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, CH_4 and CO_2).

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Just a little wood burning in Copenhagen …

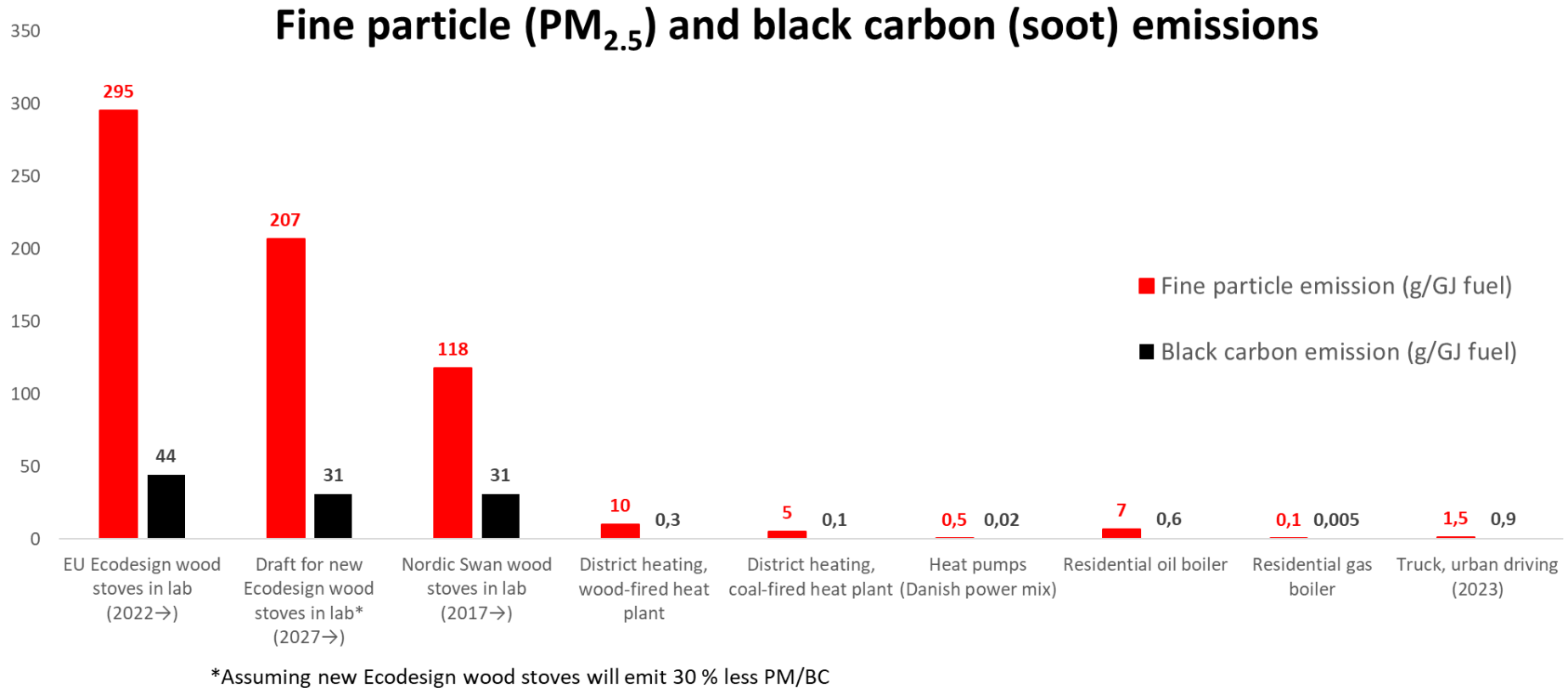
- 15,000 wood stoves in Copenhagen (660,000 citizens) emit same amount of toxic particle pollution in one winter as all traffic in the city emits within one year!
- Wood burning covers 0.3% of the energy consumption in the city but emits 37% of all $PM_{2.5}$ (fine particles).
- By replacing wood burning 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 m^3.
- Burning 1 kg of wood will pollute (at least) 1,000,000 m^3 of clean air to the WHO air quality guideline … All air covering 10,000 m^2 up to a height of 100 m!
- This is <u>not</u> aligned with the EU zero pollution vision … and generate high pollution levels in residential areas.

Very weak emission standards

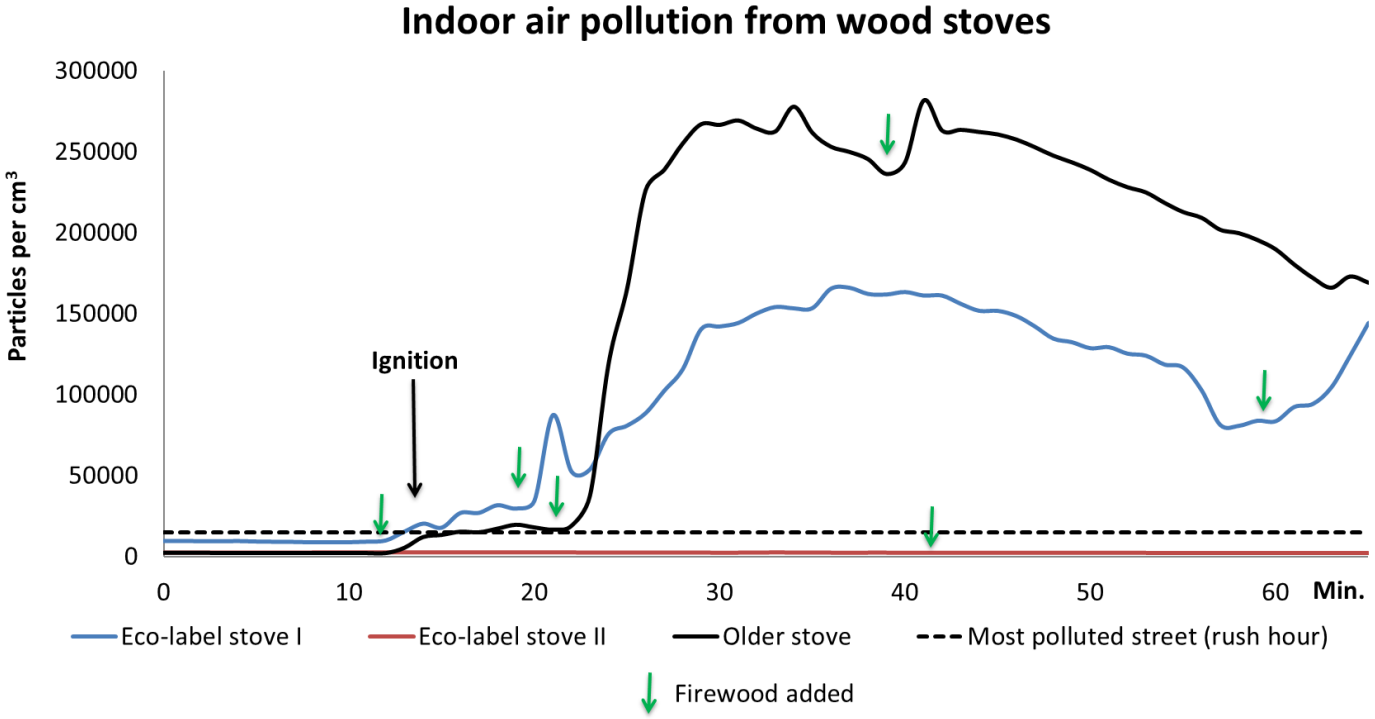
New stoves do **not** solve the problem … and what about existing?
Huge benefits by switching to district heating and heat pumps!



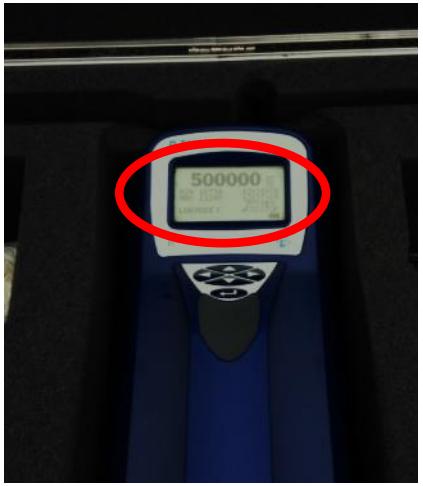
*Assuming new Ecodesign wood stoves will emit 30 % less PM/BC

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/cm^3) than new trucks with particulate filters (below 1.000 part/cm^3).

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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 without 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 with 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).

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

Electrostatic precipitators for wood stoves

		Denmark	Slovakia
Stove contribution to house heating [1)]	Urban	5 GJ (1.4 MWh)	
	Towns	15 GJ (4.2 MWh)	
	Rural	30 GJ (8.4 MWh)	
Health benefits of precipitators [2)]	Urban	395 euro	410 euro
	Towns	776 euro	1,104 euro
	Rural	1,086 euro	2,063 euro
Ownership costs [3)]	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.

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Health costs in DK per GJ of heating

			$PM_{2.5}$	NOx	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_2O	BC [2]	Total GW GWP20/100
Official GWP20 / GWP100			**1 / 1**	**84 / 28**	**264 / 298**	**3,200/900**	
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**
		GWP20/100	0	0	0	0	**0**

1) CO_2 interval for wood: Wood considered CO_2-neutral ("0") and taking the actual full CO_2-emisson 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.

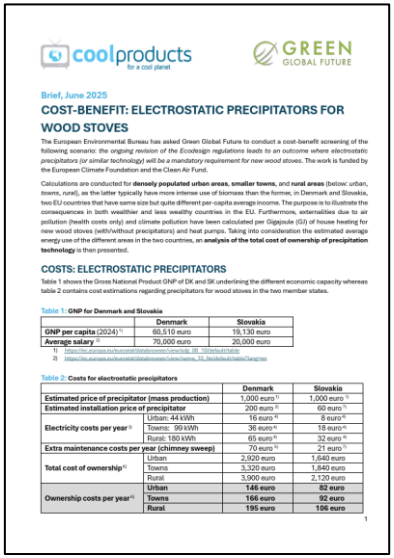
Results

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 CO_2 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



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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 Ecodesign regulations leads to an outcome where electrostatic precipitators (or 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** (below: urban, towns, rural), as the latter typically have more intense 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 Gigajoule (GJ) of house 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 underlining the different economic capacity whereas table 2 contains cost estimations regarding precipitators 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 [2]	70,000 euro	20,000 euro

1) https://ec.europa.eu/eurostat/databrowser/view/nama_10_pc/default/table?lang=en
2) https://ec.europa.eu/eurostat/databrowser/view/earn_ses_pub1e/default/table?lang=en

Table 2: **Costs for electrostatic precipitators**

		Denmark	Slovakia
Estimated price of precipitator (mass production)		1,000 euro [1]	1,000 euro [1]
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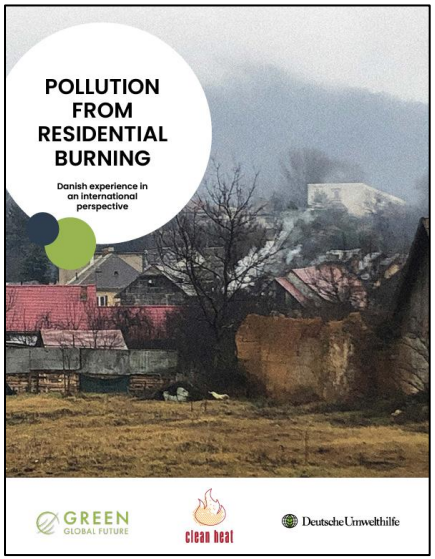

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