Residential Heating with Wood and Coal: Health Impacts and Policy Options

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Focus of this report

- Geographic scope: Europe and North America
  - Less emphasis on other countries where heating is required, including China and India
- Types of fuel: Wood and coal
  - Less emphasis on other solid fuels, such as peat, agricultural waste, garbage
- Type of heating: Single-home residential heating
  - Less emphasis on district heating
- Type of exposure: population-level exposure to ambient air pollution from heating appliances
  - Less emphasis on indoor (in-home) air pollution and emissions from *cooking* with solid fuels

1. Introduction and context

- Residential heating is an **essential energy service** required by billions of people worldwide.
- Despite availability of electricity and natural gas, many people in Europe/North America heat with wood, coal, forestry/agricultural waste, garbage.
- High **PM2.5 and CO** emissions (per unit fuel) due to incomplete combustion in the home.
- 3.7 million deaths (2012) from exposure to ambient particulate air pollution (482,000 in Europe; 94,000 in Canada/US) [GBD: 3.2 million deaths in 2010].

Source: WHO (2014) Frequently Asked Questions: Ambient and Household Air Pollution

1. Introduction and context

- Countries in North America and Europe **actively encouraging** residential heating with wood/biomass (climate change mitigation/energy security) with subsidies.
- **Economic dow** t to solid fuels in times of har
- **Trends:** Bioma or expected to increase (IEA 2 r pollutants (World Bank 2

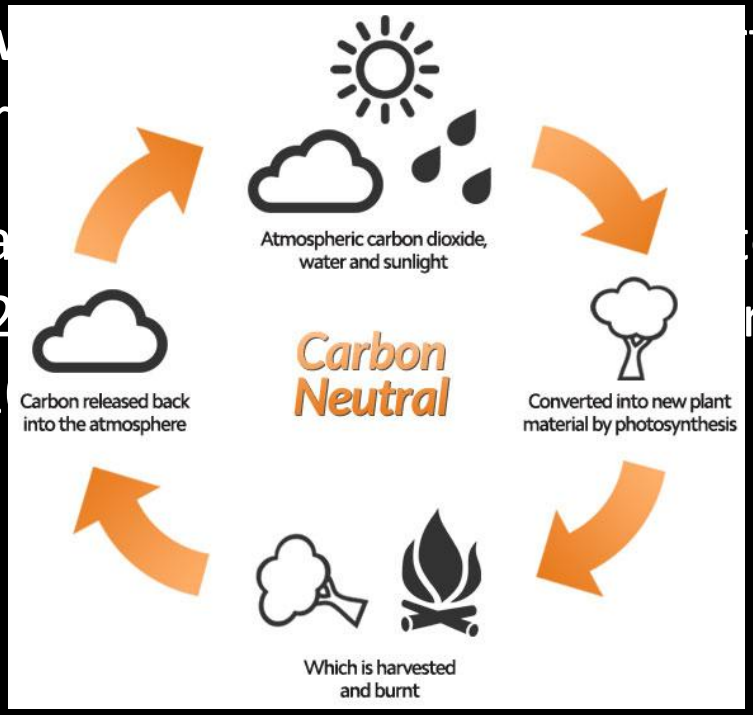


Image source: Wheildons (UK)

1. Introduction and context

- Report addresses:
  - **Persistent levels of emissions** from residential solid fuel combustion for heating.
  - Growing **evidence of health effects** from exposure to PM from this source sector.
  - **Lack of regulation** of solid fuel use for residential heating in many places.

- Report is a general policy-relevant overview of the issues, not a systematic review of the literature.

2. How important is residential heating with solid fuels as a source of air pollution?

- Important source of ambient air pollution that is expected to persist, in part due to climate change policies.
  - Also **slow adoption** of state-of-the-art combustion technologies
  - **Lack of incentives** for exchange of current inefficient stoves
- Europe: **13-21% of PM2.5 emissions** come from residential heating with wood/coal.
  - US and Canada: **10%**
  - Central Asia: **10%**
- Wood combustion is sometimes dominant source of PM2.5, especially during heating season.
  - **Infiltration** is sometimes a problem, especially when temperatures are relatively higher (homes are not as tightly shut).
  - **High intake fractions** often observed during heating season, due to of population density, meteorology.

2. Local studies of residential heating PM2.5

Location	Estimated % contribution to ambient PM	Estimated ambient woodsmoke $PM_{2.5}$ (µg/m^3)
Christchurch, NZ	90% heating season $PM_{2.5}$ [SA]	
Tasmania, AUS	77% annual $PM_{2.5}$ [SA]	~20 (winter)
Armitage, AUS		200
San Jose, USA	42% heating season PM_{10} [SA]	
Atlanta, USA	11% annual $PM_{2.5}$	
Montana, USA	55 – 77% heating season $PM_{2.5}$ [SA]	7.0 – 11
Rural New York, USA		4 – 22
Rochester, NY	17% winter $PM_{2.5}$ [SA]	3.2
Seattle, USA	7 – 31% annual $PM_{2.5}$ [SA]	
Seattle, USA	~30% heating season $PM_{2.5}$ [SA]	4
Portland, USA	27% annual $PM_{2.5}$ [SA]	7
Fairbanks, USA	60-80% winter $PM_{2.5}$ [SA]	~25
Truckee, USA	11-15 winter $PM_{2.5}$ [SA]	
Las Vegas, USA	11 - 21 [SA] annual $PM_{2.5}$	
Vancouver, CANADA		8.8
Rural BC, CANADA		11 (heating season, 7-day average)
Austria	10 – 20% winter PM_{10} [SA]	
Southern GER	59% winter PM_{10} [SA]	
Duisberg, GER	13% autumn $PM_{2.5}$ [SA]	14.7 (range: 6.3 – 28.7)
Prague, CZ	37% heating season $PM_{2.5}$ [SA]	29.6 (range: 9.5 – 53.4)
Amsterdam, NL	11% heating season $PM_{2.5}$ [SA]	25.4 (range: 6.6 – 53.9)
Helsinki, FI	18 - 29% urban sites;	1 – 3
Helsinki, FI	17% heating season [SA]	11.9 (range: 6.9 -18.3)
Northern SWEDEN	36 -81% of winter PM_{10} [SA]	

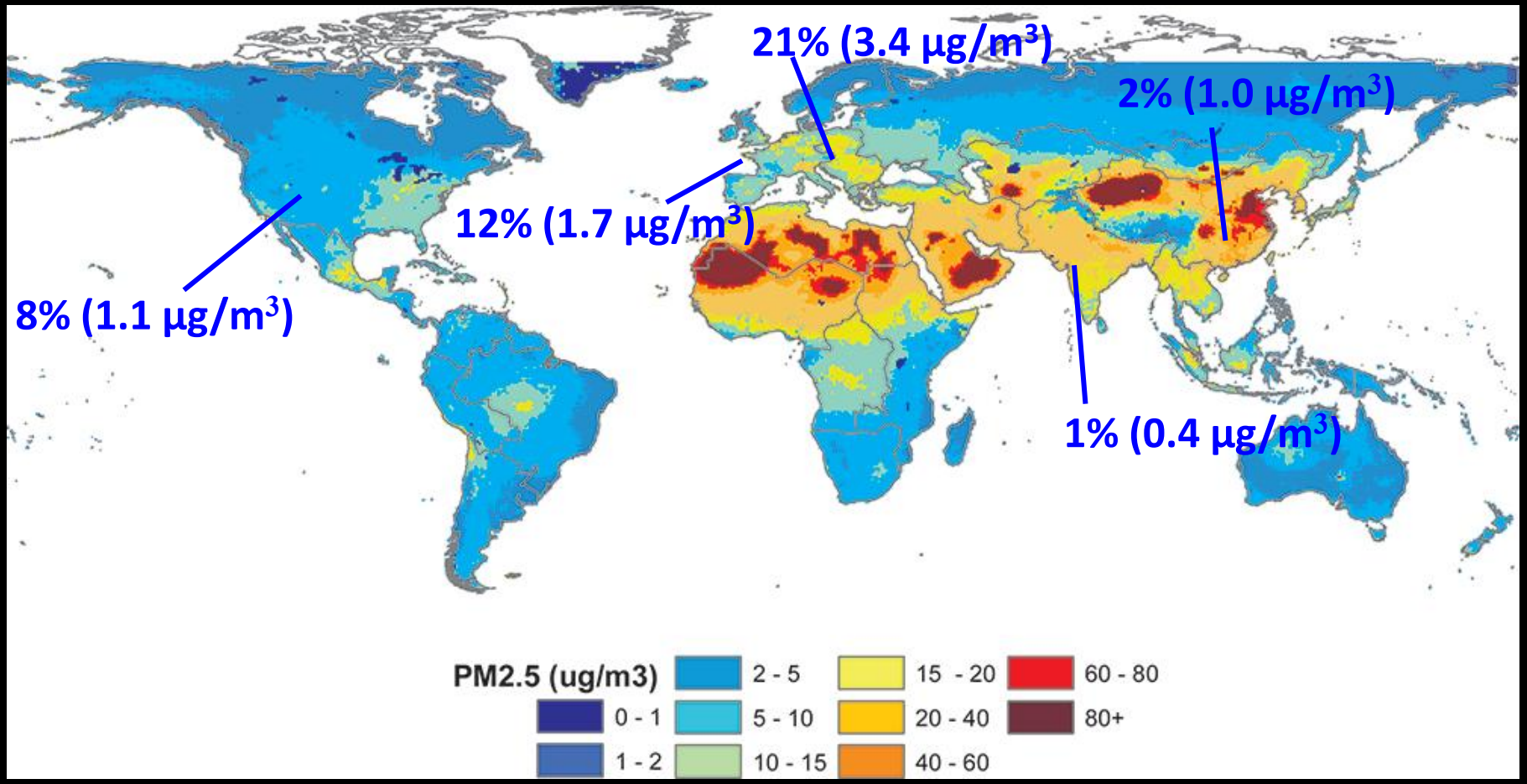
3. Is there evidence linking solid fuel heating emissions to health effects?

- Both short-term and long-term exposures to wood and coal smoke are harmful to health.
  - Contains cancer-causing compounds
  - Wood/coal smoke appears to act on human health in same way as PM from other sources (IARC: carcinogenic)
- Epidemiological studies: ambient levels of PM from wood combustion linked to respiratory diseases. Short-term exposure linked to cardiovascular health.
  - Relatively few studies conducted in developed countries
  - In developing countries, linked to pneumonia in children, chronic obstructive pulmonary disease in women, lung cancer
  - Some studies on other types of biomass combustion (forest fires, agricultural waste burning) show eye irritation, respiratory symptoms, hospitalizations (especially in vulnerable populations)

4. What is the burden of disease related to residential heating with wood and coal?

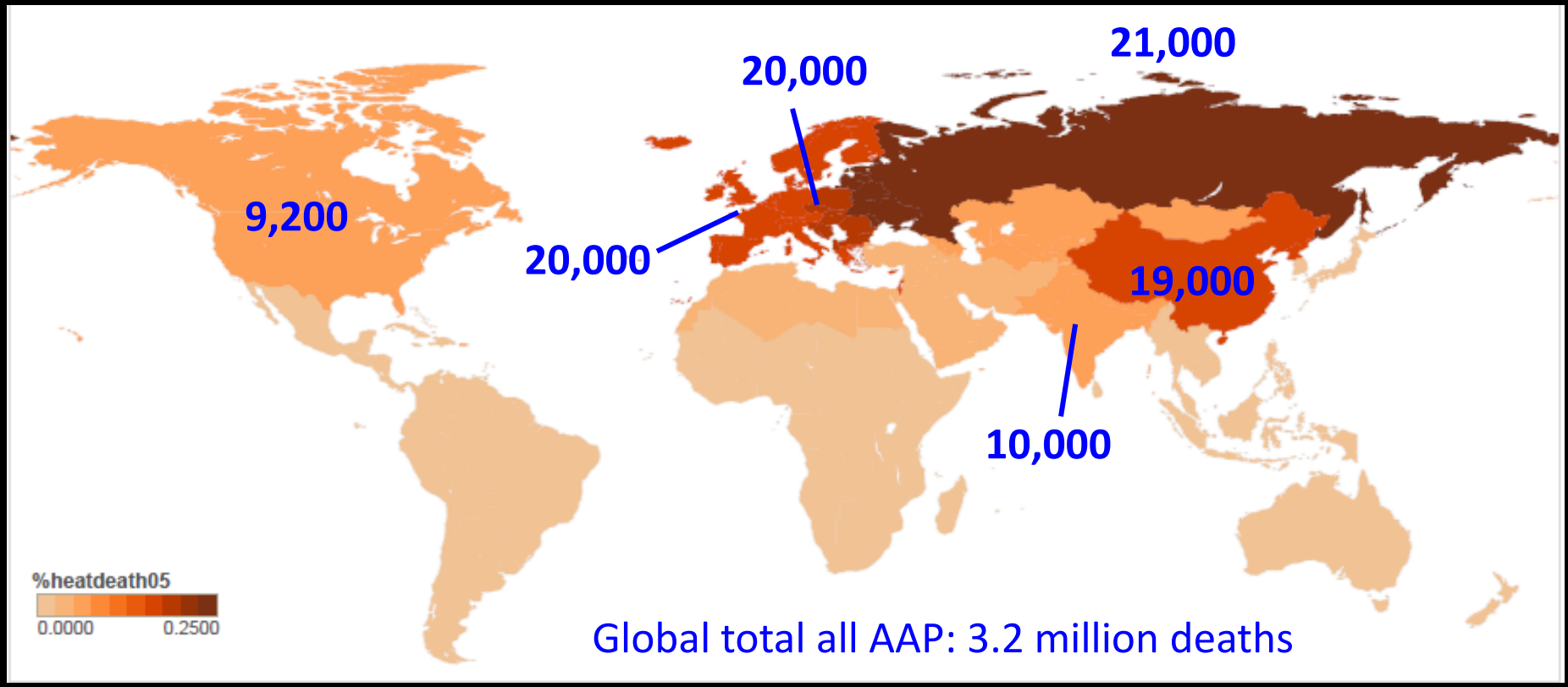
- Residential heating with wood/coal causes over 60,000 deaths each year in Europe, and 1 million DALYs (disability-adjusted life years).
- Also about 10,000 deaths in Canada/US, and 160,000 DALYs.
  - This is due to ambient air pollution exposure alone (not indoor exposure)
  - Calculated using estimates from GAINS, TM5-FASST, Global Burden of Disease
- Population-weighted annual average PM2.5 attributable to household heating with wood/coal:
  - 3.4 ug/m3 in Central Europe, 1.7 in Western Europe, 1.4 in Eastern Europe

Ambient air pollution (annual average PM2.5) From heating with solid fuels (2010)



Source: Brauer et al. (2012) Envir. Science & Tech; Chafe et al. (in preparation)

Global deaths from heating (through AAP) (by region, 2010)



Source: Brauer et al. (2012) Envir. Science & Tech; Chafe et al. (in preparation)

5. Have interventions reduced emissions, improved outdoor/indoor air quality, improved human health?

- Encouraging **fuel switching** and use of more efficient heating technologies can reduce emissions from heating devices, although results are inconsistent.
- Common interventions encourage installation of **certified woodstoves or heaters** or switching away from solid fuels.
  - Sometimes combined with education campaigns
- **Limitations** include high cost of new appliances, and long life of existing appliances.
- Studies included have been done in Australia, Canada, Ireland, and US.

6. What regulatory/voluntary measures can reduce emissions from wood heating in developed countries?

- **Eco-design** regulations and labels in EU: expected to lead to significant PM2.5 emissions from space heaters.
- **Technology-based emissions limits** in Europe (Austria, S… …ark, Germany), US and Canada.
  - …nment period for new woodstove
- A… …c…
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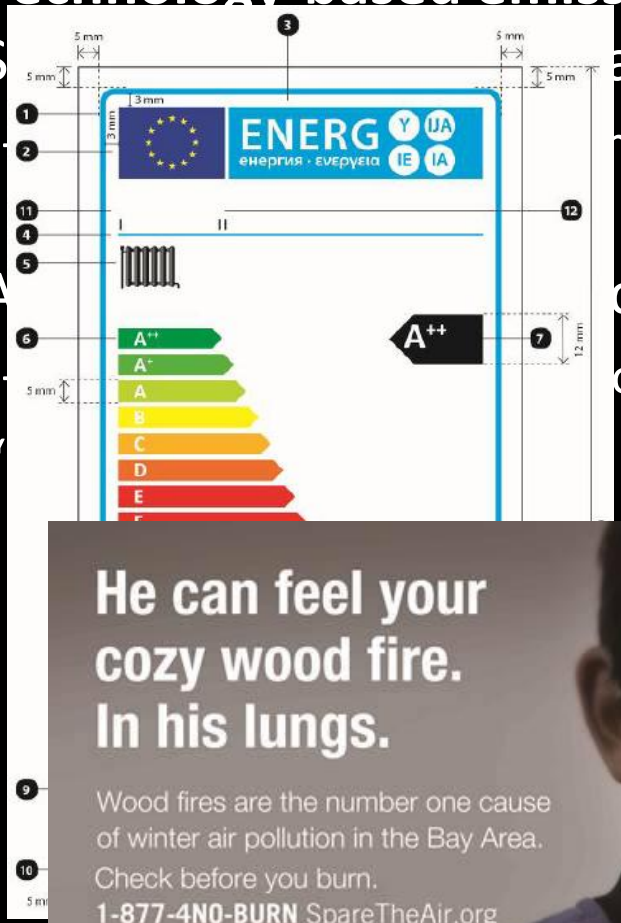

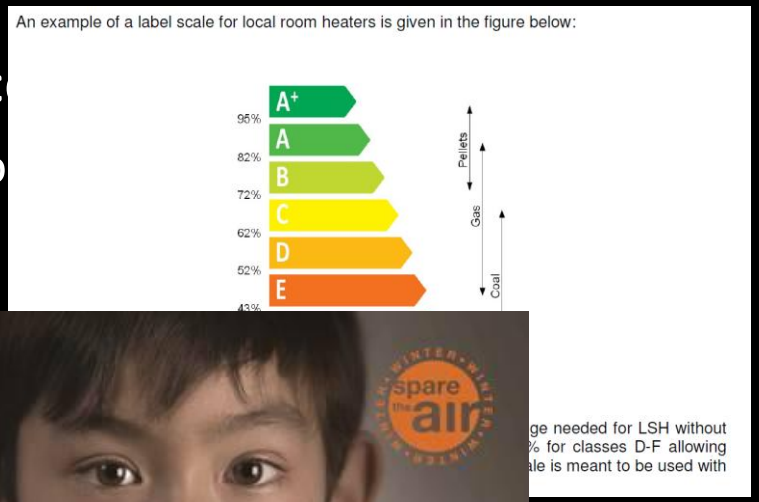

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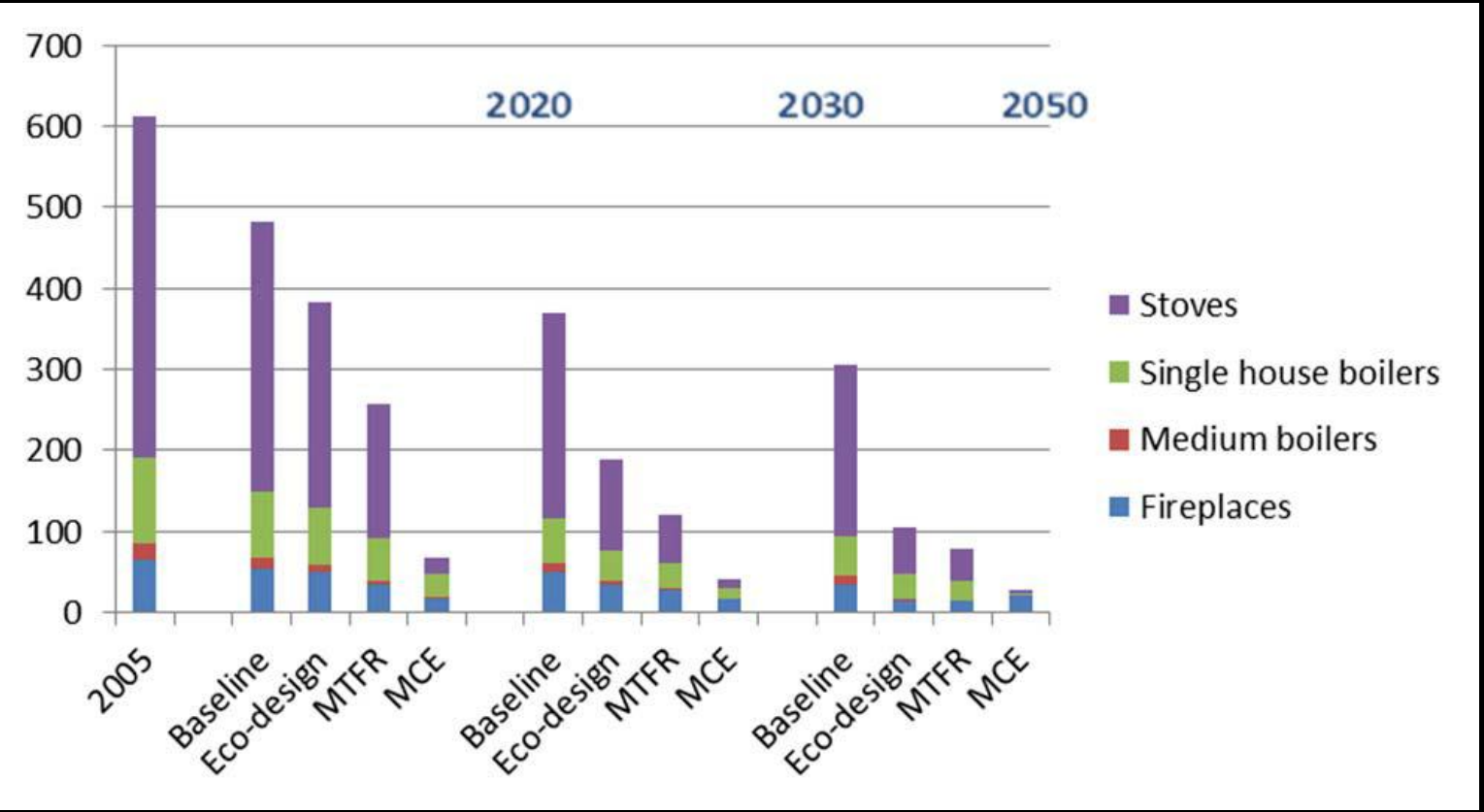

Figure 7 Impact of implementation of Eco-Design Directive on PM2.5 emissions from domestic combustion in the European Union (Cofala and Klimont, 2012).
MTFR = Maximum Technically Feasible Reduction
MCE = Maximum Control Efforts

7. What are some policy needs regarding future use of biomass for heating and energy production?

- Need for **better alignment** between climate change mitigation policies (especially that support wood combustion) and local air pollution policies.
- Need for tight, but technically achievable, **limits on primary emissions** from wood/coal heaters (to reduce BC).
- Need for greater understanding and implementation of regulations to encourage **energy efficiency.**
- Consider implementing **"no-burn" areas** and **"no-burn" days** where appropriate.
- Need for **information campaigns** about best practices for woodburning, proper upkeep of wood heaters, alternative heating fuels/appliance options.

8. What are the co-benefits for health & climate of reducing residential heating emissions?

- Co-benefits are "**win-win**" outcomes across sectors.
- Reducing emissions from residential heating can help air quality, mitigate climate change, and lead to better health, especially in the near-term.
- **Climate relevance**: if carbon is burned and released as BC or CH4, has major implications for climate.
- UNEP and WMO report advocates for dissemination of **pellet stoves** to replace current stoves/wood fuels.
  - Replacement of wood logs with pellets in Europe: 15% greater cooling in Arctic (0.1C)

9. Conclusions

- **Will be difficult to tackle outdoor air pollution problems** in many parts of the world without reducing emissions from household heating with wood/coal.
- **To protect health**, need for policy-makers to incentivize switching from solid fuel heating to gas- or electricity-based heating.
  - Or greatly improve efficiency of home wood combustion devices
  - Balance between climate implications of fossil fuel use and high current emissions of BC and CH4 from wood heating
- Climate-oriented policies that advocate for wood combustion should **promote only best available (lowest emission) technologies.**
  - Should consider local/regional air pollution implications

Timeline for completion of document

- May-June 2014: **Solicit comments/edits** from TFH members, co-authors and selected reviewers
- July 2014: **Prepare updated draft**
- September 2014: **Submit to UNECE** for translation/ distribution at LRTAP Convention Exec Body meeting (Dec 2014)
- Late 2014/Early 2015: **Submit to layout designer** for conversion to WHO brochure

Feedback requested

- Comments/suggestions on content and format?

Please feel free to contact me after the meeting:

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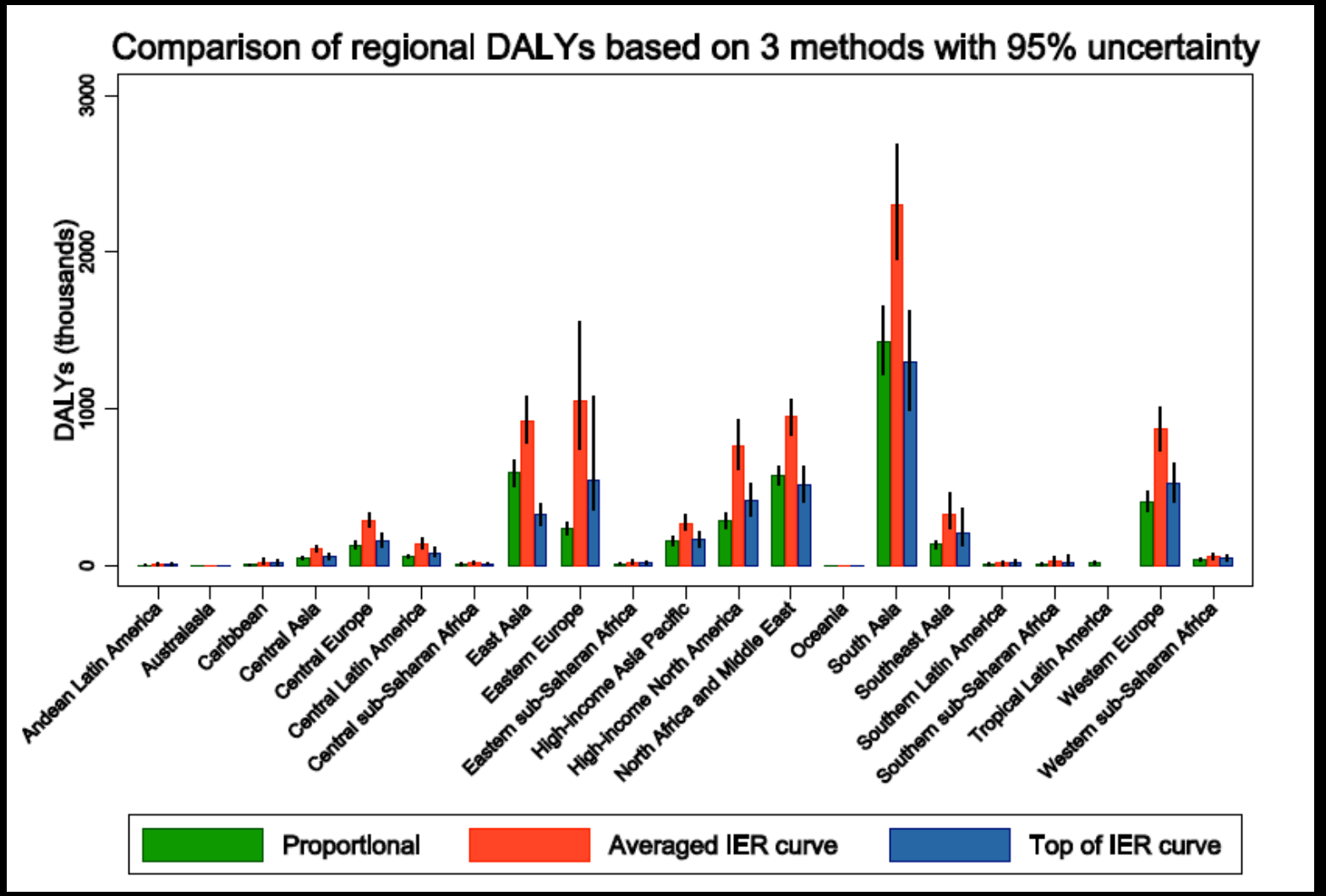
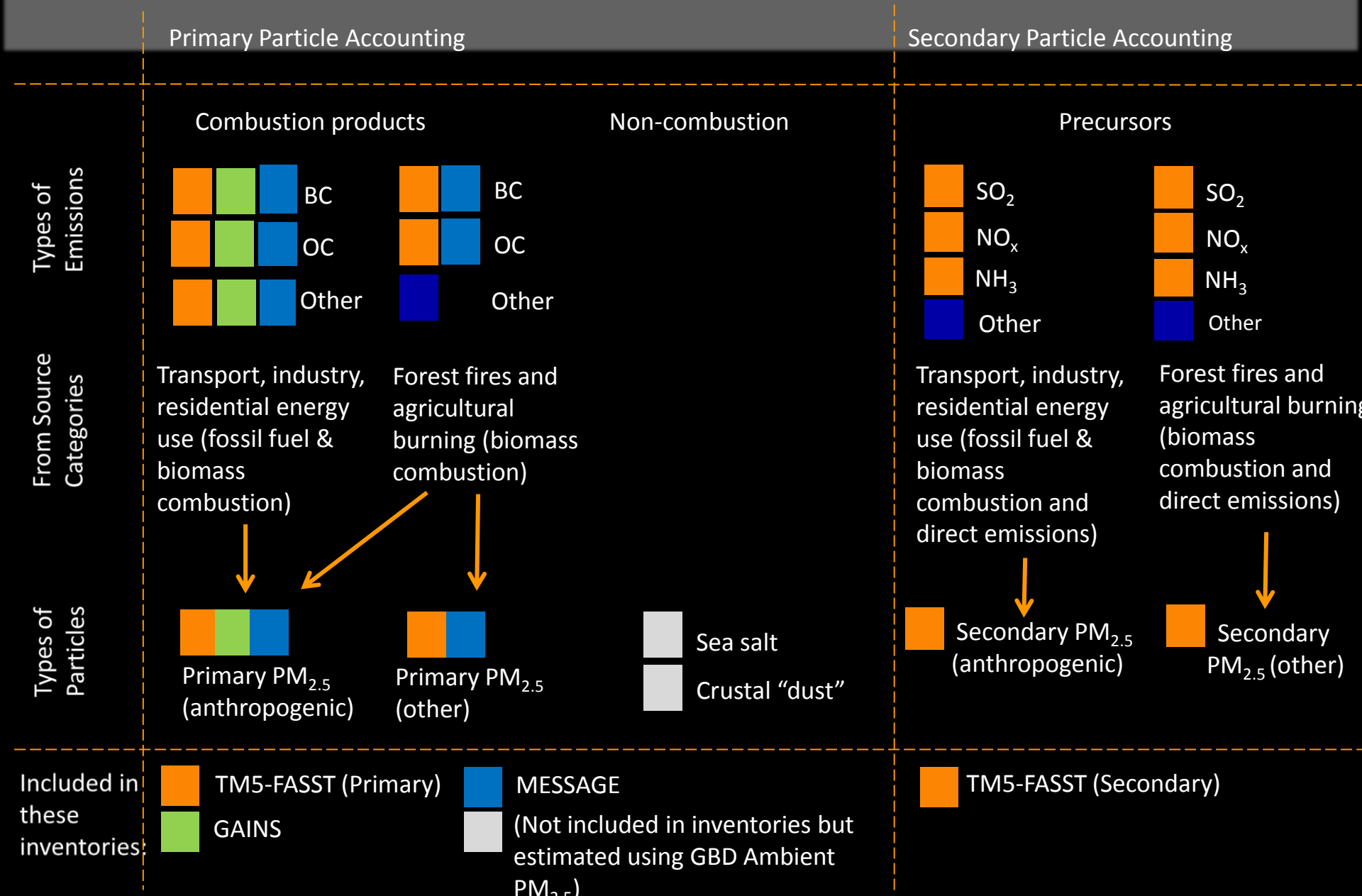
Image source: Brunekeef (Bulgaria 2009)

Method of calculating sector-specific burden from ambient air pollution GBD estimates

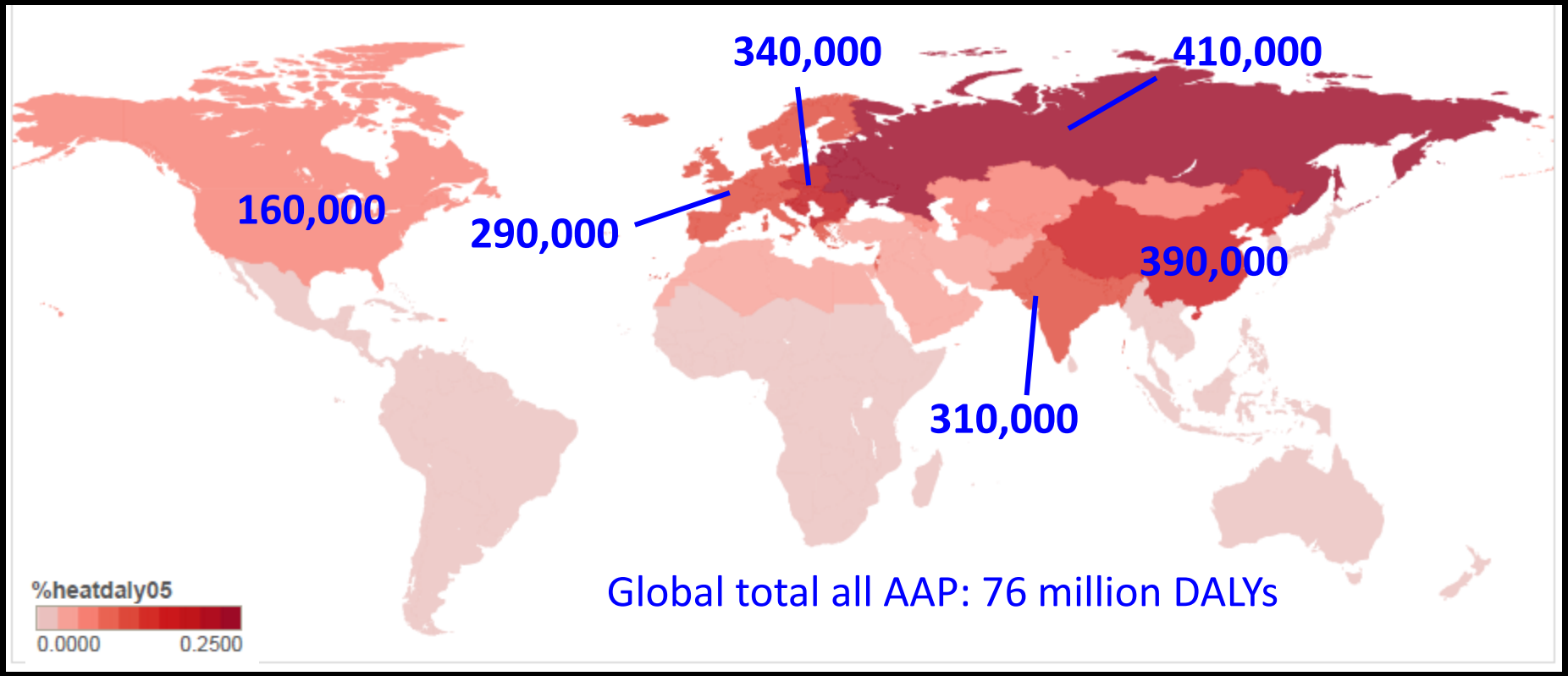


Source: World Bank (2014) Transport for Health: The Global Burden of Disease From Motorized Road Transport

Emission sources and particles covered in analysis

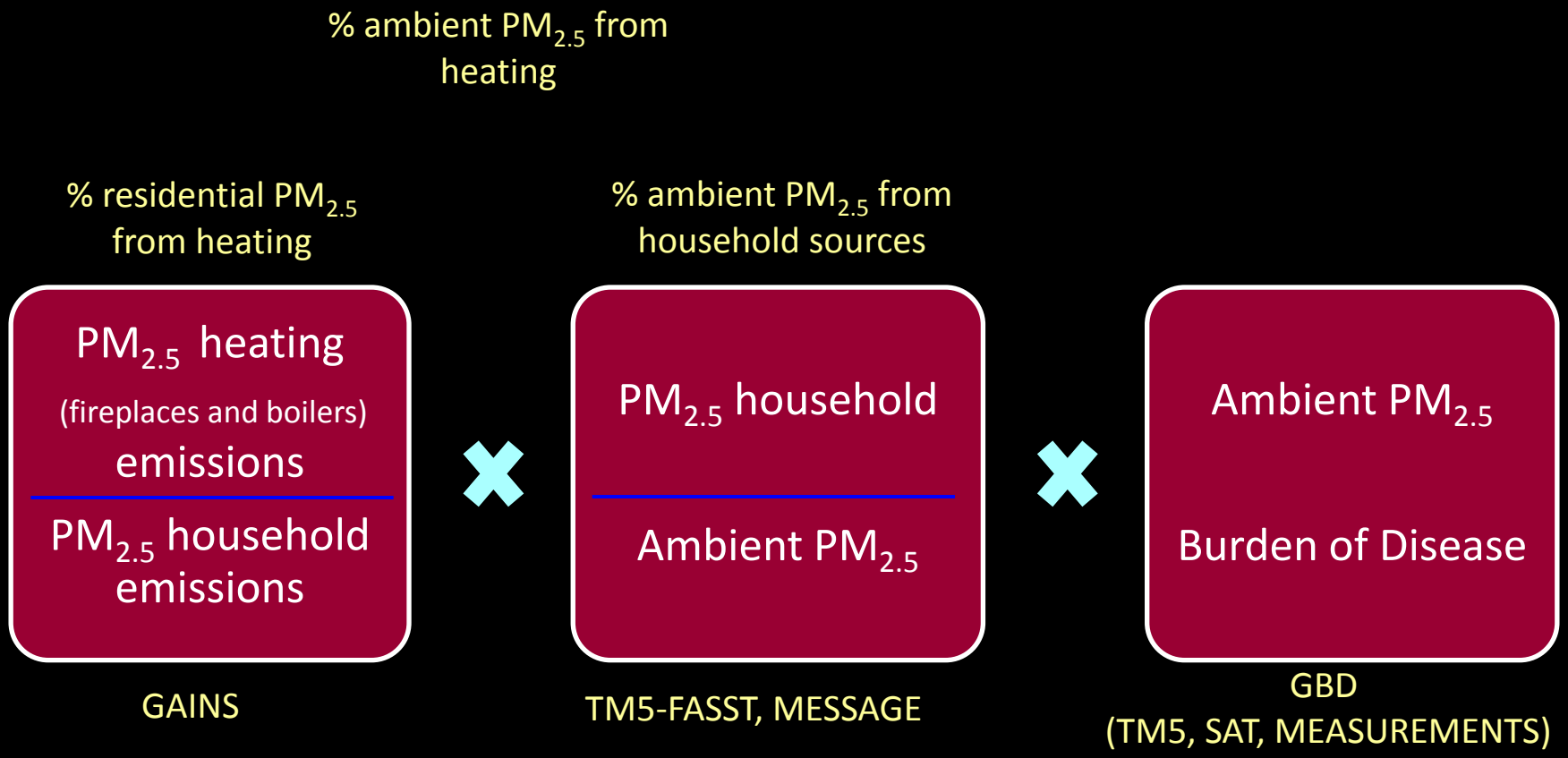


Global DALYs from heating (through AAP) (by region, 2010)



Source: Brauer et al. (2012) Envir. Science & Tech; Chafe et al. (in preparation)

Methods: calculating household heating / ambient $PM_{2.5}$



*District boilers (1-50MW) not included

Assumptions/caveats

- Household fuel use correctly split between commercial and home use.
- Escape fraction assumed to be 100%.
- All particulates attributed to household emissions are from local households (no significant input from atmospheric transport).
- Spatial misalignment is probable—using national emission totals, but heating emissions are spatially heterogeneous.
- Still much to be done to truly understand biomass fuel use at the household level, especially for heating. Need for better data.

Main points (Recap)

- Residential biomass combustion for space heating is a major source of ambient PM2.5 and BC across Europe (north and south) and in temperate forested countries on other continents.
- Household wood combustion for heating seems to be increasing in some countries due to alternative energy costs and perception as “green” option.
- As emissions from other sources go down, residential biomass combustion expected to gain prominence as a source.
- Will be hard to reach WHO AQG in some countries (especially in winter) without addressing wood burning
- Advanced “cleaner” stoves not yet widely used

Global Burden of Disease Project (2012)

Articles

A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010

Stephen S Lim†, Theo Vos, Abraham D Flaxman, Goodarz Danaei, Kenji Shibuya, Heather Adair-Rohani, Markus Amann, H Ross Anderson, Kathryn G Andrews, Martin Aryee, Charles Atkinson, Loraine J Bacchus, Adil N Bahalim, Kalpana Balakrishnan, John Balmes, Suzanne Barker-Collo, Amanda Baxter, Michelle L Bell, Jed D Blore, Fiona Blyth, Carissa Bonner, Guilherme Borges, Rupert Bourne, Michel Boussinesq, Michael Brauer, Peter Brooks, Nigel G Bruce, Bert Brunekreef, Claire Bryan-Hancock, Chiara Bucello, Rachelle Buchbinder, Fiona Bull, Richard T Burnett, Tim E Byers, Bianca Calabria, Jonathan Carapetis, Emily Carnahan, Zoe Chafe, Fiona Charlson, Honglei Chen, Jian Shen Chen, Andrew Tai-Ann Cheng, Jennifer Christine Child, Aaron Cohen, K Ellicott Colson, Benjamin C Cowie, Sarah Darby, Susan Darling, Adrian Davis, Louisa Degenhardt, Frank Dentener, Don C Des Jarlais, Karen Devries, Mukesh Dherani, Eric L Ding, E Ray Dorsey, Tim Driscoll, Karen Edmond, Suad Eltahir Ali, Rebecca E Engell, Patricia J Erwin, Saman Fahimi, Gail Falder, Farshad Farzadfar, Alize Ferrari, Marlid M Finucane, Seth Flaxman, Francis Gerry R Fowkes, Greg Freedman, Michael K Freeman, Emmanuela Gakidou, Santu Ghosh, Edward Giovannucci, Gerhard Gmel, Kathryn Graham, Rebecca Grainger, Bridget Grant, David Gunnell, Hialy R Gutierrez, Wayne Hall, Hans W Hoek, Anthony Hogan, H Dean Hosgood III, Damian Hoy, Howard Hu, Bryan J Hubbell, Sally J Hutchings, Sydney E Ibeanusi, Gemma L Jacklyn, Rashmi Jasrasaria, Jost B Jonas, Haidong Kan, John A Kanis, Nicholas Kassebaum, Norito Kawakami, Young-Ho Khang, Shahab Khatibzadeh, Jon-Paul Khoo, Cindy Kok, Francine Laden, Ratilal Lalloo, Qing Lan, Tim Lathlean, Janet L Leasher, James Leigh, Yang Li, John Kent Lin, Steven E Lipshultz, Stephanie London, Rafael Lozano, Yuan Lu, Joelle Mak, Reza Malekzadeh, Leslie Mallinger, Wagner Marcenes, Lyn March, Robin Marks, Randall Martin, Paul McGale, John McGrath, Sumi Mehta, George A Mensah, Tony R Merriman, Renata Micha, Catherine Michaud, Vinod Mishra, Khayriyyah Mohd Hanafiah, Ali A Mokdad, Lidia Morawska, Dariush Mozaffarian, Tasha Murphy, Mohsen Naghavi, Bruce Neal, Paul K Nelson, Joan Miquel Nolla, Rosana Norman, Casey Olives, Saad B Omer, Jessica Orchard, Richard Osborne, Bart Ostro, Andrew Page, Kiran D Pandey, Charles D H Parry, Erin Passmore, Jayadeep Patra, Neil Pearce, Pamela M Pelizzari, Max Petzold, Michael R Phillips, Dan Pope, C Arden Pope III, John Powles, Mayuree Rao, Homie Razavi, Eva A Rehfuess, Jürgen T Rehm, Beate Ritz, Frederick P Rivara, Thomas Roberts, Carolyn Robinson, Jose A Rodriguez-Portales, Isabelle Romieu, Robin Room, Lisa C Rosenfeld, Ananya Roy, Lesley Rushton, Joshua A Salomon, Uchechukwu Sampson, Lidia Sanchez-Riera, Ella Sanman, Amir Sapkota, Soraya Seedat, Peilin Shi, Kevin Shield, Rupak Shivakoti, Gitanjali M Singh, David A Sleet, Emma Smith, Kirk R Smith, Nicolas J C Stapelberg, Kyle Steenland, Heidi Stöckl, Lars Jacob Stovner, Kurt Straif, Lahn Straney, George D Thurston, Jimmy H Tran, Rita Van Dingenen, Aaron van Donkelaar, J Lennert Veerman, Lakshmi Vijayakumar, Robert Weintraub, Myrna M Weissman, Richard A White, Harvey Whiteford, Steven T Wiersma, James D Wilkinson, Hywel C Williams, Warwick Williams, Nicholas Wilson, Anthony D Woolf, Paul Yip, Jan M Zielinski, Alan D Lopez†, Christopher J L Murray†, Majid Ezzati†

Lancet 2012; 380: 2224–60

See Comment pages 2053, 2054, 2055, 2058, 2060, 2062, and 2063

See Special Report page 2067

See Articles pages 2071, 2095, 2129, 2144, 2163, and 2197

*Author listed alphabetically

†Joint senior authors

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See Online for appendix

For interactive versions of figures 3, 4, and 6 see http://healthmetricsandevaluation.org/gbd/visualizations/regional

Institute for Health Metrics and Evaluation (S S Lim PhD, A D Flaxman PhD, K G Andrews MPH, C Atkinson BS, E Carnahan BA, K E Colson BA, R E Engell BA, G Freedman BA, M K Freeman BA, E Gakidou PhD, R Jasrasaria BA, ...

Summary

Background Quantification of the disease burden caused by different risks informs prevention by providing an account of health loss different to that provided by a disease-by-disease analysis. No complete revision of global disease burden caused by risk factors has been done since a comparative risk assessment in 2000, and no previous analysis has assessed changes in burden attributable to risk factors over time.

Methods We estimated deaths and disability-adjusted life years (DALYs; sum of years lived with disability [YLD] and years of life lost [YLL]) attributable to the independent effects of 67 risk factors and clusters of risk factors for 21 regions in 1990 and 2010. We estimated exposure distributions for each year, region, sex, and age group, and relative risks per unit of exposure by systematically reviewing and synthesising published and unpublished data. We used these estimates, together with estimates of cause-specific deaths and DALYs from the Global Burden of Disease Study 2010, to calculate the burden attributable to each risk factor exposure compared with the theoretical-minimum-risk exposure. We incorporated uncertainty in disease burden, relative risks, and exposures into our estimates of attributable burden.

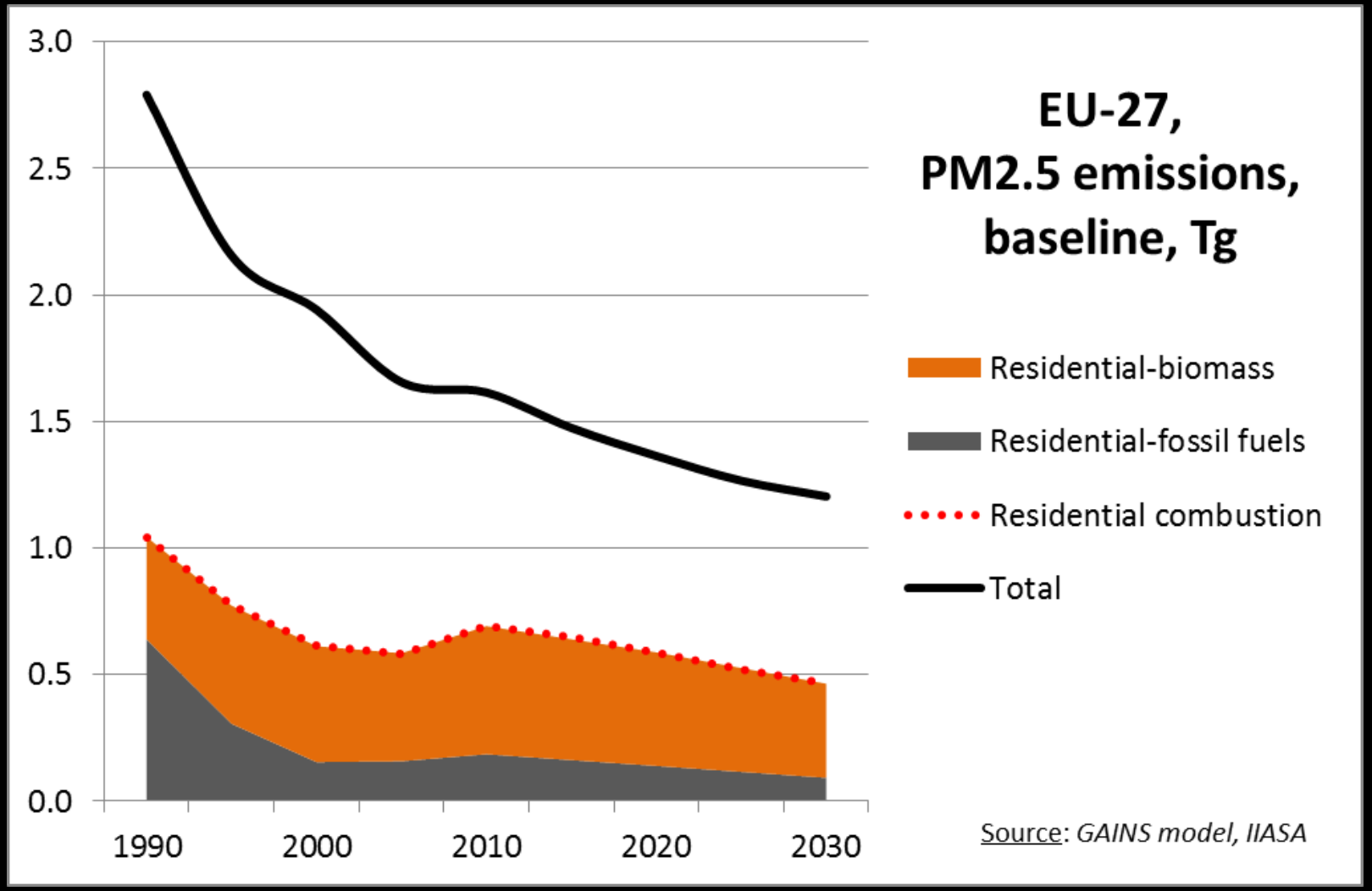
Findings In 2010, the three leading risk factors for global disease burden were high blood pressure (7·0% [95% uncertainty interval 6·2–7·7] of global DALYs), tobacco smoking including second-hand smoke (6·3% [5·5–7·0]), and alcohol use (5·5% [5·0–5·9]). In 1990, the leading risks were childhood underweight (7·9% [6·8–9·4]), household air pollution from solid fuels (HAP; 7·0% [5·6–8·3]), and tobacco smoking including second-hand smoke (6·1% [5·4–6·8]). Dietary risk factors and physical inactivity collectively accounted for 10·0% (95% UI 9·2–10·8) of global DALYs in 2010, with the most prominent dietary risks being diets low in fruits and those high in sodium. Several risks that primarily affect childhood communicable diseases, including unimproved water and sanitation and childhood micronutrient deficiencies, fell in rank between 1990 and 2010, with unimproved water

effect worldwide—attributable global DALYs decreased by 2%—but large effects in north Africa and Middle East. Household air pollution is an important contributor to ambient particulate matter pollution; we estimate that it accounted for 16% of the worldwide burden from ambient particulate matter pollution in 2010. The effects of ambient ozone pollution, which increases the risk of chronic obstructive pulmonary disease, were smaller than those of household air pollution from solid fuels or ambient particulate matter

Source: Lim et al. (2012) *Lancet*

EU-27 PM2.5 emissions, Tg

Highlighting the role of residential combustion



Source: GAINS model (IIASA); baseline energy scenario from the PRIMES model

Global PM2.5 emissions, Tg

Highlighting the role of residential combustion

Source: GAINS model (IIASA); Baseline energy scenario from the World Energy Outlook 2011 (IEA)