Cost-efficient reduction of population exposure caused by primary PM$_{2.5}$ emissions in Finland (#66)

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  • Reduction of emissions
  • Reduction of population exposure

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Fine particulate matter (PM$_{2.5}$) in Finland

Finland:

- Land area 340,000 km$^2$, population 5.4 million, low population density
- Low annual average concentrations of PM$_{2.5}$

Source: ETC/ACC, Leeuw, Horálek 2009

Greater Helsinki Area: Population 1.3 million
Components of PM concentrations in Europe vs Finland

**Modeling resolutions and components of PM concentrations:**
- 50km: Regional background (Urban background)
- 10km: Regional/Urban background
- 1km: Urban background / Local sources

**In Finland vs Central Europe:**
- lower regional/urban background
- strong local sources (e.g. domestic wood combustion, traffic spring/winter suspension)

Contribution to average winter/autumn concentrations 20% in Helsinki
(Saarikoski et al. Water Air Soil Pollut 2008 191:265-277)

Major source for PM$_{10}$, significant also in PM$_{2.5}$ in spring/winter time
Methodology
Finnish Regional Emission Scenario (FRES) model
part of the Finnish Integrated Assessment Modeling (IAM) framework

EMEP / IIASA:
- European emissions
- Long-range transport (LRT)

Finnish Meteorol. Inst. (FMI):
- Dispersion modelling FIN
  (e.g. SILAM, UDM-FMI)

Kuopio university, VTT etc.
- Emission measurements

Technical Research Center of Finland (VTT)
- FIN activity projections
  (e.g. MARKAL/TIMES)

FRES-model, SYKE

Emission module
- Emission factors, emission control technologies and costs
- Emission scenarios
- Activity pathways

Dispersion module
- Source-receptor matrices (FIN and LRT)
- Air pollution concentrations and depositions

Effect module
- PM and ozone exposure and health effects
- Critical load exceedances

Emission reduction requirements

Finnish Nat. Institute for Health and Welfare (THL):
- Health risk assessment PM
Finnish Regional Emission Scenario (FRES) model

www.environment.fi/syke/pm-modeling


- Comprehensive and congruent calculation for primary PM and gases
  - primary PM (TSP, PM$_{10-2.5}$, PM$_{1-0.1}$, chemical composition, incl. BC/OC/sulfates)
  - SO$_2$, NO$_x$, NH$_3$, NMVOCs
  - GHGs

- Abatement technologies and costs

- Aggregation: 154 sectors, 15 fuels (GAINS compatible)

- Large point sources (>200), small point sources (> 200), area emissions (1 $\times$ 1km$^2$)

- Several emission heights

- Dispersion with s-r matrices (10 $\times$ 10km$^2$ and 1 $\times$ 1km$^2$)

- LRT from EMEP

- Databases of population and critical loads
Emissions – 1 km / 1 hour resolution

Road traffic (PM$_{2.5}$)

Domestic combustion (PM$_{2.5}$)

Agriculture (NH$_3$)

Other area (PM$_{2.5}$)

Large point sources (SO$_2$)

Karvosenoja 2008
Dispersion/impacts – Various tools

1. Long-range transport impacts with EMEP 50 km resolution
2. Finnish high-stack PM emissions with 10 km resolution
3. Finnish near-ground PM emissions with 1 km resolution

1. EMEP source-receptor matrices (SRM) 50 x 50 km
2. Lagrangian SILAM based SRM 10 x 10 km
3. Gaussian UDM-FMI based SRM 1 x 1 km
Results
Primary PM$_{2.5}$ emissions in Finland 1984 - 2020

PPM$_{2.5}$ emission 1984-2020 (kilotons/a)

PPM$_{2.5}$ emission 2020 (kilotons/a)
Primary PM$_{2.5}$ emissions in Finland 1984 - 2020

PPM$_{2.5}$ emission 1984-2020 (kilotons/a)

PPM$_{2.5}$ emission and reduction potential 2020 (kilotons/a)
PPM$_{2.5}$ emission, reduction potential and cost-efficiency

Emission reduction potential in 2020 (axis: kilotons(PPM$_{2.5}$)/a) and cost-efficiency per reduced emission (colors: 1000 € / ton(PPM$_{2.5}$)).

- Euro 5/6 to all vehicles
- Street cleaning? / Dust suppression?
- End-of-pipe measures (ESP)
- Accelerated change for low-emission stoves
- Fabric filters in solid fuel plants >50MW
- Fabric filters in solid fuel plants 10-50MW
- ESPs in solid fuel plants <10MW
- ESPs in HFO plants
- Fabric filters in few individual industry plants

PPM$_{2.5}$ emission and reduction potential 2020 (kilotons/a)

Traffic
- Domestic combustion
- Power plants, Industry
- Other

13.9.2010
Modeled PM$_{2.5}$ concentrations in 2020 –

Power plants and industry

- Largest emissions from industrial processes – not located near major cities
- High-stack-emissions – efficient mixing – minor impact on concentrations
- Highest impacts on annual concentrations below 1 µg/m$^3$ from industrial process plants, not in high population density areas
Modeled PM$_{2.5}$ concentrations in 2020 – Traffic sources

- Emissions to great extent in urban areas and along highways – near high population densities
- Low-altitude-emissions – high impact on concentrations
- Impact on annual concentrations 1 to 6 µg/m$^3$ in many locations
Modeled PM$_{2.5}$ concentrations in 2020 –
Domestic wood combustion

- Residential – primary heating (small boilers) below 1 µg/m$^3$
- Residential – supplementary heat (stoves) below 2 µg/m$^3$
- Recreational wood use (stoves) below 0.5 µg/m$^3$
PPM$_{2.5}$ emission, pop. exposure and red. potential 2020

- Strongly different emission – exposure relationships for different emission sources categories (high-stack / near-ground, urban / non-urban)
- Traffic non-exhaust and residential wood stoves biggest sources of population exposure to primary PM$_{2.5}$ in Finland in 2020
- Reduction potential of population exposure largest for traffic sources
Population exposure reduction potential in 2020 (axis: µg/m³) and cost-efficiency per reduced pop. exposure (colors: M€ / µg/m³)

- Euro 5/6 to all vehicles
- Street cleaning? / Dust suppression?
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Population exposure caused by PPM_{2.5} and red. pot. 2020 (µg/m³)
Conclusions

In the future (2020) for primary PM$_{2.5}$

- Biggest cost-efficient emission reduction potential in power plants and industry
- However, only modest reductions of population exposure can be achieved with the emission abatement in power plants and industry
- Population exposure reduction potential high on accelerated renewal of traffic vehicle fleet
- Traffic non-exhaust and residential wood stoves the biggest sources to cause population exposure
  - Modest and uncertain emission reduction potential
  - Future challenge to develop efficient technologies for PM$_{2.5}$ reduction