# Measures to regulation of air pollution from residential wood combustion

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# Outline

Our department

Health burden and social costs of residential wood combustion (RWC)

National emission inventories for RWC

Historic and future emission trends for RWC

Mitigation measures for RWC

Further information

# Emissions, AQ monitoring and modelling

National air quality monitoring in Denmark and Arctic (accredited lab)

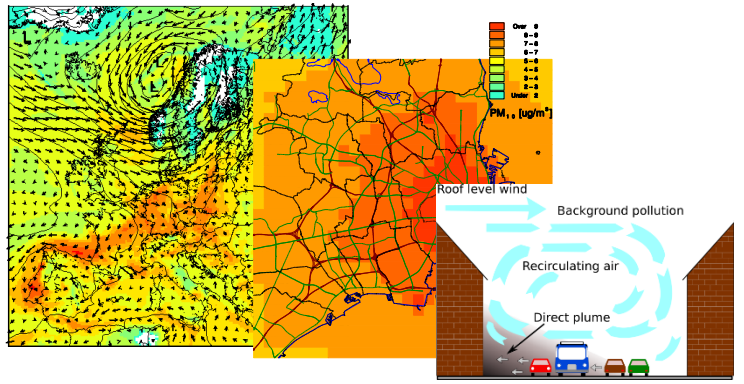
National emission inventories

Research, development and application of air quality models – from long-range to local scale

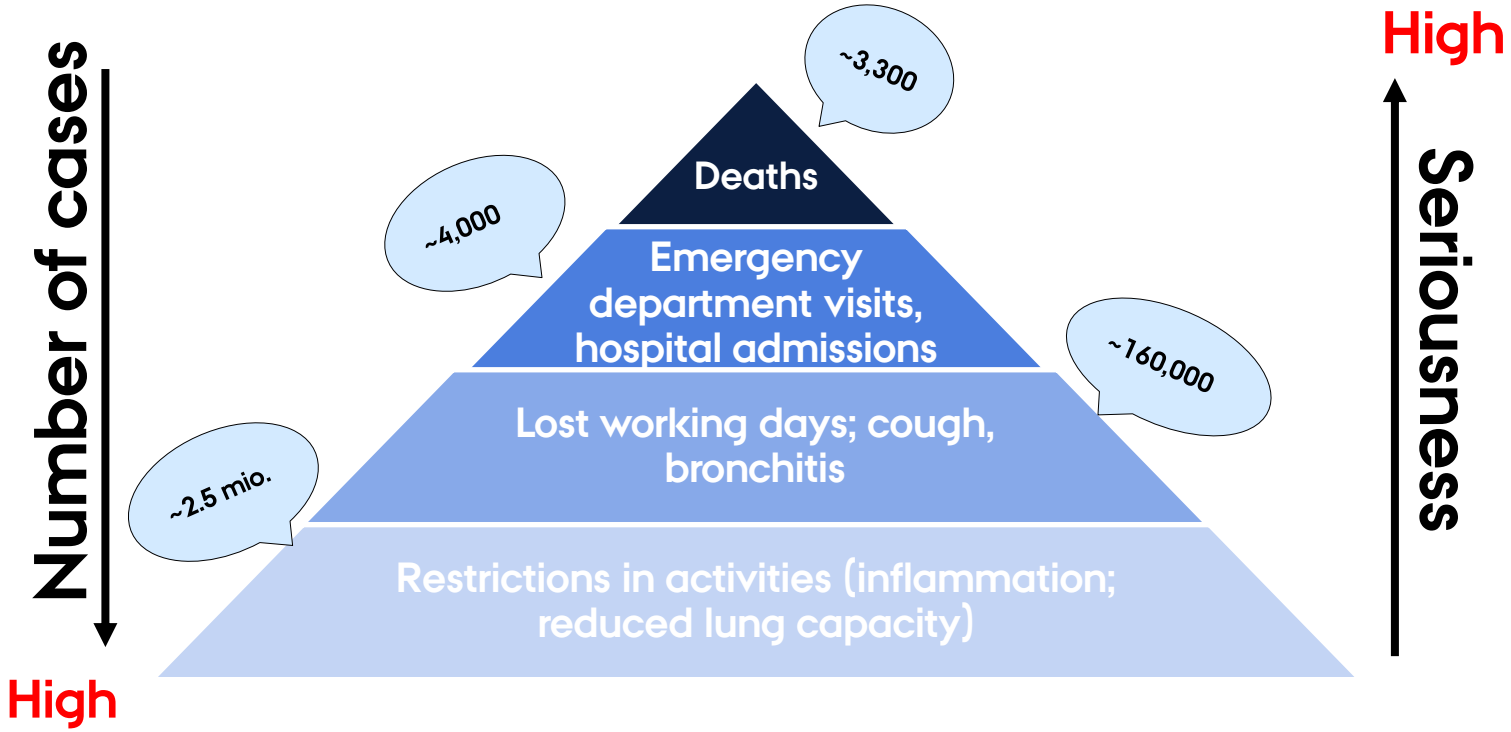
Climate modeling with focus on Arctic

Advice on AQ assessment and management for EPA, agencies, regions and munipalities

Framework contract with Ministry of Environment and Gender Equality

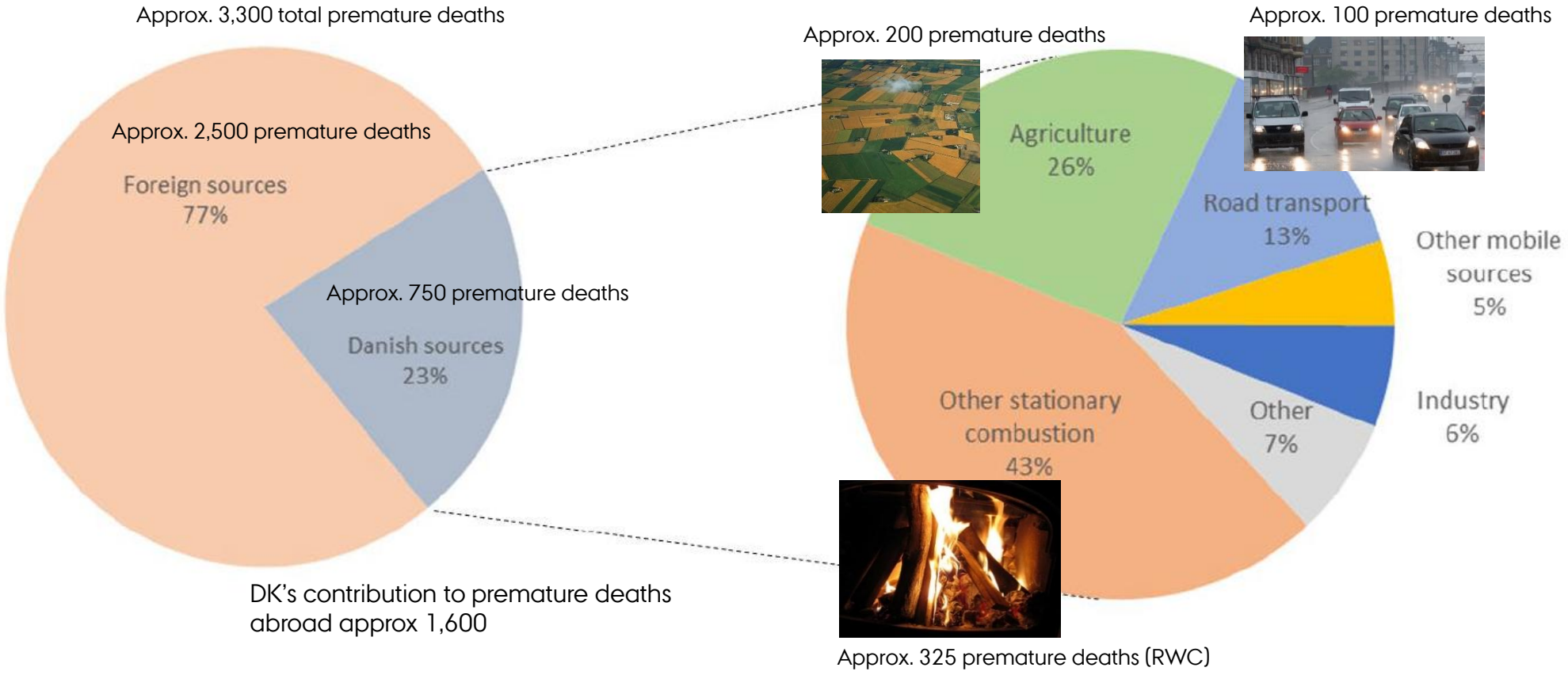


# Health effects pyramid of air pollution




From epa.gov/benmap https://www.epa.gov/benmap/how-benmap-...

# Sources to premature deaths in DK in 2023




Nordstrøm et al, 2024. Luftkvalitet 2023

# Costs to society

Costs of acute and chronic deaths (lost life years) are based social costs of statistical life ~ (DKK 36.5M) from Ministry of Finance

Other costs related to hospital expenditures, lost work etc.

Total costs for all air pollution in Denmark due to Danish and foreign sources in 2023: ~ DKK 60B

~ DKK 5,6B in 2023 for small scale combution (mainly RWC)

Annual costs per unit

- Copenhagen ~ DKK 14,000 (All, 2019, 95% wood stoves)
- Odense ~ DKK 8,000 (All, 2019, 75% wood stoves)
- Country average ~ DKK 6,000 (All)

# Residential wood burning

Large No. of wood stoves and boilers (19% and 4% of all Danish homes)

Mainly supplementary heat source in heating season and mainly for coziness

Uncontrolled polluting combustion, major source of PM, BC, BaP, dioxin

Limited dispersion due to low stack height

Nuisance and health problem

Also affects indoor environment due operation of stoves and leakages

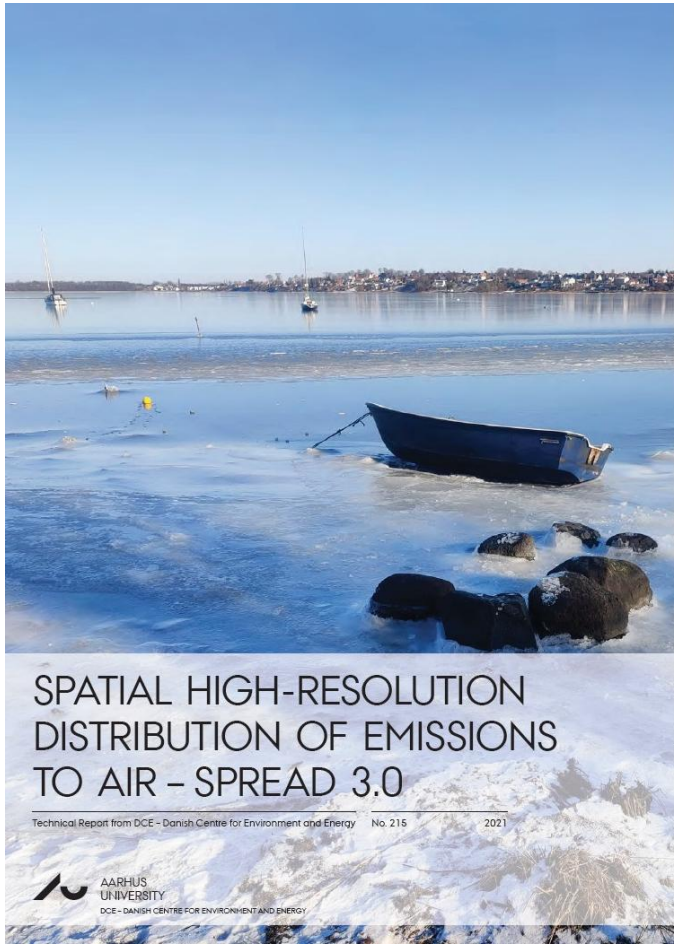
# Emission inventory for RWC

National emissions based on number of wood stove and wood pellet boilers, type depending on age, location based on chimney sweepers registers supplemented with national Central Register of Buildings and Dwellings (BBR)

Emission factors based on measurements

Wood consumption based on survey be Danish Energy Agency distributed on villas, summerhouses, apartments

National emissions are distributed geographically to 1 km x 1km based on geographic keys (SPREAD model)

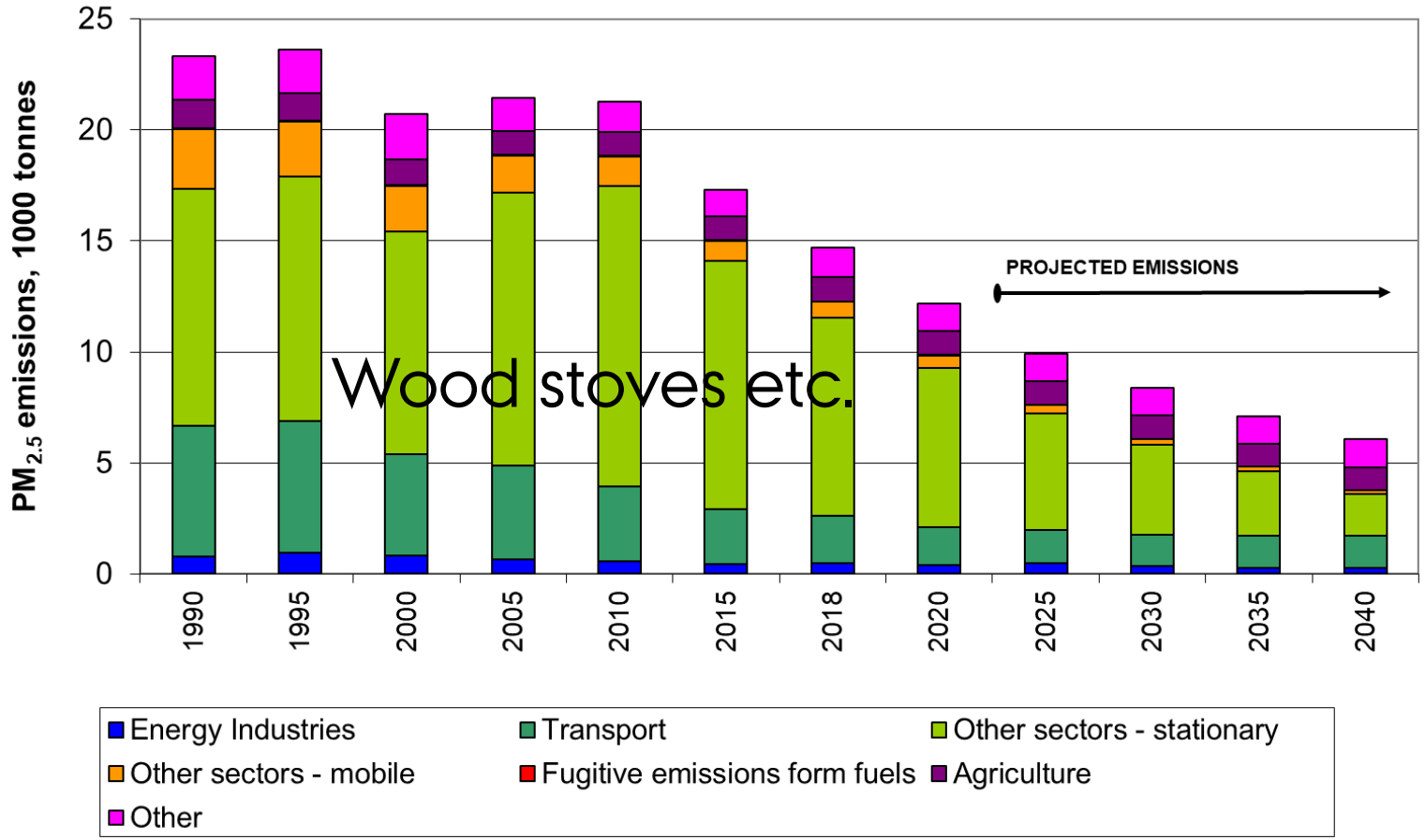



Plejdrup et al., 2021

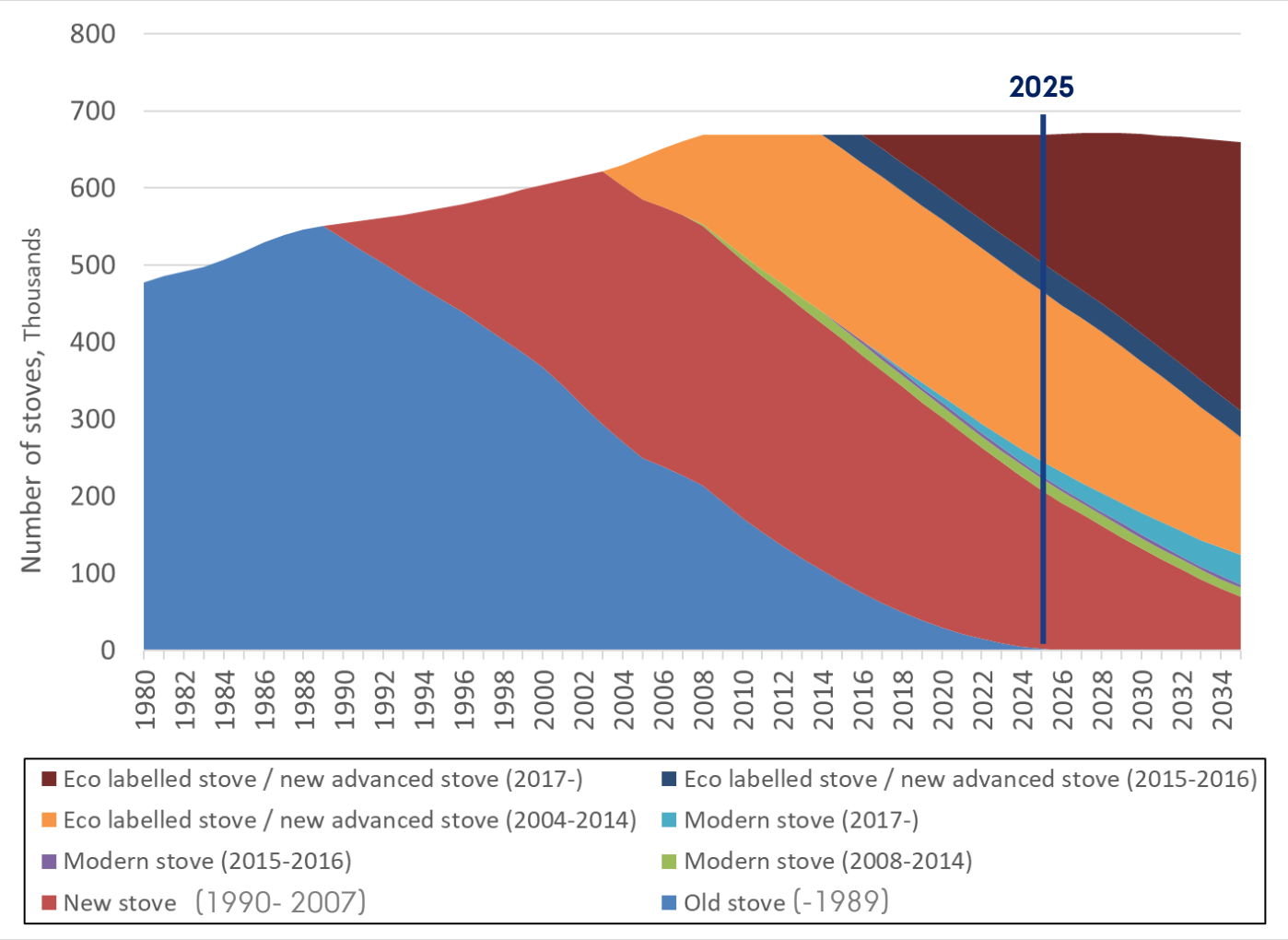
# Energy emission inventory in 2021

| 2021 emissions, kt | | | |
|---|---|---|---|
| Activity: | CO2 | NOx | PM2.5 |
| **A. Fuel combustion activities** | 27661.5 | 70.4 | 9.9 |
| **1. Energy industries** | 8108.7 | 15.2 | 0.5 |
| a. Public electricity and heat production | 6277.0 | 11.1 | 0.4 |
| b. Petroleum refining | 938.1 | 1.0 | 0.1 |
| c. Manufacture of solid fuels and other energy industries | 893.5 | 3.1 | 0.0 |
| **2. Manufacturing industries and construction** | 3734.2 | 8.1 | 0.3 |
| a. Iron and steel | 95.2 | 0.1 | 0.0 |
| b. Non-ferrous metals | NO | NO | NO |
| c. Chemicals | 220.1 | 0.2 | 0.0 |
| d. Pulp, paper and print | 58.6 | 0.1 | 0.0 |
| e. Food processing, beverages and tobacco | 906.6 | 1.1 | 0.0 |
| f. Non-metallic minerals | 1465.2 | 3.8 | 0.0 |
| g. Other (*please specify*) | 988.5 | 2.7 | 0.2 |
| **3. Transport** | 12075.0 | 32.4 | 1.5 |
| a. Domestic aviation | 85.4 | 0.4 | 0.0 |
| b. Road transportation | 11262.3 | 20.5 | 1.2 |
| c. Railways | 184.8 | 1.2 | 0.0 |
| d. Domestic navigation | 542.5 | 10.3 | 0.3 |
| e. Other transportation | NO | NO | NO |
| **4. Other sectors** | 3525.1 | 13.6 | 7.5 |
| a. Commercial/institutional | 753.8 | 1.2 | 0.1 |
| b. Residential | 1418.7 | 3.6 | 6.1 |
| c. Agriculture/forestry/fishing | 1352.5 | 8.8 | 1.2 |
| **5. Other** *(as specified in table 1.A(a) sheet 4)* | 218.6 | 1.1 | 0.1 |
| a. Stationary | NO | NO | NO |
| b. Mobile | 218.6 | 1.1 | 0.1 |

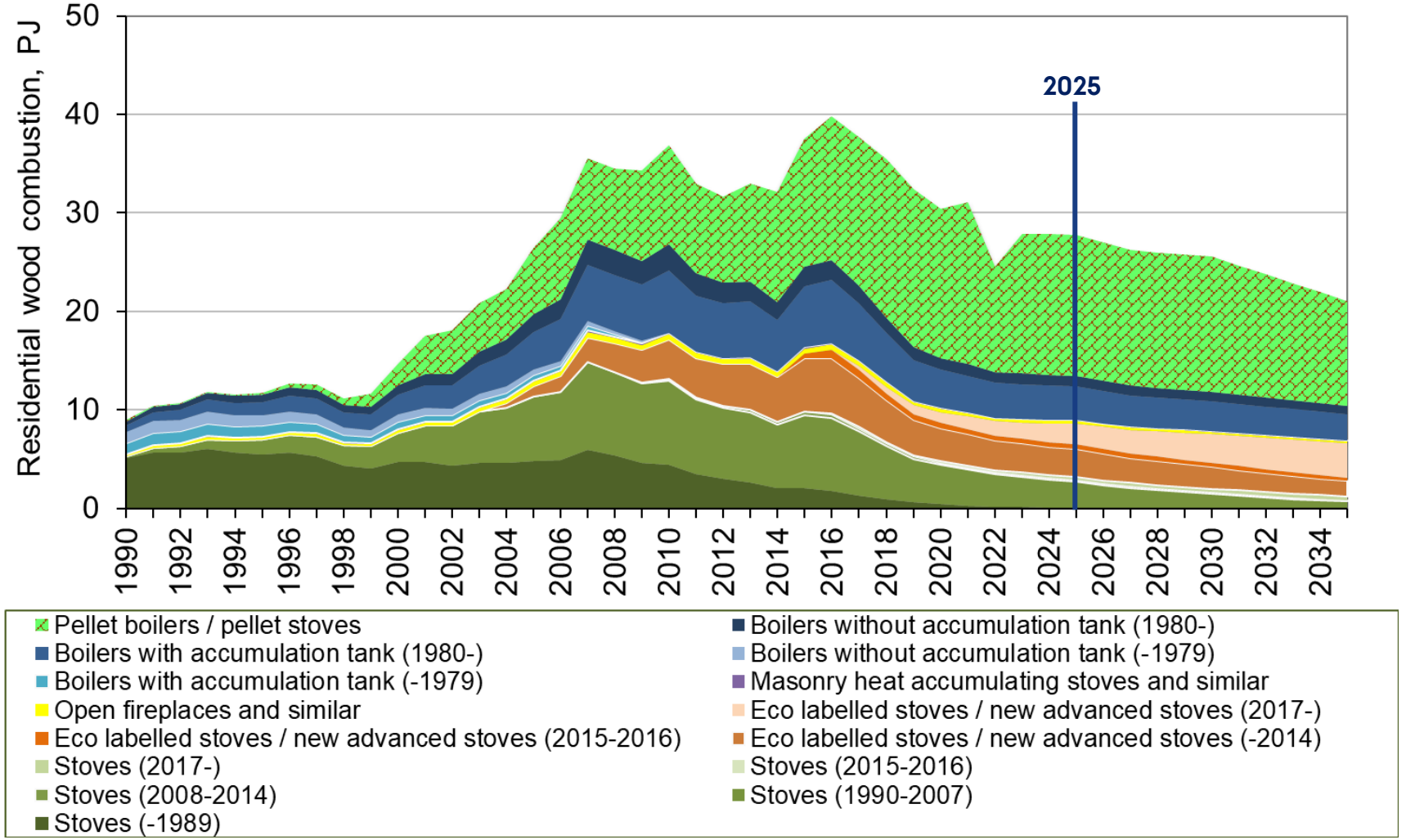
# Energy sector $PM_{2.5}$ emission trends



# Development in wood stoves



# Development in wood consumption (PJ)



# $PM_{2.5}$ emission faktors for RWC

Wood stoves provide approx. 10% of domestic heat demand

Wood-burning stoves approx. 48% of Danish $PM_{2.5}$ emissions in 2022

High emissions from older stoves compared to new once

High emissions compared to other heat sources

| Emission factor, 2021 | CO2 (kg/GJ) | NOx (g/GJ) | PM2.5 g/GJ) |
|---|---|---|---|
| Coal-fired combined heat and power plant | 94 | 14 | 2.1 |
| Gas-fired combined heat and power plant (boilers) | 55 | 28-31 | 0.1 |
| Wood-fired combined heat and power plant | 103 | 33-81 | 1.3 |
| Waste incineration plants | 42.5 - 59.2 | 85 | 0.29 |
| Oil burner | 74 | 52 | 5 |
| Natural gas boilers | 55 | 17.6 | 0.1 |
| Old wood-burning stove (before 1990) | 103 | 50 | 930 |
| Modern Nordic Ecolabelled wood-burning stove | 103 | 75 | 118 |
| Heat pump | | | |

# Is wood burning climate neutral?

In principle, $CO_2$ neutral if the wood comes from sustainable forestry, *but*

Soot (BC) from combustion is a greenhouse component

- absorbs the sun's radiation and outgoing radiation
- increases cloud formation
- when deposited on snow/ice, melting increases

Negative climate effect of soot equals the positive climate impact of $CO_2$ savings by assuming that wood burning replaces heating oil, therefore, wood burning is not $CO_2$ neutral

Felling of trees also has negative impacts on biodiversity in forests

# Hard regulation of RWC

Executive order from Ministry of Environment for regulation of **emissions** of wood stoves

- PM emissions per kg wood 10 g/kg (2008), 5 g/kg (2015) and 4 g/kg (2017)
- Also requires use of clean and dry wood

From 2022 regulated by **EU Ecodesign directive** (5 g/kg)

Executive order from 2021 requires that wood-burning stoves from before 2003 must be **scrapped or replaced** with a newer model that meets current requirements in connection with a change of house ownership

Local plan **banning chimneys** for new housing developments

# Soft regulation of RWC

Danish EPA has previously had a pool of subsidies for **scrapping** of old wood stoves from 1990/1995

Danish EPA information campaign on **top-down fire lighting** (reduce PM)

Danish EPA **information website** about wood burning (www.braendefyringsportalen.dk)

Act 2022 – Allows municipalities to **ban older** wood-burning stoves before 2008 in areas with district heating and natural gas (halve PM)

**Eco-labelling** is a voluntary scheme, Nordic Swan Ecolabel (2 g/kg). 9 out of 10 sold wood stoves are eco-labelled in Denmark

# Emerging technological measures

The **user behaviour** has a large impact on the emissions of a wood stove (wood, fire lighting, air supply etc.)

**Active optimisation** of the combustion process with mechanical and electronic control of the air supply including oxygen meter (lambda probe)

Electrostatic **particulate filter** for mounting at the top of the chimney. Reduce 90-95% of ultrafine particles and PM mass by 70-75%

**Bioethanol stove** with no chimney (coziness, less heat, biofuel, indoor pollution?)

**Subsidies** to particulate filters and replacement of wood stoves with bioethanol stoves

Particle filter for wood stoves (exodraft.dk)

Stove with bioethanol

# Other emerging measures

**Tax on wood consumption**. Other fuels are taxes but not wood. Proposal for act was given up due to administrative and practical issues

**Tax on use of wood stoves**. Tax per hour depending on type of stove and urban/countryside based on temperature measurement in chimney. Proposed by former Ecological Council

**Total ban on wood stoves**. In all of Denmark or targeting urban areas with collective heating systems

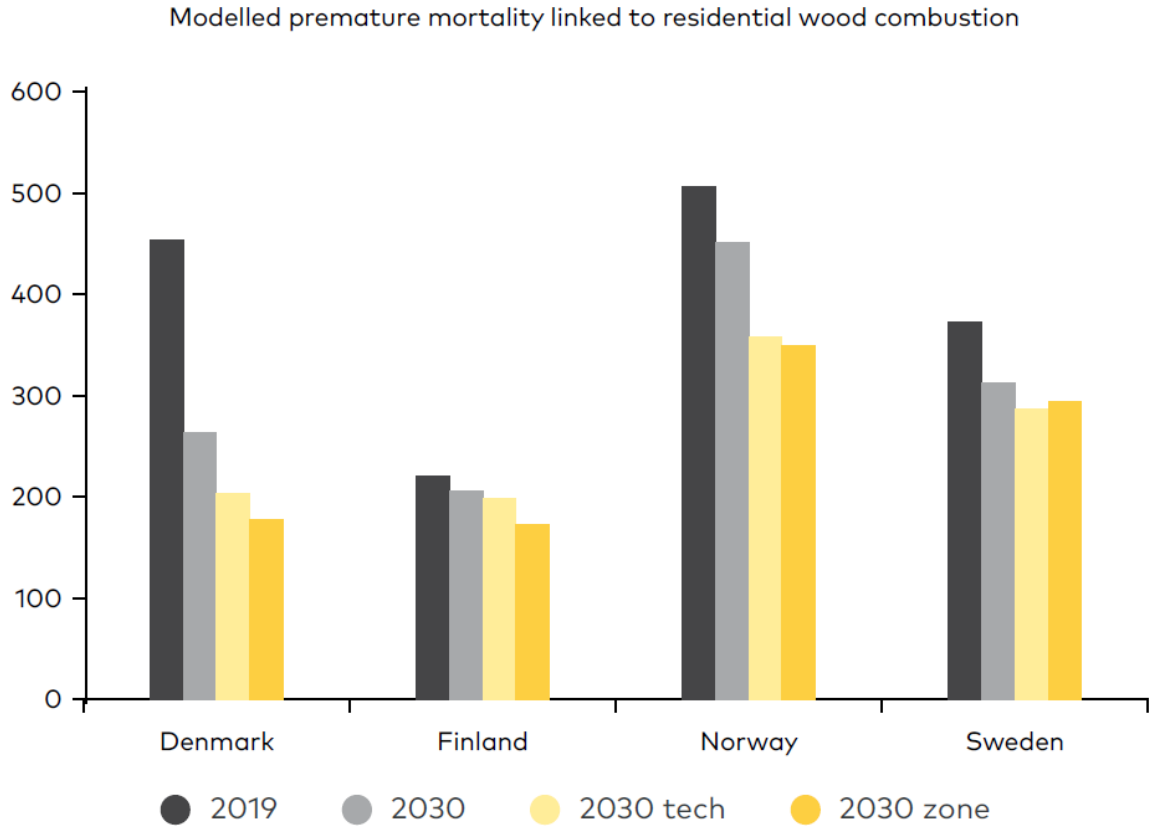
# NordSmoke project

| Type | Denmark | Finland | Norway | Sweden |
|---|---|---|---|---|
| Technology scenario | Ban on all wood stoves before 2008 – 50% replaced by new ones | Replacement of 14–20% of masonry heaters/ sauna stoves by new ones | Ban of open fireplaces and stoves produced before 1998 | Old boilers before 1998 replaced in urban areas |
| Zero emission zone-based scenario | Ban on wood stoves in areas with district heating | Ban in seven most populated urban areas | Ban in 10 most populated urban areas | Increase of district heating use, with decreased use of wood as primary heating source in urban areas |


https://www.norden.org/en/publication/policy-brief-potential-reducing-health-burden-air-pollution-residential-wood-combustion

# Reductions in premature mortality

The zone-based scenarios targeted areas with relatively high population density would bring considerably higher benefits of improved health for the emission reduction, compared to national-level measures



# Non-technical considerations

Why so hard to regulate RWC efficiently?

High awareness does not necessary lead to change in behaviour (personal gains versus burden to society)

Many feelings related to wood burning

Man and fire have been connected for 1 M years

Heat is essential to people

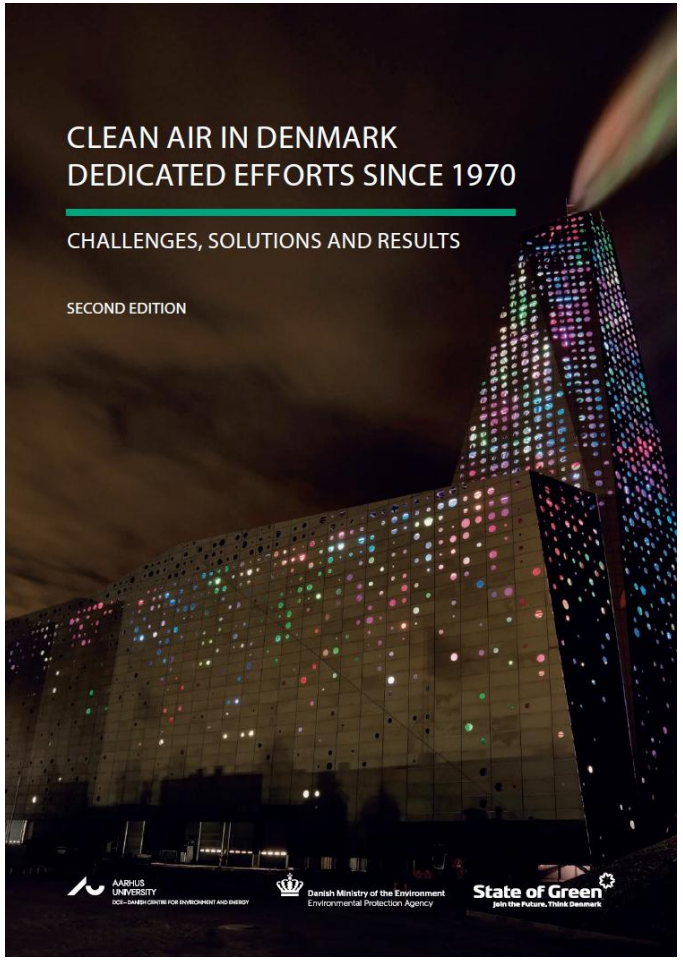
View to and sound of fire are pleasant and relaxing

A secondary heating source provides security in uncertain times

# Additional information

Publication prepared for Ministry of Environment

Historic development in emissions and air quality, and international and national regulation of all emission sources



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