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

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- Primary $PM_{2.5}$ reduction potential and cost-efficiency in 2020 for:
    - Reduction of emissions
    - Reduction of population exposure

Conclusions

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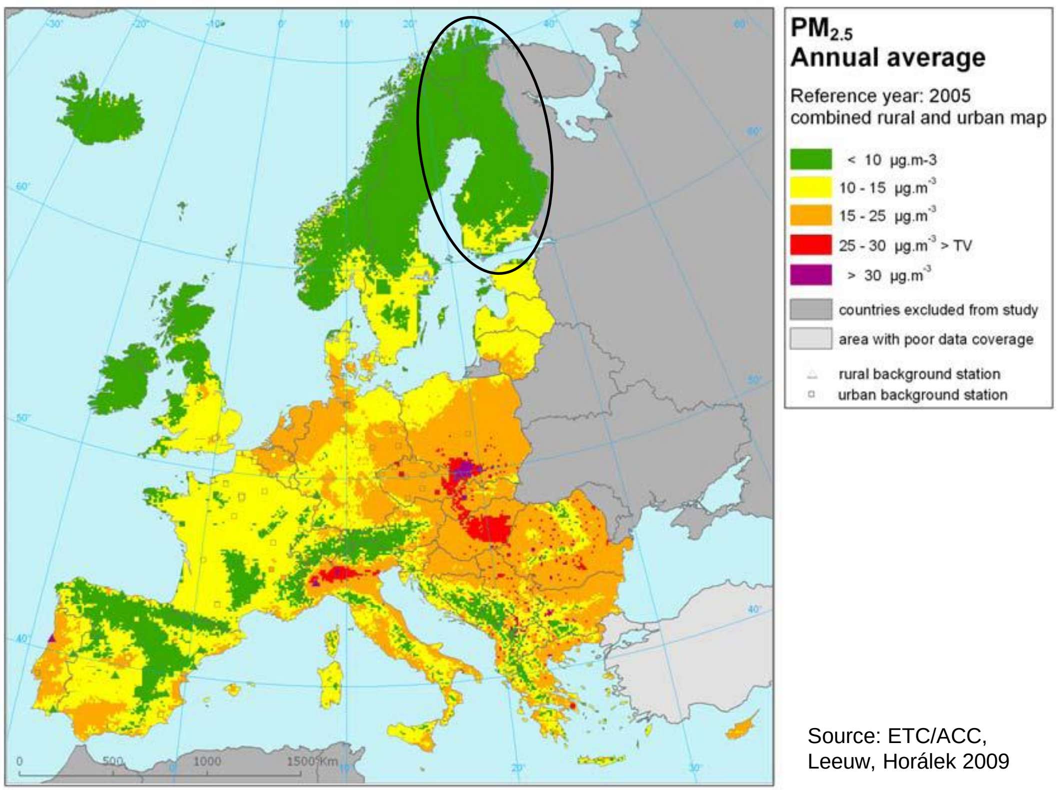
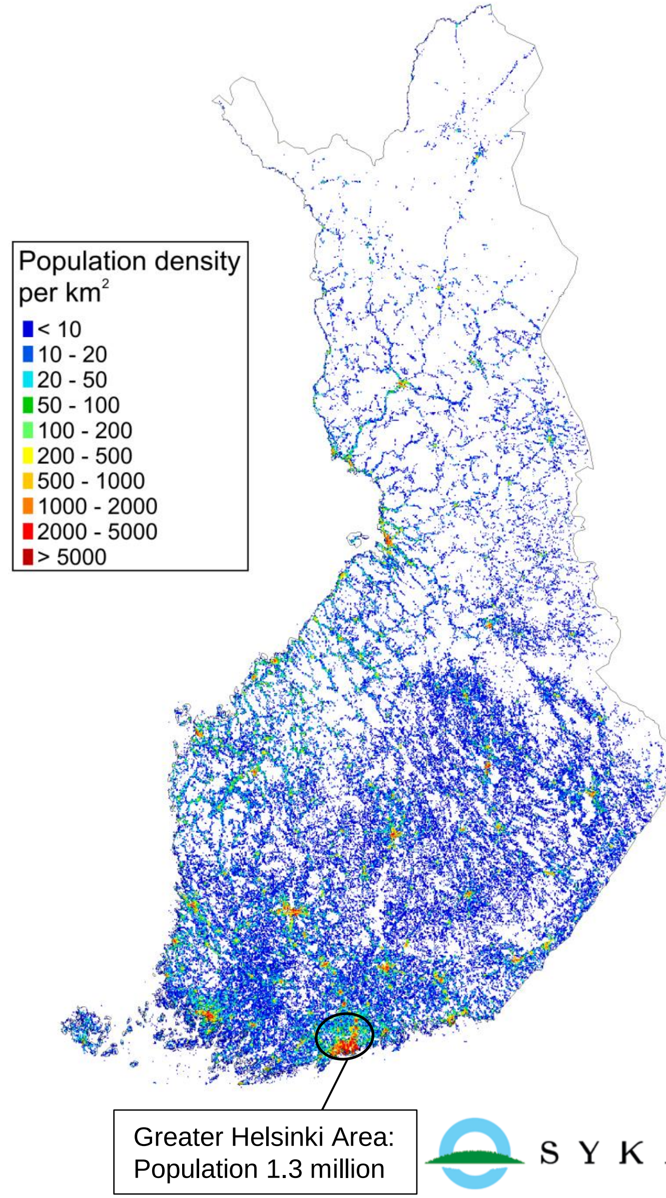
Fine particulate matter ($PM_{2.5}$) in Finland

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



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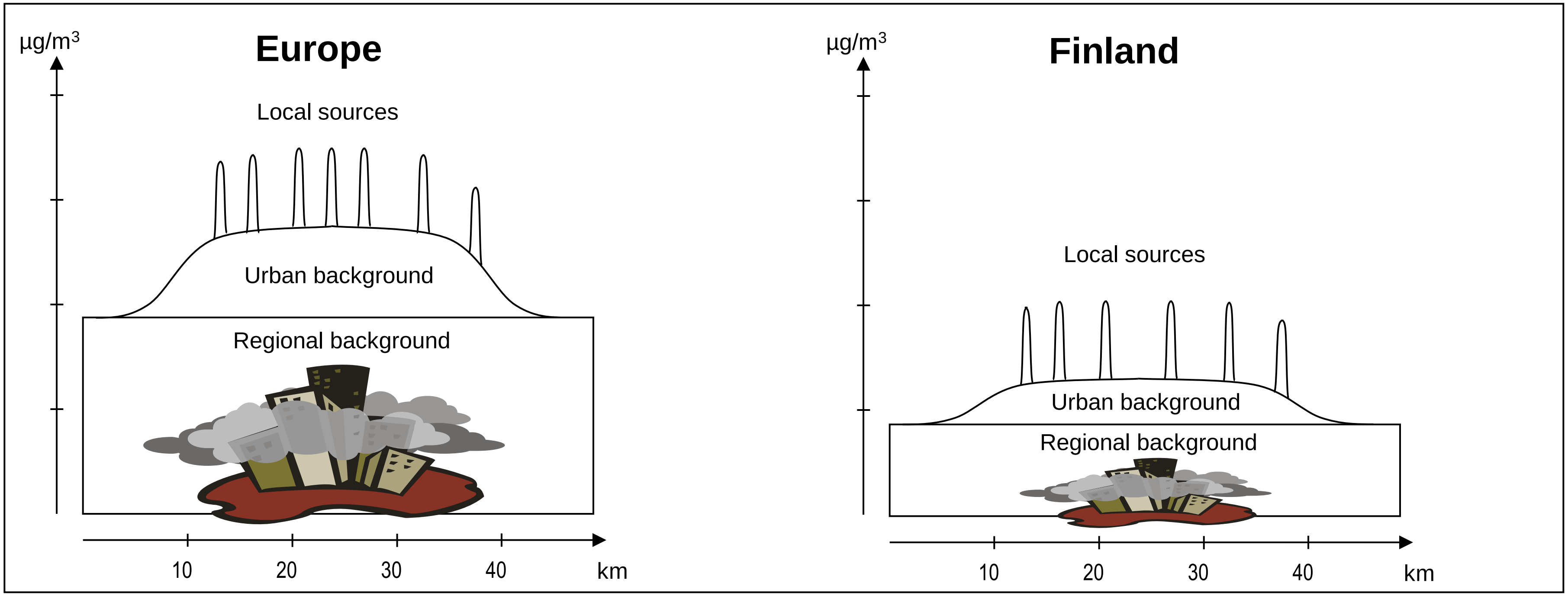
Components of PM concentrations in Europe vs Finland



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 (Vallius et al. *Sci Total Environ* 2005; Pakkanen et al. *Atm Environ* 2001)

Methodology

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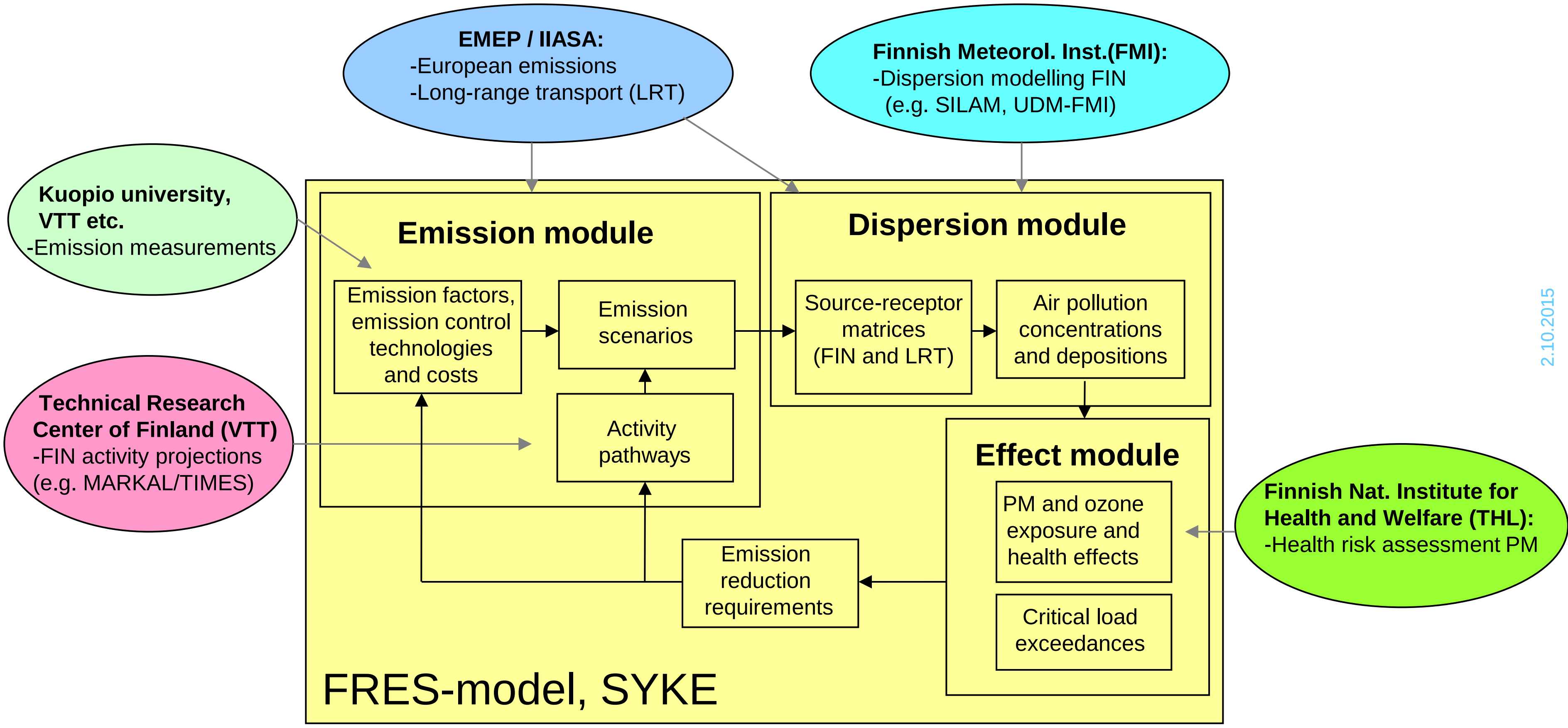
Finnish Regional Emission Scenario (FRES) model

part of the Finnish Integrated Assessment Modeling (IAM) framework



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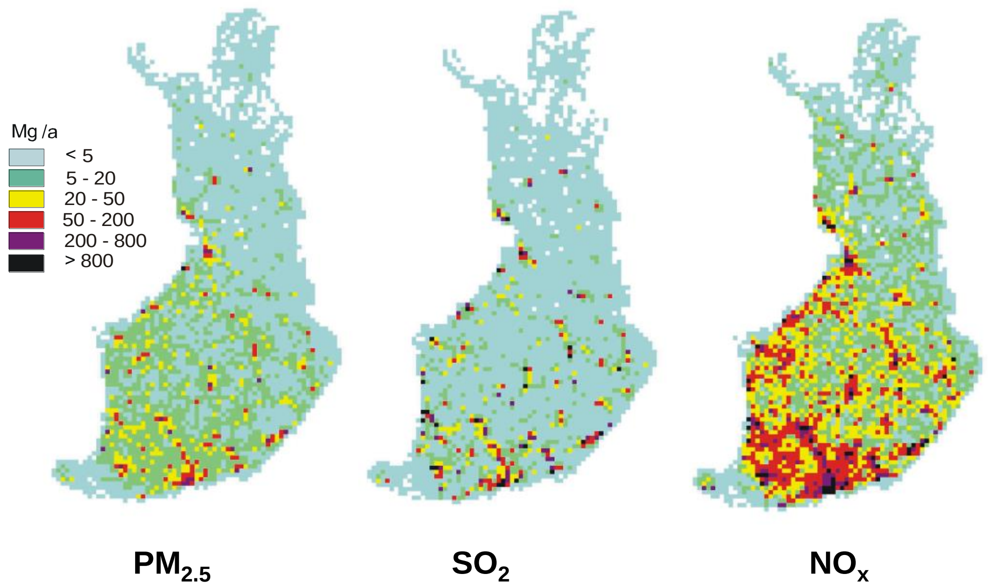
Finnish Regional Emission Scenario (FRES) model

www.environment.fi/syke/pm-modeling

- Anthropogenic emissions 1990, 2000, 2005, 2010, 2020, 2030, 2050 (several projections)
- Comprehensive and congruent calculation for primary PM and gases
  - •primary PM (TSP, $PM_{10 - 2.5 - 1 - 0.1}$, 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



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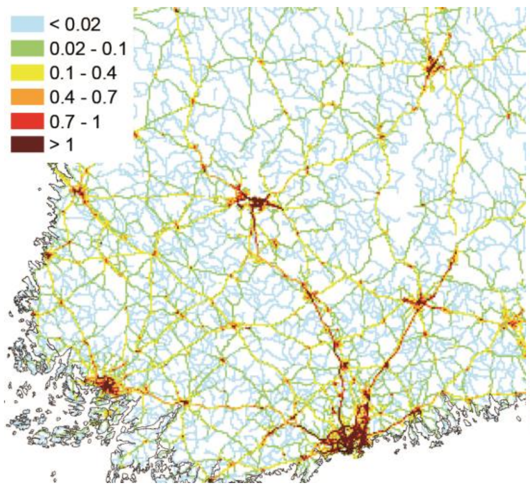
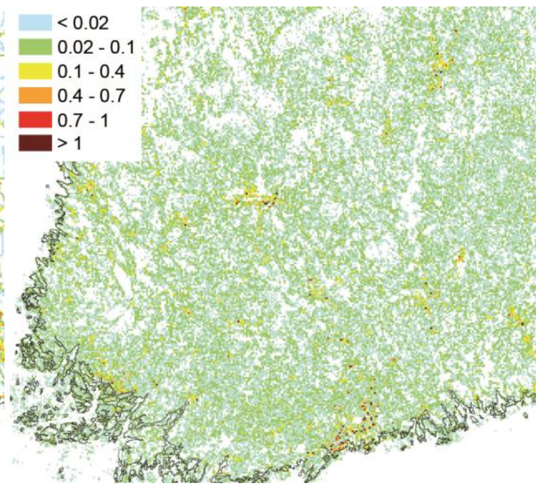
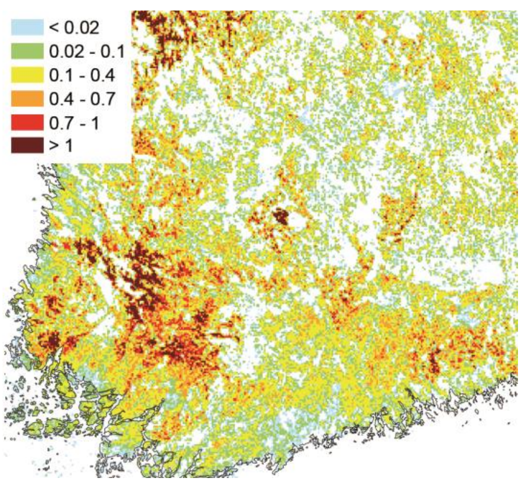
Emissions – 1 km / 1 hour resolution



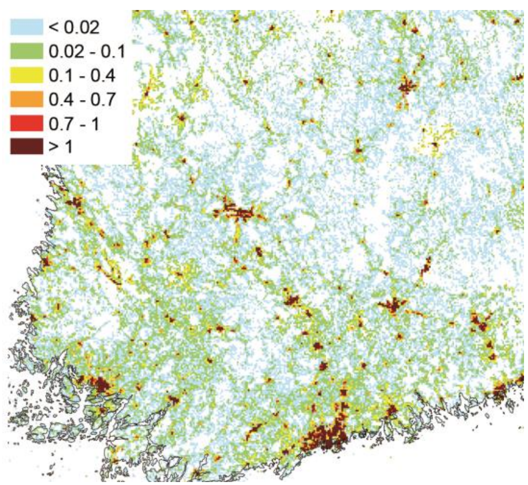
Road traffic ($PM_{2.5}$)



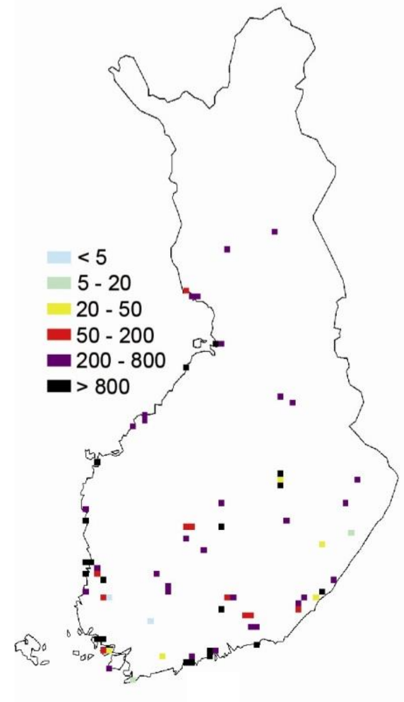
Domestic combustion ($PM_{2.5}$)



Agriculture (NH_3)



Other area ($PM_{2.5}$)



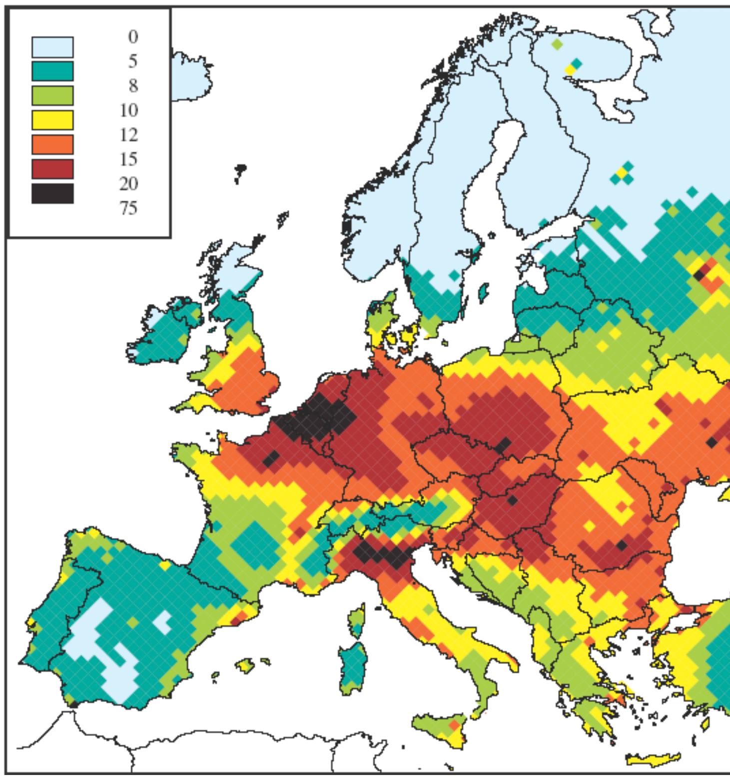
Large point sources (SO_2)

Karvosenoja 2008

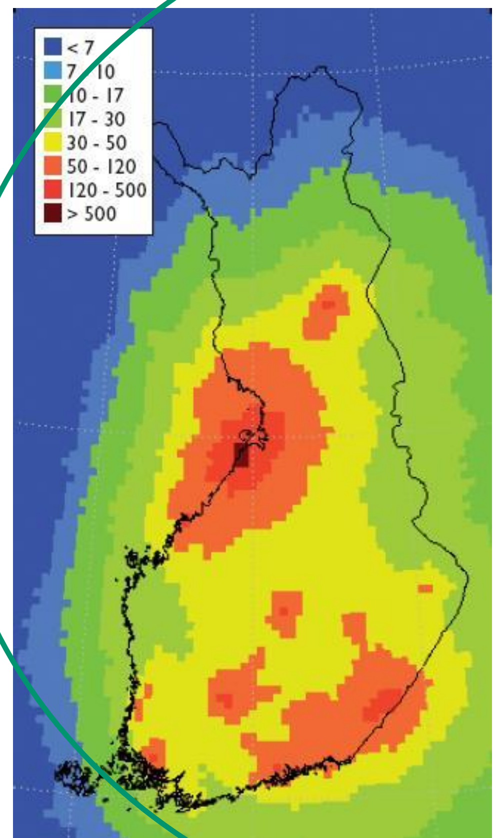
Dispersion/impacts – Various tools

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

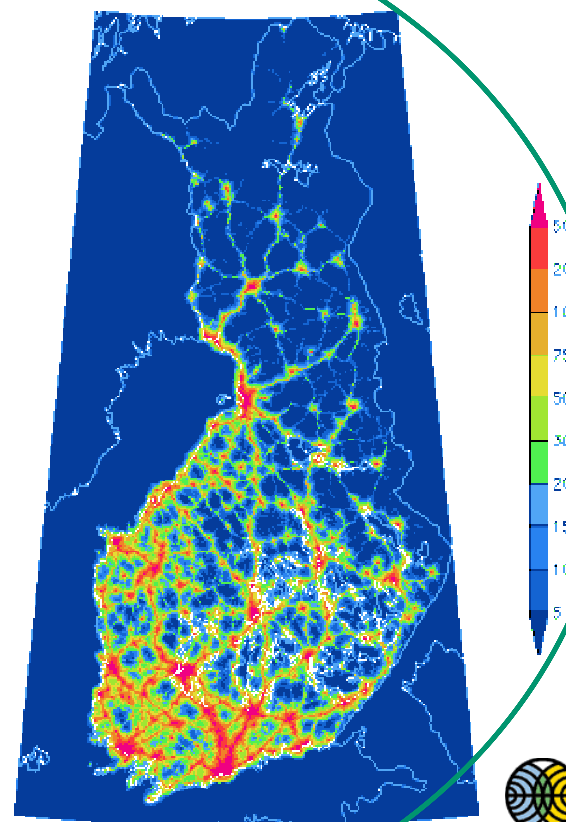
1. EMEP source-receptor matrices (SRM) 50 x 50 km



2. Lagrangian SILAM based SRM 10 x 10 km



3. Gaussian UDM-FMI based SRM 1 x 1 km



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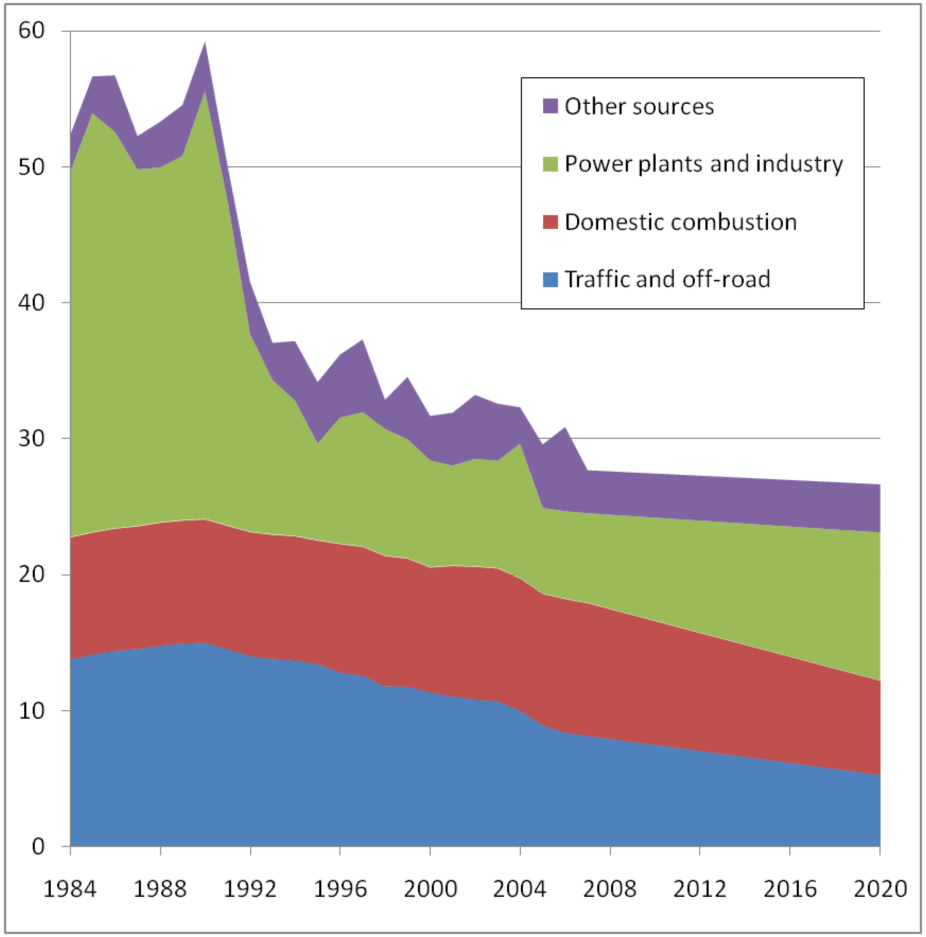
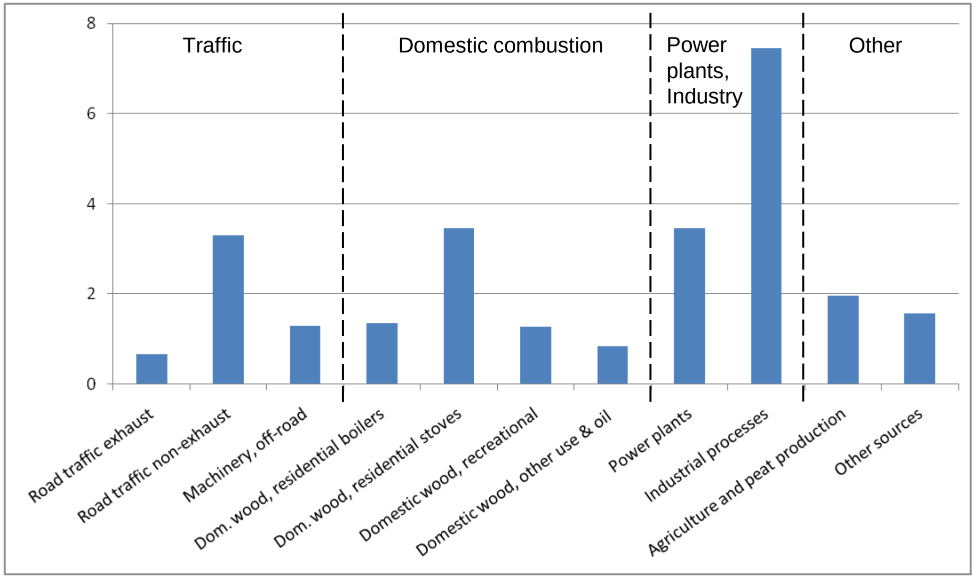
Results

Primary $PM_{2.5}$ emissions in Finland 1984 - 2020

PPM2.5 emission 1984-2020 (kilotons/a)

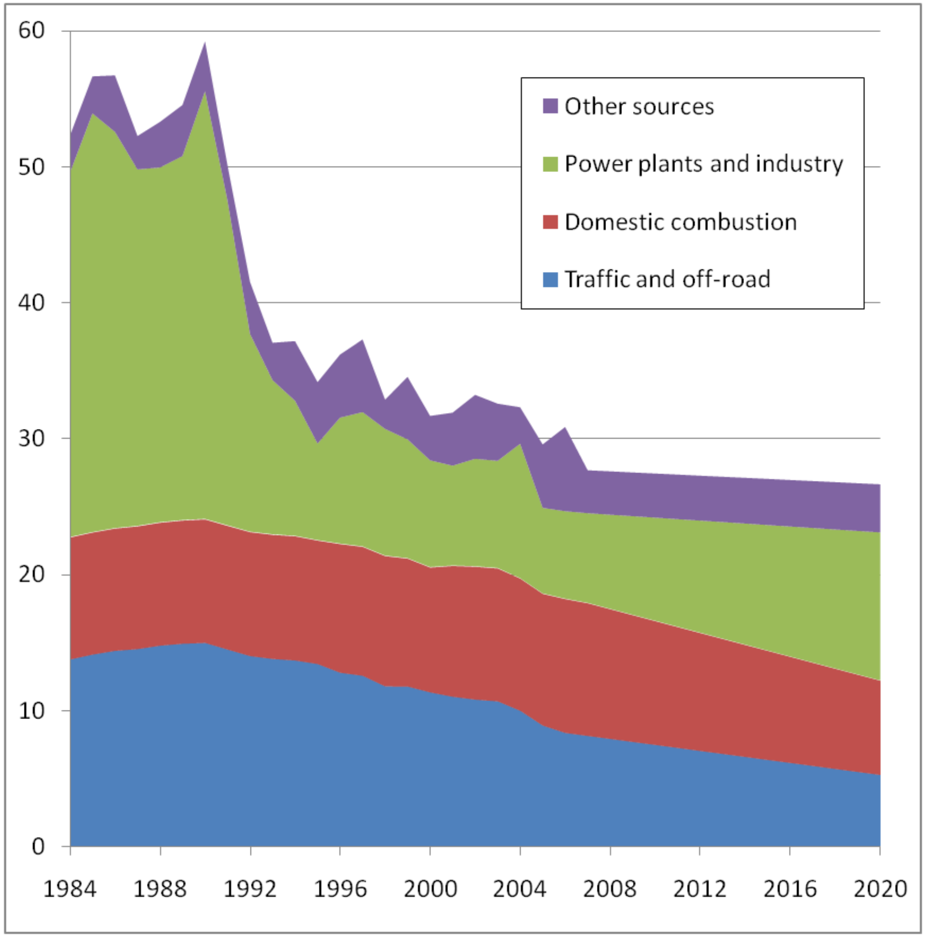


PPM2.5 emission 2020 (kilotons/a)

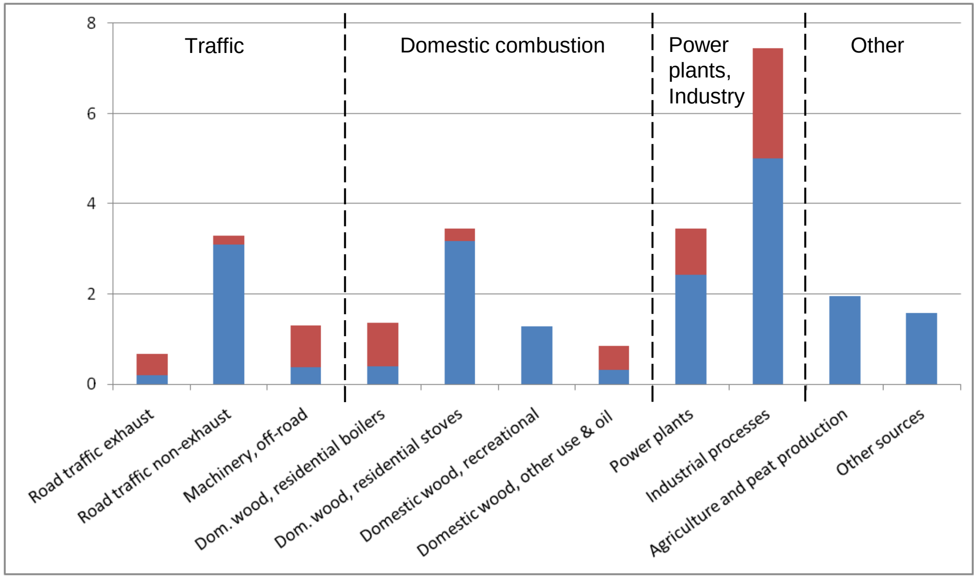


Primary $PM_{2.5}$ emissions in Finland 1984 - 2020

PPM2.5 emission 1984-2020 (kilotons/a)

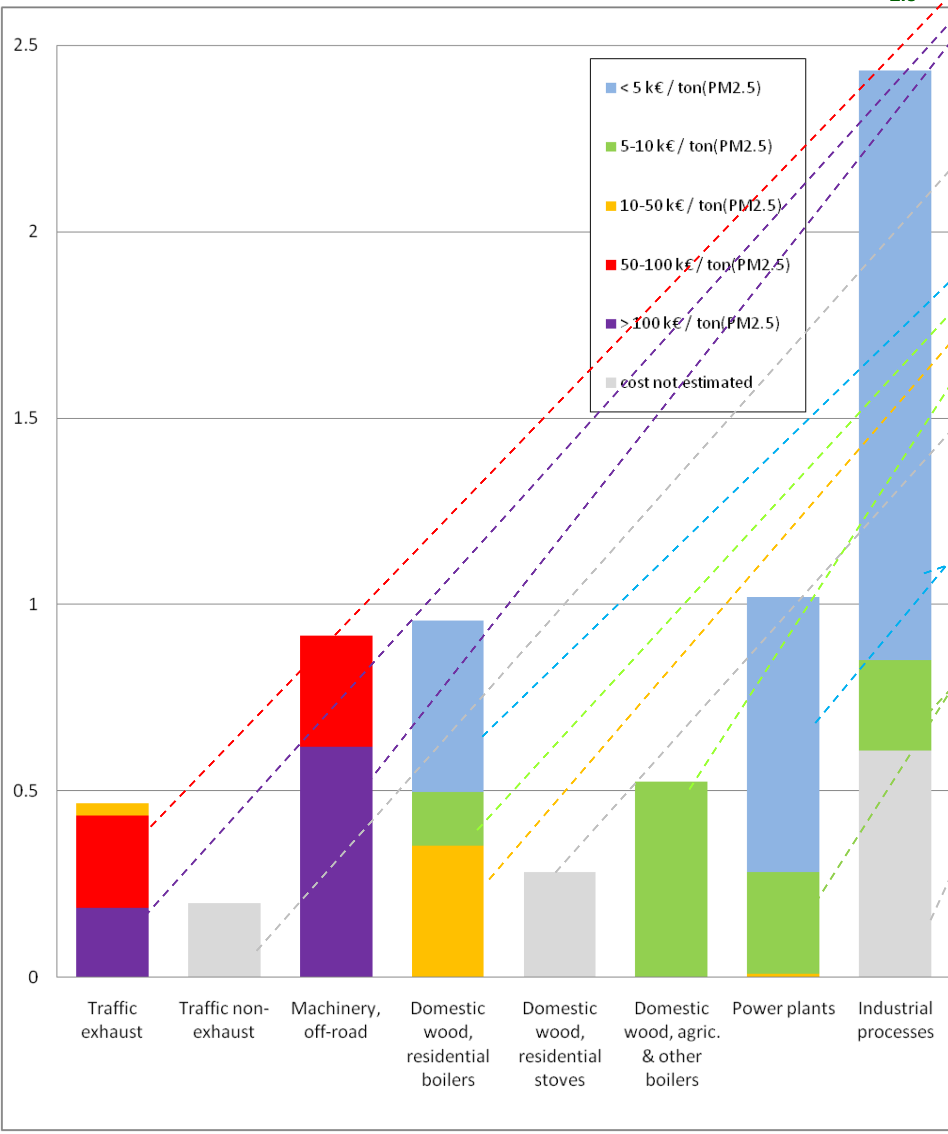


PPM2.5 emission and reduction potential 2020 (kilotons/a)



$PPM_{2.5}$ emission, reduction potential and cost-efficiency

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



Euro 5/6 to all vehicles

Street cleaning ? / Dust suppression ?

End-of-pipe measures (ESP)

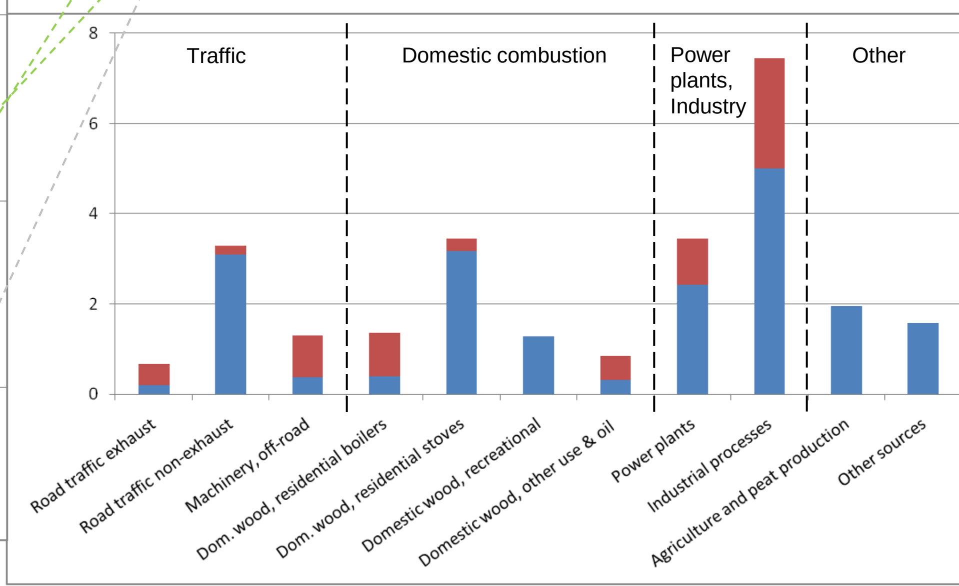
Accelerated change for low-emission stoves

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)



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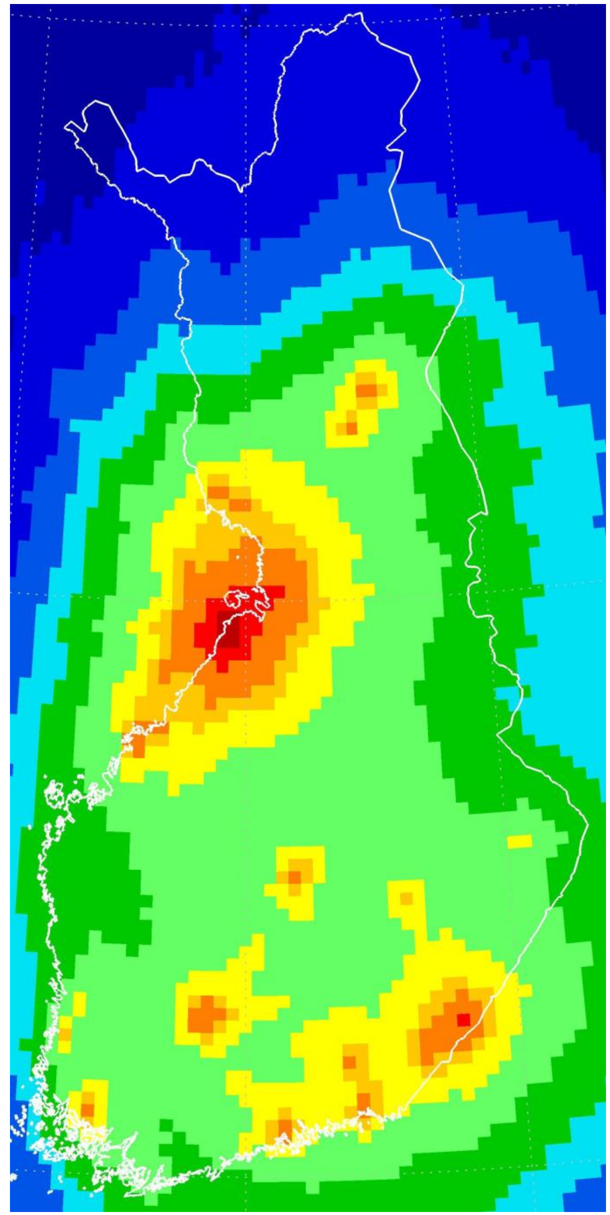
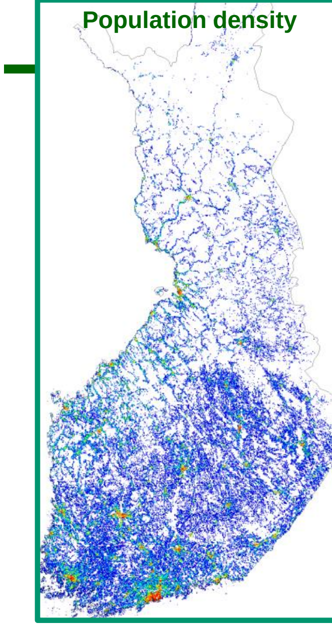
Modeled $PM_{2.5}$ concentrations in 2020 – Power plants and industry

- 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/m³ from industrial process plants, not in high population density areas





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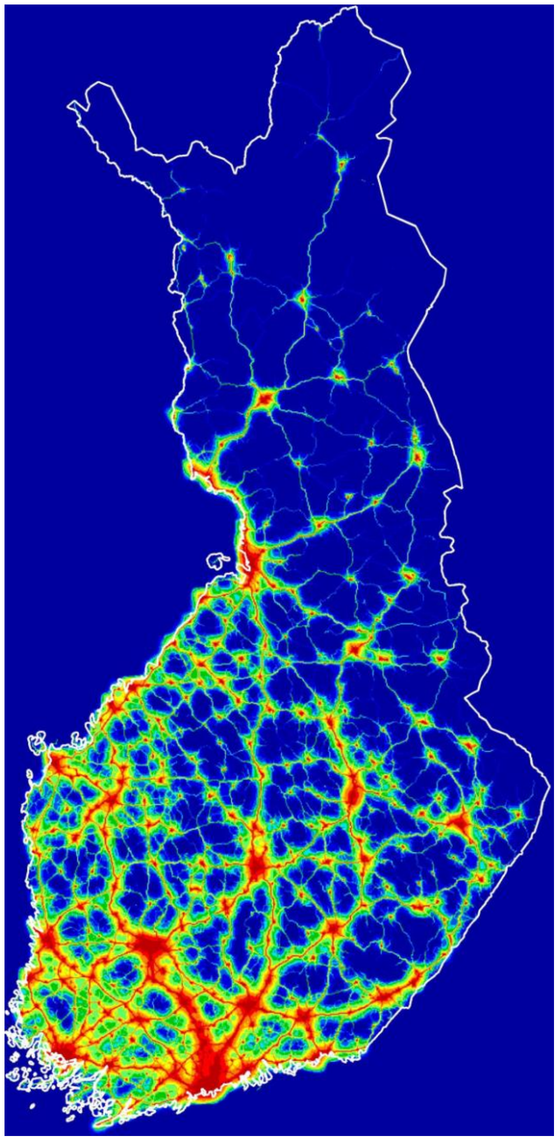
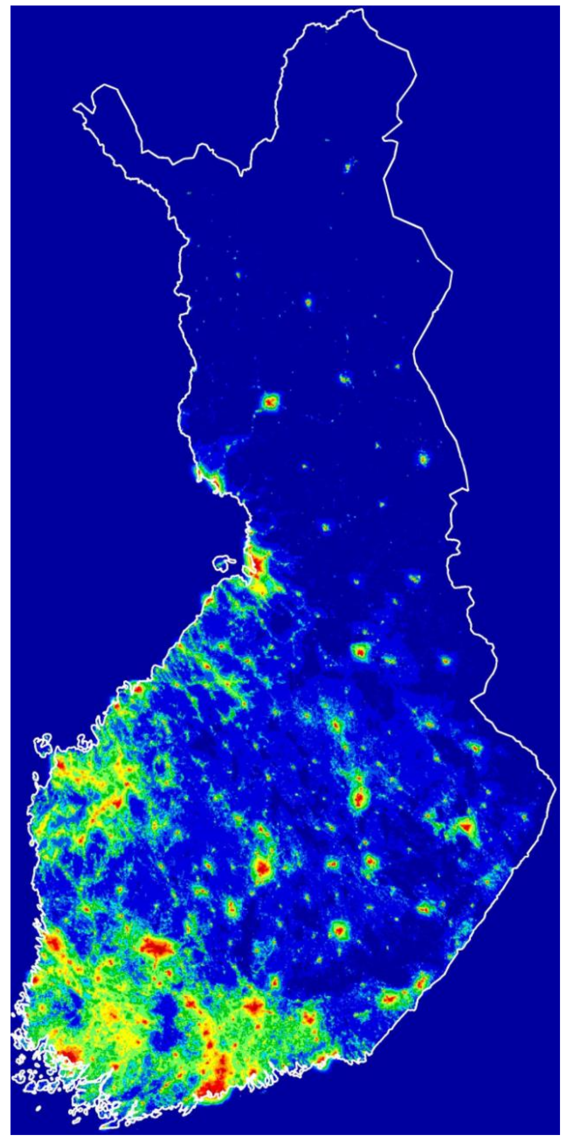
Modeled $PM_{2.5}$ concentrations in 2020 – Traffic sources

- 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/m³ in many locations

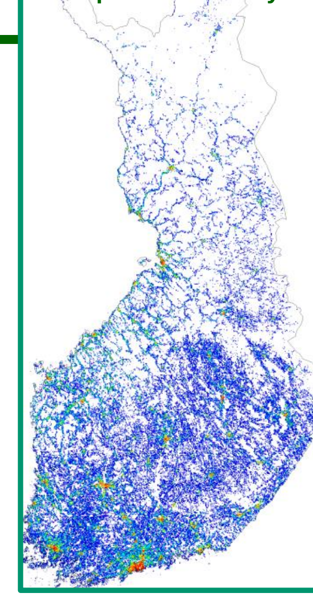
Road traffic

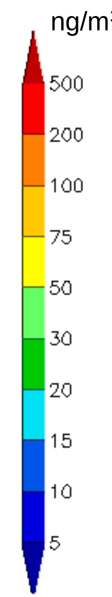


Machinery and off-road



Population density





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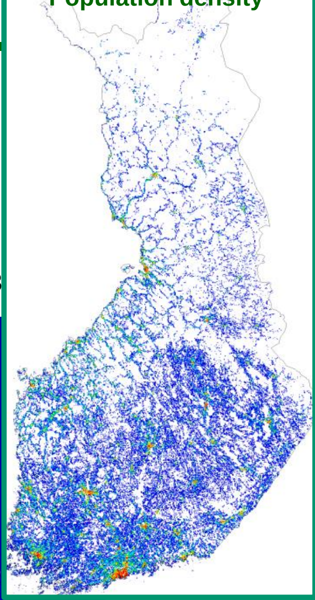
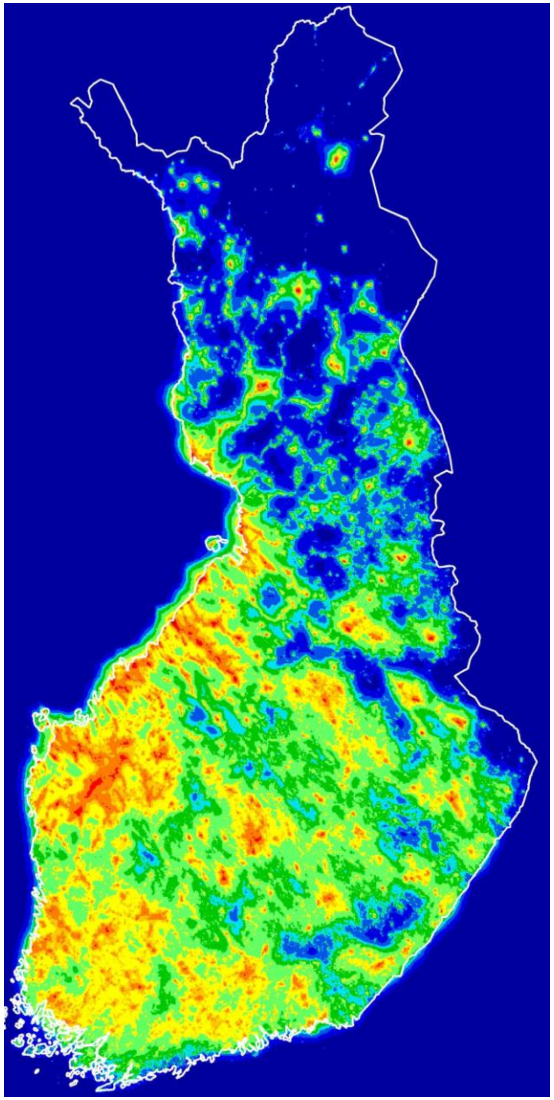
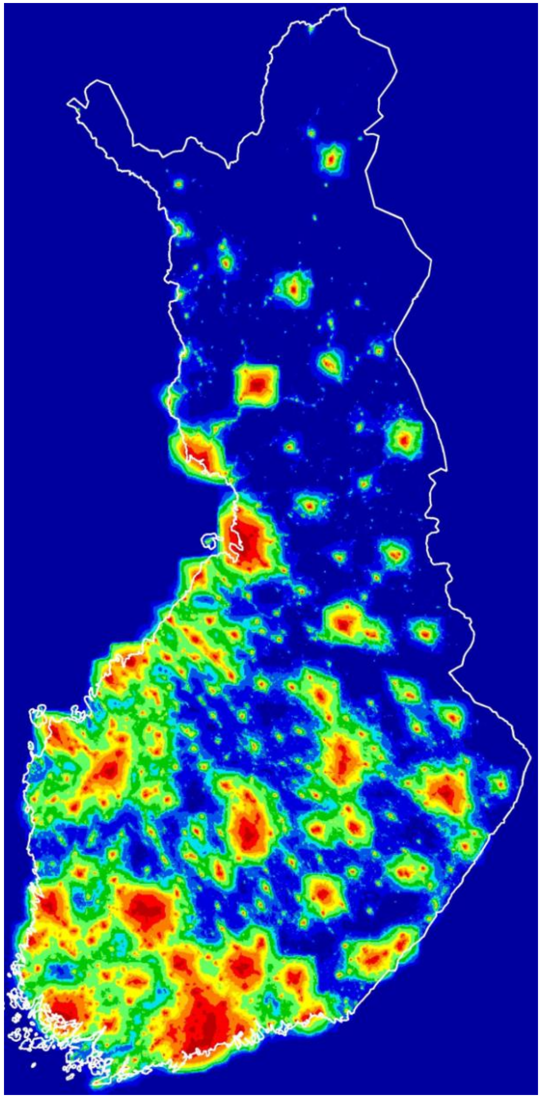
Modeled $PM_{2.5}$ concentrations in 2020 – Domestic wood combustion



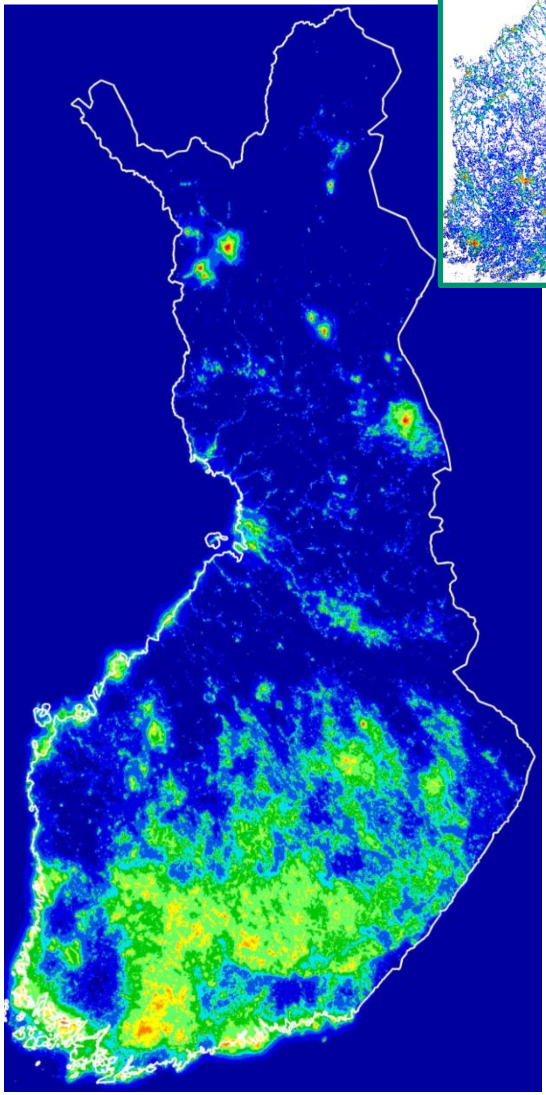
Residential – primary heating (small boilers) below 1 µg/m³



Residential – supplementary heat. (stoves) below 2 µg/m³



Recreational wood use (stoves) below 0.5 µg/m³



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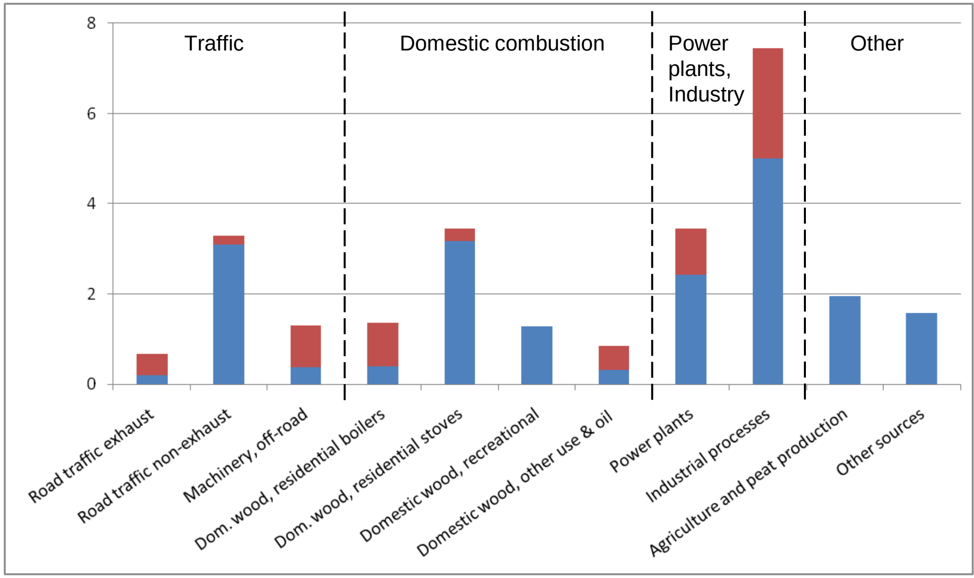
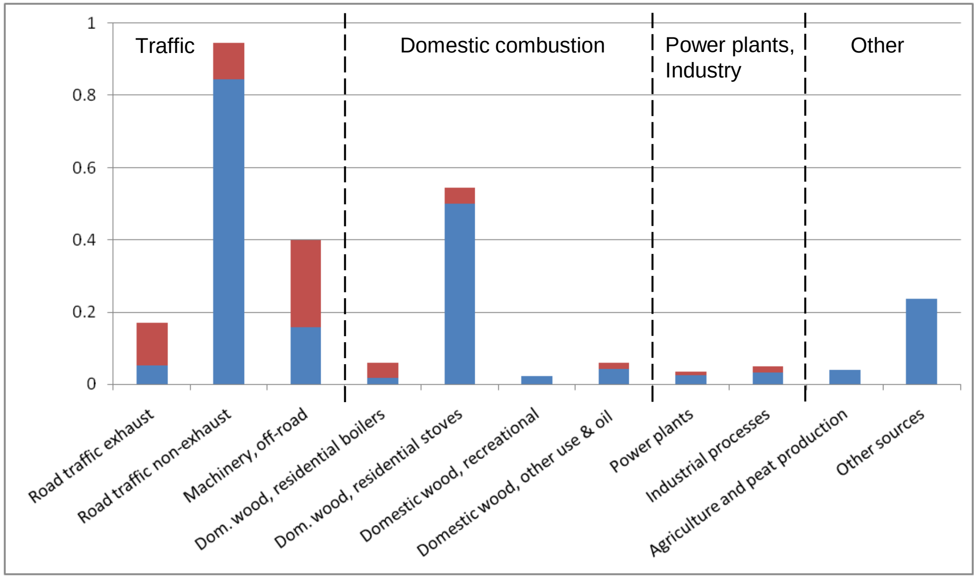
PPM$_{2.5}$ emission, pop. exposure and red. potential 2020

- 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

PPM2.5 emission and reduction potential 2020 (kilotons/a)

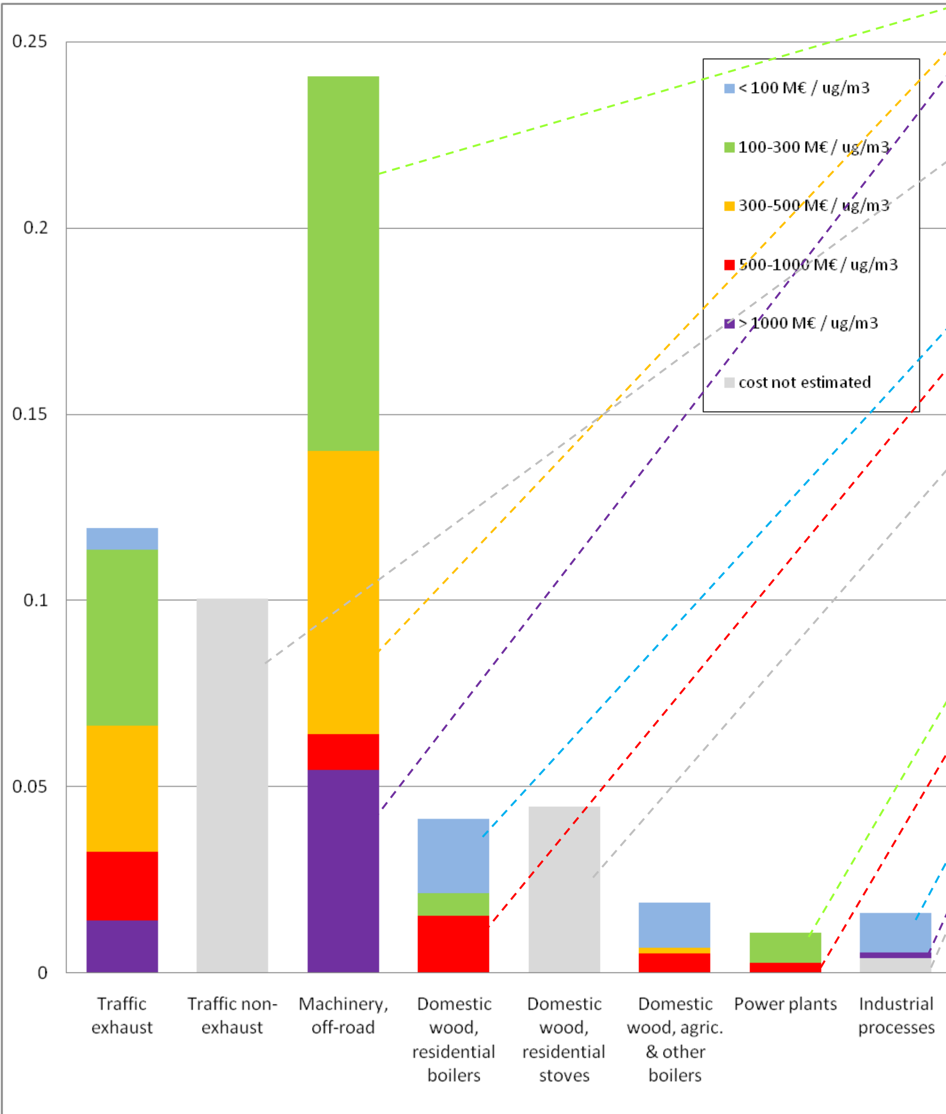


Population exposure caused by PPM2.5 and red. pot. 2020 (µg/m³)



$PPM_{2.5}$ pop. exposure, reduction pot. and cost-efficiency

Population exposure reduction potential in 2020 (axis: µg/m³) and cost-efficiency per reduced pop. exposure (colors: M€ / µg/m³)



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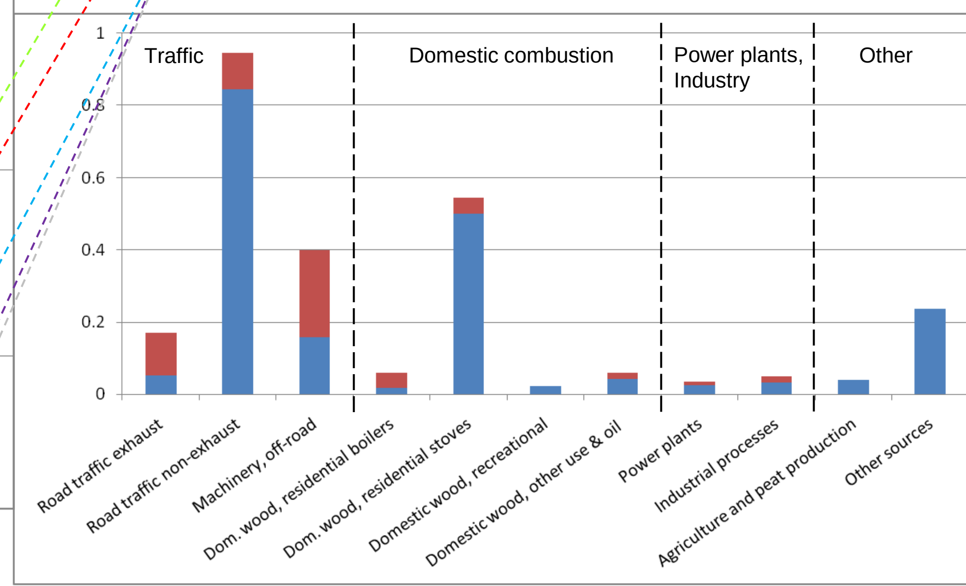

Conclusions

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

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Thank You

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