ASC\_1 = ASC\_1 - 0.275$
  - $ASC\_2 = ASC\_2 + 1.9$
  - $ASC\_3 = ASC\_3 - 0.95$
  - $ASC\_4 = ASC\_4 - 0.05$
  - $ASC\_5 = ASC\_5 + 0.1$

On polluted days the diesel cars don't drive, but people still need to get around, so we assume they can all still get to their destinations using alternative modes, and redistribute their mileages such that we assume that 5-5% of the total immobilised diesel mileage goes to slow modes (they are limited since with bad air quality people will not really want to be outside), 5% goes to ride sharing (with someone that has a non-diesel car), and the rest is distributed equally over the public transport modes (42.5% – 42.5%). This redistribution exercise provides the final mileages for a given reporting year that can be compared to the baseline mileages to derive the scaling factor that is applied to the emission calculations coming from the fleet models.

## 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 Sosnowiec.

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);
- Gminy disaggregation variables (Table 2-5).

For heating networks (district heating) we assume the following split between fuels, using national figures excluding waste derived fuels more territorial specific<sup>3</sup>: coal (89%), natural gas (7%), wood (4%).

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<sup>3</sup> [Statistics Poland, Energy statistics in 2015 and 2016. Table 8 \(13\). Public Thermal Plants - Heat Generation](#)

**Table 2-2: Methodology and source of data for Sosnowiec fuel consumptions/emissions evaluation - Industrial sources**

| Activity          | Data availability | Source | Publication   | Reference   | Disaggregation variable |
|-------------------|-------------------|--------|---|---|-------------------------|
| Industrial sector | Single facility   | EIONET | Reporting Obligations Database (ROD), Deliveries for National Emission Ceiling Directive (NECD) - Large point source (LPS) emissions data by source category (GNFR) Poland NECD 2017 Report LPS emissions 2007 2015 | <a href="http://cdr.eionet.europa.eu/pl/eu/nec_revised/lps/env_wql3ba/Annex_VI_LPS_2015_POL_TSP.xls">http://cdr.eionet.europa.eu/pl/eu/nec_revised/lps/env_wql3ba/Annex_VI_LPS_2015_POL_TSP.xls</a> | None (Point sources)    |

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources**

| Activity           | Energy vector | Data availability                         | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|--------------------|---------------|---|---------------------------|--|---|------------------------------------|-------------------------|
| Residential sector | Natural Gas   | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |
|                    |               | Level 2 (Województwa) for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 2. Zużycie gazu ziemnego  | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> |                                    | Population              |

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources (cont.)**

| Activity | Energy vector     | Data availability                         | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|----------|-------------------|---|---------------------------|--|---|------------------------------------|-------------------------|
|          | Heat <sup>4</sup> | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |
|          |                   | Level 2 (Województwa) for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 6. Zużycie ciepła   | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> |                                    | Population              |
|          | Wood              | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |

<sup>4</sup> For heating networks (district heating) we assume the following split of fuel, using national figures excluding waste derived fuels more territorial specific: coal (89%), natural gas (7%), wood (4%).

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources (cont.)**

| Activity | Energy vector | Data availability                            | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|----------|---------------|--|---------------------------|--|---|------------------------------------|-------------------------|
|          |               | Level 2 (Wojewodztwa)<br>for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 6.<br>Zużycie ciepła  | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> | Only data from district heating    | Population              |
|          | LPG           | Level 3 (Gminy) only for Sosnowiec           | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Wojewodztwa data | None                    |
|          |               | Level 2 (Wojewodztwa)<br>for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tabl. 3.<br>Zużycie gazu ciekłego (zużycie stacjonarne, bez pojazdów)              | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> | Only data from district heating    | Population              |
|          | Gasoil        | Level 3 (Gminy) only for Sosnowiec           | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Wojewodztwa data | None                    |

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources (cont.)**

| Activity       | Energy vector | Data availability                            | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|----------------|---------------|--|---------------------------|--|---|------------------------------------|-------------------------|
|                |               | Level 2 (Wojewodztwa)<br>for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tabl. 4.<br>Zużycie lekkiego oleju opałowego                                       | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> | Only data from district heating    | Population              |
|                | Coal          | Level 3 (Gminy) only for Sosnowiec           | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Wojewodztwa data | None                    |
|                |               | Level 2 (Wojewodztwa)<br>for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 1.<br>Zużycie węgla kamiennego  | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> |                                    | Population              |
| Service sector | Natural Gas   | Level 3 (Gminy) only for Sosnowiec           | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Wojewodztwa data | None                    |

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources (cont.)**

| Activity | Energy vector     | Data availability                            | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|----------|-------------------|--|---------------------------|--|---|------------------------------------|-------------------------|
|          |                   | Level 2 (Wojewodztwa)<br>for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 2.<br>Zużycie gazu ziemnego   | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> |                                    | Population              |
|          | Heat <sup>5</sup> | Level 3 (Gminy) only for Sosnowiec           | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Wojewodztwa data | None                    |
|          |                   | Level 2 (Wojewodztwa)<br>for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 6.<br>Zużycie ciepła  | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> |                                    | Population              |

<sup>5</sup> For heating networks (district heating) we assume the following split of fuel, using national figures excluding waste derived fuels more territorial specific: coal (89%), natural gas (7%), wood (4%).

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources (cont.)**

| Activity | Energy vector | Data availability                         | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|----------|---------------|---|---------------------------|--|---|------------------------------------|-------------------------|
|          | Wood          | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |
|          |               | Level 2 (Województwa) for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 6. Zużycie ciepła   | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> | Only data from district heating    | Population              |
|          | LPG           | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |
|          |               | Level 2 (Województwa) for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tabl. 3. Zużycie gazu ciekłego (zużycie stacjonarne, bez pojazdów)                 | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> | Only data from district heating    | Population              |

**Table 2-3: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and commercial sources (cont.)**

| Activity | Energy vector | Data availability                         | Source                    | Publication  | Reference   | Note                               | Disaggregation variable |
|----------|---------------|---|---------------------------|--|---|------------------------------------|-------------------------|
|          | Gasoil        | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |
|          |               | Level 2 (Województwa) for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tabl. 4. Zużycie lekkiego oleju opałowego  | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> | Only data from district heating    | Population              |
|          | Coal          | Level 3 (Gminy) only for Sosnowiec        | Urzędu Miasta Sosnowiec   | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a>   | 2013 to 2015 with Województwa data | None                    |
|          |               | Level 2 (Województwa) for all other Gminy | Główny Urząd Statystyczny | Zużycie paliw i nośników energii w 2015 roku, Tab. 1. Zużycie węgla kamiennego   | <a href="https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html">https://stat.gov.pl/obszary-tematyczne/srodowisko-energia/energia/zuzycie-paliw-i-nosnikow-energii-w-2015-roku,6,10.html</a> |                                    | Population              |

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

| Variable           | Data availability  | Sources                    | Publication                                    | Reference   | Note   |
|--------------------|--------------------|----------------------------|--|---|--|
| Technologies split | Level 1 (National) | Central Statistical Office | Energy consumption in households in 2012, 2014 | <a href="https://stat.gov.pl/download/gfx/portalinformacyjny/en/defaultaktualnosci/3304/2/2/1/energy_consumption_in_households_in_2012.pdf">https://stat.gov.pl/download/gfx/portalinformacyjny/en/defaultaktualnosci/3304/2/2/1/energy_consumption_in_households_in_2012.pdf</a> | Central heating boilers, used to produce heat and warm water, were found in 41.3% of households using solid fuels. The single-function boilers were used in 31.9% of households using solid fuels. The most traditional heating devices, such as stoves in rooms (mostly made of tiles), were used in 19.2% of households. 7% of households using solid fuels had fireplaces, usually with closed insert. In the remaining 0.6% of households, solid fuel fired cooking stoves were the only heating devices. We assume boilers for district heating and traditional stoves for the remaining appliances in residential sectors while we assume boilers in overall services appliances |

**Table 2-5: Methodology and source of data for Sosnowiec fuel consumptions evaluation – Gminy disaggregation variables**

| Variable   | Data availability | Sources                   | Publication   | Reference   | Fields  |
|------------|-------------------|---------------------------|---|---|---|
| Population | Level 3 (Gminy)   | Główny Urząd Statystyczny | Ludność w gminach według stanu w dniu 31.12.2011 r. - bilans opracowany w oparciu o wyniki NSP 2011 | <a href="http://stat.gov.pl/download/cps/rde/xbcr/gus/LUD_bilans_ludnosci_31-12-2011.xls">http://stat.gov.pl/download/cps/rde/xbcr/gus/LUD_bilans_ludnosci_31-12-2011.xls</a> | Population total by Gminy (Sheet Slaskie column Ogolem) |

### 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 Poland official projections.

The scenario was built in different steps using:

- the projections of greenhouse gas emissions and energy demand from the 7<sup>th</sup> national communication to UNFCCC<sup>6</sup> using scenario with additional measures (WAM)
- the national measures defined in the 'with measures' (adopted measures) projection in the frame of NECD<sup>7</sup>.

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.

The **Sosnowiec** BAU projections consider:

The Plan for a low-carbon economy was published in 2015 and updated<sup>8</sup> in 2016 and since then has been shaping city policy and strategies around energy and climate.

The plan lists goals for the city which include, by 2020:

- Reducing energy consumption to 3 840 GWh/year (a 5.6% reduction on 2013 consumption);
- Reducing CO<sub>2</sub> emissions to 1 517 ktCO<sub>2</sub> (a 5.2% reduction on 2013 levels); and,
- Increasing renewable energy to 104.5 GWh/year (an increase of 12% on 2013 levels).

Two main actions involve building sector:

- Thermal renovations of buildings (with 196 811 MWh/year saving and about 11%);
- Modernization District Heating (with 10 855 MWh/year saving and about 1%).

These reductions have been added to national reductions discussed before.

Socio-economic drivers' definition is reported in Table 2-6 while technologic drivers' definition is reported in Table 2-7.

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

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<sup>6</sup> [The Republic of Poland, Seventh National Communication and Third Biennial Report Under the United Nations Framework Convention on Climate Change](#)

<sup>7</sup> [EEA Eionet, Reporting Obligations Database \(ROD\), Deliveries for National Emission Ceiling Directive \(NECD\) - Projected emissions by aggregated NFR sectors](#)

<sup>8</sup> [Kompleksowy plan gospodarki niskoemisyjnej dla miasta Sosnowiec, Aktualizacja 2016](#)

consumptions reductions, and technological measures, such as for example advanced combustion technology, all the measures are valuated as technological. The NEC projections for residential & commercial are higher than emissions resulting from application of measures from UNFCCC NC. No more reductions are introduced other than UNFCCC NC ones. For industry the drivers introduced are reported in Table 2-6 from NEC.

**Table 2-6: Sosnowiec: Socio-economic drivers used to project emissions in industrial, residential and commercial sector**

| Code        | Name  | Domain              |
|-------------|---|---------------------|
| SOS_B_DH_C  | Sosnowiec BAU District heating- Hard Coal               | all Sosnowiec Gminy |
| SOS_B_DH_NG | Sosnowiec BAU District heating- Natural gas             | all Sosnowiec Gminy |
| SOS_B_DH_W  | Sosnowiec BAU District heating- Solid biomass           | all Sosnowiec Gminy |
| SOS_B_MDH   | Sosnowiec BAU Modernisation District Heating.           | all Sosnowiec Gminy |
| SOS_B_RC_C  | Sosnowiec BAU Residential & Commercial - Hard Coal      | all Sosnowiec Gminy |
| SOS_B_RC_G  | Sosnowiec BAU Residential & Commercial - Gas/Diesel Oil | all Sosnowiec Gminy |
| SOS_B_RC_L  | Sosnowiec BAU Residential & Commercial – LPG            | all Sosnowiec Gminy |
| SOS_B_RC_NG | Sosnowiec BAU Residential & Commercial - Natural gas    | all Sosnowiec Gminy |
| SOS_B_RC_W  | Sosnowiec BAU Residential & Commercial - Solid biomass  | all Sosnowiec Gminy |
| SOS_B_TRB   | Sosnowiec BAU Thermal renovations of buildings          | all Sosnowiec Gminy |

**Table 2-7: Sosnowiec: Technological drivers used to project emissions in industrial, residential and commercial sector**

| Code         | Name                       | Domain              |
|--------------|----------------------------|---------------------|
| SOS_NECI_NOx | Sosnowiec NEC Industry NOx | all Sosnowiec Gminy |
| SOS_NECI_PM  | Sosnowiec NEC Industry PM  | all Sosnowiec Gminy |

### 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 2-8: Sosnowiec: Measures coming from the Stakeholder dialog workshop**

| Code         | Description  | Scenario |
|--------------|--|----------|
| SOS_CoalB20  | Sosnowiec Ban coal on Residential & Commercial from 2020 | High     |
| SOS_CoalPB25 | Sosnowiec Partial Ban coal on Residential & Commercial   | Low      |
| SOS_I-50%25  | Sosnowiec Reduce industrial emissions by 50% on 2025     | High     |
| SOS_I-25%25  | Sosnowiec Reduce industrial emissions by 25% on 2025     | Low      |
| SOS_RH75%NOx | Sosnowiec Replace 75% >10 years old by 2025 NOx          | Low      |
| SOS_RHallNOx | Sosnowiec Replace all >10 years old by 2025 NOx          | High     |
| SOS_RH75%PM  | Sosnowiec Replace 75% >10 years old by 2025 PM           | Low      |
| SOS_RHallPM  | Sosnowiec Replace all >10 years old by 2025 PM           | High     |

We assume that:

- Regarding the measures on Ban coal on Residential & Commercial:
  - we assume that the measures don't apply to heat generated by district heating;
  - for the partial ban, we assume the ban in the areas of Pogoń (2445 households), followed by Zagórze (1446), Niwka (1141), Dańdówka (1105) and Klimontów (1002) and consider 10% of total households.
- Regarding measures to replace 75% or 100% of heating system with more than 10 years old we:
  - apply this measure to wood stoves and fireplaces, where the measure produces a strong reduction of PM emissions (wood stoves and fireplaces);
  - we take into consideration the available data about age of appliances<sup>9</sup> and assume 75% of stoves and 50% of fireplaces have more than 10 years of life;
- Regarding measures to reduce industrial emissions the Scenarios include the only plant into Sosnowiec Wojewodztwa while the emissions from plants on surrounding Wojewodztwa are kept constant.

### 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).

**Table 2-9: Sosnowiec: Measures for the Unified Policy Scenario**

| Code | Description |
|------|-------------|
|------|-------------|

<sup>9</sup> [Central Statistical Office, Energy consumption in households in 2012](#)

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|              |  |
|--------------|--|
| SOS_CoalPB25 | Sosnowiec Partial Ban coal on Residential & Commercial |
| SOS_I-25%25  | Sosnowiec Reduce industrial emissions by 25% on 2025   |
| SOS_RHallNOx | Sosnowiec Replace all >10 years old by 2025 NOx        |
| SOS_RHallPM  | Sosnowiec Replace all >10 years old by 2025 PM         |

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## 2.3 Carbon footprint

### 2.3.1 Baseline

The following tables document the methodology and data used for:

- Industrial sources (Table 2-10)
- Residential and commercial sources (Table 2-11)

For heating networks (district heating) we assume the following split between fuels, using national figures excluding waste derived fuels more territorial specific<sup>10</sup>: coal (89%), natural gas (7%), wood (4%).

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<sup>10</sup> [Statistics Poland, Energy statistics in 2015 and 2016. Table 8 \(13\). Public Thermal Plants - Heat Generation](#)

**Table 2-10: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Industrial sources**

| Activity          | Energy vector | Data availability | Source                  | Publication  | Reference   | Field                              | Disaggregation variable |
|-------------------|---------------|-------------------|-------------------------|--|---|------------------------------------|-------------------------|
| Industrial sector | Natural Gas   | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|                   | LPG           | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|                   | Gasoil        | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|                   | Coal          | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|                   | Electricity   | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |

**Table 2-11: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and services sources**

| Activity           | Energy vector      | Data availability | Source                  | Publication  | Reference   | Field                              | Disaggregation variable |
|--------------------|--------------------|-------------------|-------------------------|--|---|------------------------------------|-------------------------|
| Residential sector | Natural Gas        | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|                    | Heat <sup>11</sup> | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|                    | Wood               | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |

<sup>11</sup> For heating networks (district heating) we assume the following split of fuel, using national figures excluding waste derived fuels more territorial specific: coal (89%), natural gas (7%), wood (4%).

**Table 2-12: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and services sources (cont.)**

| Activity | Energy vector | Data availability | Source                  | Publication  | Reference   | Field                              | Disaggregation variable |
|----------|---------------|-------------------|-------------------------|--|---|------------------------------------|-------------------------|
|          | LPG           | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|          | Gasoil        | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|          | Coal          | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|          | Electricity   | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |

**Table 2-12: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and services sources (cont.)**

| Activity  | Energy vector      | Data availability | Source                  | Publication  | Reference   | Field                              | Disaggregation variable |
|---|--------------------|-------------------|-------------------------|--|---|------------------------------------|-------------------------|
| Service sector (included in industrial sector statistics) | Natural Gas        | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Wojewodztwa data | None                    |
|   | Heat <sup>12</sup> | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Wojewodztwa data | None                    |
|   | Wood               | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Wojewodztwa data | None                    |

<sup>12</sup> For heating networks (district heating) we assume the following split of fuel, using national figures excluding waste derived fuels more territorial specific: coal (89%), natural gas (7%), wood (4%).

**Table 2-12: Methodology and source of data for Sosnowiec fuel consumptions evaluation - Residential and services sources (cont.)**

| Activity | Energy vector | Data availability | Source                  | Publication  | Reference   | Field                              | Disaggregation variable |
|----------|---------------|-------------------|-------------------------|--|---|------------------------------------|-------------------------|
|          | LPG           | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|          | Gasoil        | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|          | Coal          | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |
|          | Electricity   | Level 3 (Gminy)   | Urzędu Miasta Sosnowiec | Energoekspert. Kompleksowy Plan Gospodarki Niskoemisyjnej dla Miasta Sosnowiec, Tabela 16-1. Końcowe zużycie energii w roku 2013 | <a href="http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf">http://www.sosnowiec.pl/_upload/PGN%20Sosnowiec%2011.09.2015%20a.pdf</a> | 2013 to 2015 with Województwa data | None                    |

### *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.

### *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.

## 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) and the resulting modal split (where applicable<sup>13</sup>) for various reporting years in each scenario. For the Final scenario we also present the calibrated baseline.

| Mode                       |   | Mileage change |  | Trip share (%) |
|----------------------------|---|----------------|--|----------------|
| 1  Walk                    |  | 0.972          |  | 28.3           |
| 2  Bicycle                 |  | 2.088          |   | 3.8            |
| 3  Car/van                 |  | 0.985          |  | 54.6           |
| 4  Bus/metro               |  | 0.965          |  | 8.6            |
| 5  Train/surface rail      |  | 0.990          |   | 2.2            |
| 6  Taxi                    |  | 0.928          |   | 1.2            |
| 7  Other (incl. motorbike) |  | 1.004          |   | 1.3            |

**Figure 3-1: Scenario Low Clean (2025)**

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<sup>13</sup> For scenarios where diesel mileages had to be redistributed we only made the calculations on the mileages and not on the modal split (for technical reasons).

| Mode                       | Mileage change | Trip share (%) |
|----------------------------|----------------|----------------|
| 1  Walk                    | 0.962          | 28.1           |
| 2  Bicycle                 | 2.098          | 3.7            |
| 3  Car/van                 | 0.914          | 48.9           |
| 4  Bus/metro               | 1.442          | 13.9           |
| 5  Train/surface rail      | 1.403          | 3.5            |
| 6  Taxi                    | 0.805          | 1.0            |
| 7  Other (incl. motorbike) | 0.768          | 1.1            |

**Figure 3-2: Scenario Low Clean (2035-2050)**

| Mode                       | Mileage change | Trip share (%) |
|----------------------------|----------------|----------------|
| 1  Walk                    | 0.933          | 27.7           |
| 2  Bicycle                 | 1.780          | 3.7            |
| 3  Car/van                 | 0.749          | 50.9           |
| 4  Bus/metro               | 2.547          | 12.6           |
| 5  Train/surface rail      | 2.330          | 2.9            |
| 6  Taxi                    | 0.754          | 1.1            |
| 7  Other (incl. motorbike) | 0.391          | 1.1            |

**Figure 3-3: Scenario Low Polluted (2025)**

| Mode                       | Mileage change |
|----------------------------|----------------|
| 1  Walk                    | 1.074          |
| 2  Bicycle                 | 2.247          |
| 3  Car/van                 | 0.545          |
| 4  Bus/metro               | 3.799          |
| 5  Train/surface rail      | 3.142          |
| 6  Taxi                    | 0.716          |
| 7  Other (incl. motorbike) | 0.364          |

**Figure 3-4: Scenario Low Polluted (2035)**

| Mode                       | Mileage change |
|----------------------------|----------------|
| 1  Walk                    | 0.974          |
| 2  Bicycle                 | 1.898          |
| 3  Car/van                 | 0.682          |
| 4  Bus/metro               | 3.009          |
| 5  Train/surface rail      | 2.580          |
| 6  Taxi                    | 0.716          |
| 7  Other (incl. motorbike) | 0.364          |

**Figure 3-5: Scenario Low Polluted (2050)**

| Mode                       | Mileage change | Trip share (%) |
|----------------------------|----------------|----------------|
| 1  Walk                    | 0.967          | 28.5           |
| 2  Bicycle                 | 7.111          | 14.6           |
| 3  Car/van                 | 0.542          | 35.2           |
| 4  Bus/metro               | 3.427          | 16.8           |
| 5  Train/surface rail      | 2.707          | 3.6            |
| 6  Taxi                    | 0.440          | 0.6            |
| 7  Other (incl. motorbike) | 0.223          | 0.6            |

**Figure 3-6: Scenario High (2025-2035-2050)**

| Mode                       | Trip share (%) |
|----------------------------|----------------|
| 1  Walk                    | 22.94          |
| 2  Bicycle                 | 2.10           |
| 3  Car/van                 | 57.06          |
| 4  Bus/metro               | 12.14          |
| 5  Train/surface rail      | 3.07           |
| 6  Taxi                    | 1.30           |
| 7  Other (incl. motorbike) | 1.39           |








**Figure 3-7: Trip shares in the calibrated mode choice model for the Baseline of the Final Scenario**

| Mode                       | Mileage change | Trip share (%) |
|----------------------------|----------------|----------------|
| 1  Walk                    | 1.212          | 26.7           |
| 2  Bicycle                 | 5.158          | 9.7            |
| 3  Car/van                 | 0.832          | 42.0           |
| 4  Bus/metro               | 1.244          | 14.7           |
| 5  Train/surface rail      | 1.215          | 3.4            |
| 6  Taxi                    | 1.302          | 1.6            |
| 7  Other (incl. motorbike) | 1.386          | 1.8            |








**Figure 3-8: Final Clean Scenario (2025)**

| Mode                       | Mileage change | Trip share (%) |
|----------------------------|----------------|----------------|
| 1  Walk                    | 1.327          | 28.6           |
| 2  Bicycle                 | 7.324          | 13.3           |
| 3  Car/van                 | 0.722          | 34.2           |
| 4  Bus/metro               | 1.439          | 16.5           |
| 5  Train/surface rail      | 1.601          | 4.6            |
| 6  Taxi                    | 1.095          | 1.3            |
| 7  Other (incl. motorbike) | 1.147          | 1.5            |








**Figure 3-9: Final Clean Scenario (2035-2050)**

| Mode                       | Mileage change  |
|----------------------------|---|
| 1  Walk                    |  1.411 |
| 2  Bicycle                 |  4.727 |
| 3  Car/van                 |  0.406 |
| 4  Bus/metro               |  3.545 |
| 5  Train/surface rail      |  2.995 |
| 6  Taxi                    |  1.116 |
| 7  Other (incl. motorbike) |  0.609 |

**Figure 3-10: Final Polluted Scenario (2025)**

| Mode                       | Mileage change  |
|----------------------------|---|
| 1  Walk                    |  1.417 |
| 2  Bicycle                 |  6.520 |
| 3  Car/van                 |  0.416 |
| 4  Bus/metro               |  3.300 |
| 5  Train/surface rail      |  2.812 |
| 6  Taxi                    |  1.116 |
| 7  Other (incl. motorbike) |  0.586 |

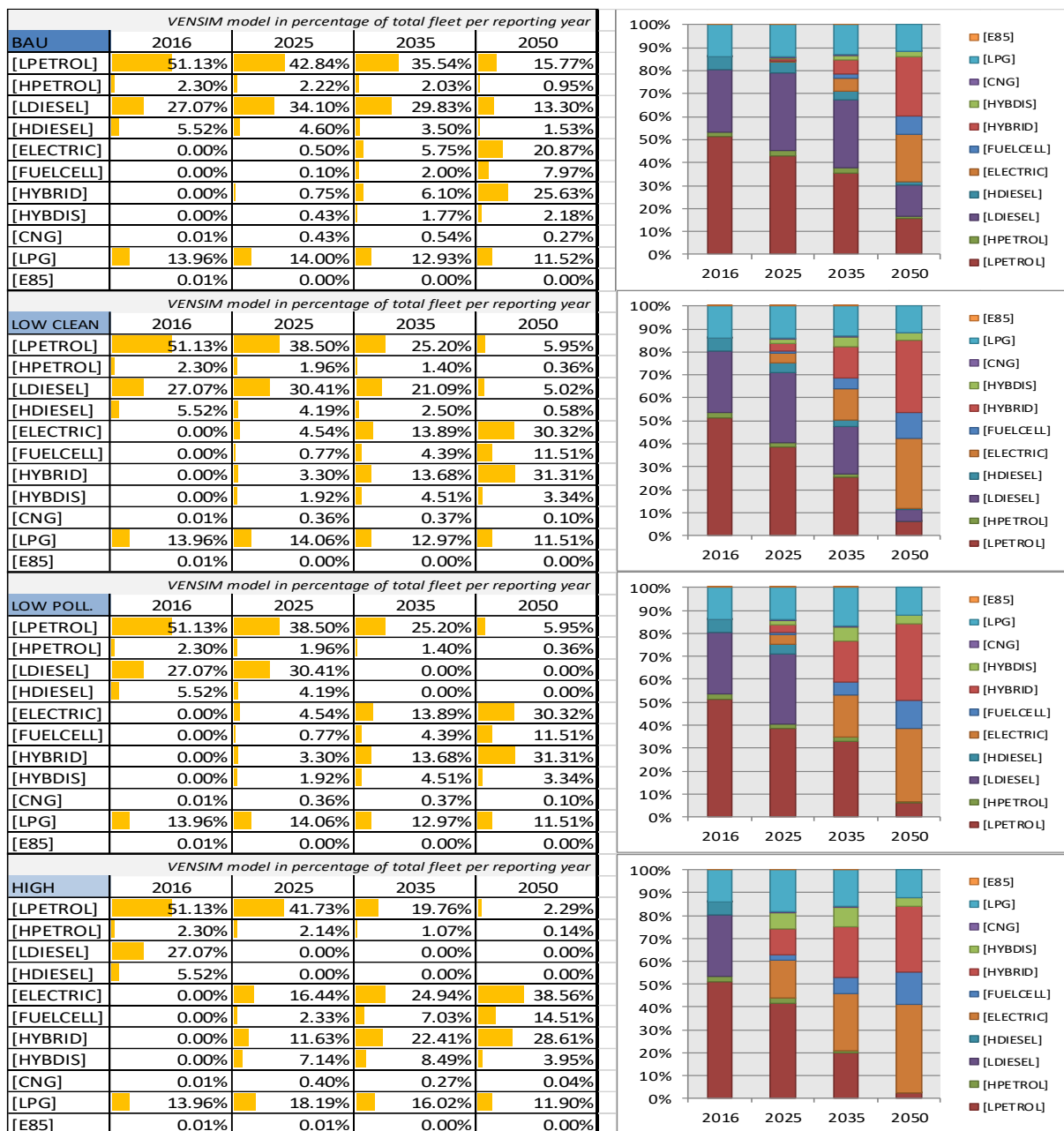
**Figure 3-11: Final Polluted Scenario (2035)**

| Mode                       | Mileage change  |
|----------------------------|---|
| 1  Walk                    |  1.318 |
| 2  Bicycle                 |  6.275 |
| 3  Car/van                 |  0.514 |
| 4  Bus/metro               |  2.839 |
| 5  Train/surface rail      |  2.482 |
| 6  Taxi                    |  1.116 |
| 7  Other (incl. motorbike) |  0.586 |

**Figure 3-12: Final Polluted Scenario (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.



**Figure 3-13: Passenger car fleet composition in the BAU and in the (Clean and Polluted, also Final) and High Scenario. Since the fleet component of the Final Scenario is the same as the one of the Low Scenario, the central two rows (Low Clean and Low Polluted) also corresponds to the Final Scenarios (Clean and Polluted).**

**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% | 67.38%  | 42.47%  | 12.96%  |
|         | Scenario 1 |         | 67.38%  | 42.47%  | 12.96%  |
|         | Scenario 2 |         | 67.38%  | 42.47%  | 12.96%  |
| PM      | Year       | 2015    | 2025    | 2035    | 2050    |
|         | BAU        | 100.00% | 43.82%  | 21.25%  | 14.00%  |
|         | Scenario 1 |         | 43.82%  | 21.25%  | 14.00%  |
|         | Scenario 2 |         | 43.82%  | 21.25%  | 14.00%  |
| PM_NE   | Year       | 2015    | 2025    | 2035    | 2050    |
|         | BAU        | 100.00% | 111.01% | 123.23% | 144.14% |
|         | Scenario 1 |         | 111.01% | 123.23% | 144.14% |
|         | Scenario 2 |         | 111.01% | 123.23% | 144.14% |

|       |            |         |         |         |         |
|-------|------------|---------|---------|---------|---------|
| MOTO  |            |         |         |         |         |
| Nox   | Year       | 2015    | 2025    | 2035    | 2050    |
|       | BAU        | 100.00% | 105.97% | 74.70%  | 22.62%  |
|       | Scenario 1 |         | 105.97% | 74.70%  | 22.62%  |
|       | Scenario 2 |         | 105.97% | 74.70%  | 22.62%  |
| PM    | Year       | 2015    | 2025    | 2035    | 2050    |
|       | BAU        | 100.00% | 69.88%  | 35.66%  | 23.67%  |
|       | Scenario 1 |         | 69.88%  | 35.66%  | 23.67%  |
|       | Scenario 2 |         | 69.88%  | 35.66%  | 23.67%  |
| PM_NE | Year       | 2015    | 2025    | 2035    | 2050    |
|       | BAU        | 100.00% | 110.46% | 122.02% | 141.66% |
|       | Scenario 1 |         | 110.46% | 122.02% | 141.66% |
|       | Scenario 2 |         | 110.46% | 122.02% | 141.66% |

|       |            |         |         |         |         |
|-------|------------|---------|---------|---------|---------|
| ZWVR  |            |         |         |         |         |
| Nox   | Year       | 2015    | 2025    | 2035    | 2050    |
|       | BAU        | 100.00% | 52.74%  | 22.72%  | 6.83%   |
|       | Scenario 1 |         | 52.74%  | 22.72%  | 6.83%   |
|       | Scenario 2 |         | 52.74%  | 22.72%  | 6.83%   |
| PM    | Year       | 2015    | 2025    | 2035    | 2050    |
|       | BAU        | 100.00% | 59.25%  | 27.05%  | 17.82%  |
|       | Scenario 1 |         | 59.25%  | 27.05%  | 17.82%  |
|       | Scenario 2 |         | 59.25%  | 27.05%  | 17.82%  |
| PM_NE | Year       | 2015    | 2025    | 2035    | 2050    |
|       | BAU        | 100.00% | 109.92% | 120.82% | 139.23% |
|       | Scenario 1 |         | 109.92% | 120.82% | 139.23% |
|       | Scenario 2 |         | 109.92% | 120.82% | 139.23% |

|       |                   |         |         |         |         |
|-------|-------------------|---------|---------|---------|---------|
| CAR   |                   |         |         |         |         |
| Nox   | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 75.19%  | 38.91%  | 6.64%   |
|       | Scenario 1_badAQ  |         | 52.20%  | 4.50%   | 1.18%   |
|       | Scenario 1_goodAQ |         | 68.67%  | 28.58%  | 3.12%   |
|       | scenario 2        |         | 10.87%  | 5.66%   | 0.94%   |
| PM    | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 55.61%  | 17.59%  | 9.68%   |
|       | Scenario 1_badAQ  |         | 39.40%  | 4.84%   | 4.77%   |
|       | Scenario 1_goodAQ |         | 51.83%  | 13.93%  | 6.87%   |
|       | scenario 2        |         | 7.48%   | 4.68%   | 3.14%   |
| PM_NE | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 120.17% | 137.12% | 154.84% |
|       | Scenario 1_badAQ  |         | 89.99%  | 74.75%  | 105.63% |
|       | Scenario 1_goodAQ |         | 118.38% | 125.26% | 141.45% |
|       | scenario 2        |         | 65.14%  | 74.32%  | 83.93%  |

|       |                   |         |         |         |         |
|-------|-------------------|---------|---------|---------|---------|
| BUS   |                   |         |         |         |         |
| Nox   | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 105.51% | 75.00%  | 22.71%  |
|       | Scenario 1_badAQ  |         | 255.29% | 190.04% | 47.95%  |
|       | Scenario 1_goodAQ |         | 96.74%  | 97.34%  | 24.56%  |
|       | scenario 2        |         | 180.80% | 64.25%  | 0.00%   |
| PM    | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 59.07%  | 30.93%  | 20.53%  |
|       | Scenario 1_badAQ  |         | 142.92% | 78.37%  | 43.35%  |
|       | Scenario 1_goodAQ |         | 54.16%  | 40.14%  | 22.21%  |
|       | scenario 2        |         | 101.22% | 26.50%  | 0.00%   |
| PM_NE | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 110.46% | 122.02% | 141.66% |
|       | Scenario 1_badAQ  |         | 281.33% | 343.55% | 398.85% |
|       | Scenario 1_goodAQ |         | 106.60% | 175.97% | 204.30% |
|       | scenario 2        |         | 378.56% | 418.17% | 485.48% |

|       |                   |         |         |         |         |
|-------|-------------------|---------|---------|---------|---------|
| VAN   |                   |         |         |         |         |
| Nox   | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 71.29%  | 40.69%  | 9.80%   |
|       | Scenario 1_badAQ  |         | 59.79%  | 23.49%  | 7.07%   |
|       | Scenario 1_goodAQ |         | 68.03%  | 35.52%  | 8.04%   |
|       | scenario 2        |         | 5.43%   | 2.83%   | 0.47%   |
| PM    | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 49.72%  | 19.42%  | 11.84%  |
|       | Scenario 1_badAQ  |         | 41.61%  | 13.05%  | 9.39%   |
|       | Scenario 1_goodAQ |         | 47.83%  | 17.59%  | 10.44%  |
|       | scenario 2        |         | 3.74%   | 2.34%   | 1.57%   |
| PM_NE | Year              | 2015    | 2025    | 2035    | 2050    |
|       | BAU               | 100.00% | 115.59% | 130.18% | 149.49% |
|       | Scenario 1_badAQ  |         | 100.50% | 98.99%  | 124.88% |
|       | Scenario 1_goodAQ |         | 114.70% | 124.25% | 142.79% |
|       | scenario 2        |         | 32.57%  | 37.16%  | 41.96%  |

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

|         |       |             |         |         |         |         |
|---------|-------|-------------|---------|---------|---------|---------|
| MIDZWVR | Nox   | Year        | 2015    | 2025    | 2035    | 2050    |
|         |       | BAU         | 100.00% | 67.38%  | 42.47%  | 12.96%  |
|         |       | UPS-good AQ |         | 67.38%  | 42.47%  | 12.96%  |
|         |       | UPS-bad AQ  |         | 67.38%  | 42.47%  | 12.96%  |
|         | PM    | Year        | 2015    | 2025    | 2035    | 2050    |
|         |       | BAU         | 100.00% | 43.82%  | 21.25%  | 14.00%  |
|         |       | UPS-good AQ |         | 43.82%  | 21.25%  | 14.00%  |
|         |       | UPS-bad AQ  |         | 43.82%  | 21.25%  | 14.00%  |
|         | PM_NE | Year        | 2015    | 2025    | 2035    | 2050    |
|         |       | BAU         | 100.00% | 111.01% | 123.23% | 144.14% |
|         |       | UPS-good AQ |         | 111.01% | 123.23% | 144.14% |
|         |       | UPS-bad AQ  |         | 111.01% | 123.23% | 144.14% |

|      |       |             |         |         |         |         |
|------|-------|-------------|---------|---------|---------|---------|
| MOTO | Nox   | Year        | 2015    | 2025    | 2035    | 2050    |
|      |       | BAU         | 100.00% | 105.97% | 74.70%  | 22.62%  |
|      |       | UPS-good AQ |         | 105.97% | 74.70%  | 22.62%  |
|      |       | UPS-bad AQ  |         | 105.97% | 74.70%  | 22.62%  |
|      | PM    | Year        | 2015    | 2025    | 2035    | 2050    |
|      |       | BAU         | 100.00% | 69.88%  | 35.66%  | 23.67%  |
|      |       | UPS-good AQ |         | 69.88%  | 35.66%  | 23.67%  |
|      |       | UPS-bad AQ  |         | 69.88%  | 35.66%  | 23.67%  |
|      | PM_NE | Year        | 2015    | 2025    | 2035    | 2050    |
|      |       | BAU         | 100.00% | 110.46% | 122.02% | 141.66% |
|      |       | UPS-good AQ |         | 110.46% | 122.02% | 141.66% |
|      |       | UPS-bad AQ  |         | 110.46% | 122.02% | 141.66% |

|      |       |             |         |         |         |         |
|------|-------|-------------|---------|---------|---------|---------|
| ZWVR | Nox   | Year        | 2015    | 2025    | 2035    | 2050    |
|      |       | BAU         | 100.00% | 52.74%  | 22.72%  | 6.83%   |
|      |       | UPS-good AQ |         | 52.74%  | 22.72%  | 6.83%   |
|      |       | UPS-bad AQ  |         | 52.74%  | 22.72%  | 6.83%   |
|      | PM    | Year        | 2015    | 2025    | 2035    | 2050    |
|      |       | BAU         | 100.00% | 59.25%  | 27.05%  | 17.82%  |
|      |       | UPS-good AQ |         | 59.25%  | 27.05%  | 17.82%  |
|      |       | UPS-bad AQ  |         | 59.25%  | 27.05%  | 17.82%  |
|      | PM_NE | Year        | 2015    | 2025    | 2035    | 2050    |
|      |       | BAU         | 100.00% | 109.92% | 120.82% | 139.23% |
|      |       | UPS-good AQ |         | 109.92% | 120.82% | 139.23% |
|      |       | UPS-bad AQ  |         | 109.92% | 120.82% | 139.23% |

|     |       |             |         |         |         |         |
|-----|-------|-------------|---------|---------|---------|---------|
| CAR | Nox   | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 75.19%  | 38.91%  | 6.64%   |
|     |       | UPS-good AQ |         | 58.01%  | 22.58%  | 2.47%   |
|     |       | UPS-bad AQ  |         | 4.35%   | 2.62%   | 0.85%   |
|     | PM    | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 55.61%  | 17.59%  | 9.68%   |
|     |       | UPS-good AQ |         | 43.79%  | 11.00%  | 5.43%   |
|     |       | UPS-bad AQ  |         | 2.84%   | 2.81%   | 3.43%   |
|     | PM_NE | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 120.17% | 137.12% | 154.84% |
|     |       | UPS-good AQ |         | 100.01% | 98.98%  | 111.76% |
|     |       | UPS-bad AQ  |         | 30.14%  | 43.49%  | 75.90%  |

|     |       |             |         |         |         |         |
|-----|-------|-------------|---------|---------|---------|---------|
| BUS | Nox   | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 105.51% | 75.00%  | 22.71%  |
|     |       | UPS-good AQ |         | 124.71% | 97.15%  | 24.51%  |
|     |       | UPS-bad AQ  |         | 245.93% | 183.98% | 46.43%  |
|     | PM    | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 59.07%  | 30.93%  | 20.53%  |
|     |       | UPS-good AQ |         | 69.82%  | 40.06%  | 22.16%  |
|     |       | UPS-bad AQ  |         | 137.69% | 75.87%  | 41.97%  |
|     | PM_NE | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 110.46% | 122.02% | 141.66% |
|     |       | UPS-good AQ |         | 137.43% | 175.62% | 203.89% |
|     |       | UPS-bad AQ  |         | 271.01% | 332.59% | 386.13% |

|     |       |             |         |         |         |         |
|-----|-------|-------------|---------|---------|---------|---------|
| VAN | Nox   | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 71.29%  | 40.69%  | 9.80%   |
|     |       | UPS-good AQ |         | 62.70%  | 32.53%  | 7.71%   |
|     |       | UPS-bad AQ  |         | 35.87%  | 22.55%  | 6.90%   |
|     | PM    | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 49.72%  | 19.42%  | 11.84%  |
|     |       | UPS-good AQ |         | 43.80%  | 16.13%  | 9.72%   |
|     |       | UPS-bad AQ  |         | 23.33%  | 12.03%  | 8.72%   |
|     | PM_NE | Year        | 2015    | 2025    | 2035    | 2050    |
|     |       | BAU         | 100.00% | 115.59% | 130.18% | 149.49% |
|     |       | UPS-good AQ |         | 105.51% | 111.10% | 127.95% |
|     |       | UPS-bad AQ  |         | 70.58%  | 83.36%  | 110.02% |

## 3.2 Spatial-temporal

- Data pre-processing

In this case the temperature dataset was retrieved from a commercial weather service company. We selected the dataset from a station near Sosnowiec: Krakow/Balice Poland, with coordinates 50.08N, 19.80E, 237m. The raw data are available in 365 files with csv ("comma-separated values") as the file extensions: that is, each day represents one .csv file. This means that we have to integrate the 365 files into a single dataset. Each file consists of more than 40 records, representing the half-hourly temperature records. However, not all files have the maximum of 48 observations, that is, the records have missing values. Each file consists of 29 variables, of which we only need two: "datetime" and "temp". Hence, a

reduction technique is required here to remove the 27 non-relevant variables. The “datetime” is in yyyymmddhhhh format, the “temp” unit in Celsius. The first technique we applied is reduction, given that we want to keep only two variables: “datetime” and “temp”. Moreover, some solutions for how to merge .csv files into a single worksheet are available online [44]. In this case, the daily 365 .csv files needed to be integrated into a single dataset. Accordingly we applied the solution via Command Prompt (cmd), which copies all the records from the 365 files into a single.txt file, which we then imported into Microsoft Excel. In this case, we applied the transformation technique. To overcome the issue of the missing values in the cleaning task, we interpolated the data. Interpolation is the process of finding and constructing unknown values based on known values [34]. As a result, we have arranged the temperature datasets into hourly (8760 records) and daily average (365 records) resolutions to be used in modelling the load profiles.

**Table 3-2: resulting intra-day profiles**

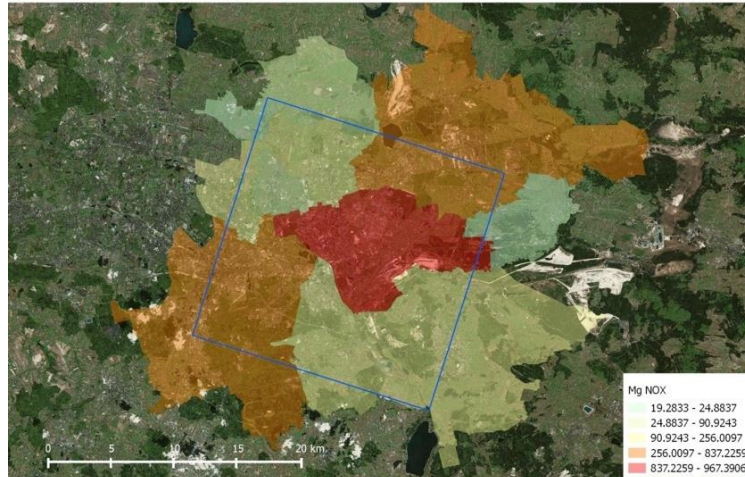
| Typical days<br>(TD) | Pattern (%)  |             |             |
|----------------------|--------------|-------------|-------------|
|                      | Commercial   | Residential |             |
|                      | NOX and PM10 | NOX         | PM10        |
| 11-02-2015           | 0,319743007  | 0,319747738 | 0,319853728 |
| 15-02-2015           | 0,328261241  | 0,328266097 | 0,328374911 |
| 12-08-2015           | 0,237476461  | 0,237473498 | 0,237407094 |
| 16-08-2015           | 0,240598803  | 0,2405958   | 0,240528524 |

### 3.3 IRCI

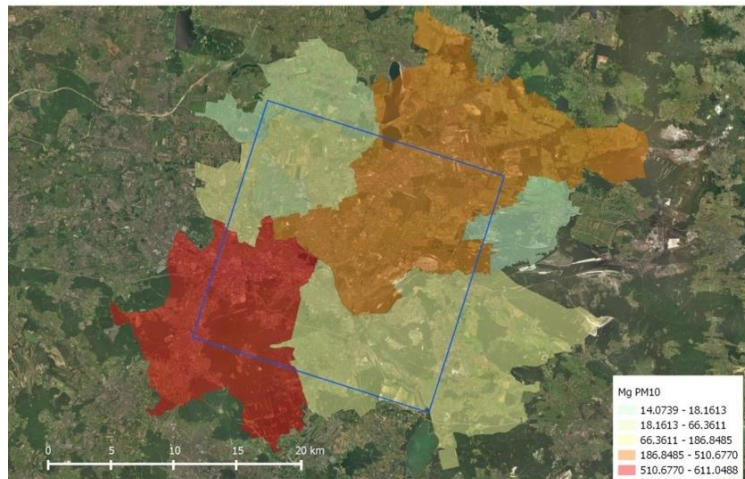
#### 3.3.1 Baseline

In the following maps the main results for NO<sub>x</sub> and PM<sub>10</sub> emissions are reported by Gminas. In detail are reported:

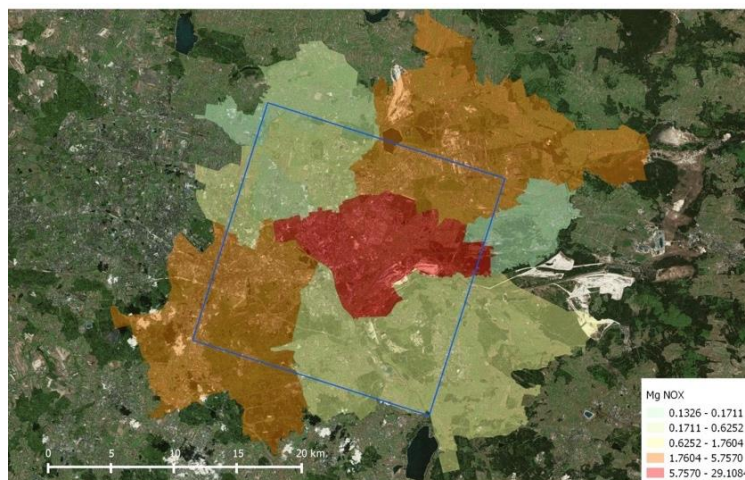
- Sosnowiec Gminy Residential, Commercial & Institutional NO<sub>x</sub> emissions for all sectors and fuels (Figure 3-14)
- Sosnowiec Gminy Residential, Commercial & Institutional PM<sub>10</sub> emissions for all sectors and fuels (Figure 3-15),
- Sosnowiec Gminy Residential, Commercial & Institutional NO<sub>x</sub> emissions from solid biomass (Figure 3-16),
- Sosnowiec Gminy Residential, Commercial & Institutional PM<sub>10</sub> emissions from solid biomass (Figure 3-17),
- Sosnowiec Gminy Residential, Commercial & Institutional NO<sub>x</sub> emissions from hard coal (Figure 3-18),
- Sosnowiec Gminy Residential, Commercial & Institutional PM<sub>10</sub> emissions from hard coal Sosnowiec (Figure 3-19),
- Industry NO<sub>x</sub> point emissions (Figure 3-20),
- Sosnowiec Industry PM<sub>10</sub> point emissions (Figure 3-21).



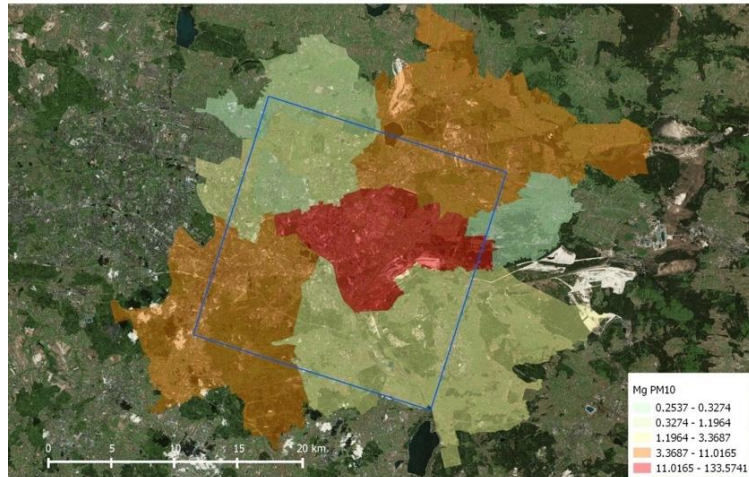
**Figure 3-14: Sosnowiec Gminy Residential, Commercial & Institutional NO<sub>x</sub> emissions – all sectors and fuels**



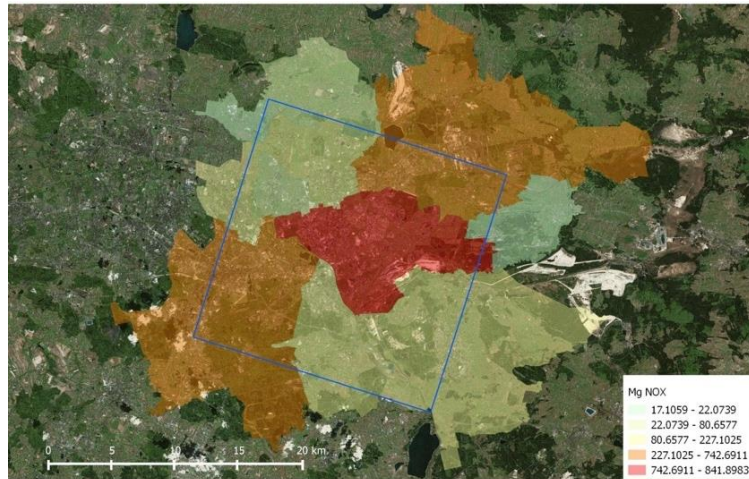
**Figure 3-15: Sosnowiec Gminy Residential, Commercial & Institutional PM<sub>10</sub> emissions – all sectors and fuels**



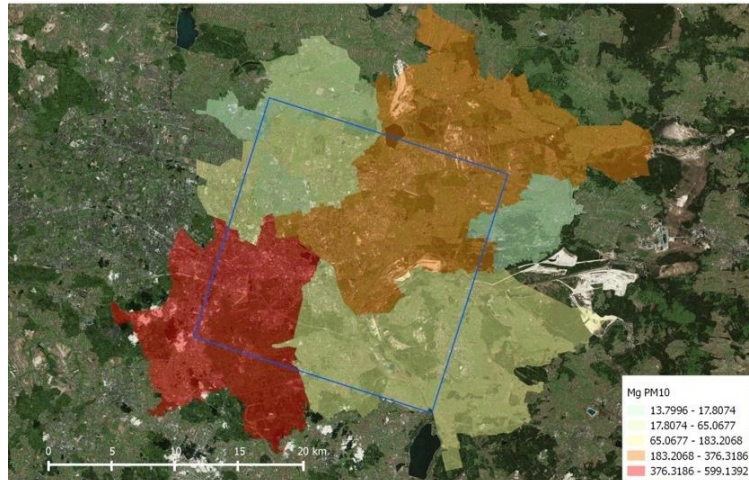
**Figure 3-16: Sosnowiec Gminy Residential, Commercial & Institutional NO<sub>x</sub> emissions – solid biomass**



**Figure 3-17: Sosnowiec Gminy Residential, Commercial & Institutional PM10 emissions – solid biomass**



**Figure 3-18: Sosnowiec Gminy Residential, Commercial & Institutional NOx emissions – hard coal**



**Figure 3-19: Sosnowiec Gminy Residential, Commercial & Institutional PM10 emissions – hard coal**

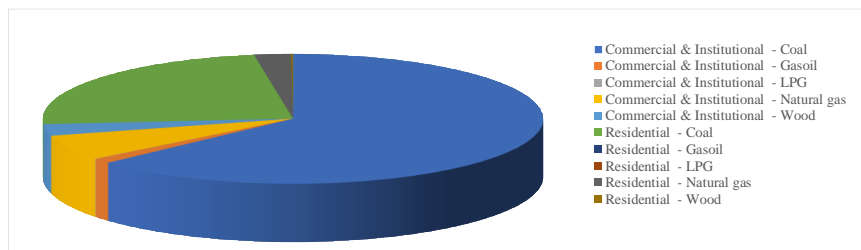


**Figure 3-20: Sosnowiec IRC Industry NOx point emissions**

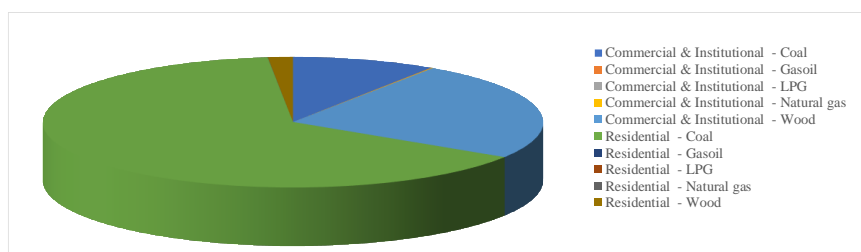


**Figure 3-21: Sosnowiec IRC Industry PM10 point emissions**

Finally, in the following Figure 3-22 and Figure 3-23 the emissions for the different activities & fuels in the only *Sosnowiec Wojewodztwa* are reported.



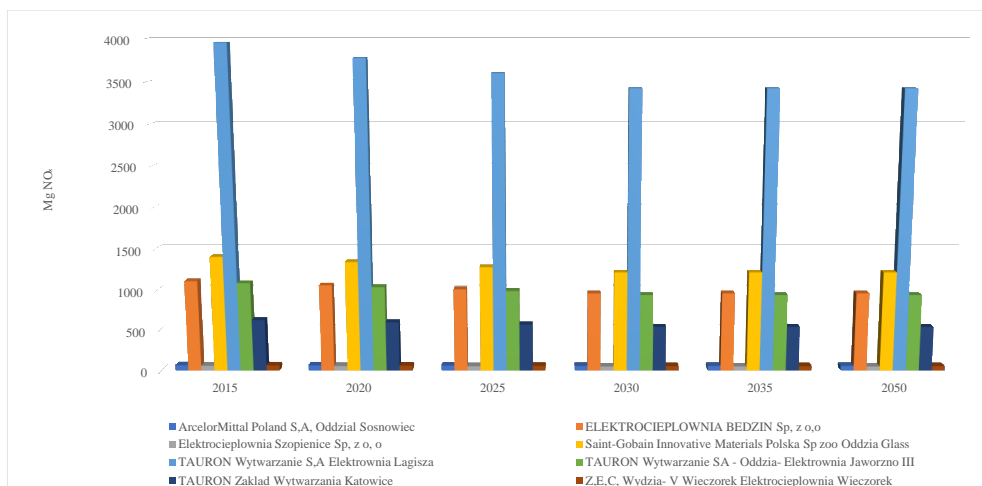
**Figure 3-22: Sosnowiec Wojewodztwa Residential, Commercial & Institutional NOx emissions**



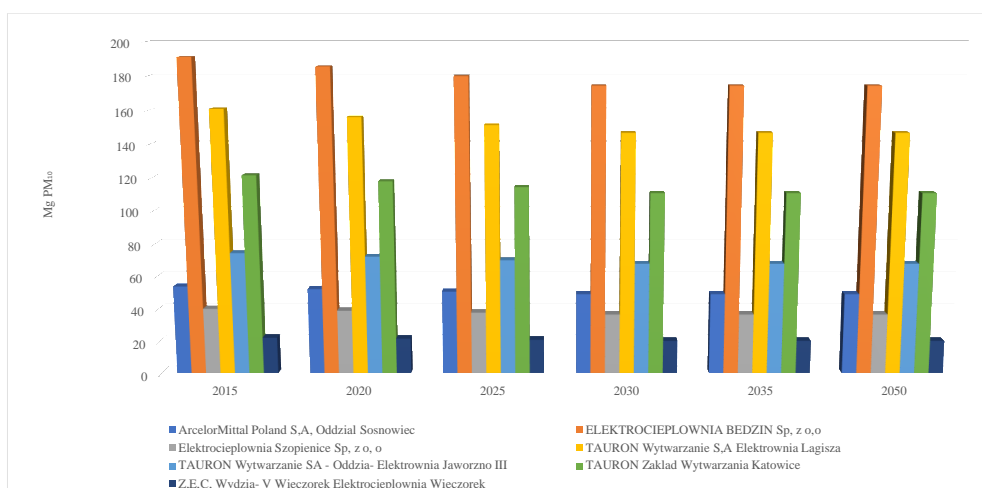
**Figure 3-23: Sosnowiec Wojewodztwa Residential, Commercial & Institutional PM10 emissions**

### 3.3.2 BAU

The evolutions of industrial area emissions are reported in Figure 3-24 for nitrogen oxides (NO<sub>x</sub>) and in Figure 3-25 for suspended particles with diameter less than 10μ (PM<sub>10</sub>). The variation is evaluated as the average variation of industrial emissions in national projection.

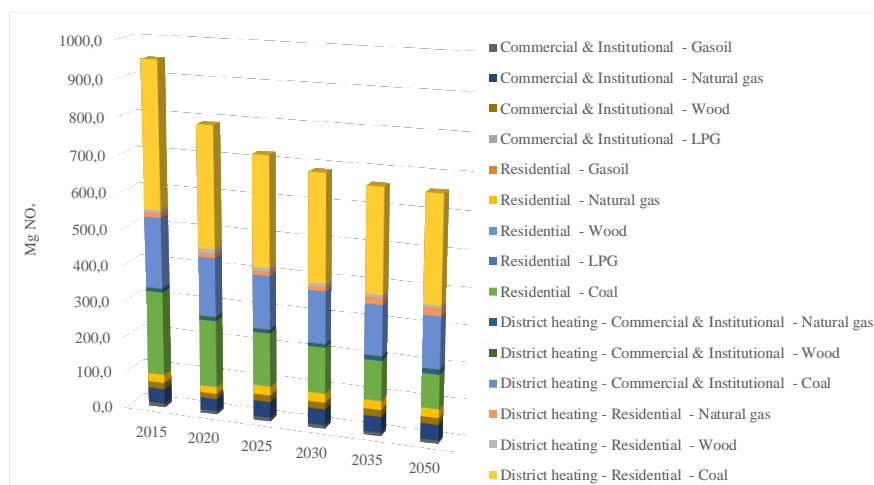


**Figure 3-24: Sosnowiec BAU Industrial main point sources NO<sub>x</sub> emissions**

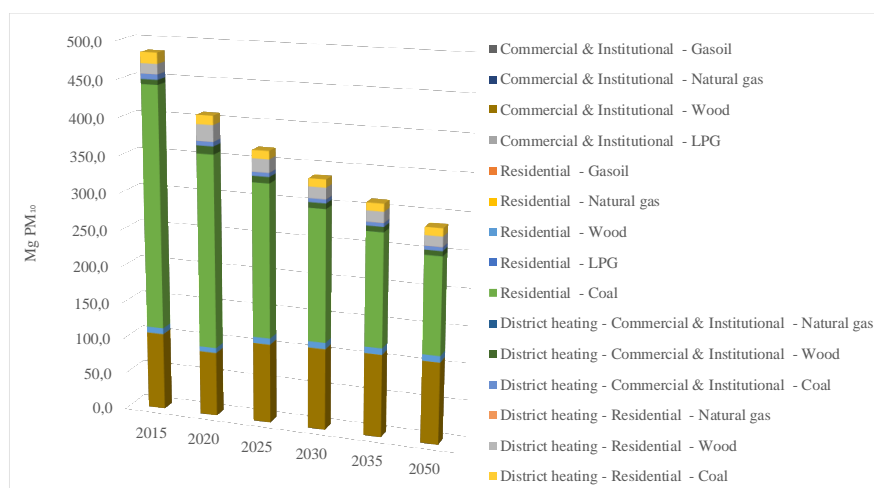


**Figure 3-25: Sosnowiec BAU Industrial main point sources PM<sub>10</sub> emissions**

In Figure 3-26 for nitrogen oxides (NO<sub>x</sub>) and in Figure 3-27 for suspended particles with diameter less than 10μ (PM<sub>10</sub>) the evolutions of emissions are reported for residential, commercial and institutional emissions.



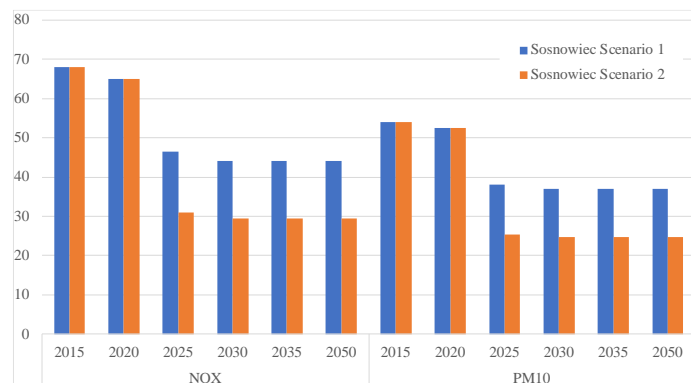
**Figure 3-26: Sosnowiec BAU total Residential, Commercial & Institutional NOx emissions**



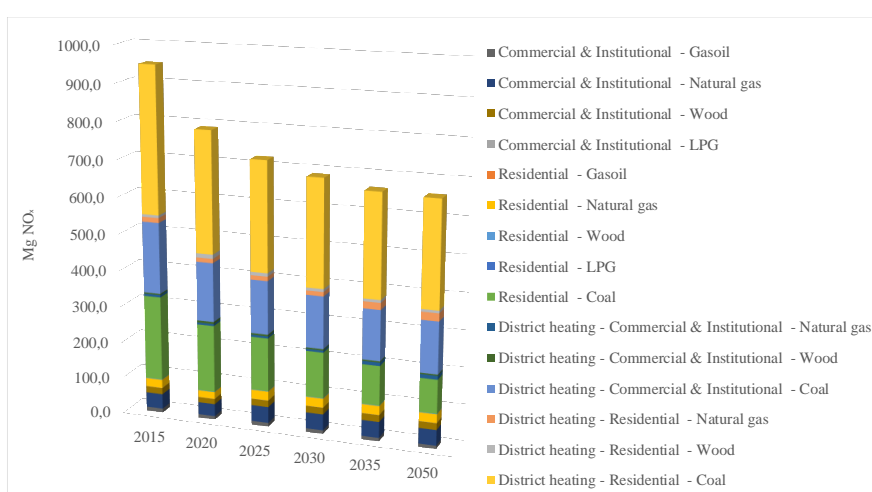
**Figure 3-27: Sosnowiec BAU Residential, Commercial & Institutional PM10 emissions**

### 3.3.3 Stakeholder dialog workshop Scenarios

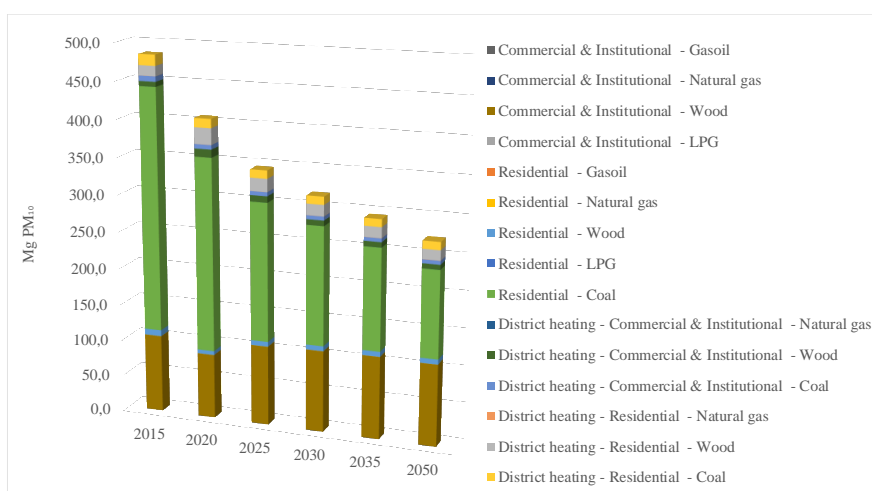
In Figure 3-29 for nitrogen oxides (NO<sub>x</sub>) and Figure 3-30 for suspended particles with diameter less than 10 $\mu$  (PM<sub>10</sub>) the trends of emissions are reported for scenario 1 ("low"); in Figure 3-31 for nitrogen oxides (NO<sub>x</sub>) and Figure 3-32 for suspended particles with diameter less than 10 $\mu$  (PM<sub>10</sub>) the trends of emissions are reported for scenario 2 ("high"). The Scenario include only the Sosnowiec Wojewodztwa while the emissions from surrounding Wojewodztwa are kept constant.



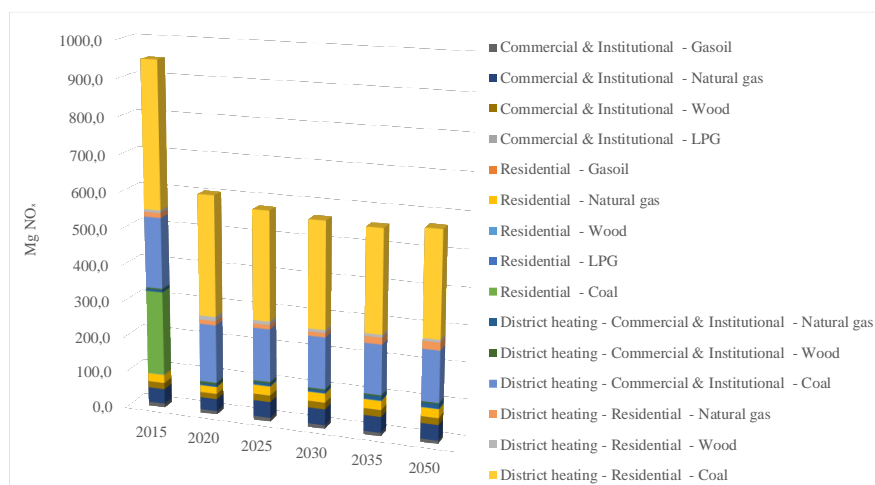
**Figure 3-28: Sosnowiec Scenario 1 (low) & 2 (high): Industrial point sources NOx and PM10 emissions inside the municipality**



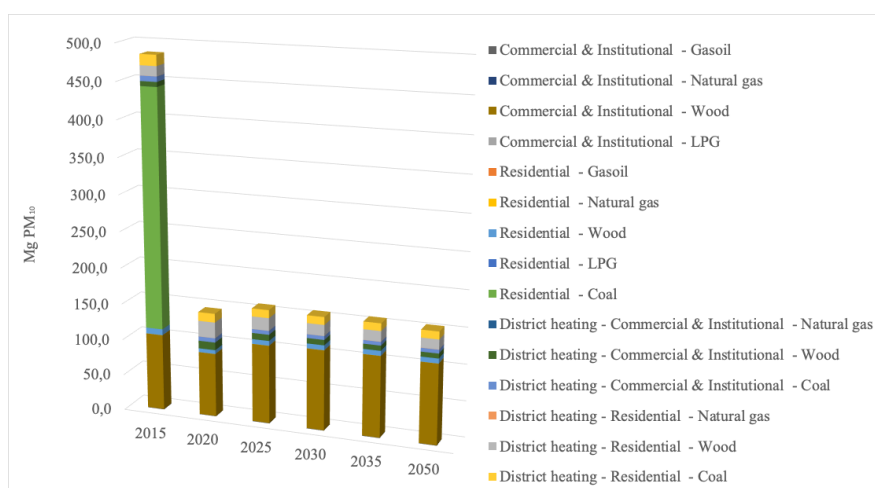
**Figure 3-29: Sosnowiec Scenario 1 (low): Residential, Commercial & Institutional NOx emissions – all sectors and fuels**



**Figure 3-30: Sosnowiec Scenario 1 (low): (renewables & efficiency): Residential, Commercial & Institutional PM10 emissions – all sectors and fuels**

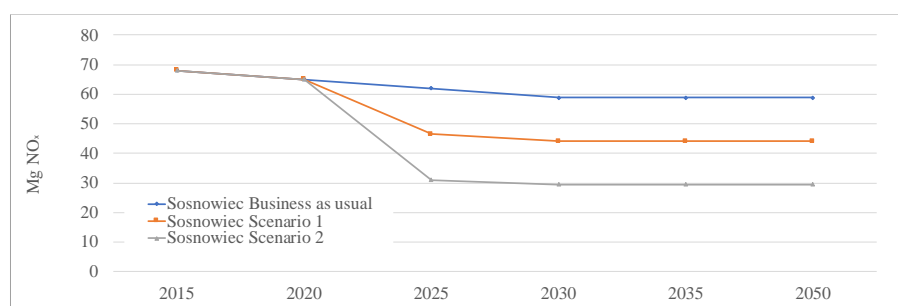


**Figure 3-31: Sosnowiec Scenario 2 (high): Residential, Commercial & Institutional NOx emissions – all sectors and fuels**

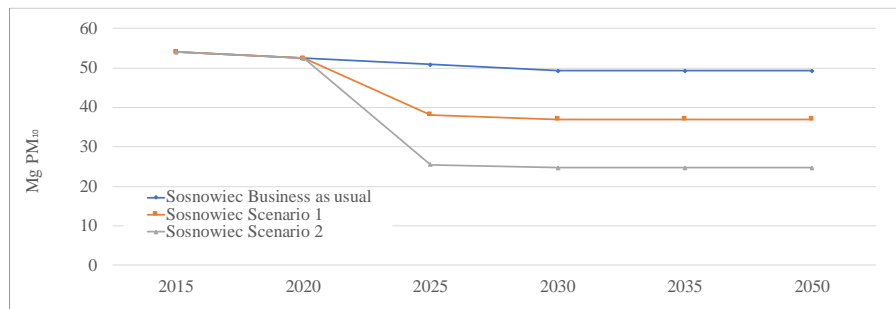


**Figure 3-32: Sosnowiec Scenario 2 (high): (renewables & efficiency): Residential, Commercial & Institutional PM10 emissions – all sectors and fuels**

In Figure 3-33 for nitrogen oxides (NO<sub>x</sub>) and Figure 3-34 for suspended particles with diameter less than 10 $\mu$  (PM<sub>10</sub>) the trends of emissions in the different scenarios are reported for industrial sources.

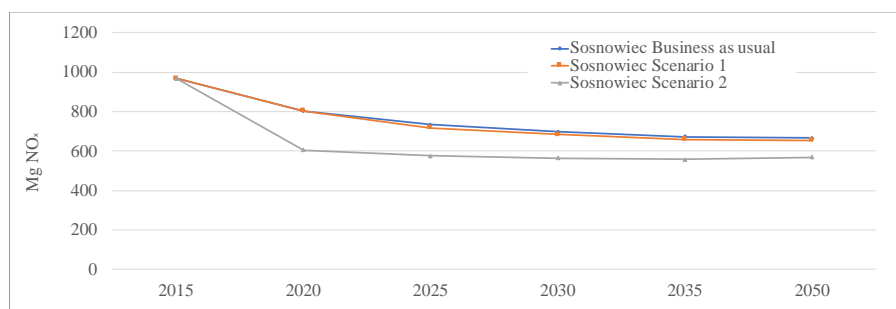


**Figure 3-33: Sosnowiec Scenarios: Industrial sources NOx emissions**

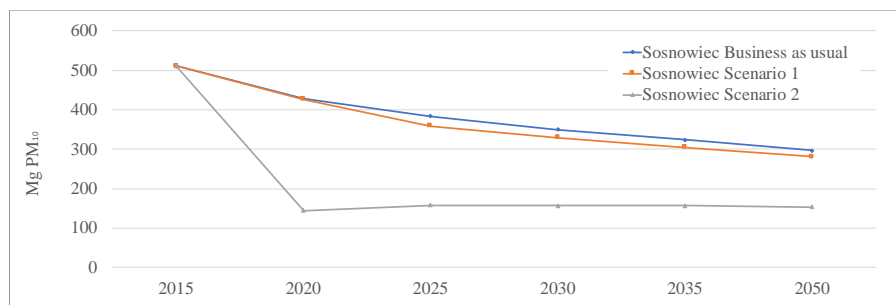


**Figure 3-34: Sosnowiec Scenarios: Industrial sources PM10 emissions**

In Figure 3-35 for nitrogen oxides (NO<sub>x</sub>) and in Figure 3-36 for suspended particles with diameter less than 10 $\mu$  (PM<sub>10</sub>) the comparison of the trends of emissions are reported for Residential, Commercial, Institutional emissions.



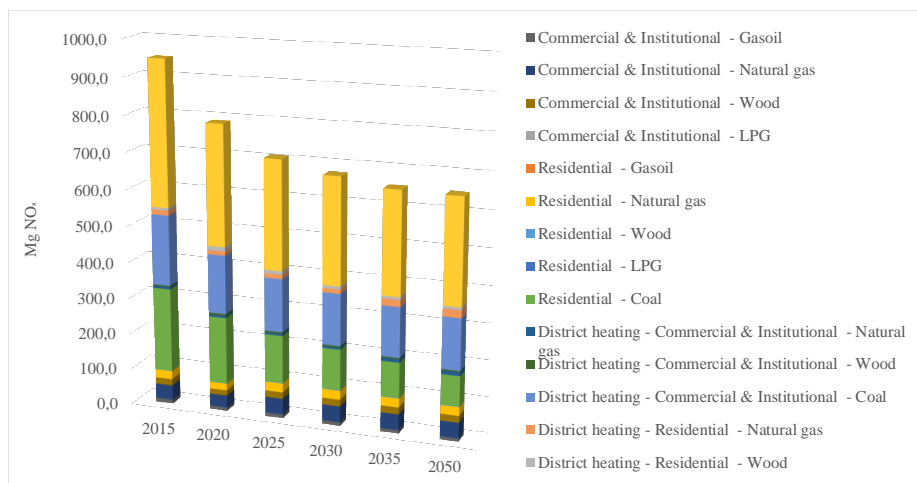
**Figure 3-35: Sosnowiec BAU & Scenarios comparison: Residential, Commercial, Institutional NOx emissions – all sectors and fuels**



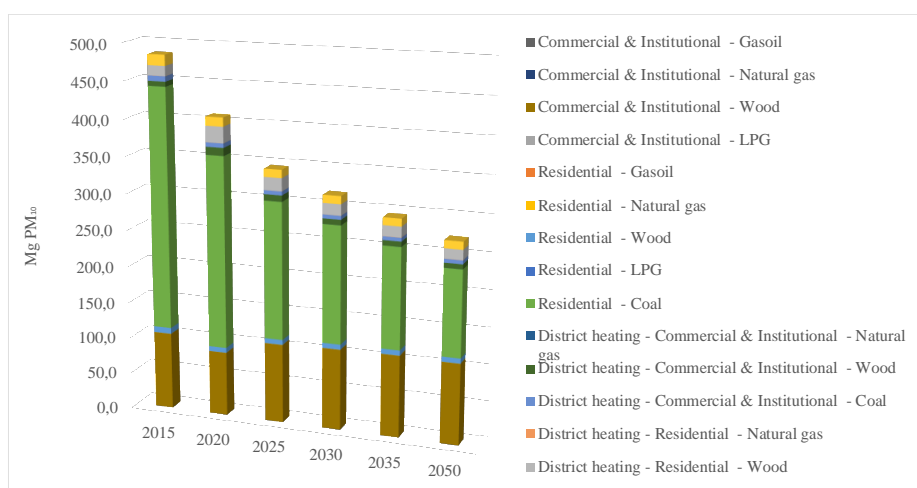
**Figure 3-36: Sosnowiec BAU & Scenarios comparison: Residential, Commercial & Institutional PM10 emissions – all sectors and fuels**

### 3.3.4 Unified Policy Scenario

In Figure 3-37 for nitrogen oxides (NO<sub>x</sub>) and Figure 3-38 for suspended particles with diameter less than 10 $\mu$  (PM<sub>10</sub>) the trends of emissions are reported for Unified Policy Scenario.

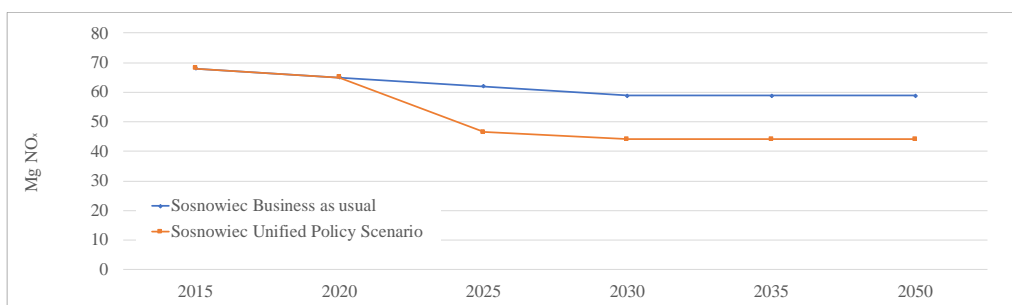


**Figure 3-37: Sosnowiec Unified Policy Scenario: Residential, Commercial & Institutional NOx emissions – all sectors and fuels**

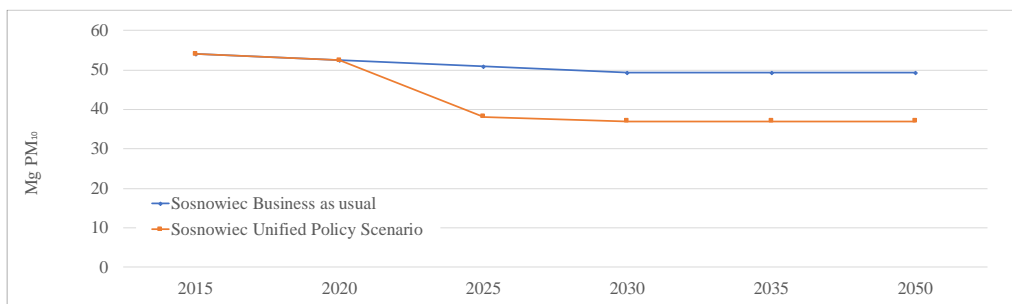


**Figure 3-38: Sosnowiec Unified Policy Scenario: Residential, Commercial & Institutional PM10 emissions – all sectors and fuels**

In Figure 3-39 for nitrogen oxides (NO<sub>x</sub>) and Figure 3-40 for suspended particles with diameter less than 10 $\mu$  (PM<sub>10</sub>) the trends of industrial emissions in the different scenarios are reported.

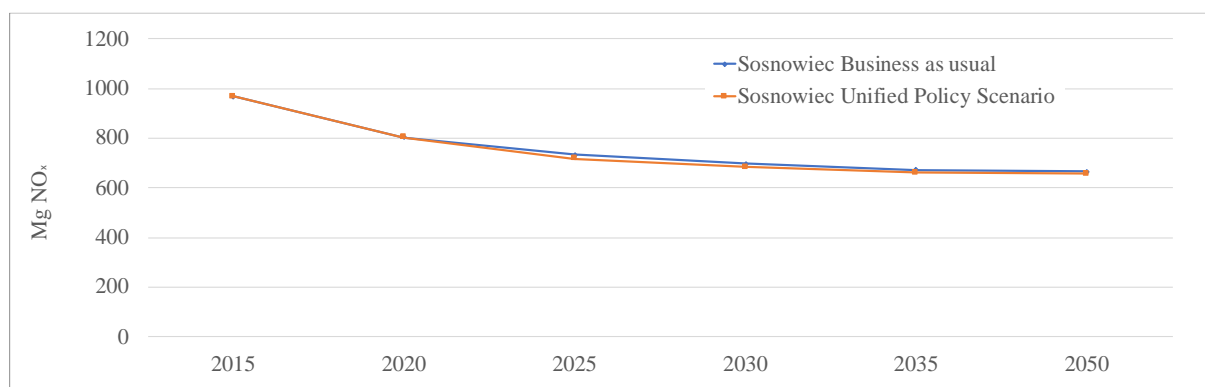


**Figure 3-39: Sosnowiec BAU & Unified Policy Scenario comparison: Industrial sources NOx emissions**

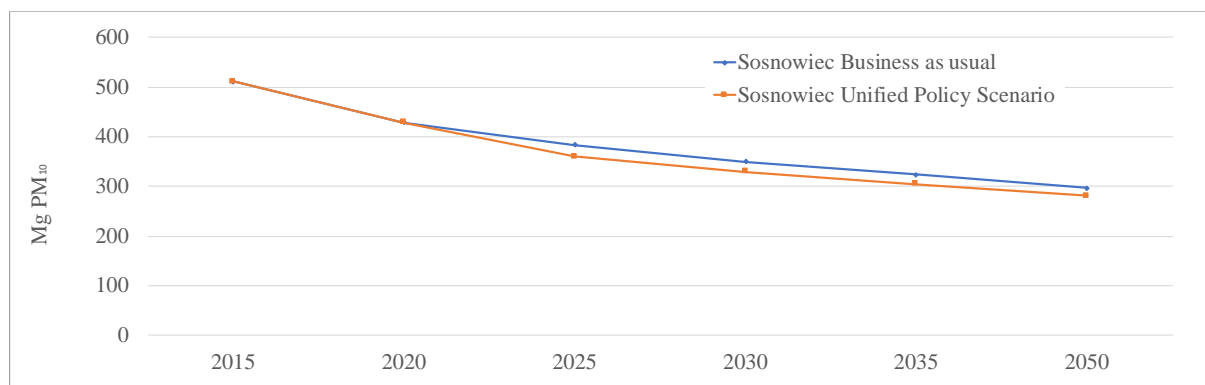


**Figure 3-40: Sosnowiec BAU & Unified Policy Scenario comparison: Industrial sources PM10 emissions**

In Figure 3-41 for nitrogen oxides (NO<sub>x</sub>) and in Figure 3-42 for suspended particles with diameter less than 10μ (PM<sub>10</sub>) the comparison of the trends of Residential, Commercial & Institutional emissions are reported for Business As Usual (BAU) and Unified Policy (UPS) scenarios.



**Figure 3-41: Sosnowiec BAU & Unified Policy Scenario comparison: Residential, Commercial & Institutional NOx emissions – all sectors and fuels**



**Figure 3-42: Sosnowiec BAU & Unified Policy Scenario comparison: Residential, Commercial & Institutional PM10 emissions – all sectors and fuel**

## 3.4 Carbon footprint

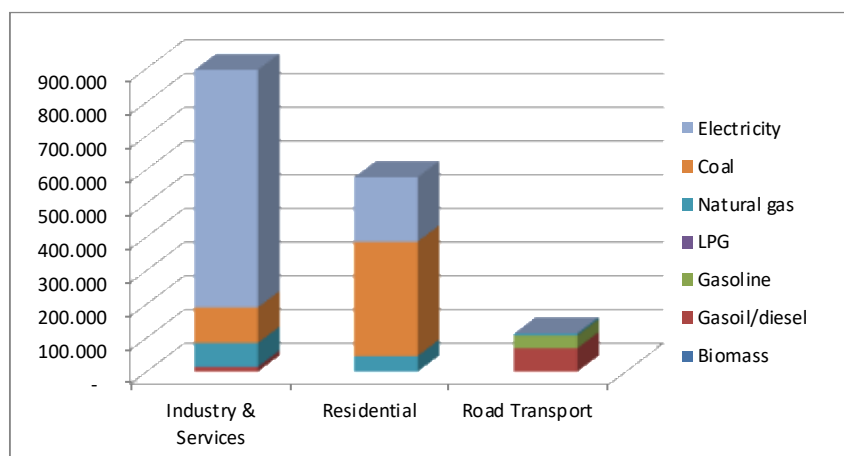
### 3.4.1 Baseline

In Table 3-3, the Carbon Footprint by fuel is reported for Sosnowiec expressed as CO<sub>2</sub>, CO<sub>2</sub> equivalent and CO<sub>2</sub> equivalent on Life Cycle.

**Table 3-3: Sosnowiec Carbon Footprint by Fuel (Mg)**

| Energy Vector | CO <sub>2</sub>  | CO <sub>2eq</sub> | CO <sub>2eq,LCA</sub> |
|---------------|------------------|-------------------|-----------------------|
| Biomass       | -                | 477               | 193                   |
| Gasoil/diesel | 74.085           | 84.868            | 74.285                |
| Gasoline      | 30.010           | 37.816            | 30.097                |
| LPG           | 772              | 956               | 772                   |
| Natural gas   | 103.449          | 122.996           | 103.449               |
| Coal          | 424.056          | 444.796           | 426.704               |
| Electricity   | 832.889          | 896.229           | 836.145               |
| <b>Total</b>  | <b>1.465.262</b> | <b>1.588.137</b>  | <b>1.471.644</b>      |

In figure below, the Carbon Footprint expressed as CO<sub>2</sub> equivalent on Life Cycle is reported by fuel and sector. The data source used reports aggregate values for industry and services fuel consumptions; in consequence also in carbon footprint the data are reported together.



**Figure 3-43: Sosnowiec Carbon Footprint (Mg CO<sub>2</sub> equivalent on Life Cycle)**

### 3.4.2 BAU

In Table 3-4 Carbon Footprint by sector is reported for Sosnowiec BAU expressed as CO<sub>2</sub>, CO<sub>2</sub> equivalent and CO<sub>2</sub> equivalent on Life Cycle. In Table 3-5 CO<sub>2</sub> equivalent on Life Cycle reductions on 2015 are reported.

**Table 3-4: Sosnowiec BAU Carbon Footprint by Sector (Gg)**

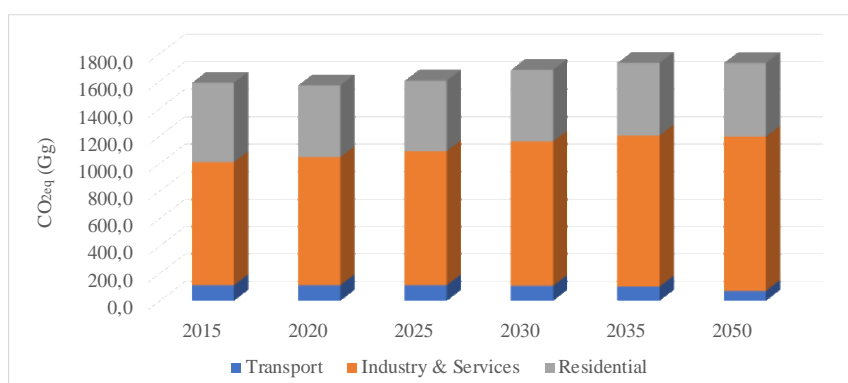
| Year  | 2015           | 2020           | 2025           | 2030           | 2035           | 2050           |
|---|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Carbon dioxide (CO<sub>2</sub>)</b>                            |                |                |                |                |                |                |
| Residential   | 540,3          | 487,5          | 477,9          | 485,6          | 491,6          | 497,1          |
| Services & Industry   | 828,4          | 861,8          | 901,5          | 971,0          | 1.016,0        | 1.037,5        |
| Transport   | 96,5           | 97,0           | 96,9           | 93,2           | 88,8           | 62,4           |
| <b>Total</b>  | <b>1.465,3</b> | <b>1.446,3</b> | <b>1.476,3</b> | <b>1.549,8</b> | <b>1.596,5</b> | <b>1.597,0</b> |
| <b>Carbon dioxide equivalent (CO<sub>2eq</sub>)</b>               |                |                |                |                |                |                |
| Residential   | 543,2          | 490,2          | 480,4          | 488,0          | 494,1          | 499,5          |
| Services & Industry   | 831,6          | 865,2          | 904,9          | 974,7          | 1.019,9        | 1.041,5        |
| Transport   | 96,8           | 97,2           | 97,2           | 93,5           | 89,1           | 62,5           |
| <b>Total</b>  | <b>1.471,6</b> | <b>1.452,5</b> | <b>1.482,5</b> | <b>1.556,3</b> | <b>1.603,0</b> | <b>1.603,6</b> |
| <b>Carbon dioxide equivalent on life cycle (CO<sub>2eq</sub>)</b> |                |                |                |                |                |                |
| Residential   | 577,5          | 522,6          | 512,9          | 521,4          | 528,7          | 534,8          |

|              |                |                |                |                |                |                |
|--------------|----------------|----------------|----------------|----------------|----------------|----------------|
| Services     | 896,4          | 932,7          | 975,8          | 1.050,7        | 1.099,4        | 1.122,6        |
| Transport    | 114,2          | 114,7          | 114,7          | 110,2          | 105,0          | 73,4           |
| <b>Total</b> | <b>1.588,1</b> | <b>1.570,0</b> | <b>1.603,3</b> | <b>1.682,3</b> | <b>1.733,1</b> | <b>1.730,9</b> |

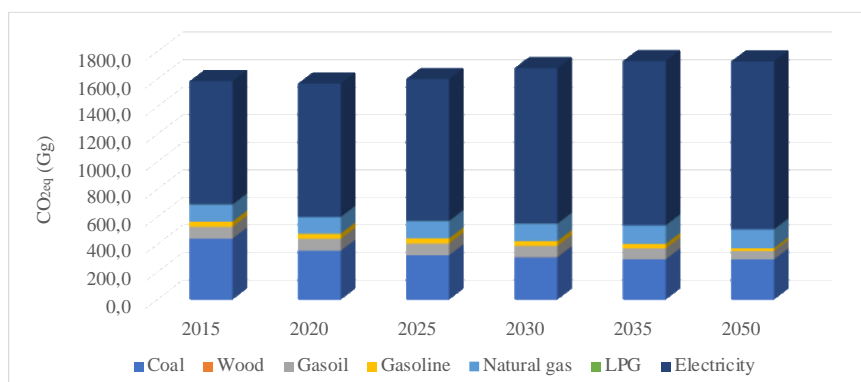
**Table 3-5: Sosnowiec BAU Carbon Footprint by Sector: index (2015=100)**

| Year  | 2015       | 2020      | 2025       | 2030       | 2035       | 2050       |
|---|------------|-----------|------------|------------|------------|------------|
| <b>Carbon dioxide equivalent on life cycle (CO<sub>2eq</sub>)</b> |            |           |            |            |            |            |
| Residential   | 100        | 90        | 89         | 90         | 92         | 93         |
| Services  | 100        | 104       | 109        | 117        | 123        | 125        |
| Transport   | 100        | 100       | 100        | 97         | 92         | 64         |
| <b>Total</b>  | <b>100</b> | <b>99</b> | <b>101</b> | <b>106</b> | <b>109</b> | <b>109</b> |

Carbon Footprint, expressed as CO<sub>2</sub> equivalent on Life Cycle, is reported in Figure 3-44 by sector and in Figure 3-45 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 3-44: Sosnowiec BAU Carbon Footprint by sector (Gg CO<sub>2</sub> equivalent on Life Cycle)**



**Figure 3-45: Sosnowiec BAU Carbon Footprint by fuel (Gg CO<sub>2</sub> 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 Sosnowiec Scenario *low* expressed as CO<sub>2</sub>, CO<sub>2</sub> equivalent and CO<sub>2</sub> equivalent on Life Cycle. In Table 3-7 CO<sub>2</sub> equivalent on Life Cycle reductions on 2015 are reported.

**Table 3-6: Sosnowiec Scenario low Carbon Footprint by Sector (Gg)**

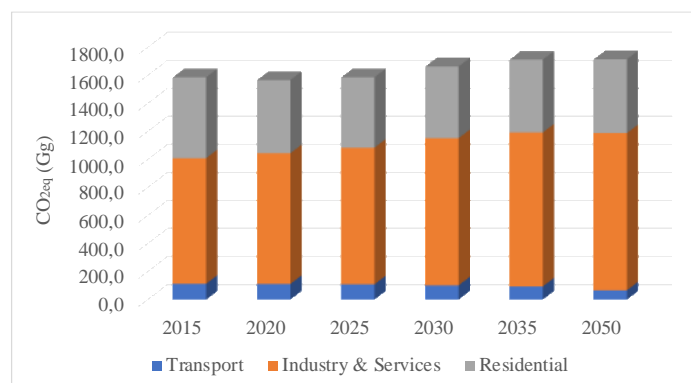
| Year  | 2015           | 2020           | 2025           | 2030           | 2035           | 2050           |
|---|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Carbon dioxide (CO<sub>2</sub>)</b>              |                |                |                |                |                |                |
| Residential   | 540,3          | 487,5          | 468,2          | 476,7          | 483,4          | 489,3          |
| Services & Industry                                 | 828,4          | 861,8          | 900,7          | 970,3          | 1.015,4        | 1.036,9        |
| Transport   | 96,5           | 95,1           | 93,3           | 87,0           | 80,3           | 57,5           |
| <b>Total</b>  | <b>1.465,3</b> | <b>1.444,4</b> | <b>1.462,1</b> | <b>1.534,1</b> | <b>1.579,1</b> | <b>1.583,8</b> |
| <b>Carbon dioxide equivalent (CO<sub>2</sub>eq)</b> |                |                |                |                |                |                |
| Residential   | 543,2          | 490,2          | 470,6          | 479,1          | 485,8          | 491,7          |
| Services & Industry                                 | 831,6          | 865,2          | 904,2          | 974,0          | 1.019,2        | 1.040,9        |
| Transport   | 96,8           | 95,3           | 93,5           | 87,2           | 80,6           | 57,6           |
| <b>Total</b>  | <b>1.471,6</b> | <b>1.450,6</b> | <b>1.468,3</b> | <b>1.540,4</b> | <b>1.585,6</b> | <b>1.590,3</b> |

| Carbon dioxide equivalent on life cycle (CO <sub>2eq</sub> ) |                |                |                |                |                |                |
|--|----------------|----------------|----------------|----------------|----------------|----------------|
| Residential  | 577,5          | 522,6          | 502,7          | 512,1          | 520,1          | 526,7          |
| Services & Industry  | 896,4          | 932,7          | 975,0          | 1.049,9        | 1.098,7        | 1.122,0        |
| Transport  | 114,2          | 112,5          | 110,2          | 102,8          | 94,8           | 67,5           |
| <b>Total</b>   | <b>1.588,1</b> | <b>1.567,7</b> | <b>1.587,9</b> | <b>1.664,8</b> | <b>1.713,6</b> | <b>1.716,2</b> |

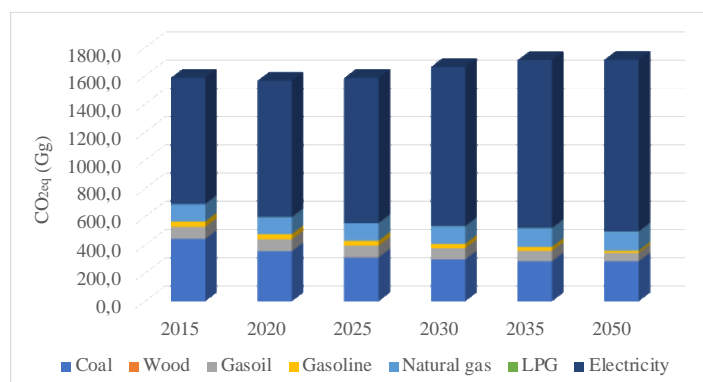
**Table 3-7: Sosnowiec Scenario low Carbon Footprint by Sector: index (2015=100)**

| Year   | 2015       | 2020      | 2025       | 2030       | 2035       | 2050       |
|--|------------|-----------|------------|------------|------------|------------|
| Carbon dioxide equivalent on life cycle (CO <sub>2eq</sub> ) |            |           |            |            |            |            |
| Residential  | 100        | 90        | 87         | 89         | 90         | 91         |
| Services   | 100        | 104       | 109        | 117        | 123        | 125        |
| Transport  | 100        | 98        | 97         | 90         | 83         | 59         |
| <b>Total</b>   | <b>100</b> | <b>99</b> | <b>100</b> | <b>105</b> | <b>108</b> | <b>108</b> |

For the Scenario 1, Carbon Footprint, expressed as CO<sub>2</sub> equivalent on Life Cycle, is reported in Figure 3-46 by sector and in Figure 3-47 by fuel.



**Figure 3-46: Sosnowiec Scenario *low* Carbon Footprint by sector (Gg CO<sub>2</sub> equivalent on Life Cycle)**



**Figure 3-47: Sosnowiec Scenario *low* Carbon Footprint by fuel (Gg CO<sub>2</sub> equivalent on Life Cycle)**

In Table 3-8 Carbon Footprint by sector is reported for Sosnowiec Scenario high expressed as CO<sub>2</sub>, CO<sub>2</sub> equivalent and CO<sub>2</sub> equivalent on Life Cycle. In Table 3-9 CO<sub>2</sub> equivalent on Life Cycle reductions on 2015 are reported.

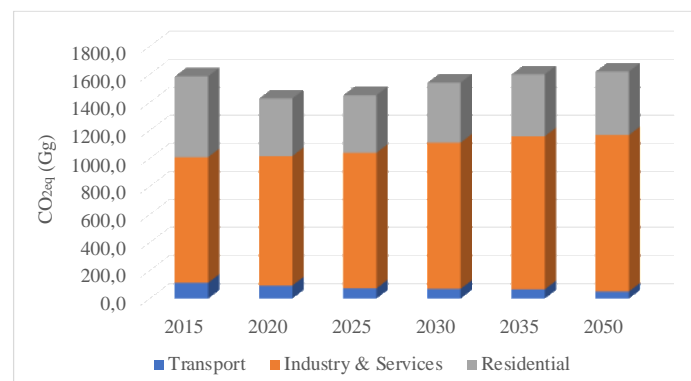
**Table 3-8: Sosnowiec Scenario high Carbon Footprint by Sector (Gg)**

| Year  | 2015           | 2020           | 2025           | 2030           | 2035           | 2050           |
|---|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Carbon dioxide (CO<sub>2</sub>)</b>                            |                |                |                |                |                |                |
| Residential   | 540,3          | 381,3          | 380,5          | 396,9          | 409,2          | 419,6          |
| Services & Industry   | 828,4          | 853,5          | 893,8          | 964,0          | 1.009,5        | 1.031,4        |
| Transport   | 96,5           | 80,0           | 63,3           | 60,4           | 57,3           | 44,7           |
| <b>Total</b>  | <b>1.465,3</b> | <b>1.314,8</b> | <b>1.337,6</b> | <b>1.421,3</b> | <b>1.476,0</b> | <b>1.495,8</b> |
| <b>Carbon dioxide equivalent (CO<sub>2eq</sub>)</b>               |                |                |                |                |                |                |
| Residential   | 543,2          | 383,3          | 382,4          | 398,8          | 411,1          | 421,6          |
| Services & Industry   | 831,6          | 856,7          | 897,2          | 967,7          | 1.013,4        | 1.035,4        |
| Transport   | 96,8           | 80,2           | 63,5           | 60,5           | 57,5           | 44,8           |
| <b>Total</b>  | <b>1.471,6</b> | <b>1.320,3</b> | <b>1.343,1</b> | <b>1.427,1</b> | <b>1.481,9</b> | <b>1.501,8</b> |
| <b>Carbon dioxide equivalent on life cycle (CO<sub>2eq</sub>)</b> |                |                |                |                |                |                |
| Residential   | 577,5          | 411,2          | 410,7          | 428,4          | 442,3          | 453,6          |
| Services & Industry   | 896,4          | 923,9          | 967,8          | 1.043,4        | 1.092,6        | 1.116,2        |
| Transport   | 114,2          | 94,2           | 74,2           | 70,6           | 67,1           | 52,1           |
| <b>Total</b>  | <b>1.588,1</b> | <b>1.429,4</b> | <b>1.452,6</b> | <b>1.542,4</b> | <b>1.601,9</b> | <b>1.621,9</b> |

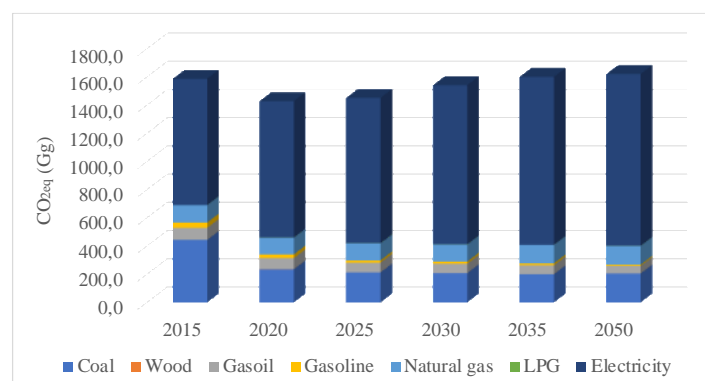
**Table 3-9: Sosnowiec Scenario high Carbon Footprint by Sector: index (2015=100)**

| Year  | 2015       | 2020      | 2025      | 2030      | 2035       | 2050       |
|---|------------|-----------|-----------|-----------|------------|------------|
| <b>Carbon dioxide equivalent on life cycle (CO<sub>2eq</sub>)</b> |            |           |           |           |            |            |
| Residential   | 100        | 71        | 71        | 74        | 77         | 79         |
| Services & Industry   | 100        | 103       | 108       | 116       | 122        | 125        |
| Transport   | 100        | 82        | 65        | 62        | 59         | 46         |
| <b>Total</b>  | <b>100</b> | <b>90</b> | <b>91</b> | <b>97</b> | <b>101</b> | <b>102</b> |

For the Scenario high, Carbon Footprint, expressed as CO<sub>2</sub> equivalent on Life Cycle, is reported in Figure 3-48 by sector and in Figure 3-49 by fuel.



**Figure 3-48: Sosnowiec Scenario *high* Carbon Footprint by sector (Gg CO<sub>2</sub> equivalent on Life Cycle)**



**Figure 3-49: Sosnowiec Scenario *high* Carbon Footprint by fuel (Gg CO<sub>2</sub> equivalent on Life Cycle)**

### 3.4.4 Unified Policy Scenario

In Table 3-10 Carbon Footprint by sector is reported for Sosnowiec Unified Policy Scenario expressed as CO<sub>2</sub>, CO<sub>2</sub> equivalent and CO<sub>2</sub> equivalent on Life Cycle. In Table 3-11 CO<sub>2</sub> equivalent on Life Cycle reductions on 2015 are reported.

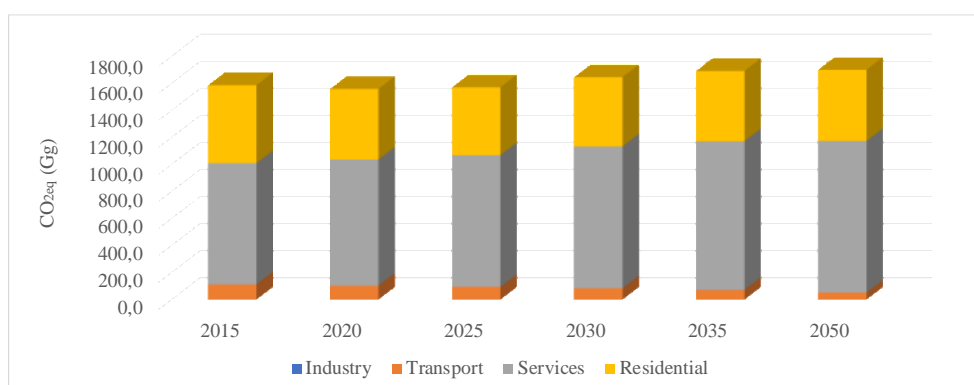
**Table 3-10: Sosnowiec Unified Policy Scenario Carbon Footprint by Sector (Gg)**

| Year  | 2015           | 2020           | 2025           | 2030           | 2035           | 2050           |
|---|----------------|----------------|----------------|----------------|----------------|----------------|
| <b>Carbon dioxide (CO<sub>2</sub>)</b>                            |                |                |                |                |                |                |
| Residential   | 540,3          | 487,5          | 468,2          | 476,7          | 483,4          | 489,3          |
| Services & Industry   | 828,4          | 861,8          | 900,7          | 970,3          | 1.015,4        | 1.036,9        |
| Transport   | 96,5           | 89,0           | 81,0           | 72,6           | 63,8           | 45,9           |
| <b>Total</b>  | <b>1.465,3</b> | <b>1.438,3</b> | <b>1.449,9</b> | <b>1.519,7</b> | <b>1.562,6</b> | <b>1.572,1</b> |
| <b>Carbon dioxide equivalent (CO<sub>2eq</sub>)</b>               |                |                |                |                |                |                |
| Residential   | 543,2          | 490,2          | 470,6          | 479,1          | 485,8          | 491,7          |
| Services & Industry   | 831,6          | 865,2          | 904,2          | 974,0          | 1.019,2        | 1.040,9        |
| Transport   | 96,8           | 89,2           | 81,2           | 72,8           | 64,0           | 46,0           |
| <b>Total</b>  | <b>1.471,6</b> | <b>1.444,5</b> | <b>1.456,0</b> | <b>1.526,0</b> | <b>1.569,0</b> | <b>1.578,6</b> |
| <b>Carbon dioxide equivalent on life cycle (CO<sub>2eq</sub>)</b> |                |                |                |                |                |                |
| Residential   | 577,5          | 522,6          | 502,7          | 512,1          | 520,1          | 526,7          |
| Services & Industry   | 896,4          | 932,7          | 975,0          | 1.049,9        | 1.098,7        | 1.122,0        |
| Transport   | 114,2          | 105,1          | 95,5           | 85,5           | 74,9           | 53,5           |
| <b>Total</b>  | <b>1.588,1</b> | <b>1.560,4</b> | <b>1.573,2</b> | <b>1.647,5</b> | <b>1.693,7</b> | <b>1.702,2</b> |

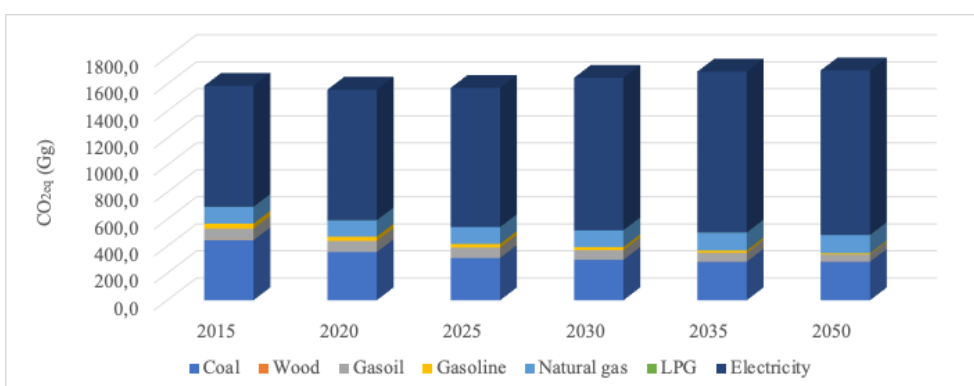
**Table 3-11: Sosnowiec Unified Policy Scenario Carbon Footprint by Sector: index (2015=100)**

| Year  | 2015       | 2020      | 2025      | 2030      | 2035      | 2050      |
|---|------------|-----------|-----------|-----------|-----------|-----------|
| <b>Carbon dioxide equivalent on life cycle (CO<sub>2eq</sub>)</b> |            |           |           |           |           |           |
| Residential   | 100        | 90        | 87        | 89        | 90        | 91        |
| Services & Industry   | 100        | 104       | 109       | 117       | 123       | 125       |
| Transport   | 100        | 92        | 84        | 75        | 66        | 47        |
| Industry  | 100        | 98        | 99        | 104       | 107       | 107       |
| <b>Total</b>  | <b>100</b> | <b>90</b> | <b>87</b> | <b>89</b> | <b>90</b> | <b>91</b> |

For the Unified Policy Scenario, Carbon Footprint, expressed as CO<sub>2</sub> equivalent on Life Cycle, is reported in Figure 3-50 by sector and in Figure 3-51 by fuel.

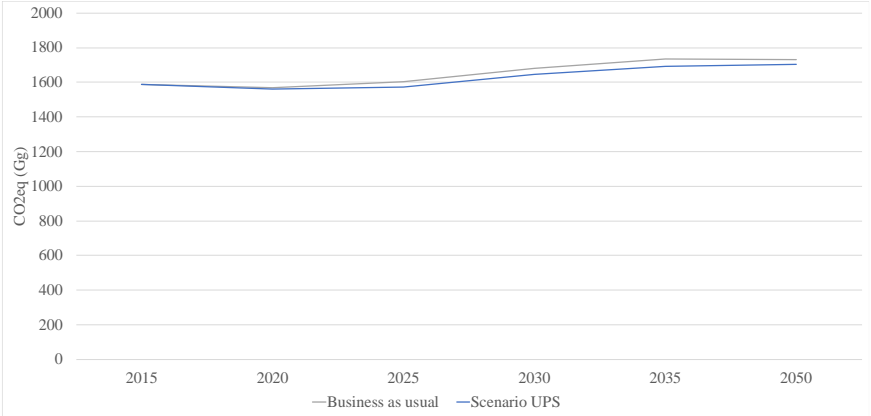


**Figure 3-50: Sosnowiec Unified Policy Scenario Carbon Footprint by sector (Gg CO<sub>2</sub> equivalent on Life Cycle)**



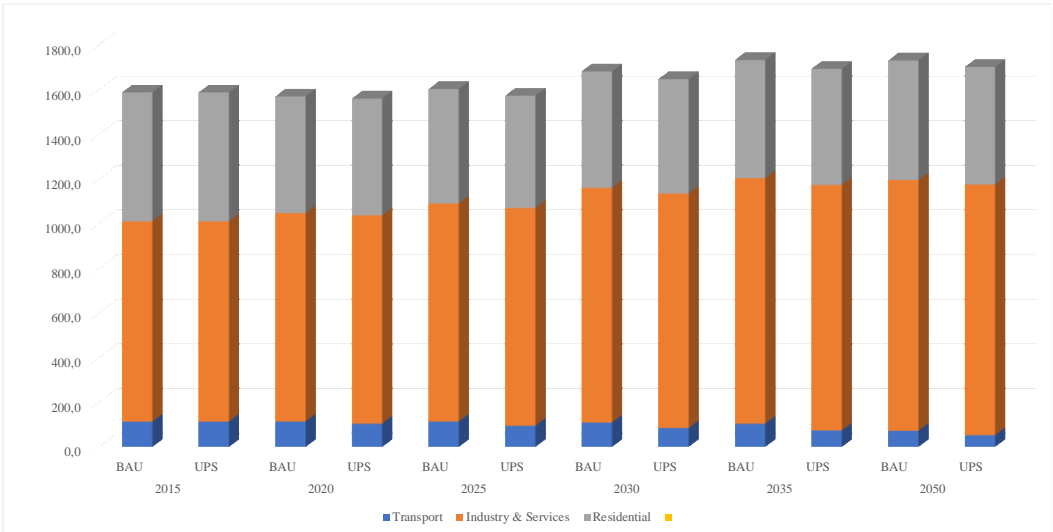
**Figure 3-51: Sosnowiec Unified Policy Scenario Carbon Footprint by fuel (Gg CO<sub>2</sub> equivalent on Life Cycle)**

Total Carbon Footprint in the business as usual (BAU) and unified policy scenario (UPS) is compared in Figure 3-52 expressed as CO<sub>2</sub> equivalent on Life Cycle. Finally, in Figure 3-55 Sosnowiec Carbon Footprint on life cycle generated by citizens' activities is reported in BAU and UPS scenario.

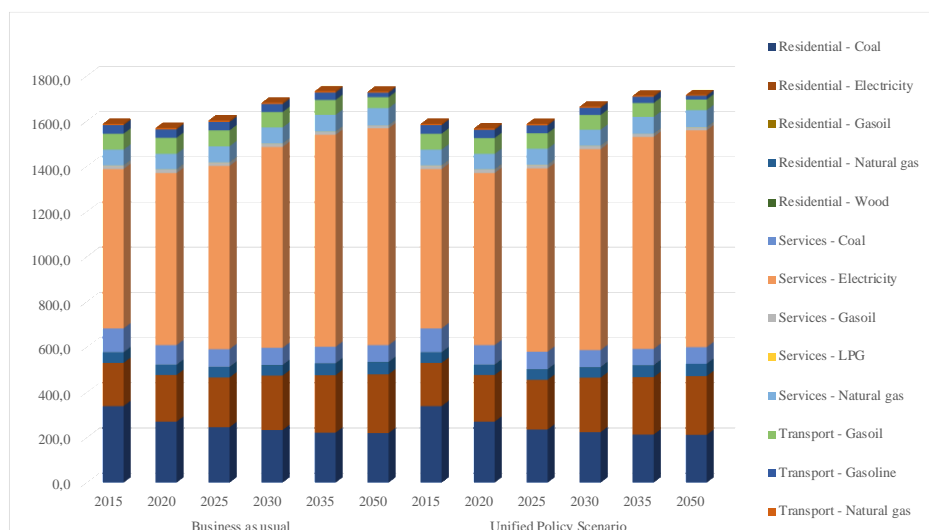


**Figure 3-52: Sosnowiec Carbon Footprint (Mg CO<sub>2</sub> equivalent on Life Cycle) by BAU scenario and final unified scenario**

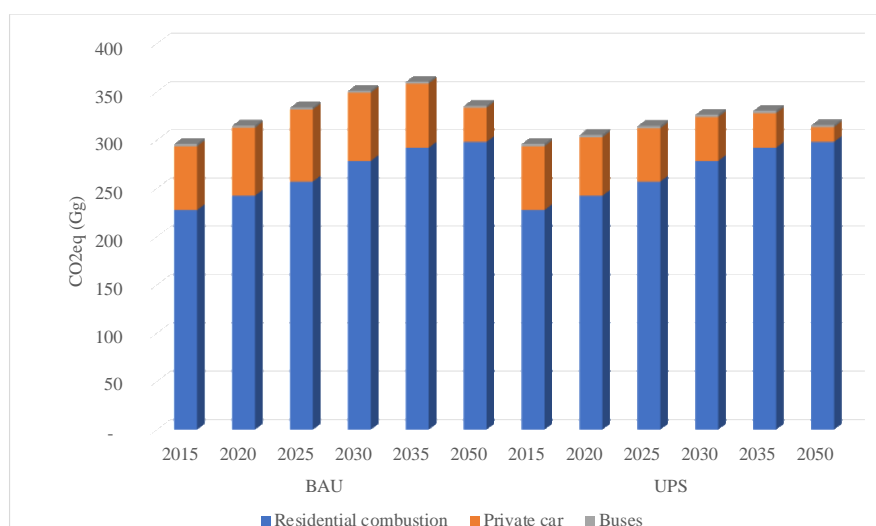
In Figure 3-53 results are reported by sector and in Figure 3-54 by sector and fuel. Finally, in Figure 3-55 Carbon Footprint on life cycle generated by citizens' activities is reported in BAU and UPS scenario.



**Figure 3-53: Sosnowiec Carbon Footprint BAU and UPS comparison by sector (Mg CO<sub>2</sub> equivalent on Life Cycle)**



**Figure 3-54: Sosnowiec Carbon Footprint BAU and UPS comparison by sector and fuel (Mg CO<sub>2</sub> equivalent on Life Cycle)**



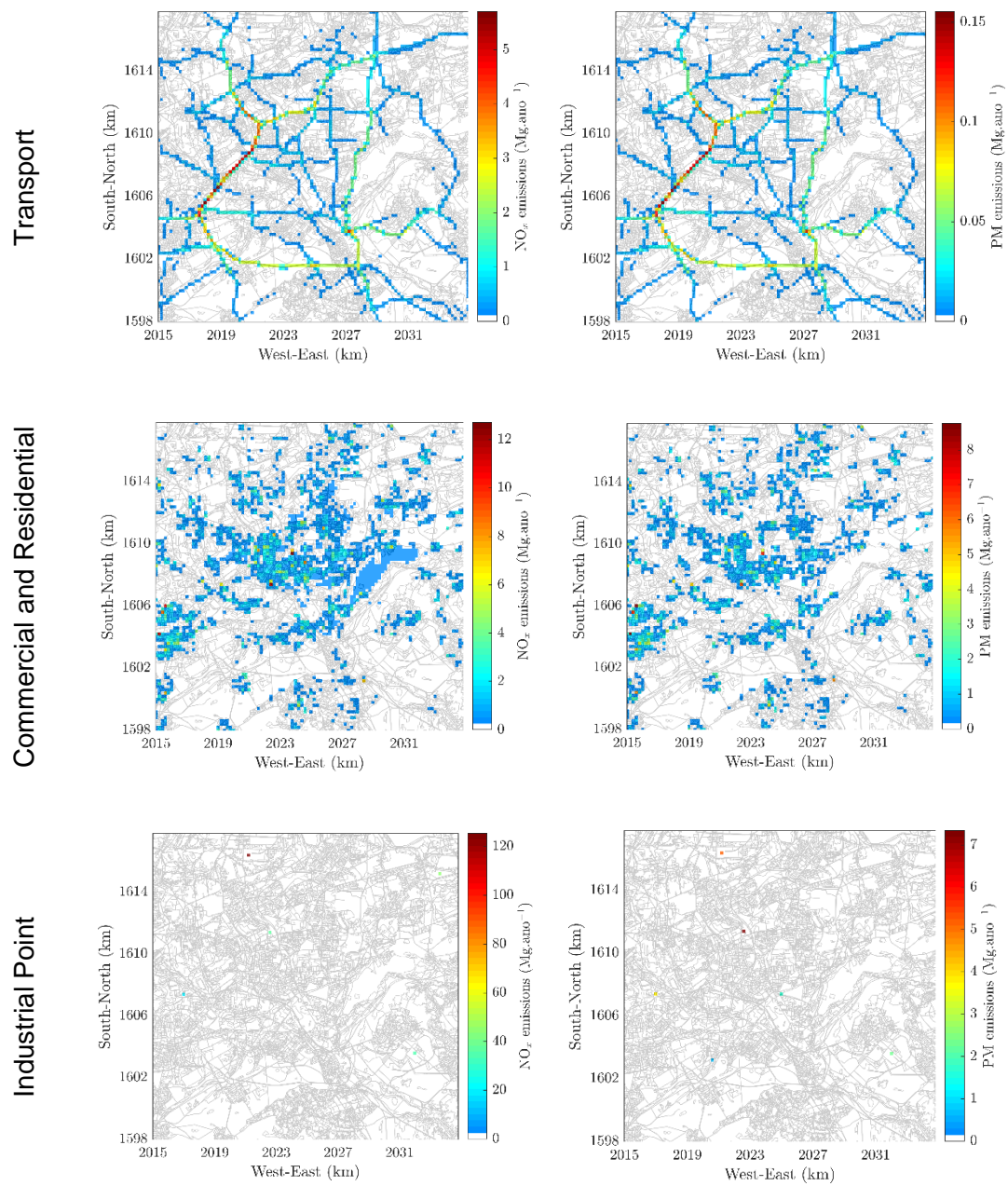
**Figure 3-55: Sosnowiec Carbon Footprint generated by citizens' activities in BAU and UPS scenario (Mg CO<sub>2</sub> equivalent on Life Cycle)**

## 3.5 Air quality impacts

### 3.5.1 Annual emissions input

Air quality simulations, start from the spatiotemporally distributed emissions from all the sources described in the previous section. Figure 3-56 shows the emission values for NO<sub>x</sub> and PM in Mg.year<sup>-1</sup> for each sector.

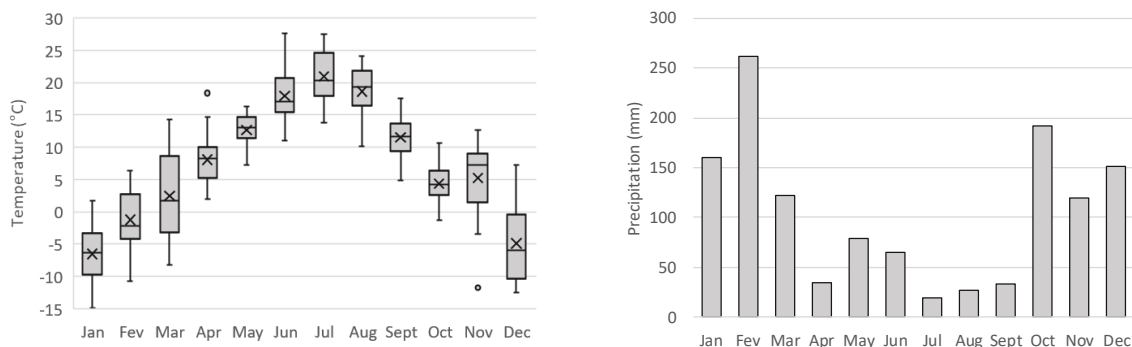
|  | NO <sub>x</sub> | PM |
|--|-----------------|----|
|  |                 |    |



**Figure 3-56: Emission values for NO<sub>x</sub> and PM by sector, in Mg.year<sup>-1</sup>**

### 3.5.2 Assessment of air quality at mesoscale: baseline year

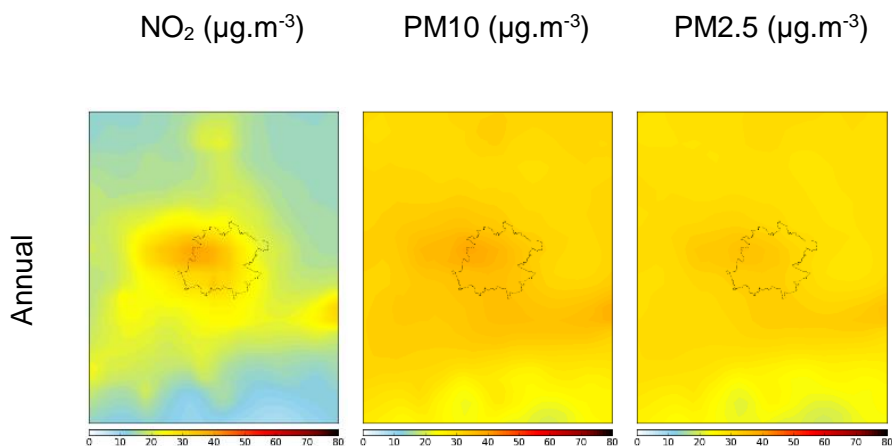
The meteorological characterization in Sosnowiec, at mesoscale, was based on the analysis of the spatial average of the following variables: temperature, precipitation and wind speed and direction. The mean air temperatures and accumulated temperature, for each month, are presented in Figure 3-57.

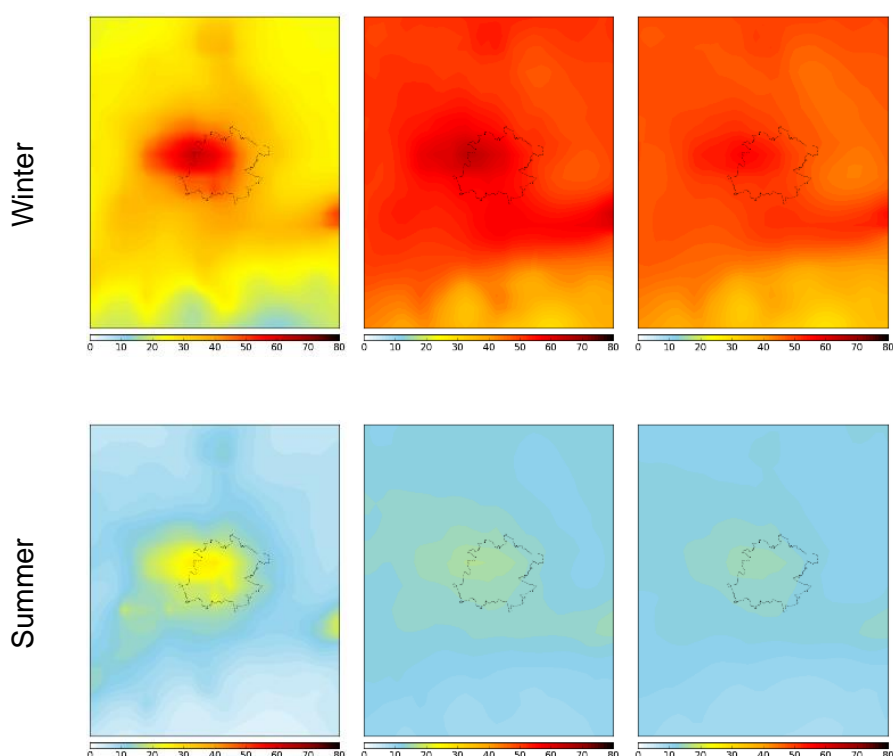


**Figure 3-57: (Left) Box and whisker plot of temperature by month; boxes indicate the lower and upper quartile; horizontal line in each box represents the median temperature; the mean temperature for each month is indicated by a x; vertical lines extending from each**

According to Figure 3-57, in Sosnowiec, the minimum mean temperatures are obtained in January, December and February, with  $-6.5^{\circ}\text{C}$ ,  $-4.9^{\circ}\text{C}$  and  $-1.2^{\circ}\text{C}$ , respectively. The month where the highest mean temperature is recorded is July, with  $18.3^{\circ}\text{C}$ , followed by August, with  $15.8^{\circ}\text{C}$ . Regarding precipitation, the months with the highest accumulated precipitation go from October to March (with values from 120 to 260 mm), while the driest month is July with 20 mm. During almost the whole year, the prevailing winds from the 3<sup>rd</sup> quadrant (SW), with a wind speed between 2 and 10  $\text{m.s}^{-1}$ .

The air quality characterization in Sosnowiec, at mesoscale, was based on concentrations fields and on a source contribution analysis. The spatial analysis was done for the average concentrations of  $\text{NO}_2$ ,  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  for the following periods: (i) annual; (ii) a typical winter month (February); and (iii) a typical summer month (August) (Figure 3-58).





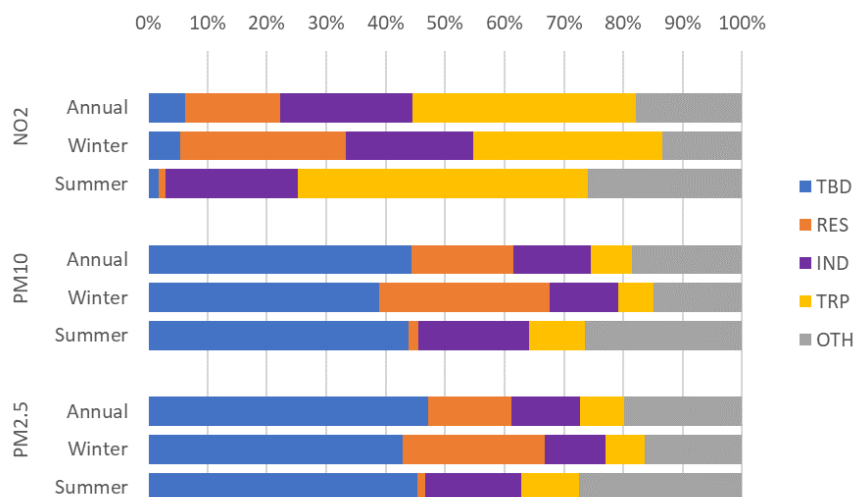
**Figure 3-58: Spatial distribution of NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations, for the different periods analysed (annual, winter and summer) in Sosnowiec.**

For each pollutant, NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub>, results presented in Figure 3-58 show similar spatial patterns for the different periods and pollutants analysed. For all pollutants, the highest concentration values are found northwest of Sosnowiec and the lowest values in the southern region 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<sub>2</sub>, the highest concentration values, for annual, winter and summer periods are 40  $\mu\text{g.m}^{-3}$ , 63  $\mu\text{g.m}^{-3}$  and 28  $\mu\text{g.m}^{-3}$ , respectively. For PM<sub>10</sub>, the maximum concentration values are close to 46  $\mu\text{g.m}^{-3}$ , for the annual average, 71  $\mu\text{g.m}^{-3}$  in winter and 26  $\mu\text{g.m}^{-3}$  in summer. For PM<sub>2.5</sub>, the highest concentration values are 35  $\mu\text{g.m}^{-3}$ , 56  $\mu\text{g.m}^{-3}$  and 15  $\mu\text{g.m}^{-3}$  for annual, winter and summer periods, respectively.

The source contribution analysis was provided to estimate the contribution to the modelled NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> 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<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentration simulated for the urban area of Sosnowiec, which was the receptor area defined in the PSAT application.

The contribution of each source group for NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations, in the urban area of Sosnowiec for the three periods previously defined, are analysed in Figure 3-59.



**Figure 3-59: Annual, winter and summer averages contribution for each source group for NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations, for Sosnowiec urban area; (TBD- transboundary transport, RES - residential and commercial combustion, IND - industrial combustion and processes, TRP - road transport and OTH - all the remaining sources).**

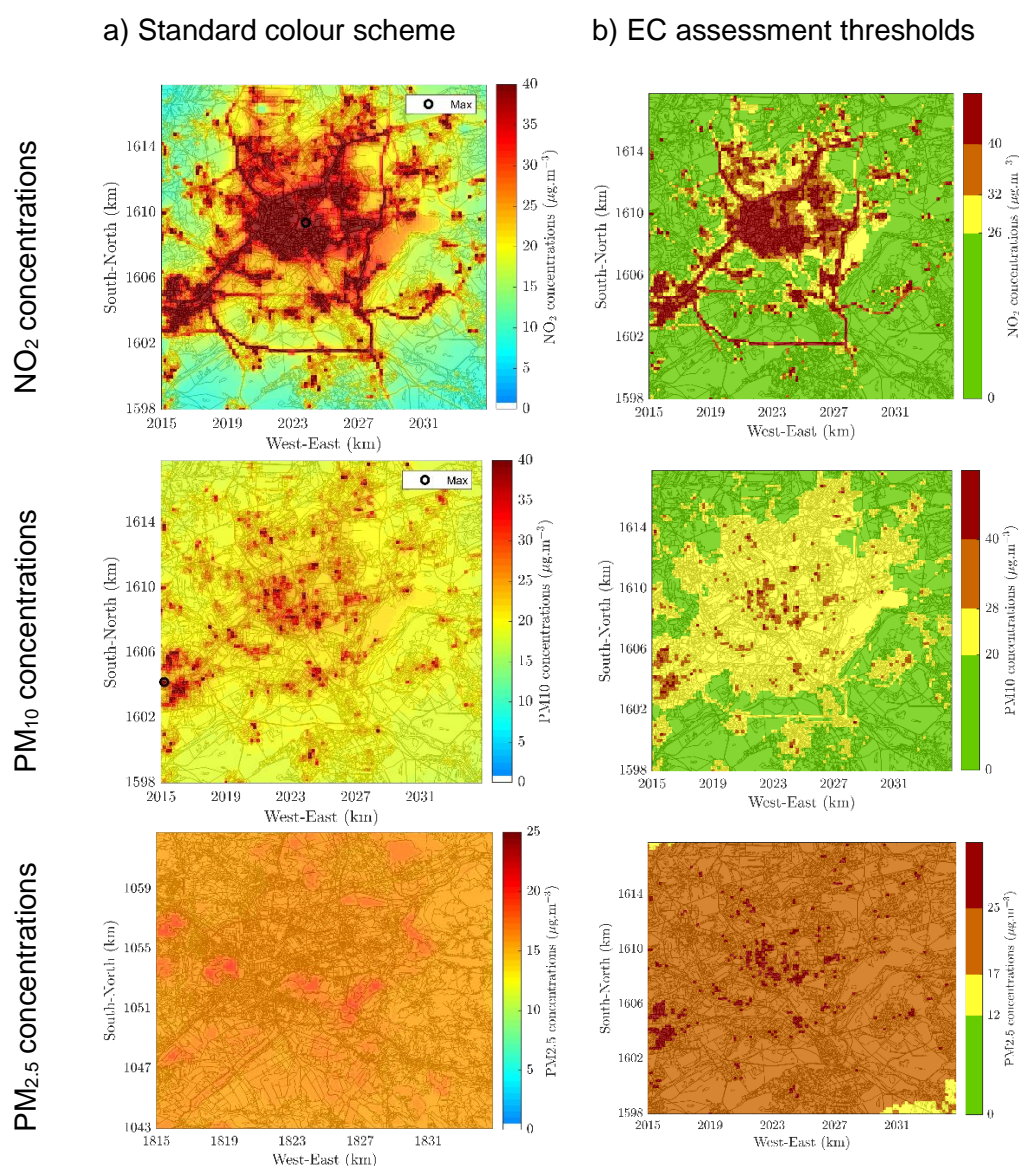
The average annual contributions of each source group reveal that, for NO<sub>2</sub>, the largest contribution is from TRP, followed by IND and RES. While RES presents higher values in the winter, TRP and IND remains almost unchanged in the three analysed periods.

For PM<sub>10</sub>, the annual average contributions of each source group reveal that one of the major contributions is from TBD (44%), highlighting the importance of transboundary transport for the PM<sub>10</sub> pollution in the study region. Source contribution results also point to a great influence of the contribution of different human activities, such as residential and commercial combustion and industrial combustion and processes, to the PM<sub>10</sub> levels, with the residential commercial combustion being higher in the winter period and the industrial combustion and processes in the summer period. For PM<sub>2.5</sub>, the analysis is similar to that of PM<sub>10</sub>.

Although the other sources (OTH) have a significant contribution for NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> 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 3-60 shows, for the baseline year, the annual average of NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations simulated by the urban scale model URBAIR, including the background concentrations and the adjustment factor. For each pollutant two colour 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<sub>2</sub> the lower assessment threshold (LAT) is 26 and the upper assessment threshold (UAT) is 32. For PM<sub>10</sub> the LAT value is 20 and the UAT value is 28, and for PM<sub>2.5</sub> the LAT value is 12 and the UAT value is 17.

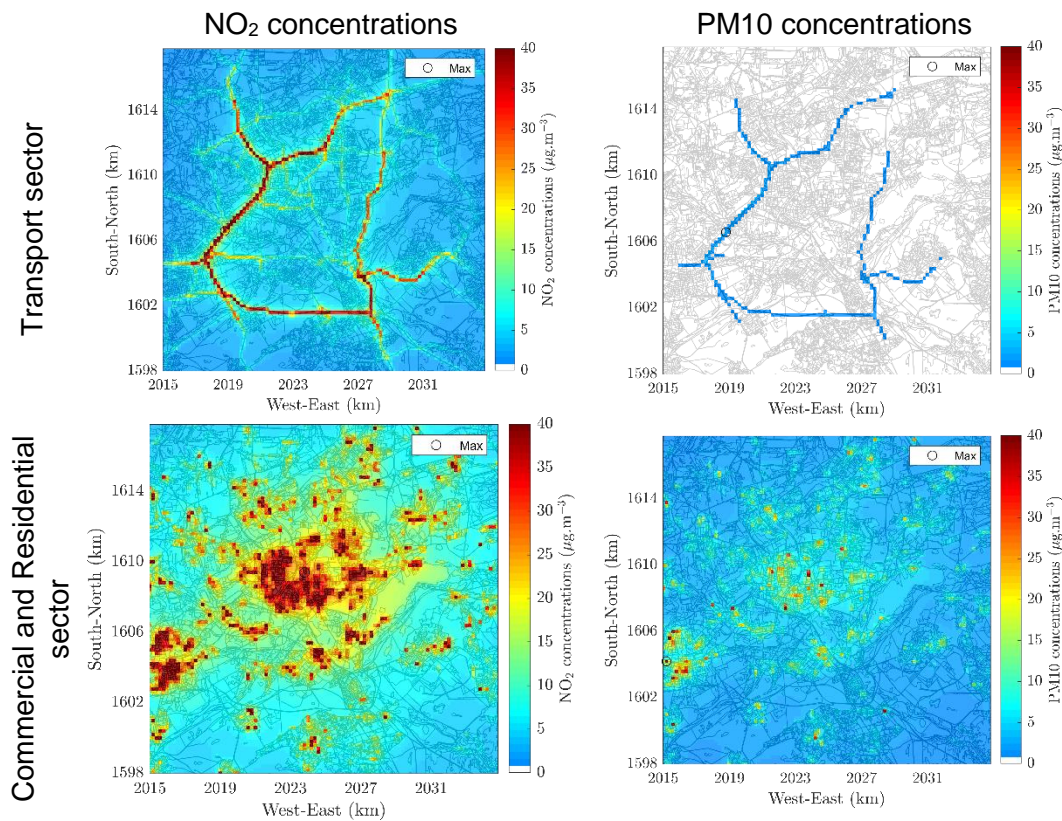


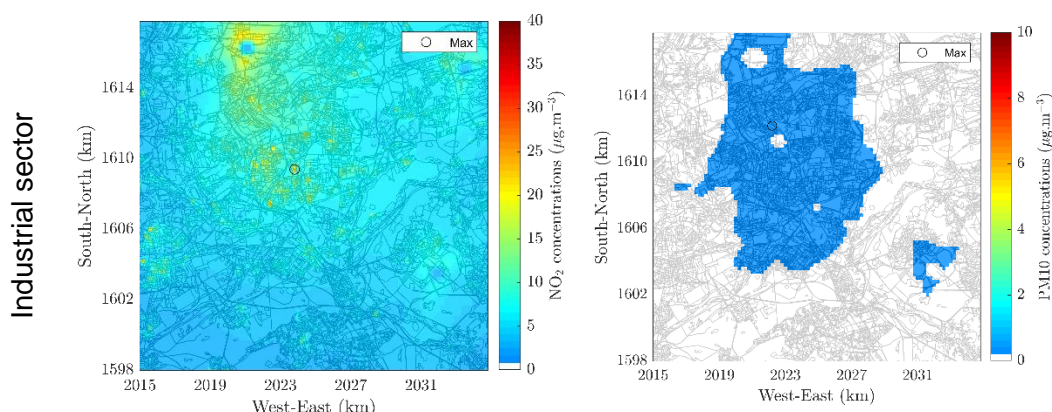
**Figure 3-60: Annual average of the NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations, including the background concentrations and the adjustment factor. a) using a standard colour scheme, and b) using a customized colour scheme based on the EC assessment thresholds**

The maximum value of the annual NO<sub>2</sub> concentrations in 2015 is equal to 207.7  $\mu\text{g.m}^{-3}$  and is located within the urban area (as indicated on the map). The main sector contributing to that maximum value is the residential and commercial, with a contribution of 85.8, followed by the industrial sector with a contribution of 11.4%, and the road transport sector with a contribution of 2.8 %. These contributions are obtained from the source apportionment analysis. The average value of the NO<sub>2</sub> concentrations over the entire domain is equal to 24.3 and the source apportionment analysis indicates that transport is contributing with 22.5%, industrial sector with 24.8% and the residential and commercial sector with 52.7% to the simulated concentrations.

The maximum value of the annual  $PM_{2.5}$  concentrations in 2015 is equal to  $62.1 \mu g.m^{-3}$  and is located within the urban area (indicated on the map). A source apportionment analysis to the cell where the maximum annual value is simulated presents a contribution of 0.1% from transport sector, 0.2% from the industrial and 99.7% from the residential and commercial sector. The average value over the entire domain is equal to  $19.3 \mu g.m^{-3}$ . For  $PM_{2.5}$  concentrations average over all the domain a source apportionment analysis allowed to determine the contribution of each sector, which indicates transport is contributing with 2.2%, industrial sector with 4.1% and the residential and commercial sector with 93.7%.

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 3-61 shows the final adjusted concentration maps for each emission sector for  $NO_2$  and  $PM_{10}$ , without adding the background. For each sector and pollutant, the maximum simulated concentration is located on the map.





**Figure 3-61: Air quality maps for NO<sub>2</sub> 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<sub>2.5</sub> concentrations maps will be the same as PM<sub>10</sub> concentration maps. For transport, the emission is different due to different PM<sub>10</sub>/PM<sub>2.5</sub> 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<sub>2.5</sub> are simulated. For transport, the maximum value simulated for PM<sub>10</sub> is 3.0 µg.m<sup>-3</sup> and for PM<sub>2.5</sub> is 1.2 µg.m<sup>-3</sup>.

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<sub>2</sub> concentrations (with the background concentrations and the adjustment factor) and the sector contribution for all the monitoring sites.

**Table 3-12: Comparison between the measurements and the simulated NO<sub>2</sub> concentrations (with the background concentrations and the adjustment factor) and contribution of each sector to the simulated values.**

| Station |                  | NO <sub>2</sub> concentrations |           | Contribution by sector for the corresponding cell (%) |                   |                      |
|---------|------------------|--------------------------------|-----------|---|-------------------|----------------------|
| ID      | Station type     | Measurement                    | Simulated | Transport sector                                      | Industrial sector | Com. and Res. Sector |
| PL0237A | Urban Background | 30.0                           | 27.3      | 13.0  | 26.6              | 60.4                 |
| PL0529A | Urban Background | 25.8                           | 45.2      | 12.5  | 18.3              | 69.2                 |
| PL0567A | Urban Traffic    | 58.3                           | 27.1      | 40.1  | 14.4              | 45.5                 |

For NO<sub>2</sub>, the major contribution for these locations comes from the commercial and residential sector. Although, as expected for the urban traffic station, the transport sector has a significant contribution.

Table 3-13 presents the comparison between the measurements and the simulated PM<sub>10</sub> concentrations (with the background concentrations and the adjustment factor) and the sector contribution for all the monitoring locations.

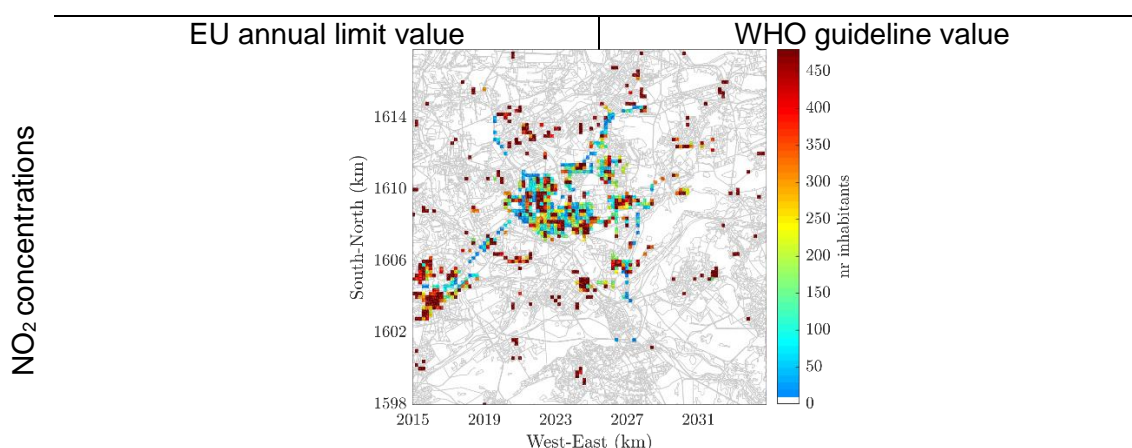
**Table 3-13: Comparison between the measurements and the simulated PM<sub>10</sub> concentrations (with the background concentrations and the adjustment factor) and contribution of each sector to the simulated values.**

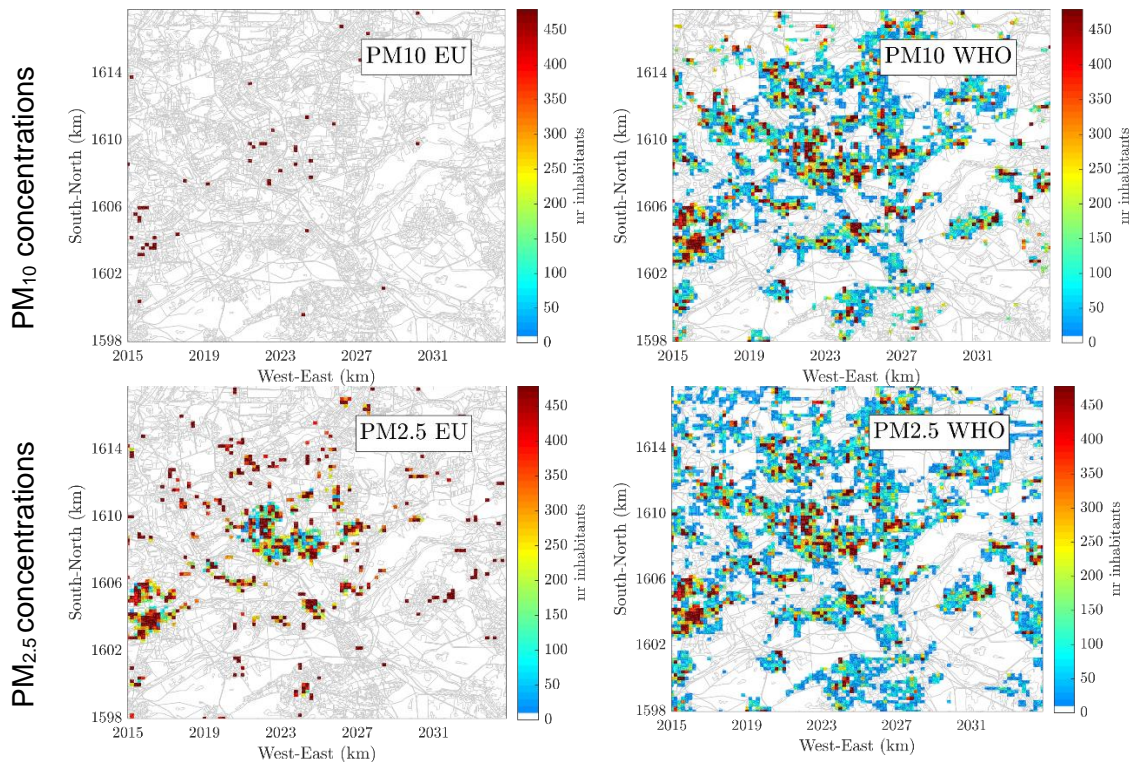
| Station |                  | PM <sub>10</sub> concentrations |           | Contribution by sector for the corresponding cell (%) |                   |                      |
|---------|------------------|---------------------------------|-----------|---|-------------------|----------------------|
| ID      | Station type     | Measurement                     | Simulated | Transport sector                                      | Industrial sector | Com. and Res. Sector |
| PL0237A | Urban Background | 41.21                           | 22.62     | 1.9   | 2.9               | 95.2                 |
| PL0529A | Urban Background | 36.96                           | 25.58     | 2.1   | 2.5               | 95.4                 |
| PL0567A | Urban Traffic    | 46.37                           | 21.33     | 8.1   | 2.7               | 89.2                 |

For PM<sub>10</sub> all the locations show a major contribution from commercial and residential sector. For PM<sub>2.5</sub>, for the year of 2015, only measured data from the traffic background monitoring station was available. The sector with the biggest contribution for PM<sub>2.5</sub> is the commercial and residential sector (92.9%).

### 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 3-62 shows the population exposure to NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> baseline concentration values.





**Figure 3-62: Population potentially exposed to values above the EU limits and WHO guideline values for NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> baseline concentrations.**

For NO<sub>2</sub> the limits established by the EU and the WHO are equivalent, being 40 µg.m<sup>-3</sup> for the annual mean. In Sosnowiec, the NO<sub>2</sub> annual limits are exceeded in 1043 cells corresponding to 59% of the total population within the urban area potentially exposed to those concentrations.

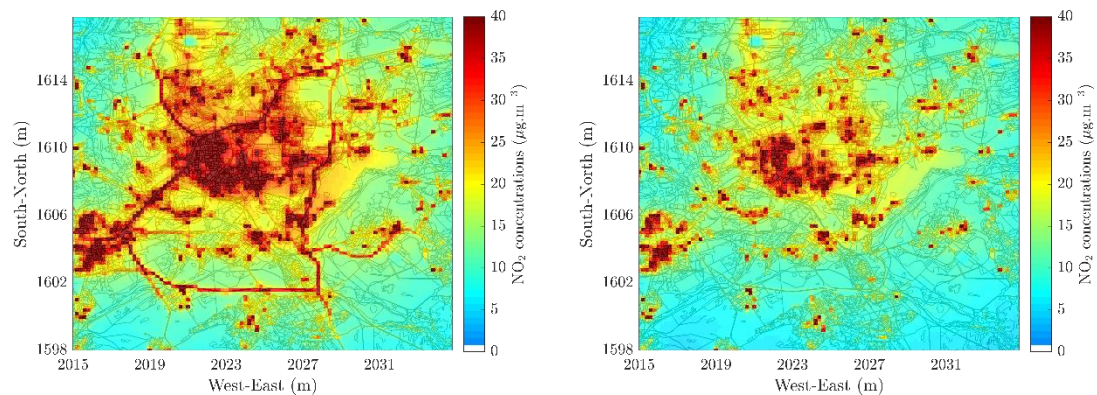
As for particulate matter, the limits diverge between both standards, with WHO showing stricter limits. PM<sub>10</sub> values under the EU annual mean limits are 40 µg.m<sup>-3</sup> and under WHO guidelines are 20 µg.m<sup>-3</sup>, for PM<sub>2.5</sub> the EU established for the annual mean limit value of 25 µg.m<sup>-3</sup> and for the WHO limits it is established at 10 µg.m<sup>-3</sup>. The EU annual legal limit value for PM<sub>10</sub> concentrations is exceeded in 46 cells, which represents 12.7% of the population within the urban area potentially exposed to those concentrations. For PM<sub>2.5</sub>, the EU annual legal limit value is exceeded in 372 cells, corresponding to 45.7% of the population potentially exposed. In the urban area of Sosnowiec 95% and 100% of the total population are potentially exposed to PM<sub>10</sub> and PM<sub>2.5</sub> concentrations, respectively, exceeding the WHO recommendations

### 3.5.5 Assessment of air quality impacts at urban scale

#### *BAU scenarios: NO<sub>2</sub> concentrations*

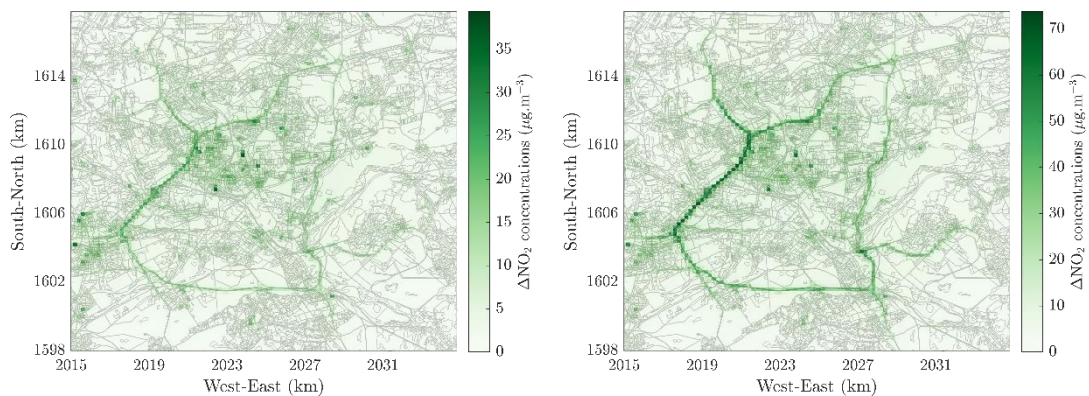
The reductions of NO<sub>x</sub> emissions in the BAU scenario will lead to reductions of the NO<sub>2</sub> concentrations. Figure 3-63 presents the NO<sub>2</sub> annual averaged concentrations considering the impacts of BAU scenario in 2025 and 2050. The maximum annual averaged NO<sub>2</sub>

concentrations will be equal to  $168.2 \mu\text{g.m}^{-3}$  in 2025 and to  $143.3 \mu\text{g.m}^{-3}$  in 2050, corresponding to an overall reduction of the maximum concentration of 26.7% and 79.9%, when compared to the baseline.



**Figure 3-63: NO<sub>2</sub> annual average concentrations in the BAU scenario (left) in 2025 and (right) 2050.**

Figure 3-64 presents the differences of the NO<sub>2</sub> concentrations between the baseline year and the BAU scenarios in 2025 and 2050. These differences are absolute concentrations obtained from the relationship  $\text{NO}_2 \text{ baseline year} - \text{NO}_2 \text{ scenarios}$  in  $\mu\text{g.m}^{-3}$ . The BAU scenario will lead to a maximum reduction of  $39.4 \mu\text{g.m}^{-3}$  of the NO<sub>2</sub> concentrations in 2025, corresponding to a reduction of 26.7%, while the spatial average over the entire the domain will reduce  $4.7 \mu\text{g.m}^{-3}$  of NO<sub>2</sub> concentrations, which corresponds to a reduction of 18.7%. In 2050 the BAU scenario will lead to a maximum reduction of the NO<sub>2</sub> concentrations of  $73.8 \mu\text{g.m}^{-3}$  which corresponds to a reduction of 79.9%, while the average over the entire domain will reduce  $9.8 \mu\text{g.m}^{-3}$  (39.5%).



**Figure 3-64: Differences of the NO<sub>2</sub> annual averaged concentrations in the BAU scenario (left) in 2025 and (right) 2050.**

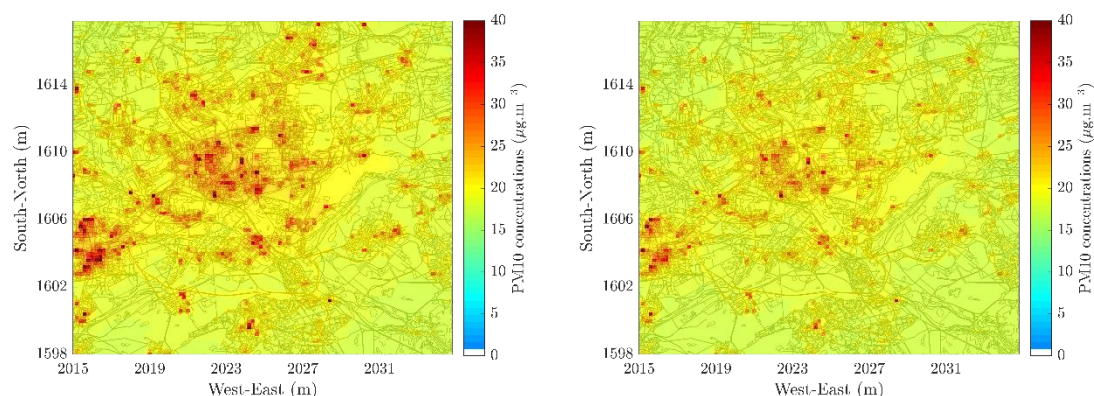
Table 3-14 summarizes the overall impacts of BAU scenarios on air quality and population exposure. The population within the urban area of Sosnowiec potentially exposed to NO<sub>2</sub> concentrations will diminish from 59.2% in the baseline year to 28.3% of inhabitants in risk of exposure with the implementation of the BAU scenario in 2050. Therefore, the simulation results indicate no compliance with the EU limits with the BAU scenario even in 2050 within 180 computational cells with inhabitants allocated.

**Table 3-14: Summary of results including the annual averages of NO<sub>2</sub> 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 in grid cells with inhabitants allocated to (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     | 7.7  | 207.7 | 24.3  | 1027 | 915           | 369524   | 59.2% |
| BAU 2025 | 6.4  | 168.2 | 19.7  | 519  | 493           | 280109   | 44.9% |
| BAU 2035 | 5.4  | 148.3 | 16.3  | 256  | 252           | 210907   | 33.8% |
| BAU 2050 | 4.9  | 143.3 | 14.5  | 180  | 180           | 176914   | 28.3% |

#### *BAU scenarios: PM<sub>10</sub> concentrations*

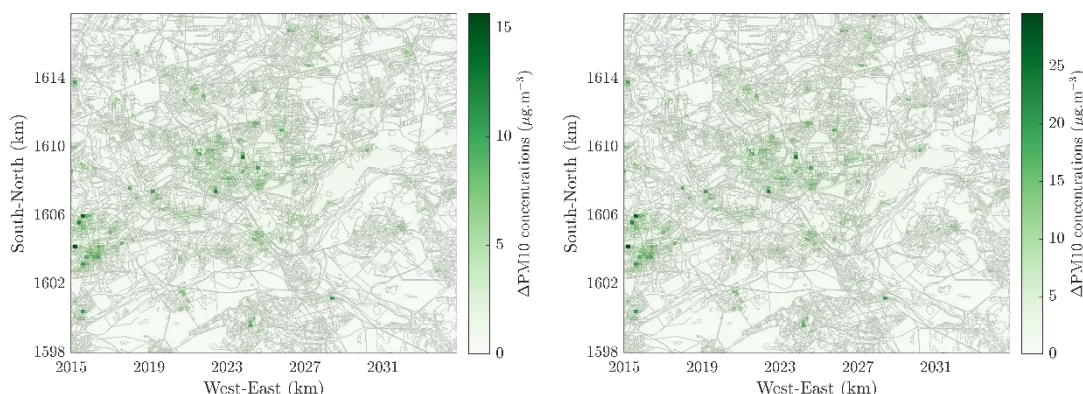
The reductions of PM emissions in the BAU scenario will also lead to reductions of the PM concentrations. Figure 3-65 presents the PM<sub>10</sub> annual averaged concentrations considering the impacts of BAU scenario in 2025 and 2050. The maximum annual averaged PM<sub>10</sub> concentrations will be equal to 59.6  $\mu\text{g.m}^{-3}$  in 2025 and to 45.7  $\mu\text{g.m}^{-3}$  in 2050, corresponding to an overall reduction of the maximum concentration of 20.8% and 39.3%, when compared to the baseline.



**Figure 3-65: PM10 annual average concentrations in the BAU scenario (left) in 2025 and (right) 2050.**

Figure 3-66 presents the differences of the PM<sub>10</sub> concentrations between the baseline year and the BAU scenarios in 2025 and 2050. The BAU scenario will lead to a maximum reduction of 15.7  $\mu\text{g.m}^{-3}$  of the PM<sub>10</sub> concentrations in 2025, corresponding to a reduction of

20.8%, while the spatial average over the entire the domain will reduce 1.1  $\mu\text{g.m}^{-3}$  of  $\text{PM}_{10}$  concentrations, which corresponds to a reduction of 5.0%. In 2050 the BAU scenario will lead to a maximum reduction of the  $\text{PM}_{10}$  concentrations of 29.6  $\mu\text{g.m}^{-3}$  which corresponds to a reduction of 39.3%, while the average over the entire domain will reduce 2.1  $\mu\text{g.m}^{-3}$  (9.2%).



**Figure 3-66: Differences of the  $\text{PM}_{10}$  annual averaged concentrations in the BAU scenario (left) in 2025 and (right) 2050.**

Table 3-15 and 3-16 summarize the overall impacts of BAU scenarios on  $\text{PM}_{10}$  concentrations and population exposure to those concentrations. The population within the urban area of Sosnowiec potentially exposed to  $\text{PM}_{10}$  concentrations above the EU legal limit value will diminish from 12.7% in 2015 to 2.0% in 2050 with the implementation of the BAU scenario. While, when considering the WHO guideline values, the population potentially exposed to  $\text{PM}_{10}$  concentrations will diminish from 95.1% in 2015 to 74.9% in 2050 with the implementation of the BAU scenario. The simulation results indicate no compliance with the EU limits in the BAU scenario even in 2050 within 4 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 1385 grid cells with inhabitants.

**Table 3-15: Summary of results including the annual averages of  $\text{PM}_{10}$  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 in grid cells with inhabitants allocated to (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     | 17.7 | 75.3 | 21.0  | 46   | 46            | 79005    | 12.7% |
| BAU 2025 | 17.4 | 59.6 | 19.8  | 16   | 16            | 37015    | 5.9%  |
| BAU 2035 | 17.2 | 49.7 | 19.1  | 5    | 5             | 15732    | 2.5%  |

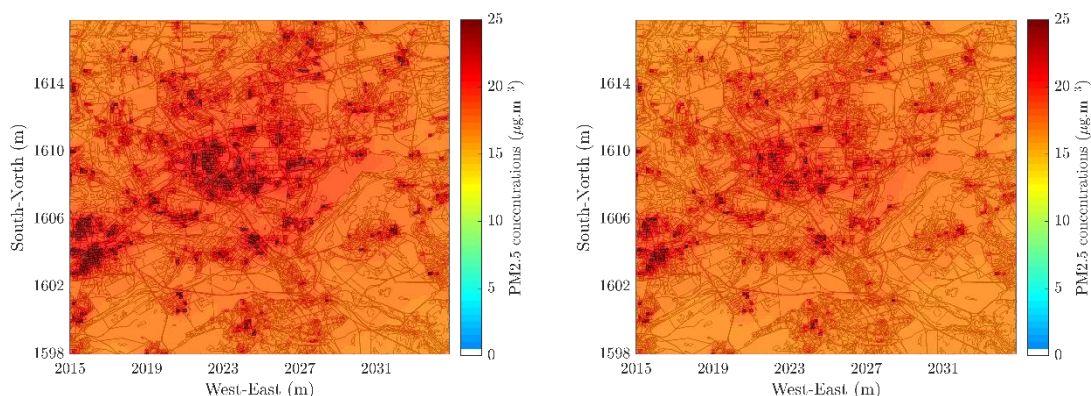
|          |      |      |      |   |   |       |      |
|----------|------|------|------|---|---|-------|------|
| BAU 2050 | 17.1 | 45.7 | 18.9 | 4 | 4 | 12576 | 2.0% |
|----------|------|------|------|---|---|-------|------|

**Table 3-16: Summary of results including the annual averages of PM<sub>10</sub> concentrations, together with the number of exceedances to the WHO guideline values (Exc.), as well as the number of exceedances to the WHO guideline values in grid cells with inhabitants allocated to (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     | 17.7 | 75.3 | 21.0  | 4899 | 3800          | 593613   | 95.1% |
| BAU 2025 | 17.4 | 59.6 | 19.8  | 3105 | 2670          | 555275   | 88.9% |
| BAU 2035 | 17.2 | 49.7 | 19.1  | 1848 | 1740          | 499245   | 79.9% |
| BAU 2050 | 17.1 | 45.7 | 18.9  | 1443 | 1385          | 467926   | 74.9% |

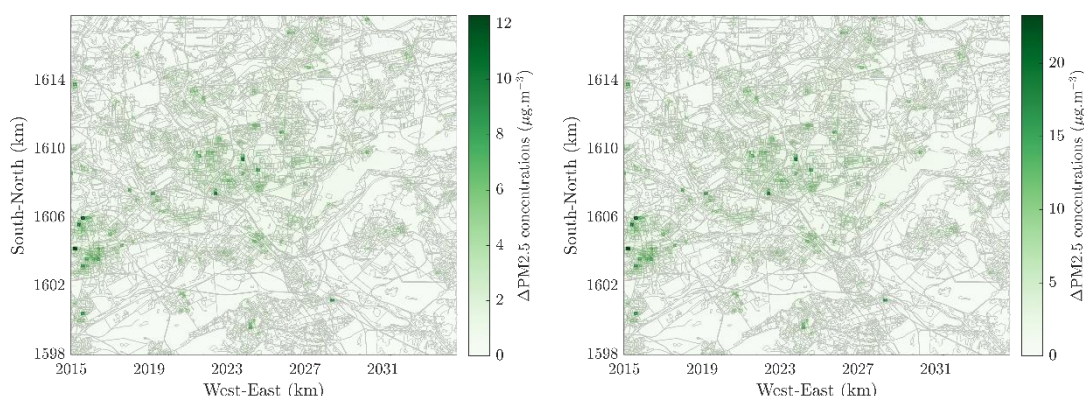
#### *BAU scenarios: PM<sub>2.5</sub> concentrations*

Figure 3-67 shows the PM<sub>2.5</sub> annual averaged concentrations considering the impacts of BAU scenario in 2025 and 2050. The maximum annual averaged PM<sub>2.5</sub> concentrations will be equal to 49.8 µg.m<sup>-3</sup> in 2025 and to 38.8 µg.m<sup>-3</sup> in 2050, corresponding to an overall reduction of the maximum concentration of 19.8% and 37.5%, when compared to the baseline.



**Figure 3-67: PM<sub>2.5</sub> annual average concentrations in the BAU scenario (left) in 2025 and (right) 2050.**

Figure 3-68 presents the differences of the PM<sub>2.5</sub> concentrations between the baseline year and the BAU scenarios in 2025 and 2050. The BAU scenario will lead to a maximum reduction of 12.3  $\mu\text{g.m}^{-3}$  of the PM<sub>2.5</sub> concentrations in 2025, corresponding to a reduction of 19.8%, while the spatial average over the entire the domain will reduce 0.9  $\mu\text{g.m}^{-3}$  of PM<sub>2.5</sub> concentrations, which corresponds to a reduction of 4.1%. In 2050 the BAU scenario will lead to a maximum reduction of the PM<sub>2.5</sub> concentrations of 23.3  $\mu\text{g.m}^{-3}$  which corresponds to a reduction of 37.5%, while the average over the entire domain will reduce 1.6  $\mu\text{g.m}^{-3}$  (7.8%).



**Figure 3-68: Differences of the PM<sub>2.5</sub> annual averaged concentrations in the BAU scenario (left) in 2025 and (right) 2050.**

Table 3-17 and 3-18 summarize the overall impacts of BAU scenarios on PM<sub>10</sub> concentrations and population exposure to those concentrations. The population within the urban area of Sosnowiec potentially exposed to PM<sub>10</sub> concentrations above the EU legal limit value will diminish from 12.7% in 2015 to 2.0% in 2050 with the implementation of the BAU scenario. While, when considering the WHO guideline values, the population potentially exposed to PM<sub>10</sub> concentrations will diminish from 95.1% in 2015 to 74.9% in 2050 with the implementation of the BAU scenario. The simulation results indicate no compliance with the EU limits in the BAU scenario even in 2050 within 4 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 1385 grid cells with inhabitants.

**Table 3-17: Summary of results including the annual averages of PM<sub>2.5</sub> 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 in grid cells with inhabitants allocated to (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     | 16.8 | 62.1 | 19.3 | 372 | 372 | 285593 | 45.7 |
| BAU 2025 | 16.6 | 49.8 | 18.5 | 170 | 170 | 183547 | 29.4 |
| BAU 2035 | 16.4 | 42.0 | 17.9 | 69  | 69  | 102317 | 16.4 |
| BAU 2050 | 16.4 | 38.8 | 17.7 | 47  | 47  | 80141  | 12.8 |

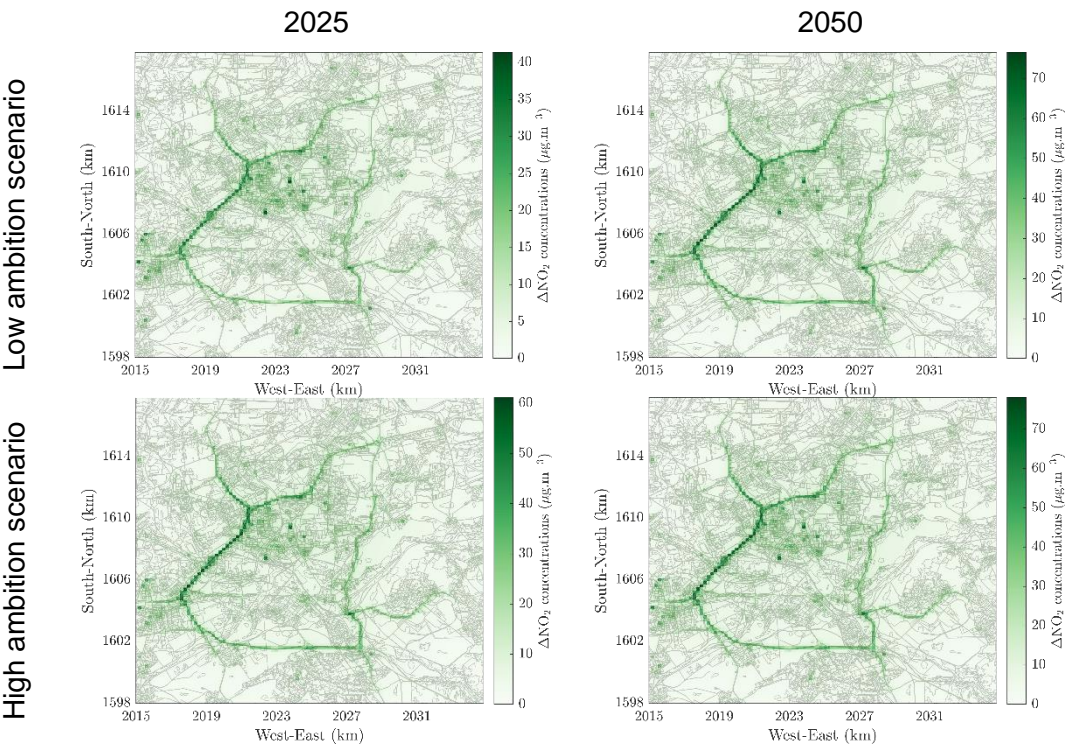
**Table 3-18: Summary of results including the annual averages of PM<sub>2.5</sub> concentrations, together with the number of exceedances to the WHO guideline values (Exc.), as well as the number of exceedances to the WHO guideline values in grid cells with inhabitants allocated to (Exc. Inhabit.), 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     | 16.8 | 62.1 | 19.3  | 10000 | 5755          | 624542   | 100% |
| BAU 2025 | 16.6 | 49.8 | 18.5  | 10000 | 5755          | 624542   | 100% |
| BAU 2035 | 16.4 | 42.0 | 17.9  | 10000 | 5755          | 624542   | 100% |
| BAU 2050 | 16.4 | 38.8 | 17.7  | 10000 | 5755          | 624542   | 100% |

#### *SDW scenarios: NO<sub>2</sub> concentrations*

The two proposed scenarios from the SDW – low and high ambition scenarios – will distinctly impact the air quality over the urban area of Sosnowiec. Figure 3-69 shows the differences of the NO<sub>2</sub> annual concentrations with the implementation of the SDW scenarios compared to the baseline year. The maximum NO<sub>2</sub> concentrations will range from 166.3 µg.m<sup>-3</sup> to 141.7 µg.m<sup>-3</sup> between 2025 and 2050 with the implementation of the low ambition scenario, while with the implementation of the high ambition scenario the maximum NO<sub>2</sub> concentrations will range from 156.6 µg.m<sup>-3</sup> to 136.7 µg.m<sup>-3</sup>. Figure 3-69 also points out that the maximum reductions of the NO<sub>2</sub> concentrations are simulated over the city centre and over the main

roads and motorways, denoting a relevant link between the reduction of NO<sub>x</sub> emissions in the transport sector and the reductions of NO<sub>2</sub> concentrations achieved with the implementation of those scenarios. The low ambition scenario will led to an overall reduction of the NO<sub>2</sub> concentrations of 20.3% over the entire computational domain in 2025, and of 40.4% in 2050. While the high ambition scenario will lead to an averaged reduction over the entire area of the NO<sub>2</sub> concentrations of 31.6% in 2025, and of 42.3% in 2050.



**Figure 3-69: Differences of the NO<sub>2</sub> annual averaged concentrations in the SDW scenarios in 2025 and 2050.**

Table 3-19 presents an overview of the overall impact of the SDW scenarios on the NO<sub>2</sub> concentrations, indicating that independently on the level of ambition of the scenarios all of them will lead to high risk of population exposure to those concentrations even in 2050. The high ambition scenario in 2050 will still led to 25.3% of the population within Sosnowiec computational domain potentially exposed to NO<sub>2</sub> concentrations above the EU annual legal limit value.

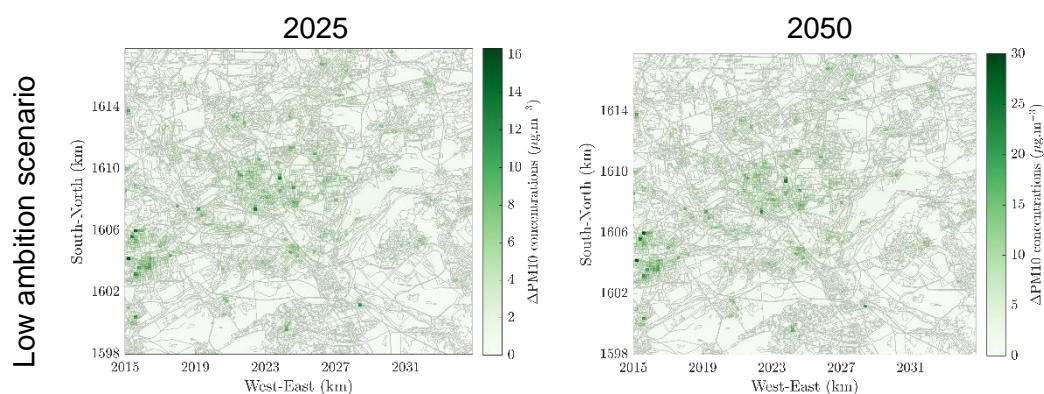
**Table 3-19: Summary of the SDW impacts including the annual averages of NO<sub>2</sub> concentrations, together with the number of exceedances to the EU legal limit value, the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit, and the corresponding % of population.**

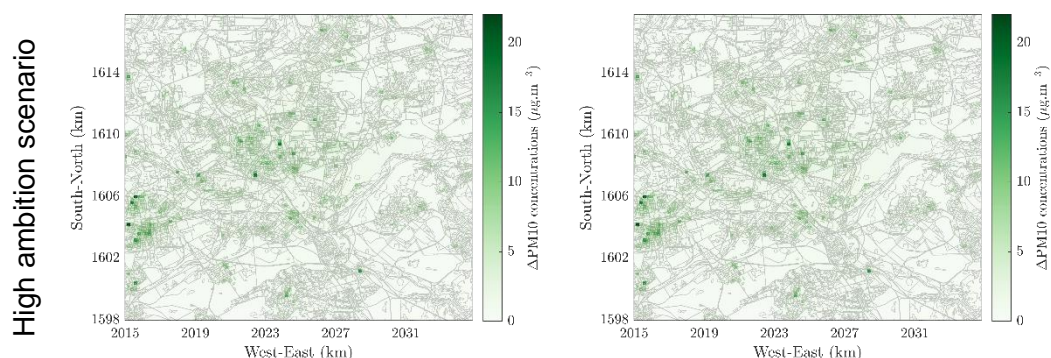
|  | Min. | Max. | Aver. | Exc. | Exc. Inhabit. | Inhabit. | Pop. |
|--|------|------|-------|------|---------------|----------|------|
|  |      |      |       |      |               |          |      |

|           |     |       |      |      |     |        |       |
|-----------|-----|-------|------|------|-----|--------|-------|
| 2015      | 7.7 | 207.7 | 24.3 | 1027 | 915 | 369524 | 59.2% |
| Low 2025  | 6.3 | 166.3 | 19.2 | 457  | 442 | 271239 | 43.4% |
| Low 2035  | 5.3 | 146.3 | 15.6 | 201  | 201 | 191170 | 30.6% |
| Low 2050  | 4.9 | 141.7 | 14.2 | 170  | 170 | 171277 | 27.4% |
| High 2025 | 5.5 | 156.6 | 16.4 | 275  | 275 | 227578 | 36.4% |
| High 2035 | 4.9 | 140.3 | 14.4 | 170  | 170 | 170321 | 27.3% |
| High 2050 | 4.7 | 136.7 | 13.8 | 148  | 148 | 157999 | 25.3% |

#### *SDW scenarios: PM<sub>10</sub> concentrations*

The overall measures impacting the PM<sub>10</sub> emissions will also promote reductions of PM<sub>10</sub> concentrations over the urban area of Sosnowiec as indicated in Figure 3-70. The differences contour maps of the annual PM<sub>10</sub> concentrations point out a maximum concentration ranging from 58.9  $\mu\text{g.m}^{-3}$  to 45.2  $\mu\text{g.m}^{-3}$  between 2025 and 2050 with the implementation of the low ambition scenario, while the high ambition scenario will lead to a maximum concentration of PM<sub>10</sub> concentrations from 41.7  $\mu\text{g.m}^{-3}$  in 2050.





**Figure 3-70: Differences of the PM<sub>10</sub> annual averaged concentrations in the SDW scenario in 2025 and 2050.**

Table 3-20 and 3-21 present an overview of the overall impact of the SDW scenarios on the PM<sub>10</sub> concentrations. The low ambition scenario will lead to an overall reduction of 5.3% over the entire computational domain in 2025, and of 9.6% in 2050. While the high ambition scenario will lead to a reduction of 7.3% in 2025, and of 10.8% in 2050.

The population within the urban area of Sosnowiec potentially exposed to PM<sub>10</sub> concentrations above the EU legal limit value will diminish from 12.7% in 2015 to 2.0% in 2050 with the implementation of the low ambition scenario, and to 1.1% in 2050 with the high ambition scenario. However, the population of Sosnowiec potentially exposed to PM<sub>10</sub> concentrations above the stricter, but still voluntary, WHO guideline values will diminish from 95.1% in 2015 to 73.7% in 2050 with the implementation of the low ambition scenario, and to 67.2% in 2050 with the high ambition scenario. The simulation results indicate no compliance with the EU limits in the low ambition scenario even in 2050 within 4 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 1288 grid cells with inhabitants. The results also indicate no compliance with the EU limits in the high ambition scenario even in 2050 within only 2 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 962 grid cells with inhabitants.

**Table 3-20: Summary of results including the annual averages of PM<sub>10</sub> 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 in grid cells with inhabitants allocated to (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     | 17.7 | 75.3 | 21.0  | 46   | 46            | 79005    | 12.7% |
| Low 2025 | 17.4 | 58.9 | 19.8  | 14   | 14            | 33033    | 5.3%  |

|           |      |      |      |   |   |       |      |
|-----------|------|------|------|---|---|-------|------|
| Low 2035  | 17.2 | 48.0 | 19.0 | 5 | 5 | 15732 | 2.5% |
| Low 2050  | 17.1 | 45.2 | 18.8 | 4 | 4 | 12576 | 2.0% |
| High 2025 | 17.3 | 53.2 | 19.3 | 7 | 7 | 19782 | 3.2% |
| High 2035 | 17.1 | 45.0 | 18.7 | 3 | 3 | 10032 | 1.6% |
| High 2050 | 17.0 | 41.7 | 18.5 | 2 | 2 | 6597  | 1.1% |

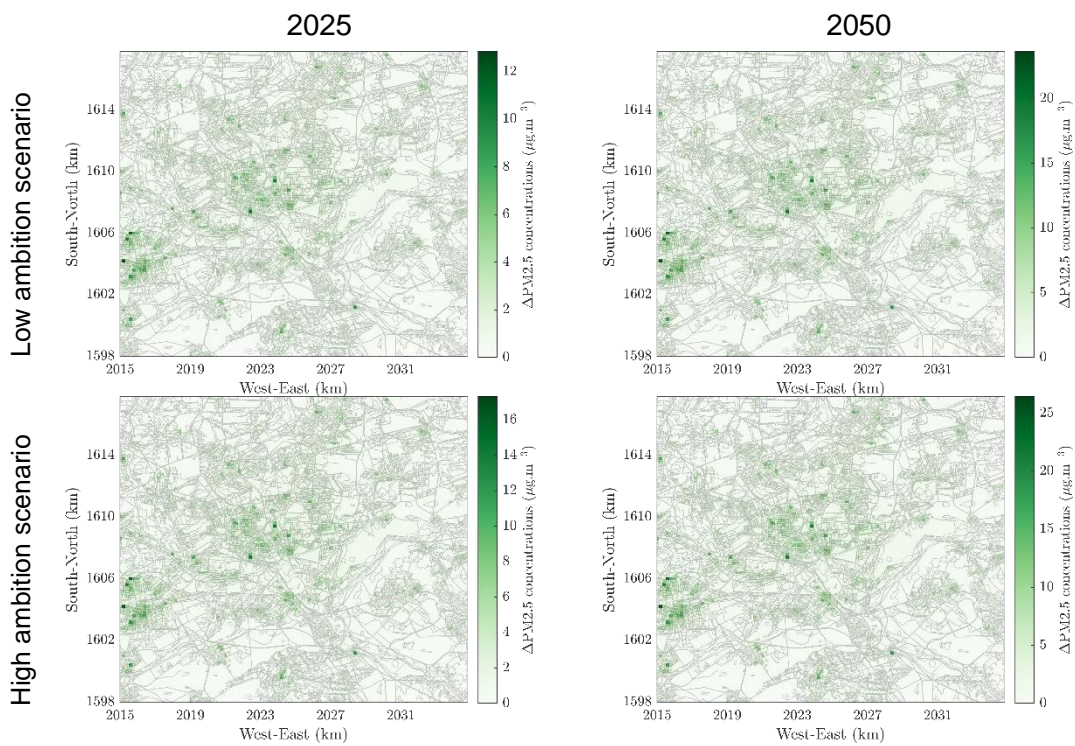
**Table 3-21: Summary of results including the annual averages of PM<sub>10</sub> concentrations, together with the number of exceedances to the WHO guideline values (Exc.), as well as the number of exceedances to the WHO guideline values in grid cells with inhabitants allocated to (Exc. Inhabit.), the 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      | 17.7 | 75.3 | 21.0  | 46   | 46            | 79005    | 12.7% |
| Low 2025  | 17.4 | 58.9 | 19.8  | 2964 | 2589          | 552146   | 88.4% |
| Low 2035  | 17.2 | 48.0 | 19.0  | 1545 | 1486          | 481387   | 77.1% |
| Low 2050  | 17.1 | 45.2 | 18.8  | 1333 | 1288          | 460383   | 73.7% |
| High 2025 | 17.3 | 53.2 | 19.3  | 2138 | 1989          | 520448   | 83.3% |
| High 2035 | 17.1 | 45.0 | 18.7  | 1243 | 1213          | 454126   | 72.7% |
| High 2050 | 17.0 | 41.7 | 18.5  | 976  | 962           | 419534   | 67.2% |

#### *SDW scenarios: PM<sub>2.5</sub> concentrations*

Figure 3-71 shows the contour maps with the differences between the proposed scenarios and the baseline of the annual PM<sub>2.5</sub> concentrations. These contour maps point out a

maximum concentration ranging from 49.3  $\mu\text{g.m}^{-3}$  to 38.5  $\mu\text{g.m}^{-3}$  between 2025 and 2050 with the implementation of the low ambition scenario, and ranging from 44.8  $\mu\text{g.m}^{-3}$  to 35.7  $\mu\text{g.m}^{-3}$  between 2025 and 2050 with the implementation of the high ambition scenario.



**Figure 3-71: Differences of the PM<sub>2.5</sub> annual averaged concentrations in the FUPS scenario in 2025 and 2050.**

Table 3-22 and 3-23 present an overview of the overall impact of the SDW scenarios on the PM<sub>2.5</sub> concentrations. The low ambition scenario will lead to an overall reduction of 4.4% of the PM<sub>2.5</sub> concentrations over the entire computational domain in 2025, and of 8.1% in 2050. While the high ambition scenario will lead to a reduction of 6.0% of the PM<sub>2.5</sub> concentrations in 2025, and of 9.1% in 2050. The population within the urban area of Sosnowiec potentially exposed to PM<sub>2.5</sub> concentrations above the EU legal limit value will diminish from 45.7% in 2015 to 12.5% in 2050 with the implementation of the low ambition scenario, and to 8.5% in 2050 with the high ambition scenario. However, all the population of the urban area of Sosnowiec will be potentially exposed to PM<sub>2.5</sub> concentrations above the stricter, but still voluntary, WHO guideline values even in 2050 with the implementation of the high ambition scenario. The simulation results indicate no compliance with the EU limits in the low ambition scenario even in 2050 within 45 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 5755 grid cells with inhabitants. The results also indicate no compliance with the EU limits in the high ambition scenario even in 2050 within 27 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 5755 grid cells with inhabitants.

**Table 3-22: Summary of results including the annual averages of PM<sub>2.5</sub> 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 in grid cells with inhabitants allocated**

to (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      | 16.8 | 62.1 | 19.3  | 372  | 372           | 285593   | 45.7% |
| Low 2025  | 16.6 | 49.3 | 18.4  | 158  | 158           | 175691   | 28.1% |
| Low 2035  | 16.4 | 40.7 | 17.8  | 57   | 57            | 91665    | 14.7% |
| Low 2050  | 16.4 | 38.5 | 17.7  | 45   | 45            | 78059    | 12.5% |
| High 2025 | 16.5 | 44.8 | 18.1  | 97   | 97            | 127487   | 20.4  |
| High 2035 | 16.4 | 38.3 | 17.6  | 44   | 44            | 76555    | 12.3% |
| High 2050 | 16.3 | 35.7 | 17.4  | 27   | 27            | 52955    | 8.5%  |

**Table 3-23: Summary of results including the annual averages of PM<sub>2.5</sub> concentrations, together with the number of exceedances to the WHO guideline values (Exc.), as well as the number of exceedances to the WHO guideline values in grid cells with inhabitants allocated to (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     | 16.8 | 62.1 | 19.3  | 10000 | 5755          | 624542   | 100% |
| Low 2025 | 16.6 | 49.3 | 18.4  | 10000 | 5755          | 624542   | 100% |
| Low 2035 | 16.4 | 40.7 | 17.8  | 10000 | 5755          | 624542   | 100% |
| Low 2050 | 16.4 | 38.5 | 17.7  | 10000 | 5755          | 624542   | 100% |

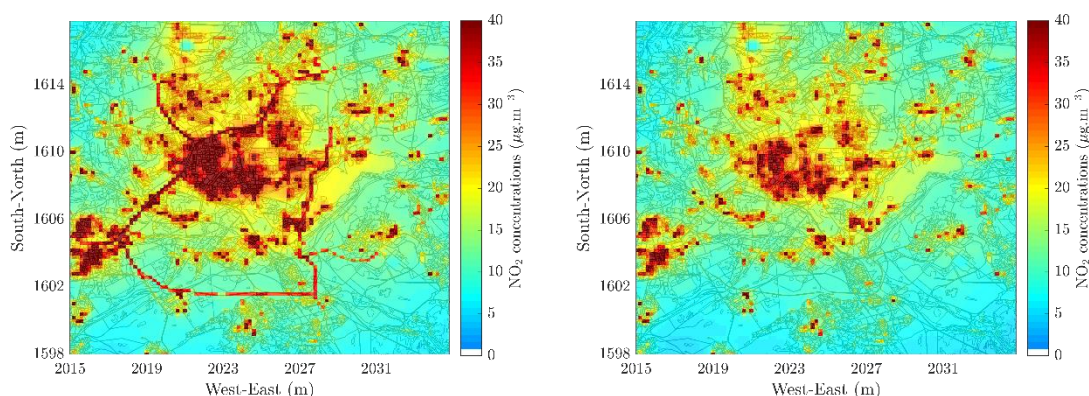
|           |      |      |      |       |      |        |      |
|-----------|------|------|------|-------|------|--------|------|
| High 2025 | 16.5 | 44.8 | 18.1 | 10000 | 5755 | 624542 | 100% |
| High 2035 | 16.4 | 38.3 | 17.6 | 10000 | 5755 | 624542 | 100% |
| High 2050 | 16.3 | 35.7 | 17.4 | 10000 | 5755 | 624542 | 100% |

### FUPS scenarios

The UPS scenario for the measures focusing on the transport sector establishes two levels of emission reduction, one to be applied for *bad air quality conditions*, and another one to be applied for *good air quality conditions*. The ClairCity quantification framework was adapted to consider these criteria. Therefore, the emission reduction targets from the bad air quality scenario were applied to the grid cells where the annual concentrations exceeded the EU limit value for NO<sub>2</sub>, PM<sub>10</sub> and PM<sub>2.5</sub> concentrations, while the good air quality scenario was applied to the grid cells below the legal limit.

### FUPS scenarios: NO<sub>2</sub> concentrations

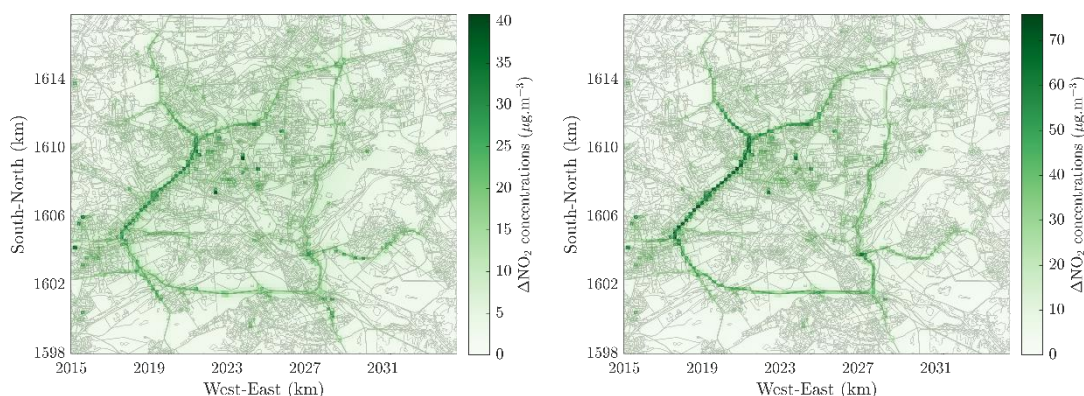
There are important reductions of NO<sub>x</sub> emissions in the FUPS scenario, which will lead to significant reductions of the NO<sub>2</sub> concentrations. Figure 3-72 presents the NO<sub>2</sub> annual averaged concentrations considering the impacts of FUPS scenario in 2025 and 2050. The maximum annual averaged NO<sub>2</sub> concentrations will be equal to 166.8 µg.m<sup>-3</sup> in 2025 and to 141.7 µg.m<sup>-3</sup> in 2050, corresponding to an overall reduction of the maximum concentration of 61.9% and 82.1%, when compared to the baseline.



**Figure 3-72: NO<sub>2</sub> annual average concentrations in the FUPS scenario (left) in 2025 and (right) 2050.**

Figure 3-73 shows the differences of the NO<sub>2</sub> annual concentrations with the implementation of the FUPS scenarios compared to the baseline year. Figure 3-73 shows also the link between the reduction of NO<sub>x</sub> emissions in the transport sector and the reductions of NO<sub>2</sub> concentrations achieved with the implementation of the FUPS scenario. The FUPS scenario

will led to an overall reduction of the NO<sub>2</sub> concentrations of 28.8% over the entire computational domain in 2025, and of 40.7% in 2050.



**Figure 3-73: Differences of the NO<sub>2</sub> annual averaged concentrations in the FUPS scenario (left) in 2025 and (right) 2050.**

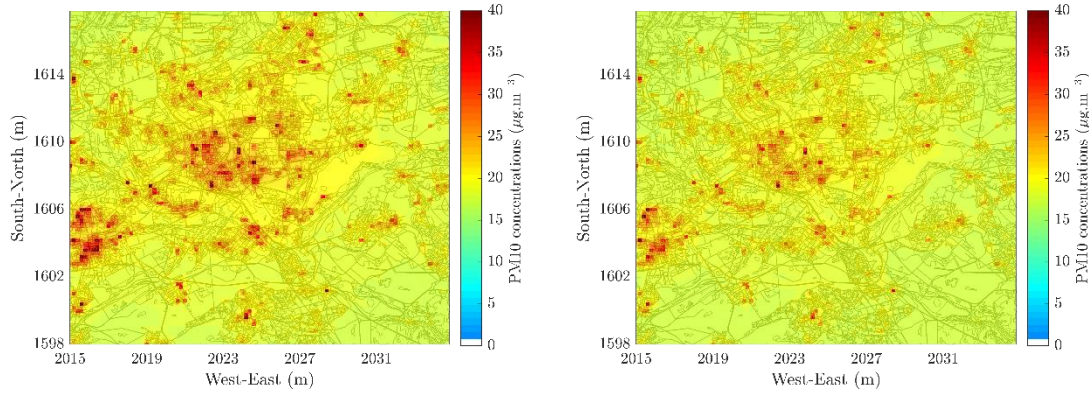
Table 3-24 shows the summary of the overall impact of the FUPS scenario on the NO<sub>2</sub> concentrations, indicating an high risk of population exposure to those concentrations even in 2050. The FUPS scenario in 2050 will still led to 27.5% of the population within Sosnowiec computational domain potentially exposed to NO<sub>2</sub> concentrations above the EU annual legal limit value.

**Table 3-24: Summary of the FUPS impacts including the annual averages of NO<sub>2</sub> 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.**

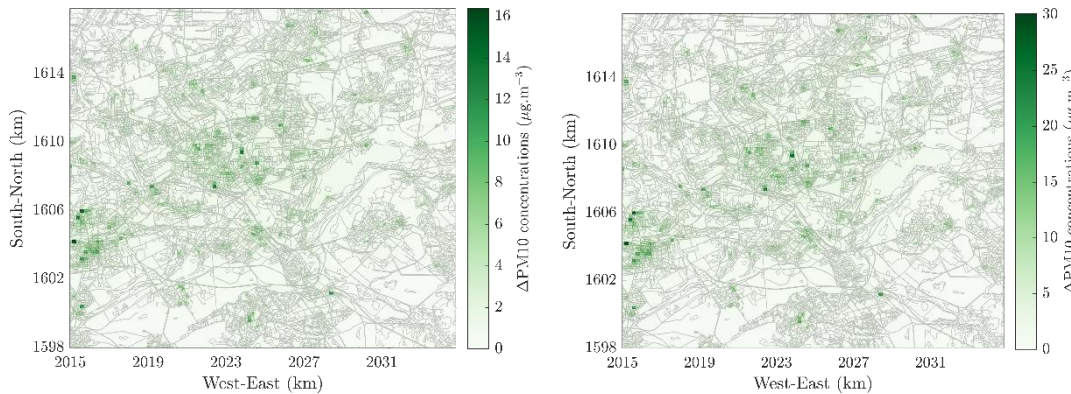
|           | Min. | Max.  | Aver. | Exc. | Exc. Inhabit. | Inhabit. | Pop.  |
|-----------|------|-------|-------|------|---------------|----------|-------|
| 2015      | 7.7  | 207.7 | 24.3  | 1027 | 915           | 369524   | 59.2% |
| FUPS 2025 | 5.6  | 166.8 | 17.5  | 475  | 459           | 274271   | 43.9% |
| FUPS 2035 | 5.0  | 144.8 | 14.9  | 214  | 214           | 196083   | 31.4% |
| FUPS 2050 | 4.8  | 141.7 | 14.2  | 171  | 171           | 171631   | 27.5% |

### *FUPS scenarios: PM<sub>10</sub> concentrations*

Figure 3-74 and Figure 3-75 present the impact of the FUPS scenario on PM<sub>10</sub> concentrations. The contour maps with the differences of the annual PM<sub>10</sub> concentrations (Figure 3-75) point out a maximum concentration ranging from 58.9  $\mu\text{g.m}^{-3}$  to 45.2  $\mu\text{g.m}^{-3}$  between 2025 and 2050 with the implementation of the FUPS scenario.



**Figure 3-74: PM10 annual average concentrations in the FUPS scenario (left) in 2025 and (right) 2050.**



**Figure 3-75: Differences of the PM10 annual averaged concentrations in the FUPS scenario (left) in 2025 and (right) 2050.**

Table 3-25 and 3-26 summarize the overall impact of the FUPS scenario on the PM<sub>10</sub> concentrations. This scenario will lead to an overall reduction of 5.6% over the entire computational domain in 2025, and of 9.7% in 2050. The population within the urban area of Sosnowiec potentially exposed to PM<sub>10</sub> concentrations above the EU legal limit value will diminish from 12.7% in 2015 to 1.6% in 2050 with the implementation of the FUPS scenario. However, the population of Sosnowiec potentially exposed to PM<sub>10</sub> concentrations above the stricter, but still voluntary, WHO guideline values will diminish from 95.1% in 2015 to 73.2% in 2050 with the implementation of the FUPS scenario. The simulation results indicate no compliance with the EU limits even in 2050 within 3 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 1245 grid cells with inhabitants.

**Table 3-25 - Summary of results including the annual averages of PM<sub>10</sub> 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 in grid cells with inhabitants allocated to (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      | 17.7 | 75.3 | 21.0  | 46   | 46            | 79005    | 12.7% |
| FUPS 2025 | 17.4 | 58.9 | 19.7  | 14   | 14            | 33033    | 5.3%  |
| FUPS 2035 | 17.2 | 49.1 | 19.0  | 5    | 5             | 15732    | 2.5%  |
| FUPS 2050 | 17.1 | 45.2 | 18.8  | 3    | 3             | 10032    | 1.6%  |

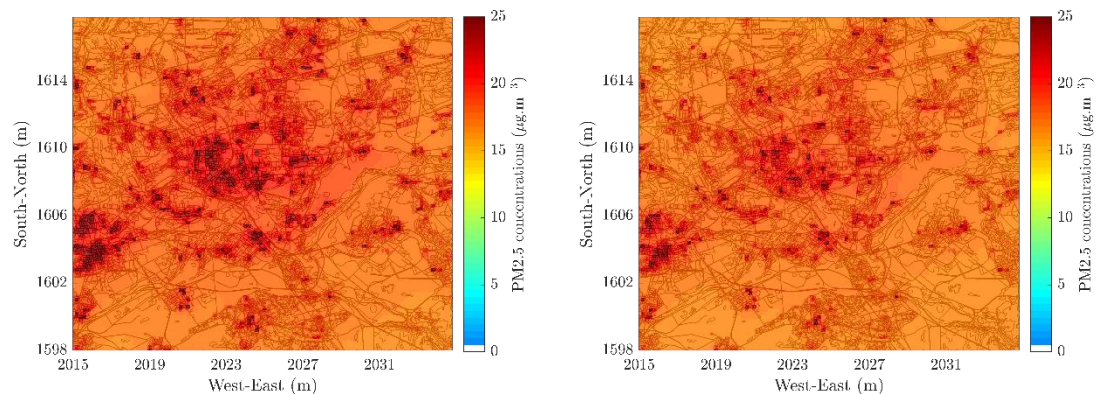
**Table 3-26: Summary of results including the annual averages of PM<sub>10</sub> concentrations, together with the number of exceedances to the WHO guideline values (Exc.), as well as the number of exceedances to the WHO guideline values in grid cells with inhabitants allocated to (Exc. Inhabit.), the 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      | 17.7 | 75.3 | 21.0  | 4899 | 3800          | 593613   | 95.1% |
| FUPS 2025 | 17.4 | 58.9 | 19.7  | 2830 | 2505          | 550033   | 88.1% |
| FUPS 2035 | 17.2 | 49.1 | 19.0  | 1613 | 1547          | 487795   | 78.1% |
| FUPS 2050 | 17.1 | 45.2 | 18.8  | 1279 | 1245          | 457115   | 73.2% |

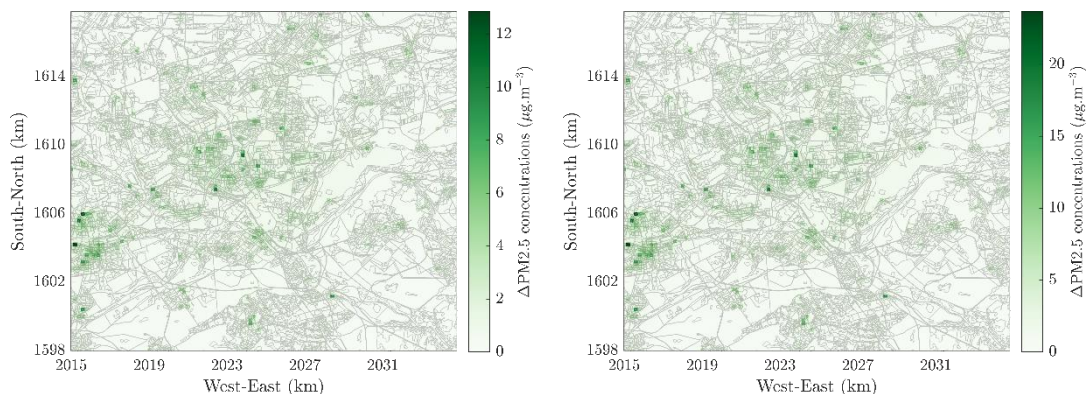
#### *FUPS scenarios: PM<sub>2.5</sub> concentrations*

Figure 3-76 and Figure 3-77 present the impact of the FUPS scenario on PM<sub>10</sub> concentrations. Figure 3-76 shows the PM<sub>2.5</sub> annual averaged concentrations considering the

impacts of FUPS scenario in 2025 and 2050. The maximum annual averaged  $\text{PM}_{2.5}$  concentrations will be equal to  $49.2 \mu\text{g}\cdot\text{m}^{-3}$  in 2025 and to  $38.4 \mu\text{g}\cdot\text{m}^{-3}$  in 2050, corresponding to an overall reduction of the maximum concentration of 20.7% and 38.1%, when compared to the baseline.



**Figure 3-76:  $\text{PM}_{2.5}$  annual average concentrations in the FUPS scenario (left) in 2025 and (right) 2050.**



**Figure 3-77: Differences of the  $\text{PM}_{2.5}$  annual averaged concentrations in the FUPS scenario (left) in 2025 and (right) 2050.**

Table 3-27 and 3-28 presents the overall impact of the FUPS scenario on the  $\text{PM}_{2.5}$  concentrations. The FUPS scenario will lead to an overall reduction of 4.6% over the entire computational domain in 2025, and of 8.1% in 2050.

The population within the urban area of Sosnowiec potentially exposed to  $\text{PM}_{2.5}$  concentrations above the EU legal limit value will diminish from 45.7% in 2015 to 12.5% in 2050 with the implementation of the FUPS scenario. However, all the population of the urban area of Sosnowiec will be potentially exposed to  $\text{PM}_{2.5}$  concentrations above the stricter, but still voluntary, WHO guideline values even in 2050 with the implementation of the high ambition scenario. The simulation results indicate no compliance with the EU limits in the FUPS scenario even in 2050 within 45 computational cells with inhabitants allocated to, and no compliance with the stricter WHO guideline values within 5755 grid cells with inhabitants.

**Table 3-27: Summary of results including the annual averages of PM<sub>2.5</sub> 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 in grid cells with inhabitants allocated to (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      | 16.8 | 62.1 | 19.3  | 372  | 372           | 285593   | 45.7% |
| FUPS 2025 | 16.5 | 49.2 | 18.4  | 155  | 155           | 172968   | 27.7% |
| FUPS 2035 | 16.4 | 41.5 | 17.8  | 65   | 65            | 98915    | 15.8% |
| FUPS 2050 | 16.4 | 38.4 | 17.6  | 45   | 45            | 78059    | 12.5% |

**Table 3-28: Summary of results including the annual averages of PM<sub>2.5</sub> concentrations, together with the number of exceedances to the WHO guideline values (Exc.), as well as the number of exceedances to the WHO guideline values in grid cells with inhabitants allocated to (Exc. Inhabit.), the number of inhabitants within the urban area potentially exposed to concentrations exceeding this limit (Inhabit.), and the corresponding % of population (Pop.).**

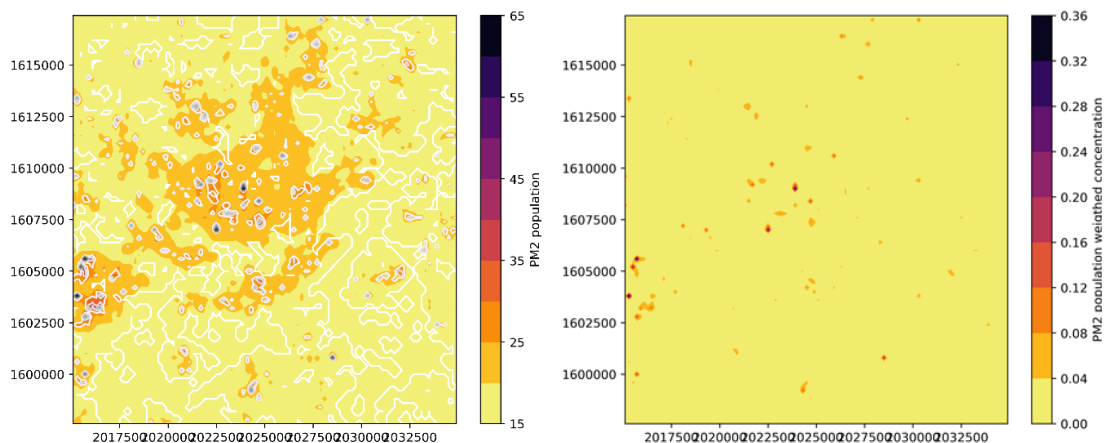
|           | Min. | Max. | Aver. | Exc.  | Exc. Inhabit. | Inhabit. | Pop. |
|-----------|------|------|-------|-------|---------------|----------|------|
| 2015      | 16.8 | 62.1 | 19.3  | 10000 | 5755          | 624542   | 100% |
| FUPS 2025 | 16.5 | 49.2 | 18.4  | 10000 | 5755          | 624542   | 100% |
| FUPS 2035 | 16.4 | 41.5 | 17.8  | 10000 | 5755          | 624542   | 100% |
| FUPS 2050 | 16.4 | 38.4 | 17.6  | 10000 | 5755          | 624542   | 100% |

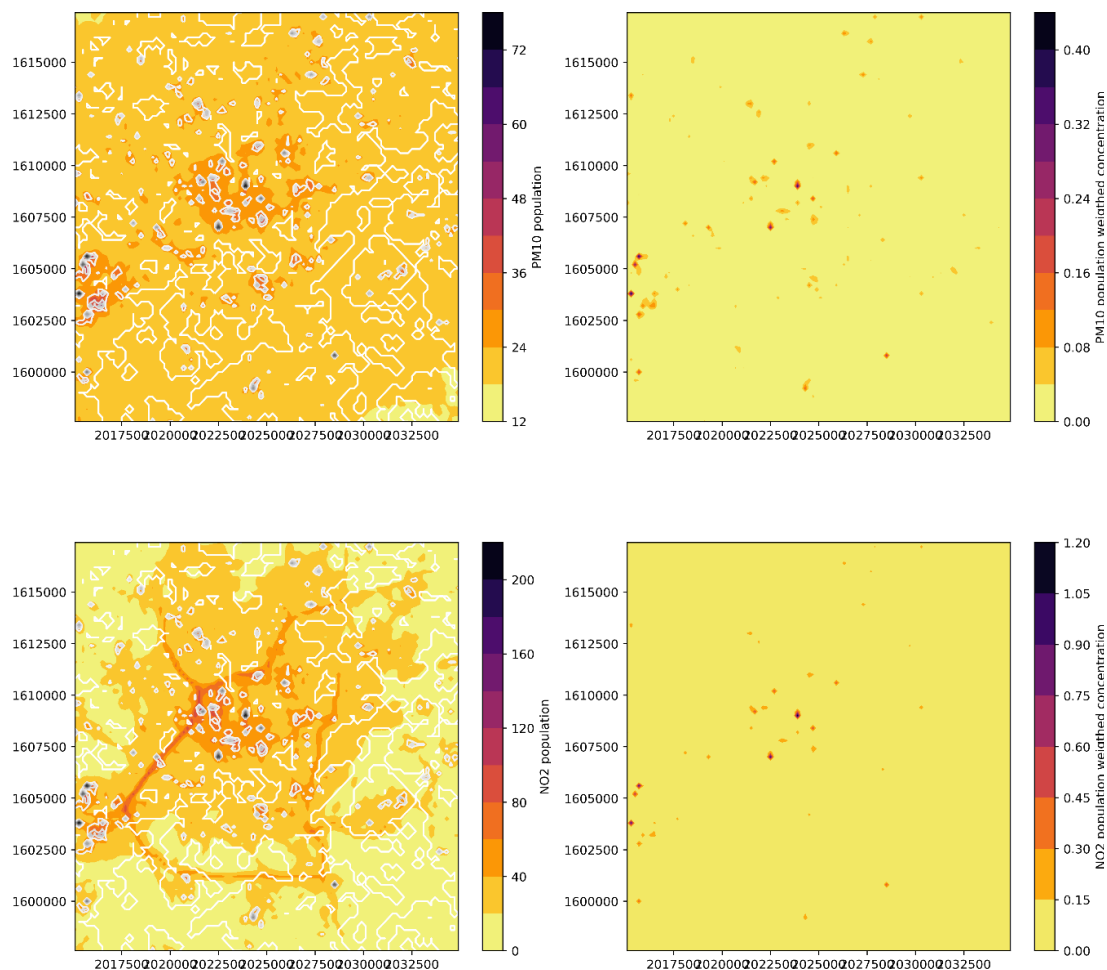
## 3.6 Health impacts

### 3.6.1 Baseline

The health impacts related to exposure to  $\text{NO}_2$ ,  $\text{PM}_{10}$ , and  $\text{PM}_{2.5}$  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 in section 3.3.6) 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 Sosnowiec, for individual pollutants. The population weighted concentration maps indicate that exposure is the highest closer to the city centre of Sosnowiec and neighbouring town Katowice (south-west of the domain).

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 879, 664, and 1194 premature deaths, and 12552, 9479, and 17039 years of life potentially lost attributed to  $\text{PM}_{2.5}$ ,  $\text{PM}_{10}$ , and  $\text{NO}_2$  pollution levels in Sosnowiec in 2015, respectively.





**Figure 3-78: Concentration maps overlaid with population density contours (left), population weighted concentration maps (right) for PM2.5 (top), PM10 (centre), and NO<sub>2</sub> (bottom) based on the baseline emission scenario (2015), for Sosnowiec.**

### 3.6.1.1 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 (see Equation [2.7.6]).

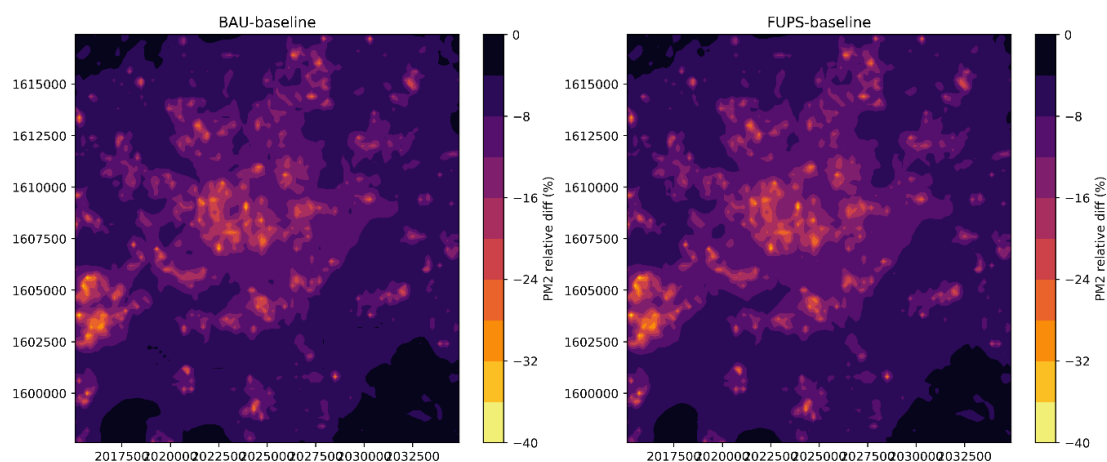
**Table 3-29: Health impact benefits of implementing emission control measures in Sosnowiec (%).**

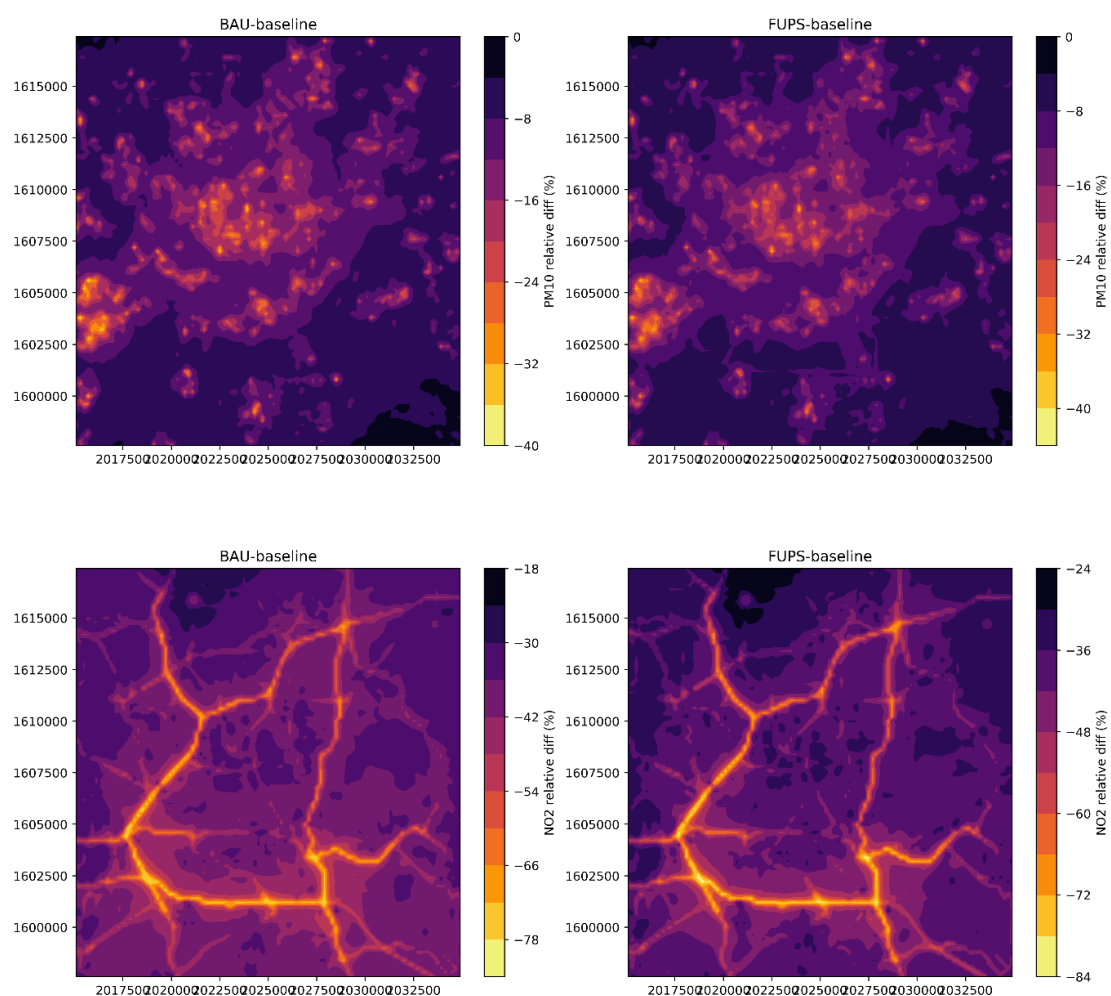
| PM2.5 |      |      | PM10 |      |      | NO2  |      |      |
|-------|------|------|------|------|------|------|------|------|
| 2025  | 2035 | 2050 | 2025 | 2035 | 2050 | 2025 | 2035 | 2050 |

|     |     |     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| BAU | -9  | -16 | -18 | -11 | -18 | -21 | -21 | -34 | -40 |
| UPS | -10 | -16 | -19 | -12 | -19 | -21 | -24 | -37 | -41 |

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. However, there is no substantial difference between implementing BAU or UPS emission scenarios in terms of human health impact reduction. According to these results, both future scenarios will be more efficient on reducing the impact of NO<sub>2</sub> on human health and less on PM<sub>2.5</sub>; the reduction on the impact will be larger at later years.

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 with the comparison between future and current emission scenario for the year 2050 are shown in Figure 3-79. Note that the maps have different scales and they show the reduction, thus the higher the negative values, the larger the reduction is. NO<sub>2</sub> concentration levels have a larger reduction across the city, reducing the impact of NO<sub>2</sub> on human health of the people living in Sosnowiec area. NO<sub>2</sub> reduction scenarios seem to be more successful to target areas where people live than the scenarios for particulate matter. There is an expected increase on the health impact benefit across the years due to the implementation of the emissions control measures for both emissions scenarios.





**Figure 3-79: Air quality impact benefits of implementing emission control measures in 2050 for Sosnowiec, BAU vs baseline on the left and UPS vs baseline on the right for PM2.5 (top), PM10 (centre), and NO<sub>2</sub> (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/d5-5c-assessment-of-impacts-sosnowiec>. 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 community is available on the link: <https://zenodo.org/communities/claircity>.