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Scenarios…what else?

New GAINS scenarios and analysis in support of the GPG questions

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Center for Integrated Assessment Modelling (CIAM)

TFIAM51, 6-8 April 2022

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Part 1

- Status of methodological improvements and extensions in GAINS
- Addressing the GPG questions
  - Development of new scenarios for extended domain
  - Draft scenario results
  - Preliminary impact assessment; focus on PM2.5

Part 2

- Impact of including harmonized condensable PM fraction (first steps)

Methodological improvements/extensions in GAINS (2021-22)

Soil NOx *(implemented)*

NMVOC from livestock manures and crop production *(April 2022)*

Slurry acidification *(June 2022)*

Mercury *(June-Sept 2022)*

Waste management *(implemented)*

Update of critical loads (CL) database *(April 2022; jointly with CCE)*

Atmospheric calculation (new source receptor (SR) coefficients)
(April 2022; jointly with MSC-W)

Methodological improvements/extensions in GAINS (2021-22)

Extended modelling domain *(April 2022; jointly with MSC-W)*

Potential updates for health and ecosystem impact assessments
(under discussion, coordinated with TFH)

Urban-rural interactions
(implemented; jointly with MSC-W; first draft results tomorrow)

Condensable fraction of PM
(I draft implementation and initial results; Jointly with TNO, MSC-W, SYKE, NILU. GAINS structure has been further developed to include FPOA[a)], CPOA[a)], and PM2.5 (new total PM2.5 including EC, FPOA, CPOA, other inorganic fine PM)*

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

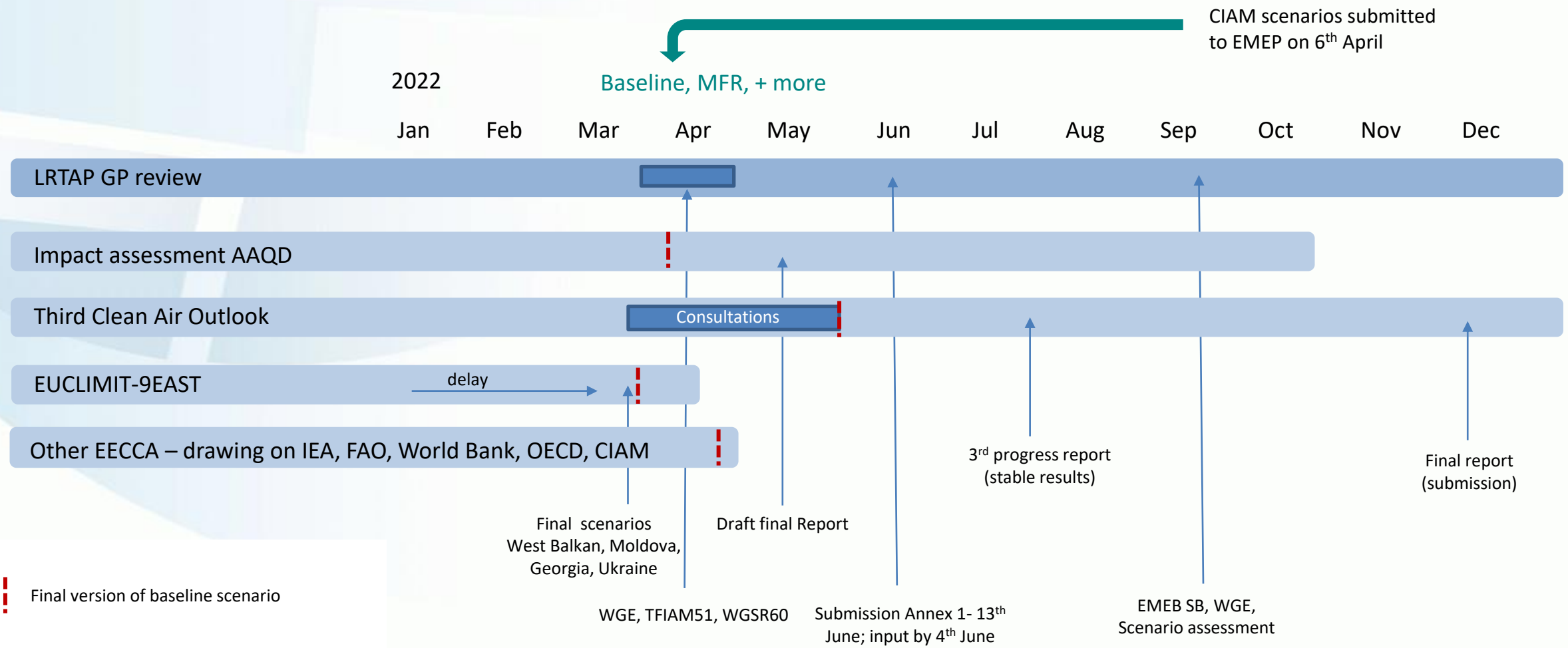
Update of historical data and development of new scenarios

- Revision of the historical data (statistics, UNFCCC CRF submissions, etc.)
- Comparison and validation of 2005/15 nationally reported emissions in 2021; *jointly with CEIP*
- Review of the recent policies and measures and national implementation progress and plans
- Baseline emissions up to 2050 (air pollutants and methane), considering
  - For the EU – Green Deal (Fit for 55) and NAPCP
  - For West Balkan, Rep of Moldova, Georgia, Ukraine newly developed PRIMES and CAPRI model scenarios,
  - 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
- MFR emissions up to 2050 (air pollutants and methane)
- Climate mitigation scenarios for West Balkan and EECCA
- Alternative ‘low’ scenario [combination of climate policy, dietary changes, and MFR for air quality]
- Update of costs; *joint with TFTEI (delayed)*

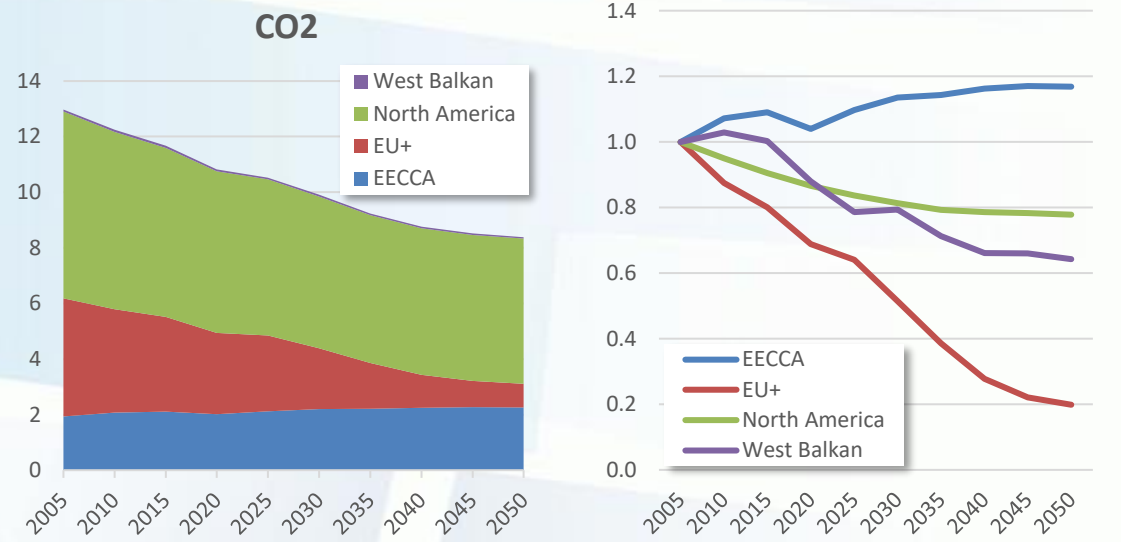
Scenario development timeline and harmonization

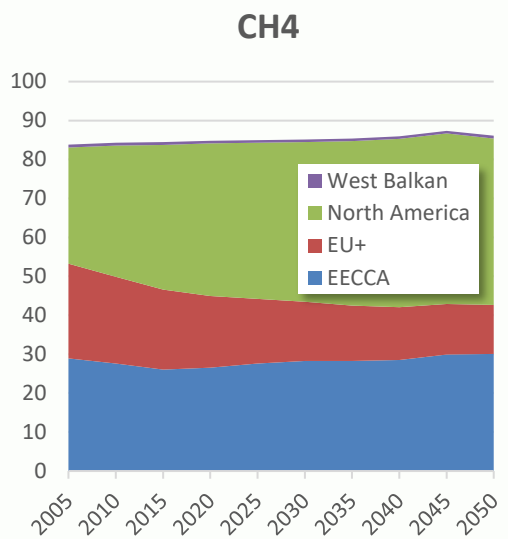
Explore synergies between several activities

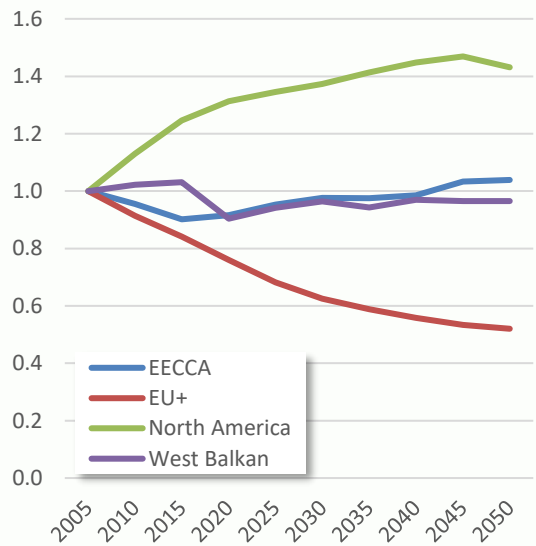
- Harmonizing to the possible extent data, baseline assumptions, and model versions

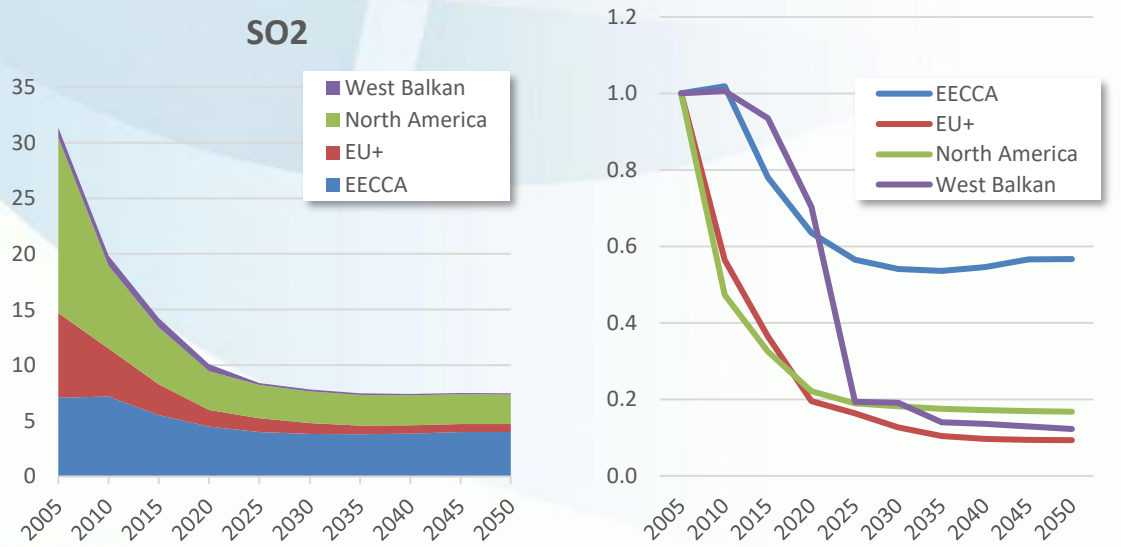


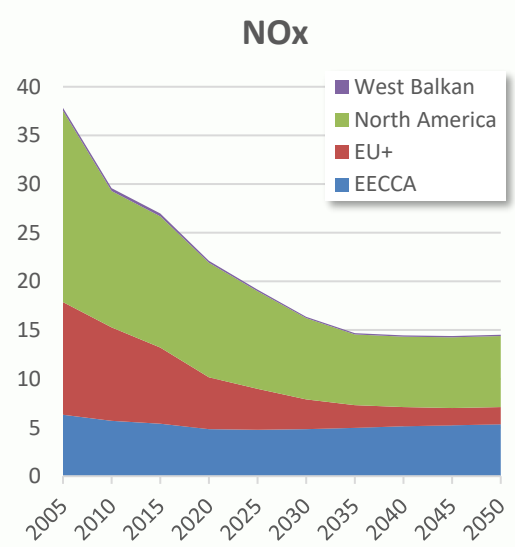
Draft baseline emission scenarios (1)

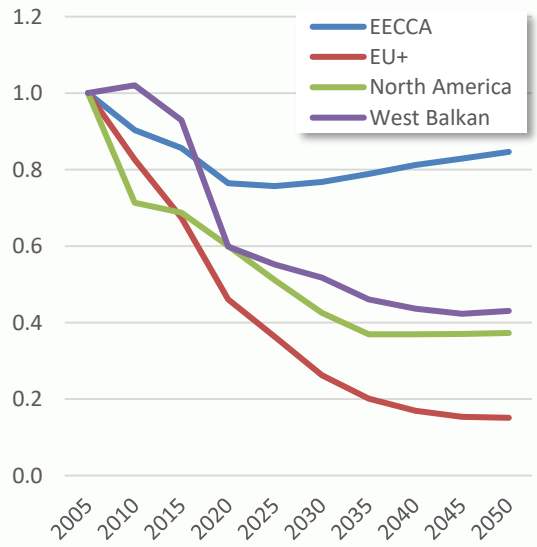






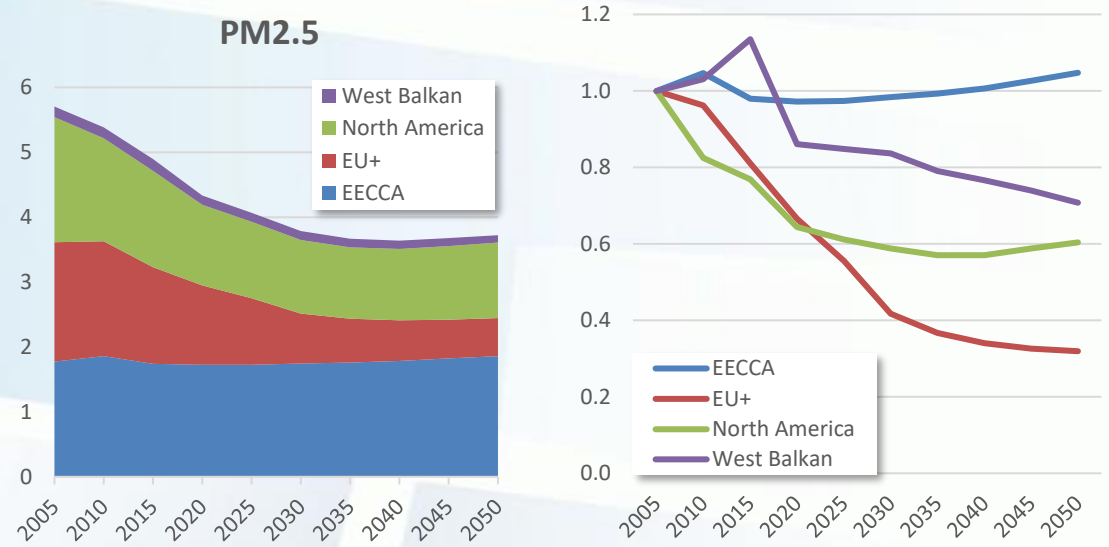


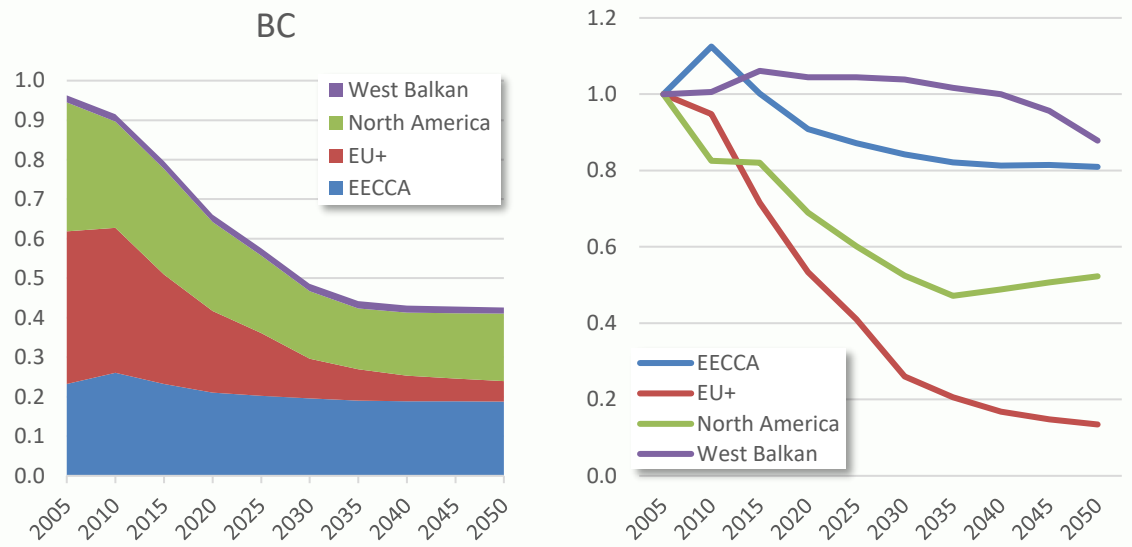


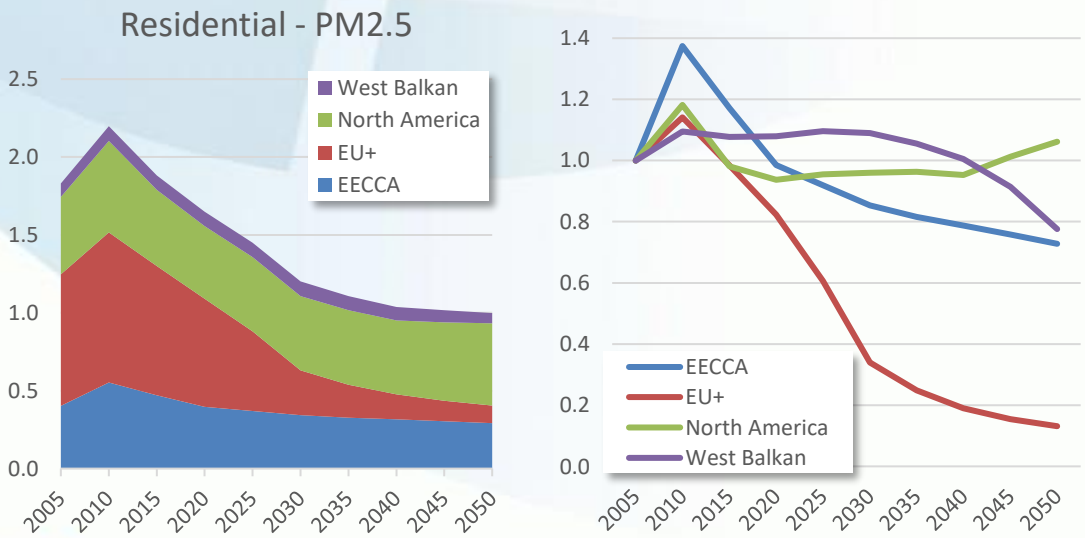


EECCA – here includes also Turkey

Draft baseline emission scenarios (2)







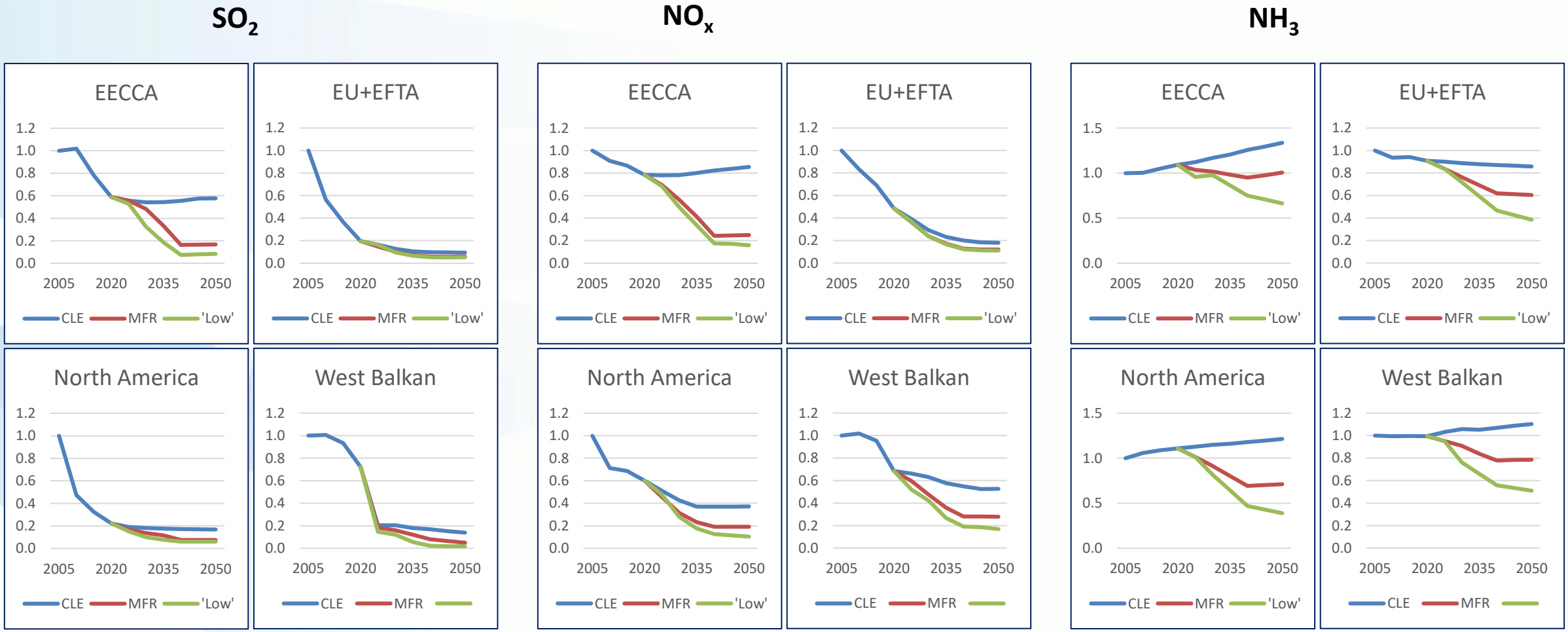
- Primary PM2.5 are expected to decline in all regions
- Residential sector share declines only slightly for the whole regions (remains at about 25-30%) but strong differences between regions,
- Black carbon emissions are expected to decline faster than PM2.5; its share drops from about 15 to 10% by 2050 – in the future largest contribution from residential combustion,
- Uncertainties in fuel use and limited information on structure of installations is critical for residential sector and total PM2.5

EECCA – here includes also Turkey

Summary of the baseline emission scenario

- Baseline assumptions vary across regions; i.e., multimodel (PRIMES, CAPRI, IEA, FAO) approach considering latest regional and national policies, also with respect to climate policy,
- Further decoupling of economic growth and air pollution emissions,
- Most regions include strengthening ambition of climate policy and air pollution legislation in the future, including West Balkan (power sector)
- These projections assume compliance – importance of enforcing what has been committed
- EECCA region projections most uncertain; downscaled from IEA global/regional projection

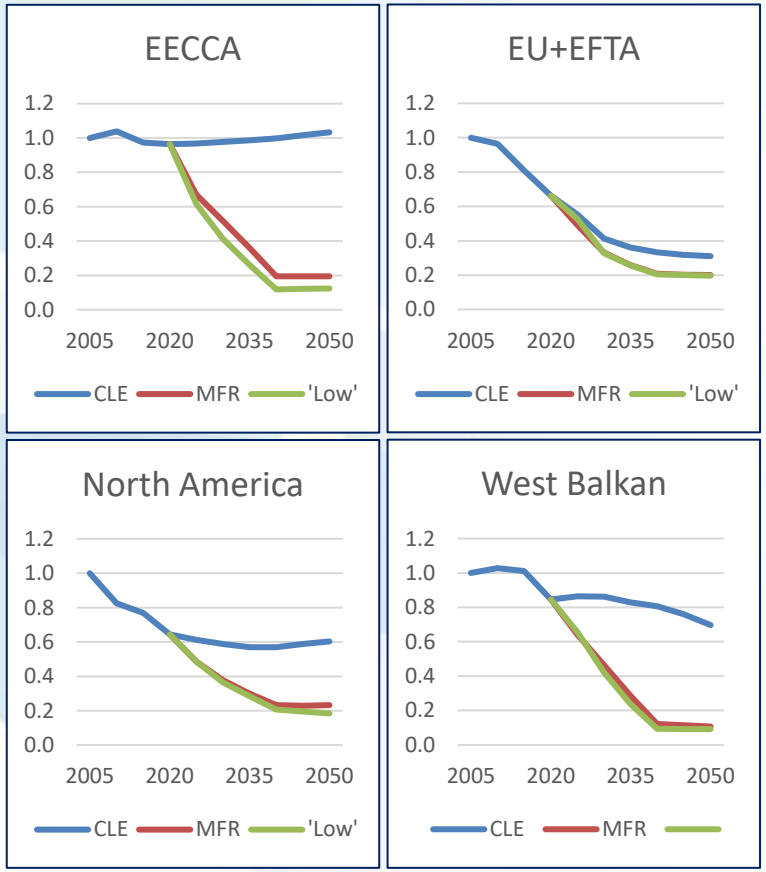
Draft Further mitigation potential (1)



EECCA – here includes also Turkey

Draft Further mitigation potential (2)

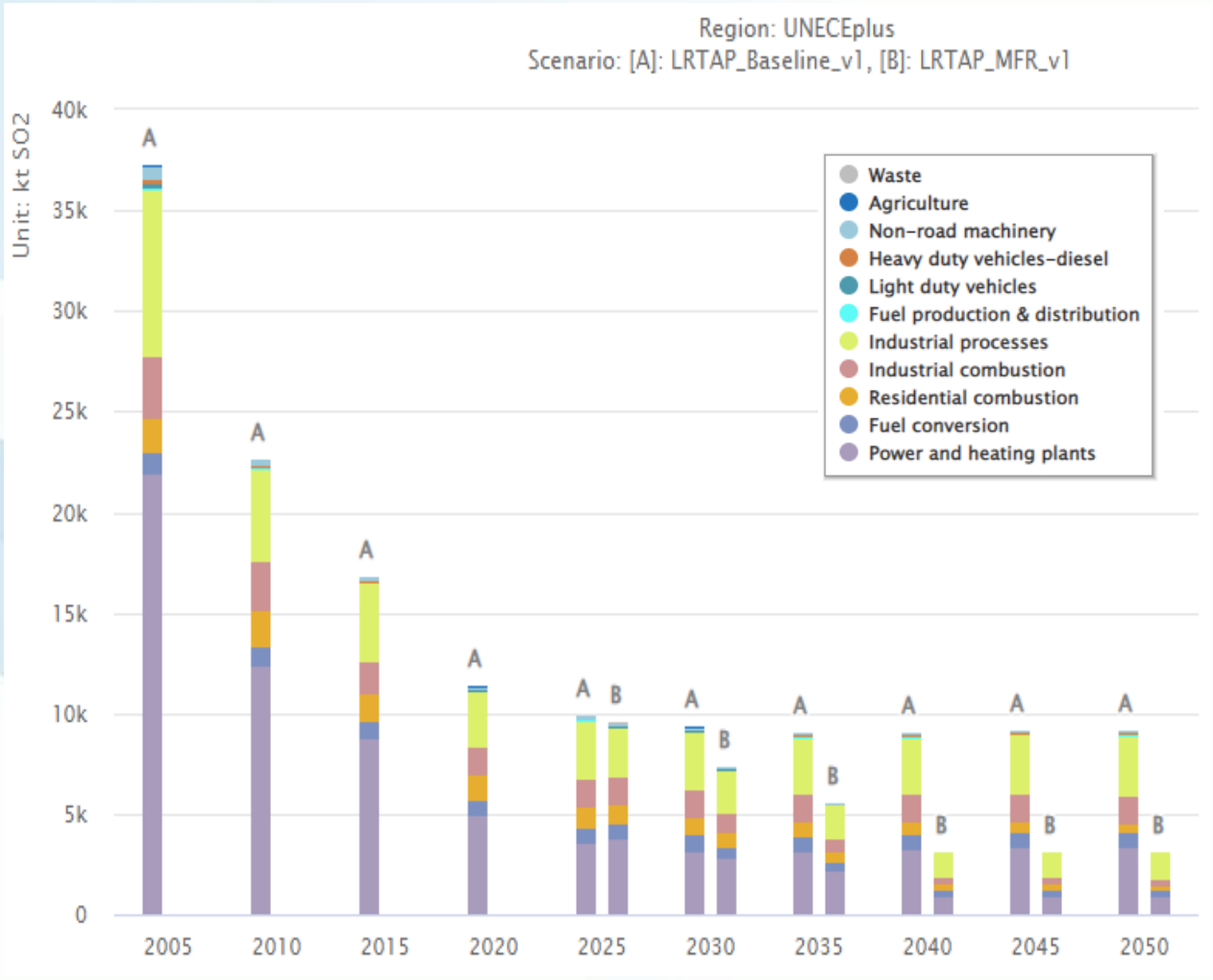
PM2.5

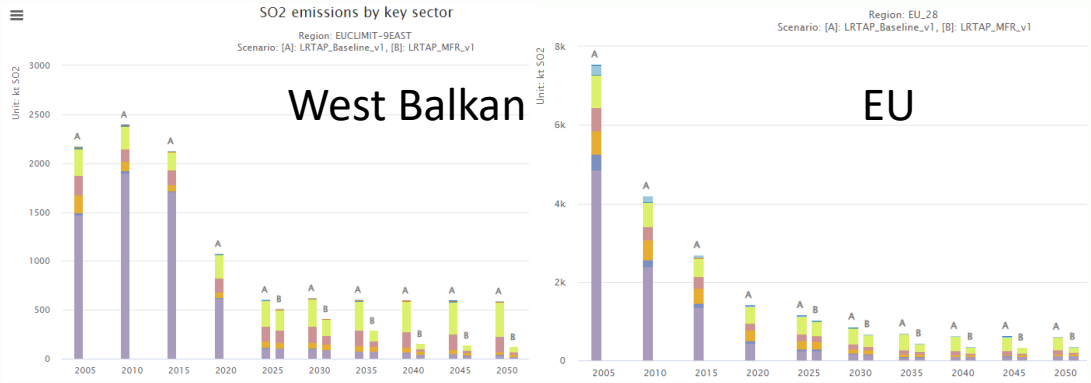


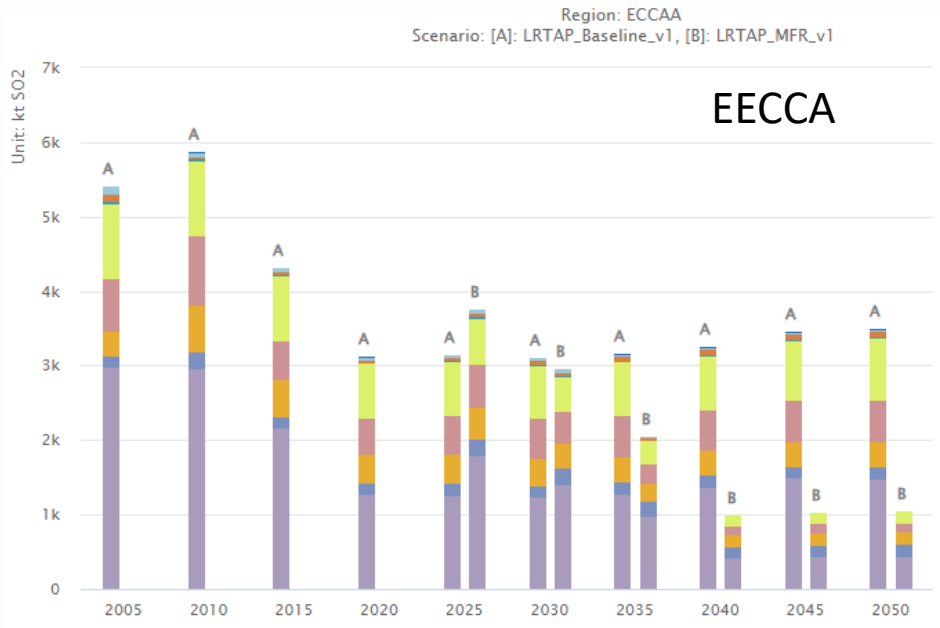
- For SO_2 – apart from EECCA, most of the further mitigation potential committed in current legislation – assuring enforcement essential!
- For NOx – similar picture to SO_2, although more further mitigation potential available; note that remoting sensing data (and N deposition measurements) indicate that emission inventories overestimate decline in emissions in the last decade
- For NH_3 – current policies very shy of mitigation, similar further potential exists across all regions (some differences for single countries where policies more advanced since a while); Overall mitigation potential much smaller than for other air pollutants - need for structural and behavioral changes (will bring significant CH_4 co-benefits) – the 'Low' scenario provides significant additional potential
- primary PM2.5 – except EU+, large potential exists, 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

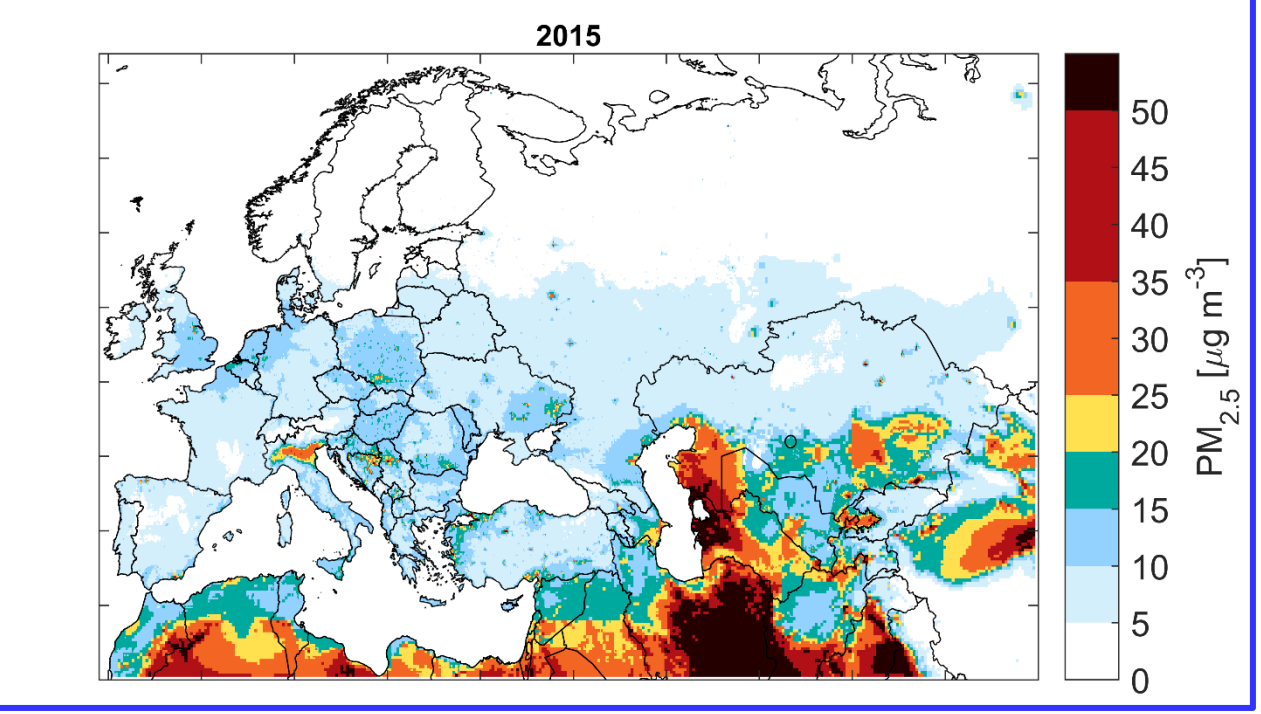
EECCA – here includes also Turkey

Further mitigation potential by sector
Baseline vs MFR scenario for SO_2








2015
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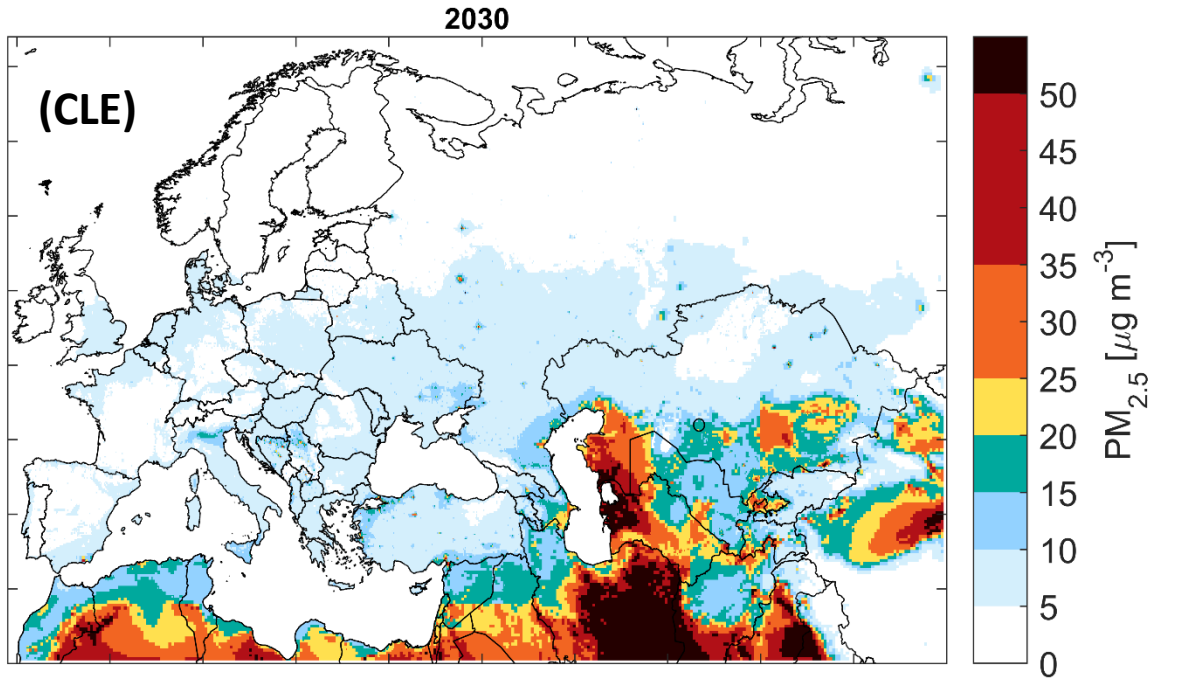
35
30
25
20
15
10
5
0
PM2.5 [μg m-3]


2030
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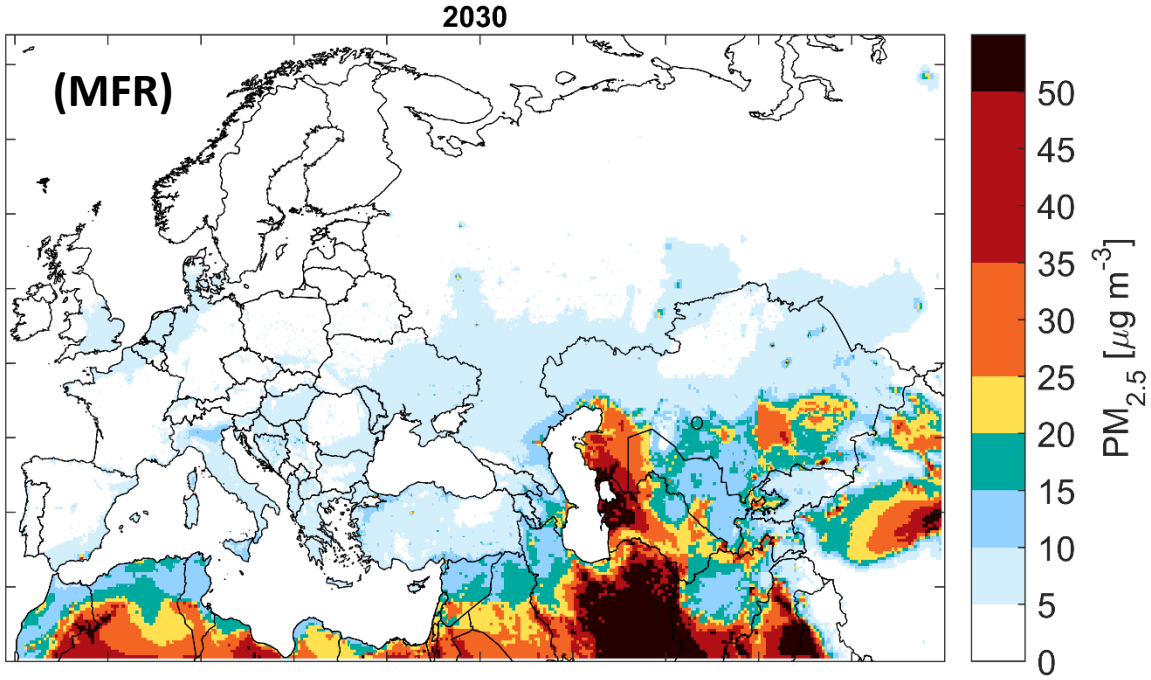
PM2.5 [μg m-3]


2030
(MFR)
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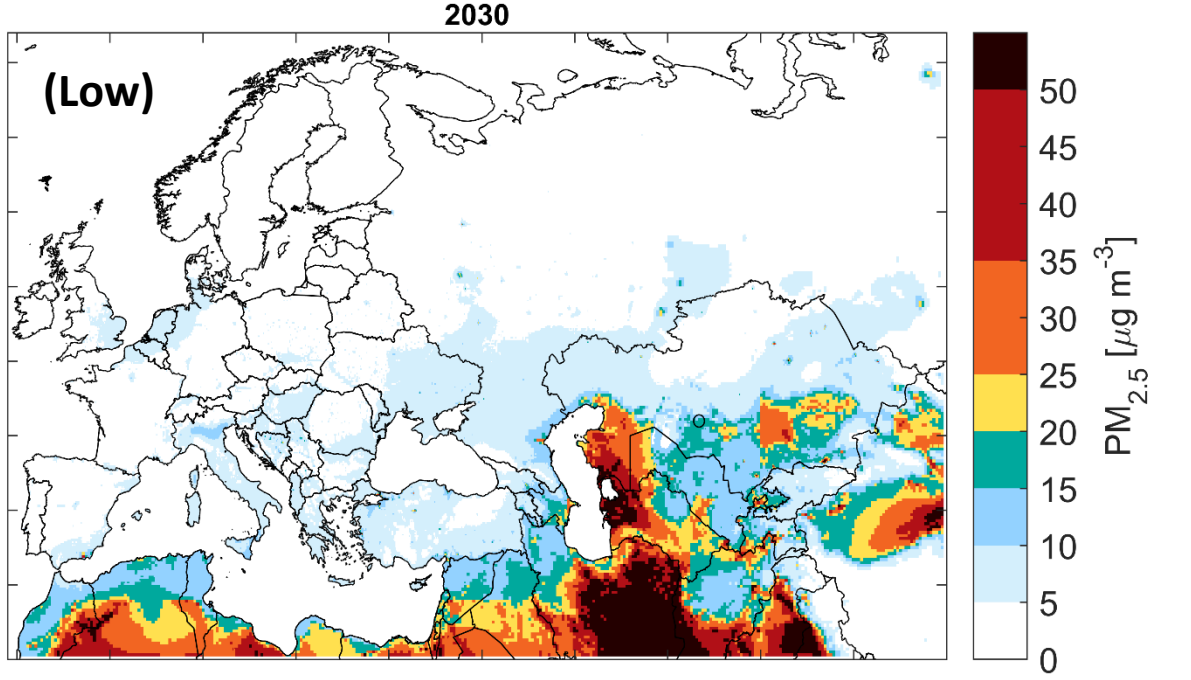
PM2.5 [μg m-3]


2030
(Low)
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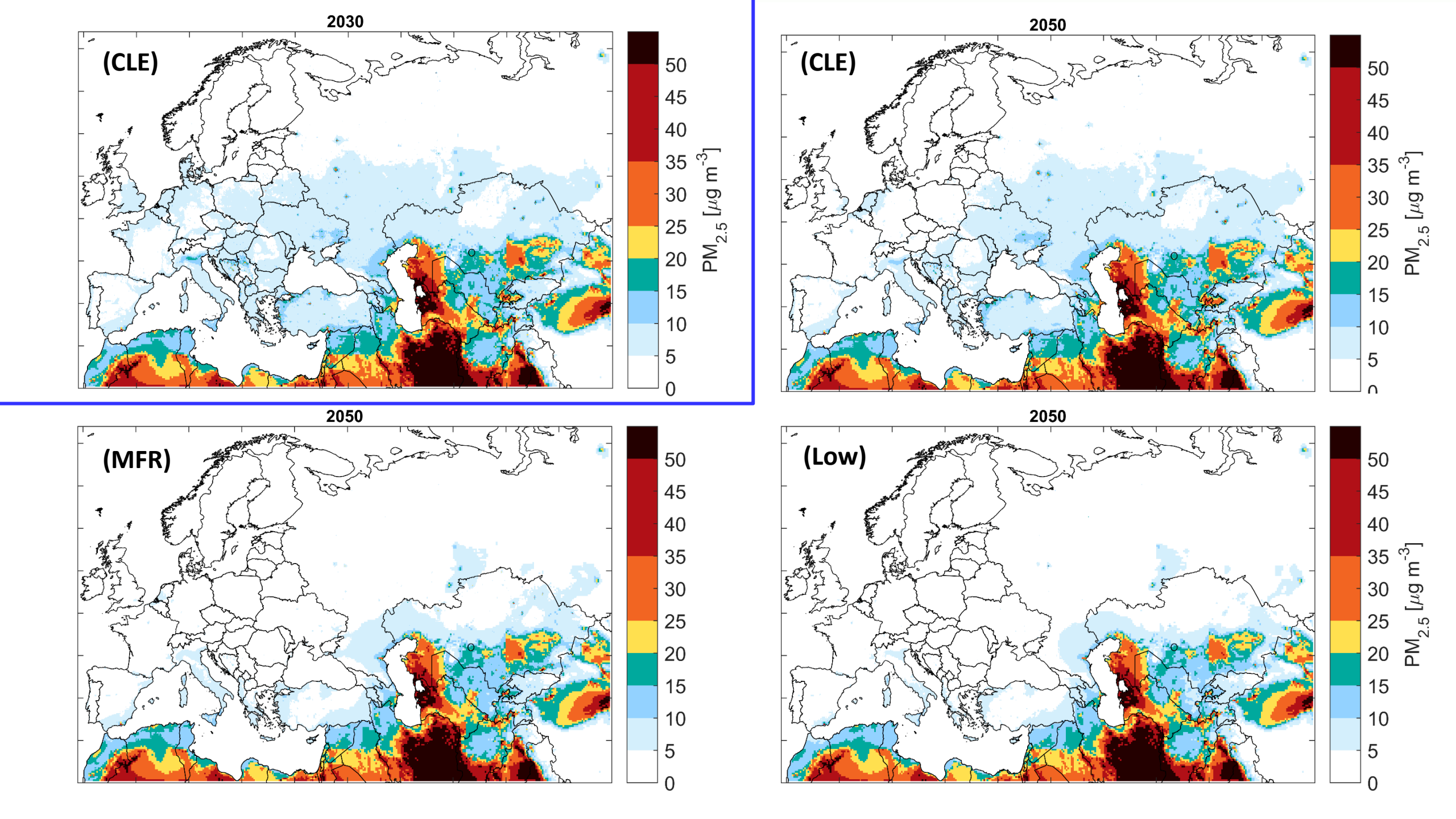
PM2.5 [μg m-3]


2030
(CLE)
2050
(CLE)
2050
(MFR)
2050
(Low)
50
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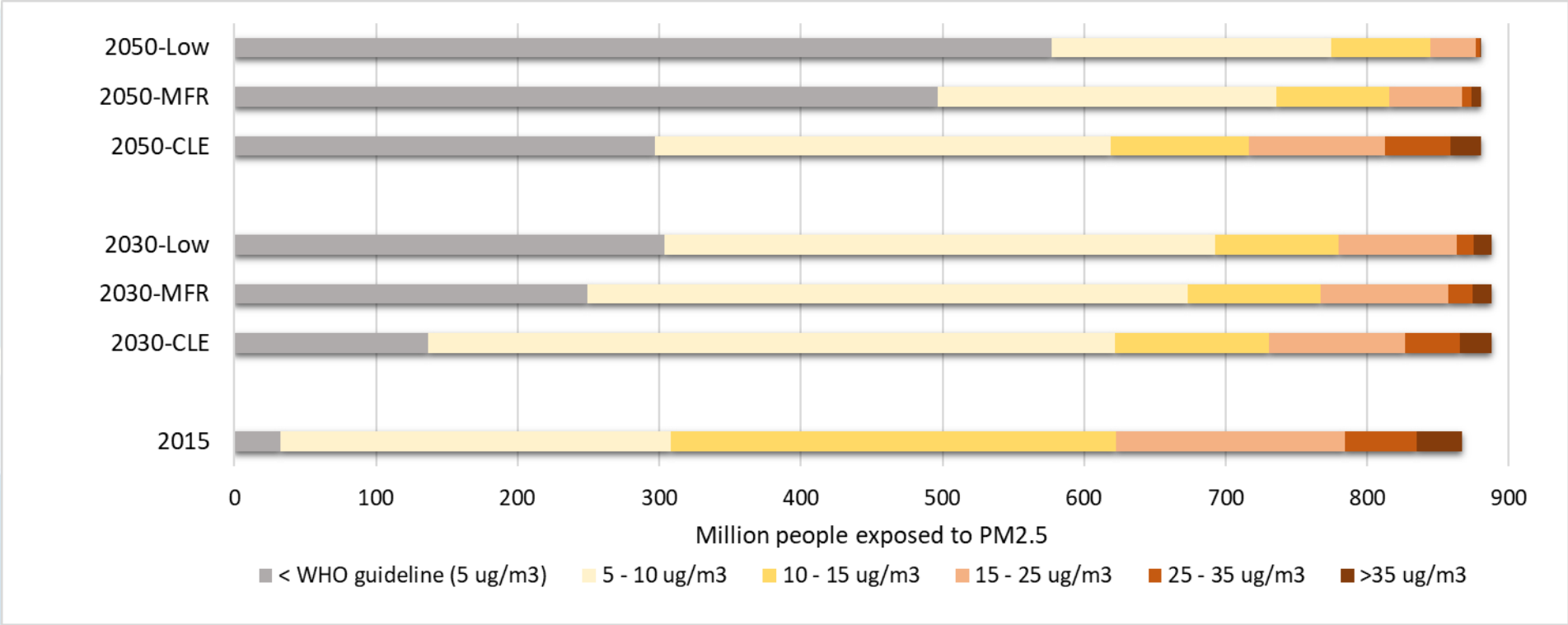
40
35
30
25
20
15
10
5
0
PM2.5 [μg m-3]

Preliminary insights from scenarios for PM concentrations

(GAINS model results; 'new' source receptor coefficients, including natural sources)

- In 2015, some areas in the EU+ still not in compliance with the current EU PM2.5 limit values and large share of population exposed to PM levels above the 2005 WHO guidelines. Higher concentrations in West Balkan, EECCA,
- The *Baseline* achieves significant improvements already by 2030 in the EU; more improvement by 2050,except EECCA. However, the 2021 WHO guidelines exceeded in large areas; in several EECCA regions concentrations decline only little
- The *MFR* scenario for 2030 does not bring large improvements – too short time, except in Balkan where more improvement appears possible. Also 2021 WHO guidelines appear not attainable across large areas
- The *MFR* scenario for 2050 show large scale improvements also across Balkan – big improvement on 2021 WHO guideline attainability
- The *Low* scenario (climate mitigation+MFR+healthier diet) bring significant reductions in many regions
- These are first results using new source receptor matrix; further validation and comparison with EMEP model and then analysis will follow

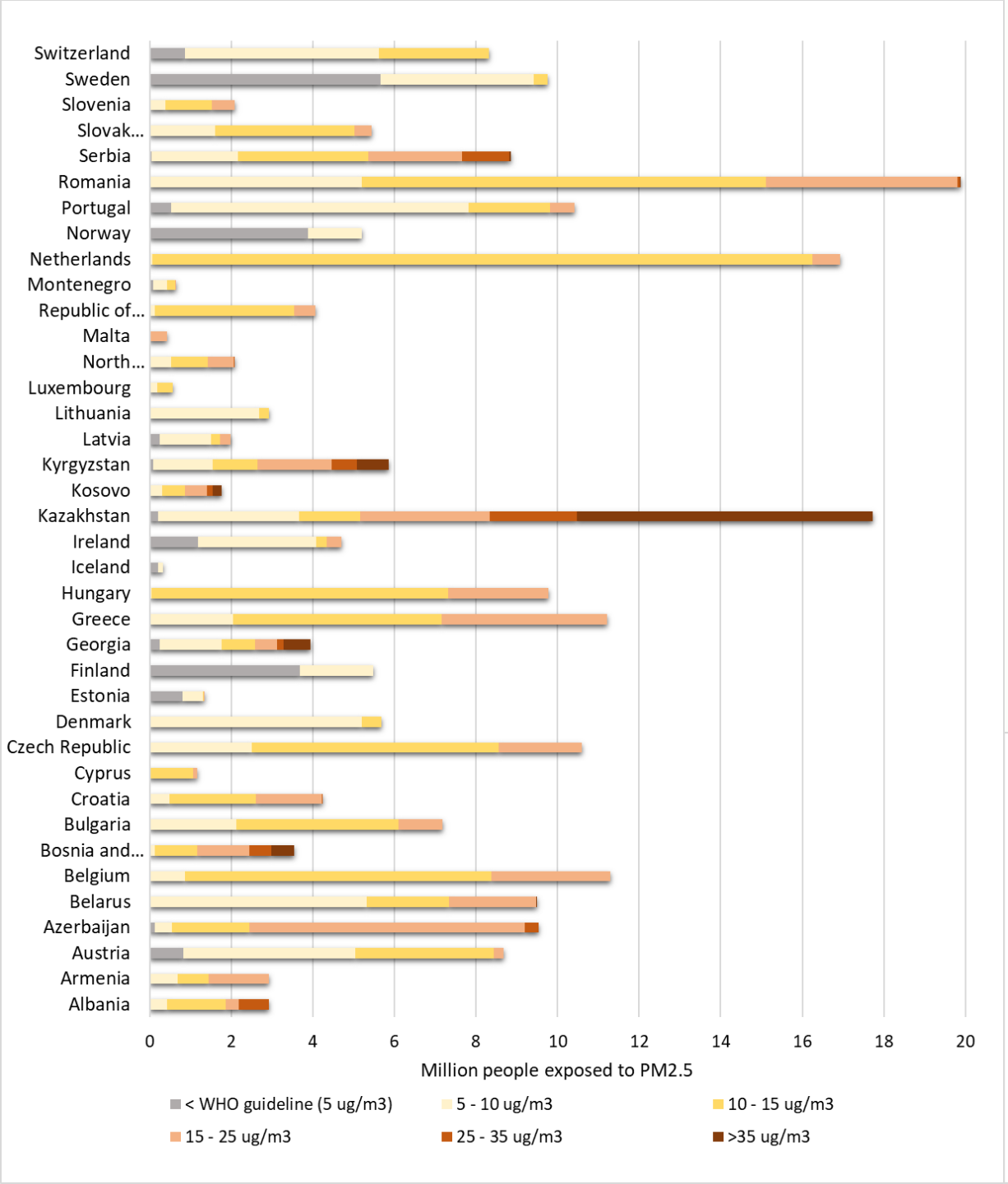
Population exposure in the UNECE domain, excl North America

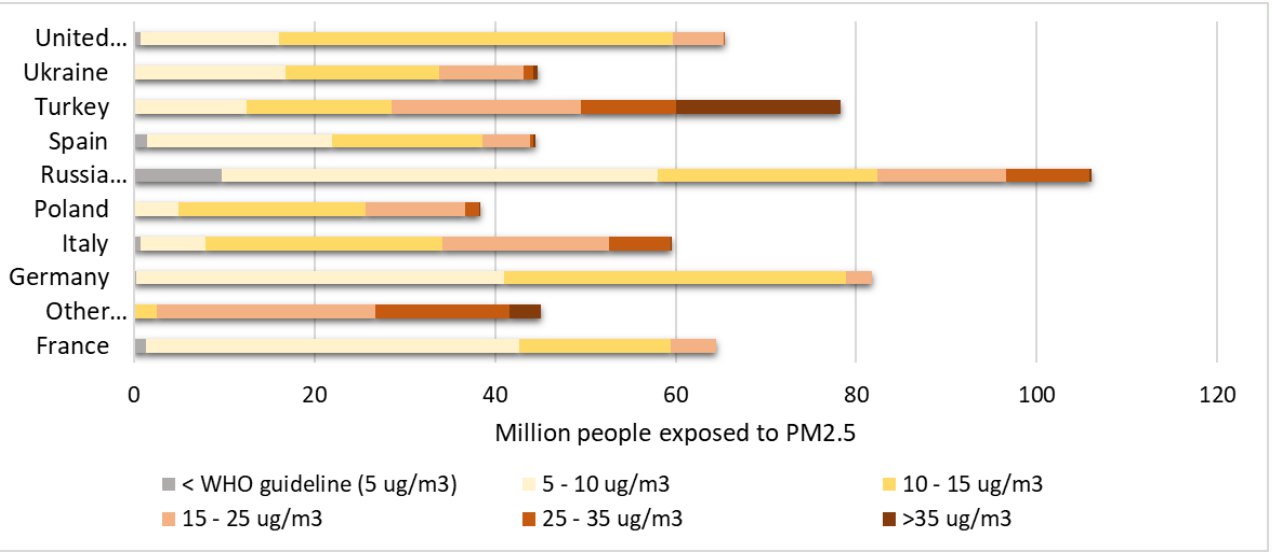


- Steady improvement in the *Baseline*,
- Not very large improvement in the MFR by 2030 but much more in 2050
- *Low* scenario provides further benefits, more than 70% of population exposed to PM2.5 levels below WHO guideline

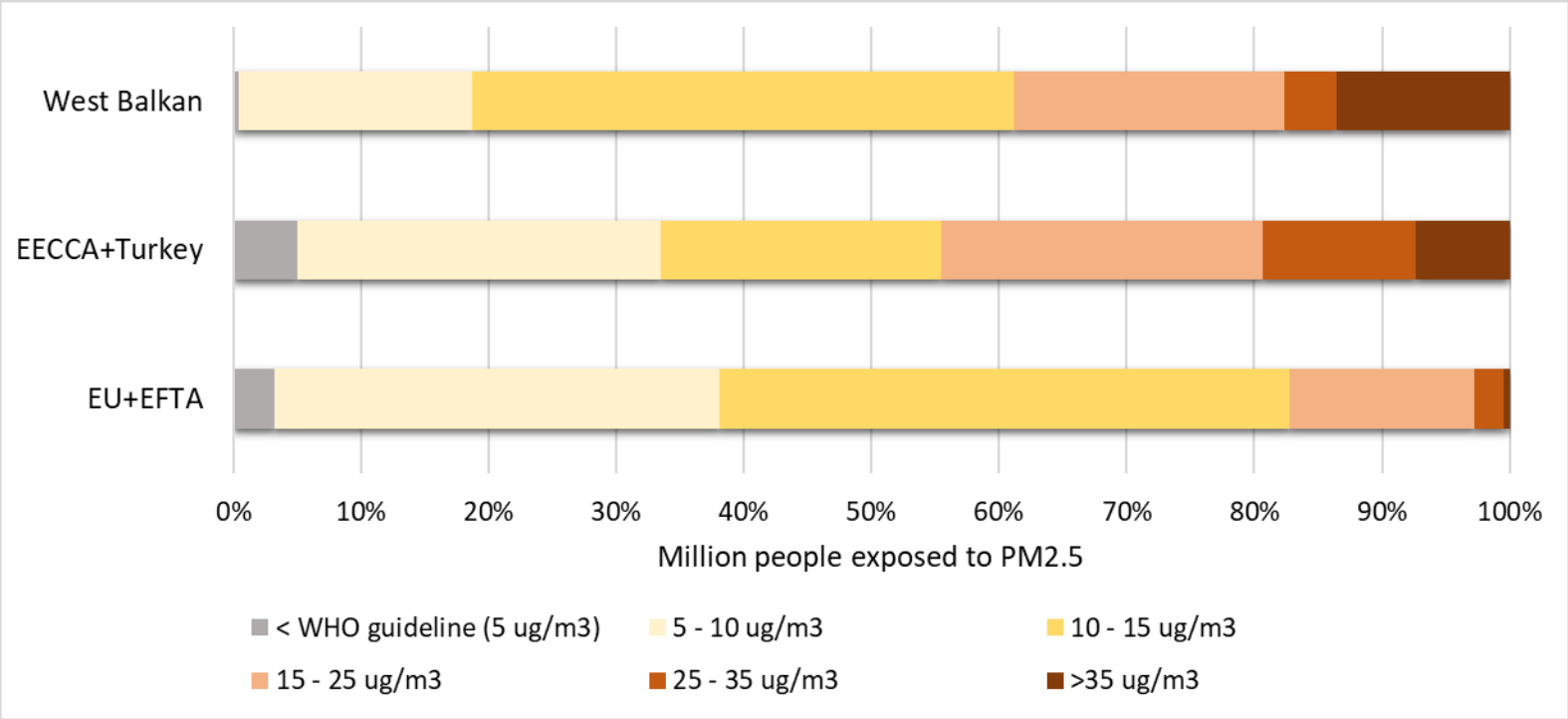
PM2.5 Population exposure by country for the whole domain - 2015

- In several countries large parts of population exposed to levels about 25 ug/m^3
- This is the case mostly in EECCA and West Balkan
- Only a handful of countries in the EU+EFTA has significant part of population below WHO guideline

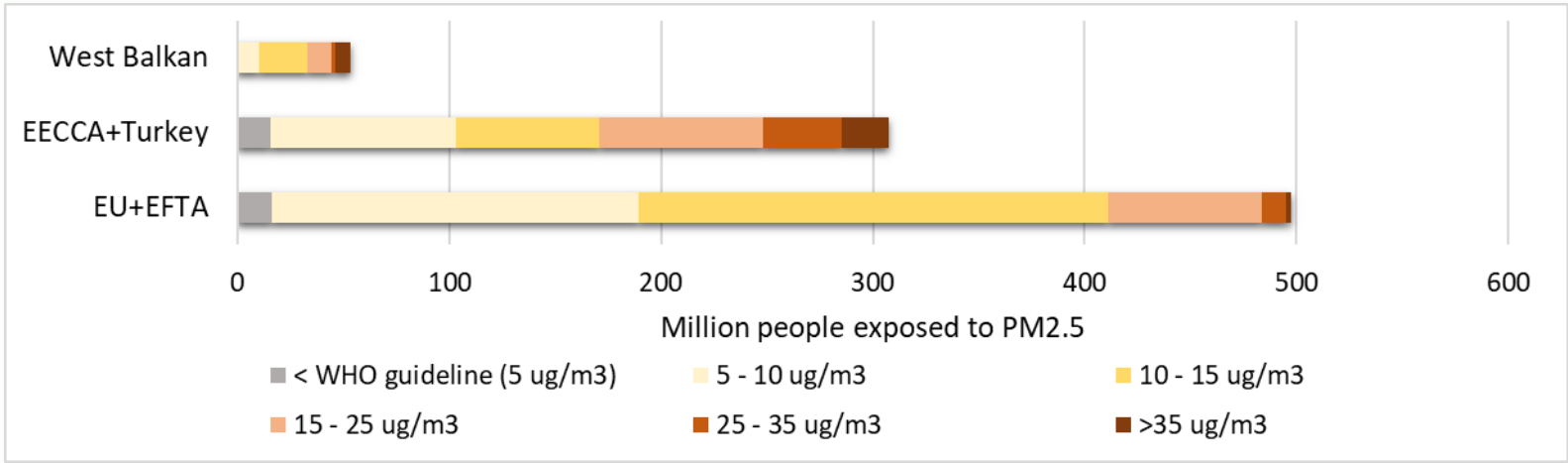


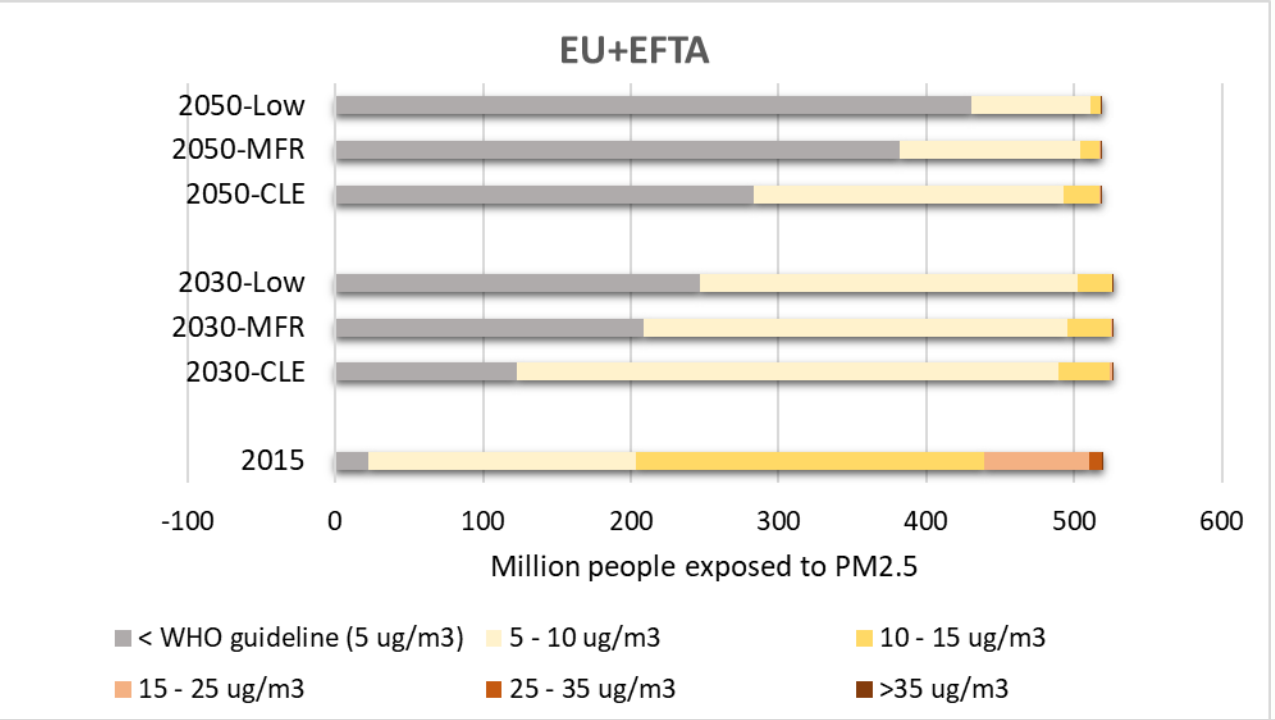


Population exposure in 2015



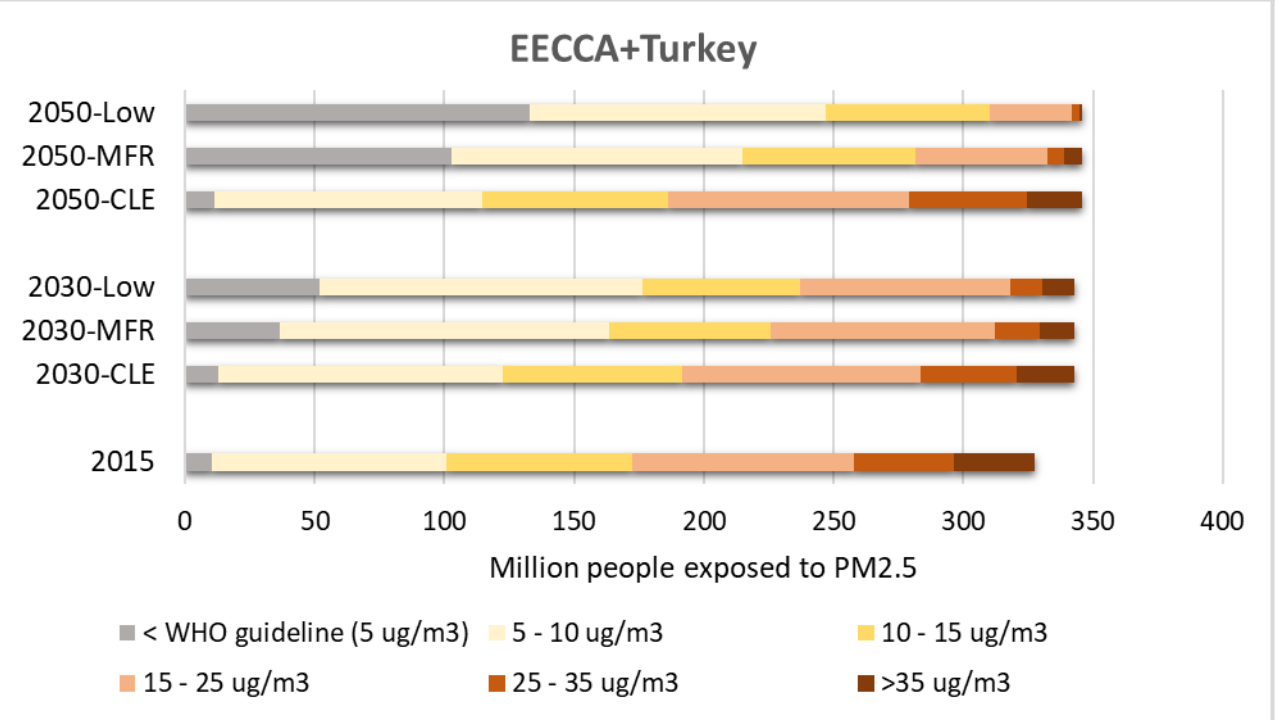
- In 2015, about 85 million people in the UNECE regions (excl North America) exposed to levels > 25 ug/m^3
- Only about 30 million below WGO guideline value

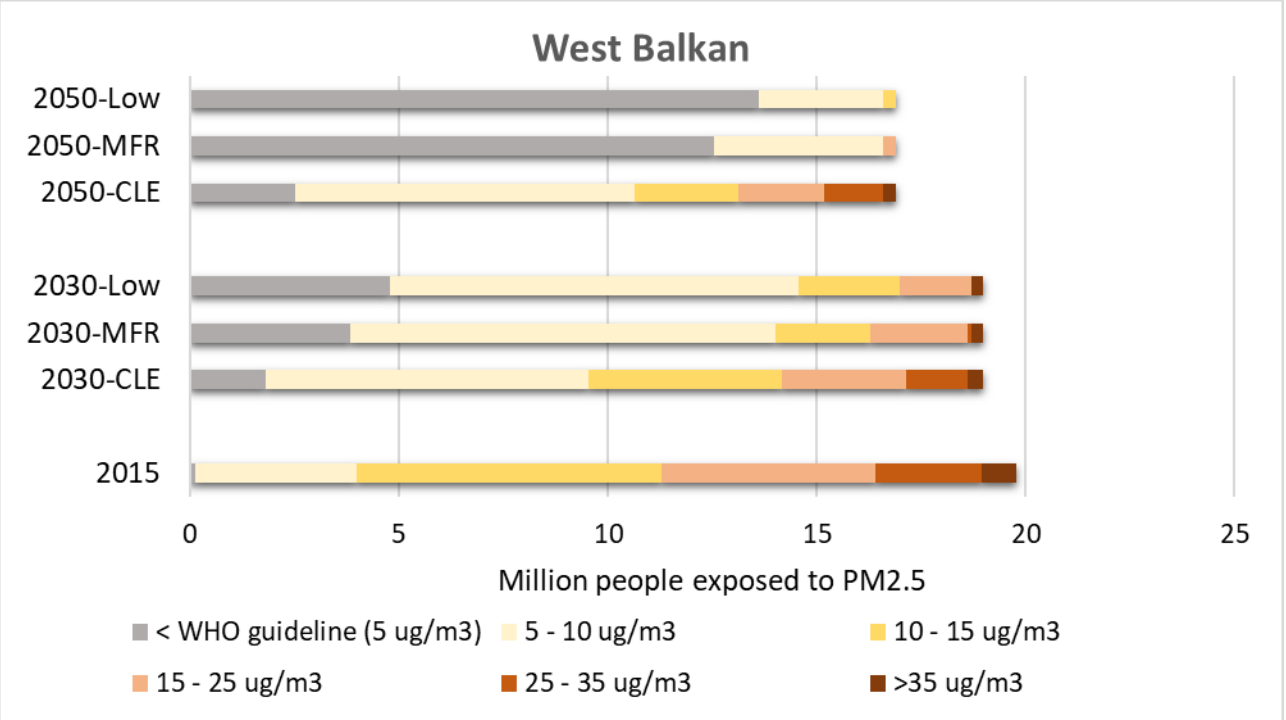




Population exposure over selected regions

- Steady improvement in the *Baseline*, except EECCA.
- Most improvement in the EU+EFTA
- In West Balkan and EECCA, current legislation leaves large part of the population above national standards and most above the WHO guideline
- Not very large improvement in the MFR by 2030 but much more in 2050
- *Low* scenario provides large additional benefits across all regions, especially Balkan and EECCA





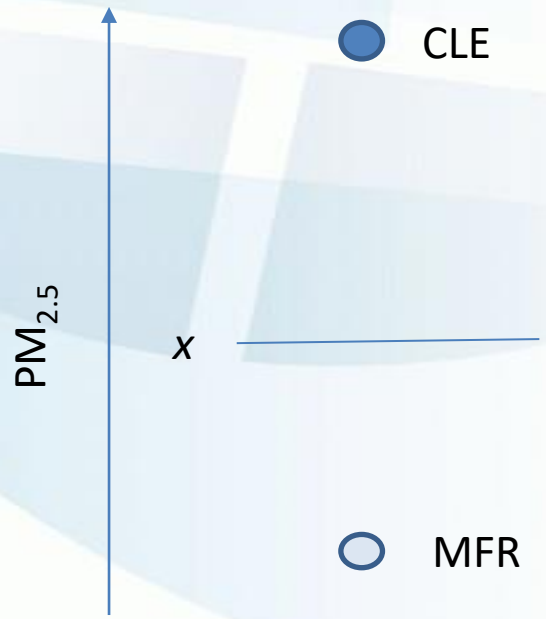
Towards cost-effectiveness analysis

- Simultaneous work within the AAQD impact assessment
- Towards alignment of the EU air quality targets with WHO
- Work ongoing jointly with MSC-W (Bruce will have an extensive presentation tomorrow)

Optimization target setting in the GAINS model

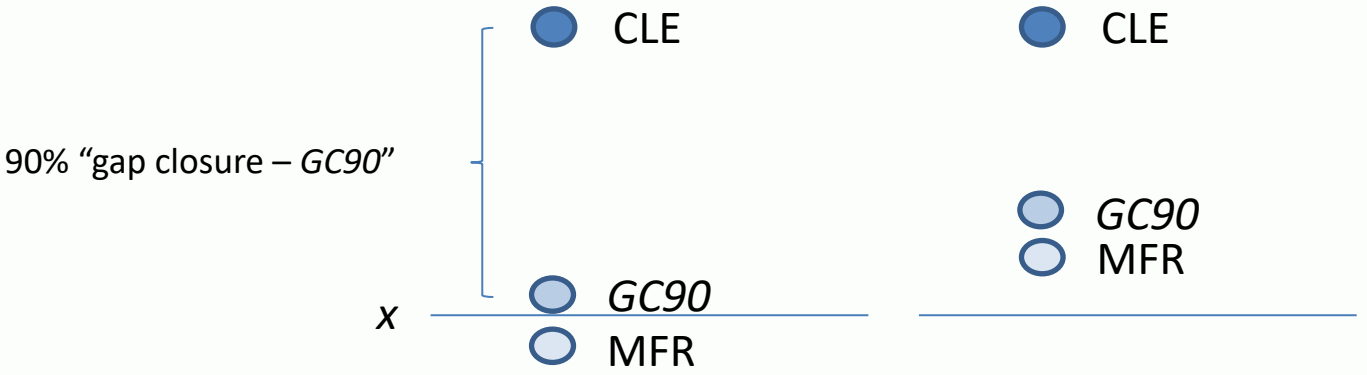
- "Target level *x*": Ideally, grid-level total $PM_{2.5}$ concentrations < *x* $\mu g m^{-3}$ in all EU-27 grid cells (CASE 1)
- This target is not achievable in all grid cells for low levels of x => need for a modified grid level target setting in order to still achieve a feasible solution:

CASE 1: MFR concentration well below *x*



Grid constraint: $PM_{2.5} < x$

CASE 2: MFR concentration just below x or >x



Example: 2030

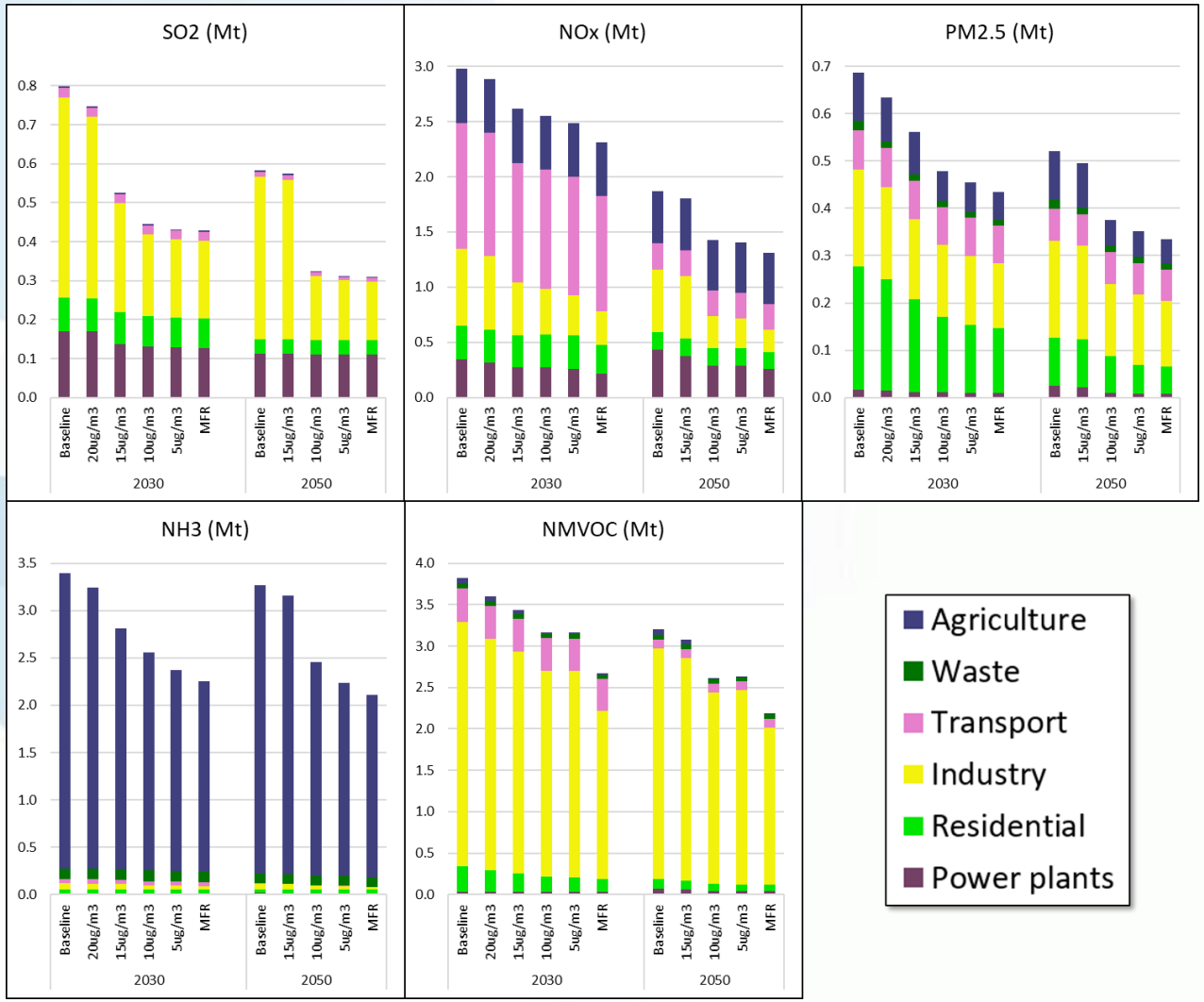
x = 10 µg m^{-3}, => ~2% grids in EU-27 > *x*

x = 5 µg m^{-3}, => ~40% grids in EU-27 > *x*

Grid constraint: $PM_{2.5} < GC90$

Emission trends (all scenarios, including optimized cases)

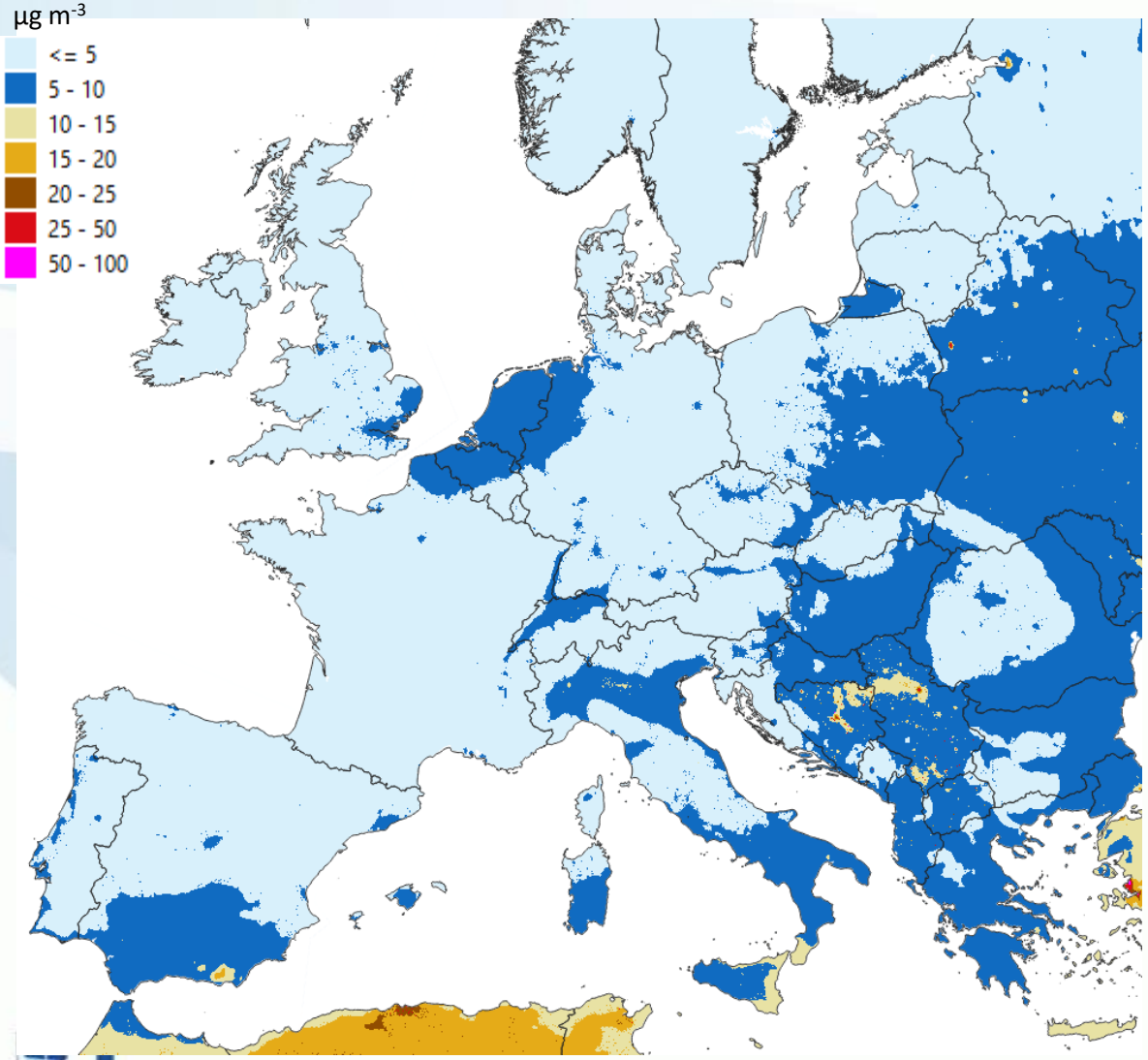
Change in total EU-27 emissions by sector



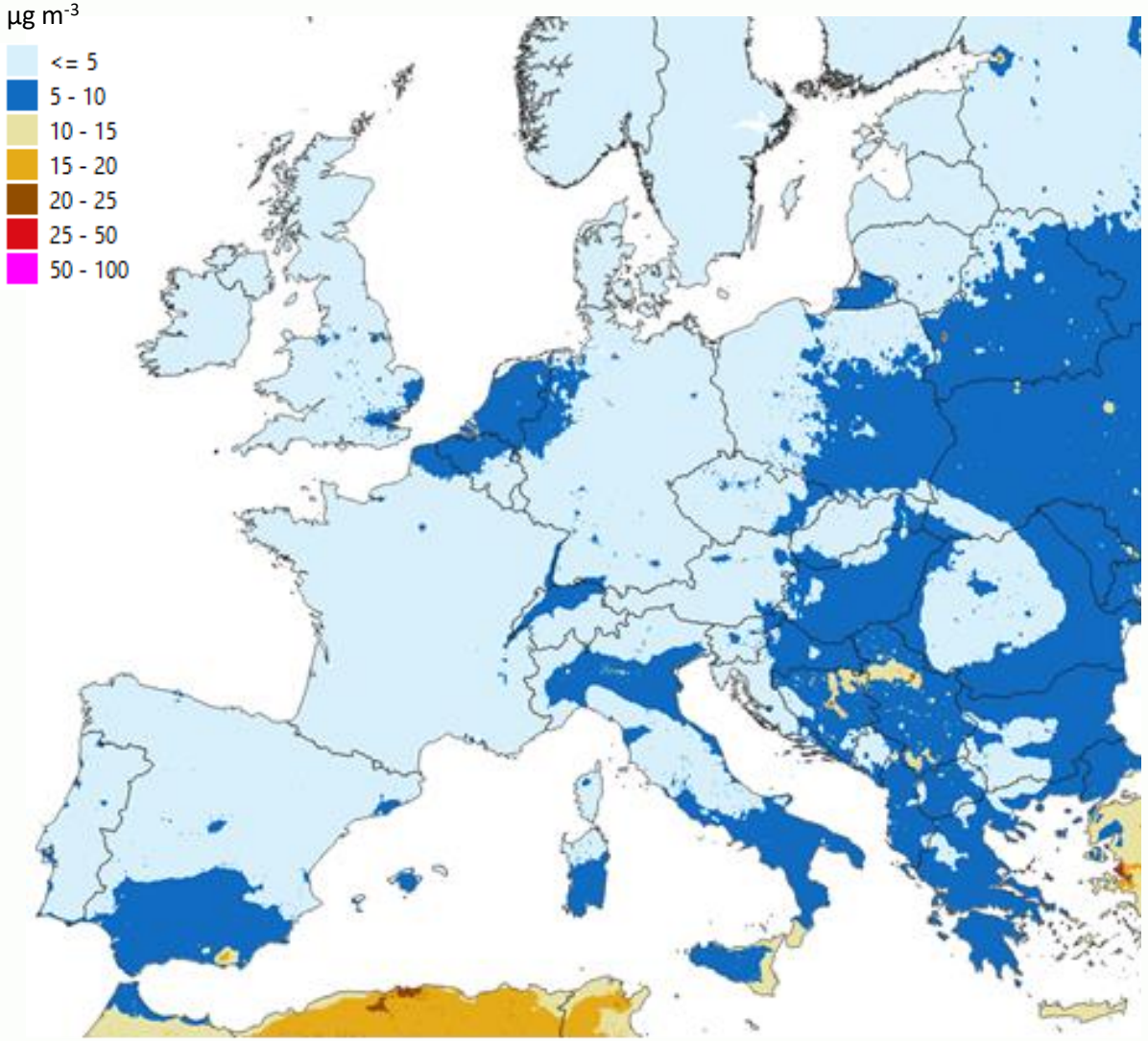
- Relates to 'background' concentrations – the indicated levels shall be met everywhere (if feasible according to the GAINS model assessment)
- 'Attaining' 20 and 15 µg/m^3 $PM_{2.5}$ concentration targets appears feasible and does not require significant additional reductions neither in 2050 nor 2030
- Additional mitigation needs to increase strongly to 'attain' the more ambitious targets of 10 and 5 µg/m^3 and reaches often near MFR levels for several pollutants
- Key further reductions seem achievable in
  - Residential sector ($PM_{2.5}$)
  - Industry (SO_2, NOx, VOC)
  - Agriculture (NH_3)
- Feasibility in some regions is an issue, both in 2030 and 2050, especially for 5 µg/m^3 target

Indicator 1 – Feasibility of low $PM_{2.5}$ concentration targets (example for 2030)

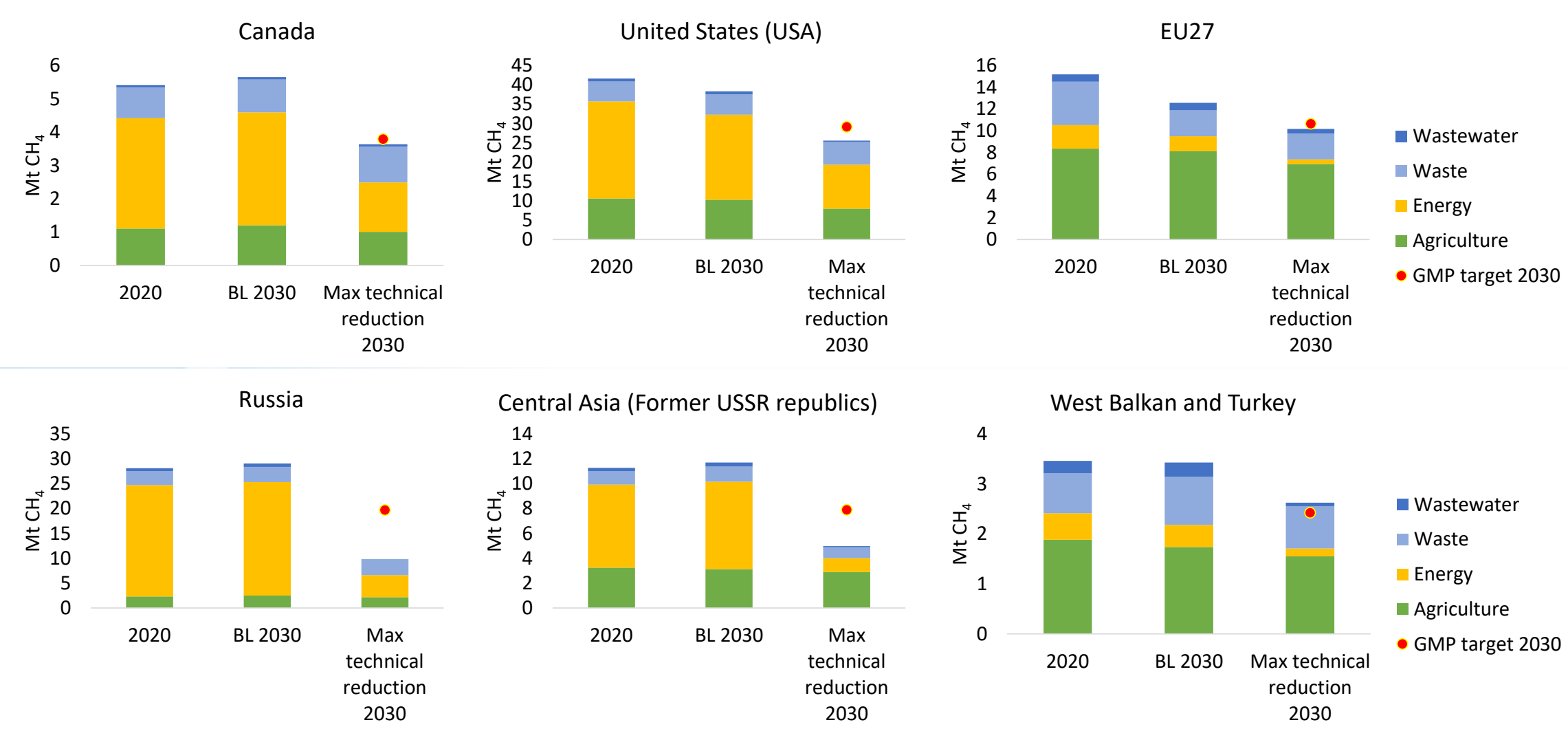
$PM_{2.5}$ concentrations in the 10 µg m^{-3} target case



$PM_{2.5}$ concentrations in the 5 µg m^{-3} target case



Feasibility to meet the Global Methane Pledge in 2030 much depends on sector composition of emissions



Source: Adapted from Höglund-Isaksson et al. 2020, for *forthcoming* paper

A few thoughts on policy drivers for CH_4 reductions in the 2030 timeframe

Energy sector:

- High profit margins (>60%) in the fossil fuel extraction sector, risk making demand-side instruments (e.g., carbon tax or tradable permits borne by consumers) weak in the short-run.
- Therefore, direct supply-side regulations needed in the 2030 timeframe, e.g., requirements to install and maintain leak detection technology in oil and gas systems or ventilation air methane oxidation on coal mine shafts.

Agricultural sector:

- Very limited potential for technical measures in the 2030 timeframe.
- Integrated approach, multi-objectives (climate, biodiversity, animal health, ecosystem protections etc.)
- Supply-side measures available in the short-run: direct regulations e.g., conditional subsidy schemes similar to EU's second pillar
- Substantial emission reductions possible in a longer timeframe, but then driven by demand-side instruments to change consumption patterns.

Waste sector:

- Limited potential in 2030 timeframe due to long decomposition times for already landfilled waste.
- For substantial reductions in the long-run: diversion of organic waste from landfills through source separation and treatment.
- Public funds needed for initial infrastructure development, operation can be private or public
- Integration of informal sector for socio-economic sustainable solutions

Further work 2022/23 [1]

- Further improvements of spatial representation of emissions, focus on residential sector *jointly with MSC-W, CEIP*
- Update of technology parameterization in GAINS (incl. applicability and costs) *jointly with TFTEI* [mid 2022]
- Completion of implementation of *condensables* in GAINS *jointly with MSC-W, TNO, NILU, SYKE* [mid 2022]
- Scenarios to assess feasibility of achieving new WHO guidelines [before June 2022]
- Cost-effective scenarios for the review of Gothenburg Protocol [Fall 2022]
- Report on extent of application of measures by Parties and their implications [2022]

Further work 2022/23 [2]

- Develop updated global Hg inventory and projections from GAINS provided to TFHTAP [summer-autumn 2022]
- 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]

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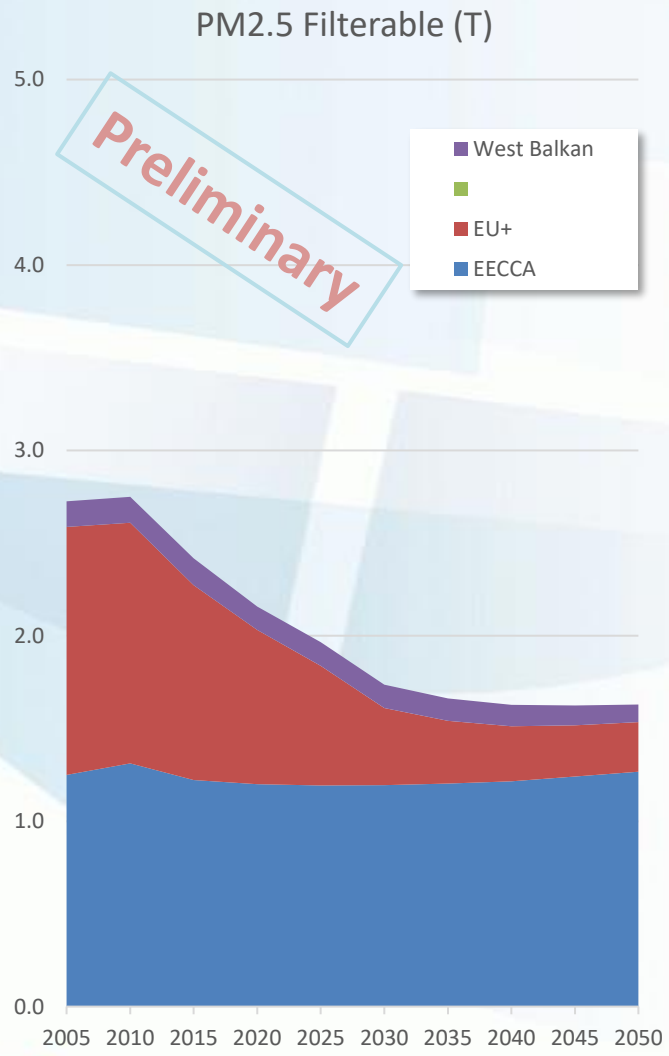
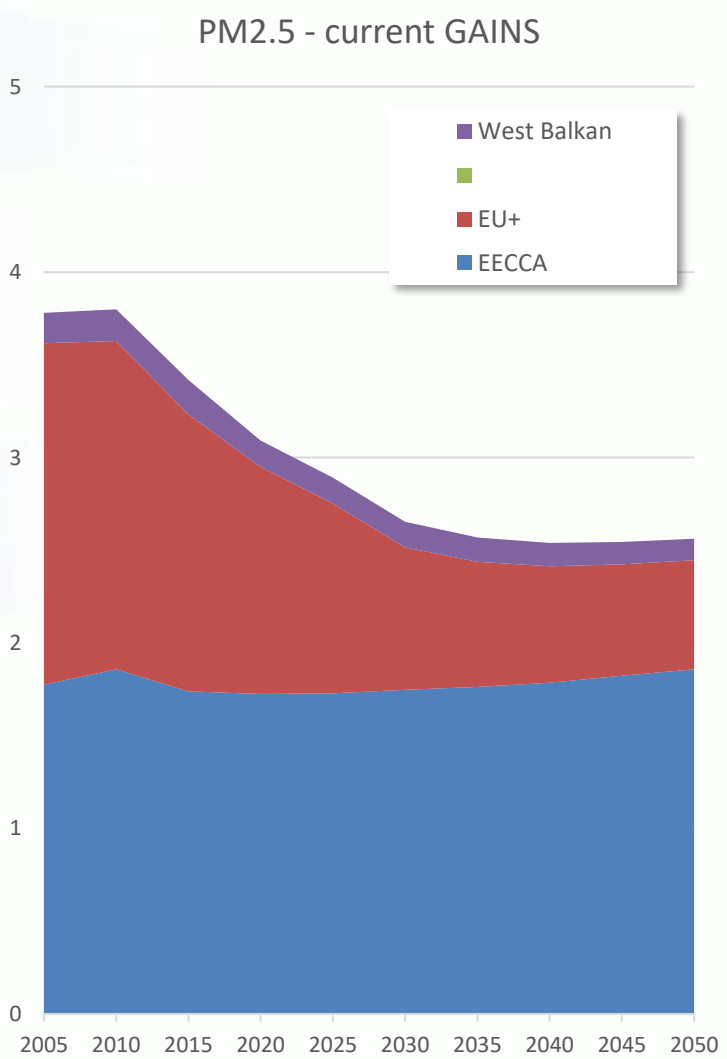
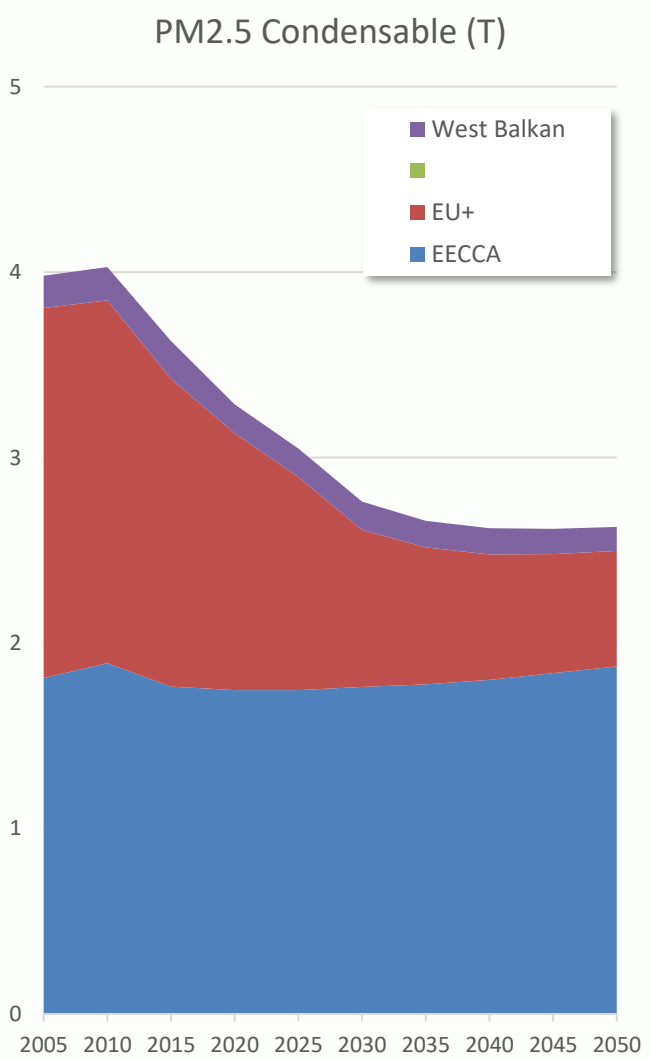
science for global insight

Preliminary results from implementation of condensable PM in GAINS

Draft baseline emission scenario for PM2.5 (total) - comparison

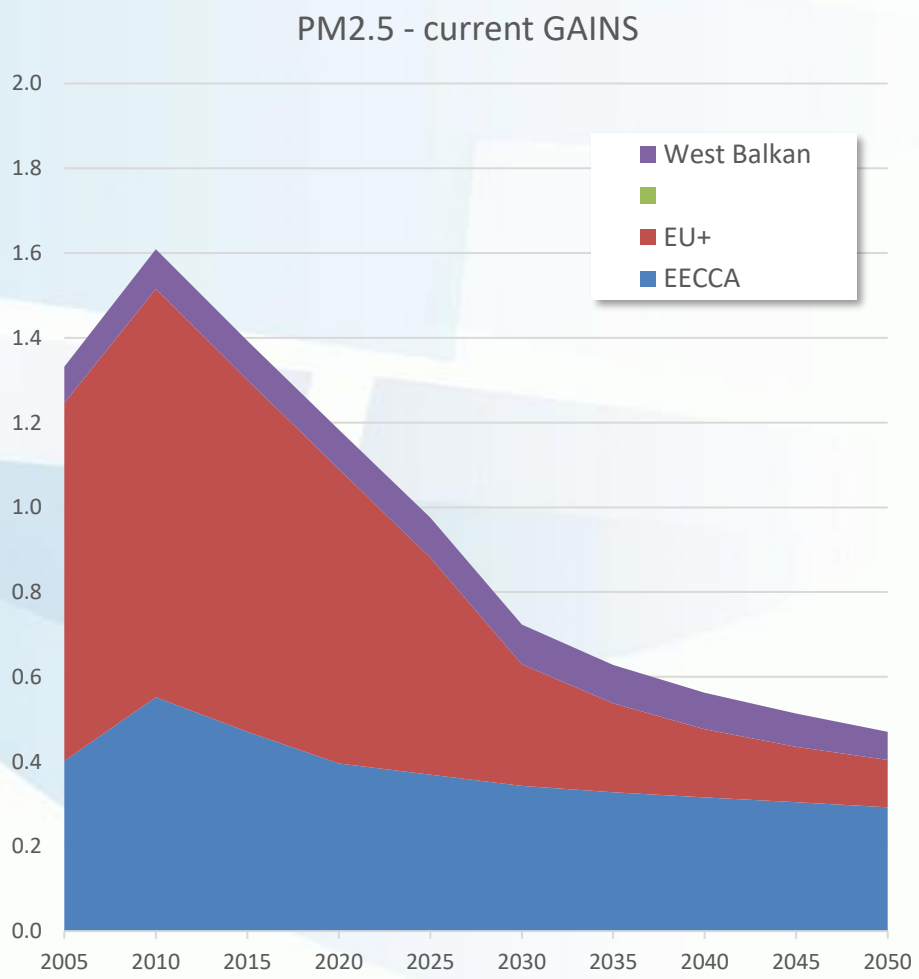


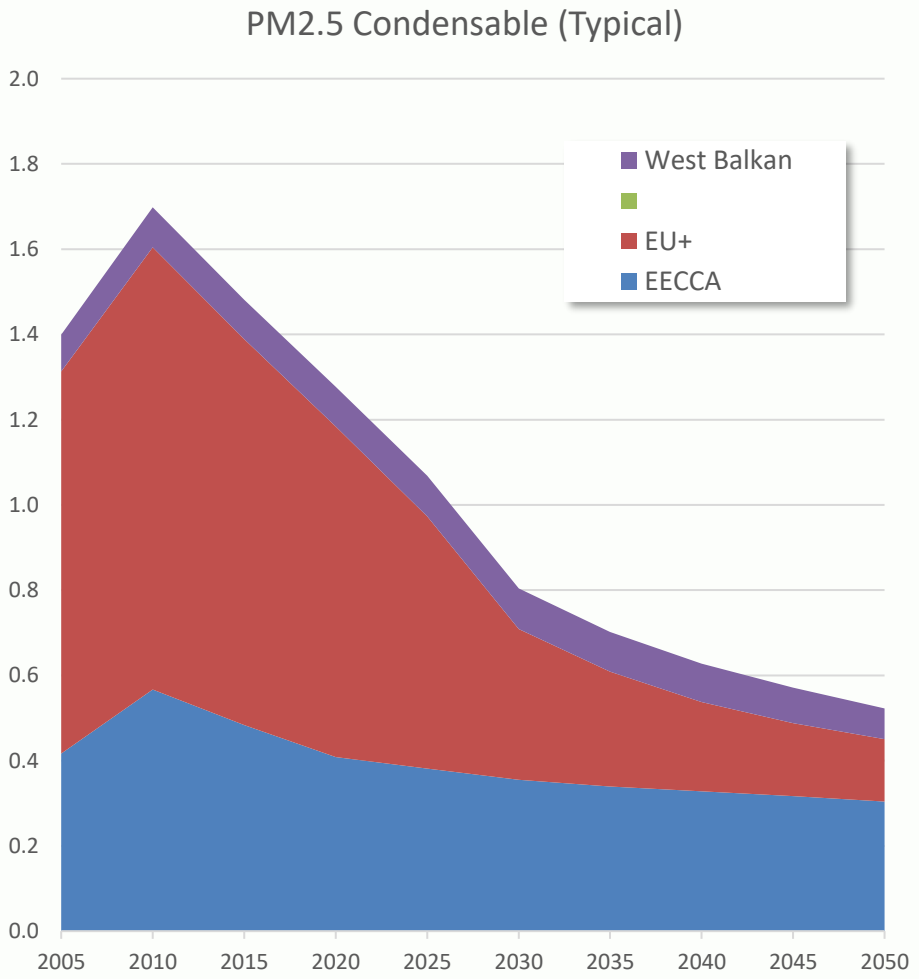




EECCA – here includes also Turkey

Draft baseline emission scenario for PM2.5 (residential) - comparison



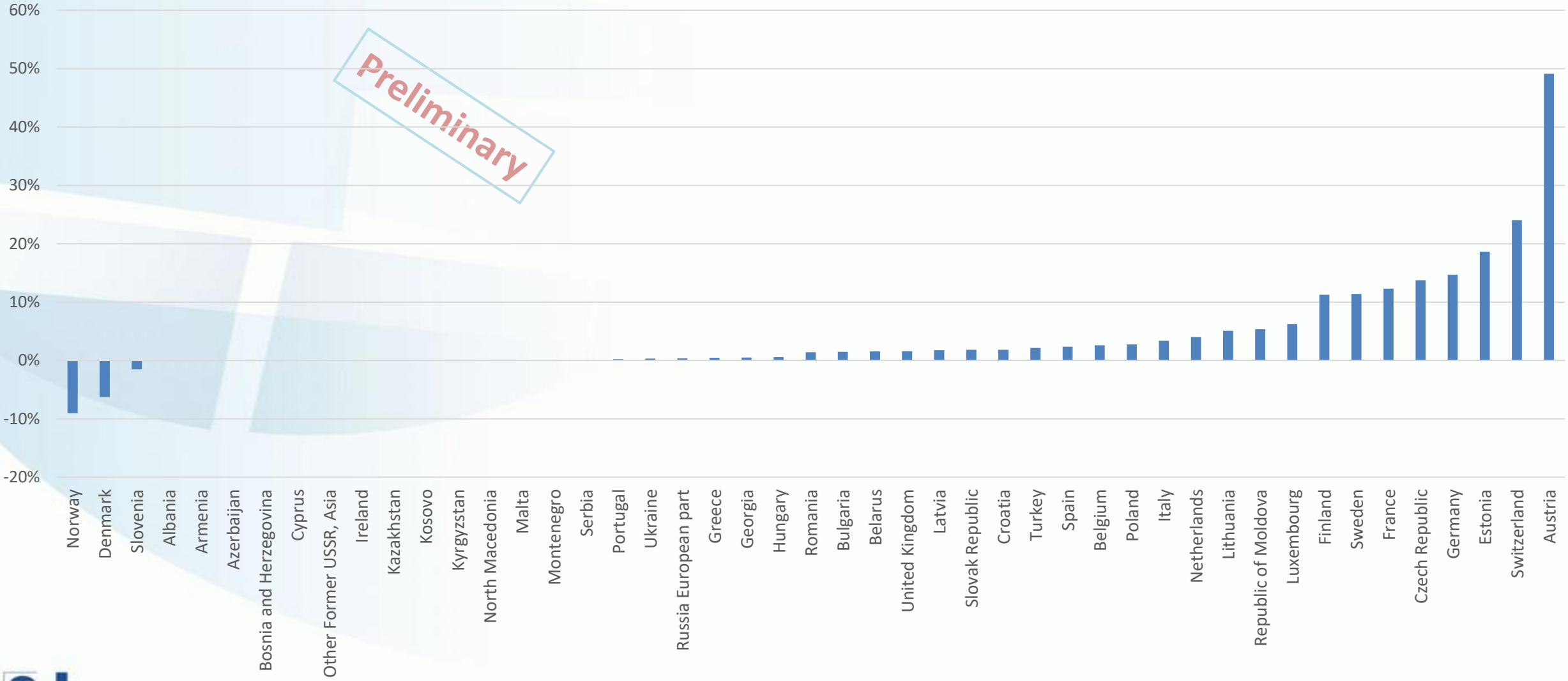


Preliminary

EECCA – here includes also Turkey

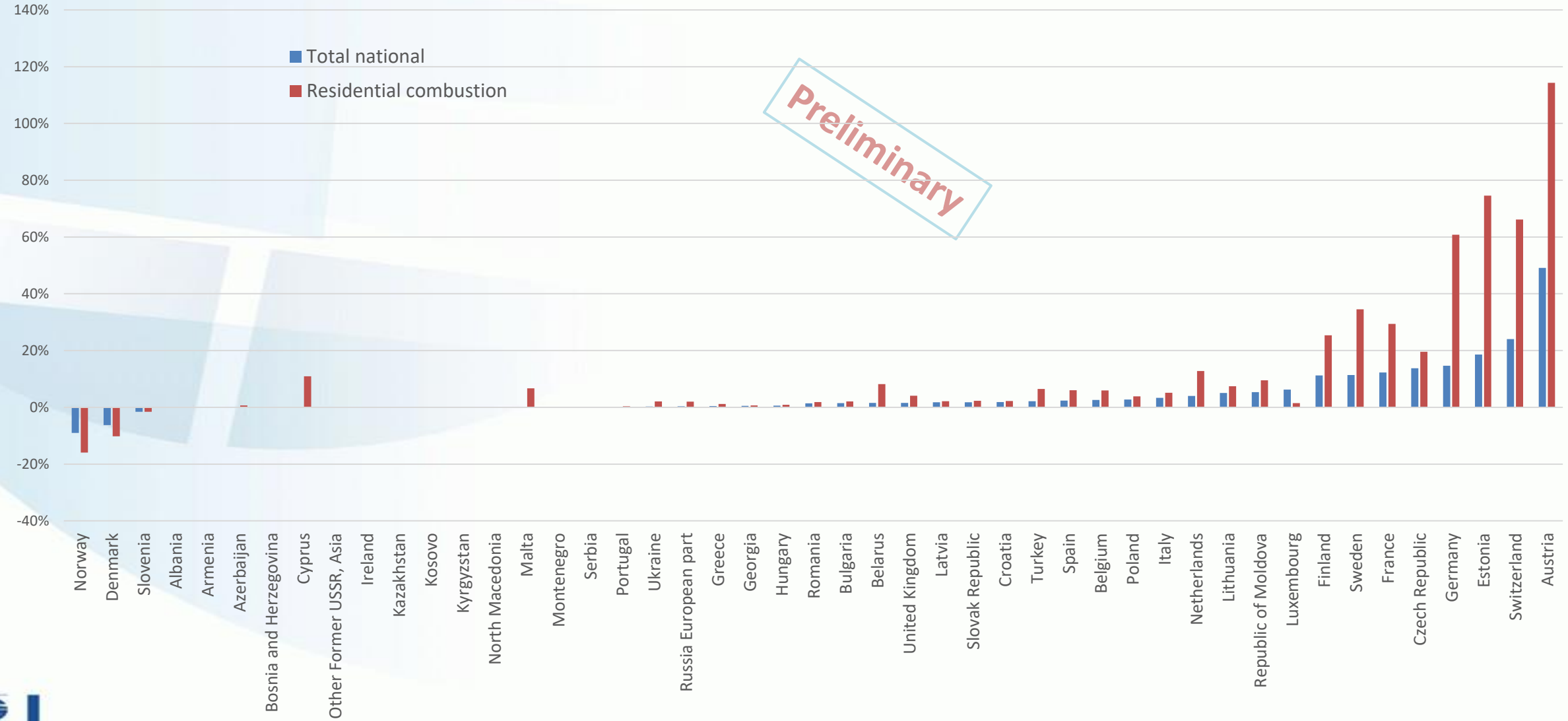
Comparison of *Total PM2.5* emissions in 2015

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

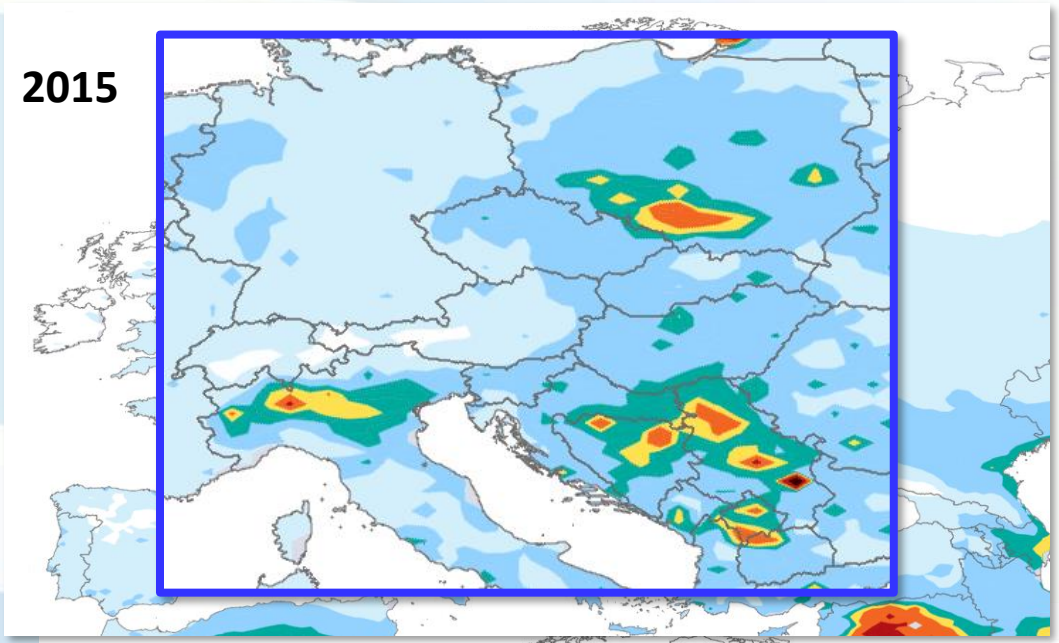


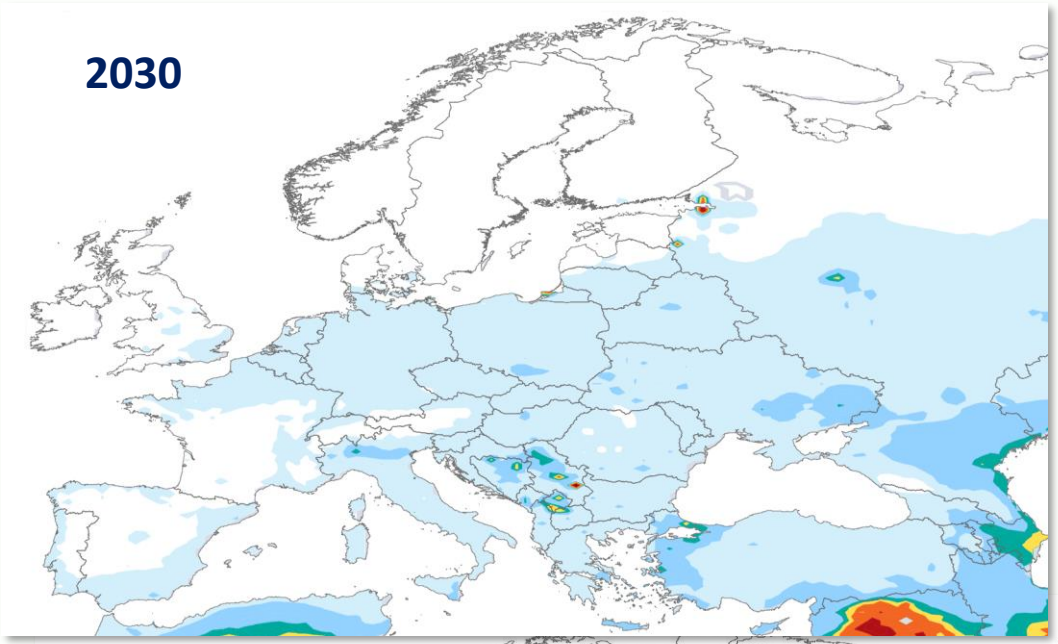
Comparison of *Total and residential PM2.5* emissions in 2015

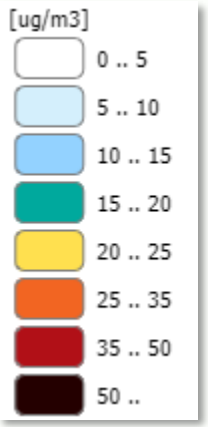
'*Typical-TNO*' residential EF with condensables vs current GAINS

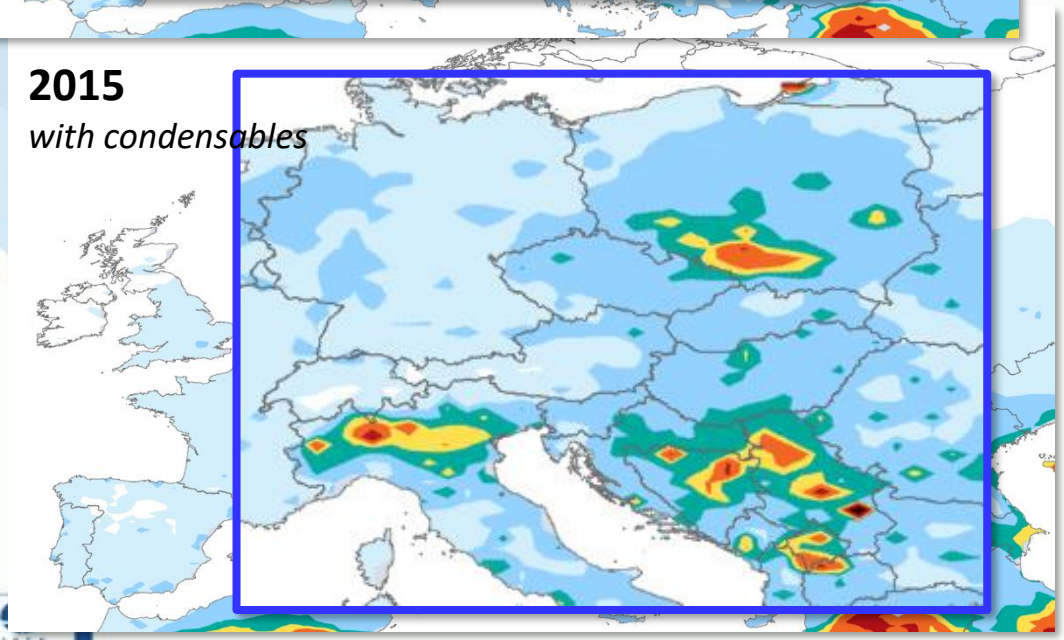


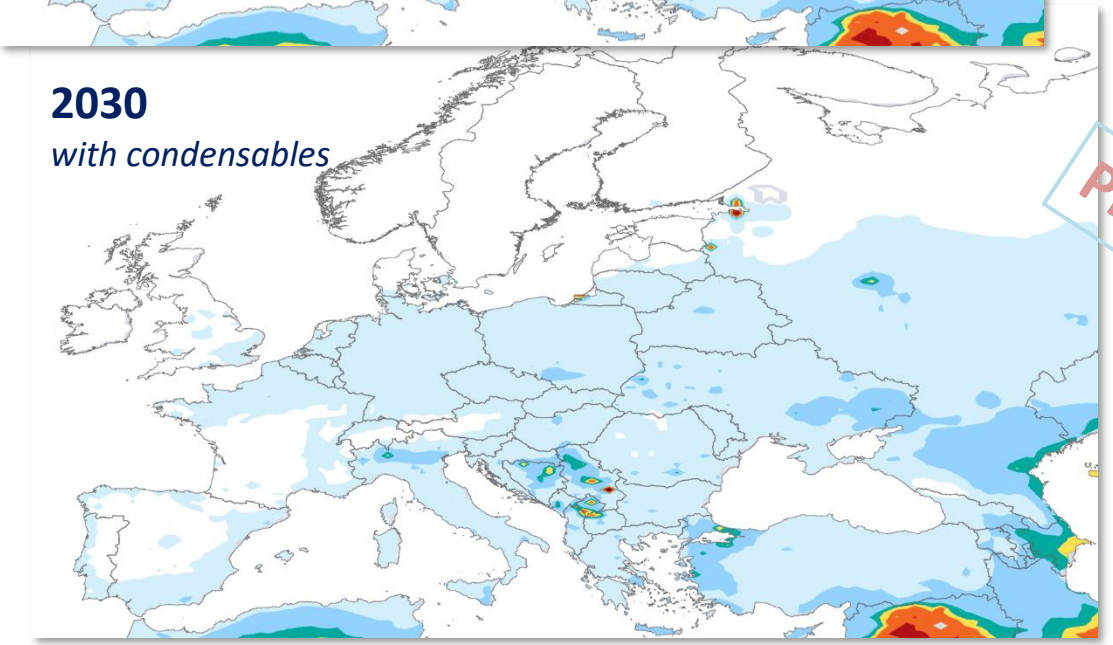
What does it mean for ambient $PM_{2.5}$ concentrations?











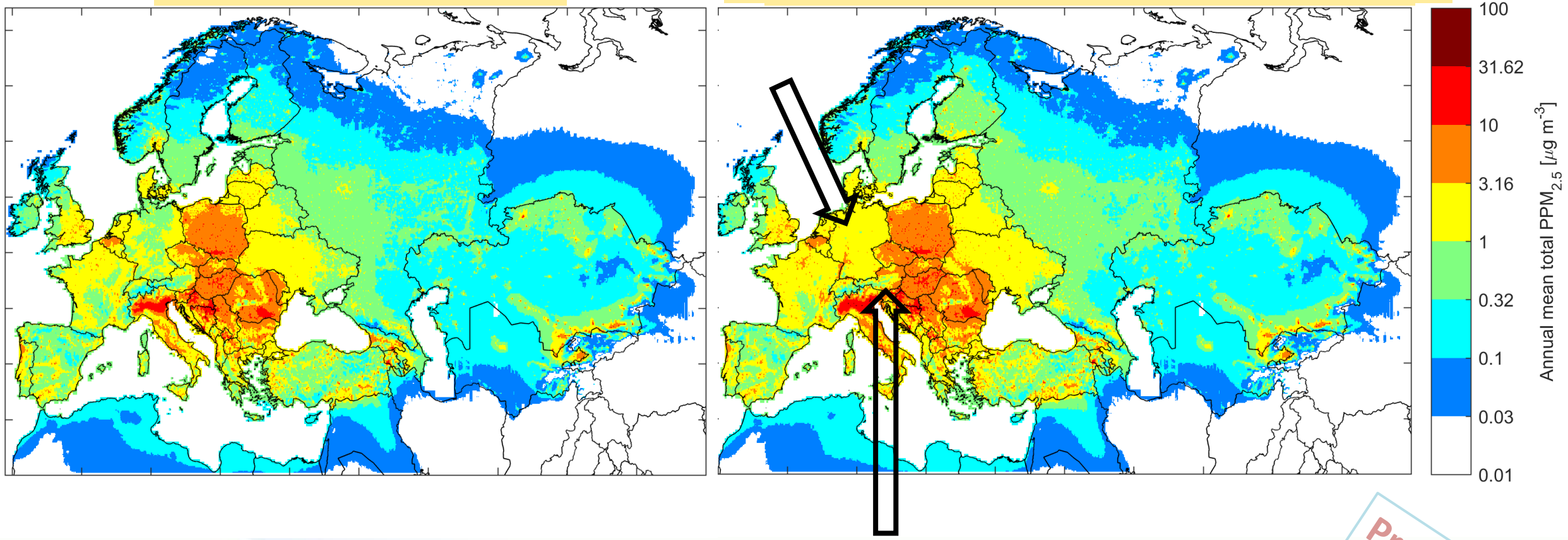
Preliminary

Implementation of new SR coefficients and condensables

Example: Primary PM from residential heating (rural)

GAINS EF (status as of March 2022)

'Typical TNO – with Condensable' EF (as implemented in GAINS)



Preliminary