

Pollution from residential heating with firewood: Setting the scene!

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Wood burning keeps people sick



Wood burning in Europe

- Dominant source to outdoor/indoor air pollution with toxic pollutants: Fine particles, black carbon, PAHs, VOCs, CO and dioxins.
- Wood smoke contains many of the same carcinogenic and health hazardous particles and PAHs as tobacco smoke – and dioxins in countries close to the sea.
- Wood smoke increases risk of cardiovascular diseases, cancer, serious lung diseases, etc.
- Contributes significantly to morbidity, premature mortality and to climate change (black carbon, CH₄ and CO₂).

Just a little wood burning in Copenhagen ...

- 15,000 wood stoves in Copenhagen (660,000 citizens) emit same amount of toxic particle pollution in one winter as all traffic in the city emits within one year!
- Wood burning covers 0.3% of the energy consumption in the city but emits 37% of all PM_{2.5} (fine particles).
- By replacing wood burning with low-cost district heating, the emission of fine particles in Copenhagen would be reduced more than if all traffic (all cars, trucks, etc.) was prohibited permanently ...

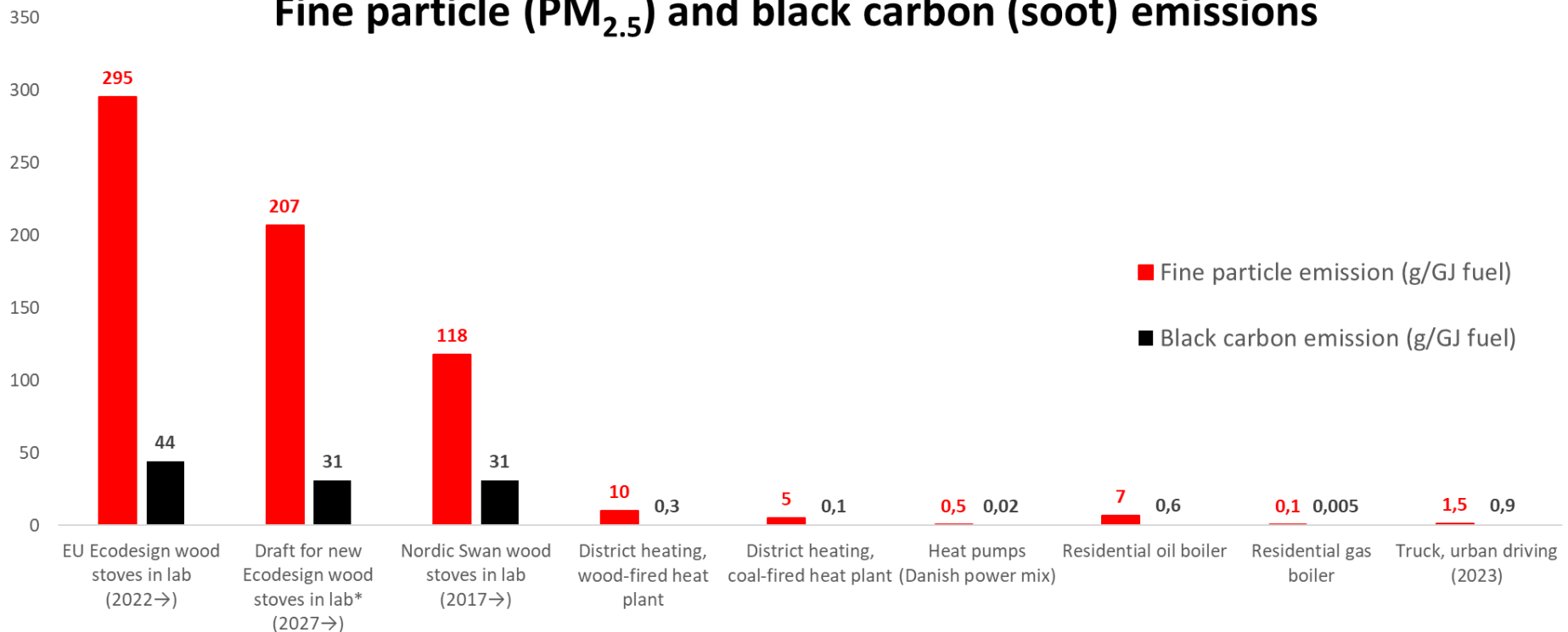
A small calculation

- A new wood stove fulfilling the Ecodesign regulation emits (during lab testing) around 5 g PM_{2.5} per kg wood burned.
- The new WHO AQ guideline is 5 microgram PM_{2.5} per m³.
- Burning 1 kg of wood will pollute (at least) 1,000,000 m³ of clean air to the WHO air quality guideline ... All air covering 10,000 m² up to a height of 100 m!
- This is not aligned with the EU zero pollution vision ... and generate high pollution levels in residential areas.

Very weak emission standards

New stoves do **not** solve the problem ... and what about existing?
 Huge benefits by switching to district heating and heat pumps!

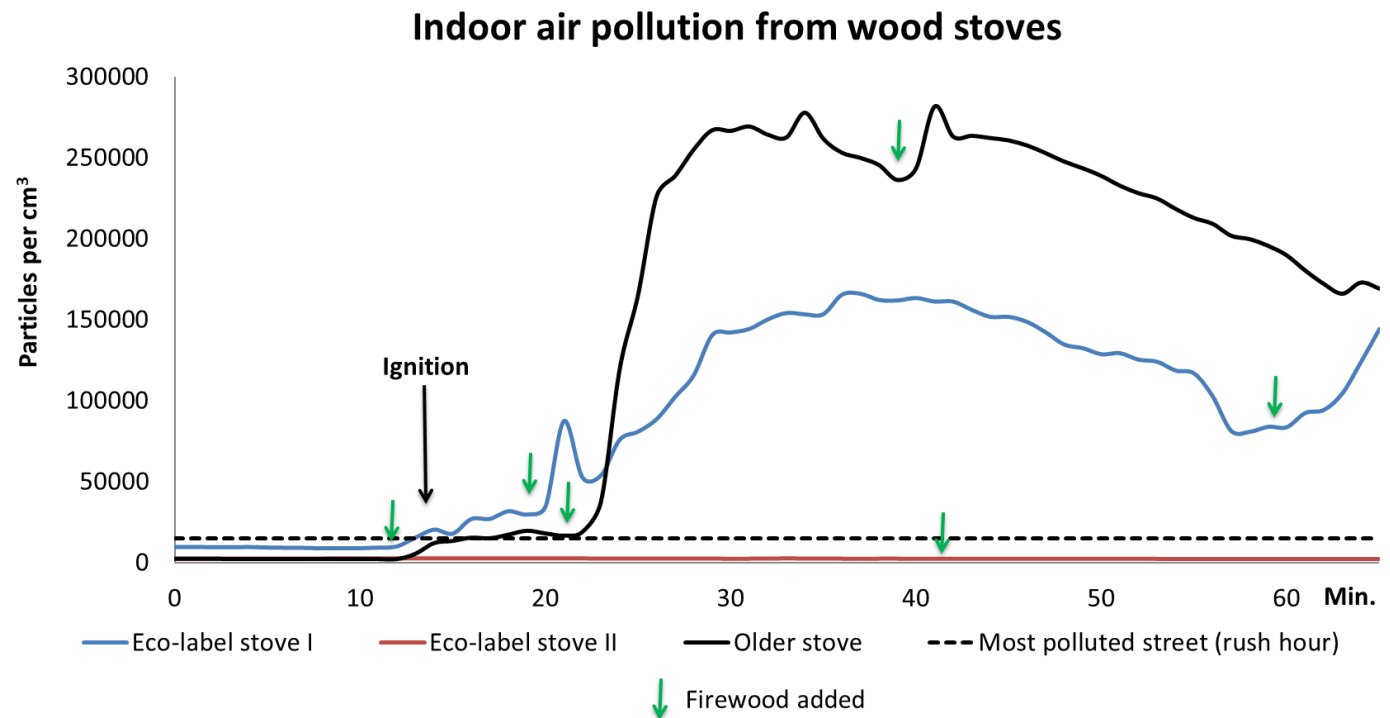
Fine particle (PM_{2.5}) and black carbon (soot) emissions



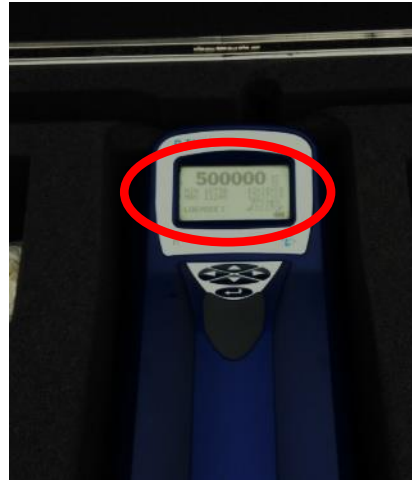
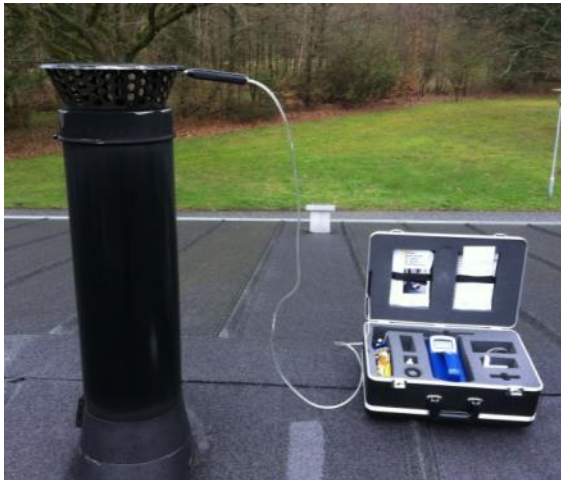
*Assuming new Ecodesign wood stoves will emit 30 % less PM/BC

Risk of very high indoor pollution levels

Some (but not all) wood stoves emit smoke directly inside homes and thereby increase indoor air pollution.



New stoves vs. new trucks



Top: Before stove measurements.

Below: After 1 h measurements.



Conclusion:

New low-emission stoves cause much higher emissions (above 500.000 part/cm³) than new trucks with particulate filters (below 1.000 part/cm³).

Costs of ownership

Electrostatic precipitators for wood stoves

		Denmark	Slovakia
Estimated price of precipitator (mass production)		1,000 euro ¹⁾	1,000 euro ¹⁾
Estimated installation price of precipitator		200 euro ²⁾	60 euro ⁷⁾
Electricity costs per year ³⁾	Urban: 44 kWh	16 euro ⁴⁾	8 euro ⁴⁾
	Towns: 99 kWh	36 euro ⁴⁾	18 euro ⁴⁾
	Rural: 180 kWh	65 euro ⁴⁾	32 euro ⁴⁾
Extra maintenance costs per year (chimney sweep)		70 euro ⁵⁾	21 euro ⁷⁾
Total cost of ownership ⁶⁾	Urban	2,920 euro	1,640 euro
	Towns	3,320 euro	1,840 euro
	Rural	3,900 euro	2,120 euro
Ownership costs per year ⁶⁾	Urban	146 euro	82 euro
	Towns	166 euro	92 euro
	Rural	195 euro	106 euro

1) The current price (<https://www.pejseringen.dk/exodraft-braendeovnsfilter>) of an electrostatic precipitator being sold in very low quantities is 2,300 euro. If required by Ecodesign regulations, mass production is expected to reduce the price to max. 1,000 euro (confirmed by the producer *Exodraft* and by https://cea-europe.org/wp-content/uploads/2024/11/CEA_Studie_20241125.pdf).

2) Depending on the access to the chimney (here it is assumed that the chimney can be reached e.g., by using a simple ladder).

3) Assuming that the filter (stove) is used 400/1,200/2,400 hours per year in urban/towns/rural areas (in use 70W / standby: 2W).

4) https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_price_statistics

5) Performed by the chimney sweeper once a year during mandatory inspection (assumed reachable e.g., by using a simple ladder).

6) Assuming that the lifetime of the precipitator is 20 years: <https://www.epa.gov/sites/default/files/2020-07/documents/cs6ch3.pdf>

7) Assumed 30 % of the price in Denmark since average salary in Slovakia is around 30 % of the average salary in Denmark.

0.2-0.5% of
incomes in
DK and SK

Benefits (per GJ of house heating)

Electrostatic precipitators for wood stoves

			Denmark	Slovakia	
Health cost per kg of PM _{2.5} ¹⁾	Urban: > 3,000 citizens/km ²		325 euro	338 euro ⁵⁾	
	Towns: 1,500-3,000 citizens/km ²		213 euro	303 euro ⁵⁾	
	Rural: < 100 citizens/km ²		149 euro	283 euro ⁴⁾	
Emissions from a new stove <u>without</u> precipitator		PM _{2.5} emission ²⁾	0.347 kg		
		Health costs (euro)	Urban	113	117
			Towns	74	105
			Rural	52	98
Emissions from a new stove <u>with</u> precipitator		PM _{2.5} emission ³⁾	0.104 kg		
		Health costs (euro)	Urban	34	35
			Towns	22	32
			Rural	16	29
Health benefits (avoided costs) of precipitators (euro)		Urban	79	82	
		Towns	52	74	
		Rural	36	69	

1) https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2023/N2023_54.pdf (Multiplying with 1.09 to get 2025 prices).

2) Assuming 85% energy efficiency and using emission factors of <https://dce2.au.dk/pub/SR435.pdf> (Ecodesign stoves = 295 g/GJ).

3) Assuming an average fine particle removal of 70% over the lifetime by the precipitator.

4) Assuming that the rural PM_{2.5} emission from stoves in Slovakia has a cost being 1.9 higher than rural stoves in Denmark due to the much higher regional population density in central Europe <https://www.eionet.europa.eu/etcs/etc-atni/products/etc-atni-reports/etc-atni-report-04-2020-costs-of-air-pollution-from-european-industrial-facilities-200820132017>

5) Assuming that the cost increase from rural areas to more densely populated areas (towns and urban) in Slovakia are 31% of corresponding cost increase in Denmark since the Slovakian GNP is 31% of the Danish GNP (table 1).

Cost-Benefit (per GJ of house heating per year)

Electrostatic precipitators for wood stoves

		Denmark	Slovakia
Stove contribution to house heating¹⁾	Urban	5 GJ (1.4 MWh)	
	Towns	15 GJ (4.2 MWh)	
	Rural	30 GJ (8.4 MWh)	
Health benefits of precipitators²⁾	Urban	395 euro	410 euro
	Towns	776 euro	1,104 euro
	Rural	1,086 euro	2,063 euro
Ownership costs³⁾	Urban	146 euro	82 euro
	Towns	166 euro	92 euro
	Rural	195 euro	106 euro
Benefit to cost ratio	Urban	2,7	5,0
	Towns	4,7	12,0
	Rural	5,6	19,4

1) Assuming 400/1,200/2,400 hours of precipitator (stove) use a year in Urban/towns/rural areas and a typical new stove.

2) Calculated from health benefits due to less pollution for stoves with precipitators in table 3 (e.g. 5GJ · 79€/GJ = 395€).

3) From annual costs calculations (table 2).

Results

It is a socially beneficial investment (benefit-to-cost ratio > 1) if the revised Ecodesign regulations mandate the use of electrostatic precipitators for stoves.

Health costs in DK per GJ of heating

			PM _{2.5}	NO _x	NH ₃	SO ₂	Total cost
Average cost in euro per kg (wood stoves/power plants) ¹⁾			140/74	57/24	38/--	25/24	---
New wood stoves ²⁾	Wood	Kg	0.347	0.094	0.043	0.013 ⁴⁾	55.7 euro
		Euro	48.6	5.3	1.5	0.3	
New wood stove with precipitator ³⁾	Wood	Kg	0.104	0.094	0.043	0.013	21.6 euro
		Euro	14.5	5.3	1.5	0.3	
Heat pumps ⁴⁾ (1/3 of power plant)	Coal	Kg	0.001	0.006	0	0.004	0.31 euro
		Euro	0.07	0.14	0	0.10	
	Gas	Kg	<0.001	0.009	0	<0.001	0.22 euro
		Euro	---	0.22	---	---	
	Wood	Kg	<0.001	0.011	0	<0.001	0.26 euro
		Euro	---	0.26	0	---	
	Wind/sun/hydro	Kg/euro	0	0	0	0	0

1) https://dce.au.dk/fileadmin/dce.au.dk/Udgivelser/Notater_2023/N2023_54.pdf (Multiplying with 1.09 to get 2025 prices).

2) <https://dce2.au.dk/pub/SR435.pdf> assuming 85% efficiency (Stoves (2015-2016) p. 114 are fulfilling the present Ecodesign regulations).

3) Assuming that precipitators on new stoves in the Ecodesign directive remove about 70% of PM_{2.5}

4) https://envs.au.dk/fileadmin/envs/Emission_inventories/Emission_factors/Emf_internet_energy_GHG.htm and 300% heat efficiency.

Results

The health costs of air pollution from a new wood stove meeting current Ecodesign regulations are approximately 180 times higher per GJ of household heating than those from a coal-powered electric heat pump.

Global warming per GJ of house heating

			CO ₂ ¹⁾	CH ₄	N ₂ O	BC ²⁾	Total GW
Official GWP20 / GWP100			1 / 1	84 / 28	264 / 298	3,200/900	GWP20/100
New wood stove	Wood	Kg	0-121 ⁵⁾	0.1 ⁵⁾	0.005 ⁵⁾	0.052 ³⁾	175-296 / 51-172
		GWP20/100	0-121	8.4/2.8	1.3 / 1.5	166 / 47	
New wood stove with precipitator ⁴⁾	Wood	Kg	0-121	0.1	0.005	0.016 ⁴⁾	61-182 / 18-139
		GWP20/100	0-121	8.4/2.8	1.3 / 1.5	51 / 14	
Heat pump ⁵⁾ (1/3 of power plant)	Coal	Kg	32	<0.001	<0.001	<0.001	32 / 32
		GWP20/100	32	---	---	---	
	Gas	Kg	19	<0.001	<0.001	<0.001	19 / 19
		GWP20/100	19	---	---	---	
	Wood	Kg	0-33	0.001	<0.001	<0.001	0-33 / 0-33
		GWP20/100	0-33	0.1/---	---	---	
	Wind/sun/ hydro	Kg	0	0	0	0	0 0
		GWP20/100	0	0	0	0	

1) CO₂ interval for wood: Wood considered CO₂-neutral ("0") and taking the actual full CO₂-emission from wood burning into account ("121").

2) BC: Black Carbon.

3) <https://dce2.au.dk/pub/SR435.pdf> assuming 85% energy efficiency. (Stoves 2015-2016 p. 114 fulfill the present Ecodesign regulations).

4) Assuming that precipitators on new stoves in the Ecodesign directive remove about 70% of BC: https://sites.uef.fi/real-life-emissions/wp-content/uploads/sites/321/2024/10/Presentation_Olli_LIFE_10-10-2024_-4.pdf

5) https://envs.au.dk/fileadmin/envs/Emission_inventories/Emission_factors/Emf_internet_energy_GHG.htm with 300% heat efficiency.



Results

A wood stove complying with current Ecodesign regulations causes significantly more global warming per GJ of household heating than a heat pump powered by coal-based electricity (true even when assuming that CO₂ from wood are entirely carbon neutral).

Further information

Cost-Benefit study_Electrostatic precipitators for new wood stoves in the EU

General info on pollution from residential heating

Brief, June 2025
COST-BENEFIT: ELECTROSTATIC PRECIPITATORS FOR WOOD STOVES

The European Environmental Bureau has asked Green Global Future to conduct a cost-benefit screening of the following scenario: the ongoing revision of the Emissions legislation leads to an outcome where electrostatic precipitators (for similar technology) will be a mandatory requirement for new wood stoves. The work is funded by the European Climate Foundation and the Clean Air Fund.

Calculations are conducted for **densely populated urban areas, smaller towns, and rural areas** (cities, urban, towns, rural), as the latter typically have more efficient use of biomass than the former. In Denmark and Slovakia, two EU countries that have same size but quite different per-capita average income. The purpose is to illustrate the consequences in both wealthier and less wealthy countries in the EU. Furthermore, externalities due to air pollution (health costs only) and climate pollution have been calculated per GtCO₂e (50 of biomass heating for new wood stoves (with/without precipitators) and heat pumps. Taking into consideration the estimated average energy use of the different areas in the two countries, an analysis of the total cost of ownership of precipitation technology is then presented.

COSTS: ELECTROSTATIC PRECIPITATORS

Table 1 shows the Gross National Product (GNP) of DK and SK underlying the different economic capacity whereas table 2 contains cost estimations regarding precipitation for wood stoves in the two member states.

Table 1: GNP for Denmark and Slovakia


	Denmark	Slovakia
GNP per capita (2024) ¹⁾	60,510 euro	19,130 euro
Average salary	70,000 euro	20,000 euro

1) <https://data.oecd.org/gdp/gdp-per-capita-denmark.htm>, <https://data.oecd.org/gdp/gdp-per-capita-slovakia.htm>

Table 2: Costs for electrostatic precipitators




	Denmark	Slovakia
Estimated price of precipitator (mass production)	1,000 euro ¹⁾	1,000 euro ¹⁾
Estimated installation price of precipitator	200 euro ¹⁾	80 euro ¹⁾
Electricity costs per year ¹⁾	10 euro ¹⁾	4 euro ¹⁾
Extra maintenance costs per year (chimney sweep)	35 euro ¹⁾	18 euro ¹⁾
Total cost of ownership ¹⁾	1,035 euro ¹⁾	210 euro ¹⁾
Ownership costs per year ¹⁾	148 euro	62 euro
	Urban	148 euro
	Towns	148 euro
	Rural	195 euro

1) <https://www.energinet.dk/da/energi/elektricitet/elektricitet-i-huset>



POLLUTION FROM RESIDENTIAL BURNING

Donish experience in an international perspective



Indoor air pollution from wood stoves and fireplaces

We spend most of our lives in our homes where good air quality is vital for our health and wellbeing.

According to the Danish Health Authority, air pollution is one of the biggest risk factors in relation to mortality. The pollution increases the risk of cancer, cardiovascular diseases, blood clots, diabetes, chronic bronchitis, asthma, allergy and other severe diseases. That makes air pollution one of the causes of the diseases that every third person suffers from in many industrialised countries. At the same time, air pollution worsens the day-to-day quality of life for millions of people living with a lung disease.

Fortunately, we can easily reduce air pollution in our homes if we pay attention to the pollution sources and by using our common sense. This leaflet focuses on indoor air pollution from wood stoves and fireplaces, however plenty of other significant pollution sources exist in our homes. Read more at www.godtindeklima.nu

Unknown pollution
 According to the Danish Environmental Protection Agency, wood smoke is the most health hazardous source to outdoor air pollution. The smoke contains the same harmful particles and carcinogenic tar substances as tobacco smoke. However, only few people consider that wood stoves and fireplaces can contribute significantly to the pollution inside their homes.

Wood stoves and fireplaces can release high amounts of health hazardous particles directly to the air in your living room. From there the pollution can easily spread to the rest of the house. The air in your home can reach pollution levels to more than 10 times the levels that are seen at the most polluted streets during rush hour.

Regardless of how you kindle you fire and regardless of the age (old or new) of your wood stove, your indoor air can become significantly polluted. Measurements from the Technical University of Denmark show that new ecolabelled wood stoves also tend to cause severe indoor air pollution, and smoke extractors do not seem to solve the problem either.

Healthy Indoor Environment
www.godtindeklima.nu

Did you know that your wood stove or fireplace can contribute significantly to the pollution inside your home? Read more at www.godtindeklima.nu

to ensure that future wood stoves do not pollute the indoor air. It is uncertain if this will be decided. However, an indoor limit value for new stoves will not make a difference for homes with existing wood stoves and fireplaces.

Solutions
 The best solution is to use central heating and cease to use the wood stove, fireplace, etc. You can preserve the cozy atmosphere without fire, by using an electric wood stove or TV fireplace. This eliminates the pollution.

If you cannot do without wood burning, then settle for 3-5 minutes with through draft at least once an hour (windows open on both sides of the house) - remember to turn off your radiators meanwhile to avoid heat loss. Always keep the door(s) closed to adjacent rooms to avoid the air pollution from spreading to the rest of the house.

A wood stove can cause severe air pollution in your house

There are no limit values defined for how much wood stoves and fireplaces are allowed to pollute the air in your house. We have requested a limit value to be included in EU's new Ecodesign Directive

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