European Commission

$PM_{2.5}$ and ozone impacts in the UNECE region: role of precursors and sources

TASK FORCE ON INTEGRATED ASSESSMENT MODELLING (TFIAM)
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Unit Air and Climate

Methodology

- TM5-FAst Scenario Screening Tool (TM5-FASST)
- $PM_{2.5}$ and ozone-related impacts on human health and agricultural crop production
- $PM_{2.5}$ and ozone-related mortality based on GBD 2017 (ozone also on Turner et. al., 2016)
- Health exposure metrics:
  p.w. $PM_{2.5}$,
  p.w. SDMA8h (6-month mean of daily max 8 h average concentrations)
- Crop exposure metrics:
  AOT40
  crop-growing-season mean of daytime ozone during 7 (M7) or 12 (M12) hours (depending on the crop)
- The used approach does not consider the chemistry connected to the secondary organic aerosol
- ECLIPSE V6b scenarios (IIASA)
  https://previous.iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv6b.html

Sources

We evaluate the share of individual sectors by subtracting sector emissions one by one from the total, and computing the difference in outcome with the total-emissions outcome (so called brute-force approach)

Sectors:
- energy production (ENE),
- industrial combustion and processes (IND),
- gas venting and flaring (FLR),
- solvent production and use (SLV),
- transport (TRA),
- international shipping (SHP),
- agriculture (AGR),
- open burning of agricultural waste (AWB),
- residential combustion (DOM) and
- waste (WST).

Fire emissions, including large-scale biomass burning and savannah burning, were added from SSP2-CMIP6 (projections) and van Marle et al. (2017) subtracting the AWB emissions to avoid double counting.

Also **natural emissions** from **dust** and **sea salt** (SS) are considered for $PM_{2.5}$
international aviation and **biogenic emissions** are not included.

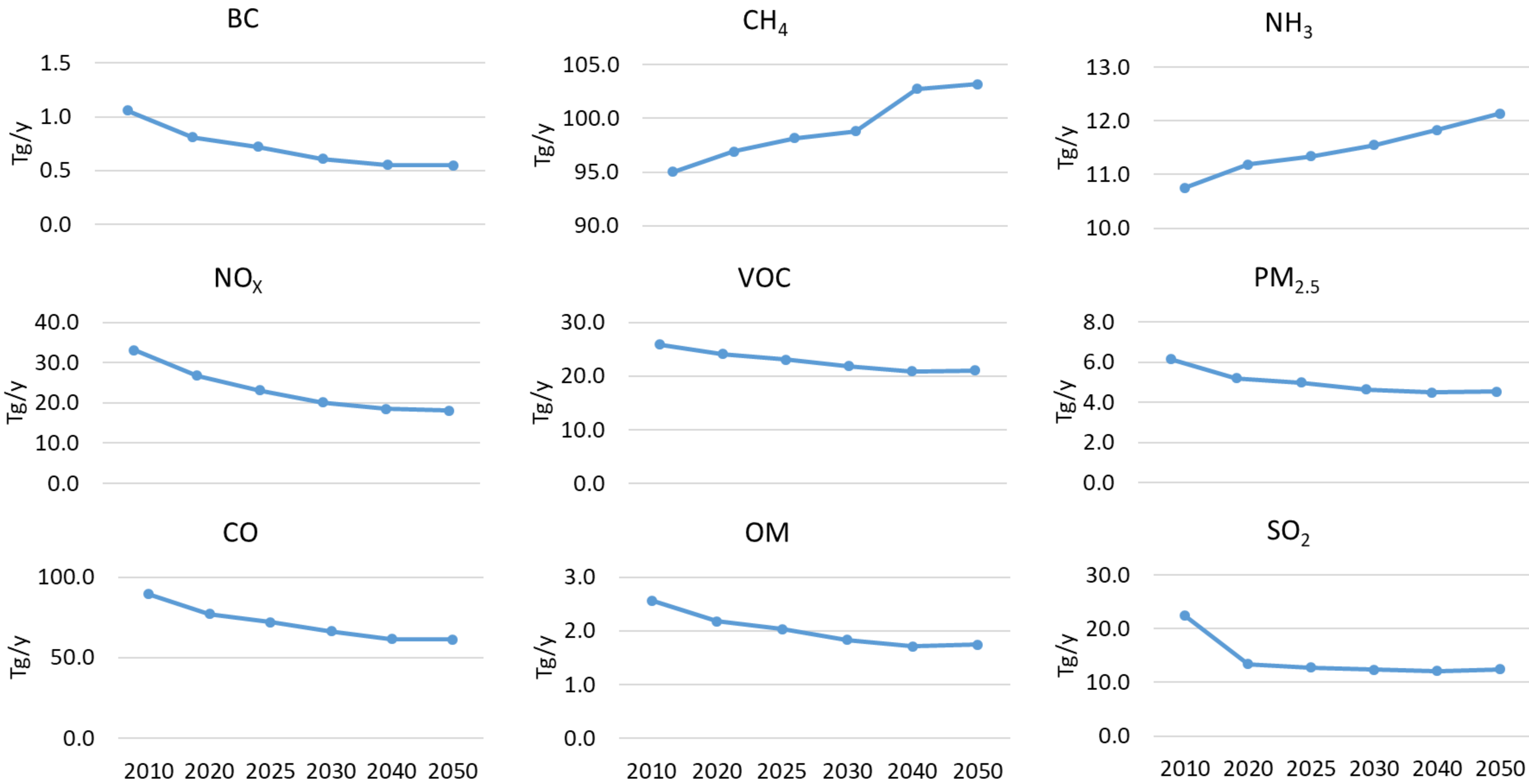
ECLIPSE v6b scenarios (IIASA)

◯ discussed in this presentation

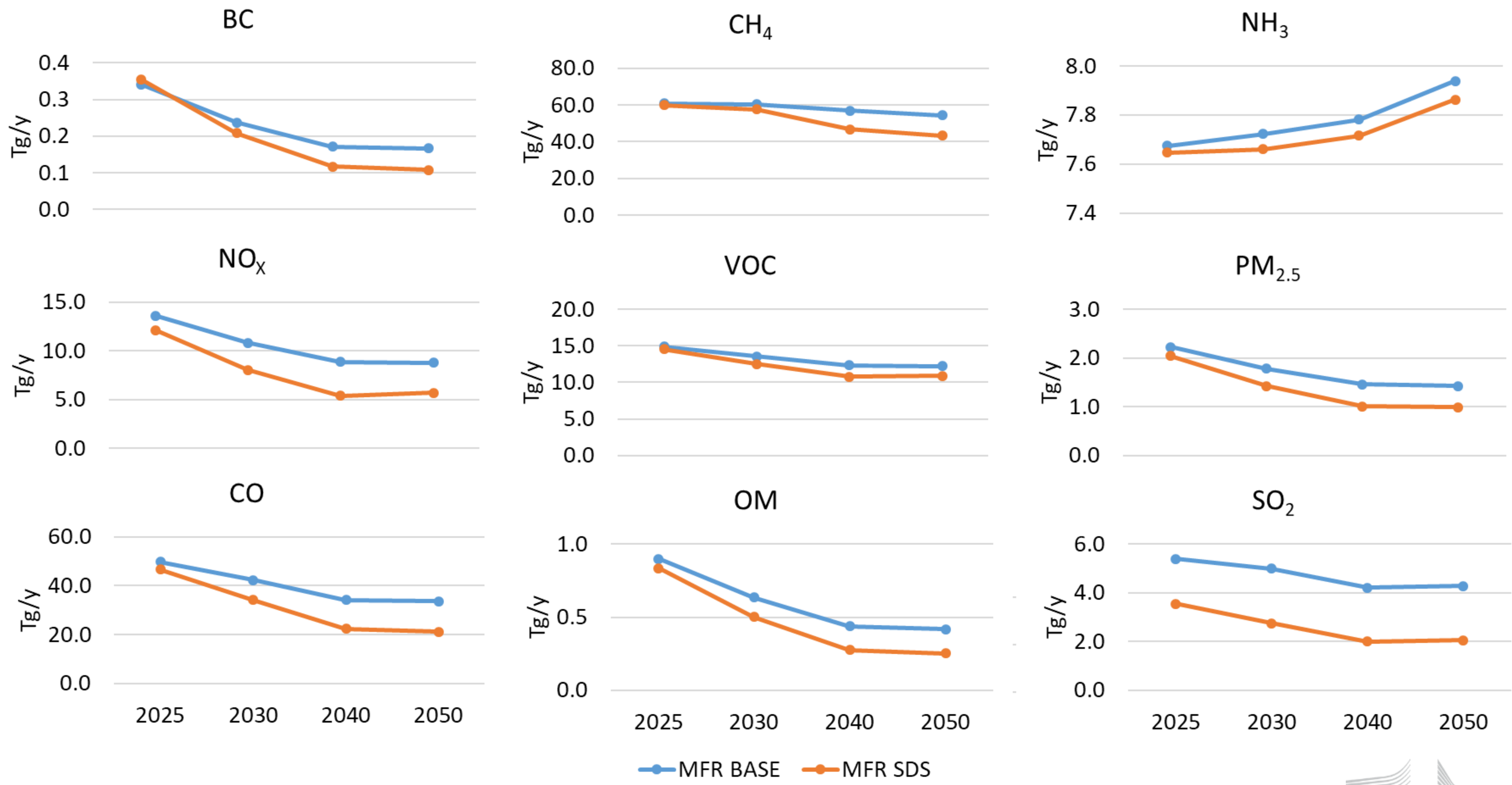
Scenario	Abbr.	Air quality policy	Climate policy
Current legislation (baseline)	CLE	IEA World Energy Outlook 2018 New Policy Scenario (NPS[1]) Includes announced energy policies in EU (2030 renewable energy and energy efficiency targets) China, USA, Japan and Korea.	Paris Agreement NDCs
Maximum technical reduction baseline	MFR base	Based on NPS[1] as CLE. best currently available technology and no cost limitations. However, no further technological improvements are foreseen.	Paris Agreement NDCs
Maximum technical reduction sustainable development	MFR SDS	Based on IEA sustainable development scenario (SDS). Includes outcomes of energy-related SDGs	Paris Agreement goal: global average temperature increase < 2 °C.
No further control baseline	NFC base	Based on NPS[1] as CLE. No new measures beyond 2015-2018 . Turnover of stock is included.	Paris Agreement NDCs
No further control current energy policies	NFC CPS	Based on IEA current policy scenario (CPS[2]) that reflects 2018 laws and regulations. Excludes the announced policies.	No Paris Agreement NDCs

[1]In NPS, fossil fuel subsidies phased out in all net-importing countries, and in net-exporting countries where specific policies have been announced.
[2]In CPS fossil fuel subsidies phased out only in countries that already have relevant policies in place.

Emissions in UNECE according to the ECLIPSE V6b CLE scenario



Emissions in UNECE according to ECLIPSE V6b MFR base and SDS scenarios



Apportionment of ozone by precursors and regions

ECLIPSE 6Vb scenarios (CLE, MFR and NFC)

SET 1 CLE_ALL (Standard run)

SET 2 UNECE_ALL_OFF

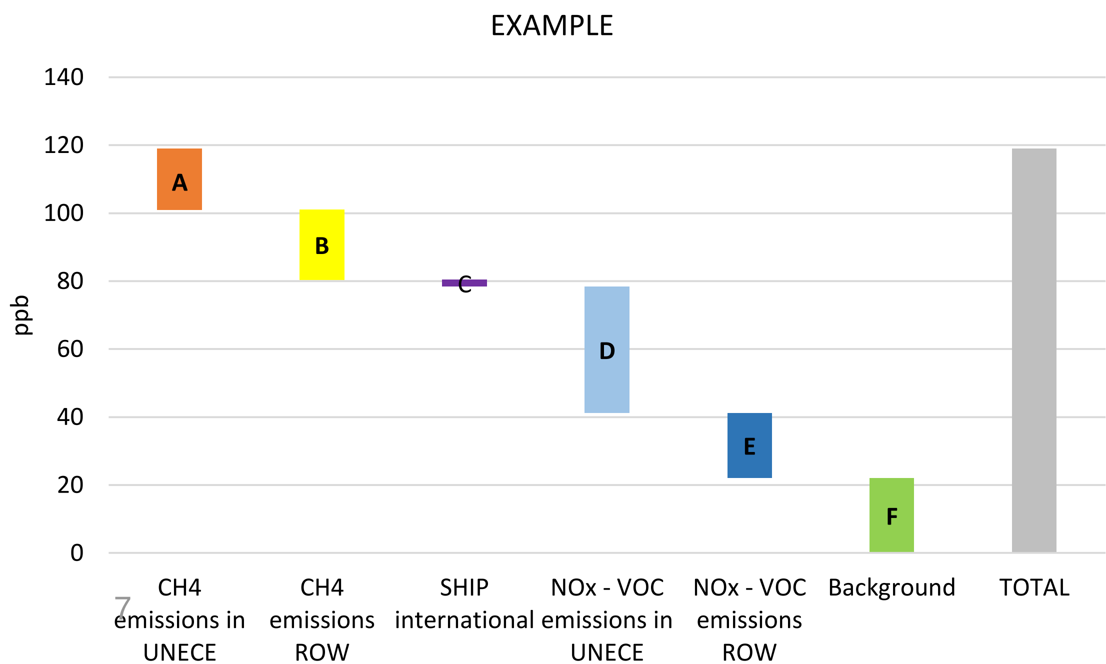
SET 3 ROW_ALL_OFF

SET 4 SHIP_OFF

SET 5 ALL_CH_4_OFF

SET 6 UNECE_CH_4_OFF

CH_4	emissions in UNECE	A	SET 1 – SET 6
	emissions outside UNECE (ROW)	B	SET 1 – SET 5 – A
SHIP	SHIP international	C	SET 1 – SET 4
NOx - VOC	emissions in UNECE	D	SET 1 – SET 2 – A – C
	emissions outside UNECE (ROW)	E	SET 1 – SET 3 – B – C
Other sources	background including: lightning and soil NOx, biogenic NMVOC and CH_4, stratospheric O_3 intrusion	F	SET 1 - (A+B+C+D+E)



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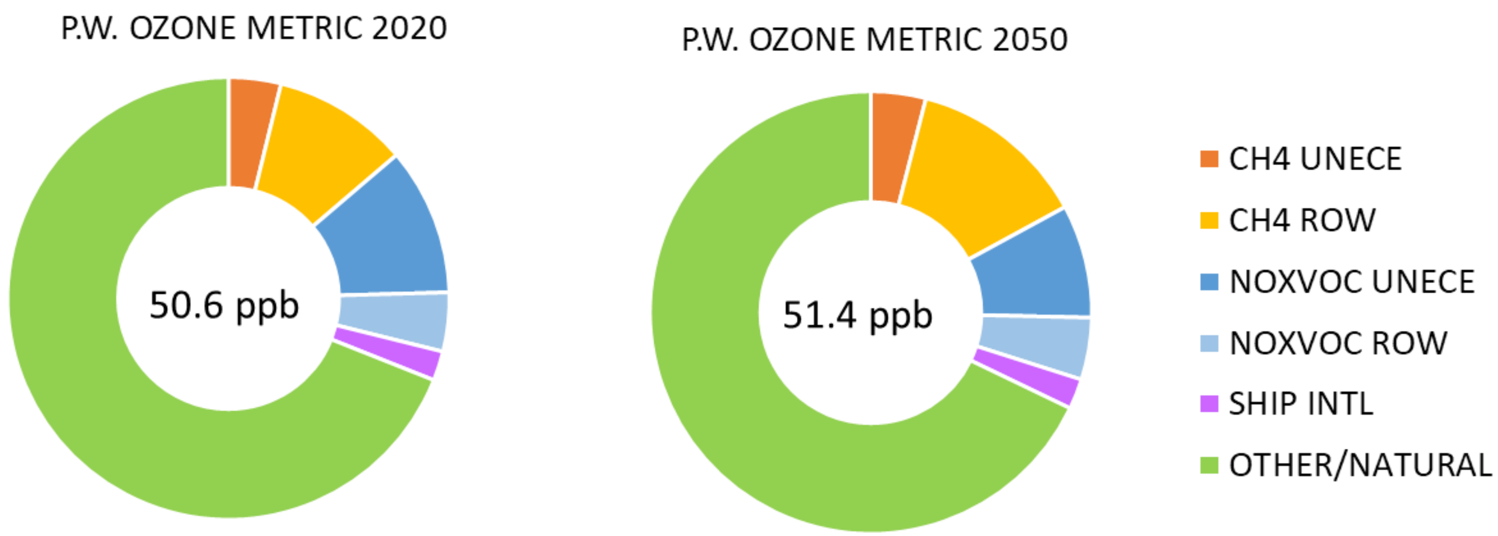
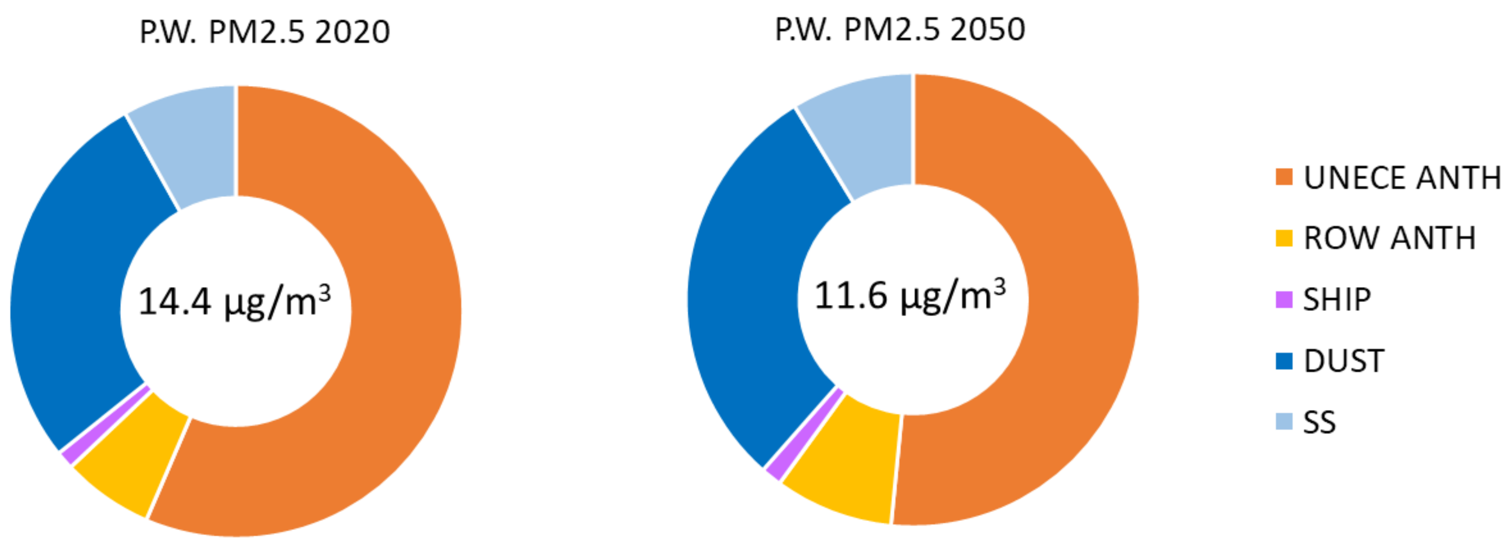
Population weighted exposure indicators in UNECE by source region (CLE)



Background/Natural is the dominant ozone exposure source

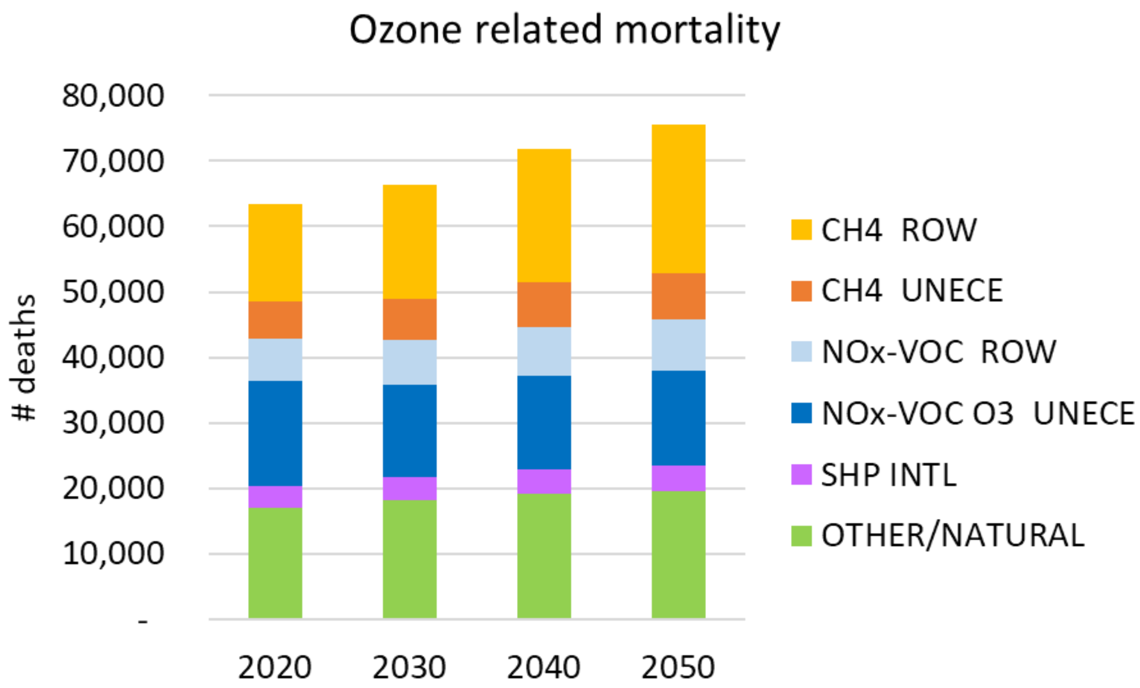
The decreasing impact of NOx-VOC emissions between 2020 and 2050 is overturned by the growing role of CH_4 emissions from ROW

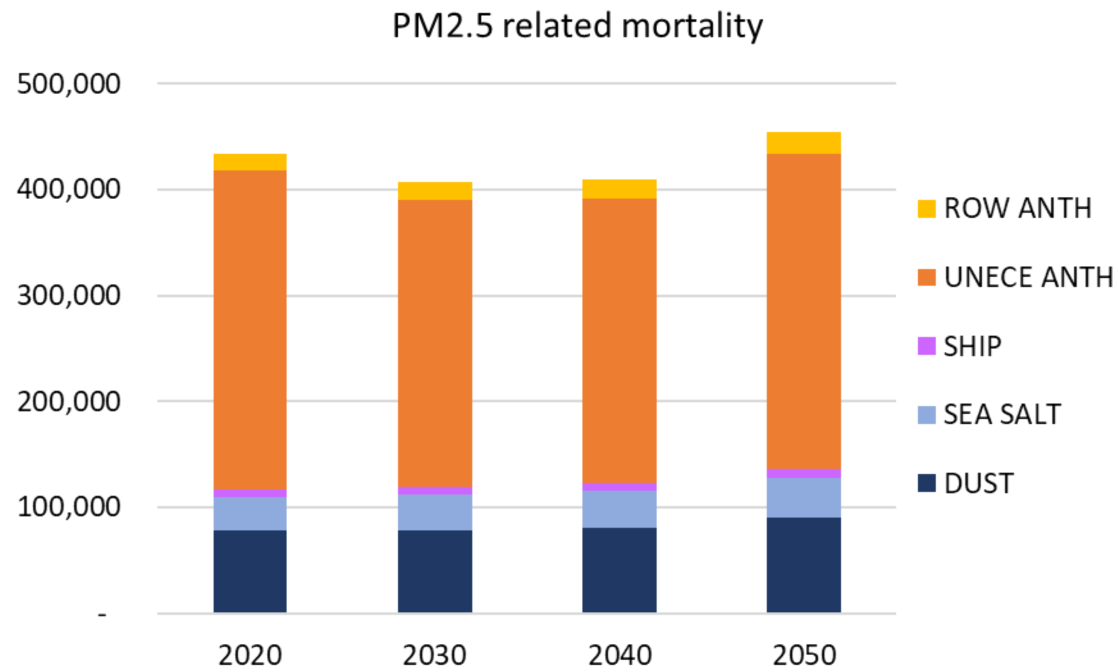


The anthropogenic UNECE emissions are the main $PM_{2.5}$ exposure source followed by dust

Belis and Van Dingenen, 2022 (in preparation) Preliminary results. Do not cite or quote

Mortality in UNECE associated with precursors and geographic sources (CLE)





MORT(source) = METRIC_SHARE(source)*TOT_MORT(METRIC)

Background exposure considers only the fraction above the 29.1 ppb threshold in the exposure – response function.

O_3 related mortality shows an increasing trend mainly due to growth of CH_4 in ROW

$PM_{2.5}$ related mortality decreases and then increases mainly due to changes in UNECE anthropogenic sources. The increase in 2050 likely due to population and population age structure changes.

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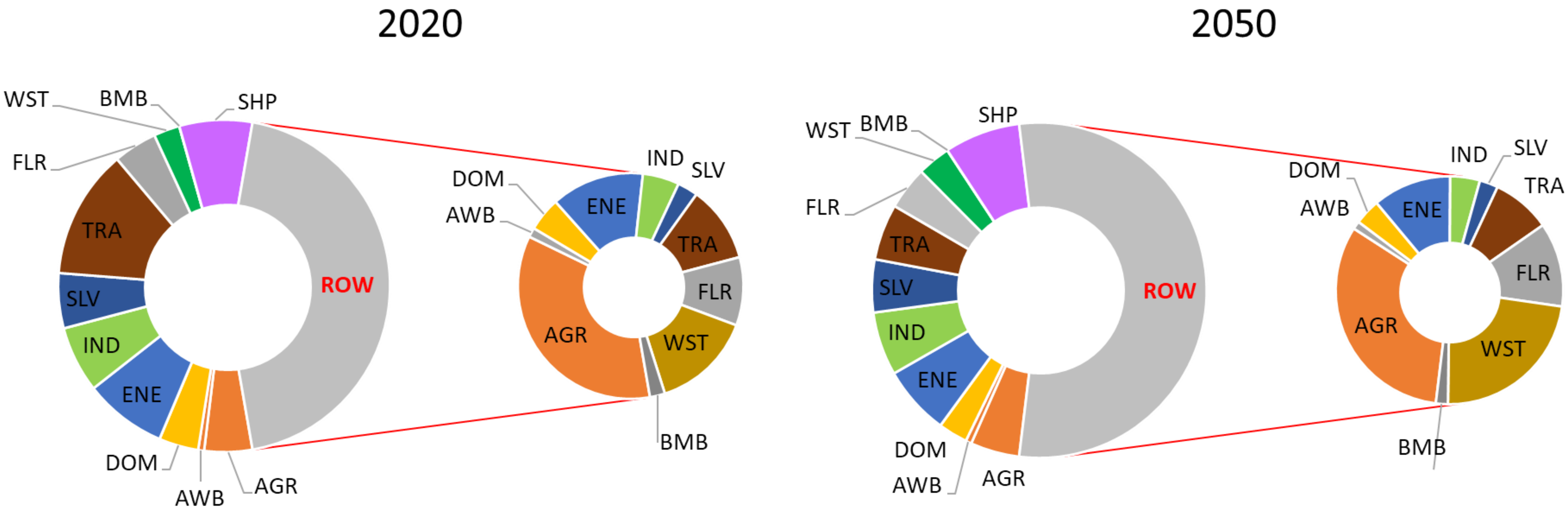
O_3 mortality in UNECE split by anthropogenic sources (CLE)



ROW is an important contributor to O_3 mortality in UNECE and the share grows in 2050 compared to 2020 (mainly associated with higher CH_4 impact from AGR)

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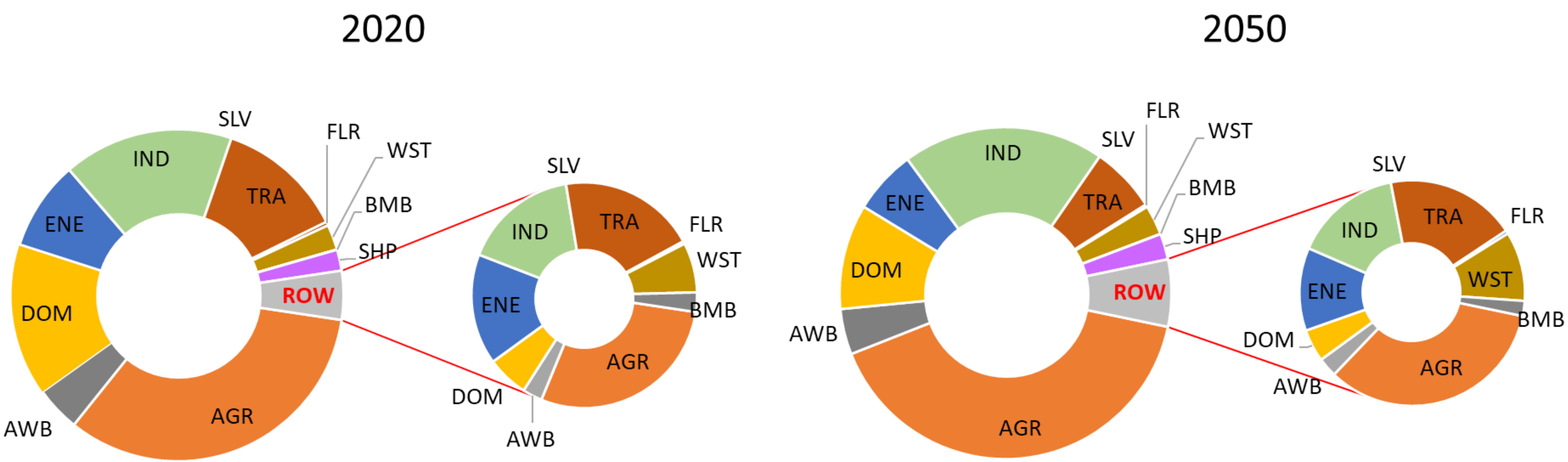
$PM_{2.5}$ mortality in UNECE split by anthropogenic sources (CLE)



ROW has a limited role in $PM_{2.5}$ mortality in UNECE. Most important UNECE anthropogenic sources are AGR, IND, DOM and TRA

AGR (NH_3) and IND increase while DOM and TRA (NOx-VOC) decrease between 2020 and 2050

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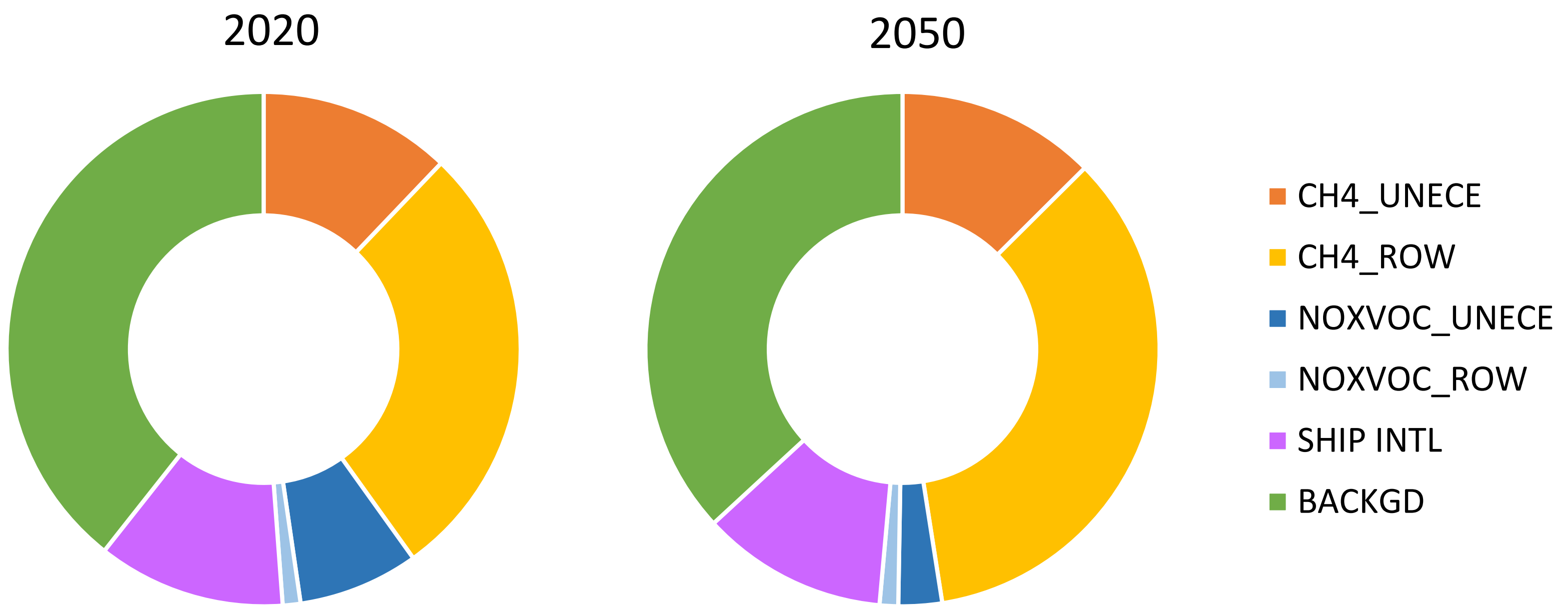
Crop exposure indicators (M7 and M12) in UNECE by source region (CLE)



Considered crops:
Wheat
Maize
Soybean
Rice

Natural background and CH_4 ROW emissions are main responsible for crop exposure in UNECE countries.
International Shipping is more important here than in human exposure.
The impact of NOx-VOC emissions from UNECE decreases between 2020 and 2050 while the CH_4 share from ROW grows in the same time window

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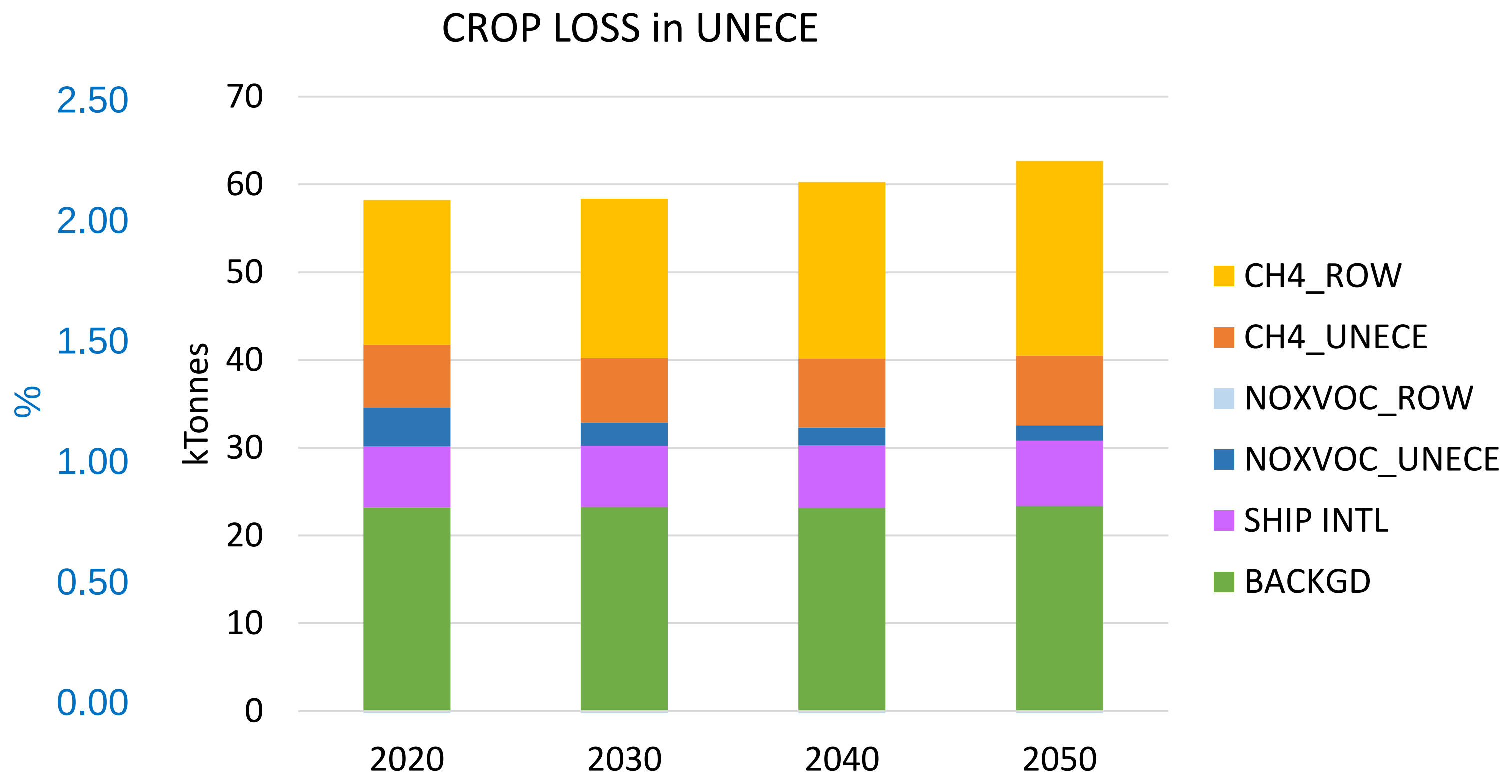
Crop losses in UNECE associated with precursors and geographic sources (CLE)

CROP RYL in UNECE



kTonnes are ‘nominal estimates’ and based on year 2010 production numbers

The overall impact of ozone on crops grows slightly between 2020 and 2050 both in absolute mass and relative yield loss (RYL).

The decreasing role of NOx-VOC emissions from UNECE is overturned by the growing impact of CH_4 emissions from ROW .

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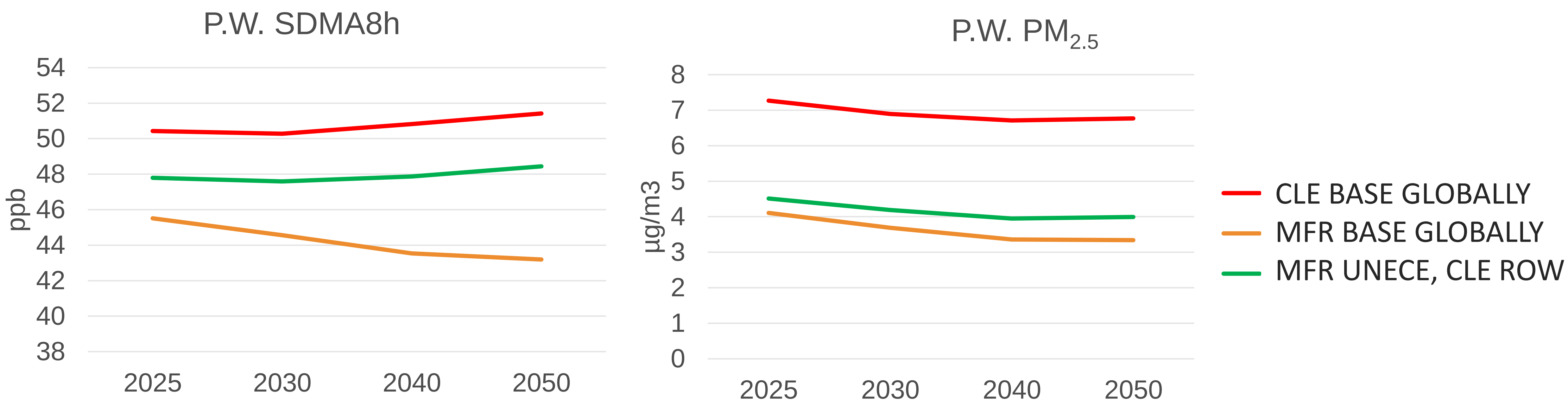
MFR base vs MFR only in UNECE



Implementing MFR base (globally) leads to a considerable reduction in human exposure and mortality for both pollutants compared to CLE. It actually reverts the increasing trend in ozone-related mortality.
Implementing MFR only in UNECE leads to a limited reduction of the ozone-related mortality (no reversion of the increasing trend). On the contrary, the reduction of $PM_{2.5}$-related mortality is similar to the one observed by implementing MFR everywhere.
These results suggest that implementing MFR policies in the ROW is needed to tackle the ozone-related mortality in UNECE.

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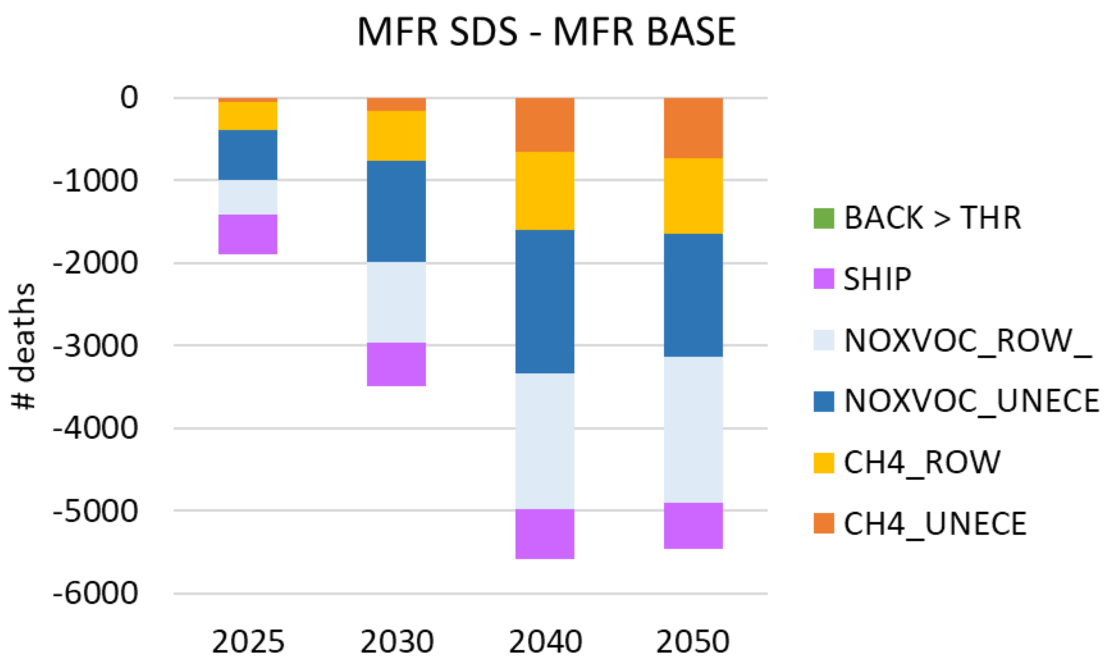
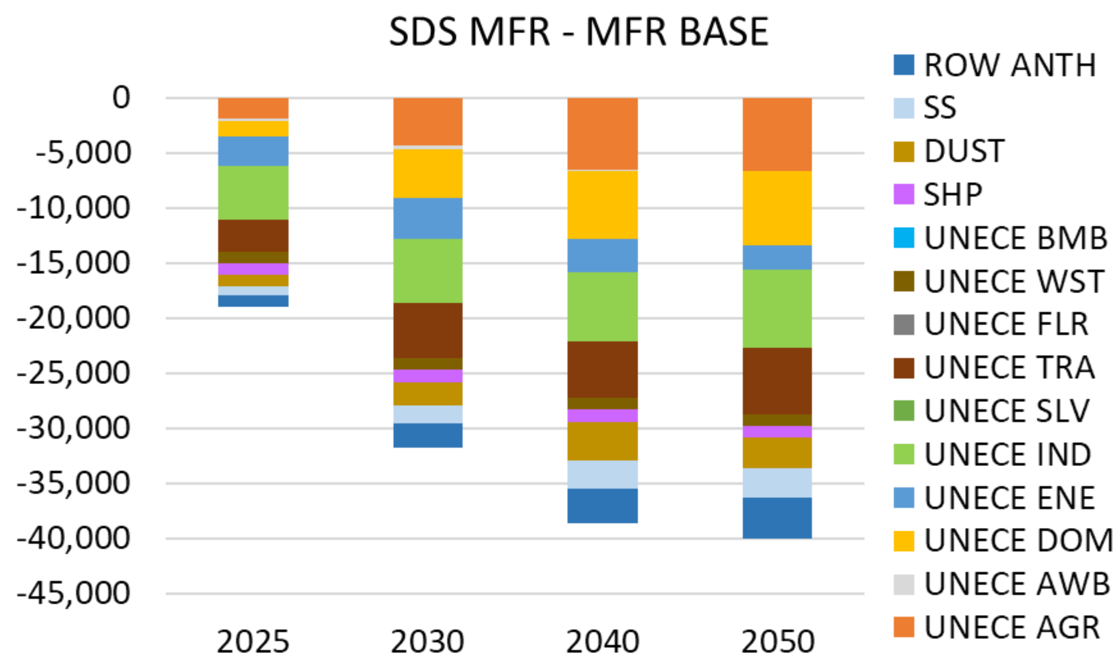
MFR base vs MFR SDS Delta mortality

Ozone



$PM_{2.5}$



The difference between these two scenarios is partially due to the benefit of climate mitigation measures beyond the NDCs in SDS scenario. However, to be interpreted with caution because climate measures are not the only difference between the two scenarios.

The lower ozone-related mortality in SDS is mainly due to NOx-VOC precursor emission reductions.

The difference in the $PM_{2.5}$-related mortality is due to reductions of anthropogenic sources in UNECE (AGR, DOM, IND and TRA).

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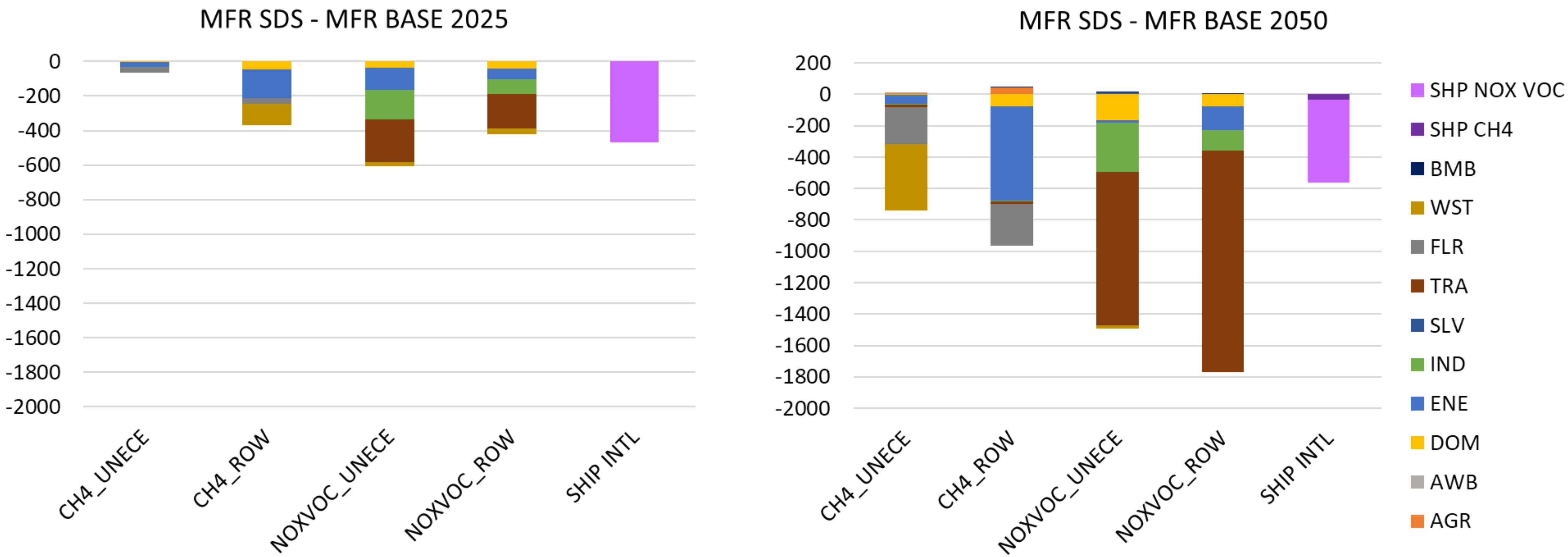
MFR base vs MFR SDS Delta mortality (cont)

Ozone



A more detailed analysis of ozone-related mortality shows that the sources responsible for the differences between MFR base and SDS are mainly NOx-VOC precursor emissions from TRA, IND, SHP and DOM.
The share of CH_4 abatement increases considerably, in 2050 compared to 2020, due to reductions in ENE from ROW and WST in UNECE and FLR in both.

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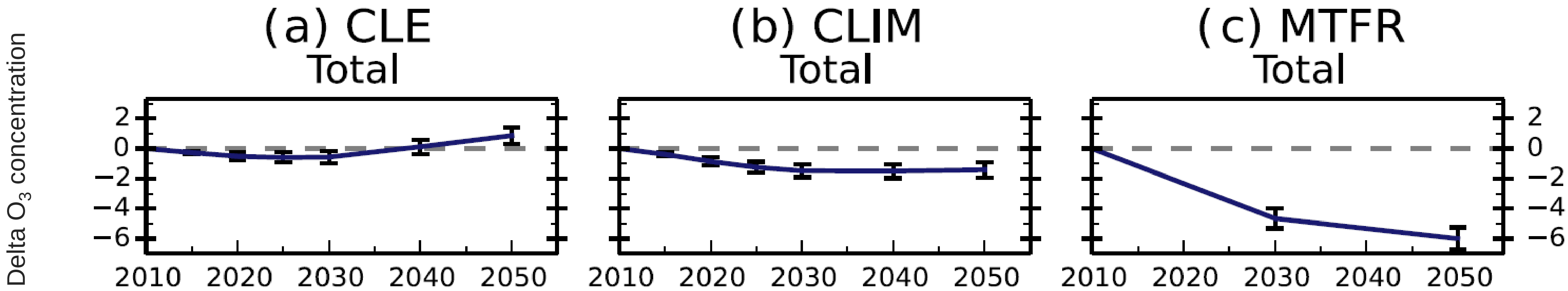
Belis and Van Dingenen, 2022 (in preparation) Preliminary results. Do not cite or quote

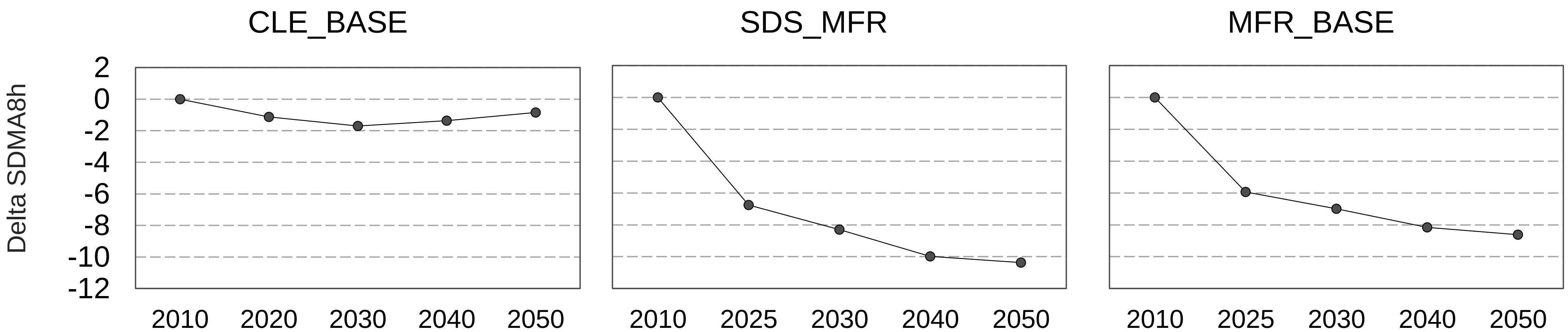
Delta O_3 concentration over Europe (reference 2010)

From: Turnock et al. 2018 ACP

Eclipse v5a



Eclipse v6b



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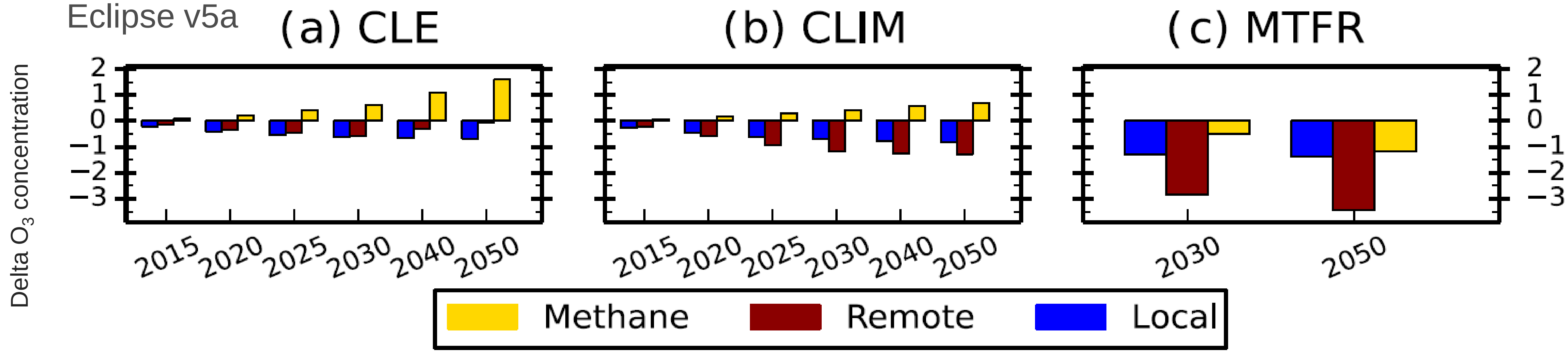
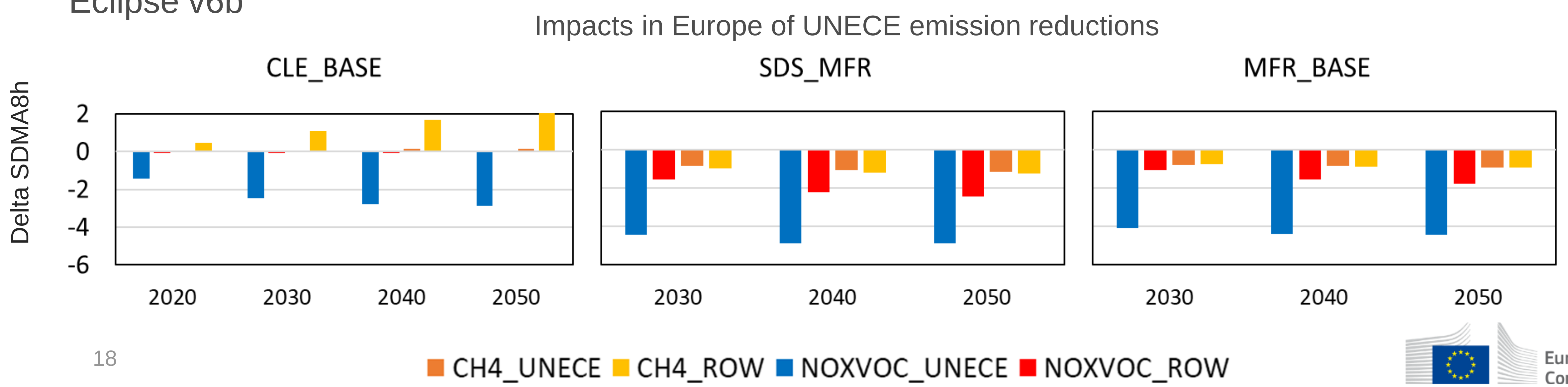


Eclipse v6b



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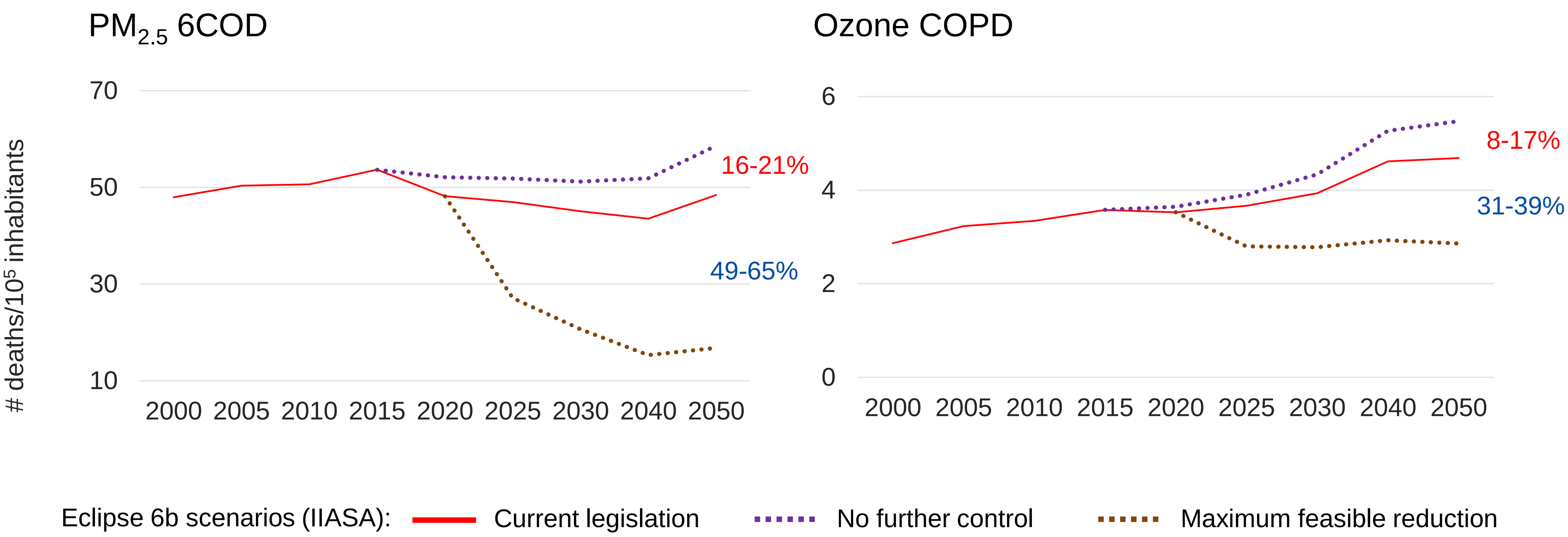
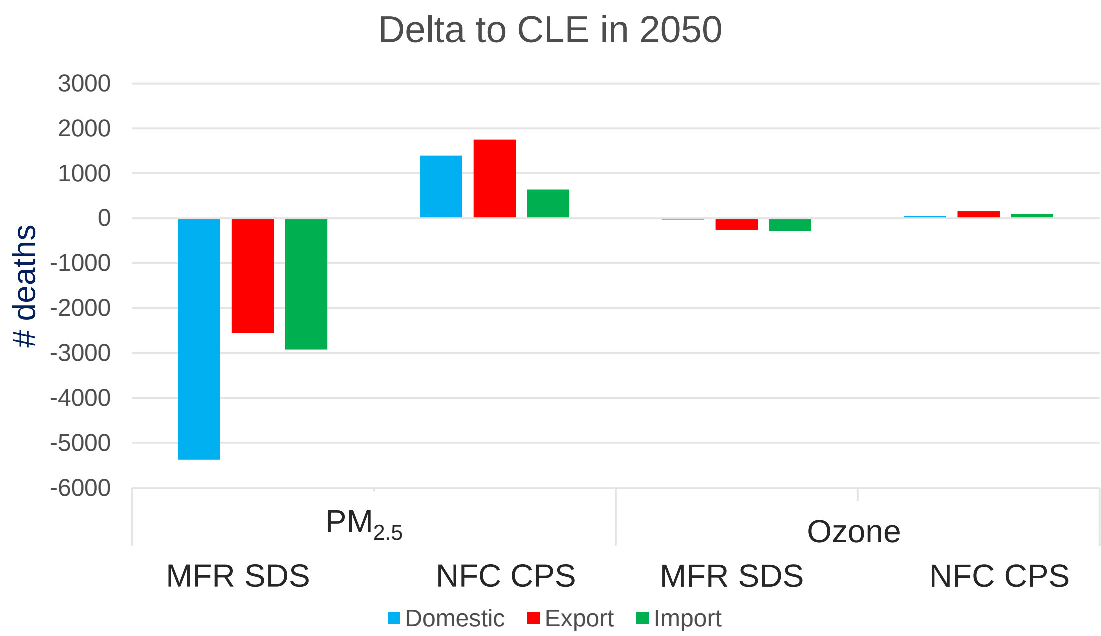
Trends of mortality associated with $PM_{2.5}$ and ozone in the WB

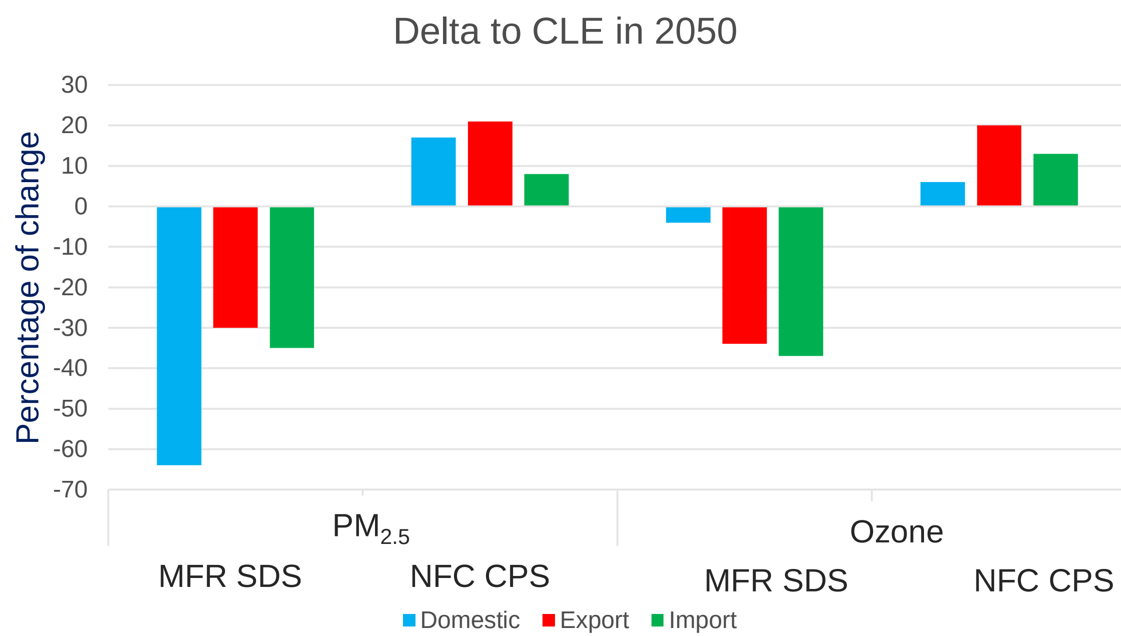


six causes of death (COD): chronic obstructive pulmonary disease (COPD), lung cancer (LC), lower respiratory airway infections (LRI), diabetes mellitus type 2 (DMT2), ischemic heart disease (IHD), and stroke

Belis C.A., Van Dingenen R., F. Dentener and Klimont Z., 2021; Journal of Environmental Management (in review)

Variations of transboundary air pollution impacts in the WB





Domestic: emission and impact in WB,
Export: emission in WB and impact elsewhere,
Import: emission elsewhere and impact in WB

Belis C.A., Van Dingenen R., F. Dentener and Klimont Z., 2022; Journal of Environmental Management (in review)

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TM5-FASST developments in progress

- Introduction of updated source-receptor coefficients on the basis of new EMEP runs
- Update of health impacts to GBD 2019
- Estimation of YLL
- Include morbidity health outcomes
- Estimation of external costs due to health impacts
- Incorporate impacts on ecosystems (N deposition, ozone damage to natural vegetation)

Final remarks

- Background/Natural is the dominant ozone exposure source in the UNECE region while anthropogenic UNECE emissions are the main $PM_{2.5}$ exposure sources.
- Projected O_3 related mortality in UNECE presents an increasing trend between 2020 and 2050 mainly due to the growing impact of CH_4 emissions outside the region
- $PM_{2.5}$ related mortality initiallly decreases and then increases between 2020 and 2050 mainly due to changes in the anthropogenic emissions within the UNECE region
- Agriculture is the most important single $PM_{2.5}$ anth. source (NH_3) and the impact is projected to increase. It also contributes to O_3 levels via CH_4 emissions, especially in ROW.
- The overall impact of ozone on crops grows slightly between 2020 and 2050 both in absolute mass and relative yield loss (RYL)
- Implementing MFR only in UNECE countries leads to a limited future reduction of the ozone-related exposure (and mortality) in the UNECE region compared to MFR globally.
- In the MFR scenarios, the abatement of ozone-related mortality is mainly due to NOx-VOC precursor emission reductions.

Thank you