

Nordic SLCP project – improved emission inventories

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Outline

- ➔ The Nordic SLCP project
- ➔ Measurement program, residential wood burning
- ➔ Preliminary results: boilers, stoves
- ➔ Some preliminary conclusions

The Nordic SLCP project

- ➔ Focus on Black Carbon (but also EC/OC, PM_{2.5}, CH₄, NMVOC).
- ➔ 2013-2015: Background analysis and identification of knowledge gaps
 - Report available at <http://dx.doi.org/10.6027/TN2015-523>
 - Background analysis provided basis for designing a measurement program
- ➔ 2015-2017: Emission measurements (residential biomass combustion), development of emission factors, inventory methodology
- ➔ 2016-2017: Identify relevant actions/measures for reduced emissions of SLCP in the Nordic countries

- ➔ Coordinate/cooperate with other relevant international activities, e.g. emission inventory work within TFEIP

Residential biomass combustion

- ➔ Emission factors for PM in the Nordic countries based on different measurement standards.
- ➔ Generally lower emission factors for PM_{2.5} in Sweden, based on hot flue gas measurements (without condensables), while e.g. Danish and Norwegian emission factors are based on diluted sampling (with condensables). Norwegian based on Norwegian standard
- ➔ Differences may also be due to different assumptions regarding operational conditions, e.g. the extent of bad firing habits (incomplete combustion due to restricted air supply) which will produce higher emissions.

National Nordic emission factors for PM_{2.5}

Boilers

	Technology	EF PM _{2.5} (g/GJ)
DK	Old boiler, pre-1980, no acc	1800
DK	Old boiler, pre-1980, acc	900
FI	Manually Fed without accumulator	672
DK	New boiler, post-1980, no acc	413
DK	New boiler, post-1980, acc	206
FI	Manually Fed with accumulator	77
FI	Manually Fed Modern	77
SE	Boiler wood logs	150
FI	Automatic Fed Wood Chips	48
SE	Boiler wood chips	100
DK	Pellet boilers/stoves	32
FI	Automatic Fed Pellets	29
SE	Boiler pellets	30

Stoves

	Technology	EF PM _{2.5} (g/GJ)
DK	Old stove, stove pre-1990	930
FI	Iron stoves conventional	835
NO	Stove old technology (before 1998)	1036
DK	New stove, with DS mark 1990-2005	740
NO	Stove new technology (after 1998)	614
DK	Modern stove, conforming with Danish legislation (2008)	608
FI	Iron stoves modern	835
DK	Eco labelled stove	206
SE	Stove wood logs	100
FI	Kitchen range	142
DK	Pellet boilers/stoves	29
SE	Stove pellets	30

Source: TN2015:523

Measurement program

- ➔ Residential biomass appliances representative for the Nordic countries
- ➔ BC, EC, OC, PM_{2.5}, CH₄, NMVOC
- ➔ Test methods (operational conditions and firing schemes):
 - Boilers: EN 303-5
 - Room heaters: EN 16510 series, including part load (according to proposed revision)
 - Norwegian standard NS 3058
 - Startup phase (ignition) sampled separately
- ➔ Sampling: Dilution tunnel (according to Norwegian standard 3058)
- ➔ Performed in cooperation by SP Technical Research Institute of Sweden (boilers) and Danish Technological Institute (DTI) in Denmark (stoves)

The boiler population

- Modern
 - ➔ P1 Inverse combustion and λ -probe
 - ➔ P2 Inverse combustion and flue gas fan
 - ➔ P3 Inverse combustion and flue gas fan
 - ➔ P4 Inverse combustion and natural draught
- Old
 - ➔ P5 "Simple" boiler
 - ➔ P6 Old combination boiler (oil+wood)
- Pellets
 - ➔ P7 Traditional pellet burner in an oil or combination boiler
 - ➔ P8 Advanced pellets burner in boiler designed for pellet firing
 - ➔ P9 Pellet boiler with integrated grate burner
 - ➔ P10 Wood chip boiler

The stove population

- ➔ A0 Modern medium class wood stove
- ➔ A1 DIY wood stove (simple "building market stove")
- ➔ A2 Modern popular wood stove
- ➔ A3 State of the art wood stove
- ➔ A4 Traditional Nordic cast iron stove
- ➔ A5 Traditional Nordic tiled stove
- ➔ A6 Traditional Nordic slow heat release appliance
- ➔ A8 European type pellets stove
- ➔ A9 Traditional Nordic sauna stove

A1 Simple



A2 Modern



A3 State-of-the-art



A9 Sauna



A4 Cast iron stove



A5 Tiled stove



A6 Slow heat release



A8 Pellets



Test cases

Nominal and part load (where relevant)

Two stoves tested at high load, and also according to NS3058

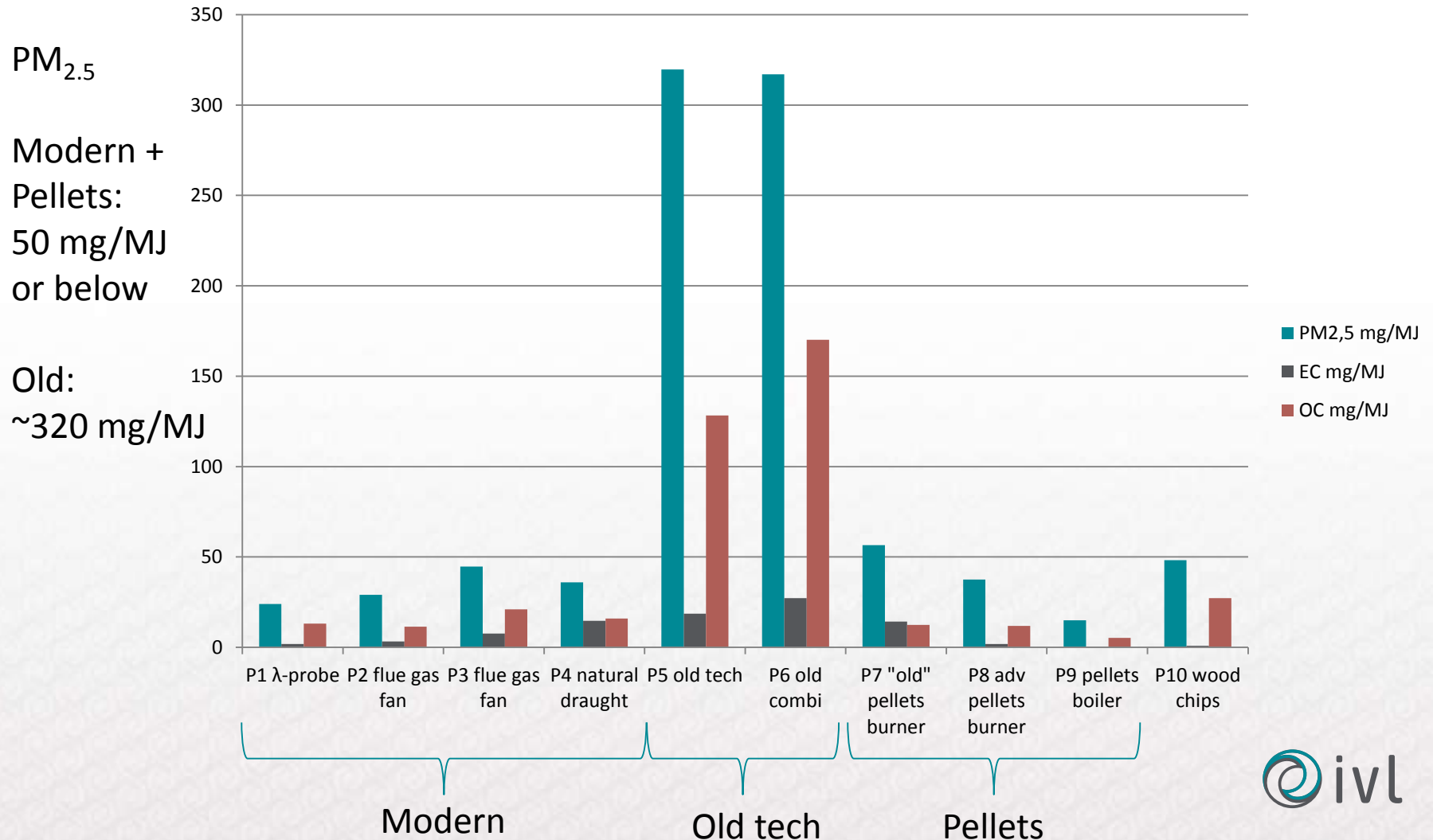
Boiler type	Boilers no	Test at nominal heat load	Test at 30 % part load
Log wood boiler for accumulator operation	P1, P2, P3, P4	Yes	No
Log wood boiler not necessarily for accumulator operation	P5, P6	Yes	Yes
Pellet boiler	P7, P8, P9	Yes	Yes
Wood chip boiler	P10	Yes	Yes

Appliance type Stoves	Appliance no	Test at nominal heat load	Test at part load	Test at high load	Test acc. to NS 3058
Log-wood non-accumulating Appliance	A1, A2	Yes	Yes	Yes	Yes
Log-wood non-accumulating Appliance	A3, A4, A5	Yes	Yes	No	No
Slow heat release appliance	A6	Yes	No	No	No
Pellet stove	A7, A8	Yes	Yes	-	-
Sauna stove	A9	Yes	No	No	No

Fuel quality

Fuel type	Water content, %	Ash content, %	Net calorific value, dry basis, MJ/kg
Standard log wood (SLW)	16 - 20	$\leq 1,0$	>17
Moist log wood (MLW)	25 - 30	$\leq 1,0$	>17
Dry log wood (DLW)	10-14	$\leq 1,0$	>17
Wood pellets (WP)	≤ 12	$\leq 0,5$	>17
Standard wood chips (SWC)	20 - 30	$\leq 1,5$	>17
Moist wood chips (MWC)	40 - 50	$\leq 1,5$	>17

Preliminary results PM_{2.5} boilers: nominal load, standard fuel



Modern wood boilers, nominal load influence of fuel quality

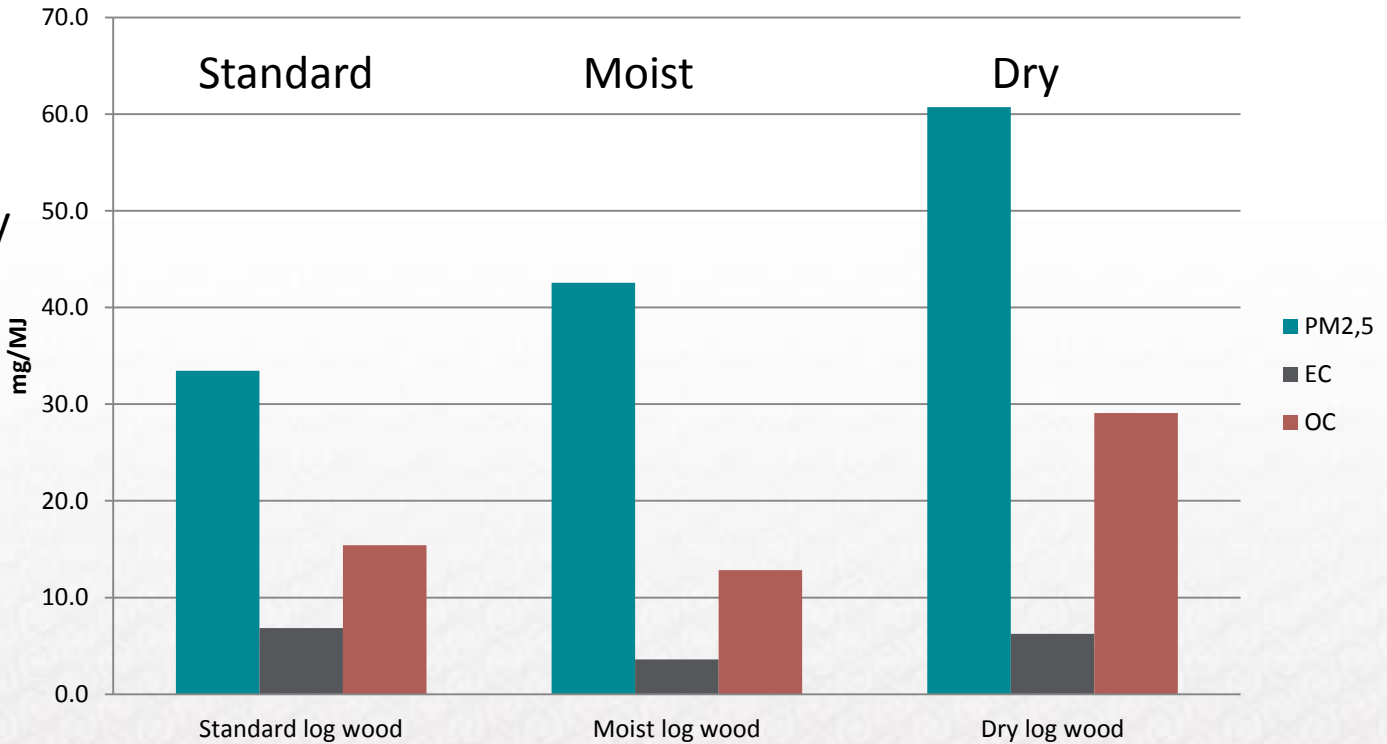
(mean values for P1-P4)

PM_{2.5}

30-60 mg/MJ

Both moist and dry
log wood produce
higher emission

But still low
emissions

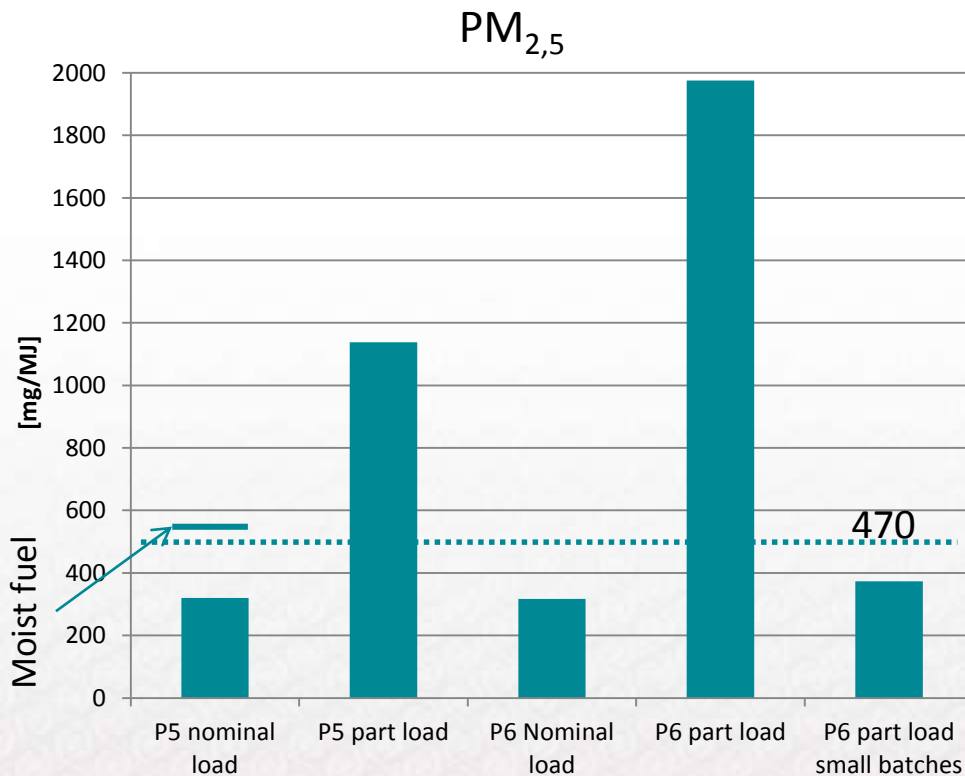


Guidebook Advanced/ecolabelled boiler:

PM_{2.5} 93 mg/MJ

BC 26 mg/MJ (28%)

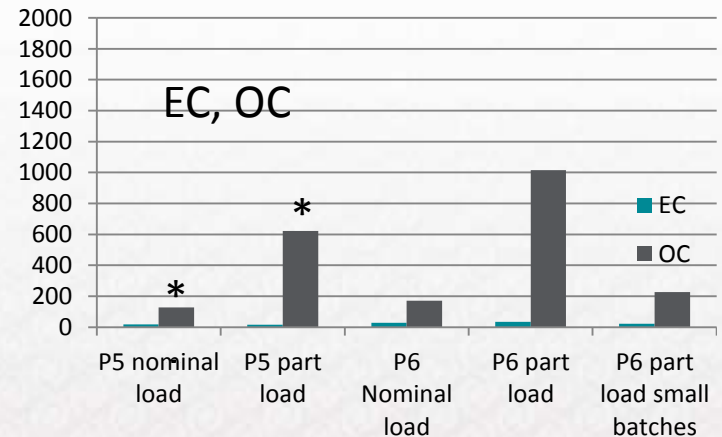
Old technology wood boilers, standard fuel influence of load



Guidebook Conventional boiler:
 PM_{2,5}: 470 mg/MJ, BC: 75 mg/MJ (16%)

PM_{2.5}
 300-2000 mg/MJ

Nominal load ~320 mg/MJ
 Nominal load, moist fuel 525 mg/MJ
 Part load 1140 and 1975 mg/MJ
 Part load, small batches 375 mg/MJ



* = values above analyzer limit,
 values are greater than presented

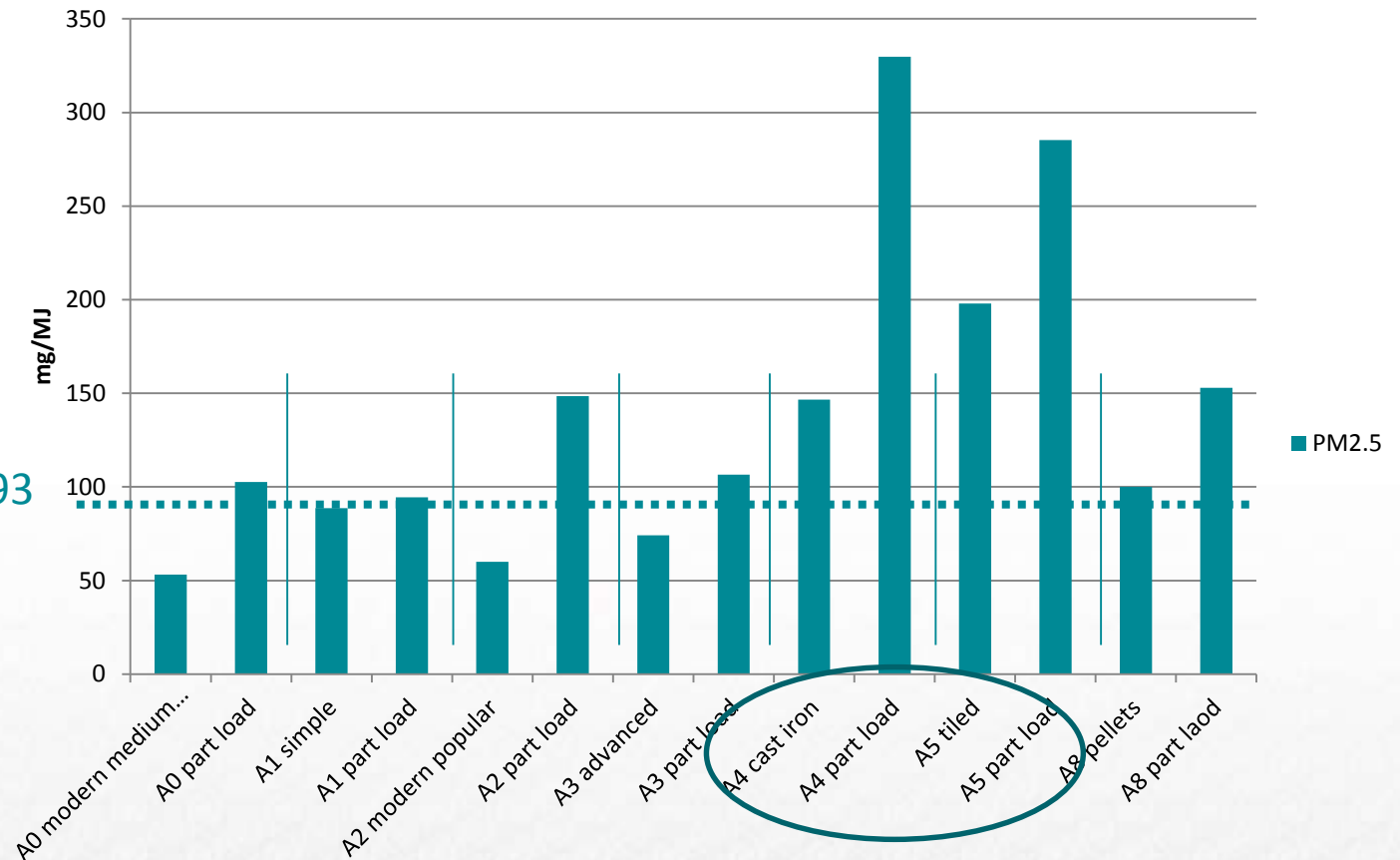


Stoves, nominal and part load

PM_{2.5}
Nominal load:
50-200 mg/MJ

Part load:
100-330 mg/MJ

PM_{2.5}, 93



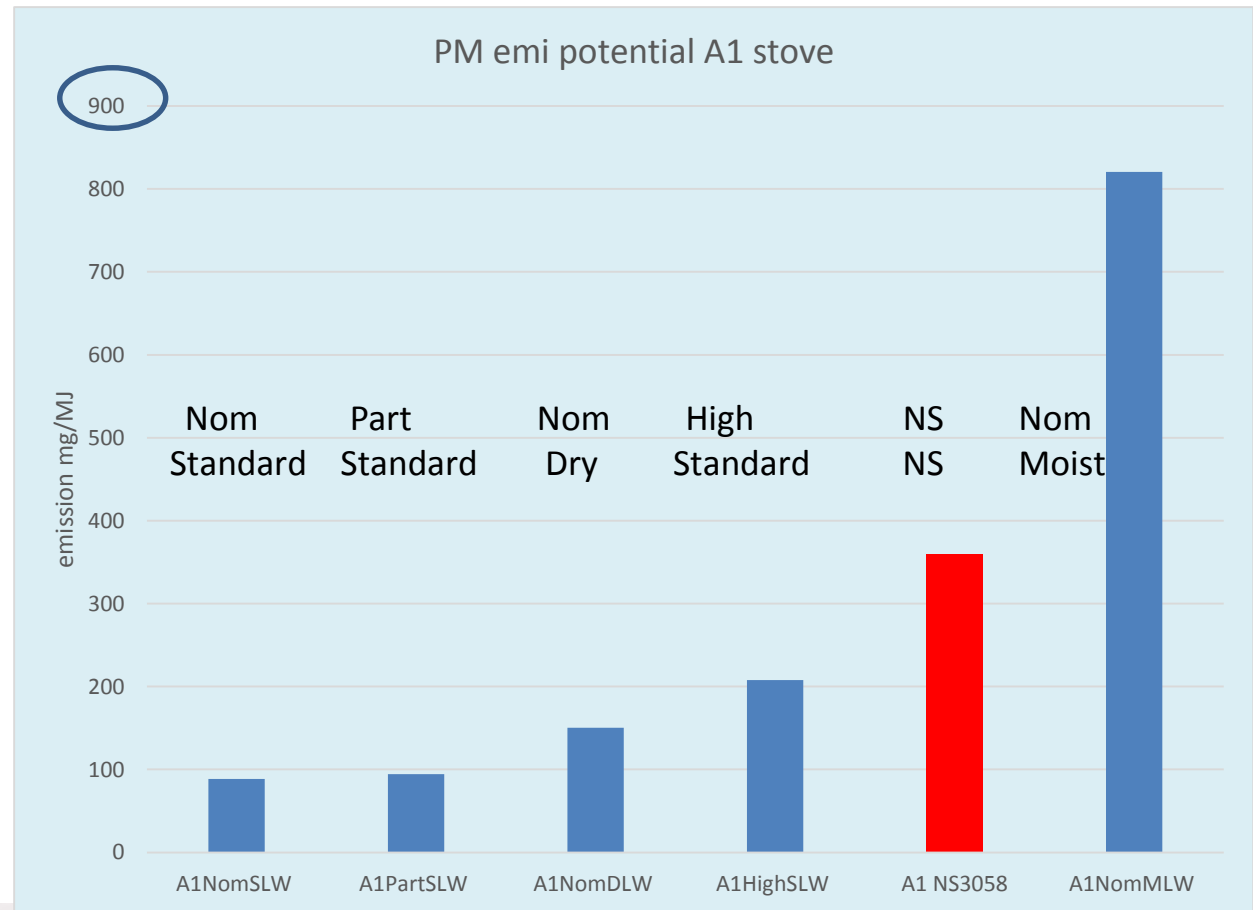
Technology	PM _{2.5}	95% conf interval
	mg/MJ	PM _{2.5}
Conventional stove	740	370-1480
Energy efficient stove	370	285-740
Advanced/ecolabelled stoves	93	19-233
Pellet stoves and boilers	29	9-47

Emissions PM_{2.5} – A1 stove

Simple "building market stove": 100-800 mg/MJ

NS3058 weighted average PM emission is 4 times the ordinary Standard log wood (SLW) emission,

but only 44% of the Moist log wood (MLW) emission



Some preliminary conclusions

- Emissions of PM from modern boilers and from integrated pellets boilers are comparable and low, condensables less important
- Emissions from old technology boilers much higher, especially at part load conditions, condensables important
- Cast iron stove and tiled stove higher emissions than other stoves, especially at part load
- Moist fuel wood resulted in 8x higher PM emissions in a simple stove sold today
- Emissions highly dependent on operational conditions (part load, fuel moisture)
- Detailed activity data (technologies) and assumptions regarding operational conditions essential for emission inventory

And....

- ➔ BC, CH₄ and NMVOC still to be evaluated
- ➔ EC and OC to be evaluated more thoroughly
- ➔ Emission factors for PM_{2.5} still preliminary,
 - Ignition phase
 - Part load – fuel quality assumptions
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Thank you for your attention

Project group

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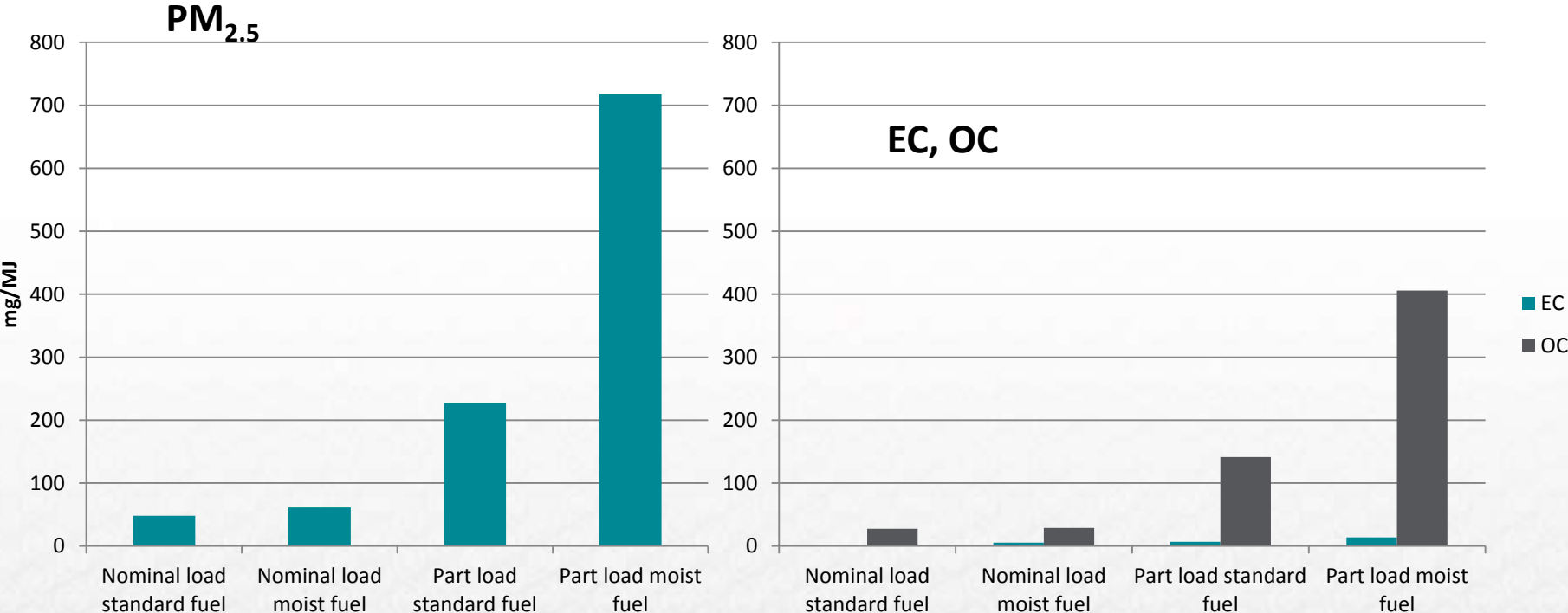
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Wood chip boiler, fuel and load

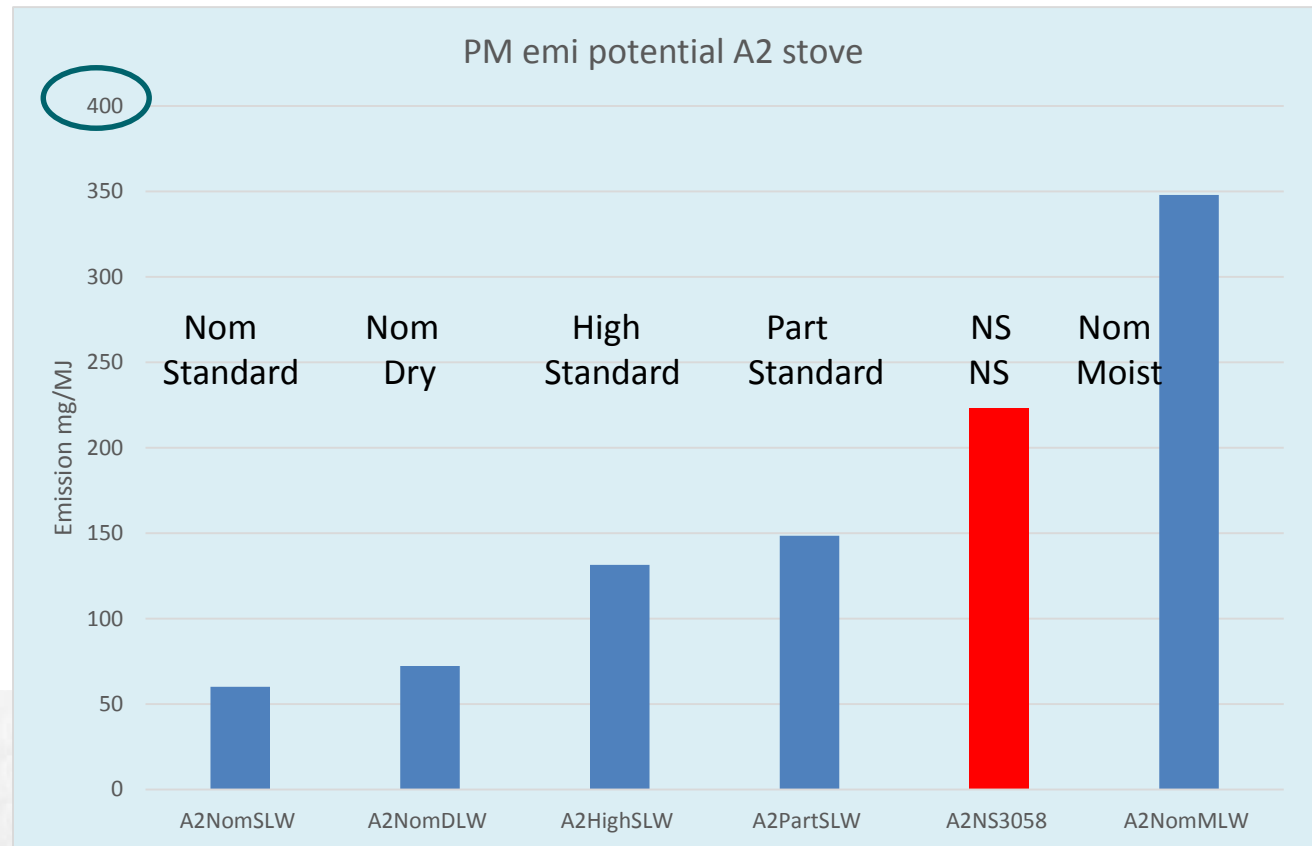
PM_{2.5}: 50-700 mg/MJ



Emissions $PM_{2.5}$ – A2 stove

Modern popular stove: 55-350 mg/MJ, standard-moist

NS3058 weighed average emission is slightly less than 4 times the ordinary Standard log wood (SLW) emission, but only 64% of the Moist log wood (MLW) emission



Preliminary results: stoves nominal load, standard fuel

PM_{2.5}: 50-200 mg/MJ

Cast iron stove and old tiled stove 150-200 mg/MJ

