



Bioenergy and air pollution: Health effects

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Presentation contents

- CAFE assessment of PM_{2.5}-associated health impacts in Europe
- NMR/HLG and ERANET concerted actions on particulate air pollution, biomass combustion and health
- Highlights from Finnish interdisciplinary scientific research on biomass combustion emissions and wild-fire smoke episodes and their impacts on urban air pollution and health
- Recommendations from the NMR/HLG and ERANET concerted actions



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Why is there a need for strict control of particulate air pollution?

- **Fine particulate matter (PM_{2.5}; diameter ≤ 2.5 μm) causes the largest disease burden of all environmental factors to the European populations**
 - **Current long-term PM_{2.5} exposures** associated with **~350 000 premature annual deaths**, hospital admissions, and restricted activity in tens of millions of children and subjects with chronic cardiovascular or pulmonary disease in the EU25 (CAFE 2005)
 - **No clear threshold for health effects** at low daily average PM₁₀/PM_{2.5} concentrations (< 5 μg/m³), and **even 1-hour peak concentrations** associated with severe respiratory and cardiac events
 - **Ultrafine particles (diameter ≤ 0.1 μm) and coarse thoracic particles (PM_{10-2.5}; diameter 2.5-10 μm)** associated with health effects that are independent of concurrent PM_{2.5} levels



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EU-CAFE assessment on the health impacts of PM_{2.5} in the EU25 in 2000 (population ~450 million)

● Premature death cases	347 900
● Life years lost	3 618 700
● Infant death cases	677
● New cases of chronic bronchitis	163 800
● Hospital admission cases (heart + lung)	100 300
● Lower respiratory symptom days (5-14 y)	192 756 400
● Restricted activity days (15-64 y)	347 687 000
● Value of health damage	268 - 781 billion € / year



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CAFE assessment on health impacts of PM_{2.5} in three Nordic countries (2000) (population ~20 million)

● DK: premature death cases	3 270
● FI: premature death cases	1 270
● SE: premature death cases	3 280
● New cases of chronic bronchitis	3 510
● Hospital admission cases (lung + heart)	2 143
● Lower respiratory symptom days (5-14 y)	> 4.4 million
● Restricted activity days in adults (15-64 y)	> 7.2 million
● Value of health damage	5,8 – 17,6 billion € / year



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Which sources and chemical compositions are the most hazardous to health?

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- **Epidemiological evidence of variable strength on the harmfulness** of traffic exhaust, small-scale coal and wood combustion, locally or transnationally transported wild-fire and resuspended road dust particles
 - **Reasonably strong epidemiological evidence on soot (EC/BC)**; suggestive toxicological evidence on transition metals (e.g. Cu, Ni, V, Fe, Zn), PAH-compounds, quinones and soil minerals
 - Epidemiological and toxicological studies suggest that PM compositions originating from the same combustion source may have **different impacts on air quality and health in different climates and seasons** (e.g. via transformation of the organics)
 - Epidemiological and toxicological studies suggest that **fresh PM compositions from local combustion sources may be more potent per mass unit** than the aged compositions from regional and long-range transport



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NORDAIR concerted action project

- **Funding:** NMR Sea and Air Group in May 2004 - Dec 2005
- **Project team:** Raimo O. Salonen (FI), Marko Vallius (FI), Tom Bellander (SE), Bertil Forsberg (SE), Hans C Hansson, (SE), Risto Hillamo (FI), Steffen Loft (DK), Finn Palmgren (DK), Göran Pershagen (SE) and Per E. Schwarze (N)
- **Work content:** (1) **Inventory of major on-going research projects** on urban air pollution and health in Nordic countries, (2) Recognition of **the most important Nordic aspects** in this area for policy-making and new research, and (3) Proposal of **an area of the highest priority** for Nordic collaborative action



NORDAIR recommendations on high priority areas for Nordic research and policy-making

- Traffic-derived combustion PM in cold climate
- Road dust and other traffic-related non-exhaust PM
- **Small-scale wood burning and other biomass combustion aerosols**
- Impacts of long-range transported pollutants



NORDAIR-BIOS concerted action project

- **Funding:** Nordic Council of Ministers, Sea and Air Group in Aug 2005 – Dec 2006
- **Steering Group:** Raimo O. Salonen (FI), Marko Vallius (FI), Bertil Forsberg (SE), Finn Palmgren (DK), Per E. Schwarze (NO)
- **Participants:** 18 Nordic biomass emission, air quality and health researchers, 1 air quality expert from USA (G Allen), 1 emission expert from Austria (I Obernberger) and 5 administrators as observers
- **Work content:** (1) Wood combustion aerosols from residential heating and transnationally transported biomass combustion aerosols, and (2) Science-based recommendations for reduction of air quality and health impacts & identification of gaps in scientific knowledge



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BIOMASS-PM concerted action project

- **Funding:** ERANET Bioenergy Programme 1/2007-9/2008
- **Steering group members and country coordinators:** Jorma Jokiniemi (FI), Kati Hytönen (FI), Ingwald Obernberger (AT), Raimo O. Salonen (FI) and Christoffer Boman (SE)
- **Participants:** A total of 33 scientists from 10 emission, air quality and health research teams from Finland, Austria, Germany and Sweden
- **Objectives:** (1) Strengthen interdisciplinary scientific evidence on the advantages of new combustion technologies and after-treatment in small-scale biomass heating systems, and (2) Determination of feasible methods for particle emission measurements, sampling and physicochemical & toxicological characterisation

Website: www.biomasspm.fi

- Final report and presentations of final dissemination workshop



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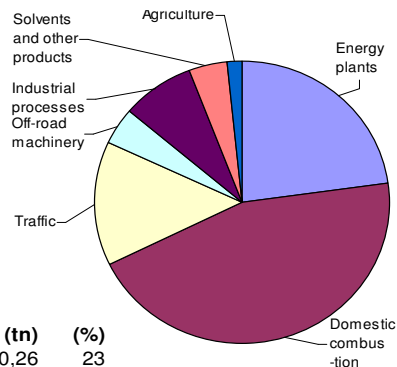


Bioenergy and emissions

- Bioenergy use is promoted in **decentralised heating systems**, but they are currently less energy efficient and cause more air quality problems than large power plants
 - Domestic wood combustion is responsible for **25% of all PM_{2.5} emissions**, 65% of PAH emissions and 25% of all NMVOC emissions in Finland – situation similar to many other EU-countries (Karvosenoja 2004; Karvosenoja et al. 2008)
 - The main reasons for large PM_{2.5} emissions from domestic heating appliances (commonly 20 kW) are **poor combustion technology, poor biomass fuel quality and operational errors of the users** (e.g., overloading, restriction of air supply)
 - **Small heating plants** (commonly 20 MW) using biomass, peat or heavy fuel oil have **no obligation to use the most efficient flue gas after-treatment technology** - no PM emission limits!



Assessed contribution of wood combustion is ~25% to the total PM_{2.5} emissions in Finland (Karvosenoja et al. 2008)



PM _{2.5} emissions in 2005	(tn)	(%)
Energy plants	7740,26	23
Domestic combustion	15359,71	45
Traffic	4930,24	14
Off-road machinery	1356,00	4
Industrial processes	2804,70	8
Solvents and other products	1398,72	4
Agriculture	560,04	2
Other	12,27	0
Sum	34161,93	100



Residential biomass heating → air quality → health

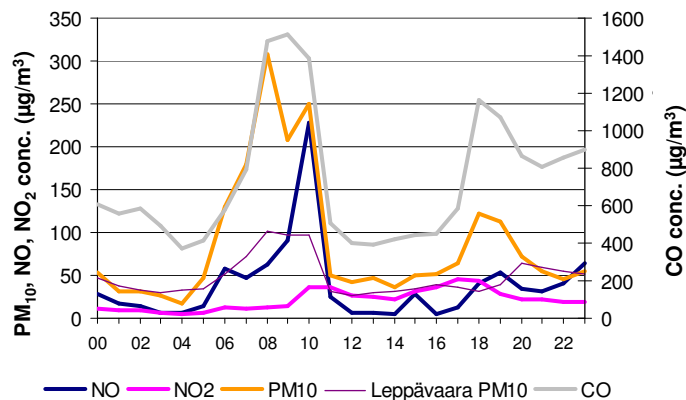
- **A high probability of elevated exposures** in the neighbourhoods to **PM₁₀, PM_{2.5}, PAH, CO** and **NMVOC**
- **Release of combustion emissions from domestic heating appliances and small power plants is close to the ground:**
 - Poor aerosol mixing in cold season days leads to elevated local outdoor pollutant concentrations ⇒ **penetration indoors**
 - Use of domestic heating appliances most active in the evenings, when also the neighbours are at home
- **Little research done until now on air quality problems, and the human exposure and health effects related to poor biomass combustion in residential areas**
 - **Increased asthma attacks** have been reported as reviewed by Boman et al. (2003) and Naeher et al. (2007)

Are these particulate compositions as harmful to the health of children and cardiac patients as those from traffic exhaust?



Residential biomass heating and air quality

Lintuvaara, Espoo, Finland 13.10.2005



One day with weak winds: higher PM₁₀ concentrations than with busy traffic in Leppävaara (Espoo) or Helsinki downtown (YTV, Helsinki, 2006)



Experimental human and animal studies on biomass combustion emissions

- **Controlled acute exposures of human subjects to diluted combustion emissions in exposure chamber to answer few, selected scientific questions** (Barregård et al. 2007; Sandström et al.)
 - Monitoring of respiratory and cardiovascular functions, and biochemical response markers in a limited number of experiments
 - Mild inflammation and increased blood coagulation reported
- **Controlled acute, subacute and subchronic exposures of animals (rats, mice) to aerosolized or liquid-suspended emission particles from biomass combustion to answer a somewhat larger number of selected scientific questions** (see e.g. Zelikoff et al. 2002)
 - Monitoring of respiratory and cardiovascular functions, biochemical response markers, and structural changes in the lungs
 - Mild inflammation, decreased host defence against bacterial infections etc. reported



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Experimental cell studies on biomass combustion emissions

- **Controlled exposures of key target cells (macrophages, epithelial cells) of the respiratory tract to liquid-suspended emission particles from biomass combustion to answer a larger number of scientific questions** (see, e.g. Zelikoff et al. 2002) **and to aid technological development of combustion installations**
 - Measurement of biochemical markers of a **wide range of mechanistic health end points** (inflammation, genotoxicity, cytotoxicity, cell cycle) in mammalian cells
 - **Inflammatory and cytotoxic activities** of air particles are anticipated to be linked with the non-carcinogenic respiratory and cardiovascular effects, and **genotoxic activity** with the lung cancer risk among human subjects
 - Increased inflammatory activity, cell death and genotoxicity, and cell cycle arrest reported



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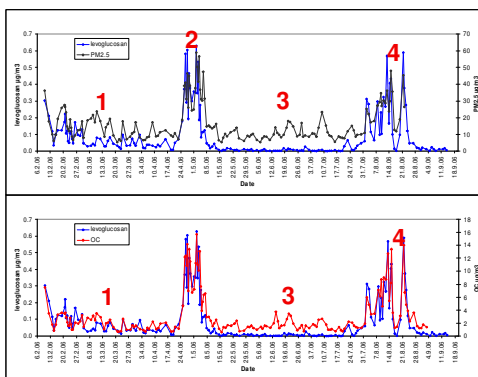
Wildfire smoke episodes 1

- **Smoke-haze episodes from forest, bush and peat fires are common features in Southern and Northern Europe**
 - **Incomplete biomass combustion** gives rise to large amounts of potentially harmful particulate (PM_{2.5}, PAH) and gaseous (CO, NMVOC) emissions
 - **The combustion-derived pollutants** can episodically cause profound increases in PM₁₀ and PM_{2.5} concentrations, and in the carbonaceous composition of the particulate mass
 - **The smoke-haze episodes** appear annually in certain months and can last for weeks each time, and the episodes are likely to become more prevalent with climate change in Europe
 - ⇒ **Smoke aerosols affect populations not only locally but also at distances hundreds or thousands of kilometres away**
 - ⇒ **Premature deaths of about 10 subjects with cardiorespiratory disease per typical episode week** has been estimated for southern Finland (Hänninen et al. 2009)



Wildfire smoke episodes 2

Helsinki, Finland – annual data 2006 by FMI



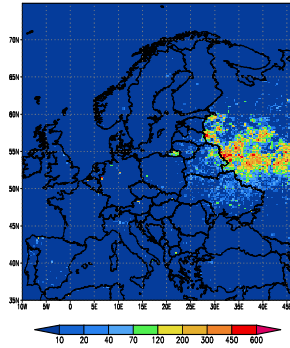
The impacts of (1) local small-scale wood combustion and (2 and 4) episodes of wild fire smoke on the PM_{2.5} (upper panel) and organic carbon (lower panel) concentrations were identified with the help of specific marker – levoglucosan (blue lines); (3) the low biomass-smoke June-July (Saarnio et al., submitted).



Wildfire smoke episodes 3

Helsinki, Finland – 10 August 2006

Emission derived from MODIS tempr.anomaly,tons_PM
Total 20.4-15.5.2006



The location of wildfires and their emissions can be assessed from satellite images, and the transportation of smoke-haze can be modelled (Saarikoski et al., 2007).



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NORDAIR-BIOS recommendation on wildfire smoke episodes

- **National internet portals** should be established for presentation and instantaneous dissemination of on-line air quality data collected from continuously operating local monitoring networks in order to facilitate **early detection of regional episodes of particulate air pollution** caused by transnational transport of forest fire or wildfire smoke-haze
 - **Early warning of the susceptible population groups** such as elderly subjects with chronic cardiovascular or respiratory disease and asthmatic subjects of all ages
 - The National Reference Laboratories of Air Quality Monitoring in the Nordic countries are recommended to **share on-line with each other their pooled on-line air quality data**



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NORDAIR-BIOS & BIOMASS-PM recommendations on small-scale systems

Measures have to be implemented to reduce PM emissions from residential biomass combustion systems:

- The future increase in biomass energy should be primarily made in **community-level plants with high-quality controls** for the combustion process and emissions
- **Substitution of old residential combustion devices** by modern low emission systems should be promoted
- Provision of appropriate **“user training” for non-automatically fed systems** (stoves/boilers)
- Support of **R&D of low-dust combustion technologies**
- Support of **R&D and application of appropriate filter technologies** for residential biomass combustion systems
- **Emission limits and test standards** should be harmonized on a European level



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BIOMASS-PM research needs 1

- **More information on the impact of real-life user practices on particulate emissions** is needed as well as on the overall impact of small-scale biomass combustion emissions on **local and regional air quality**
- **More information is needed about the association between different kinds of particulate matter emissions from biomass combustion installations and their adverse health effect potential** as assessed by experimental human and animal studies



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BIOMASS-PM research needs 2

- **Cell studies should provide a generic concept** on the association of inorganic and organic chemical constituents with the inflammatory, cytotoxic and genotoxic activities of particulate emissions from a series of combustion technologies and biofuels
- **Interdisciplinary research** between the aerosol scientists and epidemiologists:
 - New short-term panel studies with personal exposure monitoring and source-specific exposure modelling are needed
 - GIS-based cohort studies on chronic respiratory and cardiovascular diseases and cancer are needed

