Task Force on Integrated Assessment Modelling
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Domestic Heating: an increasingly important source of PM and PAHs driven by Climate Mitigation Policies

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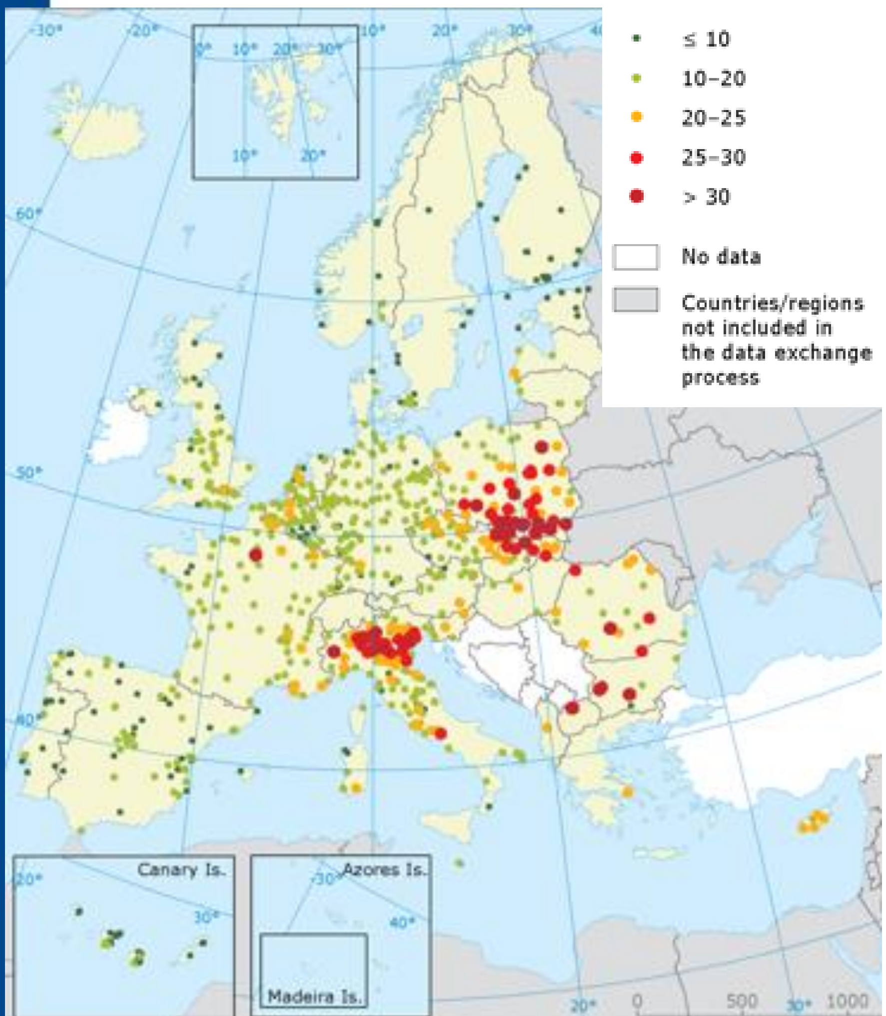
European Topic Centre
on Air Pollution and Climate Change Mitigation

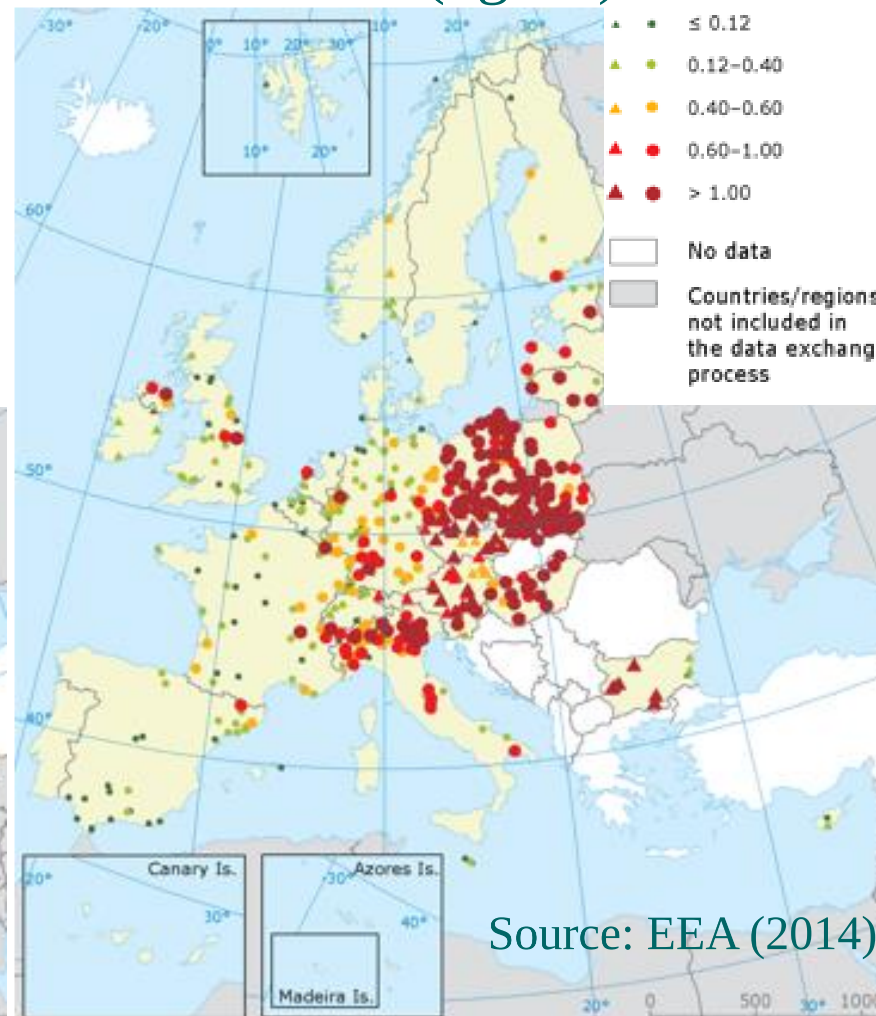
European Environment Agency

Status: 2012 annual mean conc.

PM2.5 (µg/m³)



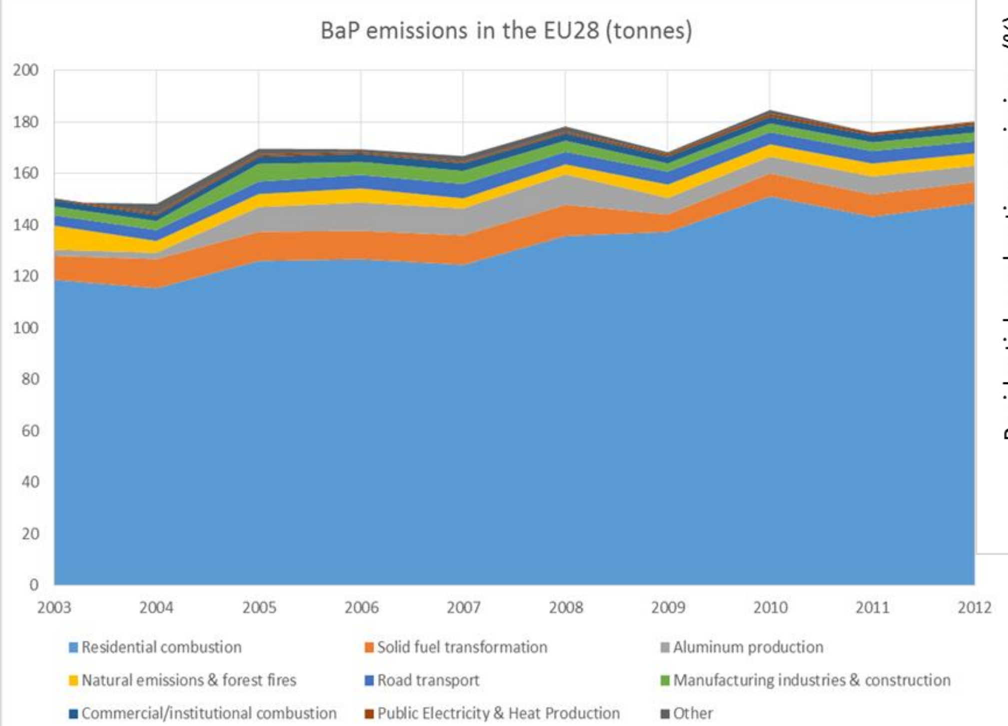
BaP (ng/m³)



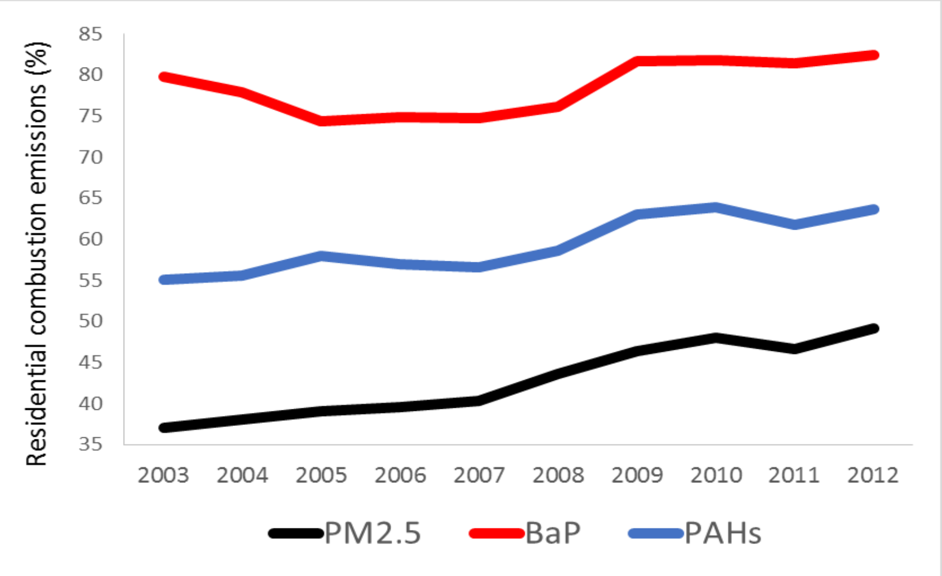
Source: EEA (2014)

Development in emissions

- Residential combustion emits 82 % of BaP, 64% of PAHs, and 49% of PM2.5 total emissions in EU-28 in 2012
- Increasing trend 2003-2012: 25% BaP, 26% PAHs, 11% PM2.5



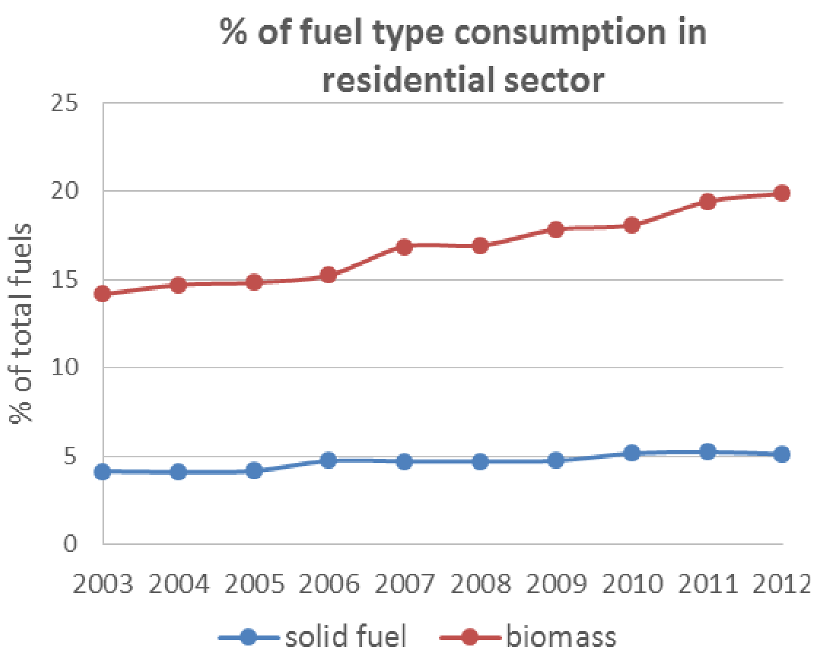
Development residential comb. share of total EU emissions

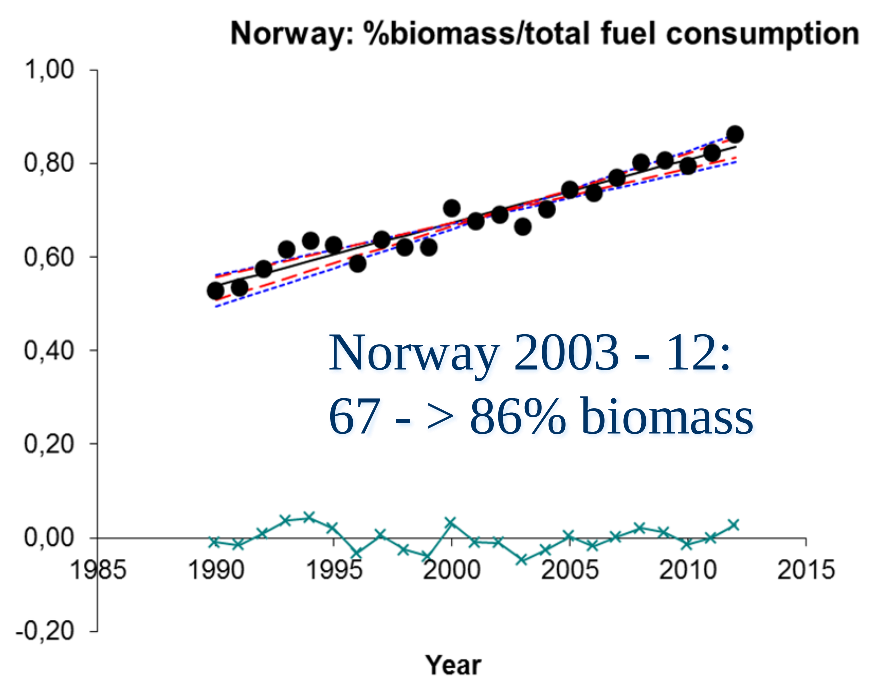


Development in emissions

- Residential combustion has seen an increase of:
  - 27% in the use of biomass (wood)
  - 12% if the use of solid fuels (coal)

  in EU-28 2003-2012





Population exposure in urban areas

% of urban popul exposed to conc. above EU/WHO values

Pollutant	EU reference value	Exposure estimate (%)	WHO AQG	Exposure estimate (%)
$PM_{2.5}$	year (25)	**10 – 14**	year (10)	**94 – 96**
PM_{10}	day (50)	**21 – 30**	year (20)	**69 – 89**
O_3	8-hour (120)	**14 – 17**	8-hour (100)	**97 – 99**
NO_2	year (40)	**8 – 13**	year (40)	**8 – 13**
BaP	year (1 ng/m^3)	**24 – 28**	year (0.12 ng/m^3)	**77 – 88**
SO_2	day (125)	**< 1**	day (20)	**37 – 42**
CO	8-hour (10)	**< 2**	8-hour (10)	**< 2**
Pb	year (0.5)	**< 1**	year (0.5)	**< 1**
Benzene	year (5)	**< 1**	year (1.7)	**10 – 12**

Estimate for 2010 – 2012. *Source: EEA (2014)*

European exposure: Methodology I
BaP concentration map

Primarily data:
- ★ measurement data

Secondary data:
- ★ dispersion model output (EMEP / CHIMERE)
- ★ altitude (rural map)
- ★ meteorology (FF- rural map, T- urban map)
- ★ population density

The secondary data for the ***linear regression model*** were selected based on their relation with measured AQ data. The ***Linear regression model is followed by kriging of its residuals (residual kriging)***

Measured and CTM data are ***logarithmically transformed***, due to the lognormal distribution of these data.

kriging – geostatistical method (i.e. knowledge of the spatial structure of air quality field is utilized, using variogram)

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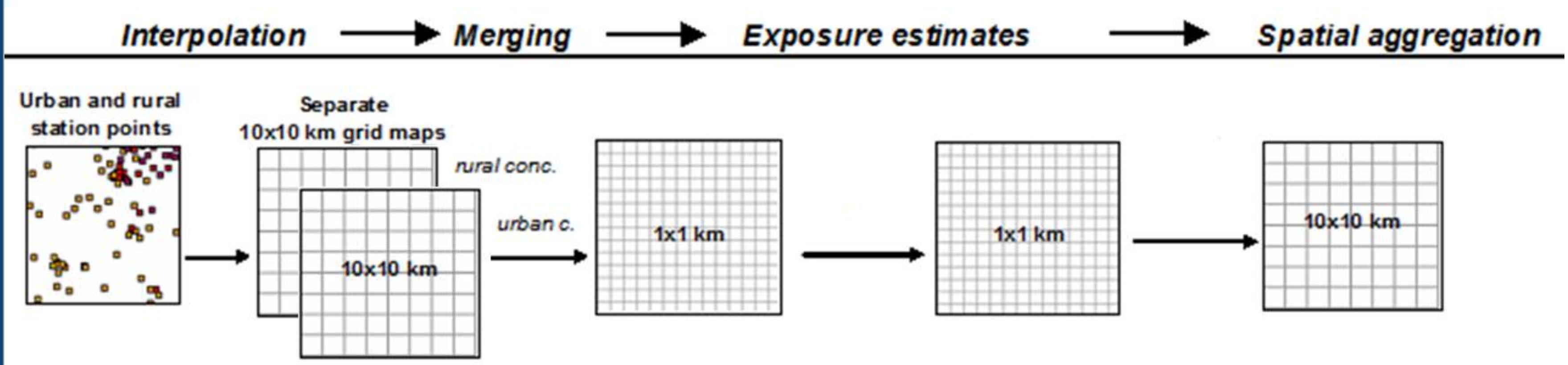
European exposure: Methodology II
BaP concentration map

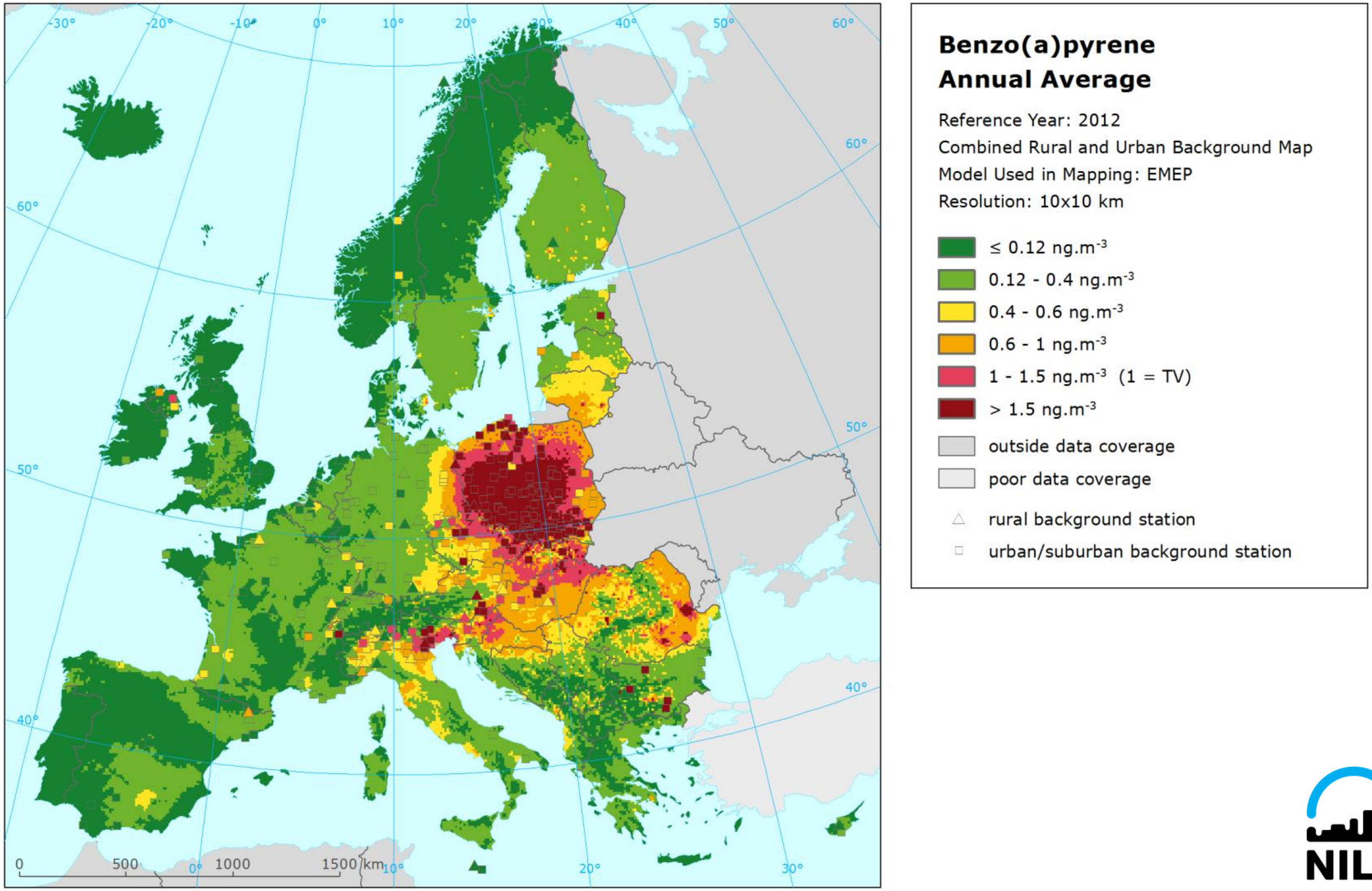
Separate mapping of rural and urban air quality
due to different character of urban and rural air quality

BaP, $PM_{2.5}$ – urban/suburban concentrations are in general higher than the rural concentrations

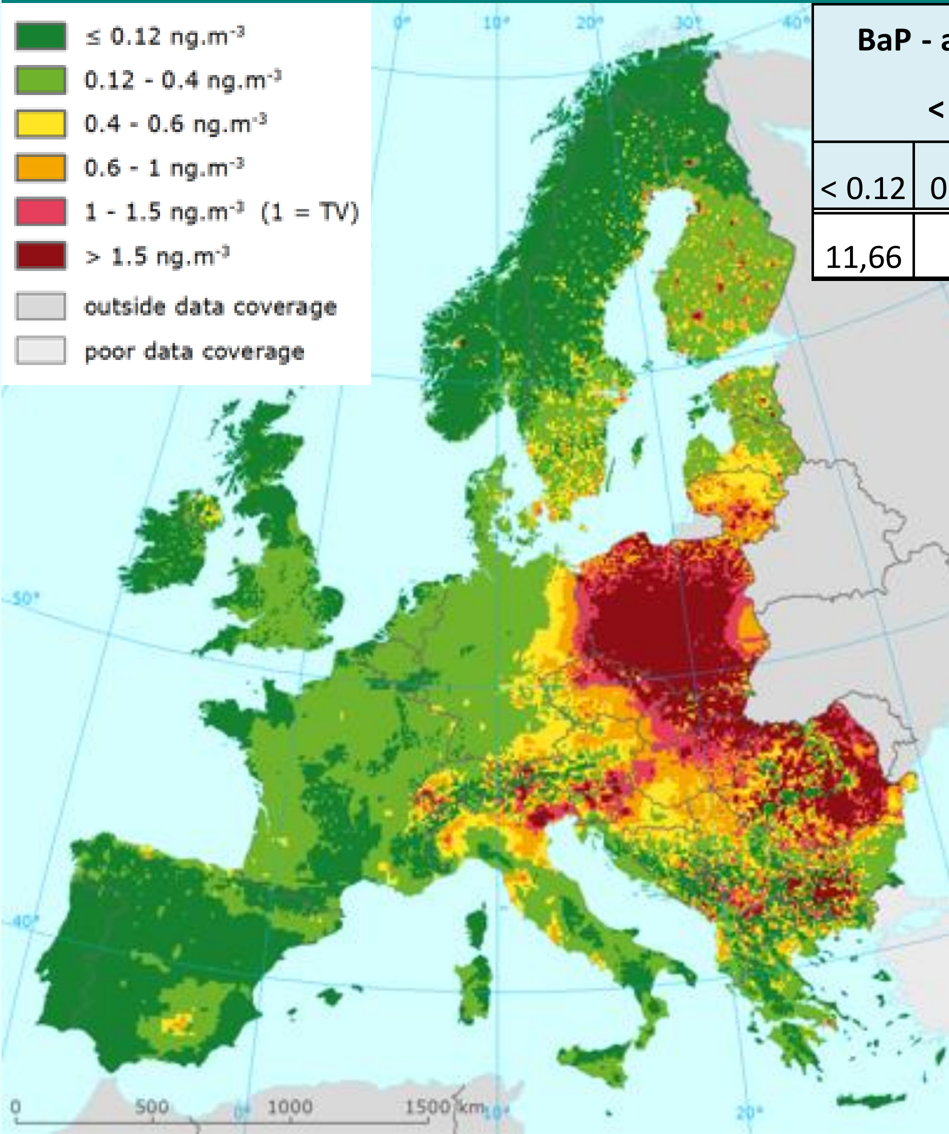
Rural map – based on rural background stations
Urban background map – based on urban and suburban backgr stations
Final maps are created by merging rural and urban background maps, using *population density*.



Interpolated BaP concentration map



Population exposure to BaP



BaP - annual mean, exposed population (%)						BaP popul. weighted conc. (ng/m^3)
< Target value (TV)				> TV		
< 0.12	0.12-0.4	0.4-0.6	0.6-1.0	1.0-1.5	> 1.5	
11,66	46,73	10,44	10,71	6,82	13,64	0,84

- Only 12 % of the European popul. live in areas with BaP conc. under the WHO Ref. level of 0.12 ng/m^3
- 20% live above the TV
- Estimated lung cancer incidence:

  550 - 600 in Europe

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Underestimated PAHs health impacts

- PAHs have several health impacts: **lung cancer**, skin and bladder cancer, genotoxicity and mutagenicity; affects children's' cognitive development, & linked to cardiovascular morbidity and mortality;
- *BaP is* a marker for total exposure to carcinogenic PAHs & only contributes to *part of the total carcinogenic potential of PAHs*;
- Airborne PAHs are deposited on soil and water and may be bioaccumulated in the food chain. In addition to inhalation *humans are also exposed to airborn PAHs through consumption of food and water*;
- *Concentrations and exposure to BaPs are underestimated* in this study, mainly due to the lack of measurement data.

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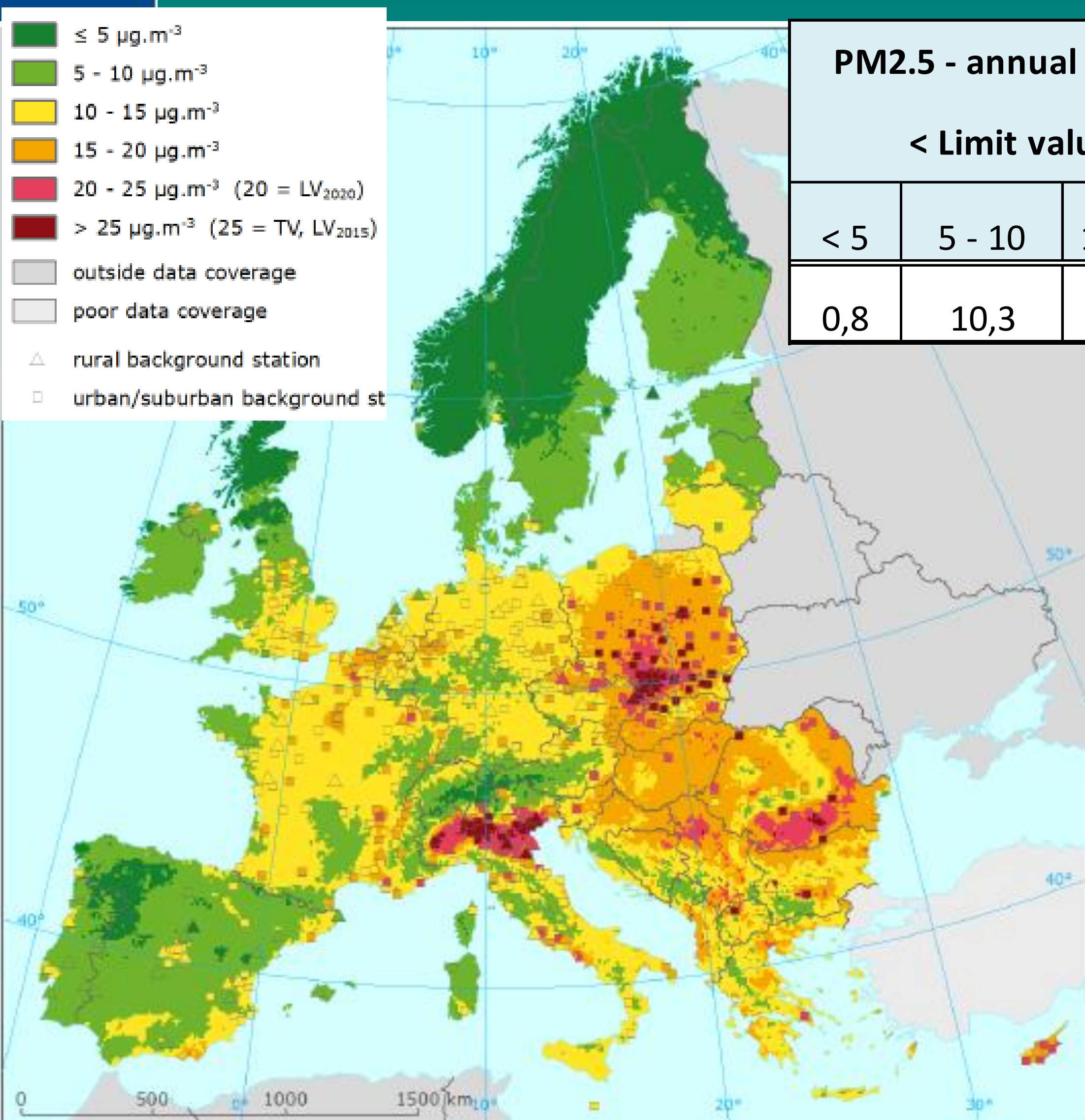
Population exposure to PM2.5



PM2.5 - annual mean, exposed population (%)						PM2.5 popul. weighted conc. (µg/m^3)
< Limit value (LV_{2020})				> LV_{2020}		
< 5	5 - 10	10 - 15	15 - 20	20 - 25	> 25	
0,8	10,3	47,2	23,7	9,1	9,0	15,6

- Only 11 % of the European population live in areas under the WHO GL of 10 µg/m^3
- 18% live above the LV_{2020}
- Estimated premature death:

458 000 in Europe,
430 000 in EU28,
1 470 in Norway

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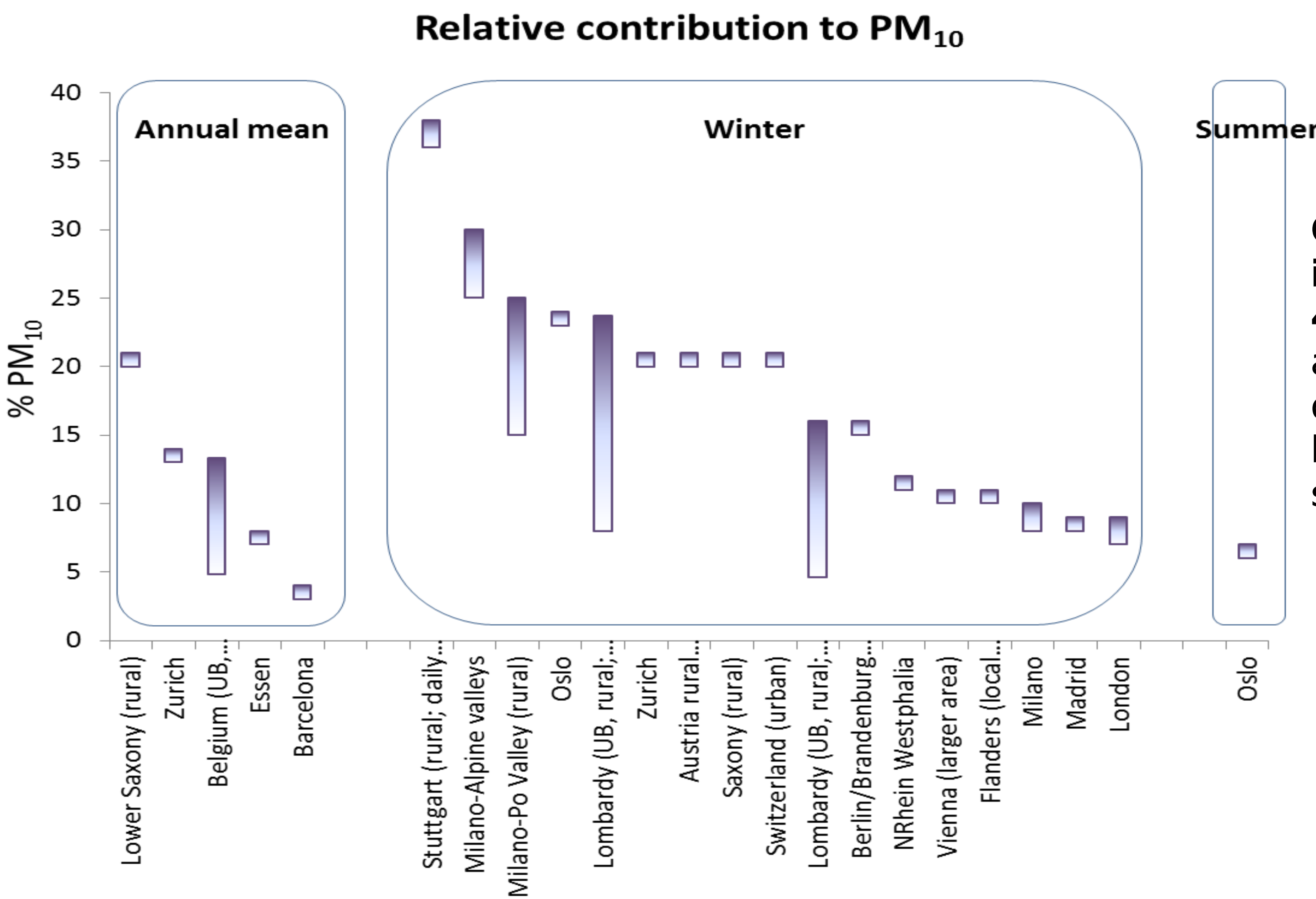
Contributions from residential sector emissions to ambient air PM concentrations

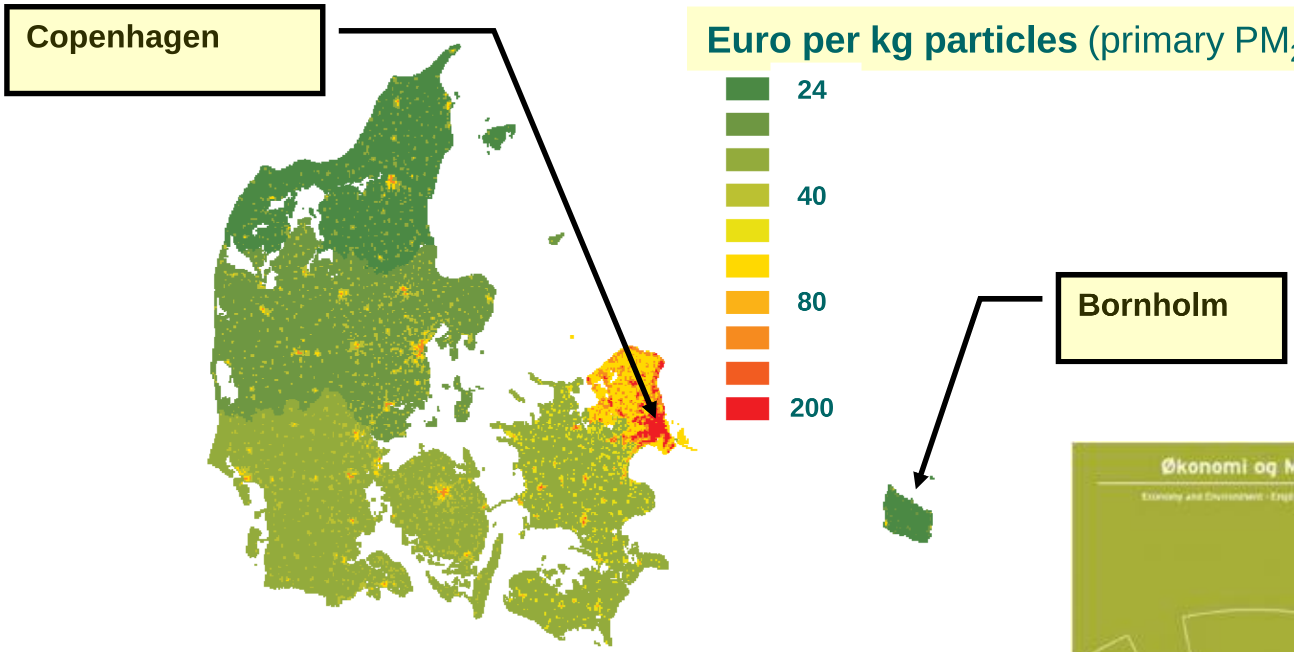


Contribution is <5% to 40% of PM10 and PM2.5 during the heating season

Review of source apportionment studies
In ETC/ACM Technical Paper 2015/1

What are the health related costs of using wood stoves? (Danish example)

For an **old stove in Copenhagen**: **5.5 Euro/hour**.
For a **modern stove in Copenhagen**: **: 1 Euro/hour**
In the countryside:**13 Eurocents/hr** for a **modern stove** in the isle of Bornholm.

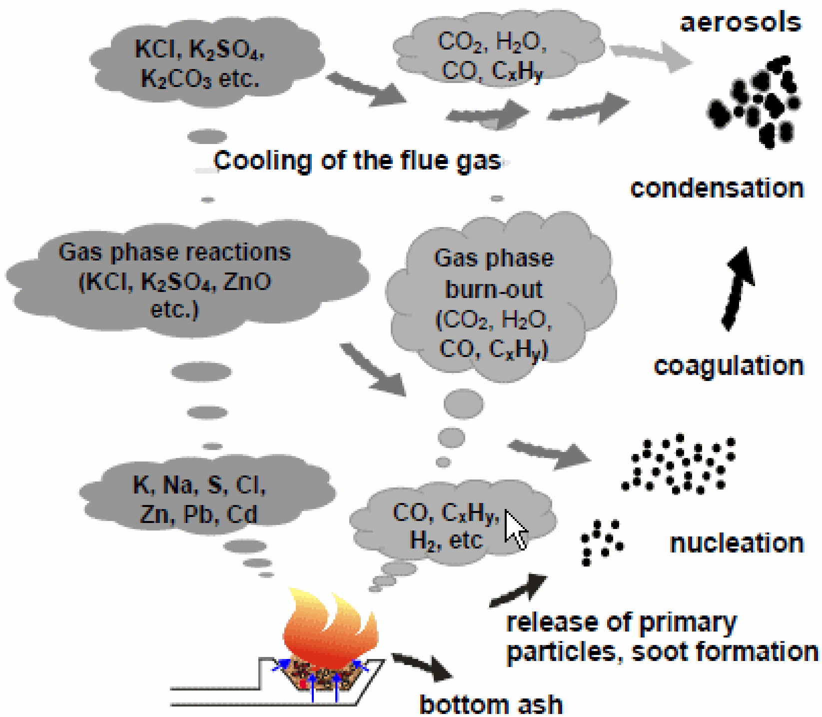


Sources: "**Economy and Environment, 2016**". Danish Economic Councils. Brandt, J., S.S. Jensen, M.S. Andersen, M.S. Plejdrup, O.K. Nielsen, 2016: **Health effects and health costs from emission sectors in Denmark**. Aarhus Universitet, DCE – Nationalt Center for Miljø og Energi, 47 – Scientific report from DCE - National Center for Environment and Energy no. 182. http://dce2.au.dk/pub/SR182.pdf

Very difficult to quantify emissions from biomass combustion !!

Emission factors depend on:

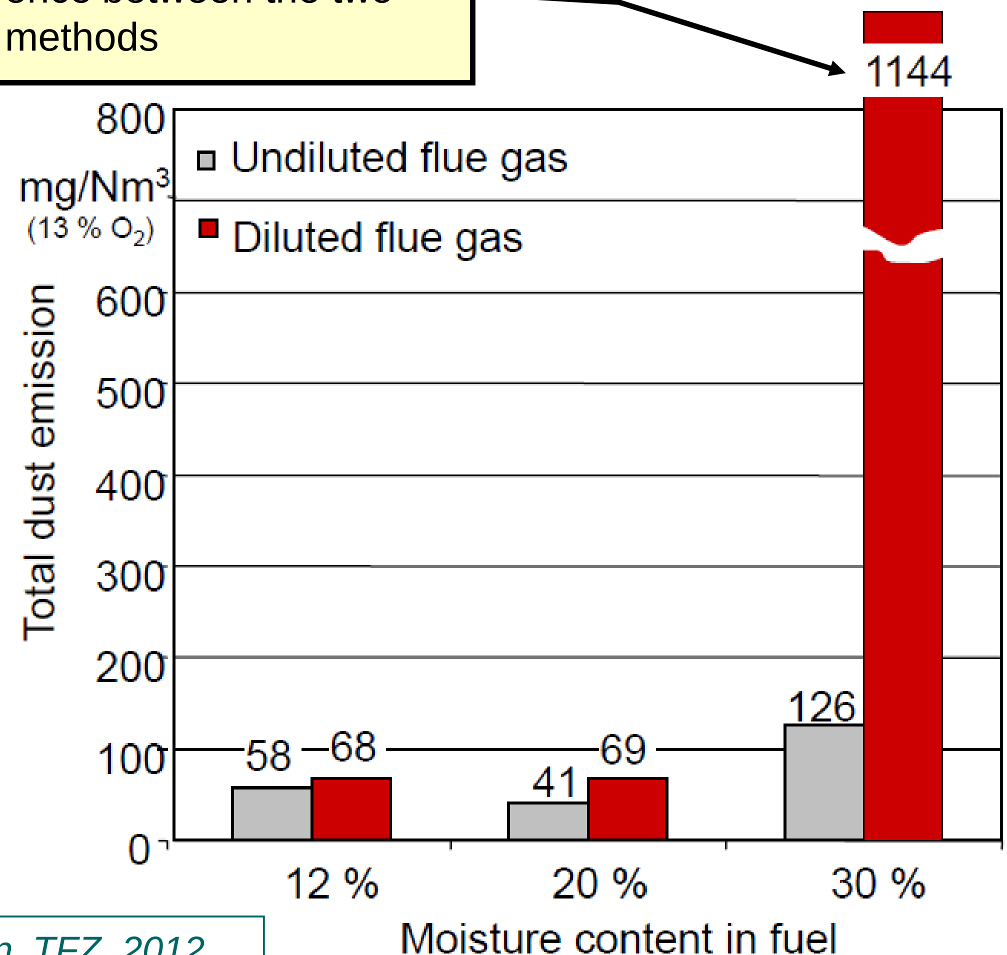
- Type of stove
- Age of stove
- Type of wood /Briquettes
- Humidity content in wood
- Woodlog sizes & numbers
- Ignition (Top Down/ under wood)
- Air / draft in chimney (air opening/ ventilation, design stove & chimney)
- Measuring method!



Source: Obernberger et al., 2007

PM emission: Importance of moisture content and of measuring method

For very moist wood there is almost a factor 10 difference between the two measurement methods



From Hans Hartmann, TFZ, 2012.

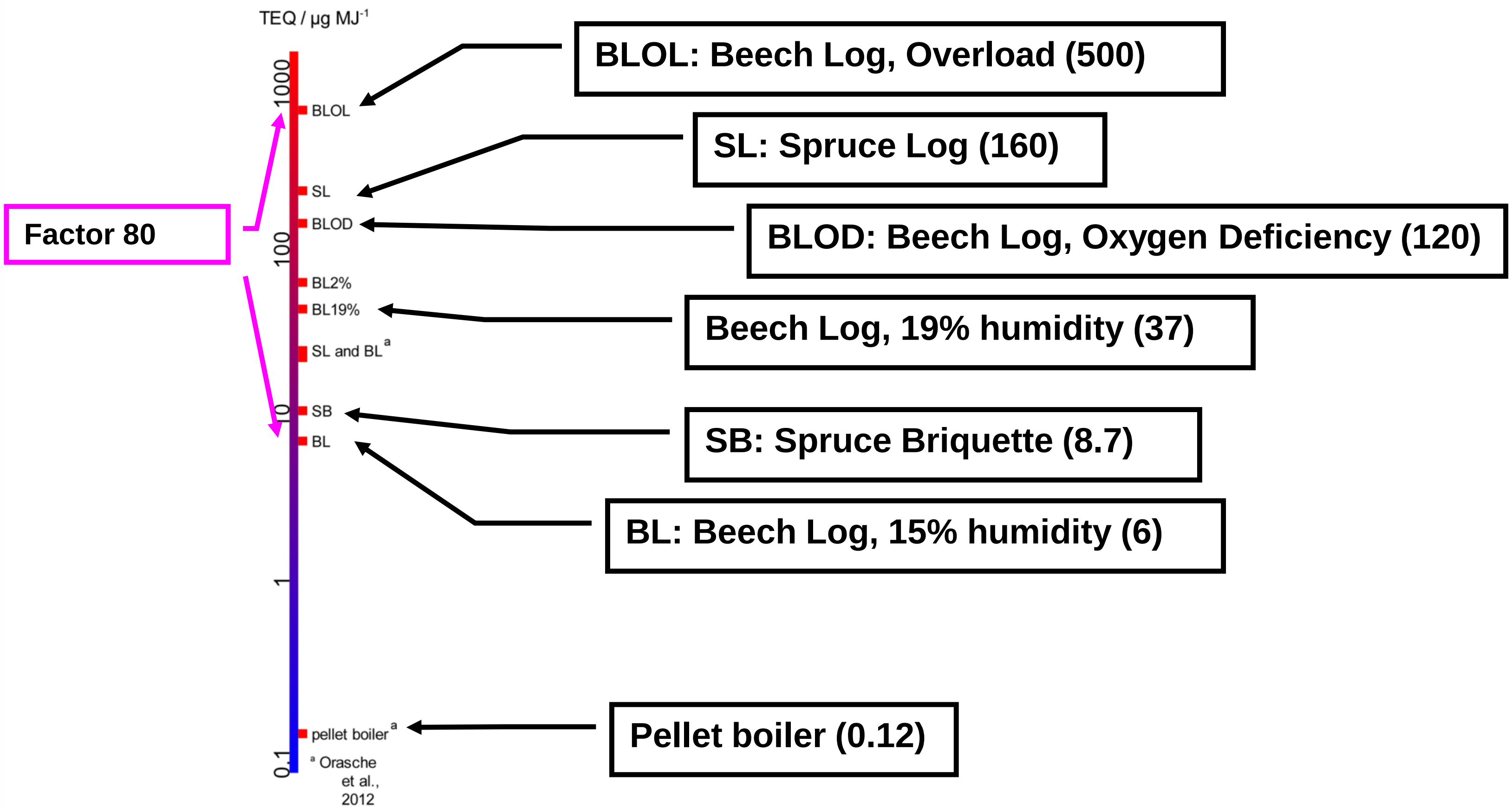
PM emission strongly depends on oxigen supply, load, refill

- Examples from study on effect of combustion conditions *by Klippel and Nussbaumer (2007):*

Combustion conditions	**Emission: Particle concentration in flue gas**	**Comments**
Optimal conditions	16 mg/m^3	1.5 kg wood per batch, very dry wood (12 % moisture).
Typical conditions	220-240 mg/m^3	4 kg wood per batch, 20% moisture content in wood.
Typical conditions, but too late refill	3000 mg/m^3	As above, but next batch on weakly burning remains from previous fill.
Poor conditions	6000 mg/m^3	Filled stove and shut air inlet.

Nussbaumer et al. (2008) reported a 50 – 80 % reduction in PM emissions with “ignition from above” compared to traditional ignition from the bottom. The reduction potential is not so large for all wood stoves.
Source: H.R. Olesen, 2016

There are also large variations o the PAH emission factors [µg/MJ]



Source: H.R. Olesen, 2016 based on J. Orasche et al., 2013

Discussion: Biomass combustion from the air quality perspective

- The residential combustion sector is a ***main contributor to exceedances of BaP and PM2.5*** target/ limit values in Europe

- BUT there are very large uncertainties in emission inventories

- with emissions at ***low-height*** often in ***densely populated*** areas leading to important health impacts.

- Leading also to a substantial increase in PM (PAH) indoor concentrations (very dependent in stove type)

  - … further health impacts!!

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Discussion: Biomass combustion from the climate perspective

- Biomass for domestic heating: 43% of RES in 2012 in the EU28 playing key role in meeting “20-20-20” targets.

- Impacts of biomass combustion on climate:
  - emissions of CH_4 and BC (warming effect) + OC / other PM (cooling effect)

    = ? net effect ?

  - LCA by Solli et al. (2009) estimates 30-50% of CO_2 emissions compared to heating with electricity in Norway (Nordic mix)

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Thank you for your attention!

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Benzo(a)pyrene in Europe: Ambient air concentrations, population exposure and health effects☆

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ABSTRACT

This study estimated current benzo(a)pyrene (BaP) concentration levels, population exposure and potential health impacts of exposure to ambient air BaP in Europe. These estimates were done by combining the best available information from observations and chemical transport models through the use of spatial interpolation methods. Results show large exceedances of the European target value for BaP in 2012 over large areas, particularly in central-eastern Europe. Results also show large uncertainties in the concentration estimates in regions with a few or no measurement stations. The estimation of the population exposure to BaP concentrations and its health impacts was limited to 60% of the European population, covering only the modelled areas which met the data quality requirement for modelling of BaP concentrations set by the European directive 2004/107/EC. The population exposure estimate shows that 20% of the European population is exposed to BaP background ambient concentrations above the EU target value and only 7% live in areas with concentrations under the estimated acceptable risk level of 0.12 ng m^{-3}. This exposure leads to an estimated 370 lung cancer incidences per year, for the 60% of the European population included in the estimation. Emissions of BaP have increased in the last decade with the increase in emissions from household combustion of biomass. At the same time, climate mitigation policies are promoting the use of biomass burning for domestic heating. The current study shows that there is a need for more BaP measurements in areas of low measurement density, particularly where high concentrations are expected, e.g. in Romania, Bulgaria, and other Balkan states. Furthermore, this study shows that the health risk posed by PAH exposure calls for better coordination between air quality and climate mitigation policies in Europe.

1. Introduction

Polycyclic Aromatic Hydrocarbons (PAHs) are a class of complex organic chemicals of increasing concern for their occurrence in the environment and effects. PAHs are considered among the most dangerous air pollutants due to their carcinogenic and mutagenic character. They can be transported over long distances in the atmosphere (Halsall et al., 2001; Bjørseth et al., 1979) resulting in a widespread distribution on the continental scale, and they bio-accumulate in the food chain. Under certain atmospheric conditions and due to their low vapour pressure and large molecular weight, PAHs are believed to contribute to the fine particulate matter toxic potential (Dejmek et al., 2000; Binkova and Sram, 2004; Ohura et al., 2004; Hertz-Picciotto et al., 2007; Rubes et al., 2007; Soucy et al., 2007; Sram et al., 2011, 2013).

Due to their toxic and ecotoxic characteristics PAHs pose a threat to humans and the environment. Furthermore, the health risk posed by PAH exposure suggests a continuing need for their control through air quality management (Kim et al., 2013). The international community has therefore implemented policies to reduce their emissions. The Protocol to the UN-ECE Convention on Long-range Transboundary Air Pollution (CLRTAP) on persistent organic pollutants (POPs) (UNECE, 1998) obliges the parties to report PAH emissions and has as objective to control, reduce or eliminate

☆ This paper has been recommended for acceptance by David Carpenter.

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