International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

Ambient air pollution: The role of cities
EPCAC Position Paper Sections 2 & 3

Gregor Kiesewetter, Philippe Thunis, Andreas Eisold, Martine Ouwersloot, Maaike Lammerts-Huitema, Martin Lutz, Rob Maas, Guus Velders

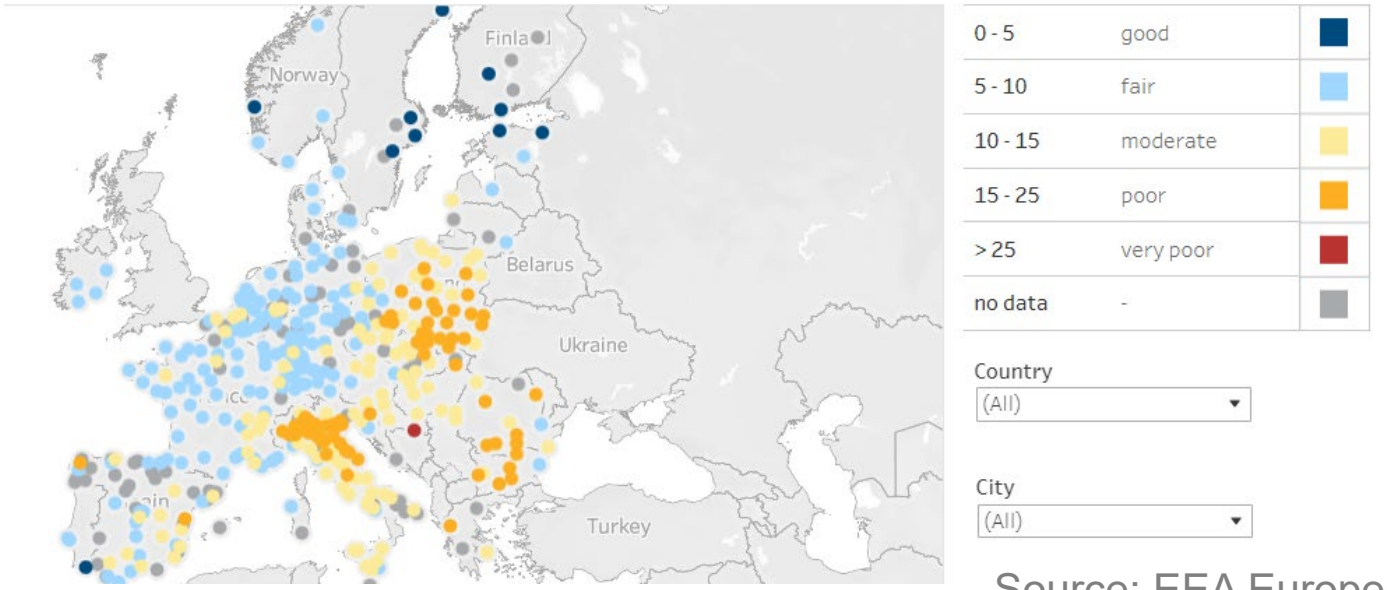
kiesewet@iiasa.ac.at

EPCAC Meeting, RIVM/virtual, 26 Sep 2024

Air pollution is still a problem, especially in cities

- In 2021 97 % of the urban population in the EU was exposed to concentrations of particulate matter ($PM_{2.5}$) above the WHO air quality guidelines (EEA, 2024). For nitrogen dioxide (NO_2) and ozone (O_3) this was 90 % and 94 %, respectively.
- $PM_{2.5}$ mass is currently the most proven metric for assessing health burden of air pollution. NO_2 and ozone are further relevant metrics.
- Cities are both important emitters and receptors of pollution.

Annual mean $PM_{2.5}$ (2022-2023 avg)



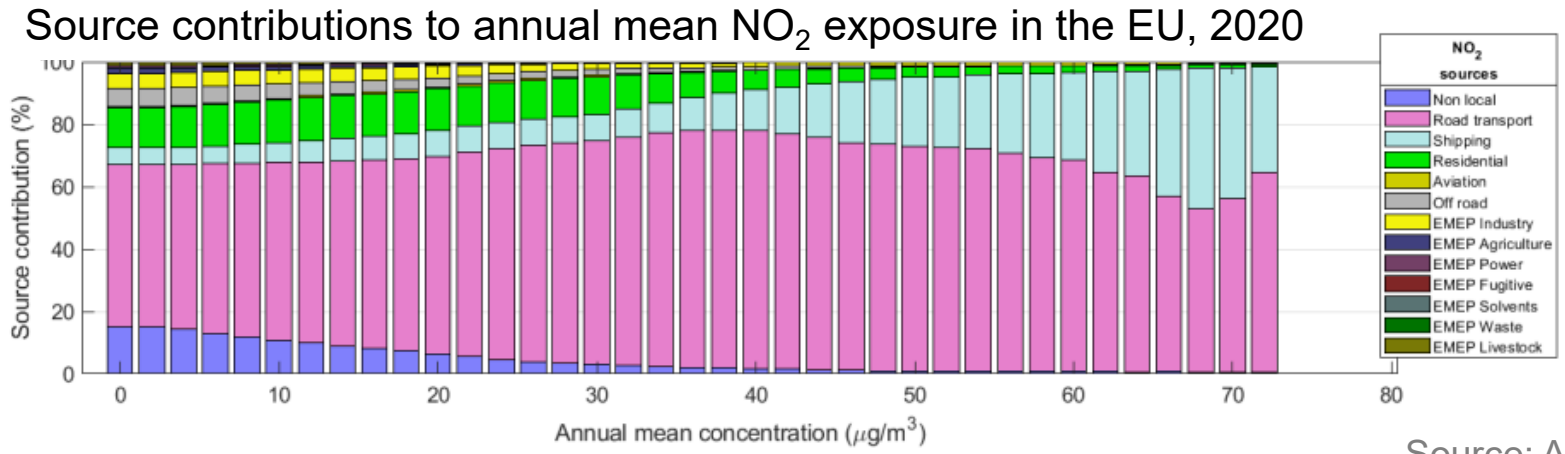
Source: EEA European city air quality viewer

Contributions to cities: $PM_{2.5}$

- Primary and secondary PM play a role (PPM more local, SIA more regional)
- Contributions from a wide range of sectors. Residential, traffic, agriculture, industry important.
- Both local as well as distant sources are important. The local share depends strongly on city characteristics:
  - Large cities in isolated locations are dominated by local sources, also
  - cities in mountainous terrain and therefore local inversions, and
  - cities with local use of solid fuels for heating.
  - Large industrial facilities in individual cities can play a big role.
  - Smaller cities tend to be more influenced by regional transport.
- Different assessments give somewhat different estimates on sector importance. Two examples are the JRC Urban Atlas and the IIASA/GAINS model assessments.
- Hot spots versus average exposure makes a difference.

Contributions to cities: NO_2, O_3

- NO_2:
  - Mostly from road transport (diesel), shipping (harbors).
  - Local contribution dominant.

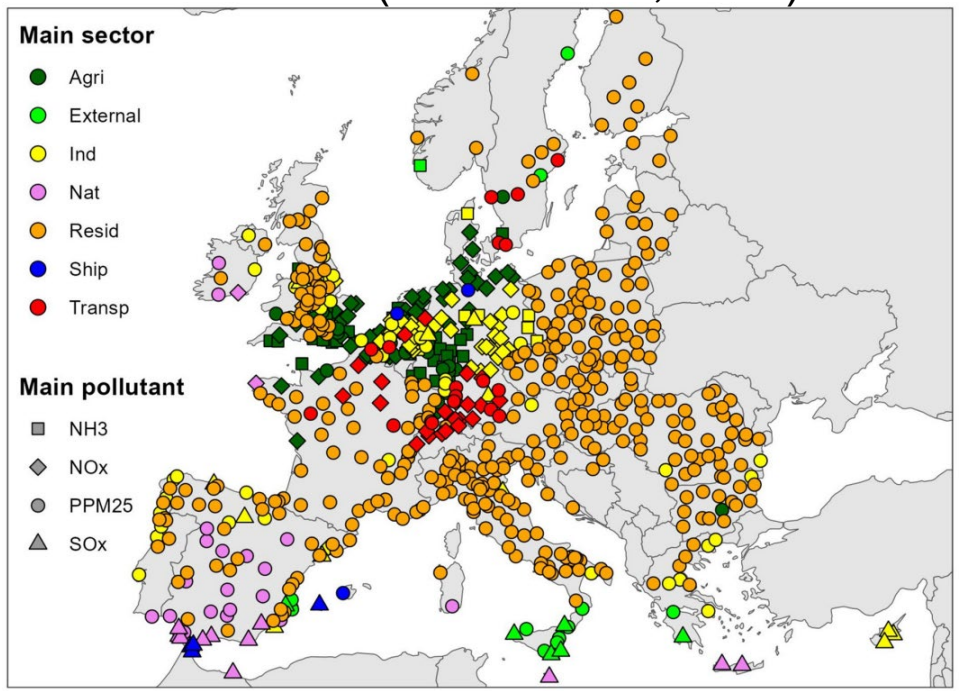


Source: AAQD IA support study (2022)

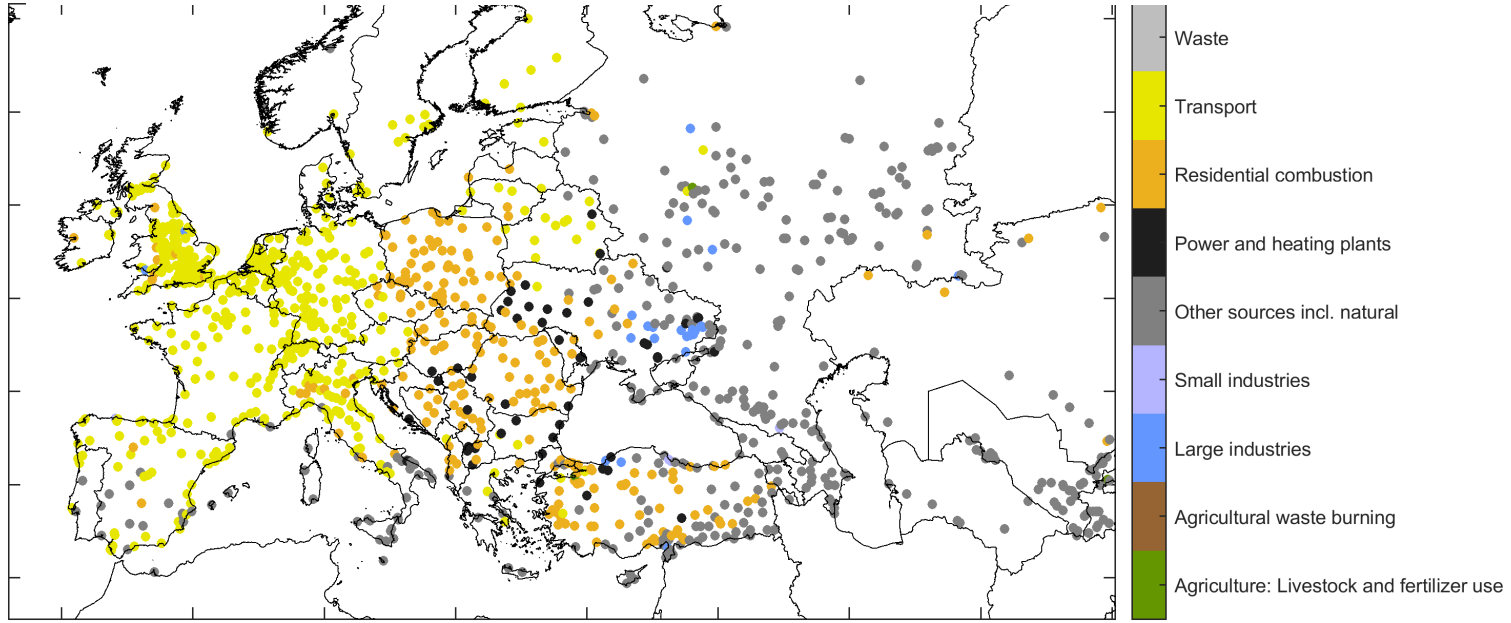
- O_3: is a secondary pollutant. Cities can be locally a sink (titration) or source through emissions of NOx (traffic, industry, heating) and NMVOCs (solvents, …).

Dominant sectors for $PM_{2.5}$ in cities

JRC urban atlas (Thunis et al., 2023): 2019



IIASA / GAINS model (Kiesewetter et al., in prep.): 2015



Similarities:

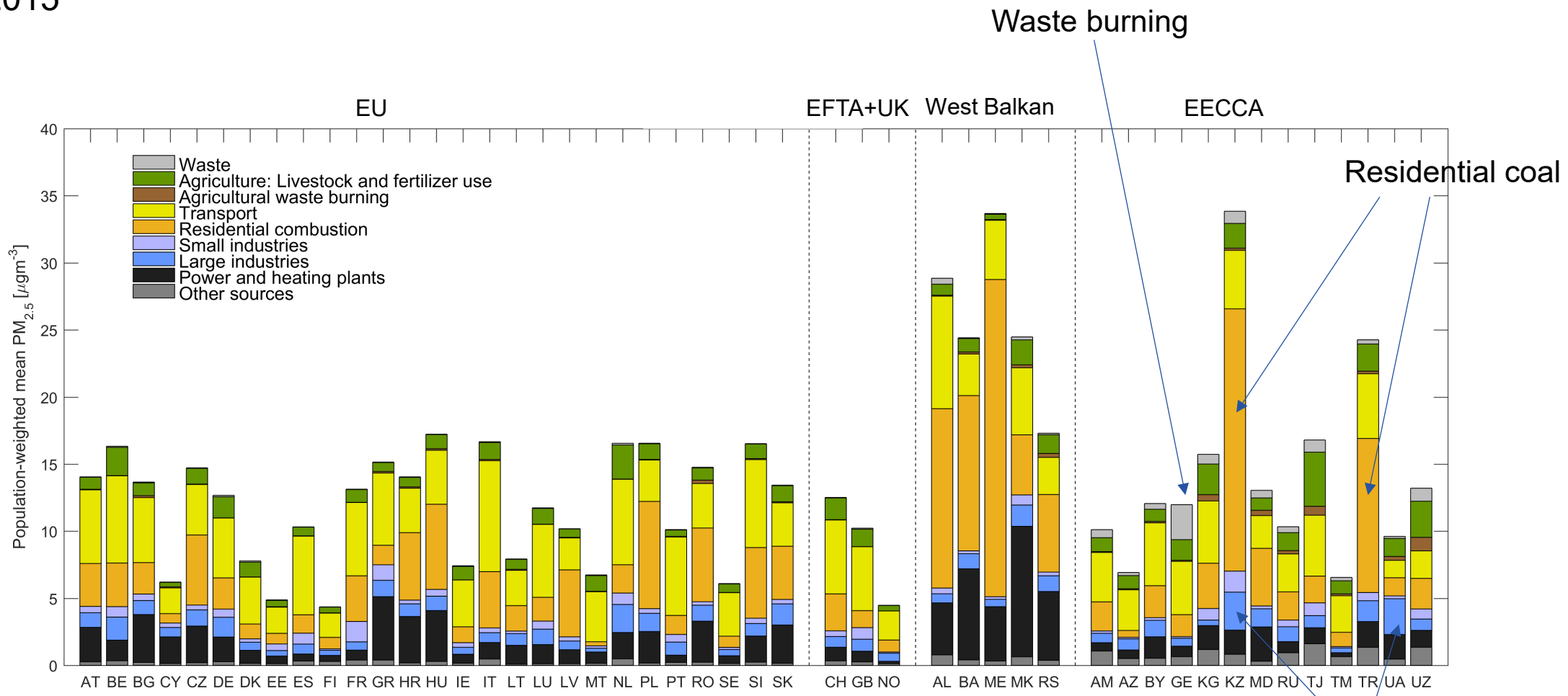
- Residential sector in Eastern and Southeast Europe
- Agriculture important in BeNeLux
- Dust in Southern Europe

Differences:

- GAINS would not see agriculture dominant
- Residential vs traffic in Western Europe

Source contributions to cities (country average)

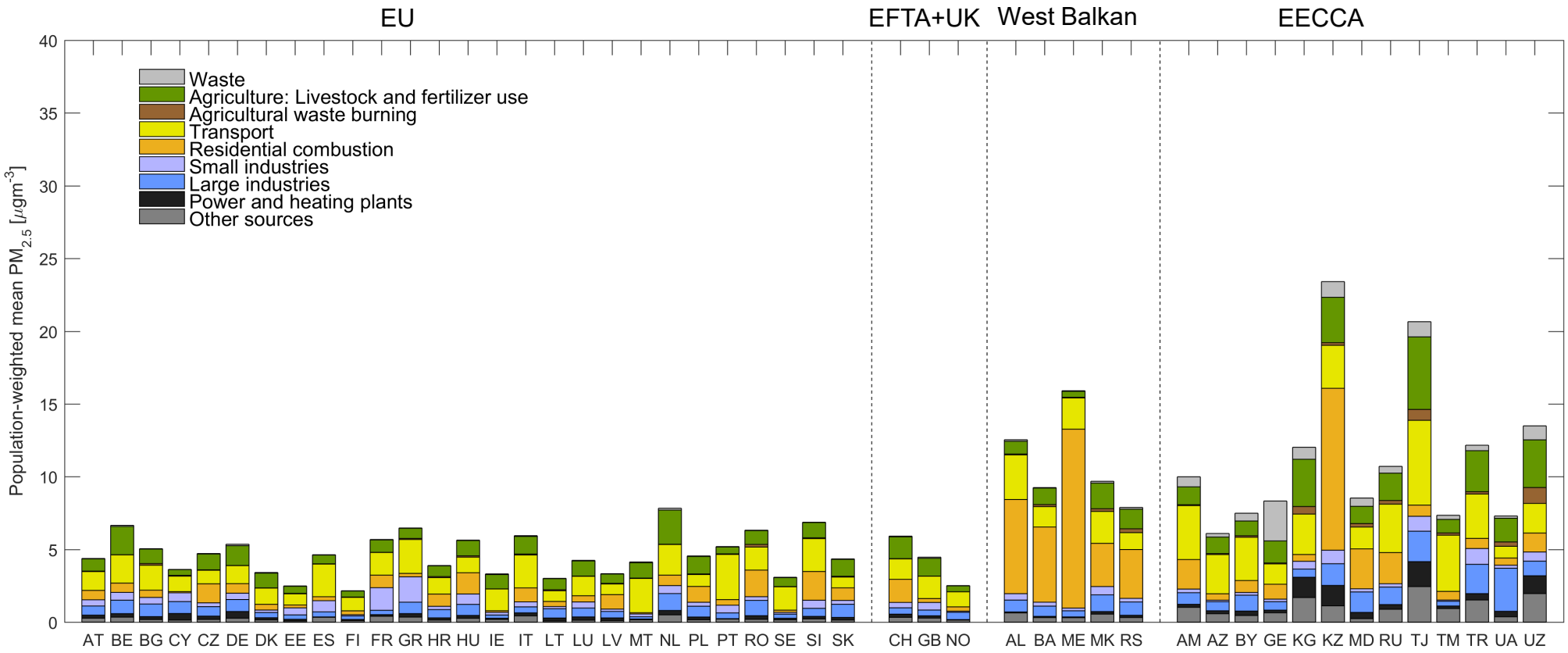
2015



Preliminary results: GAINS calculations for Gothenburg Protocol Revision scenarios

Source contributions to cities (country average)

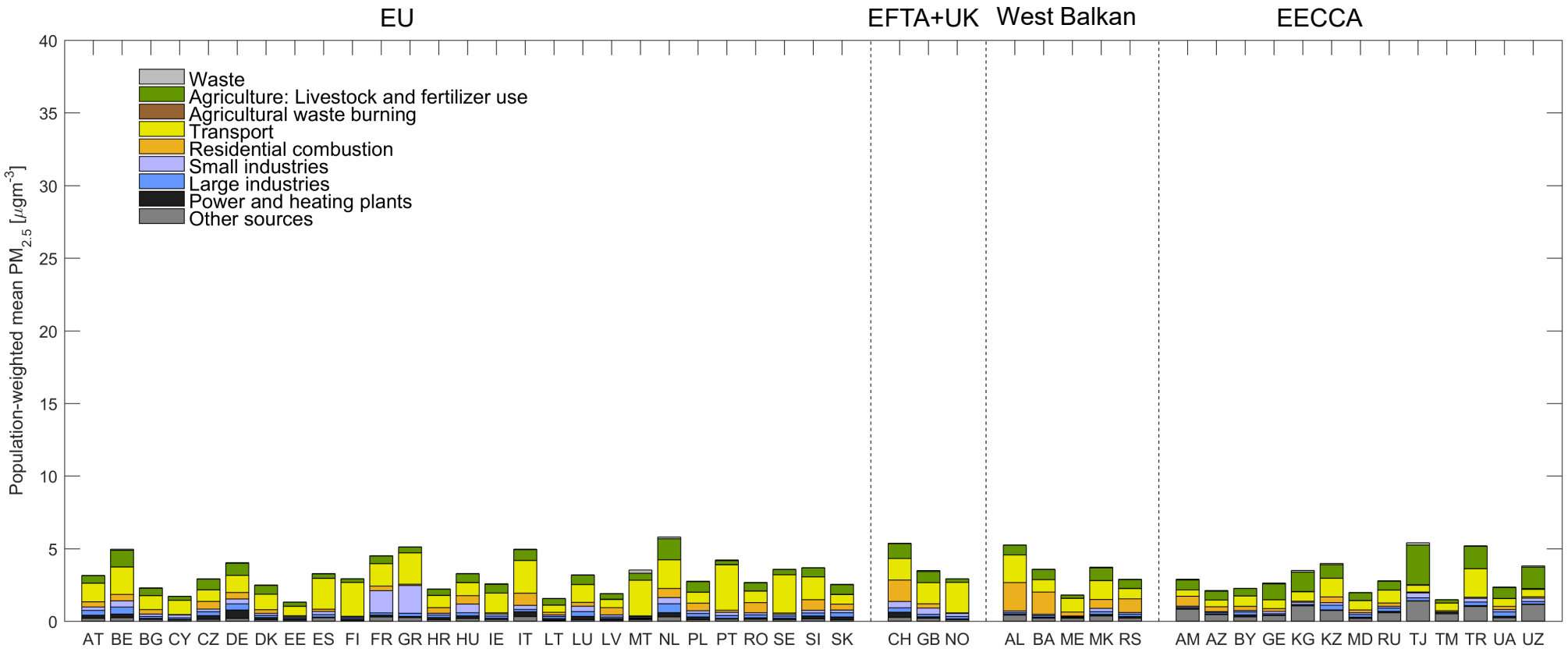
2040
Baseline scenario for Gothenburg Protocol Revision
(stated energy policies, current air pollution legislation)



Preliminary results: GAINS calculations for Gothenburg Protocol Revision scenarios
Draft of the policy brief describing the scenarios: here

Source contributions to cities (country average)

2040
LOW scenario: ambitious climate policies, maximum feasible pollution controls, diet shift



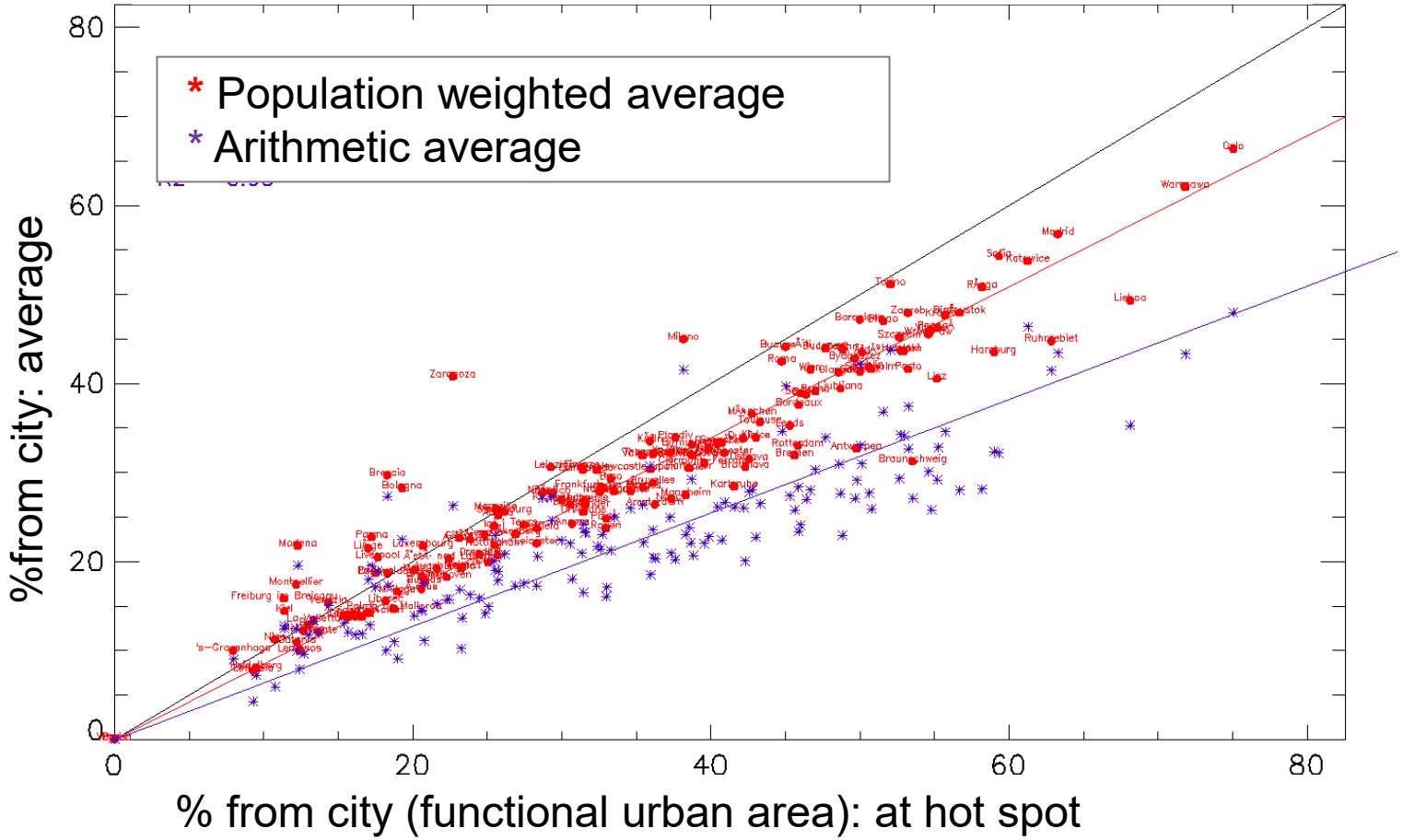
Preliminary results: GAINS calculations for Gothenburg Protocol Revision scenarios
Draft of the policy brief describing the scenarios: here

Some difficult questions

- What is the city definition?
  - GAINS: Urban core (UCDB)
  - JRC urban atlas: Functional urban area / commuting zone
  - EEA: ?
- Do we care more about city-center concentrations or population exposure averaged across the city?
- How to account for secondary pollution created in ambient air from precursors with different spatial / sectoral origin? (e.g. $NH_4^-NO_3^+$)
  - Could be split according to sensitivity of PM mass to emission reductions of the different precursors
  - Could be combined into one category (Traffic+Agriculture, Industry+Agriculture)
  - Tagging (mass transfer method)
- A lot depends on emission distribution urban-rural. How to derive credible inventories and splits?
  - Residential heating: urban population typically uses cleaner fuels but not 100%. Individual cities are very different depending on availability of district heating networks, piped gas
  - Traffic: vehicle mileage is different inner urban vs inter urban. Statistics are often poor.
  - Industry: actual location of plants
- Depending on pollutant and dominant source sectors, the resolution of models plays a role.
  - NO_2: high resolution required ~100m; $PM_{2.5}$ ~km resolution; O_3 ? (often done with coarse resolution but could lead to overestimation in cities)

Hot spots vs city average

Contributions from city (functional urban area) to itself

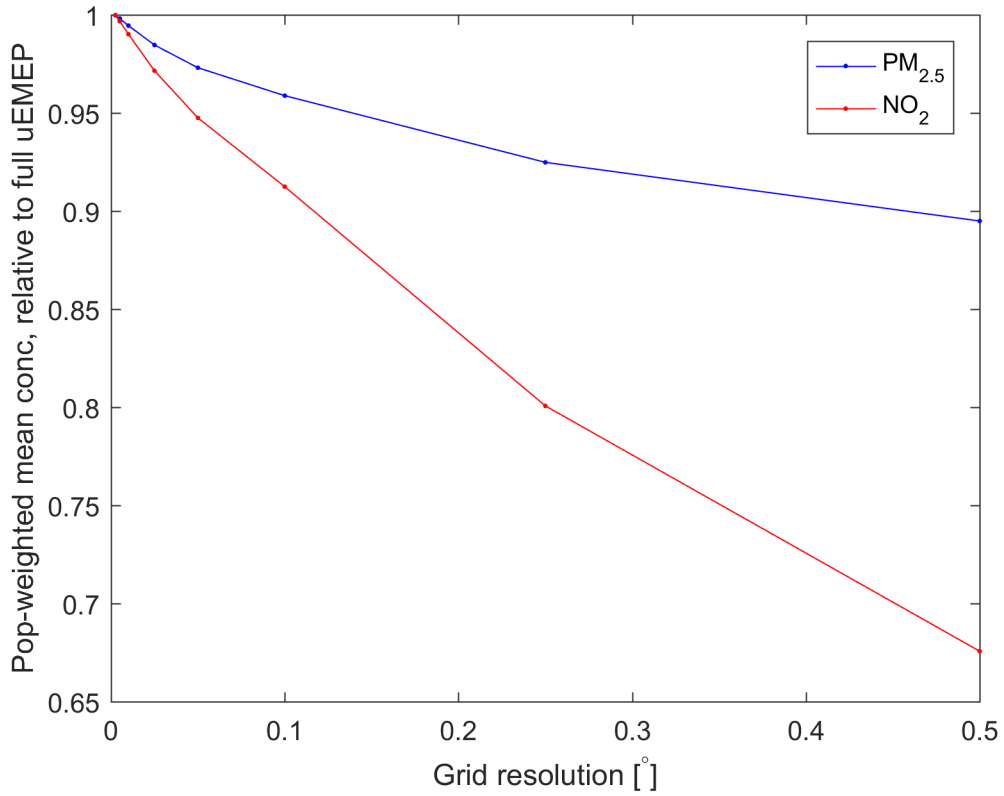


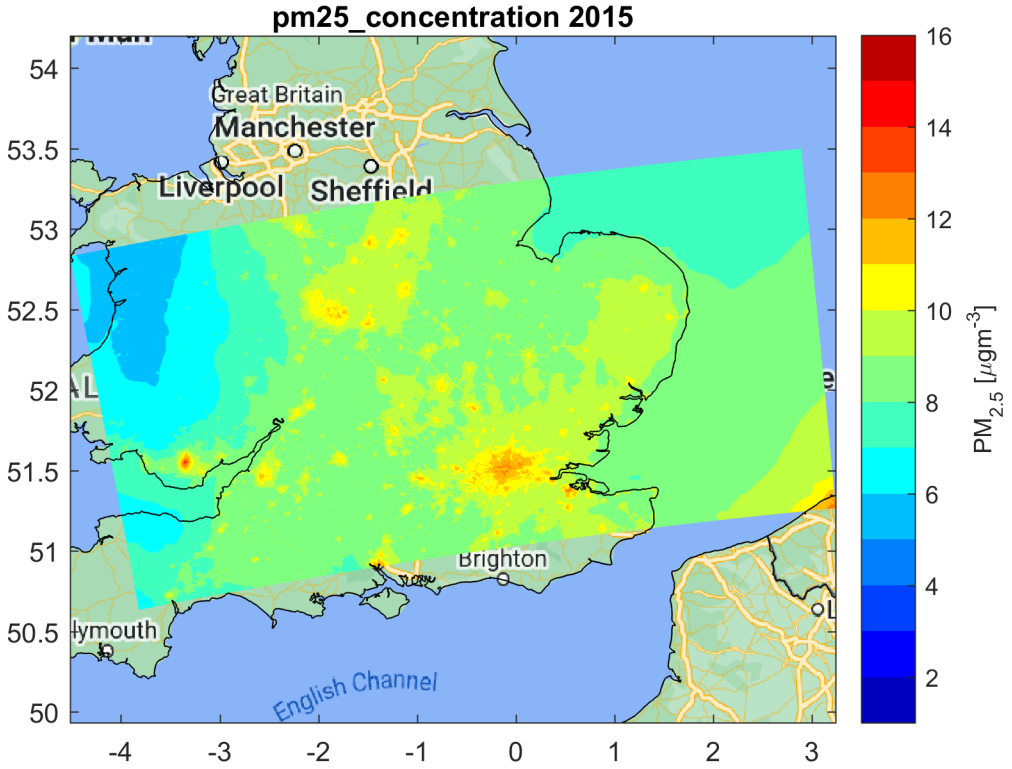
Comparison of population exposure and hot-spot based source apportionment for 150 EU cities. Emissions for all sectors are reduced at FUA level.

City average exposure (pop-weighted): contribution of city to itself 16% lower than for hot spot
City area average: contribution of city to itself 37% lower than for hot spot

Reference: Thunis et al., in preparation

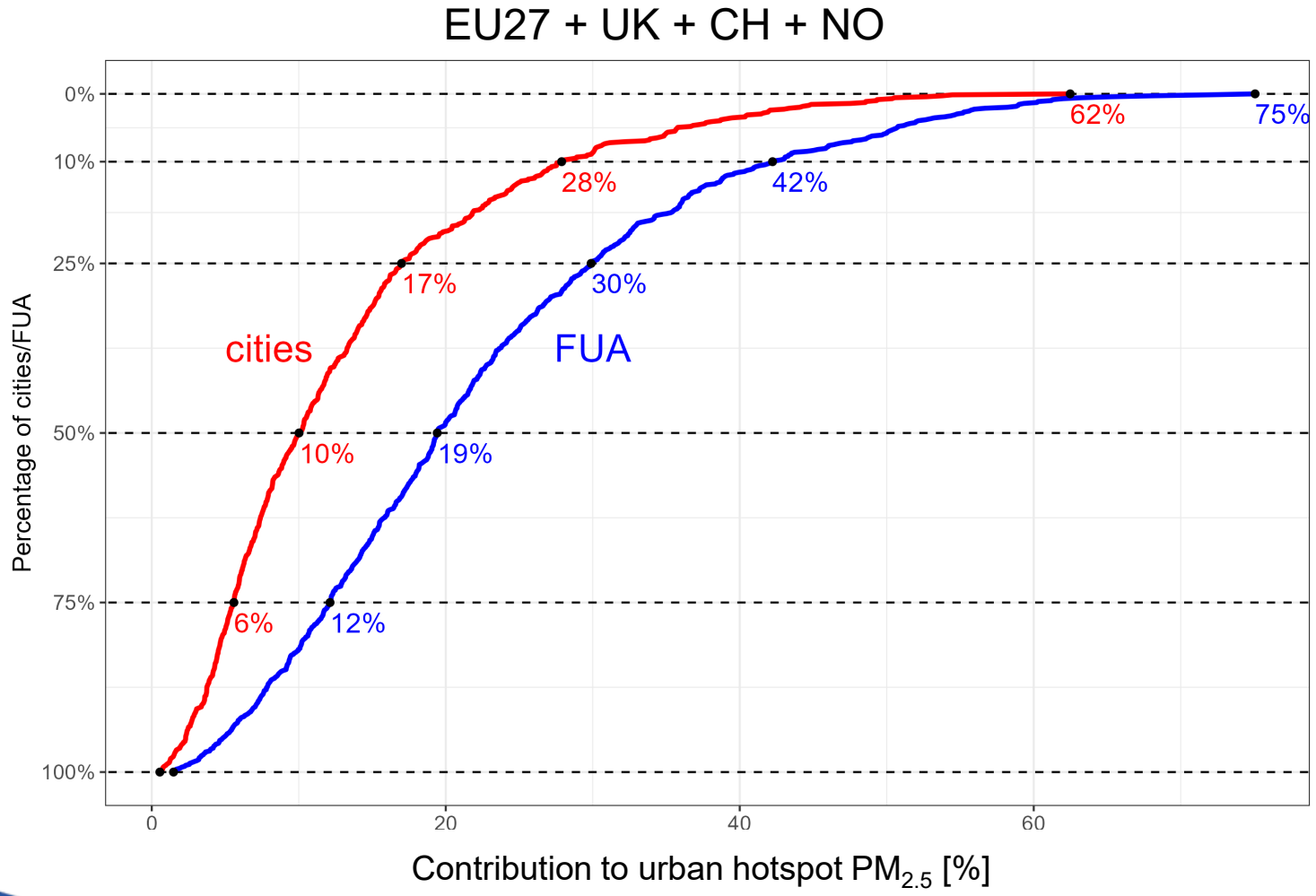
The role of model resolution





Post analysis of uEMEP simulations by Denby et al., 2024 (~AAQD Impact Assessment 2023)

Contributions to urban max $PM_{2.5}$ from different spatial scales



Cities
Greater cities

Example:
50% of cities contribute more than 10%.
10% of cities contribute more than 28%.

Source: Zauji-Salani et al.

Conclusions

- Cities are both emitters and recipients of pollution. $PM_{2.5}$ is contributed by local and remote sources. NO_2 is mostly local, O_3 more regional
- Source contributions to urban $PM_{2.5}$ show similarities among countries in parts of UNECE. Particularly in West Balkan, the residential sector is dominant and will stay unless policy action is taken.
- Local contributions vary from city to city, can be dominant for large/isolated cities. Typically not dominant in the EU but much larger in West Balkan & EECCA. Nonetheless, also long-range contributions remain important everywhere.
- Local origin of pollution does not necessarily mean (only) local action can solve the issue. Depends on the source sector.