Agricultural Non-Methane Volatile Organic Compounds (NMVOCs)

Katrin Kaltenegger[1], David Simpson[2], Chris Heyes[1], Zbigniew Klimont[1],

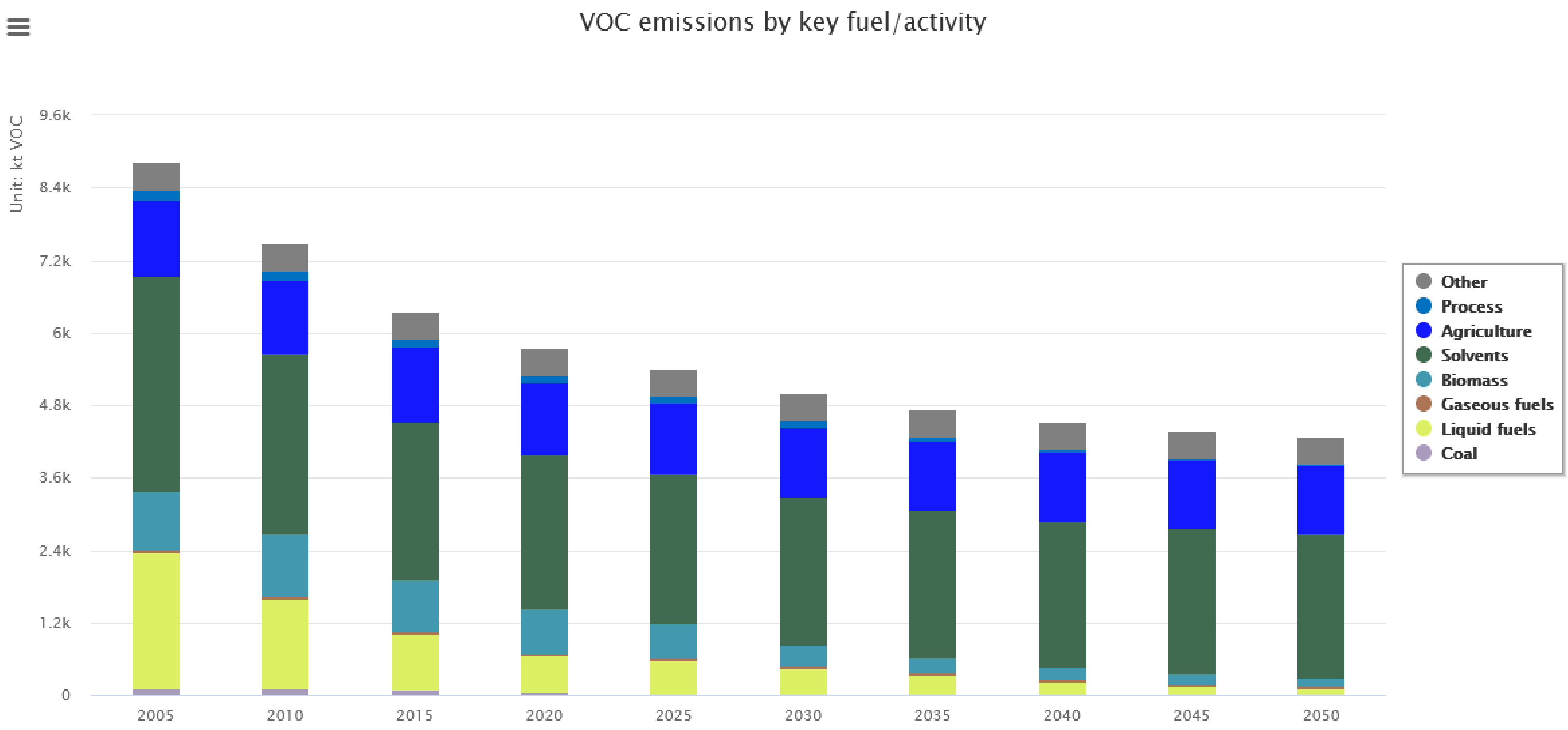
kalteneg@iiasa.ac.at

[1]International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria

[2] EMEP MSC-W, Norwegian Meteorological Institute, Oslo, Norway

Background

- Contribute to ground level ozone formation and can impact human and ecosystem health (Species - MIR)
- Legislation
  - National Emission Ceilings Directive 2001/81/EC (NECD) (Base year 2005)
  - Gothenburg Protocol
  - Directive 96/62/EC on ambient air quality assessment
    - Directive 2000/69/EC sets limit values for benzene concentrations
- Agricultural NMVOCs are non negligible
  - Livestock: Silage feeding (fermentation), manure storage and application/ grazing
  - Crop- /Grassland: Flowering (species dependent)


VOC emissions by key fuel/activity
Unit: kt VOC
9.6k
8.4k
7.2k
6k
4.8k
3.6k
2.4k
1.2k
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Other
Process
Agriculture
Solvents
Biomass
Gaseous fuels
Liquid fuels
Coal

4/19/2023

GAINS emission calculations

Dairy cattle and other cattle:

$$E_{NMVOC} = AAP_{animal} \times (E_{NMVOC,silage\_store} + E_{NMVOC,silage\_feeding} + E_{NMVOC,hous} + E_{NMVOC,store} + E_{NMVOC,appl} + E_{NMVOC,graz}) \quad (48)$$

where: CRF, IIR GAINS IIR, experts

$$E_{NMVOC,silage\_store} = MJ \times x_{house} \times (EF_{NMVOC,silage\_feeding} \times Frac_{silage}) \times Frac_{silage\_store} \quad (49)$$

$$E_{NMVOC,silage\_feeding} = MJ \times x_{hous} \times (EF_{NMVOC,silage\_feeding} \times Frac_{silage}) \quad (50)$$

$$E_{NMVOC,house} = MJ \times x_{hous} \times (EF_{NMVOC,house}) \quad (51)$$

GAINS

$$E_{NMVOC,manure\_store} = E_{NMVOC,hous} \times (E_{NH3,storage\_}/E_{NH3,hous}) \quad (52)$$

$$E_{NMVOC,appl.} = E_{NMVOC,\ hous} \times (E_{NH3appl.}/E_{NH3hous})$$

$$E_{NMVOC,graz} = MJ \times (1 - x_{hous}) \times EF_{NMVOC,graz}$$

All livestock categories other than cattle:

CRF, IPCC

$$E_{NMVOC,silage\_store} = VS \times x_{hous} \times (EF_{NMVOC,\ silage\ feed} \times Frac_{silage}) \times Frac_{silage\_store} \quad (55)$$

$$E_{NMVOC,silage\_feeding} = VS \times x_{hous} \times (EF_{NMVOC,silage\_feeding} \times Frac_{silage}) \quad (56)$$

$$E_{NMVOC,hous} = VS \times x_{hous} \times (EF_{NMVOC,hous}) \quad (57)$$

$$E_{NMVOC,manure\_store} = E_{NMVOC,hous} \times (E_{NH3,storage\_}/E_{NH3,\ hous}) \quad (58)$$

$$E_{NMVOC,appl.} = E_{NMVOC,hous} \times (E_{NH3appl.}/E_{NH3hous}) \quad (59)$$

$$E_{NMVOC,graz} = kg\ VS \times (1 - x_{hous}) \times EF_{NMVOC,graz} \quad (60)$$

EMEP/EEA Guidebook 2019

GAINS emission calculation

- Tier 2 – emep/EEA Guidebook 2019
- Silage feed information from informative inventory report (IIR), direct contacts or default
- Energy intake for cattle from common CRF, IIR or direct contacts
- VS for all other animals from CRF, IIR, direct contacts or IPCC V4 Chapter 10 defaults
- % housing and NH_3 fractions from GAINS

GAINS emission calculation

Table 3.3 Estimation of NMVOC Tier1 EFs in kg ha^{-1} a^{-1}

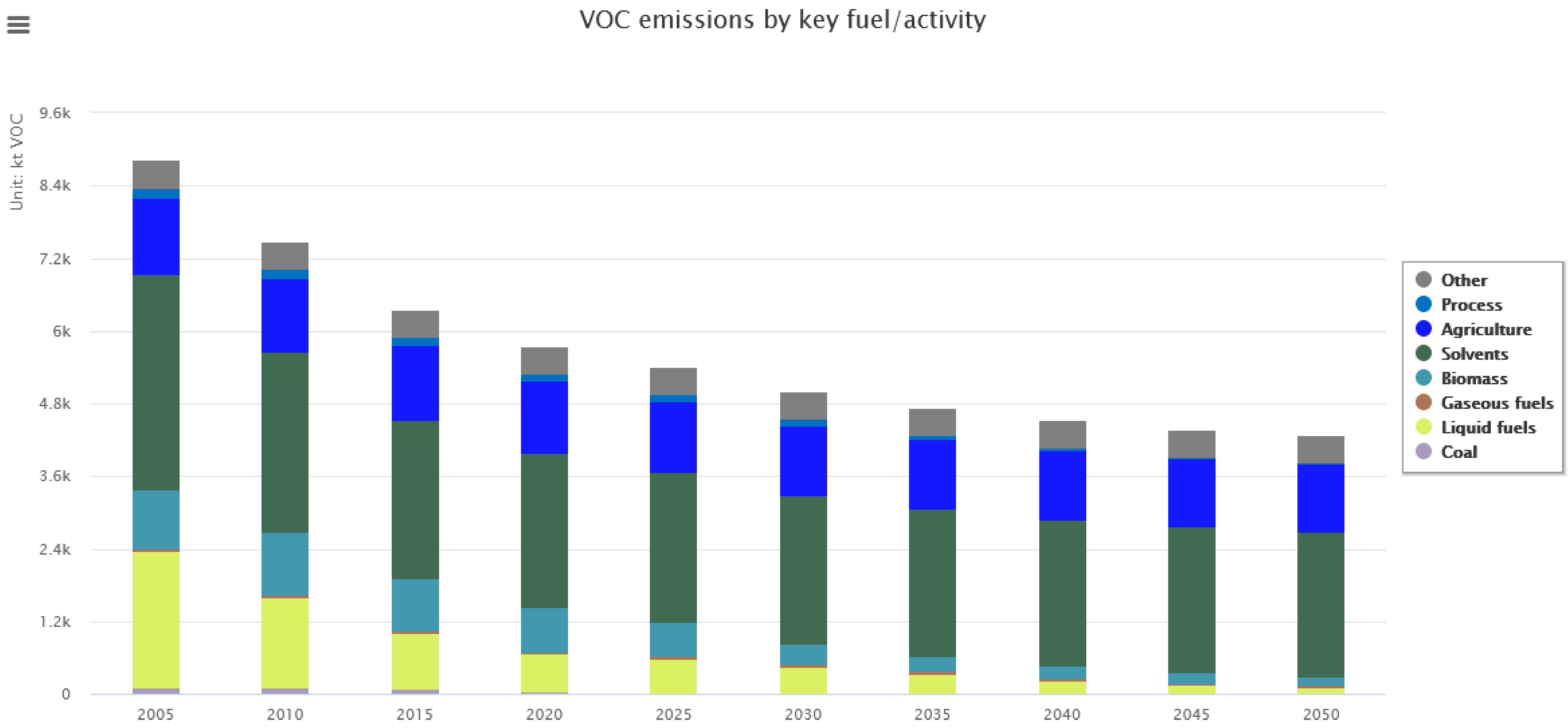
	NMVOC, kg DM^{-1} ha^{-1}*	Fraction of year emitting	NMVOC, kg DM^{-1} a^{-1}	Mean yield of crop, kg DM ha^{-1}	NMVOC, kg ha^{-1}a^{-1}	Crops distribution	Weighted EF, kg NMVOC ha^{-1} a^{-1}
Wheat	2.60×10^{-8}	0.3	6.82×10^{-5}	4700	0.32	0.35	0.11
Rye	1.41×10^{-7}	0.3	3.70×10^{-4}	2800	1.03	0.05	0.05
Rape	2.02×10^{-7}	0.3	5.30×10^{-4}	2500	1.34	0.10	0.13
Grass (15 °C)	1.03×10^{-8}	0.5	4.51×10^{-5}	9000	0.41	0.25	0.10
Grass (25 °C)	4.67×10^{-8}	0.5	2.05×10^{-4}	9000	1.85	0.25	0.46
Tier1 NMVOC EF (sum of weighted EFs)							0.86

*DM: dry matter; Source: König et al. (1995), Lamb et al. (1993), FAO (2012).

FAOSTAT

EMEP/EEA Guidebook 2019

Results


VOC emissions by key fuel/activity
Unit: kt VOC
9.6k
8.4k
7.2k
6k
4.8k
3.6k
2.4k
1.2k
0
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050
Other
Process
Agriculture
Solvents
Biomass
Gaseous fuels
Liquid fuels
Coal

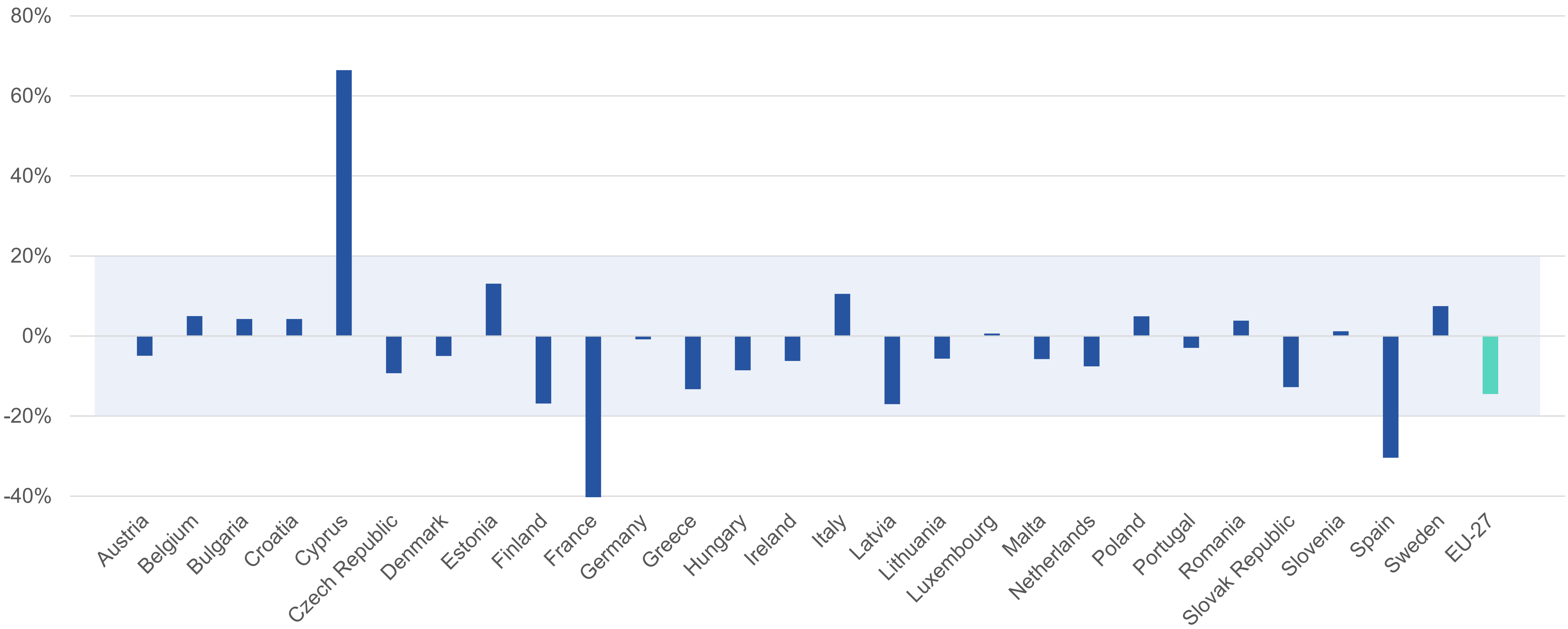
Impact on emission reduction commitment (ERC)

	2025		2030		
Country	Indicative ERC [1]	Baseline	ERC [2]	Baseline	Baseline + NMVOC agriculture
Austria	29%	47%	36%	53%	42%
Belgium	28%	50%	35%	52%	46%
Bulgaria	32%	39%	42%	47%	44%
Croatia	41%	57%	48%	66%	62%
Cyprus	48%	58%	50%	62%	54%
Czech Rep.	34%	47%	50%	54%	50%
Denmark	36%	50%	37%	52%	39%
Estonia	19%	53%	28%	56%	48%
Finland	42%	58%	48%	66%	60%
France	48%	55%	52%	58%	50%
Germany	21%	35%	28%	39%	32%
Greece	58%	67%	62%	70%	67%
Hungary	44%	49%	58%	54%	48%
Ireland	29%	31%	32%	35%	21%
Italy	41%	46%	46%	52%	48%
Latvia	33%	46%	38%	50%	46%
Lithuania	40%	37%	47%	43%	39%
Luxembourg	36%	38%	42%	45%	35%
Malta	25%	40%	27%	40%	39%
Netherlands	12%	28%	15%	29%	20%
Poland	26%	38%	26%	50%	44%
Portugal	28%	45%	38%	49%	44%
Romania	35%	45%	45%	62%	56%
Slovakia	25%	43%	32%	48%	47%
Slovenia	38%	42%	53%	45%	40%
Spain	31%	33%	39%	36%	31%
Sweden	31%	45%	36%	49%	43%
EU-27	35%	45%	41%	50%	43%

[1] The ERCs for 2025 are the linear interpolations between the ERCs for 2020 a
[2] The ERCs for 2030 originate from the Annex II of NECD

Klimont, Z., et al., 2022

Differences to NFR



Confusion

Table 3.3 Estimation of NMVOC Tier1 EFs in kg ha^{-1} a^{-1}

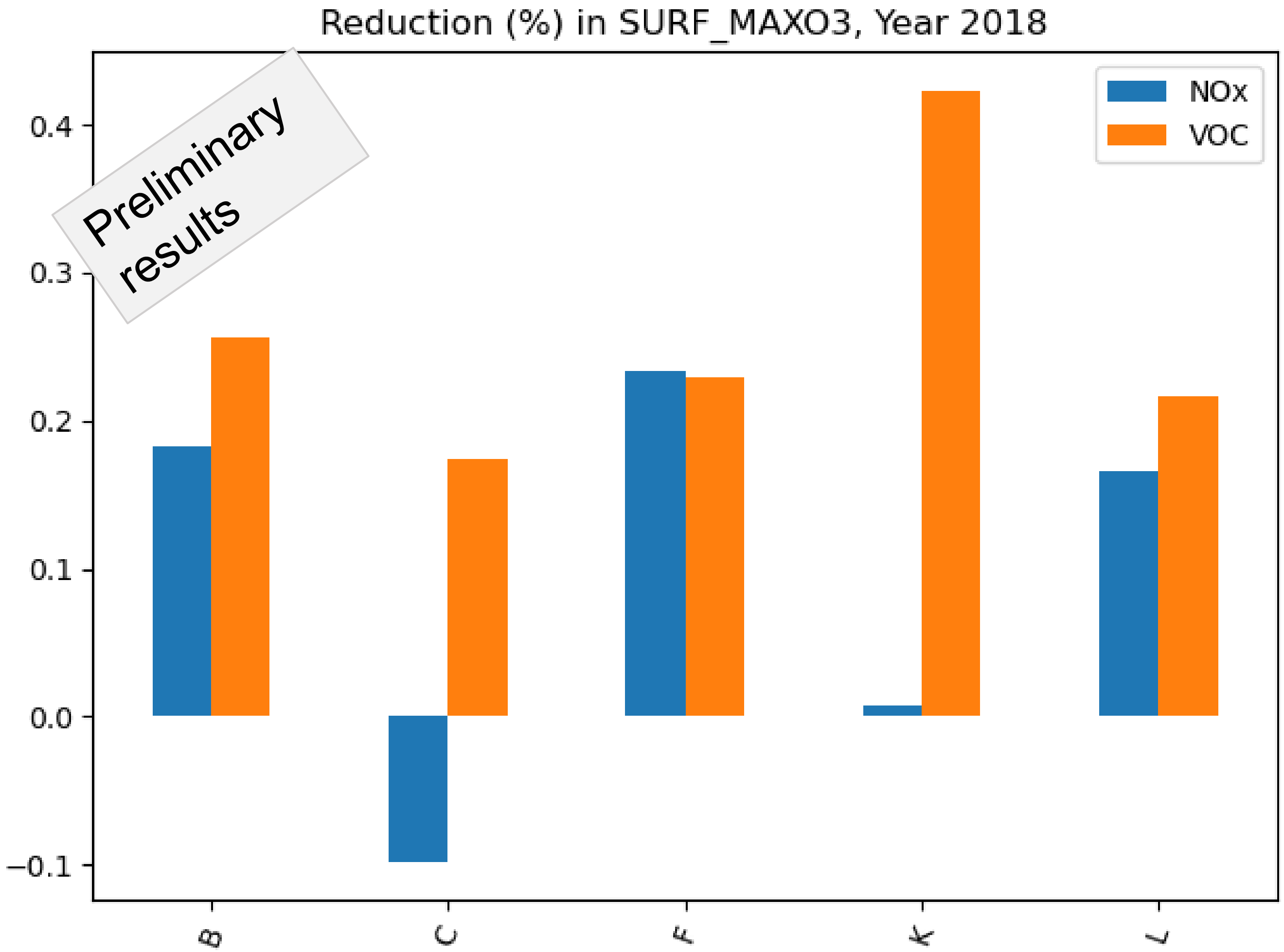
	NMVOC, kg DM^{-1} ha^{-1*}	Fraction of year emitting	NMVOC, kg DM^{-1} a^{-1}	Mean yield of crop, kg DM ha^{-1}	NMVOC, kg $ha^{-1}a^{-1}$	Crops distribution	Weighted EF, kg NMVOC ha^{-1} a^{-1}
Wheat	2.60×10^{-8}	0.3	6.82×10^{-5}	4700	0.32	0.35	0.11
Rye	1.41×10^{-7}	0.3	3.70×10^{-4}	2800	1.03	0.05	0.05
Rape	2.02×10^{-7}	0.3	5.30×10^{-4}	2500	1.34	0.10	0.13
Grass (15 °C)	1.03×10^{-8}	0.5	4.51×10^{-5}	9000	0.41	0.25	0.10
Grass (25 °C)	4.67×10^{-8}	0.5	2.05×10^{-4}	9000	1.85	0.25	0.46
Tier1 NMVOC EF (sum of weighted EFs)							0.86

*DM: dry matter; Source: König et al. (1995), Lamb et al. (1993), FAO (2012).

Impact on ozone (David)

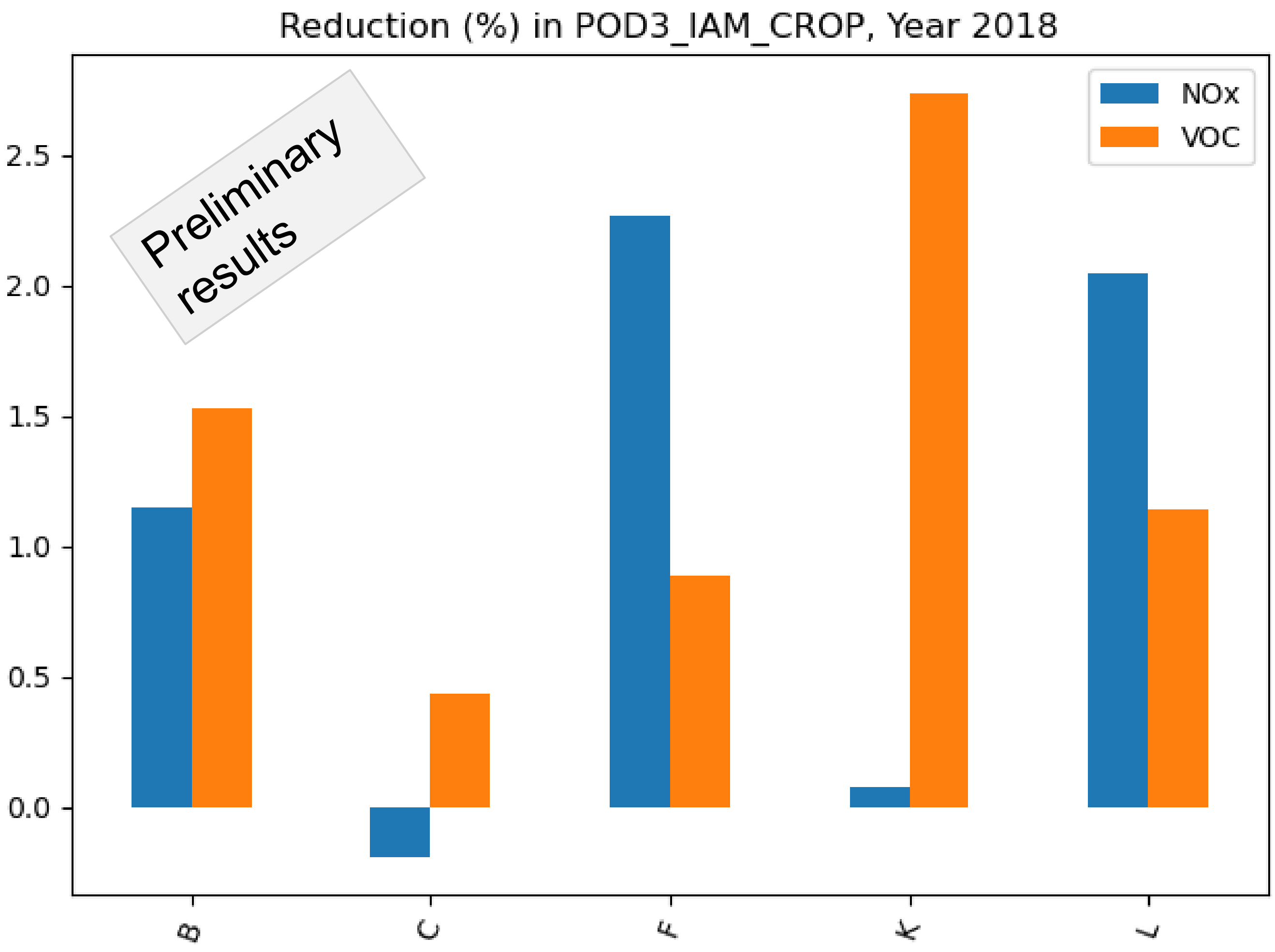
- Speciation from TNO (J. Kuenen)
- Emissions and spatial distribution of 19 categories of agriculture from IIASA
- Version rv4.51 of the EMEP MSC-W chemical transport model (Simpson et al., 2012, 2022)
- Maps with 0.2×0.3 degree lon/lat

Effect on ozone



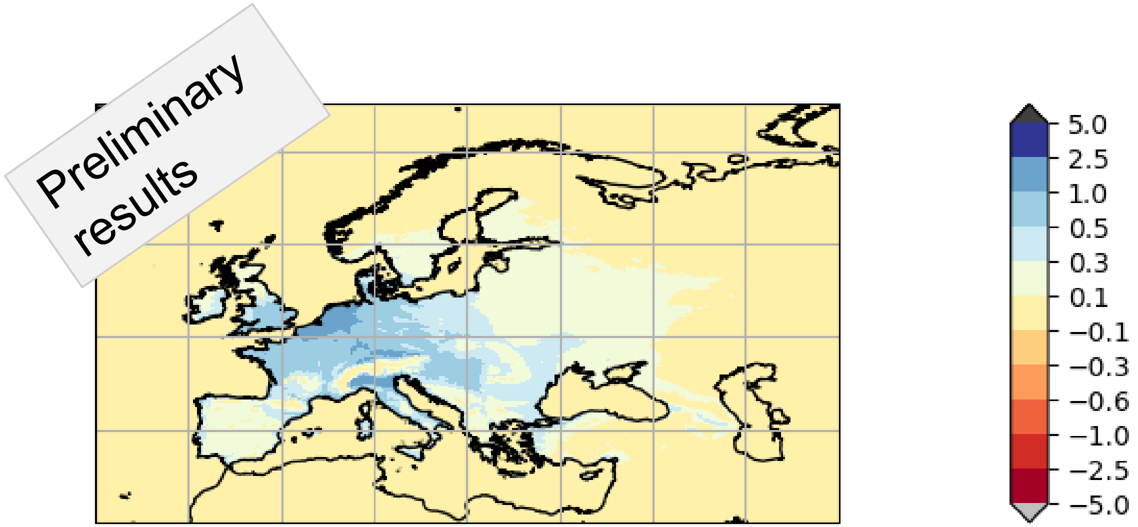
Reductions in mean of daily max. O_3 over central Europe in 2018 due to removal of NO_X or VOC emissions in GNFR classes B (Industry), C (small combustion), F (road transport), K (Agriculture livestock) and L (other agriculture)

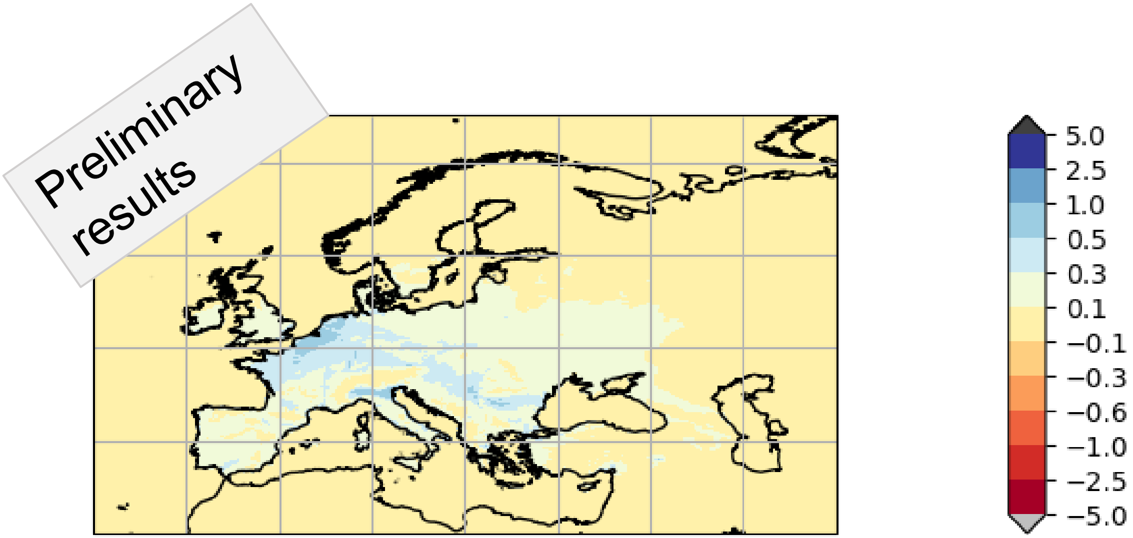
Effect on ozone



Reductions in mean of POD3-IAM-CROP over central Europe in 2018 due to removal of NO_X or VOC emissions in GNFR classes B (Industry), C (small combustion), F (road transport), K (Agriculture livestock) and L (other agriculture)

Effect on ozone





Reductions in mean of POD3-IAM-CROP in mmole/m2 over central Europe in 2018, due to removal of VOC emissions in GNFR K (Agriculture livestock - left) and L (other agriculture - right)

References

EMEP/EEA: EMEP/EEA air pollutant emission inventory guidebook 2019 Guidebook - 3.B Manure management, Publications Office of the European Union, Luxembourg, 2019a.

EMEP/EEA: EMEP/EEA air pollutant emission inventory guidebook 2019 Guidebook - 3.D Crop production and agricultural soils, Publications Office of the European Union, Luxembourg, 2019b.

FAO: Crops and livestock products; FAOSTAT database., 2022a.

FAO: Land Use; FAOSTAT database., 2022b.

Klimont, Z., et al., 2022. Support to the development of the third Clean Air Outlook. https://circabc.europa.eu/ui/group/cd69a4b9-1a68-4d6c-9c48-77c0399f225d/library/bb998537-f96a-4ec5-b5ad-dd4e7fd144ed.

Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L. D., Fagerli, H., Flechard, C. R., Hayman, G. D., Gauss, M., Jonson, J. E., Jenkin, M. E., Nyíri, A., Richter, C., Semeena, V. S., Tsyro, S., Tuovinen, J.-P., Valdebenito, A., and Wind, P.: The EMEP MSCW chemical transport model – technical description, Atmos. Chem. Physics, 12, 7825–7865, https://doi.org/10.5194/acp-12-7825-2012, 220 2012.

Simpson, D., Gonzalez Fernandez, I., Segers, A., Tsyro, S., Valdebento, A., and Wind, P.: Updates to the EMEP/MSC-W model, 2021–2022, in: Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components. EMEP Status Report 1/2022, pp. 133–146, The Norwegian Meteorological Institute, Oslo, Norway, available from www.emep.int, 2022.