



— 70 years —
1950-2020

The background image is a composite scene. It features a snowy mountain range under a blue sky with scattered clouds. In the foreground, there are several white wind turbines on a rocky, snow-covered island. To the left, a large white ship is on the water, and a smaller blue boat is in the foreground. In the distance, a city skyline is visible through a light haze. The overall scene is bright and clear.

Emission levels and emission factors for modern wood stoves

SusWoodStoves presentation at Progetto Fuoco, IEA workshop on Sustainable low emission wood stoves

28 February 2024

Øyvind Skreiberg

Chief Scientist, SINTEF Energy Research, Norway

SusWoodStoves

Increased sustainability for the wood stove value chain

Background

Wood log combustion is important in and for Norway and contributes much to residential space heating and relieves the pressure on the electricity grid, as well as provides energy security when the electricity grid goes down. However, wood log combustion contributes also to air pollution, and there is a need to increase the sustainability through stove, building integration and value chain optimization, which is the main project focus.

Goals

- 1) Speciation and quantification of particulate and gaseous emission levels from wood stoves for representative stove technologies and operating conditions,
- 2) Reduction of climate and health related emission levels through emission reduction and energy efficiency measures,
- 3) Optimum building integration of stoves,
- 4) Assessment of value chain performance of existing and improved stove technologies and connected systems for different stove-building configurations in Norway,
- 5) Techno- and socio-economic assessments of the current and future role of wood stoves in the Norwegian energy market,
- 6) Development of a roadmap for sustainable wood stoves in Norway,
- 7) Education of highly skilled candidates within this area and training of industry partners,
- 8) Monitoring of activities and state-of-the-art within this area and dissemination of knowledge to the industry partners, and other interested parties when applicable.



Project title: Sustainable wood stoves through stove, building integration and value chain optimization (SusWoodStoves)

Project leader: SINTEF Energy Research

Partners: NTNU, Jøtul AS, Nordpeis AS, Norsk Kleber AS, Norsk Varme

Project period: 2021-2024 (26)

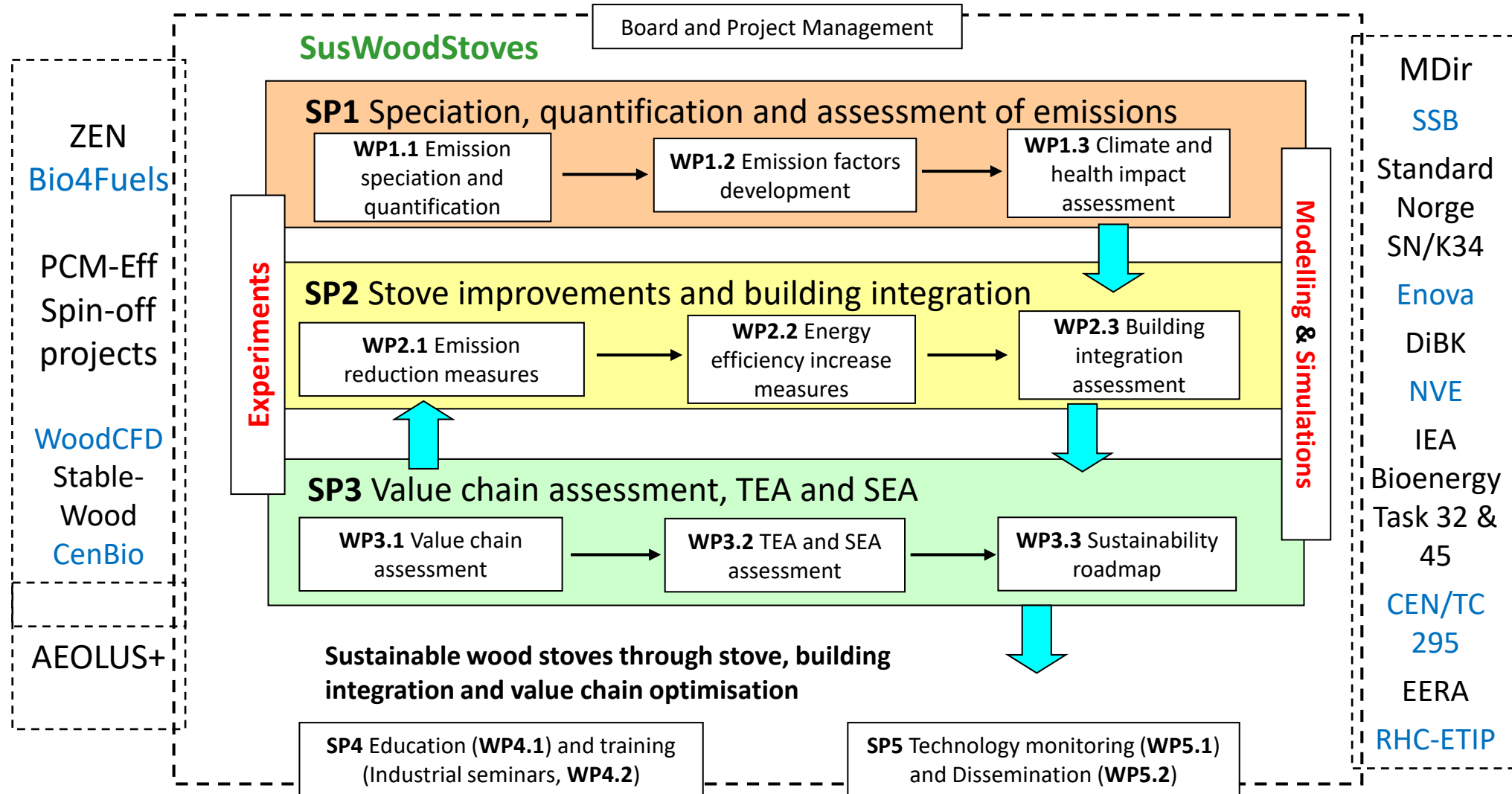
Type: Knowledge building project for the industry

Financing: 18.6 mill. NOK (15.1 from Research Council of Norway)

Project number: 319600

SusWoodStoves - Project structure

More info on the project [homepage](#)



SusWoodStoves - SP1

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A Critical Review and Discussion on Emission Factors for Wood Stoves

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[Link](#)

Large variations exist in emission factors used in national emission inventories in the Nordic countries as well as when comparing with EMEP/EEA 2019 emission factors

There is a real need to derive more representative emission factors for wood stoves and to align these for inclusion in national emission inventories

Note: When using particulate emission factors for wood stoves derived using the Norwegian type approval standard in an atmospheric modelling tool, together with emission factors from other emission sources (e.g. traffic), and comparing with measurements, it is comparable (i.e. "real life").

SusWoodStoves - SP1

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How much has the modern wood stoves improved since 1998?

(from when only clean-burning stoves could be sold in the Norwegian market)

Emission Levels and Emission Factors for Modern Wood Stoves

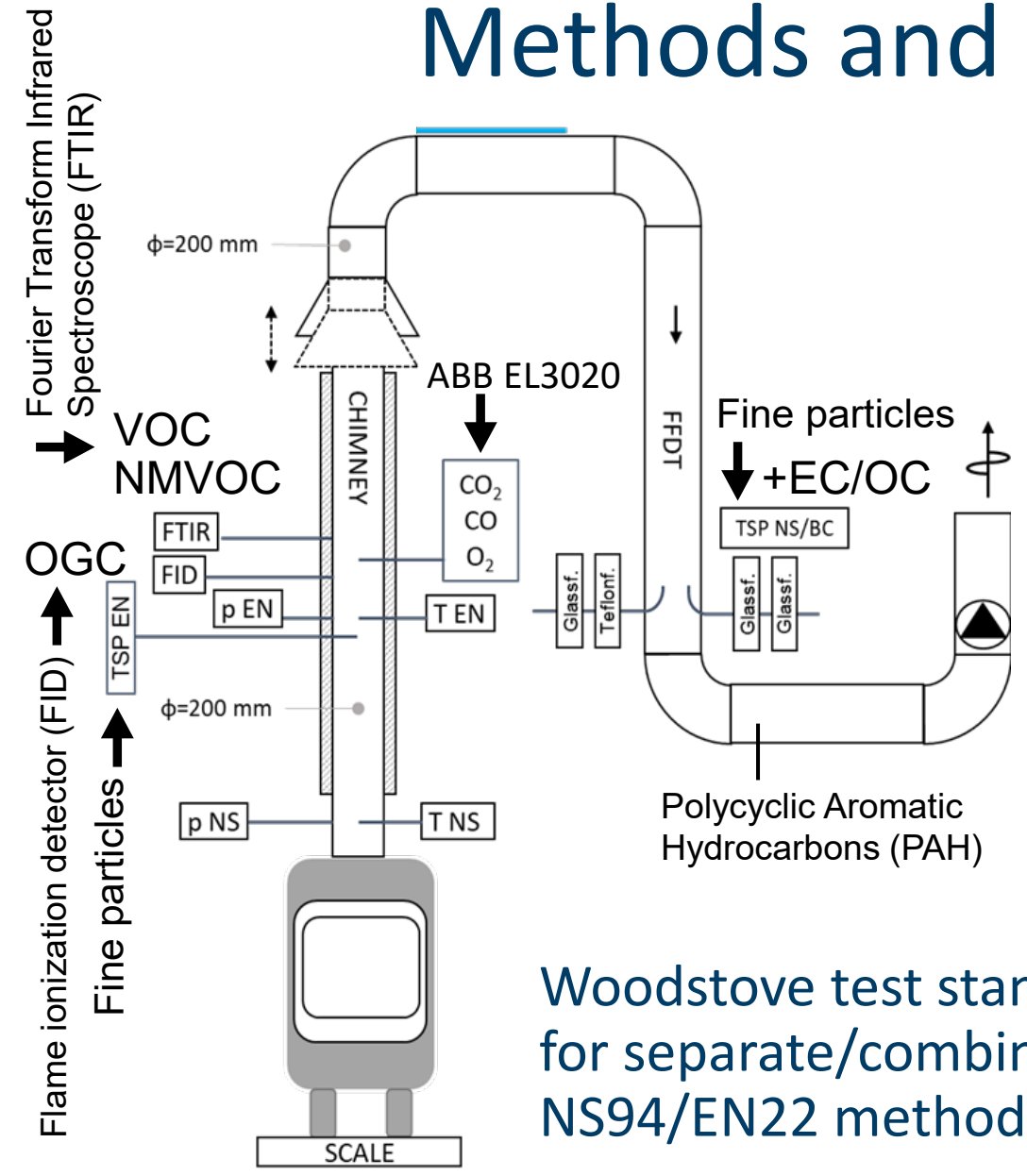
Øyvind Skreiberg*, Morten Seljeskog, Franziska Kausch, Roger Khalil

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[Link](#)

Primary emission reduction measures

Methods and materials



Woodstove test stand for separate/combined NS94/EN22 methods



Primary emission reduction measures

Results

Current and recommended new emission factors for modern wood stoves, in g/kg dry fuel

	"Old" new stove	New new stove	Part load	Nominal load	Reduction	Part load / nominal load
TSP	8.44	3.84	5.44	2.39	55%	2.27
PM ₁₀	8.30	3.81	5.40	2.38	54%	2.27
PM _{2.5}	7.85	3.78	5.34	2.34	52%	2.28
CO	85.73	23.89	35.21	15.59	72%	2.26
NMVOC	15.22	3.54	6.10	2.32	77%	2.63
CH ₄	3.88	0.95	1.94	0.42	76%	4.59
EC	0.65	1.05	0.93	0.87	-61%	1.07
OC	4.50	1.33	2.53	0.79	70%	3.21
NO _x	0.69	0.66	0.67	0.68	4%	0.98
N ₂ O	0.02	0.02	0.02	0.01	31%	1.46
NH ₃	0.05	0.05	0.05	0.04	0%	1.40
SO ₂	0.30	0.14	0.13	0.15	54%	0.89
HCN		0.0013	0.0011	0.0014		0.80

- Emission factors about three times higher at part load vs. nominal load
- Carbonaceous particles are hard to remove even in new stoves
- NO_x - no significant reduction

"Old" new stove - an average for stoves produced from 1998 to 2016

New new stove - an average for representative stoves of today (2022)

Summary

- Today`s modern wood stoves emits on average 50+% less particles and 70+% less harmful gaseous compounds, than the average of new stoves since 1998
- Fine particles as soot/black carbon is difficult to reduce even if the combustion conditions are much improved
- No NOx emission reduction, despite the staged-air combustion principle
- End-users should preferably operate their appliance at nominal loads
- Automated wood stoves would be necessary for minimum user interaction
- Radical design changes are necessary for abatement of some emission compounds
- National emission inventories should be updated according to the progress of any technology, including wood stoves, responsible for harmful emissions

SusWoodStoves - SP1



SusWoodStoves - Sustainable wood stoves through stove, building integration and value chain optimisation



Report

Revised emission factors for wood stoves

Authors:

Øyvind Skreiberg, Morten Seljeskog, Franziska Kausch

Report No:

2023:00869 - Restricted

Client (pos partner):

SusWoodStoves project consortium

Summary:

Today the best wood stoves outperform the staged air combustion wood stoves introduced in the 1990s, as further continuous improvements have been carried out and new and improved designs have been introduced. Hence, in national emission inventories this should be considered, so the mean emission factors used for the overall modern wood stove category reflect the continuous improvements over the last decades. The measurements carried out in this work made it possible to provide such emission factors for the modern wood stove category, for a wide range of emission compounds. The results show that most emissions of unburnt have been much reduced the last decades. However, for black carbon and for emissions due to minor and trace elements in the wood, this is not the case. Further targeted development and/or new combustion concepts are needed to significantly reduce both black carbon and NOx emissions.

The emission factors have been presented to the Norwegian authorities

Emissions from modern wood stoves

[Link](#)

January 2024

Factsheet: Emissions from modern wood stoves

Emissions from wood burning are strongly reduced the last decades, thanks to continuous research and technology development. This is one of the results from the knowledge building project [SusWoodStoves](#), supported by the Research Council of Norway and industry.

In [SusWoodStoves](#) we have compared the emission factors that today are used in the Norwegian national emission inventory for modern wood stoves with three modern wood stoves.

Then we found that the three modern wood stoves on average has:

- 52 % lower emissions for the smallest (and most dangerous) particles (PM2.5)
- 72 % lower emissions for CO (carbon monoxide)
- 76 % lower emissions for CH₄ (methane)
- 77 % lower emissions for other relatively light gases (NMVOC)
- 70 % lower emissions for the heaviest gas compounds that condense out as liquid particles in the atmosphere

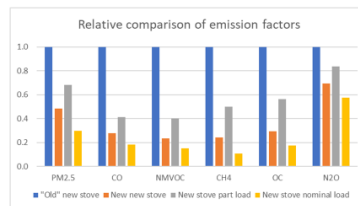
The emission inventory must be updated

The results are good news that also must be reflected in our national emission inventory. Updated emission factors (per kg dry wood) must be used when the total emissions from the wood stove fleet in Norway is calculated based on technology type (old stove: before 1998; modern stove: from 1998; and open fireplace) and the wood consumption in these.

Read more in the SINTEF blog [Research and Development Reduce Emissions from Wood Burning](#). And in the scientific publication [Emission levels and emission factors for modern wood stoves](#).

At the same time the stove efficiency has been improved, being on average 80%, which gives further reduced emissions per kWh net heat output.

Want to know more? Contact: [@yvind Skreiberg](#)
Chief Scientist at SINTEF Energy Research



[Link](#)

#ENERGY BIOENERGY

Research and Development Reduce Emissions from Wood Burning



BY ØYVIND SKREIBERG
FEBRUARY 8, 2024

COMMENTS
0



SusWoodStoves - SP2

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Energy Efficiency Increase by Improved Operation and Control in Wood Stoves

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[Link](#)

Stove efficiencies of around **80%** was achieved for all three stoves, with the highest efficiency achieved for the stove with the highest heat storage capacity

The potential for further efficiency increases in wood stoves is significant, as during the combustion process the total efficiency in these modern wood stoves can approach **90%**

The efficiency used by Statistics Norway today is 75% for modern wood stoves. Old stoves: 50%. Open fireplaces: 15%.

SusWoodStoves - SP2



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Reducing Emissions from Current Clean-Burn Wood Stove Technology by Automating the Combustion Air Supply and Improving the End-User Interaction – Two Important Primary Measures

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Automating the combustion air has a high potential to reduce emissions of PM, CO, and OGC, as well as increasing the efficiency

Good ignition is crucial to achieve low emissions

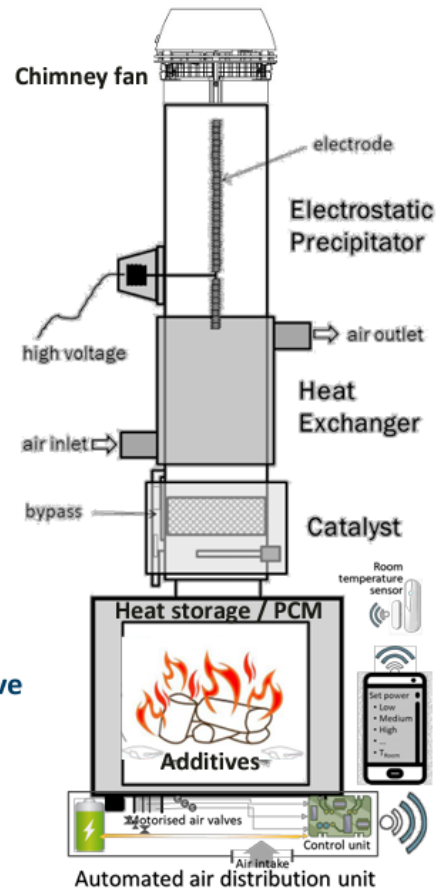
No significant differences in emissions were found when comparing birch, spruce and pine

Primary emission reduction measures

Summary

- Automating the combustion air has a high potential to reduce emissions of PM, CO, and OGC, as well as increasing the efficiency even at more realistic test conditions.
- The effect of end-user operation as for the ignition from cold stove, and use of fuel with varying properties, showed significant variation in emissions over the ignition period.
- Good ignition, when firing according to NS94, can be achieved repeatedly by assuring that the fuel catches fire before closing the door and/or reduce the primary/secondary air flows.
- **Bad ignition** due to **over-/under** firing and **dense stacking**, can produce at least **twice as much PM and CO** and **3-4 times the OGC**, compared to correct ignition.
- **No significant differences** in emissions were found when comparing **birch, spruce, and pine**, for wood with equal moisture content.
- However, **burning pine, showed higher** emissions of total carbon particles, as elemental and organic carbon, on the same level as with poor ignition.

SusWoodStoves - SP2



Report

Secondary Measures to mitigate wood stove emissions

D2.1.2

Author:

Morten Seljeskog

Report No:

2023:01381 - Restricted

Client (pos partner)

SusWoodStoves project consortium

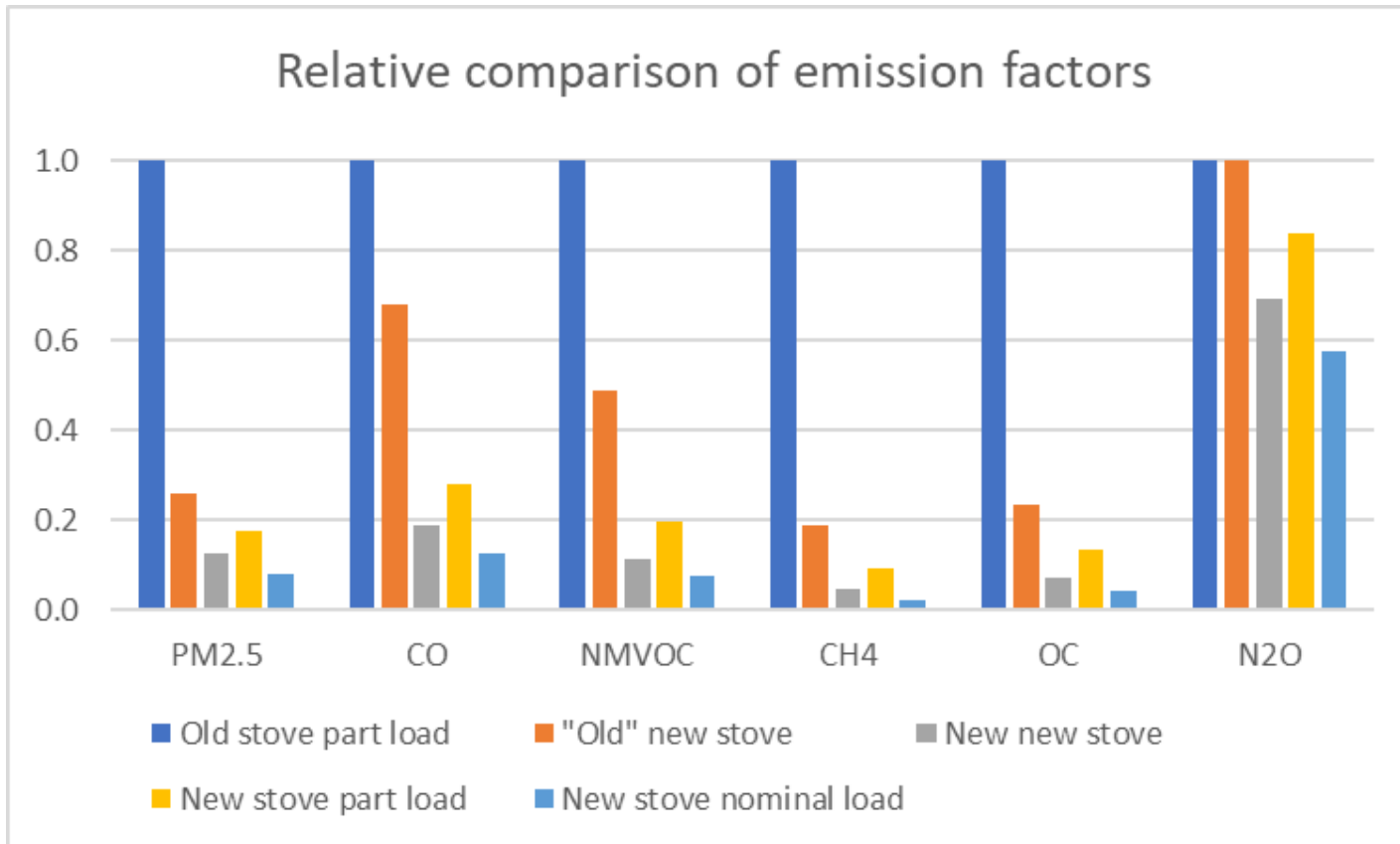
Secondary measures

The main recommendation from this report, is that the best solution in terms of emission reductions and efficiency increase, for old small-scale room heaters, is still to replace those for new ones

Most secondary measures referred to in this report, even commercial ones like ESPs or retrofit catalysts, still need more research/development before they constitute a real alternative regarding emission reductions

SusWoodStoves - SP2

PhD study - ongoing (first publication is in progress)



Climate impact of wood stove use

Health impact of wood stove use

Climate and health impacts are also reduced alongside environmental impacts

Different with respect to GWP factors, and geographical and seasonal dependent GWP for several compounds, and BC is important!

Different with respect to health influence, and PM is important!




Old stove - an average for stoves produced before 1998

"Old" new stove - an average for stoves produced from 1998 to 2016

New new stove - an average for representative stoves of today (2022)

SusWoodStoves - SP3

Measurement of the Wood Stove Impact on the Electric Power Consumption of a Norwegian Detached House

Abolfazl Mohammadabadi¹ (✉) , Øyvind Skreiberg² , and Laurent Georges¹ 

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PhD study - ongoing
(first publication is published)

The study underscores the potential of wood stoves to reduce electric power consumption during mornings and evenings, thus reducing the stress on the electricity grid

PhD study - Building integration and electricity grid interaction

SusWoodStoves - SP4

2 PhD

Master and summer students

Workshops

SusWoodStoves - SP5

<https://www.sintef.no/en/projects/2021/suswoodstoves-sustainable-wood-stoves-through-stove-building-integration-and-value-chain-optimisation/publications/#menu>

Numerous dissemination efforts towards the public, and some also in English language

#ENERGY BIOENERGY

The 10 commandments of wood burning stoves



BY ØYVIND SKREIBERG
NOVEMBER 13, 2023

COMMENTS

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Take home messages

- Modern wood stoves have much improved during the last 25 years, resulting in large reductions in most emissions of unburnt, and increased energy efficiency
- Environmental, climate and health impacts are reduced accordingly
- Still, proper operation and wood quality is key
- Automation of the air supply contributes to automatic proper operation
- End-users should preferably operate their appliance at nominal load
- Different wood species give mostly similar emissions of unburnt
- National emission inventories should be updated according to the progress of any technology, including wood stoves, responsible for harmful emissions
- However, too large variations in emission factors for most species can be seen in national emission inventories today



— **70 years** —
1950-2020

Technology for a better society