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science for global insight

CIAM: Progress in 2021/22

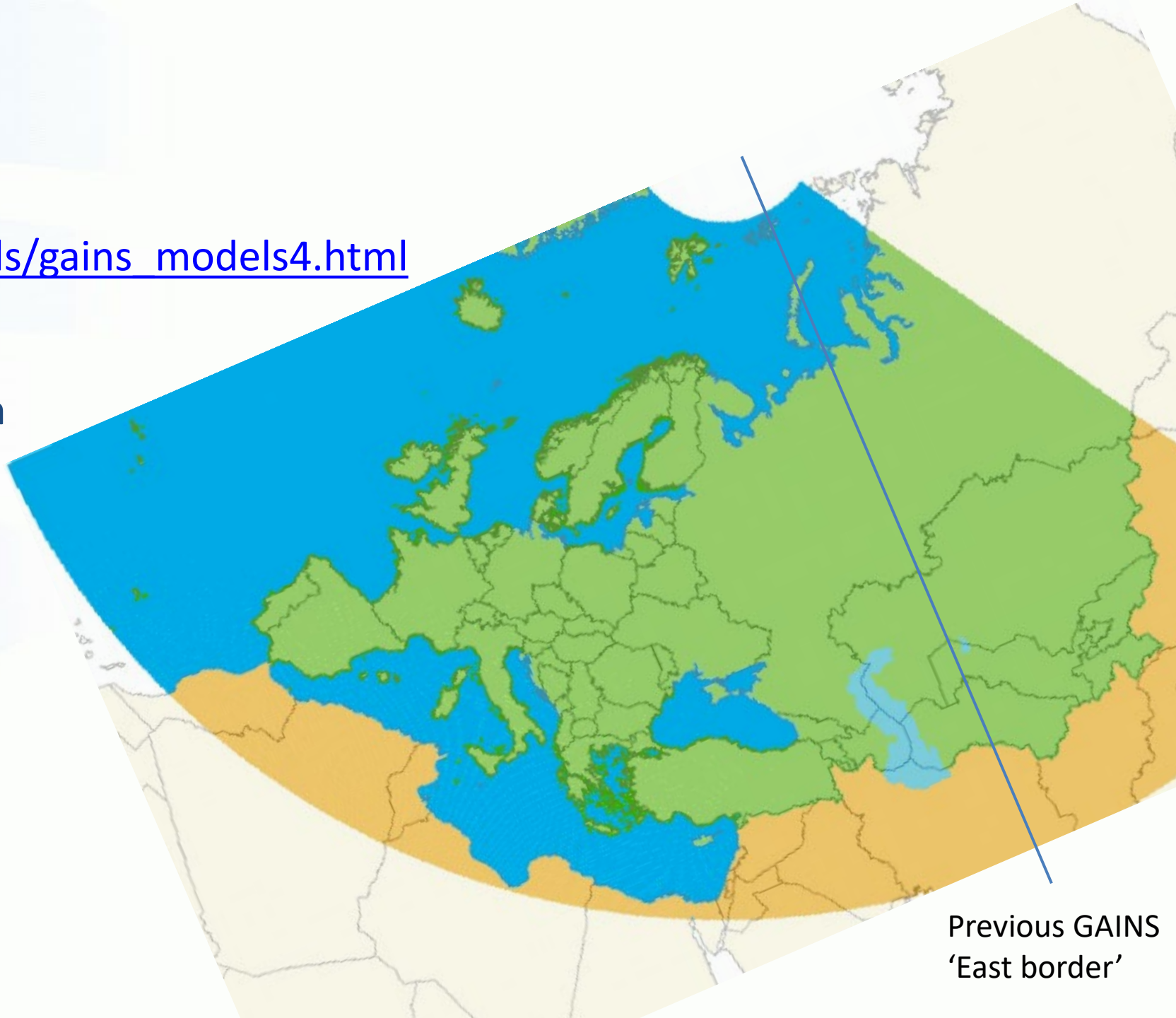
Z. Klimont, G. Kiesewetter, W. Schöpp, C. Heyes, F. Wagner, P. Rafaj, L. Höglund-Isaksson, A. Gomez-Sanabria, L. Warnecke, K. Kaltenegger, F. Brocza, W. Winiwarter, B. Nguyen, S. Zhang, R. Sander,

Center for Integrated Assessment Modelling (CIAM)

8th joint session of the Steering Body to EMEP and the Working Group on Effects,
12-16, September 2022, Geneva

Content

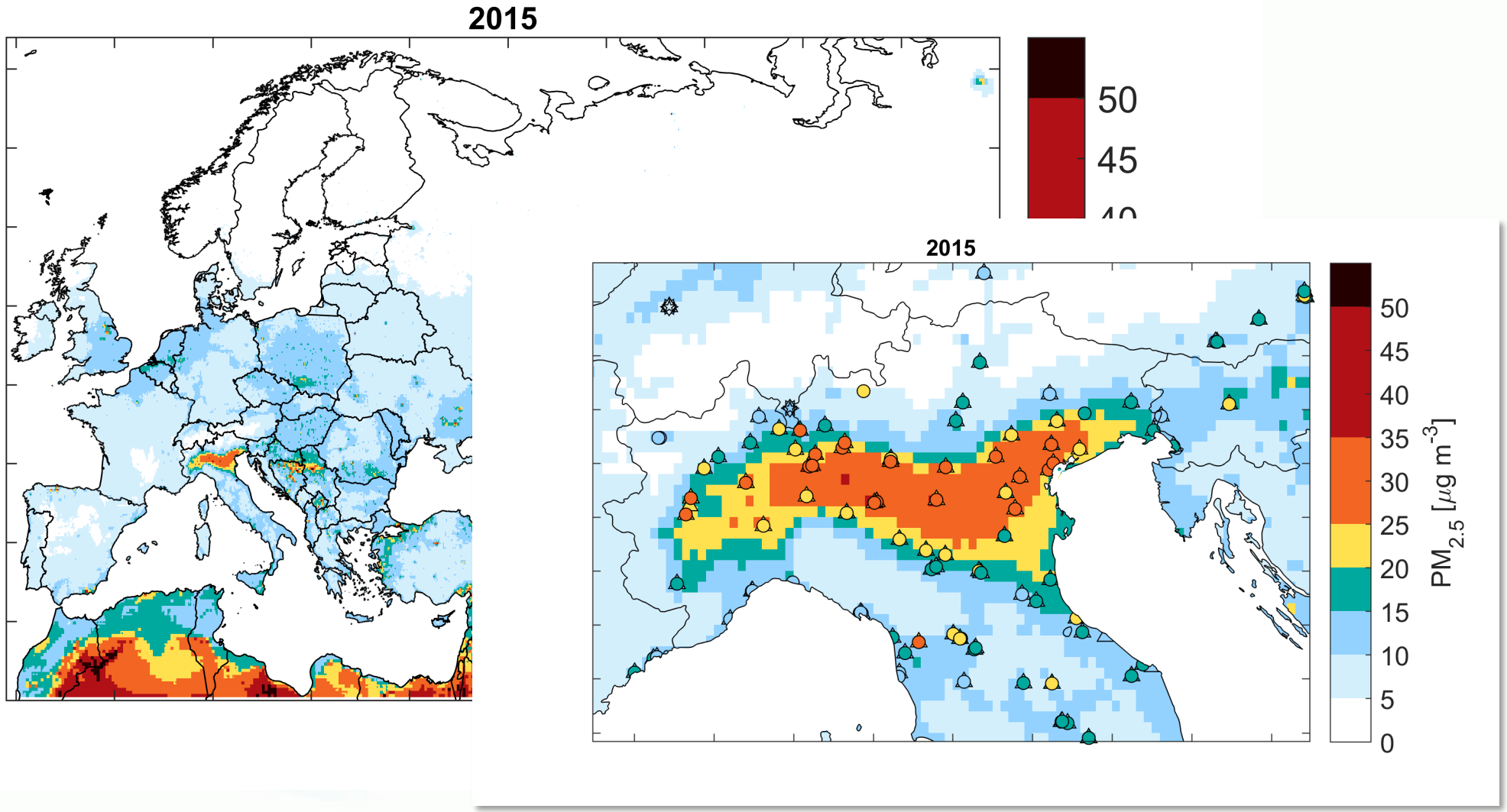
- GAINS model updates
  https://gains.iiasa.ac.at/models/gains_models4.html
- New scenarios
- Synergies with other European projects
- Emission trends and impacts
- Condensable PM
- Across the scales
- Mercury
- Outlook 2023



Methodological improvements/extensions in GAINS (2021-22)

- Agriculture: **Soil NOx and NMVOC** *(implemented; methods consistent with the Guidebook and recent literature)*
- New **waste management** module and scenarios *(implemented;* Gomez-Sanabria *et al.,* 2022)
- Atmospheric calculation (**new source receptor (SR) coefficients**) *(implemented; jointly with MSC-W)*
- **Extended modelling domain** *(implemented; jointly with MSC-W)*
- **Update of critical loads** (CL) database to use 2021 CL *(implemented; jointly with CCE)*
- Updates for **health and ecosystem impact assessments** *(under discussion, coordinated with TFH and discussions within the AAQD and CAO3 work for the EU)*
- Urban-rural interactions; **source apportionment in cities** *(implemented; jointly with MSC-W; validation continues)*
- **Condensable fraction of PM** *(draft implementation and analysis of selected scenarios; jointly with TNO, MSC-W)*
- **Mercury**, update of data, methods, new global scenarios *(implemented; method and initial scenarios presented at meetings including TFHTAP)*
- **Methane**, update of mitigation potential, costs; *(contribution to TFHTAP, 'Synergies' document, Global Methane Assessment (UNEP, 2021), AMAP Assessment (2021))*

Ambient $PM_{2.5}$ concentrations



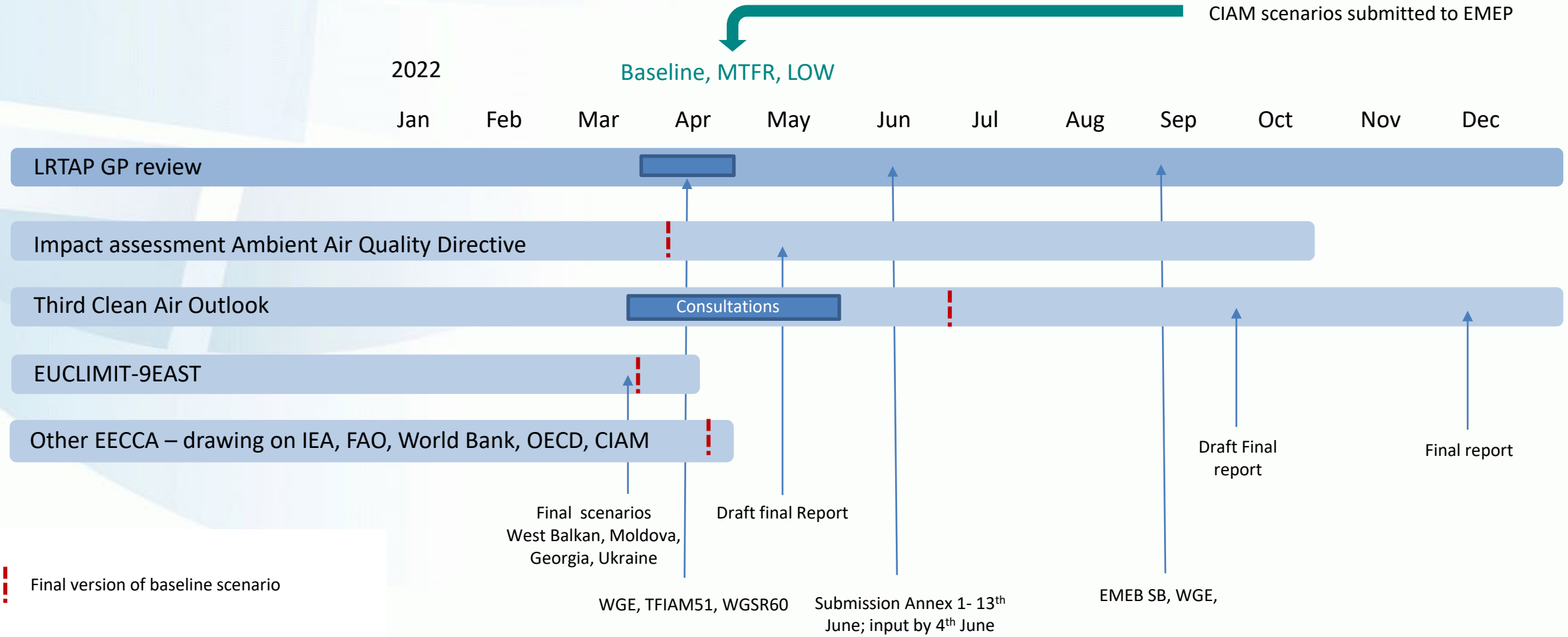
Development of new scenarios

- ***Baseline*** (air pollutants and methane up to 2050)
  - Update of the historical data and comparison and validation with nationally reported emissions in 2021; *jointly with CEIP*
  - Review of the recent policies and measures and national implementation progress and plans
  - Energy and agriculture for the EU and UK – Green Deal (Fit for 55); the MIX55 scenario
  - For West Balkan, Rep of Moldova, Georgia, and Ukraine newly developed PRIMES and CAPRI model scenarios; development supported by the EU within the EUCLIMIT-9EAST project
  - EFTA, Turkey, and remaining EECCA activity projections derived from IEA World Energy Outlook and FAO
  - Recent shock events have not been considered; scenarios developed before the Ukraine war
- Maximum technically Feasible Reduction '***MTFR***' (air pollutants and methane)
- Alternative '***LOW***' scenario (air pollutants and methane)
  - Climate policies compatible with Paris goals; for the whole region
  - *MTFR* for air quality, including shipping sources
  - 'Healthy diet' and more – scenarios for *Growing better*… study (https://www.foodandlandusecoalition.org/)

Scenario development timelines and harmonization across other activities

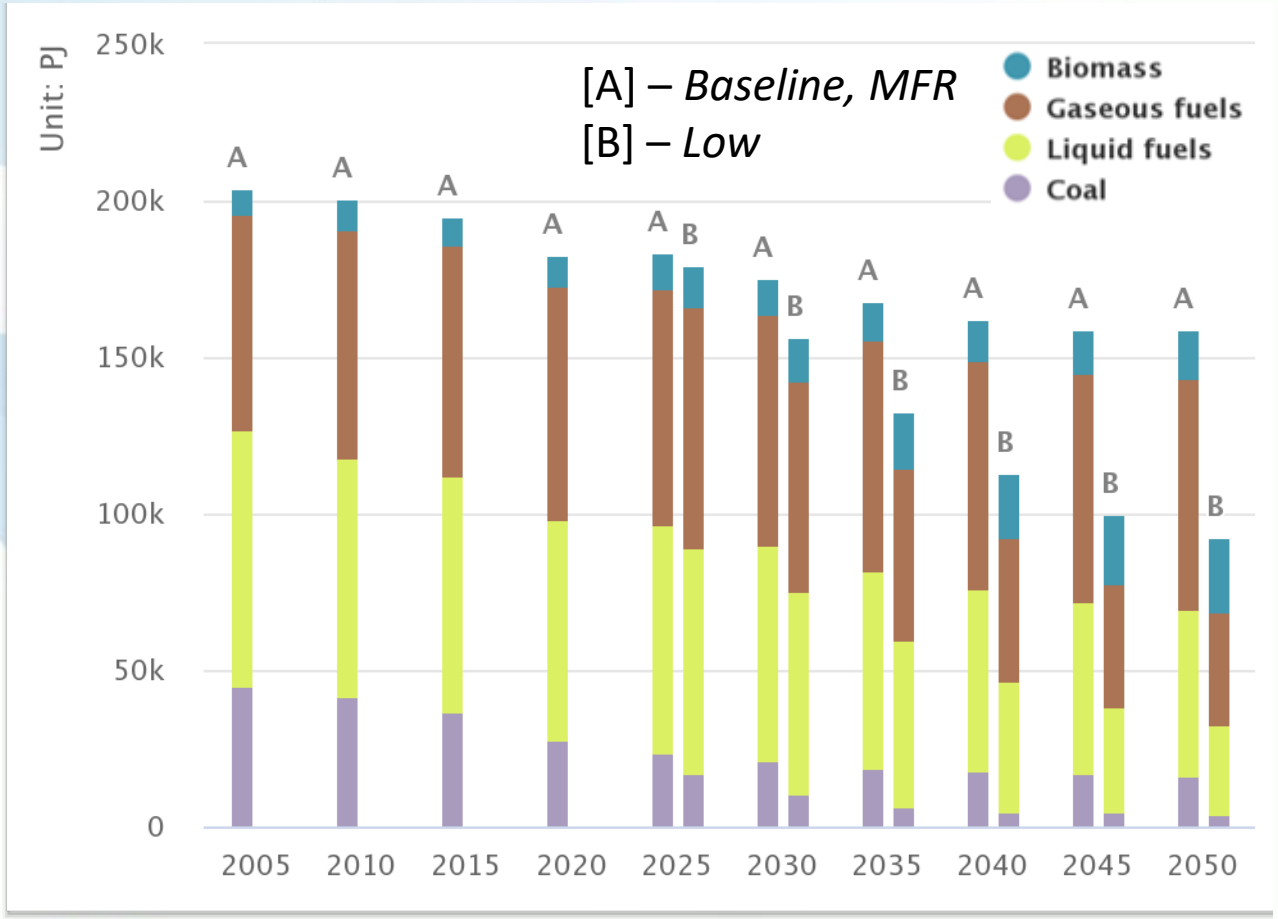
Explore synergies between several activities

- Harmonizing to the possible extent data, baseline assumptions, and model versions

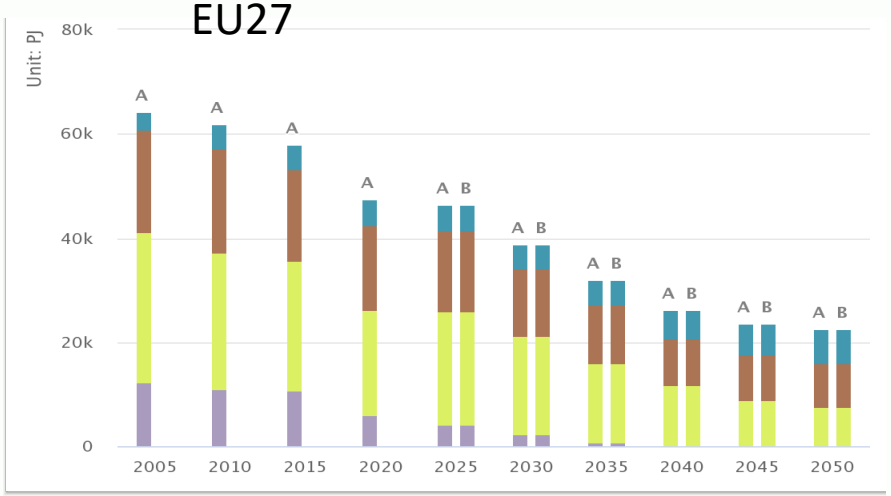


Fossil fuel use in the scenarios

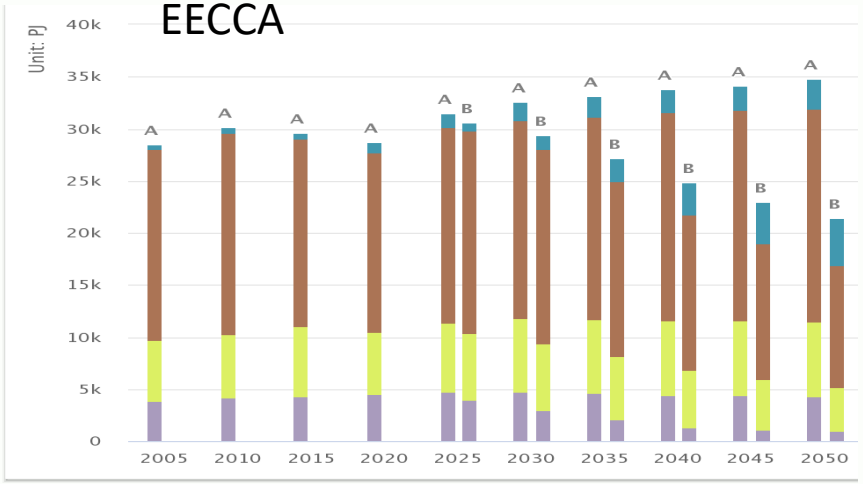
EU + EFTA + UK + West Balkan + EECCA + Türkiye + North America



EU27

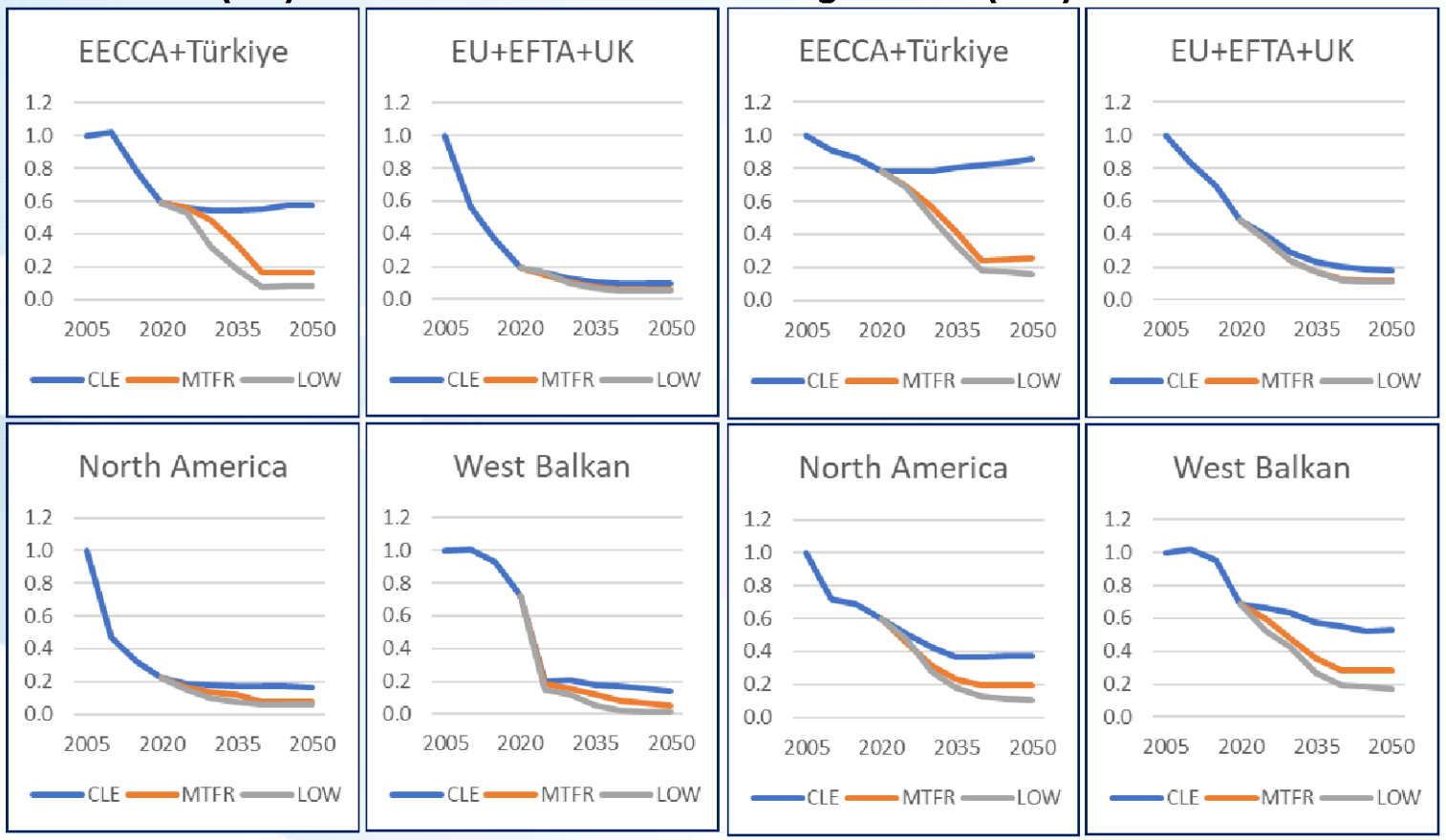


EECCA



Emission trends and mitigation potential in the UNECE region (1)

Sulfur dioxide (SO_2) **Nitrogen oxides (NOx)**

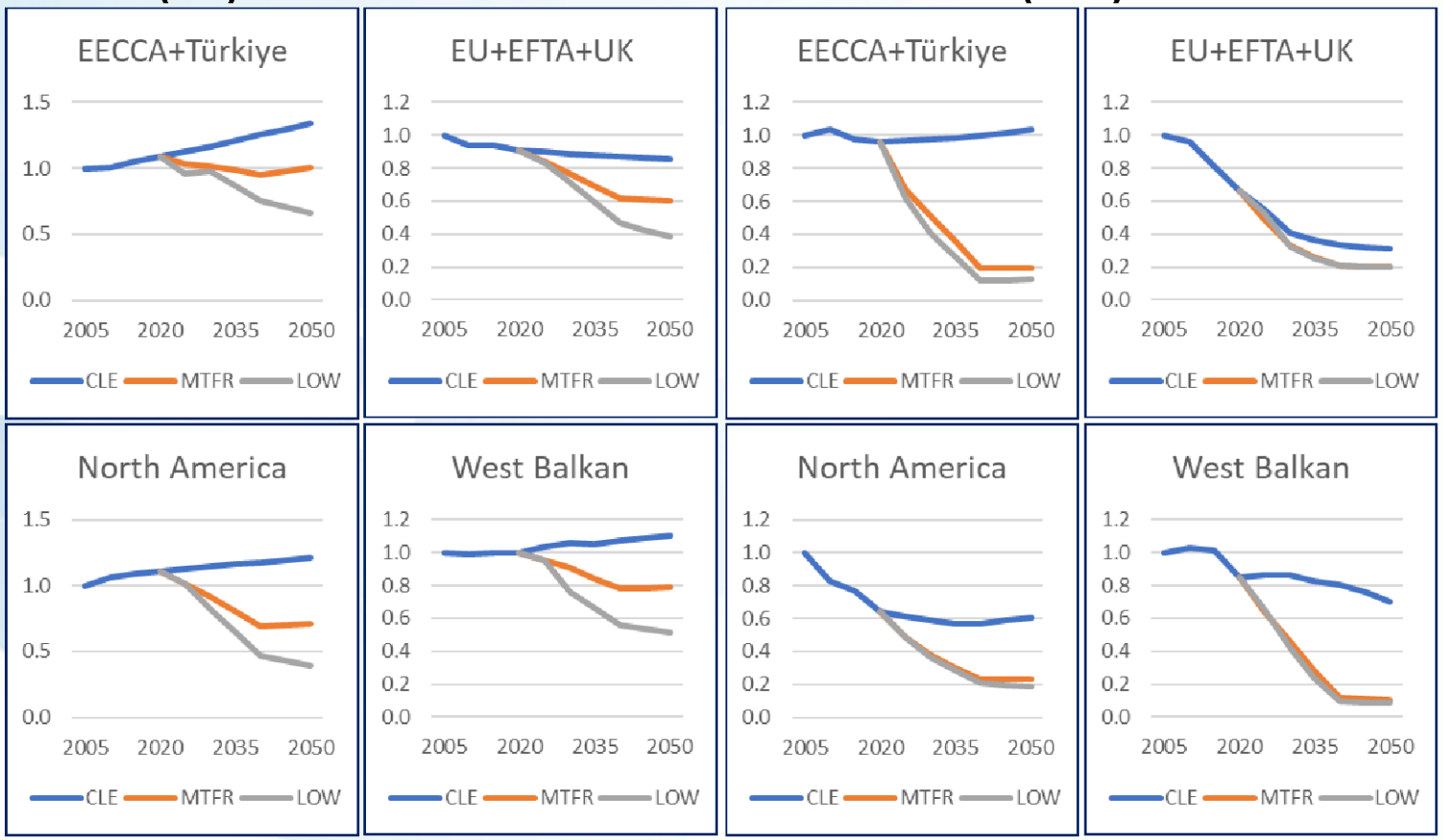


Source: GAINS model

- For SO_2 – apart from EECCA, most of the further mitigation potential committed in current legislation – <u>assuring enforcement essential!</u>
- For NOx – similar picture to SO_2, although larger mitigation potential available;
  <u>*Remote sensing data (and N deposition measurements) indicate that emission inventories overestimate decline in emissions in the last decade*</u>

Emission trends and mitigation potential in the UNECE region (2)

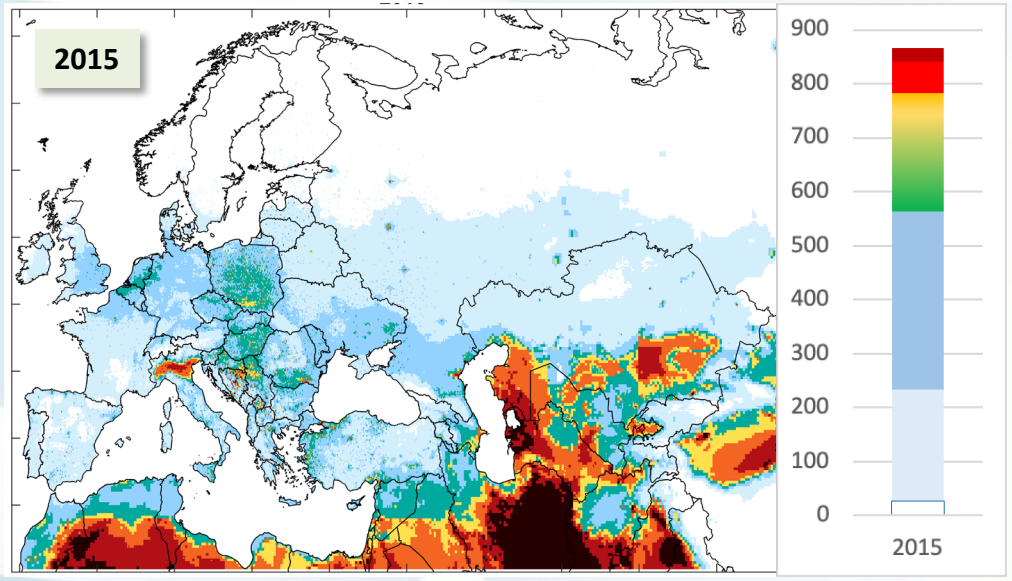
Ammonia (NH_3) **Particulate matter ($PM_{2.5}$)**

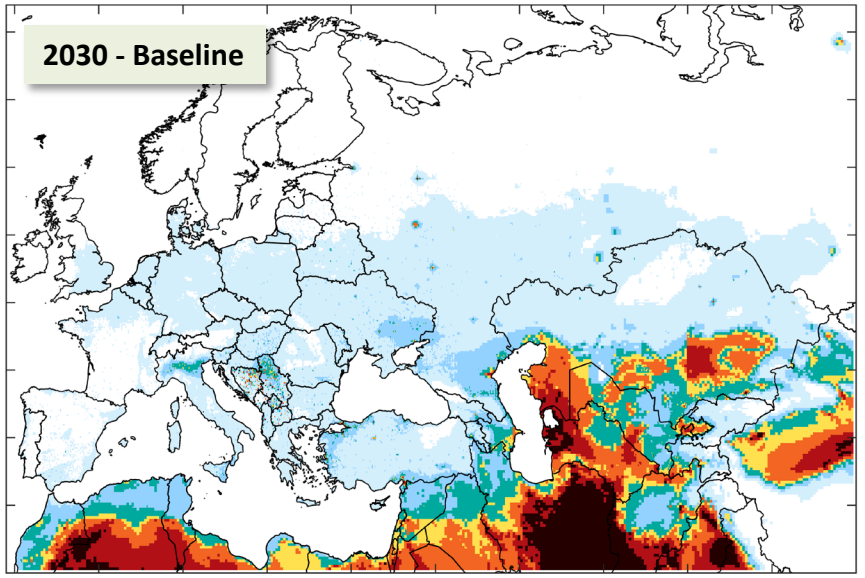


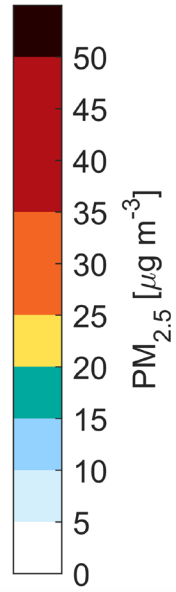
Source: GAINS model

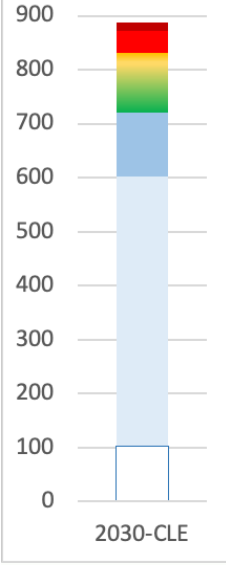
- For NH_3 – current policies include little mitigation, similar further potential exists across all regions; Overall mitigation potential much smaller than for other air pollutants - need for structural and behavioral changes
- primary PM2.5 – large potential exists in some regions, especially in EECCA and West Balkan (industry and residential sector coal and wood)
- The newly developed 'LOW' scenario offers significant further mitigation for NH_3 only, and co-benefits for methane (not shown); for SO2, NOx, PM2.5, additional mitigation not large but in relative terms might halve emissions in 2050

$PM_{2.5}$ concentrations and population exposure (mln)

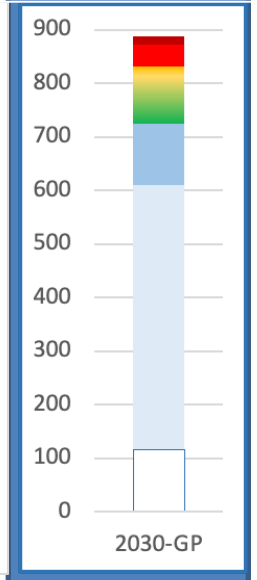


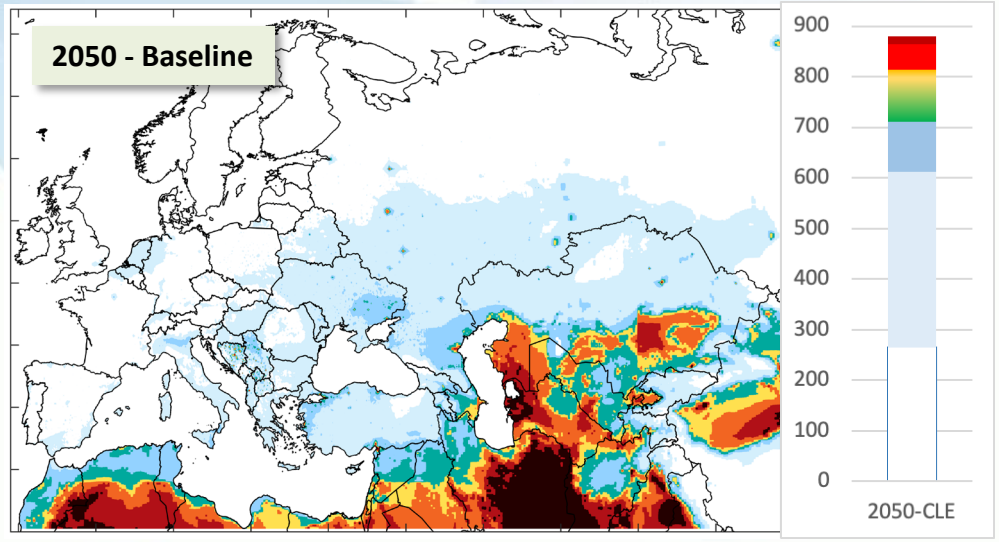


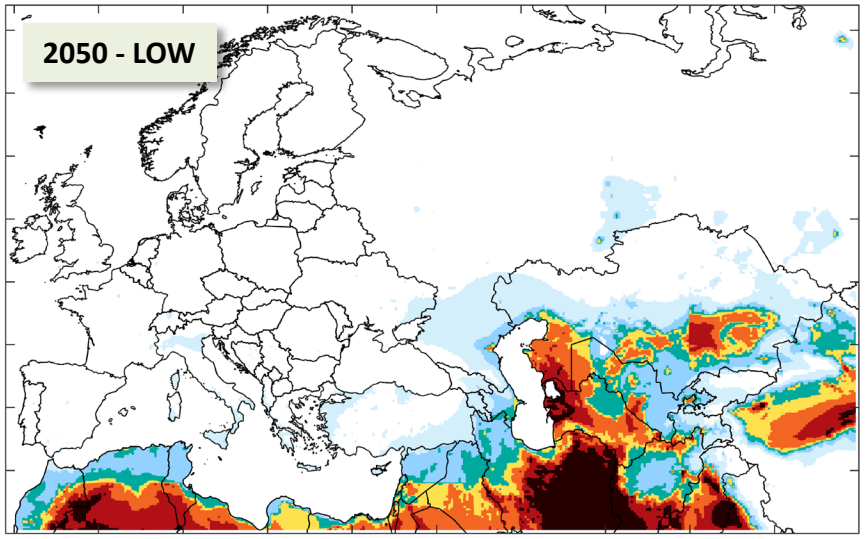


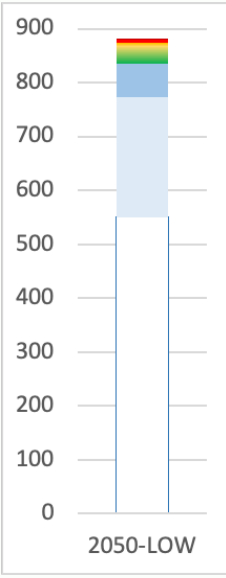


GP compliance





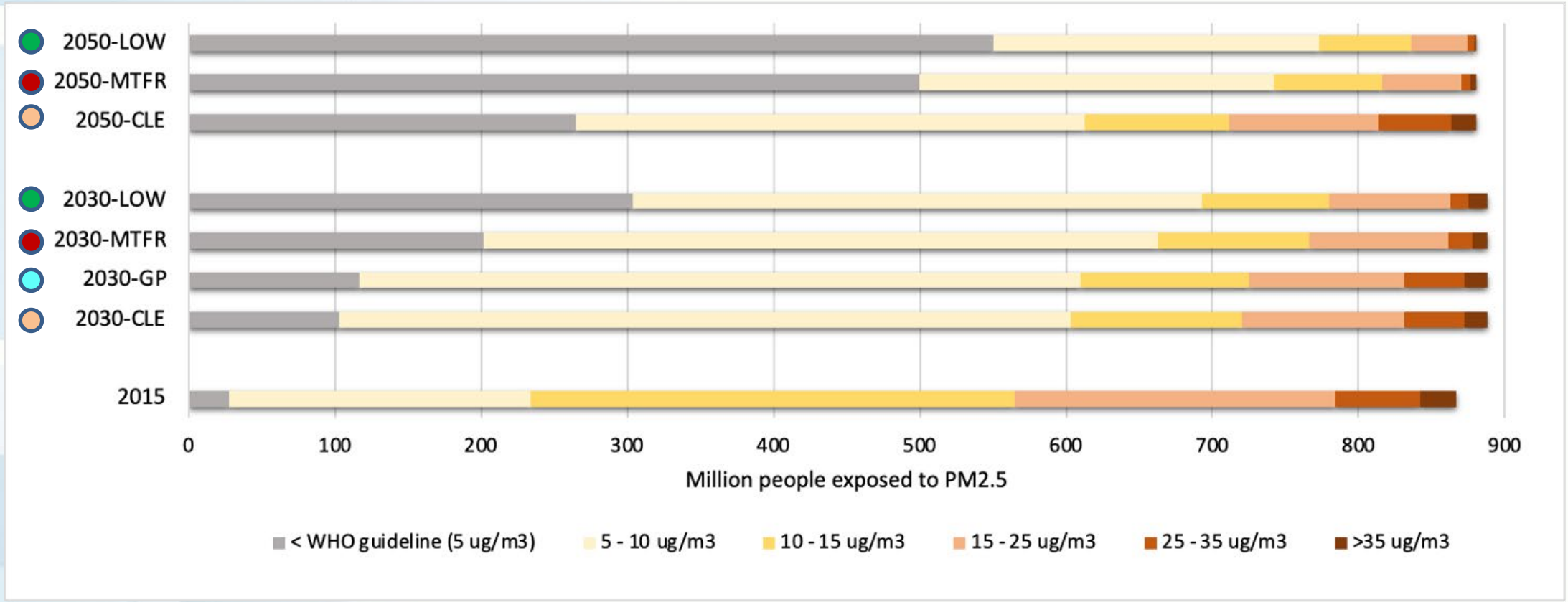




Population exposed to levels below WHO AQG increases by about 14 million in 2030

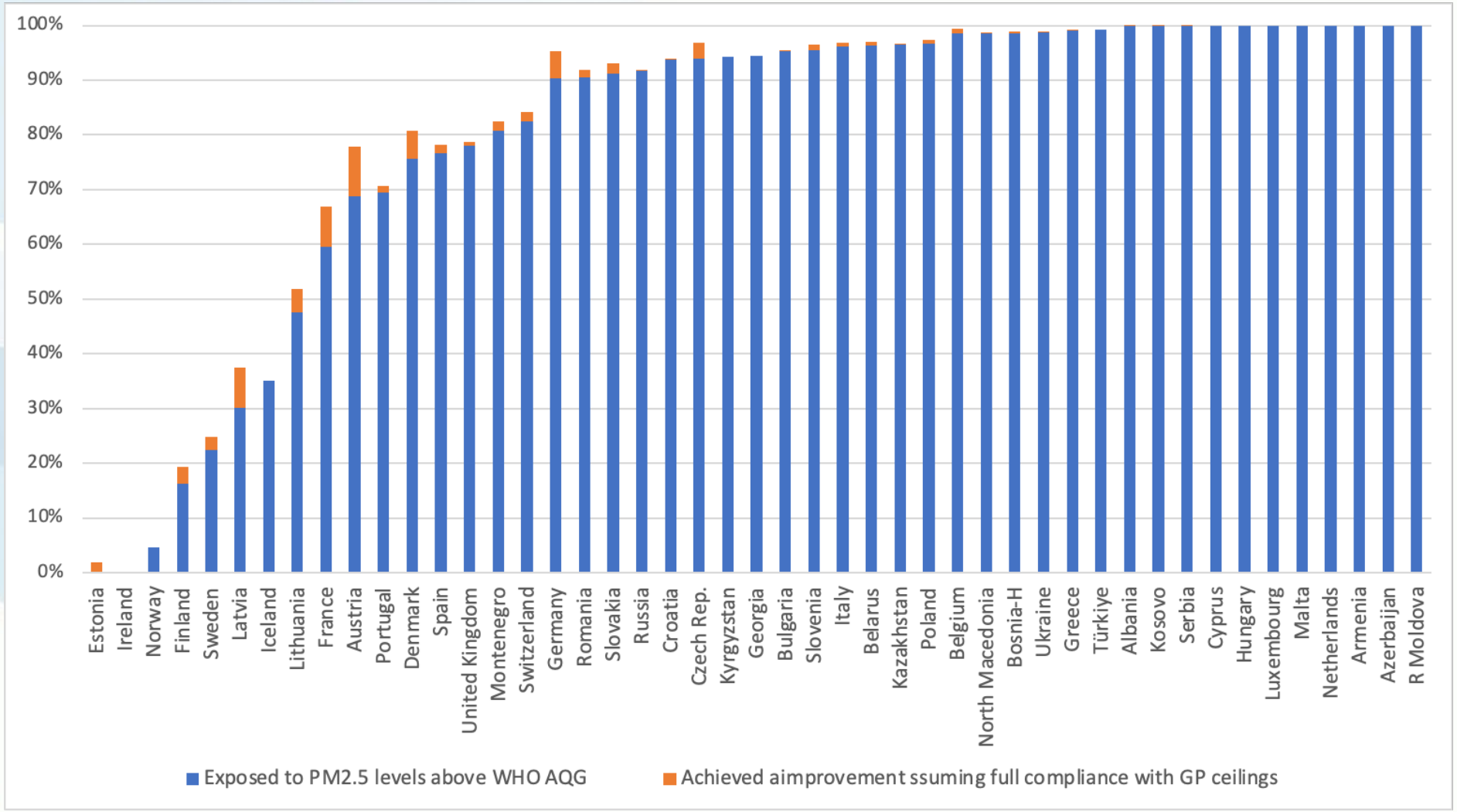
Source: GAINS model

$PM_{2.5}$ population exposure in the UNECE domain, excl North America



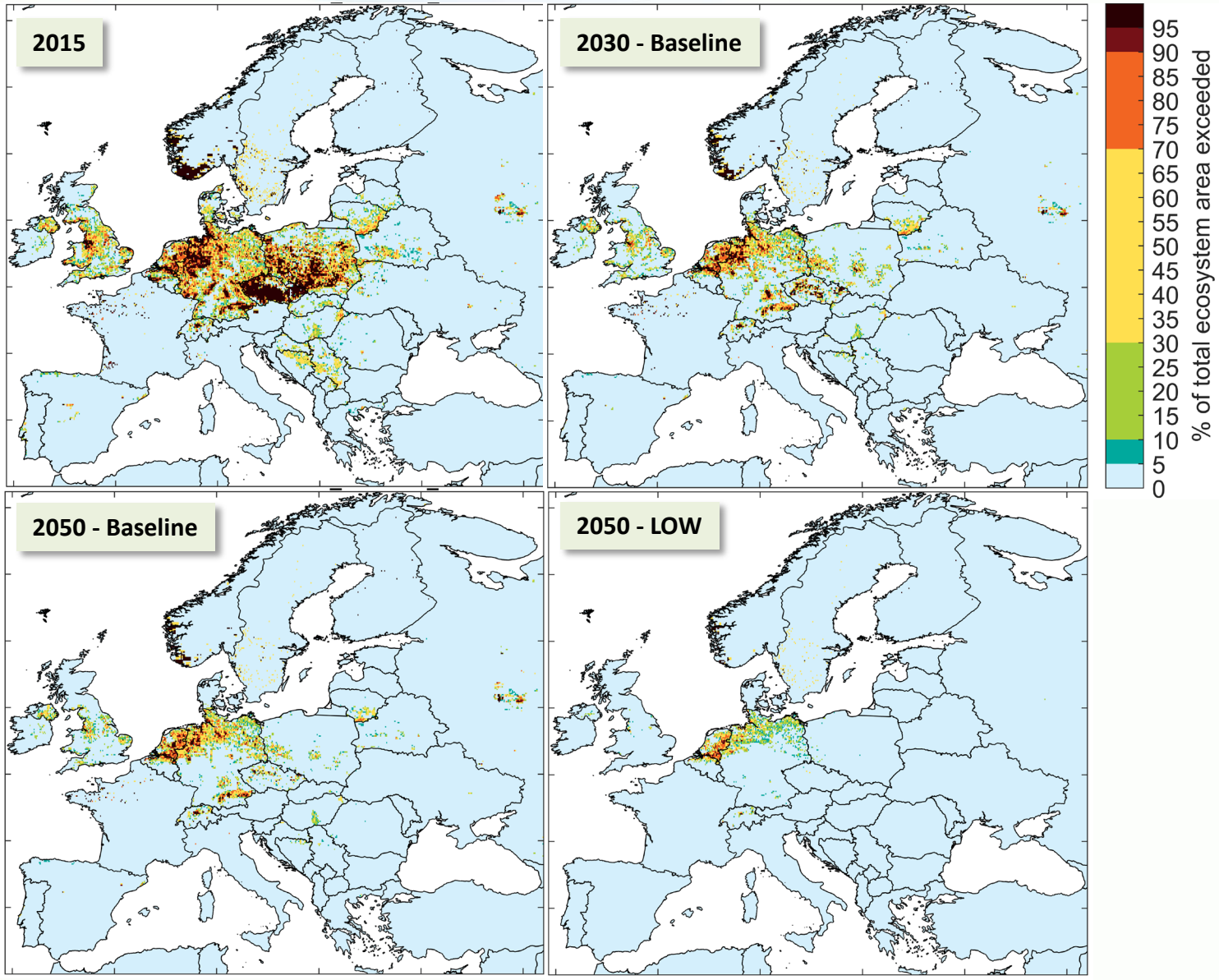
- Steady improvement in the ***Baseline*** *(CLE)*,
- Full compliance with **GP ceilings** in 2030 is estimated to assure air quality within WHO guideline for another 14 million people (compared to the *Baseline*),
- Some improvement in the ***MTFR*** scenario by 2030 and much more significant improvements estimated for 2050,
- ***LOW*** scenario provides further benefits – nearly 65% of population exposed to $PM_{2.5}$ levels below WHO guideline

Share of population exposed to $PM_{2.5}$ concentration levels above the WHO guidelines in 2030 in the *Baseline* scenario

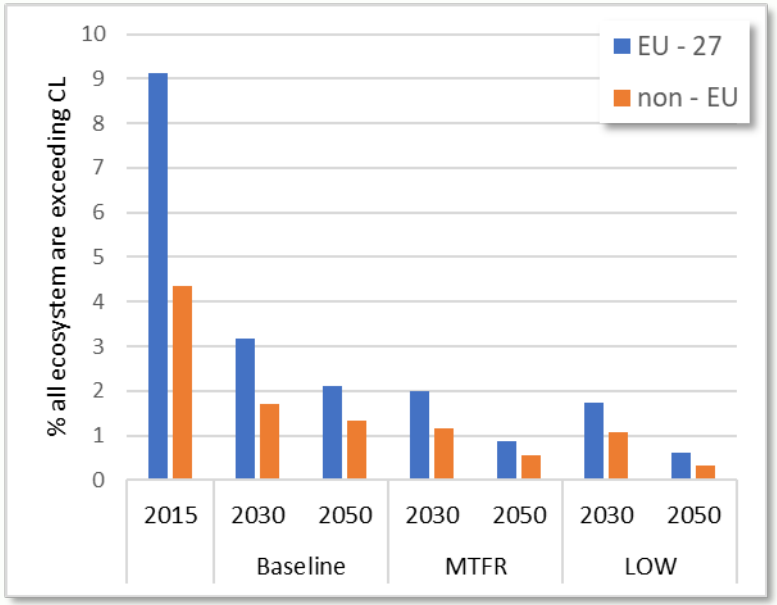


Full compliance with **GP ceilings** in 2030 is estimated to assure air quality within WHO guideline for another 14 million people (compared to the *Baseline*)

Acidification

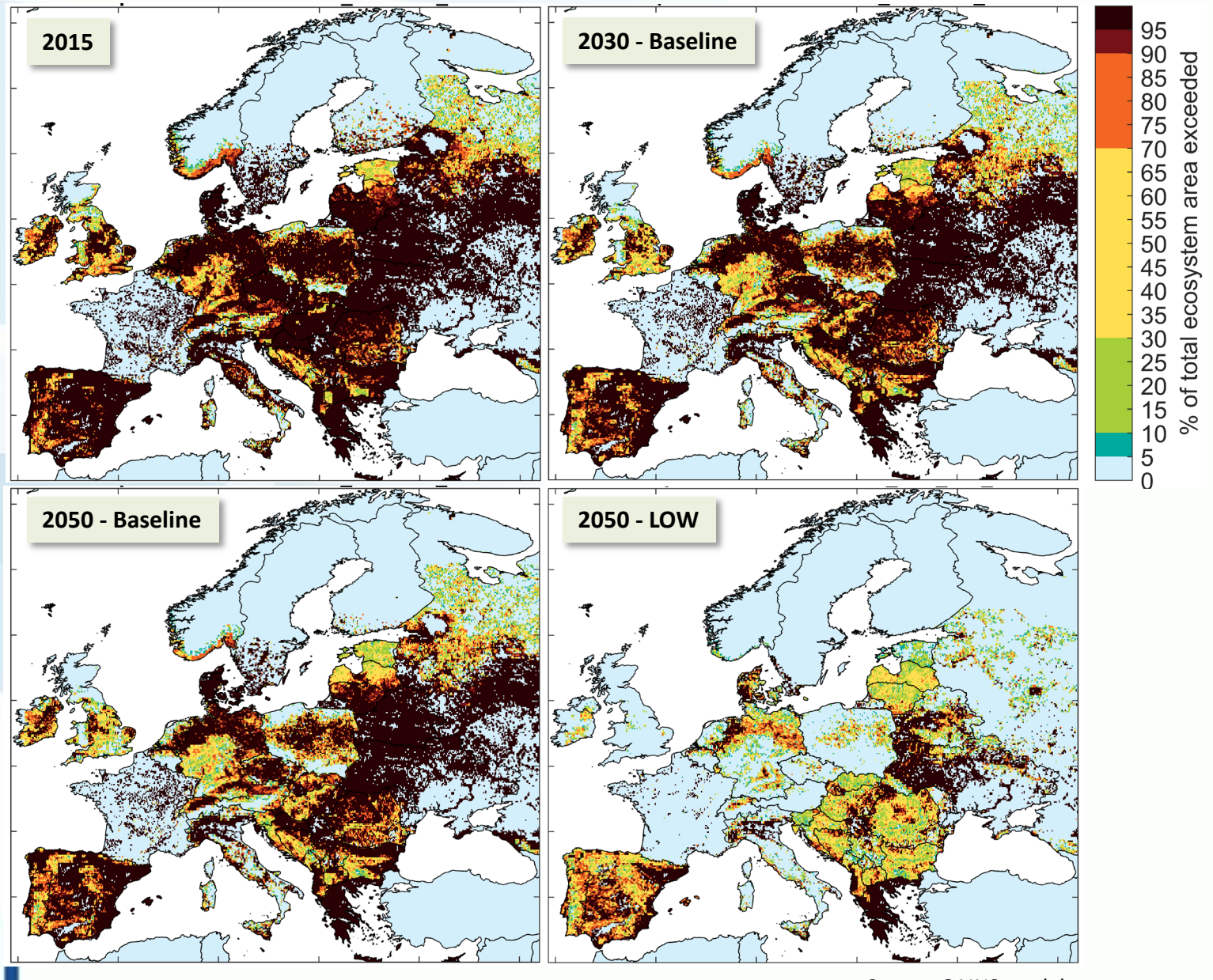


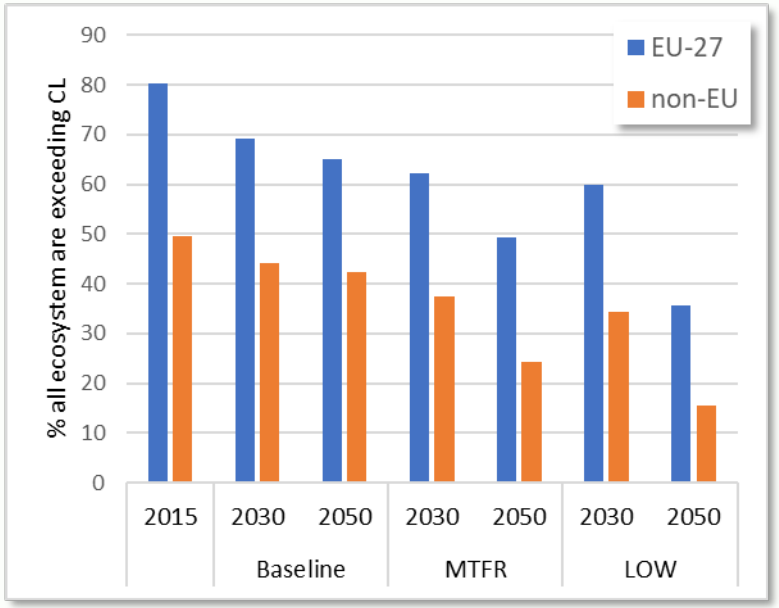
Source: GAINS model



Compared to the *Baseline,* achieving GP ceilings in 2030, could reduce ecosystem area where CLs are exceeded by about 6%, i.e., ~4,700 km^2 [not shown in the charts above]

Eutrophication





Compared to the *Baseline,* achieving GP ceilings in 2030, could reduce ecosystem area where CLs are exceeded by about 1%, i.e., ~17,000 km^2
[not shown in the charts above]

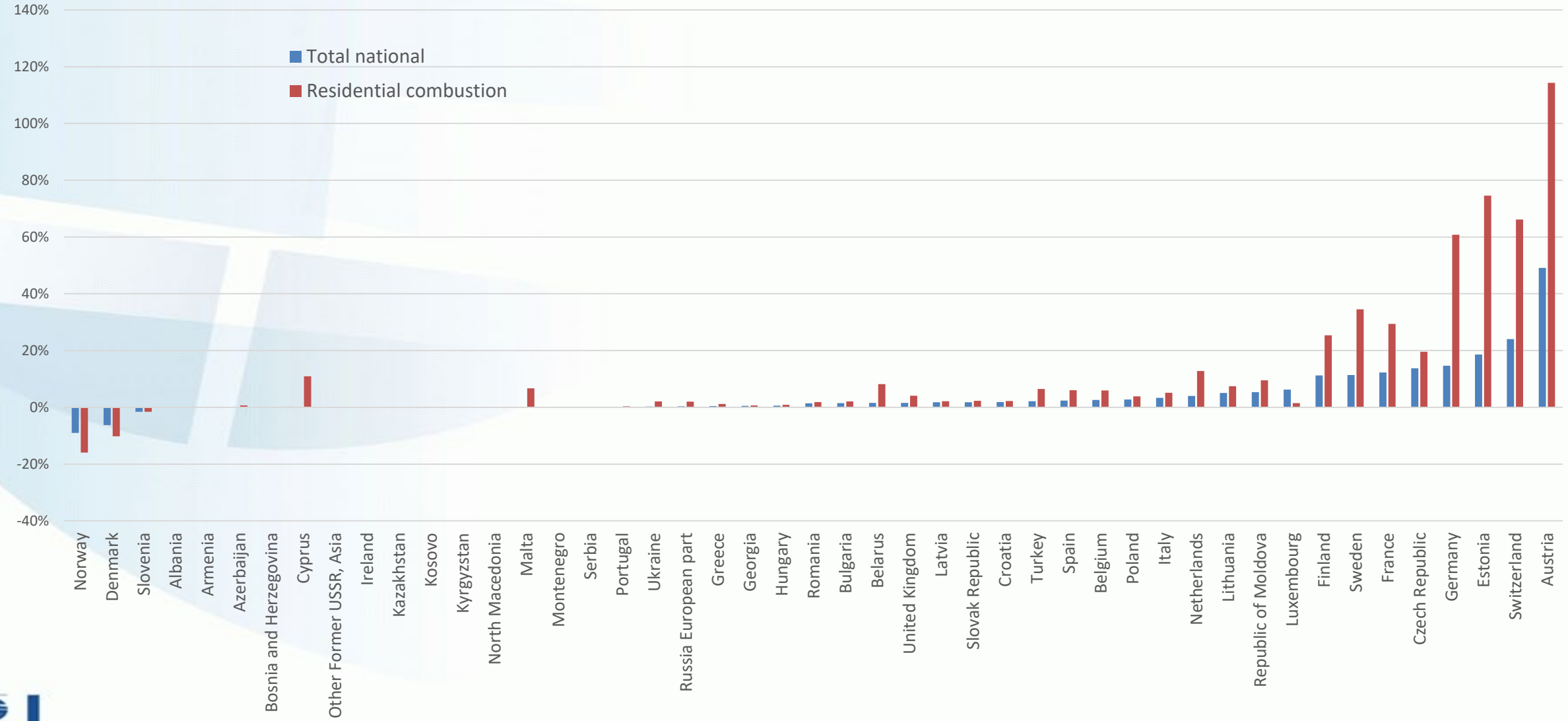
Extending GAINS to include condensable fraction in PM

- Current speciation of primary particulate matter (PM)
  - TSP, PM_{10}, $PM_{2.5}$, PM_{1}, BC, OC, OM
- Including condensable fraction of PM
  - *Joint project with TNO, MSC-W, SYKE, NILU; funded by the Nordic Council of Ministers*
  - *Extending the structure in GAINS to include FPOA[a)], CPOA[a)], and $PM_{2.5}$* (new total $PM_{2.5}$ including EC, FPOA, CPOA, other inorganic fine PM)*
- Examples given further refer to the '*typical*' emission factor scenario developed by TNO and the GAINS model emission factors set as of April 2022

[a)] FPOA – Filterable Primary Organic Aerosols; CPOA – Condensable POA

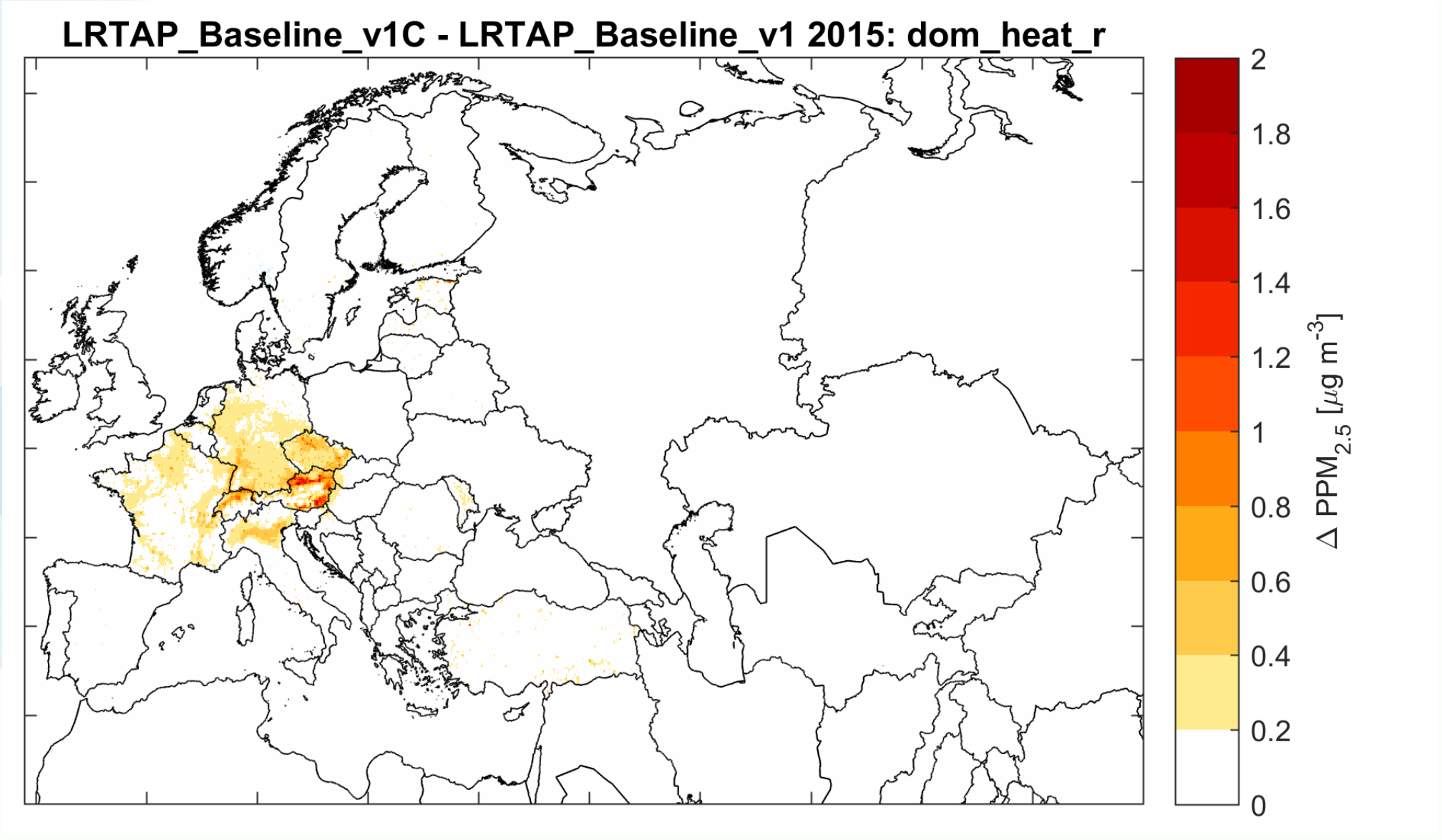
Comparison of *Total and residential PM2.5* emissions in 2015

'*Typical-TNO*' residential EF with condensables vs current GAINS



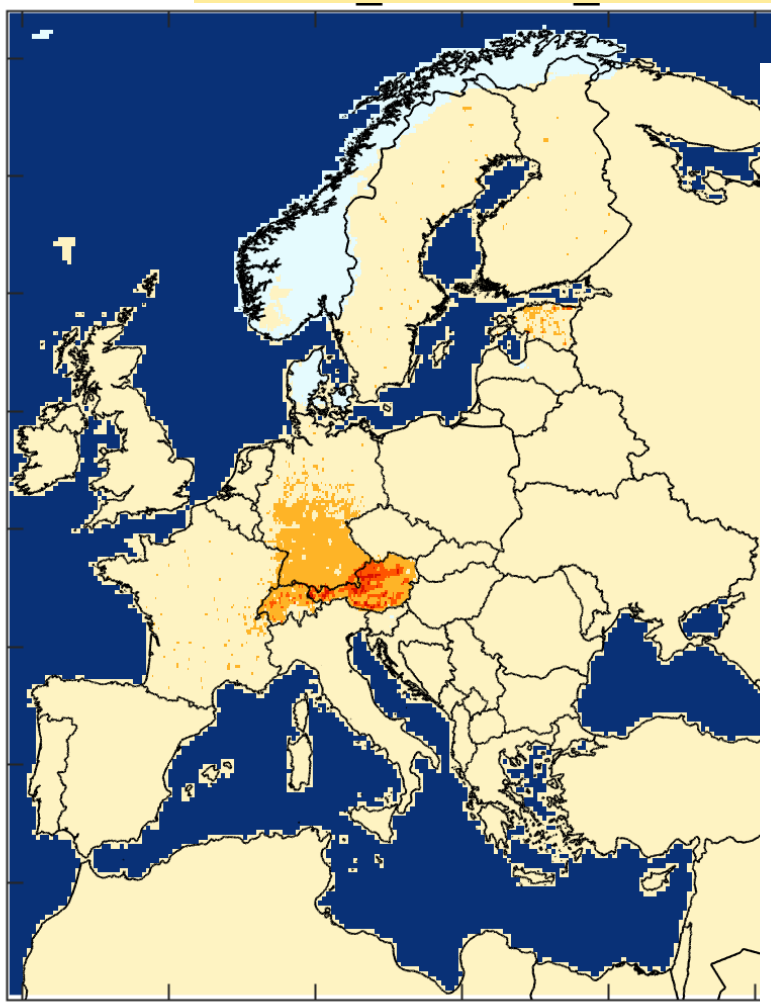
Change in $PM_{2.5}$ concentrations due to emissions from residential/rural heating ONLY

Impact of including 'consistent – *typical*' Efs including condensable PM, compared to the current GAINS Efs datasets;

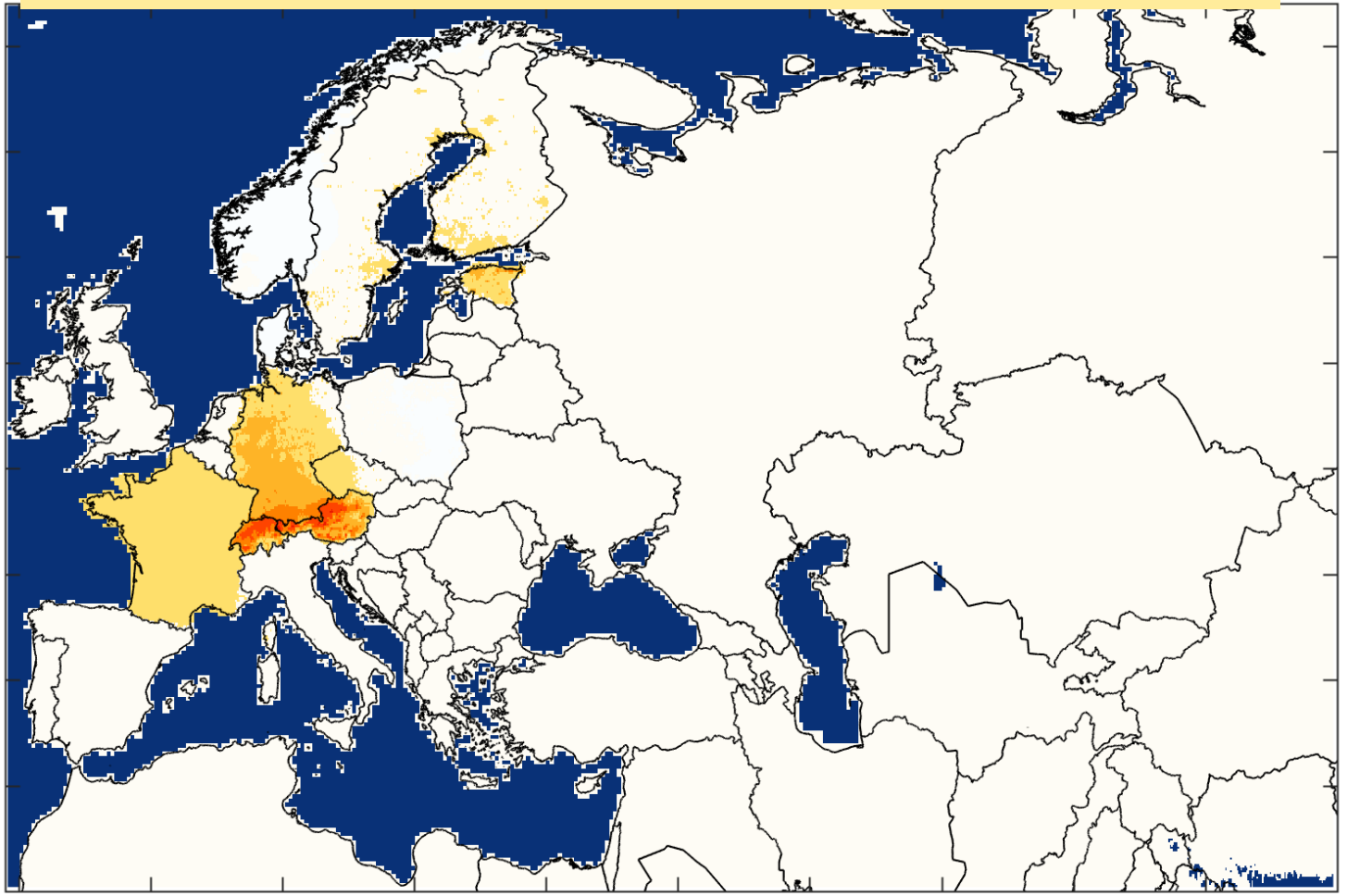


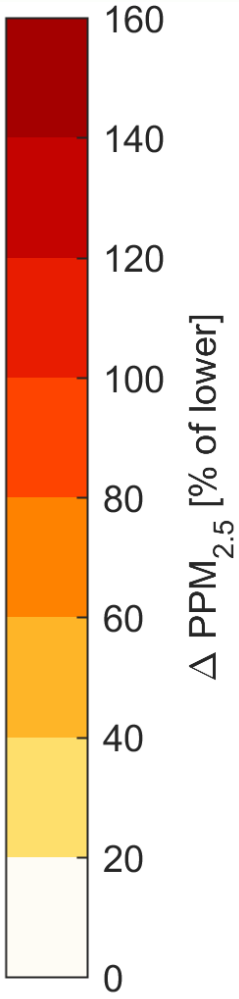
Relative impact on concentrations of PM2.5 in 2015

Total PM2.5 (2015)

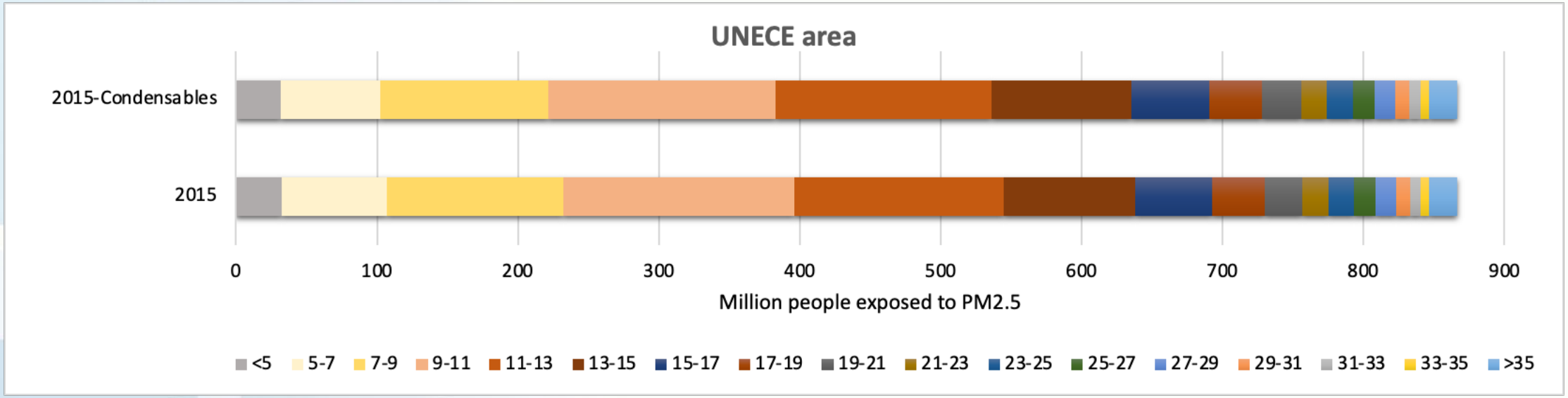


Residential heating (rural) PM2.5 (2015)





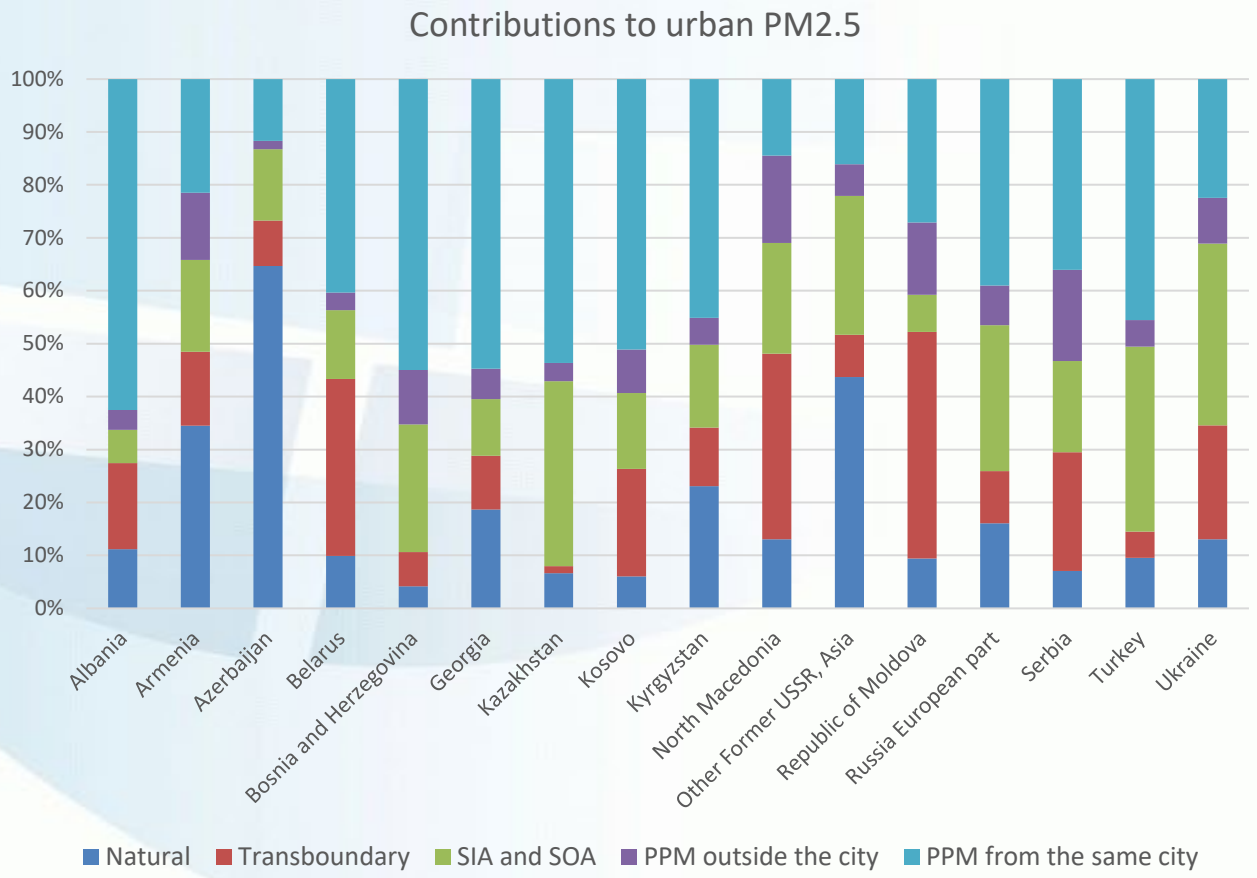
What does it mean for exposure?



- According to these estimates, the differences between current GAINS implementation vs data set with harmonized emission factors including condensable '*typical Efs*', the differences are not very large, e.g.,:
  - 0.5 million more (from about 83 million) are exposed to levels > 25 ug/m3
  - About 0.6 million less (from about 32 million) are in the category below WHO guideline

The results exclude North America

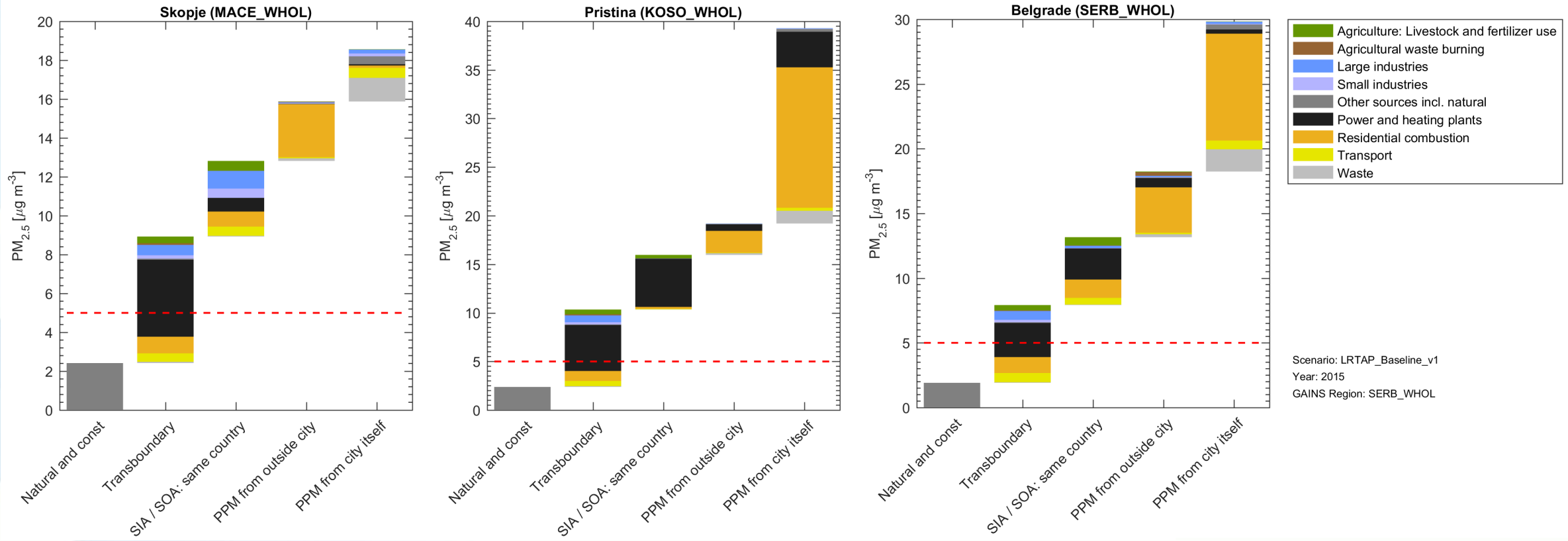
Contributions to urban $PM_{2.5}$: West Balkan / EECCA 2015



- Contributions vary strongly between countries
- Often local contributions play a larger role than in Western Europe, owing to topography and local sources
- Balancing urban vs rural heating fuels, and checking availability of district heating is crucial
- Planning for further bilateral interactions with national and regional experts

PPM – Primary particualte matter

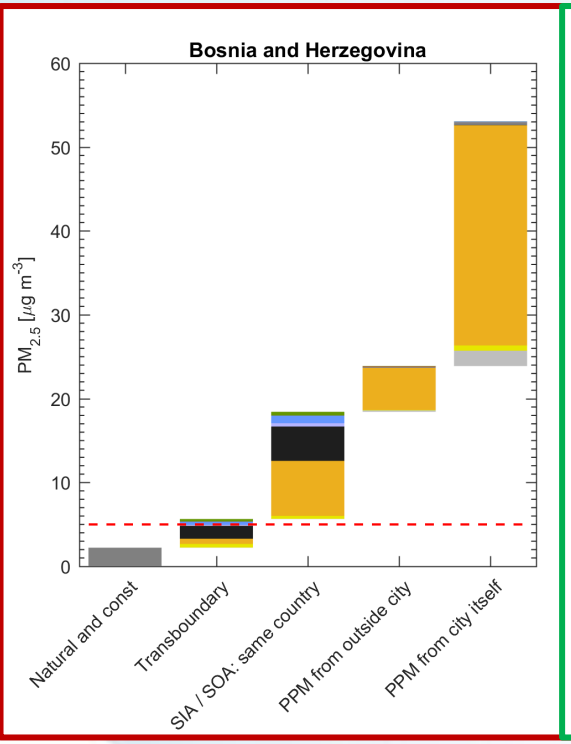
Source contributions to cities: examples, West Balkan (2015)

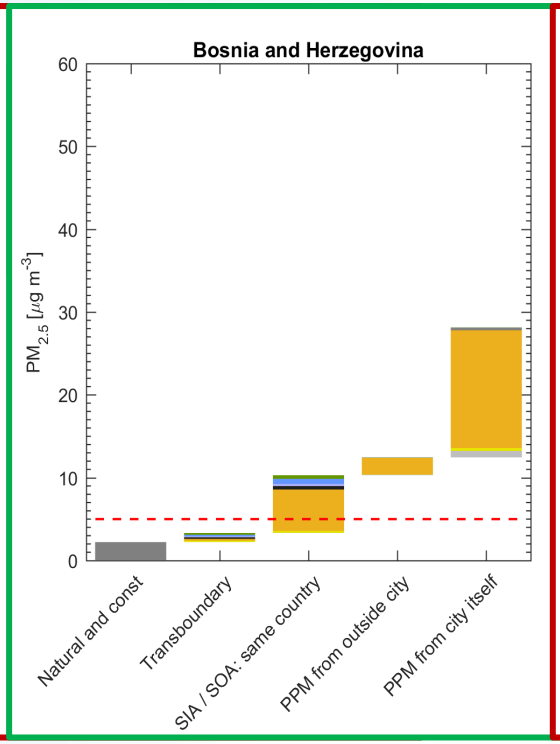


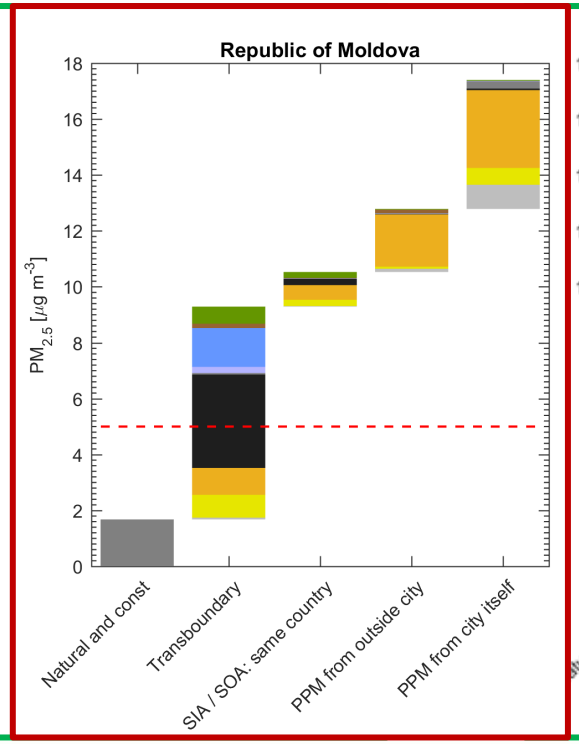
- Important role of residential sector
- Also power/heating plants

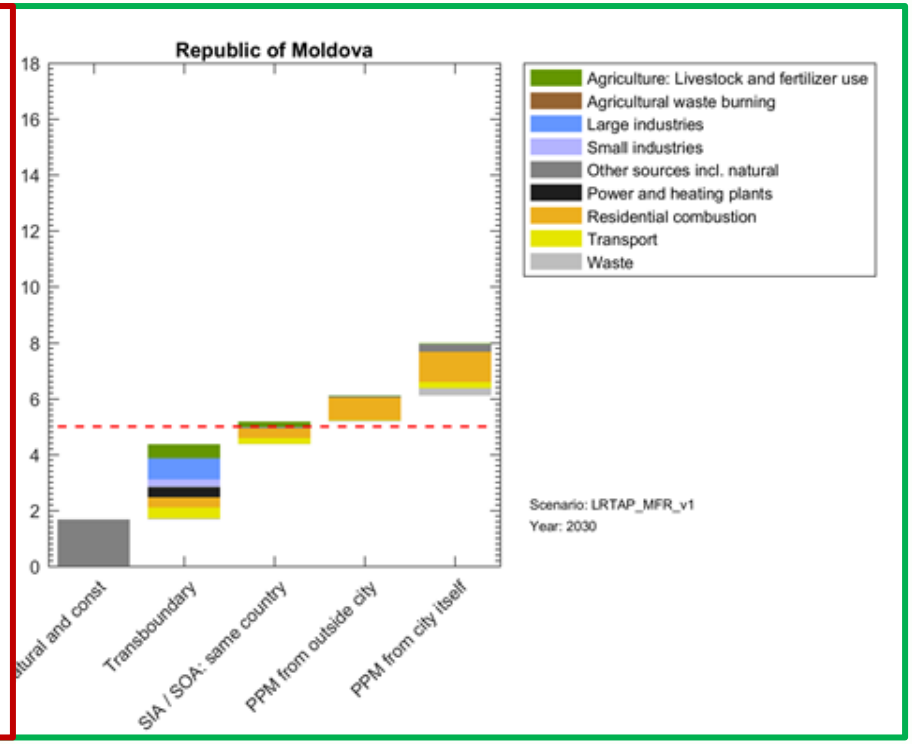
Availability of district heating needs to be checked! (both at national and city level)

Selected country means (West Balkan and EECCA): 2015 and 2030 Baseline CLE







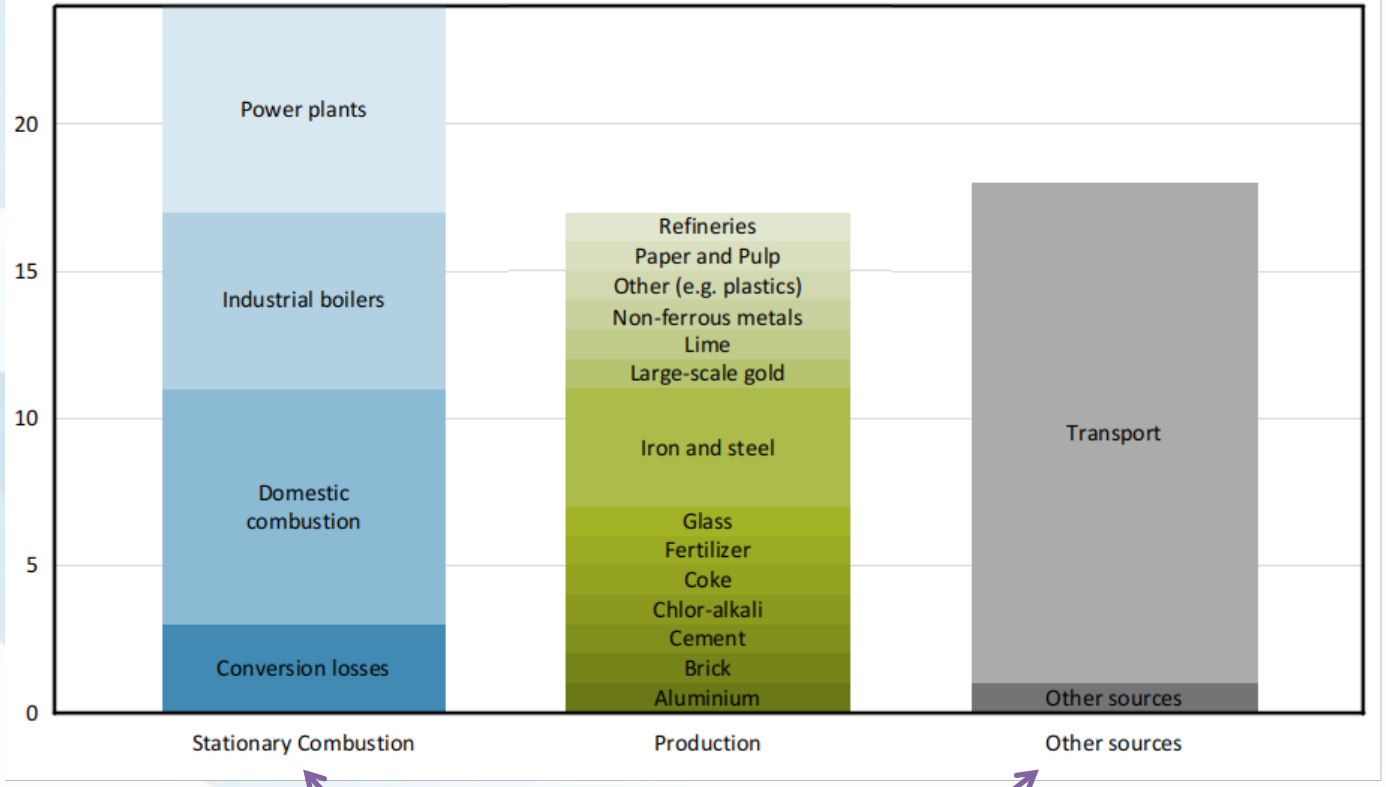


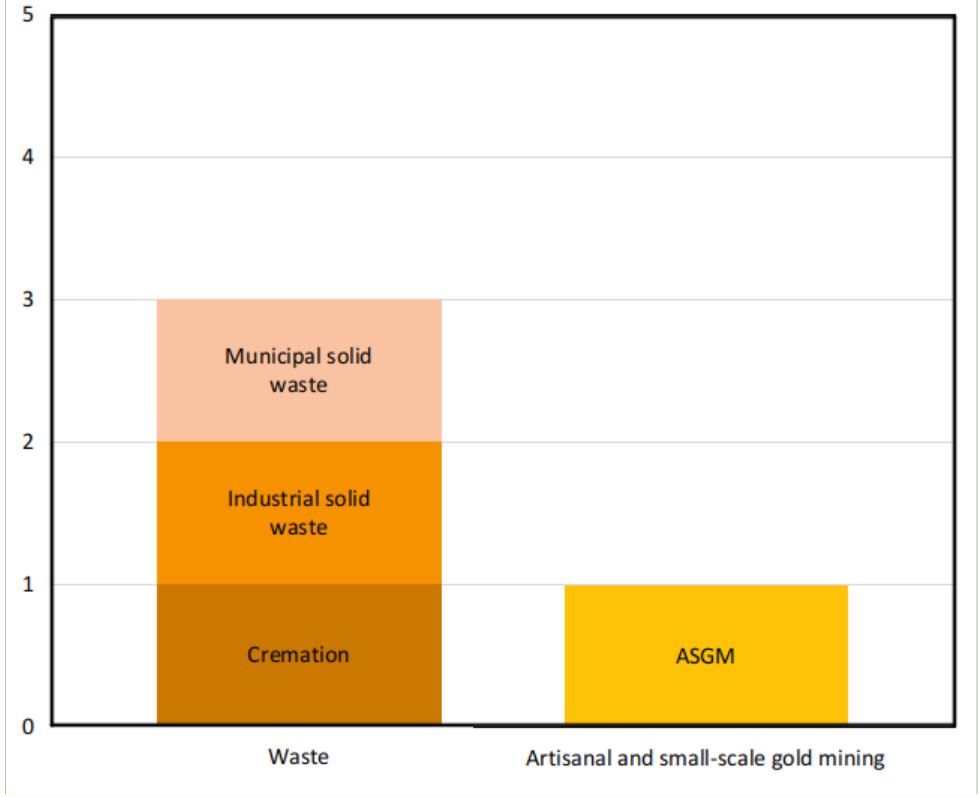
Modelling mercury emissions and abatement scenarios with GAINS

- Model development, data and policy representation update (2021/22; IIASA report focusing on Hg removal technologies – Brocza F., 2021)
- Presentations at TFHTAP meetings in 2021 and 2022
- Int'l Conference on Hg as a global pollutant (ICMGP '22), July 2022:
  - Poster
  - Workshop (slides + recording)
  - Several communities expressed interest

Sectoral resolution of mercury emissions in GAINS

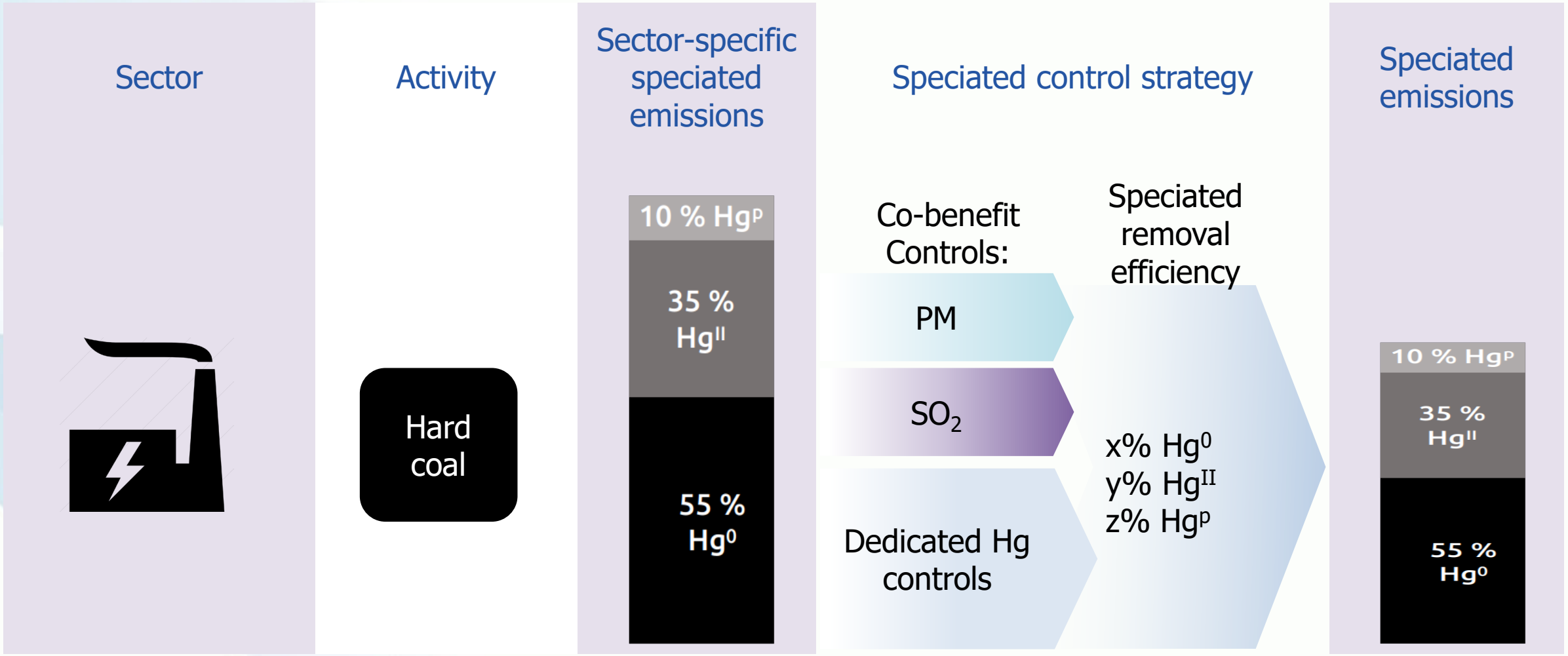
Y-axis: Number of GAINS sectors with associated Mercury emissions





Further split according to fuel types:
Brown coal (2), hard coal (3), coke, biomass, waste, diesel, heavy fuel oil, ...

Mercury representation in GAINS



Further work 2022/23 [1]

- Further improvements of spatial representation of emissions, focus on residential sector *jointly with MSC-W, CEIP*
- Further update of technology parameterization in GAINS (incl. applicability and costs) *jointly with TFTEI* [2022/2023]
- Further work on *condensables* in GAINS; development of further scenarios *jointly with MSC-W, TNO, NILU* [2023]
- Report on extent of application of measures by Parties and their implications [2022/23]
- Scenarios to assess feasibility of achieving new WHO guidelines [2022]
- Finalize the development of the updated global Hg inventory and projections in GAINS; share with other TFHTAP, MSC-E, 'Mercury Community' [2022/23]

Further work 2022/23 [2]

- Scenario development for the (potential) revision of the Gothenburg Protocol, including cost-effectiveness analysis of specific measures and assessment of the implication of improved modelling, i.a., inclusion of condensables and marine deposition targets (*support of CCE*) [2023]
- Assessment and exploration of emission scenarios related to mitigation potential in comparison to the baseline, taking into account interactions at the regional and global scale with assessment of scenarios for consideration by WGSR
  jointly TFIAM, TFHTAP, CIAM [2022/23]
- Support the Forum (FICAP) to the extent that is desirable and feasible [2022/23]
- Further work, consultations, training with EECCA countries [2023]

1st GAINS Model User Community meeting 2022

Potential dates: 22-23 November or 29-30 November, 2022

Format: Hybrid; in person in Laxenburg, Austria

The goal is to connect the growing international GAINS model user community and to enhance the information flow between model developers, model users and other stakeholders. The meeting offers a platform for sharing experiences and best practices in supporting air quality management processes in different regional contexts, as well as a forum to discuss potential new features of the modelling framework.

- **Day 1** will be dedicated to both recent applications of the tools in research projects and decision making processes, as well as to recent model updates
- **Day 2** will be dedicated to current and future projects, user needs, and emerging opportunities to support assessment and decision making processes.

Let us know whether you are interested in attending the meeting and contributing to the agenda in the form of a presentation or a discussion piece by sending an **email** to gains.workshop@iiasa.ac.at

Summary for minutes