HEALTH IMPACT RESULTING FROM THE INTRODUCTION OF LOW-EMISSION ZONES

A COMPARATIVE INTERRUPTED TIME SERIES ANALYSIS OF A NATURAL EXPERIMENT IN THREE BELGIAN CITIES USING INDIVIDUAL-LEVEL HEALTH OUTCOMES

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onafhankelijke ziekenfondsen / mutualités libres

HEAL HEALTH AND ENVIRONMENT ALLIANCE

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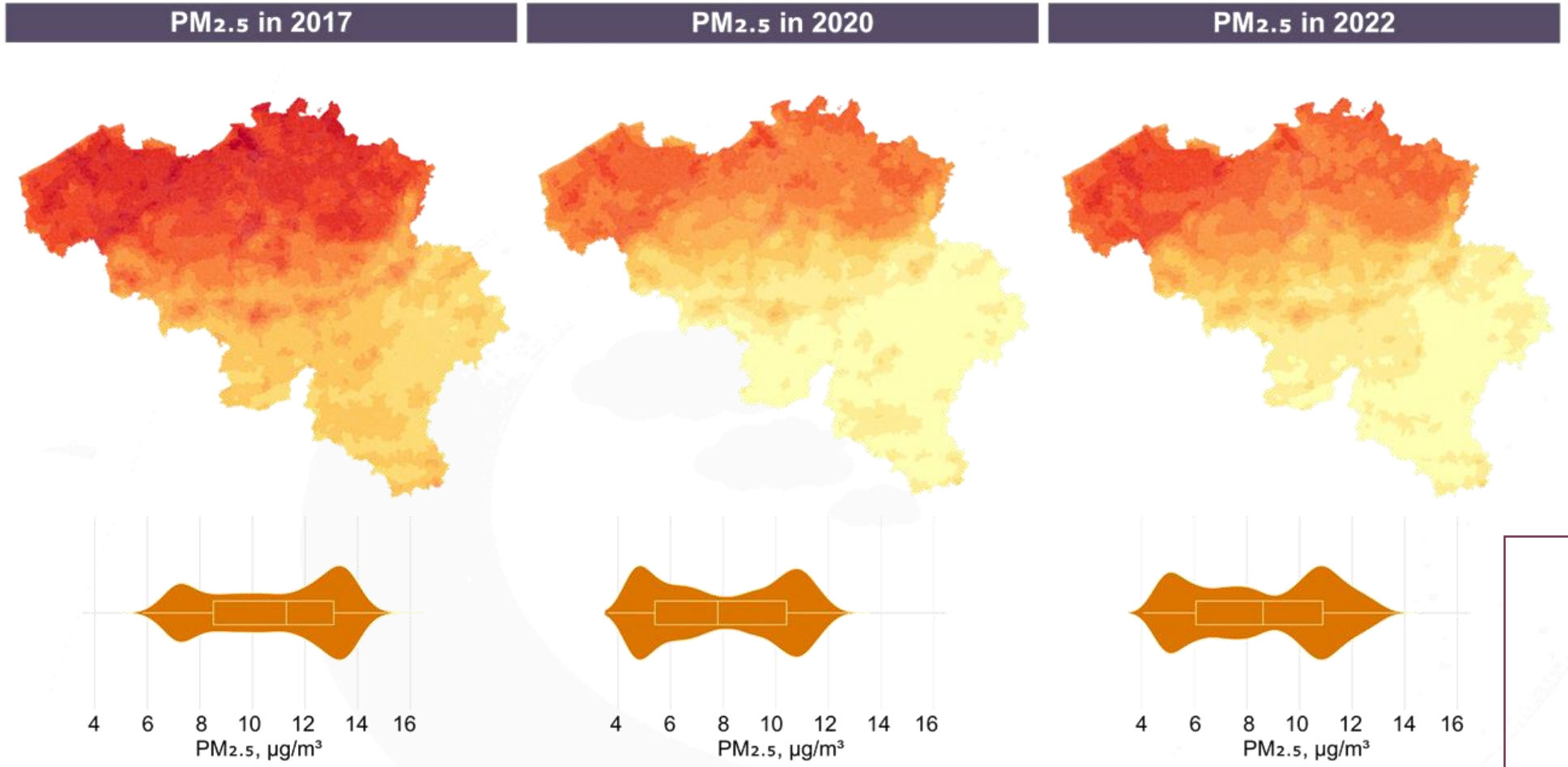
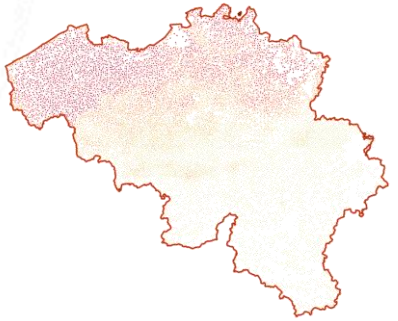
AIR QUALITY HAS IMPROVED, BUT THE MAJORITY OF BELGIANS ARE EXPOSED TO AIR POLLUTION LEVELS ABOVE WHO GUIDELINES





1.5% of members of Mutualités Libres meet WHO AQG (5µg/m³)

Own visualisation and calculation by census tract and for individual members based on ATMO-Street air pollution data provided by Irceline

STRONG EVIDENCE ABOUT THE IMPACT OF AIR POLLUTION ON HEALTH IN BELGIUM

Residential green space, air pollution, socioeconomic deprivation and cardiovascular medication sales in Belgium: a nationwide ecological study

Aerts et al. Science of the total environment, 2020

Association of air pollution and green space with all-cause general practitioner and emergency room visits: a cross-sectional study of young people and adults living in Belgium

Vranken et al. Environmental Research, 2023

Impact of short-term exposure to air pollution on natural mortality and vulnerable populations: a multi-city case-crossover analysis in Belgium

Demoury et al. Environmental Health, 2024

Short-term exposure to ambient air pollution and onset of work incapacity related to mental health conditions

Bruyneel et al. Environment International, 2022

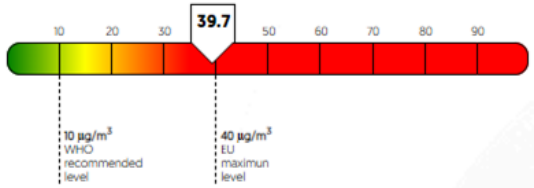
In utero exposure to air pollutants and mitochondrial heteroplasmy in neonates

Cosemans et al. Environmental Science & Technology, 2023

REDUCING AIR POLLUTION LEVELS COULD PREVENT THOUSANDS OF DEATHS IN EUROPEAN CITIES EVERY YEAR (data for 2015)

ANTWERP

NO2 (ANNUAL MEAN)



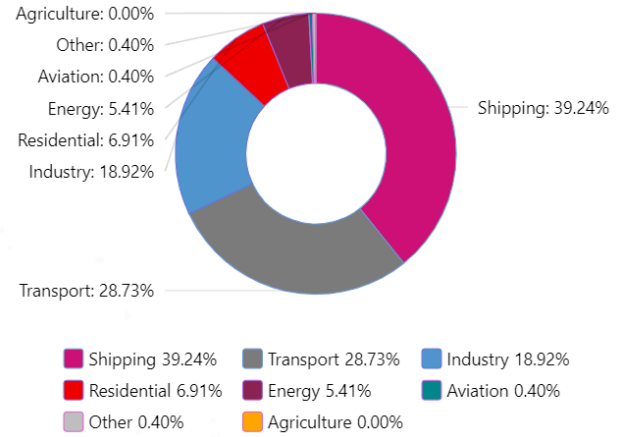
RANKING POSITION

2/858

DEATHS THAT COULD BE AVOIDED

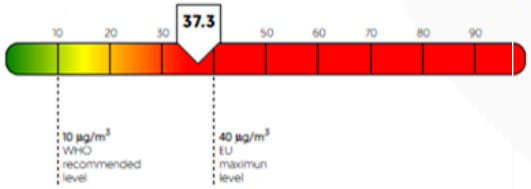
254

IF NEW WHO GUIDELINES (2021) WERE MET



BRUSSELS

NO2 (ANNUAL MEAN)



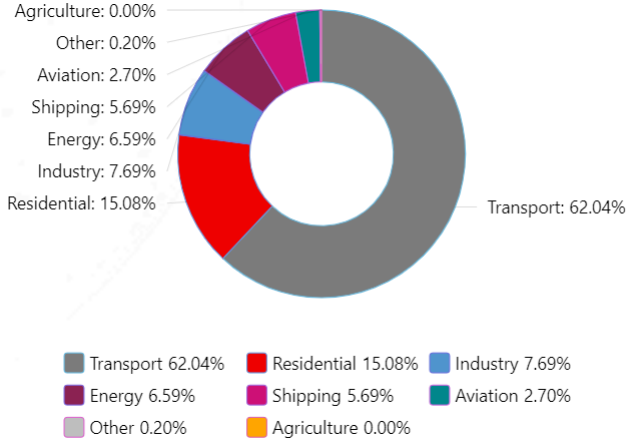
RANKING POSITION

8/858

DEATHS THAT COULD BE AVOIDED

433

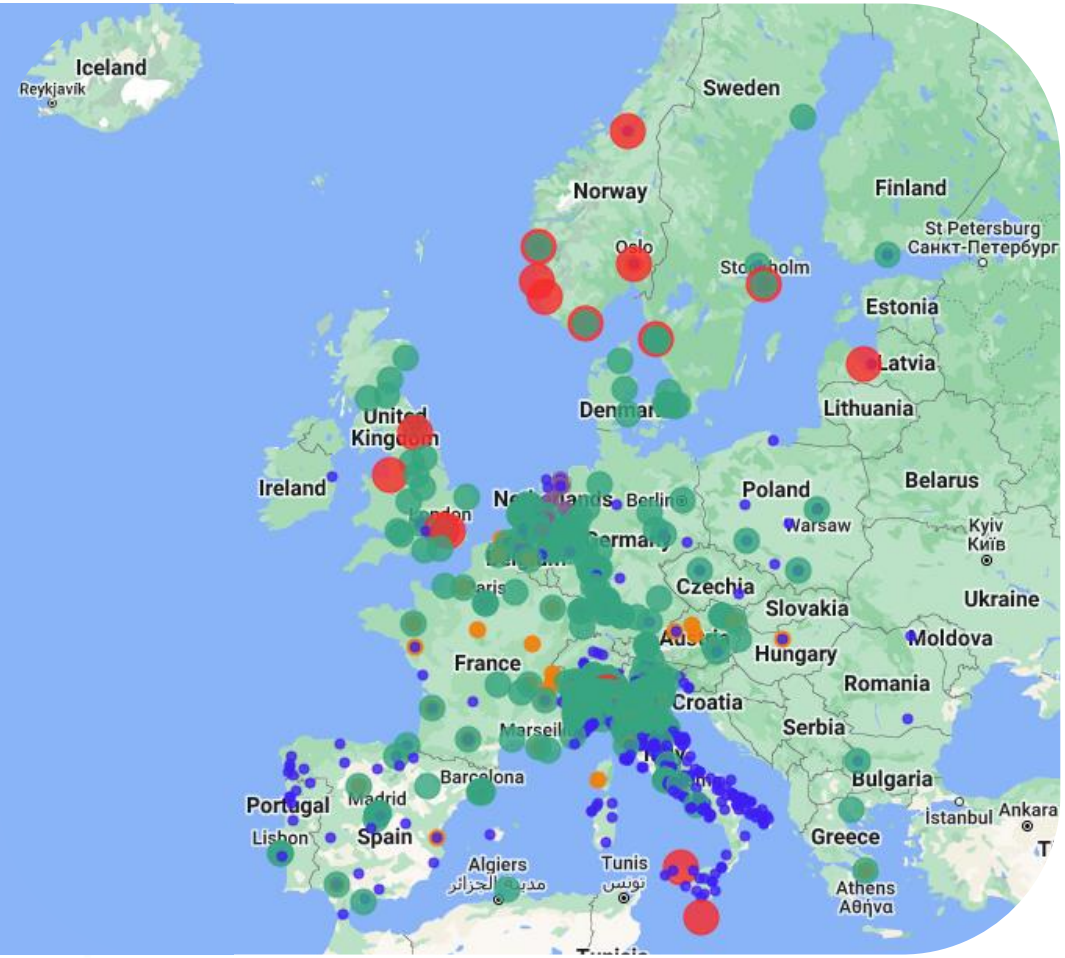
IF NEW WHO GUIDELINES (2021) WERE MET



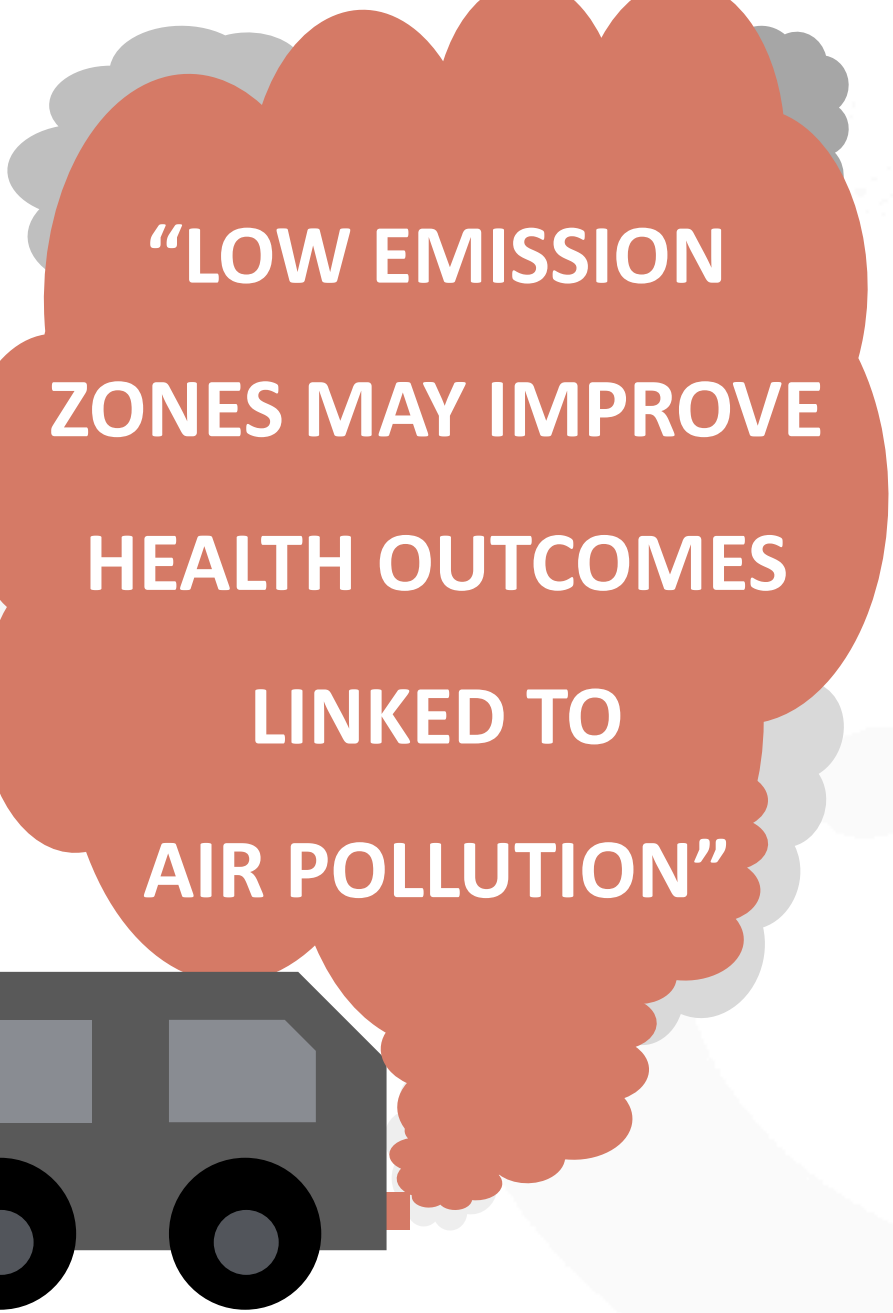
ISGlobal Ranking of cities. Note: data are for 2015/2018

URBAN VEHICLE ACCESS REGULATIONS
TO IMPROVE ISSUES SUCH AS AIR QUALITY

- Low Emission Zone ✓
- Urban Road Tolls ✓
- Other Access Regulation ✓
- Pollution Emergency ✓
- Zero Emission Zone ✓



https://urbanaccessregulations.eu/ (provided by Sadler Consultants Europe GmbH)



- ✓ Systematic review of **8 STUDIES** covering Low-Emission Zones in Germany, Japan and the UK
- ✓ 5 of 6 studies: reductions in **CARDIOVASCULAR DISEASE** subcategories
- ✓ 2 of 5 studies: improvements in **RESPIRATORY OUTCOMES**
- ✓ 2 German studies showed that **HEALTH BENEFITS TENDED TO GROW OVER 3- AND 5-YEAR PERIODS**
- ✓ 1 study in Japan detected **IMPROVEMENTS IN LUNG CANCER RATES 6 TO 9 YEARS LATER**

Chamberlain et al. Health effects of low emission and congestion charging zones: a systematic review. Lancet Public Health, 2023

SOCIOECONOMIC POSITION, AIR POLLUTION AND BENEFITS FROM LEZ

ROME

Wealthy residents…

- ✓ are more likely to live in the city centre
- ✓ are exposed more than disadvantaged groups to higher air pollution concentrations
- ✓ because the LEZ targeted the central area of the city, they profited more

LONDON

More deprived areas…

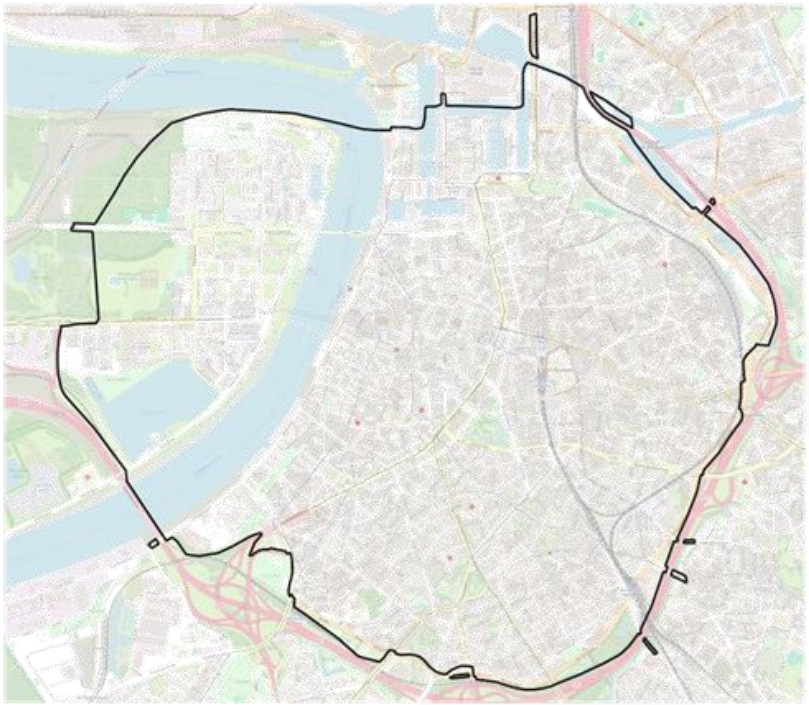
- ✓ have higher air pollution concentrations
- ✓ experienced greater air pollution reductions and mortality benefits compared to the least deprived areas

Note: contradicting findings have also emerged likely resulting from different levels of analyses and deprivation measures, see Verbeek & Hinckx, 2022.

Cesaroni et al. Health benefits of traffic-related air pollution reduction in different socioeconomic groups: the effect of low-emission zoning in Rome. Occup Environ Med, 2011
Logika Consultants. Air Pollution and Inequalities in London: 2019 Update, Greater London Authority, 2021

THERE ARE 3 LOW-EMISSION ZONES IN BELGIUM

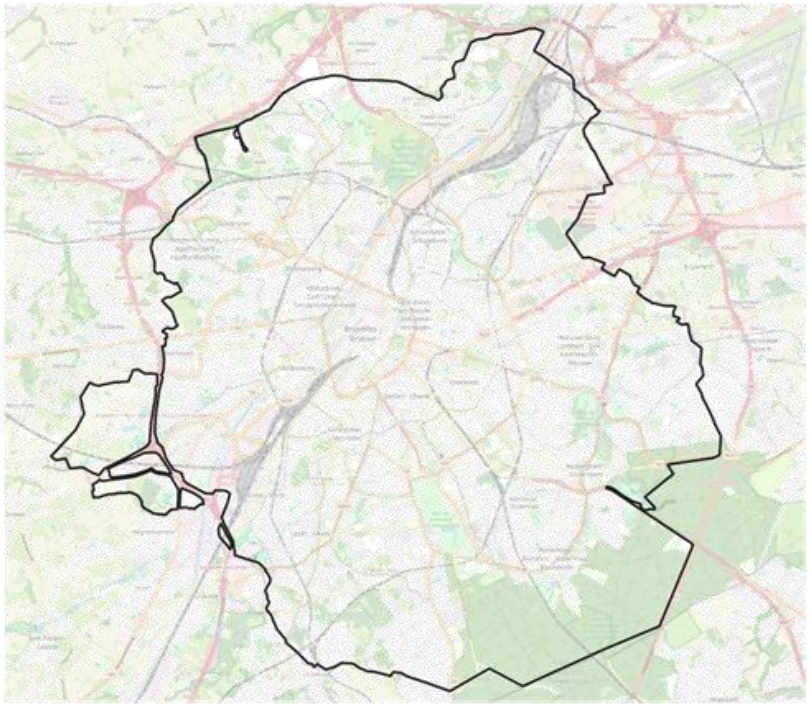
ANTWERP LEZ



LEZ since 2017

stricter regulations in 2020

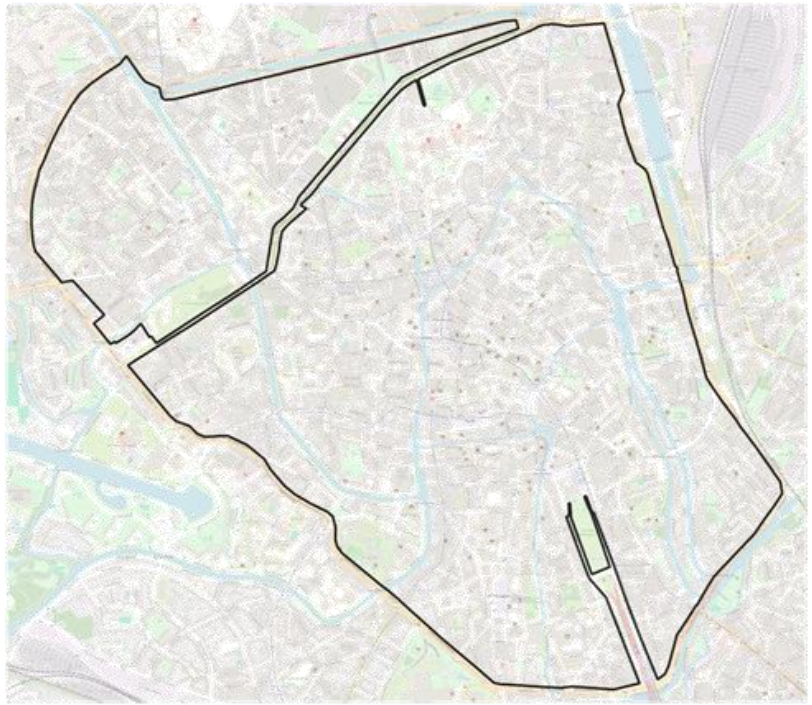
BRUSSELS LEZ



LEZ since 2018

stricter regulations in 2019, 2020 and 2022

GHENT LEZ



LEZ since 2020

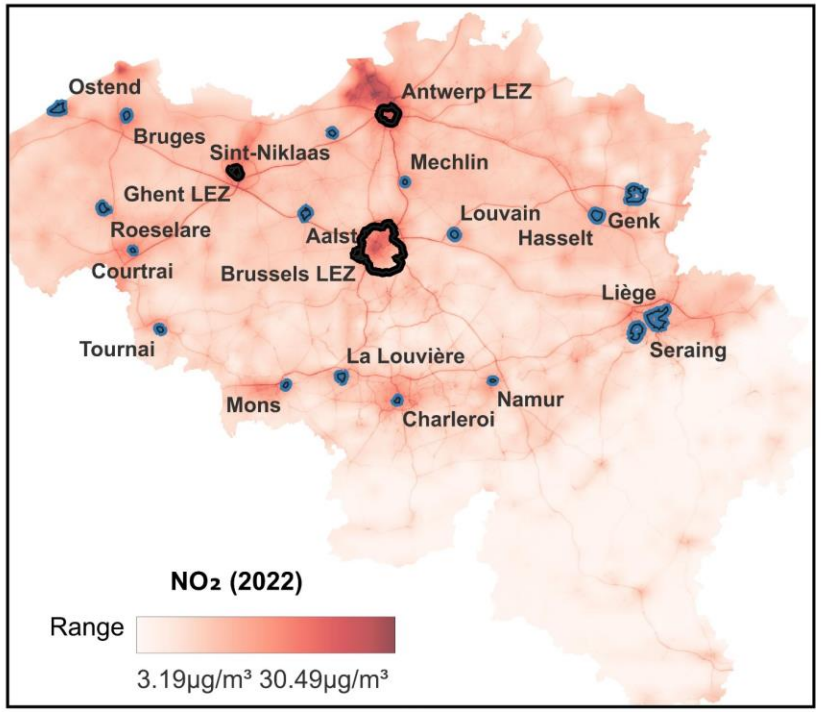
LOW-EMISSION ZONES PLAUSIBLY CREATE EXOGENOUS VARIATION IN AIR POLLUTION, AND SUBSEQUENTLY IMPACT HEALTH

Study objectives

I. Evolution of **AIR QUALITY** since the implementation of the LEZs, compared to other cities

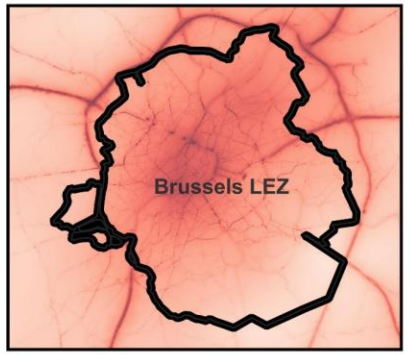
II. Differential exposure to air pollution according to **SOCIOECONOMIC POSITION**, and the evolution thereof since the implementation of the LEZ

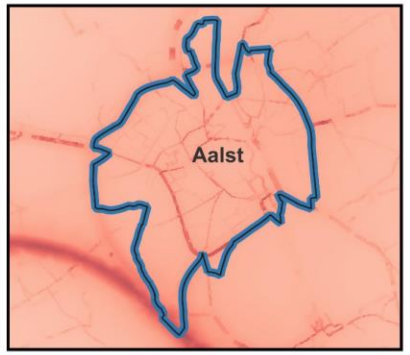
III. **HEALTH IMPACT** of the implementation of the LEZs, compared to other cities

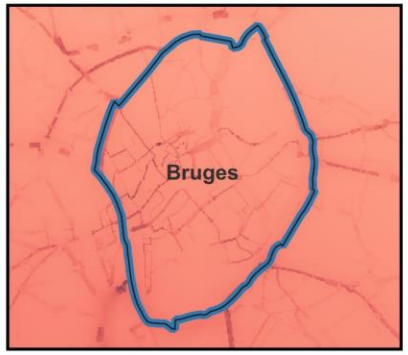

Ostend
Antwerp LEZ
Bruges
Sint-Niklaas
Mechlin
Ghent LEZ
Louvain
Genk
Roeselare
Aalst
Hasselt
Courtrai
Brussels LEZ
Liège
Tournai
La Louvière
Seraing
Mons
Namur
Charleroi
NO₂ (2022)
Range
3.19µg/m³ 30.49µg/m³

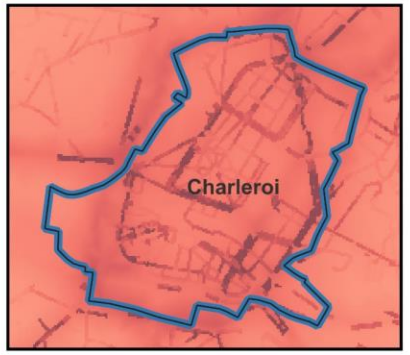

Ghent LEZ

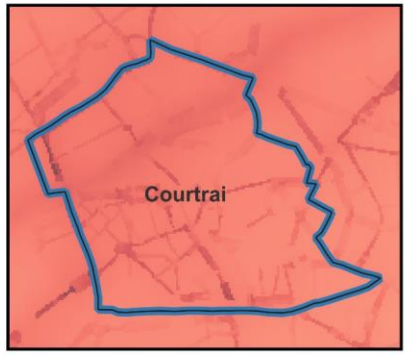

Antwerp LEZ

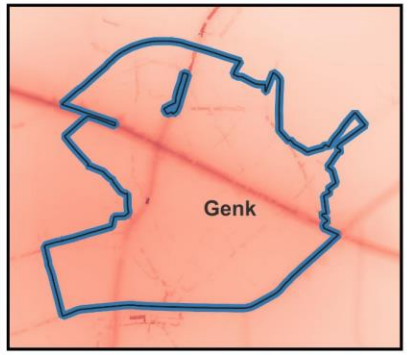

Brussels LEZ

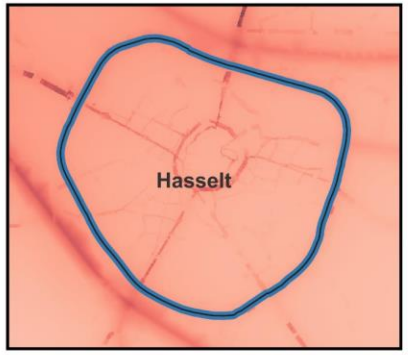

Aalst

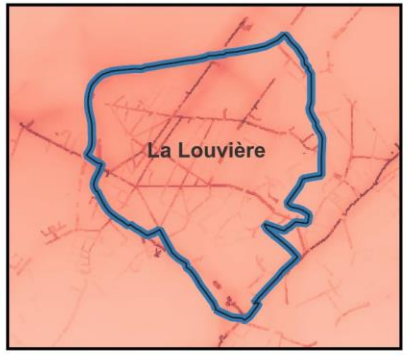

Bruges

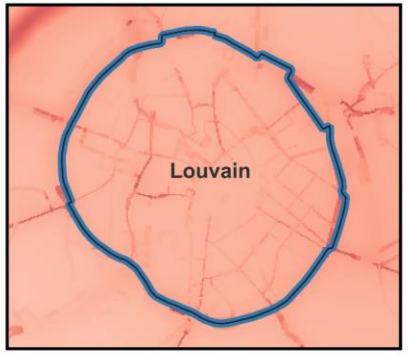

Charleroi

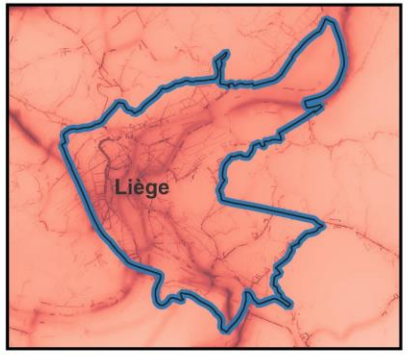

Courtrai


Genk

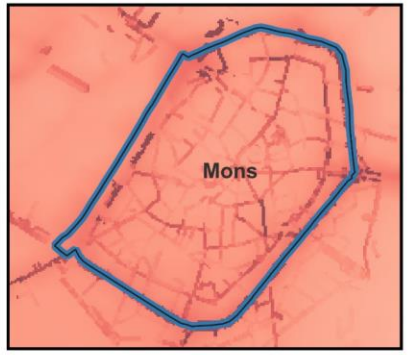

Hasselt

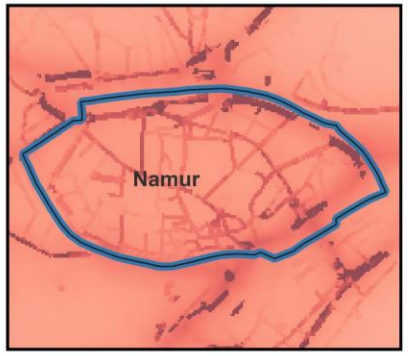

La Louvière

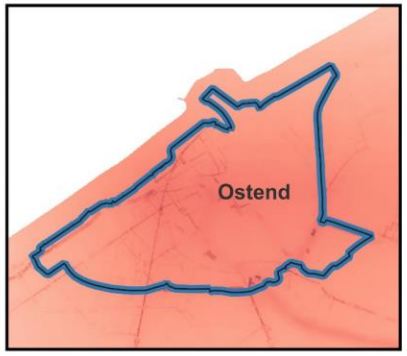

Louvain


Liège

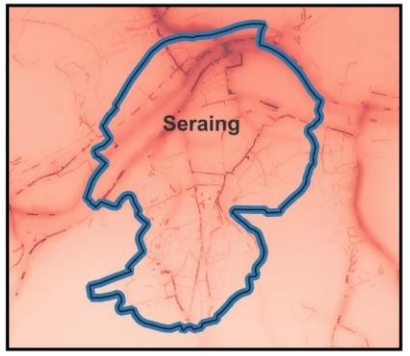

Mechlin

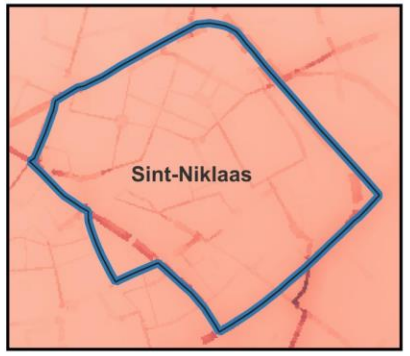

Mons

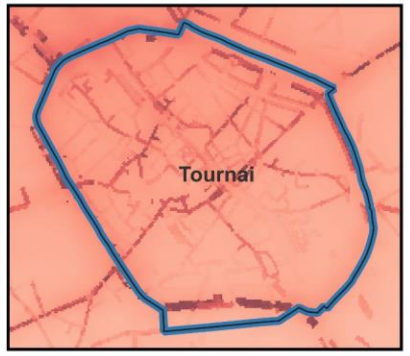

Namur


Ostend


Roeselare

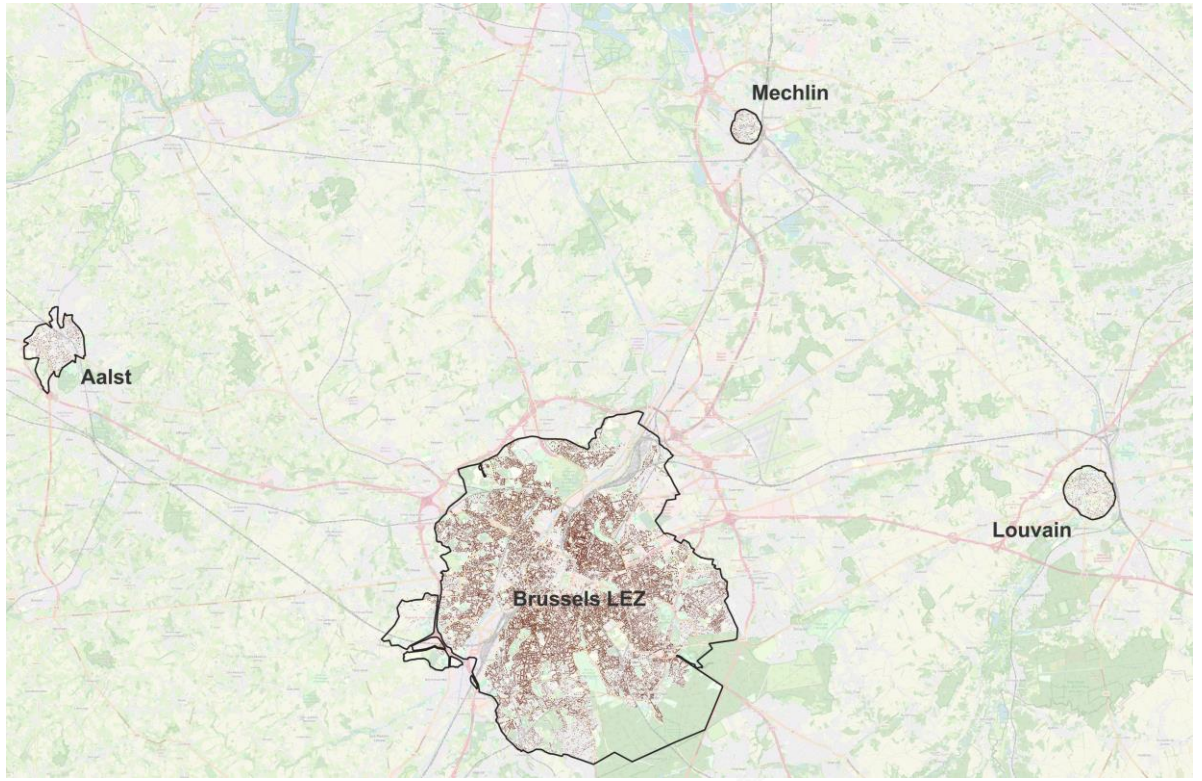

Seraing


Sint-Niklaas


Tournai

STUDY POPULATION

The study population comprises **175.691 MEMBERS** of the Independent Health Insurance Funds (~2.2 million members) **LIVING AT THE SAME ADDRESS DURING THE STUDY PERIOD (01-01-2014 TO 31-12-2023)** within either the 3 LEZ or 17 control cities



Example of geolocation of members of the Independent Health Insurance Funds

I. IMPROVEMENT OF AIR QUALITY IN THE LEZ CITIES, COMPARED TO CONTROL CITIES

AIR QUALITY MEASURES ARE DERIVED FROM HIGH SPATIAL RESOLUTION AIR QUALITY MODELS

Air quality measures include average annual concentrations of **$PM_{2.5}$, PM_{10}, NO_2 AND BC FOR 2016-2022**, and are **CALCULATED FOR ALL INCLUDED INDIVIDUAL MEMBERS** from ATMO-Street data provided by the Belgian Interregional Environment Agency

Note: average annual concentrations for the pollutants were **ALSO CALCULATED FOR THE FULL GEOGRAPHICAL AREA** for the 3 LEZs and 17 control cities – findings did not statistically significantly differ from findings based on the concentrations calculated for our members

*Modelled data used in this study originate from ATMO-Street, an integrated model chain that models air quality at high resolution

STATISTICAL ANALYSIS:
REPEATED MEASURES ANCOVA

- ✓ Random coefficient model approach, with **BASELINE** as covariate

  (sensitivity analysis: baseline*year)

- ✓ **ANTWERP COMPARED WITH FLEMISH CONTROL CITIES** since LEZ was implemented in 2017

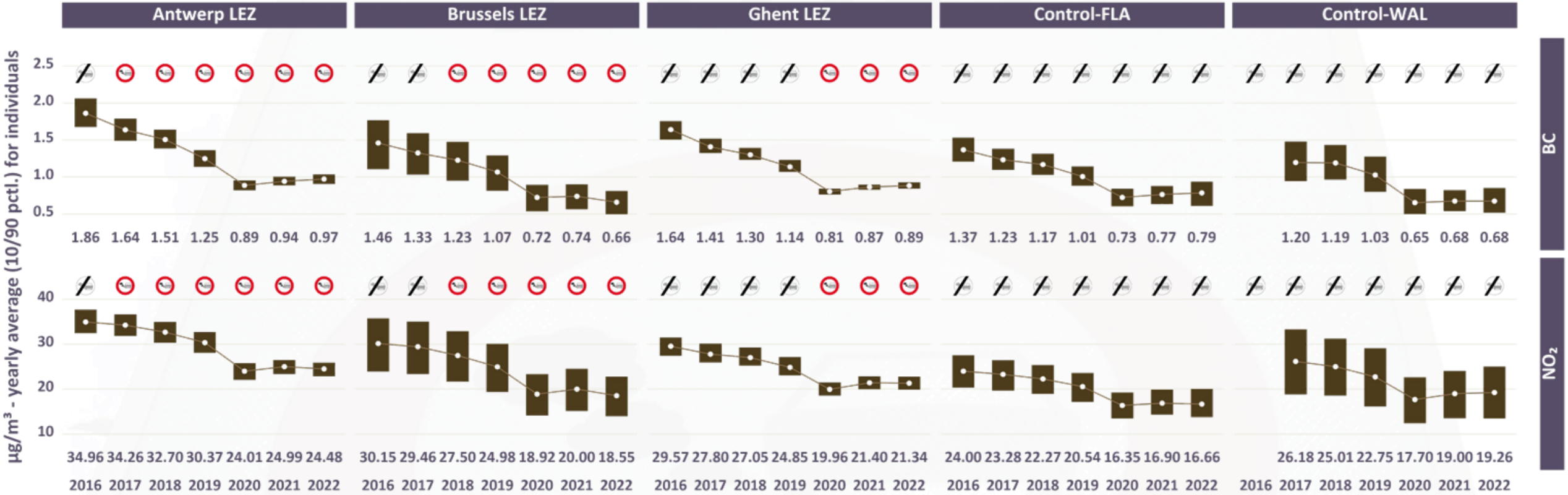
  and no pre-LEZ ATMO-Street data for Wallonia available in 2016 (so no baseline available)

- ✓ **BRUSSELS COMPARED WITH FLEMISH AND WALLOON CONTROL CITIES**

- ✓ **GHENT NOT EVALUATED**, for now, as LEZ implementation coincided with COVID-19, and few

  post-measures are available

FINDINGS: AIR POLLUTION OVER TIME FOR LEZ AND CONTROL CITIES



ANTWERP vs CONTROL CITIES IN FLANDERS

	BC	NO_2
pre-LEZ (2016)	−	−
LEZ (2022)	−	−
change 2017-2022	↘	↘

BRUSSELS vs CONTROL CITIES IN FLANDERS

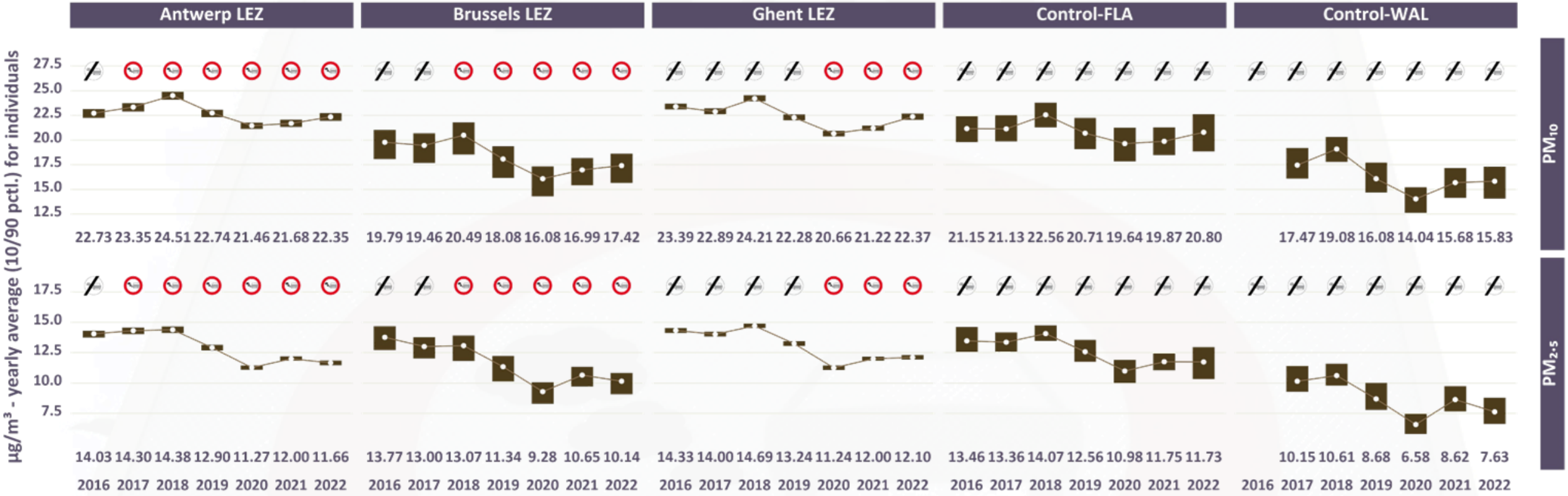
	BC	NO_2
pre-LEZ (2017)	−	−
LEZ (2022)	+	−
change 2018-2022	↘	↘

BRUSSELS vs CONTROL CITIES IN WALLONIA

	BC	NO_2
pre-LEZ (2017)	−	−
LEZ (2022)	+	+
change 2018-2022	↘	↘

− (pre-)LEZ worse than control + (pre-)LEZ better than control ↘ Larger improvement in LEZ than in control

FINDINGS: AIR POLLUTION OVER TIME FOR LEZ AND CONTROL CITIES



ANTWERP vs CONTROL CITIES IN FLANDERS

	PM_{10}	$PM_{2.5}$
pre-LEZ (2016)	−	−
LEZ (2022)	−	+
change 2017-2022	↘	↘

BRUSSELS vs CONTROL CITIES IN FLANDERS

	PM_{10}	$PM_{2.5}$
pre-LEZ (2017)	+	+
LEZ (2022)	+	+
change 2018-2022	↘	↘

BRUSSELS vs CONTROL CITIES IN WALLONIA

	PM_{10}	$PM_{2.5}$
pre-LEZ (2017)	−	−
LEZ (2022)	−	−
change 2018-2022	↘	↘

− (pre-)LEZ worse than control + (pre-)LEZ better than control ↘ Larger improvement in LEZ than in control

II. SOCIOECONOMIC POSITION &

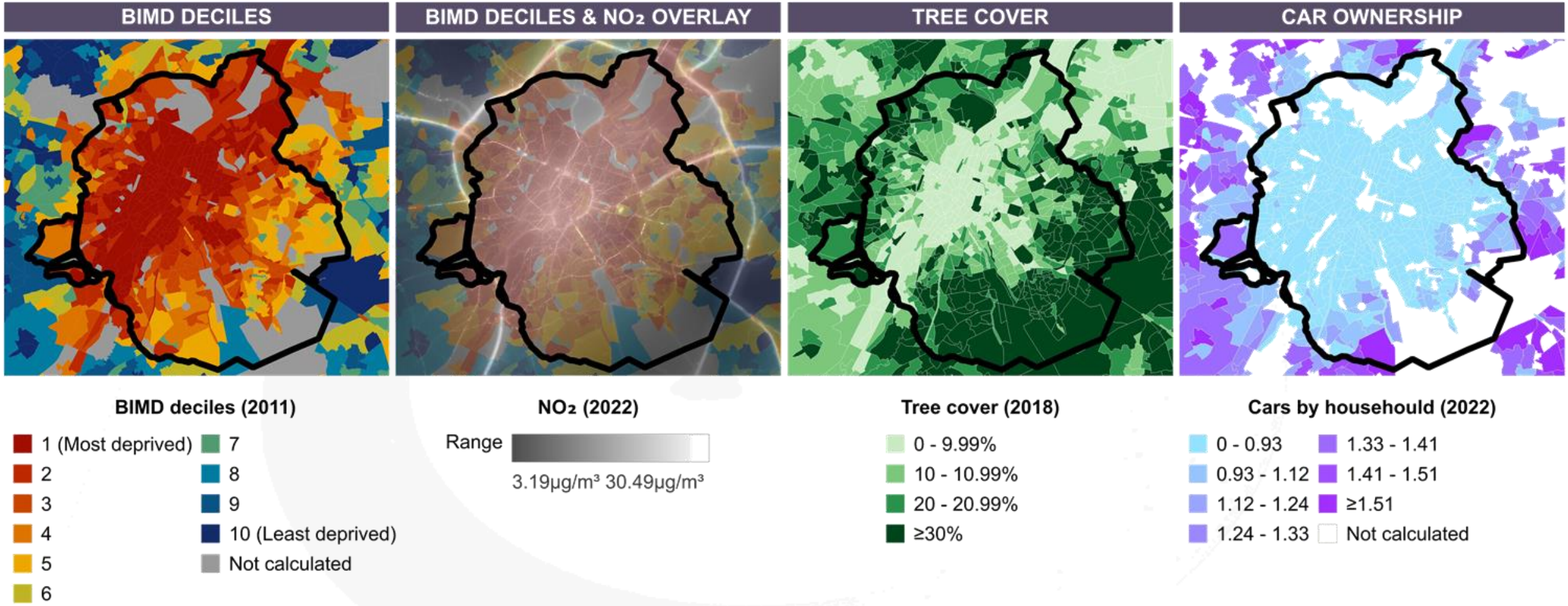
(THE EVOLUTION OF) EXPOSURE TO AIR POLLUTION

STATISTICAL ANALYSIS:
REPEATED MEASURES ANCOVA

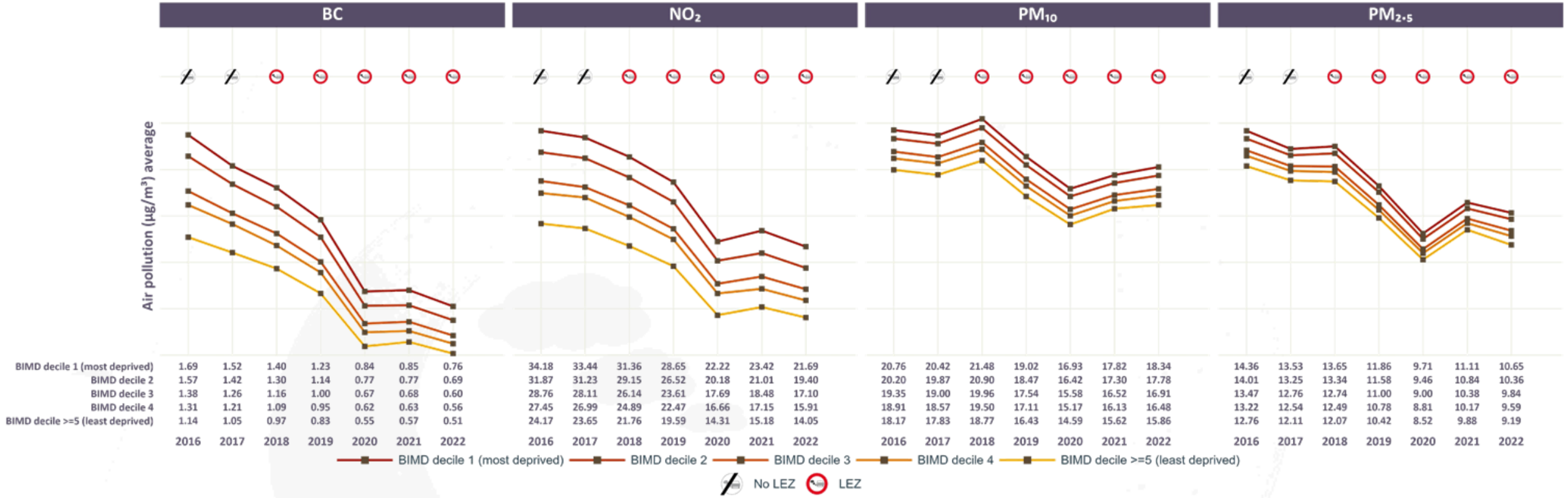
- ✓ Measure of deprivation: **BELGIAN INDICES OF MULTIPLE DEPRIVATION (BIMD) DECILES** (for the year 2011), with a focus on **BRUSSELS**
- ✓ BIMD (income, employment, education, housing) without the health deprivation domain
- ✓ BIMD deciles were categorized as 1 – Most deprived (n=263), 2 (n=146), 3 (n=112), 4 (n=75), ≥5 – Least deprived (n=94), for a total of 690 census tracts
- ✓ Random coefficient model approach, with **BASELINE** as covariate (sensitivity analysis: baseline*year)

Otatova et al. Measuring small-area level deprivation in Belgium: The Belgian Index of Multiple Deprivation. Spat Spatiotemporal Epidemiol, 2023

FINDINGS: DIFFERENTIAL EVOLUTION OF AIR POLLUTION WITHIN LEZ ACCORDING TO SOCIOECONOMIC STATUS (IN BRUSSELS)



FINDINGS: DIFFERENTIAL EVOLUTION OF AIR POLLUTION WITHIN LEZ ACCORDING TO SOCIOECONOMIC STATUS (IN BRUSSELS)



- ✓ Controlling for the pre-LEZ value (in 2017), there is a **STATISTICALLY SIGNIFICANT DIFFERENCE IN THE CHANGE IN BC AND NO_2** over time across BIMD deciles | for BC there is a systematically slower decrease with lesser deprivation | for NO_2 there is a slower decrease for BIMD decile ≥5 → **MORE DEPRIVATION = MORE RAPID DECREASE**
- ✓ Controlling for the pre-LEZ value (in 2017) there is **NO STATISTICALLY SIGNIFICANT DIFFERENCE IN THE CHANGE IN PM_{10} AND $PM_{2.5}$** over time across BIMD deciles
- ✓ Exposure to these **POLLUTANTS REMAINS STATISTICALLY SIGNIFICANTLY HIGHER IN MORE DEPRIVED BIMD DECILES**

III. HEALTH IMPACT FROM THE INTRODUCTION OF LEZs

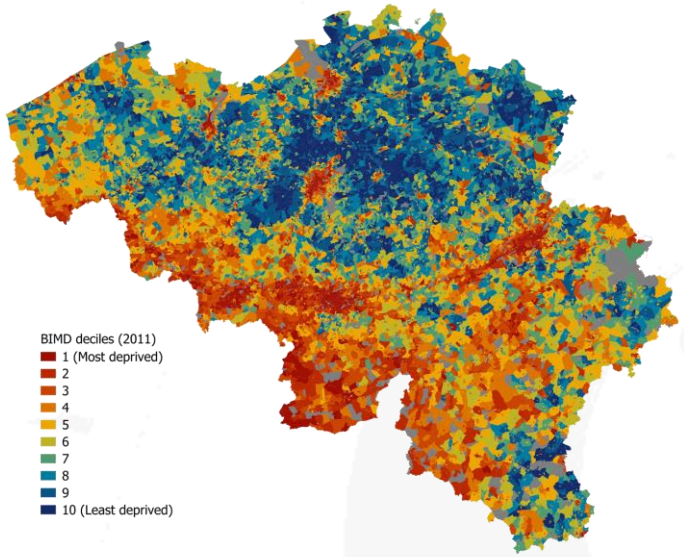
AIR POLLUTION-RELATED HEALTH OUTCOMES ARE MEASURED FROM INDIVIDUAL-LEVEL HEALTH CARE EXPENDITURE DATA

Repeated measurements, equally spaced by year, were created for:

- ✓ Number of all-cause **IN-HOURS/OUT-OF-HOURS GENERAL PRACITIONER VISITS**
- ✓ Number of all-cause **EMERGENCY ROOM VISITS**
- ✓ Chronic (≥90 DDD) use of drugs:
  - **DIABETES** (A10A & A10B)
  - **CARDIOVASCULAR DISEASE** (C01 C02 C03 C07 C08 C09)
  - **OBSTRUCTIVE AIRWAY DISEASES** (R03)
  - **ANTIDEPRESSANTS** (N06A)
  - **ANTITHROMBOTIC AGENTS** (B01)

PROPENSITY MATCHING TO BALANCE MEMBERS LIVING IN LEZ AND CONTROL CITIES

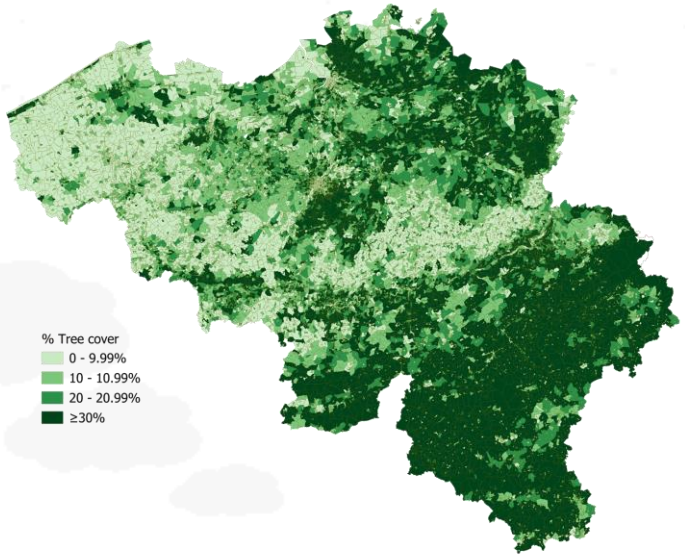
BELGIAN INDICES OF MULTIPLE DEVRIVATION



BIMD deciles combine information from 6 domains: income, employment, education, housing, health and crime

Data for 2011

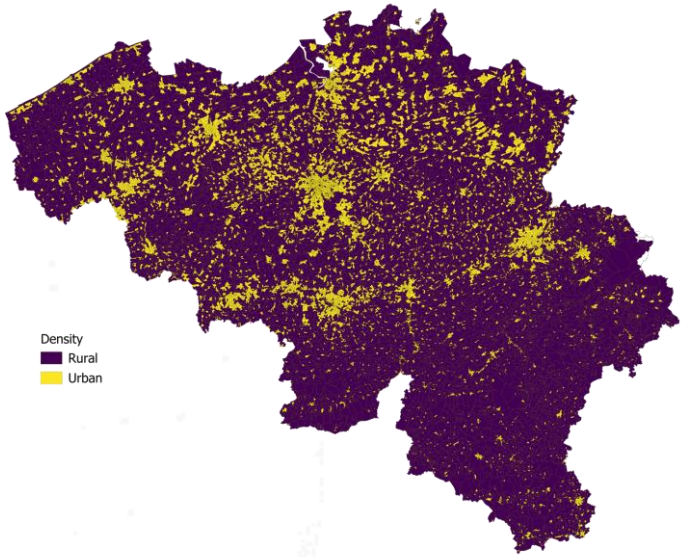
TREE COVER



High Resolution Layers from the Copernicus Land Monitoring Service Dominant Leaf Type and Grassland 10 × 10 m raster data

Data for 2018

URBAN/RURAL



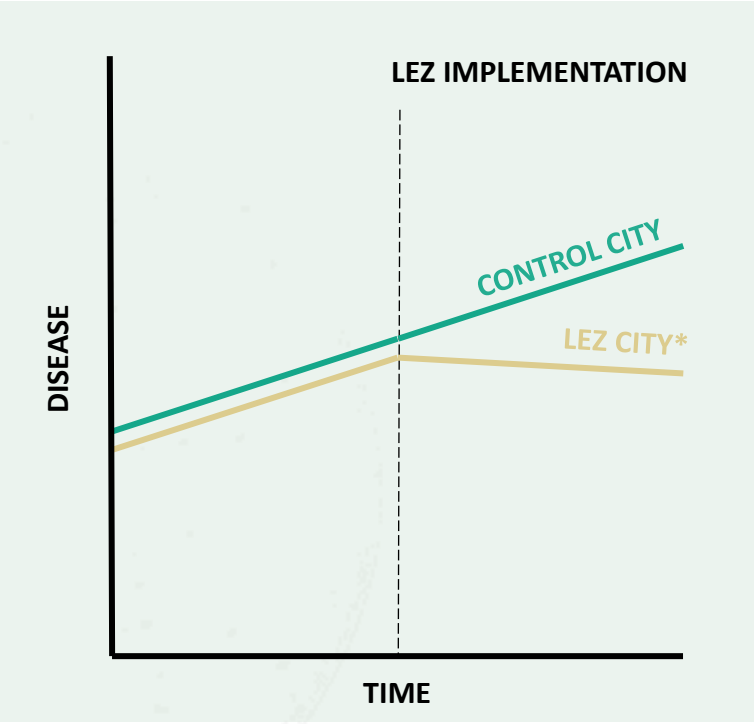
Having a population density of more or less than 600 inhabitants/km^2 at the level of the census tract, respectively

Data for 2014

Individual-level characteristics included in the analysis are **AGE** **GENDER** and **NATIONALITY**

STATISTICAL ANALYSIS: INTERRUPTED TIME SERIES ANALYSIS WITH CONTROL GROUP

- ✓ Generalized Estimating Equations (GEE) to account for repeated outcome measures
- ✓ Negative binomial GEE to the count outcomes
- ✓ Binary logistic GEE to the binary outcomes
- ✓ Estimation and testing on the event probability scale
- ✓ Subgroup analyses by age categories and BIMD



* The curve may take a different shape e.g. a slope change following a lag

CONCLUSION

- ✓ Air pollution concentrations in Belgium **STILL LARGELY EXCEED WHO AQG LEVELS**
- ✓ Compared to control cities, **BC, NO_2, PM_{10} and $PM_{2.5}$ SHOWED A LARGER DECREASE IN ANTWERP AND BRUSSELS SINCE THE IMPLEMENTATION OF THE LEZ**
- ✓ In Brussels, **MORE DEPRIVED NEIGHBOURHOODS BEAR THE HEAVIEST BURDEN**, but for NO_2 and BC more deprived neighbourhoods **BENEFITED MOST** since the implementation of the LEZ