Emission estimates on a national scale - experiences of Nordic countries

IPCC Expert meeting on Short-Lived Climate Forcers
Geneva 28 May 2018

Karin Kindbom

ivl
SVENSKA
MILJÖINSTITUTET

Outline of the presentation

- Project framework
- Important sources of BC and $PM_{2.5}$
- Residential wood combustion
  - Emission factors and emission measurements
  - Activity data – collection of data

ivl

Nordic SLCP project: Improved emission inventories of Short-Lived Climate Pollutants

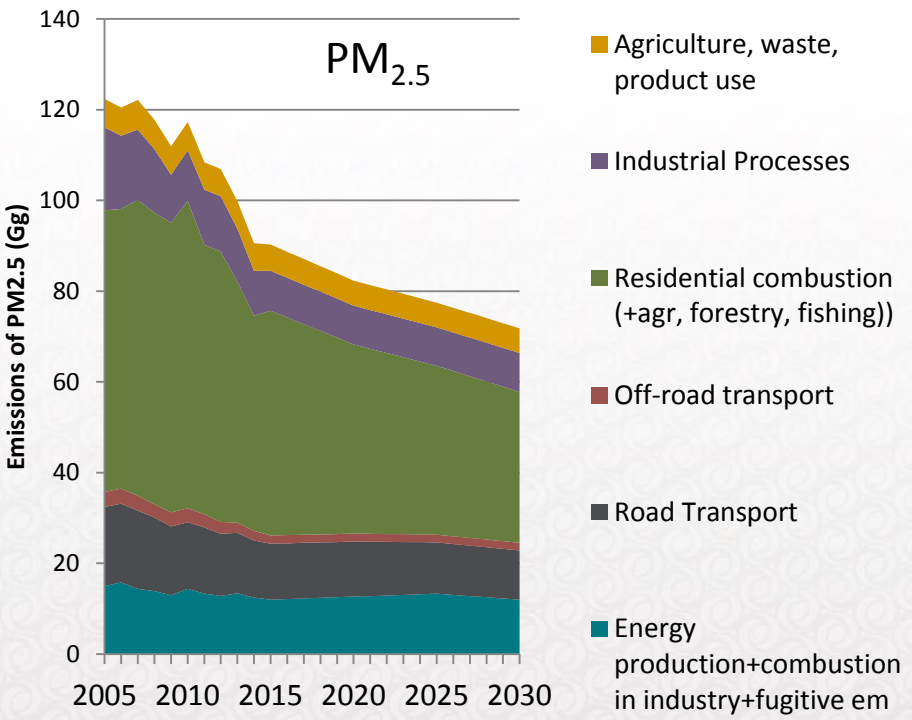
- 2013-2015: Background analysis and identification of knowledge gaps (TN2015:523)
- 2015-2017: Emission factors for SLCP emissions from residential wood combustion in the Nordic countries (TN2017:570).
- 2016-2018: Potentials for reducing the health and climate impacts of residential biomass combustion in the Nordic countries (TN2018:530)
- 2017-2018: Measures to reduce emissions of Short-Lived Climate Pollutants (SLCP) in the Nordic countries (TN2018:533)

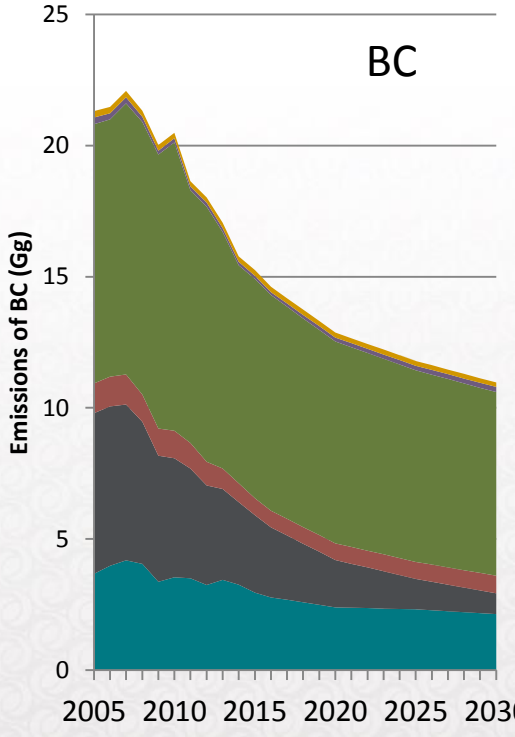
  - Karin Kindbom, Tina Skårman, Erik Fridell, Ingrid Mawdsley, Sweden
  - Ole-Kenneth Nielsen, Morten Winther, Denmark
  - Kristina Saarinen, Maija Lappi, Heikki Lamberg, Finland
  - Kári Jónsson, Páll Valdimar Kolka Jónsson, Iceland
  - Kristin Aasestad, Norway

ivl

Nordic emission inventories and projections

- Residential wood combustion is a major source of $PM_{2.5}$ and BC in the Nordic countries (Denmark, Finland, Norway, Sweden)
- Depending on country, emission estimates include more or less uncertainty, need for better knowledge





Factors influencing estimated emissions from residential wood burning

Emission factors

- Emission measurement method for deriving emission factors
- Combustion technology, e.g. older or modern
- Operation and handling, ”bad firing habits” gives higher emissions
- Fuel quality, e.g. moisture. Influences combustion efficiency and emission level

Activity data

- Fuel amount used /combustion technology
- Share of fuel combusted under ”bad combustion conditions”

ivl

Measurement program: Emission factors Residential wood combustion

- Residential biomass appliances representative for the Nordic countries
- EC, OC, $PM_{2.5}$, CH_4, NMVOC
- Test methods (operational conditions and firing schemes):
  - Boilers: EN standard 303-5
  - Room heaters/stoves: EN 16510 series
  - Norwegian standard NS 3058
- Sampling: Dilution tunnel
- Additional test cases to simulate ”bad combustion behaviour”
  - Part load, high load, moist fuel, dry fuel
- Technologies grouped for emission factors to be useful in inventories

ivl

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

ivl

A1 Simple

A2 Modern

A3 State-of-the-art

A9 Sauna

A4 Cast iron stove

A5 Tiled stove

A6 Slow heat release

A8 Pellets

Results from measurement program

- Older technologies generally higher emission levels than modern
- ”Bad combustion” can increase emission levels significantly
- Important to take ”bad combustion” into account in the national emission factors

EC

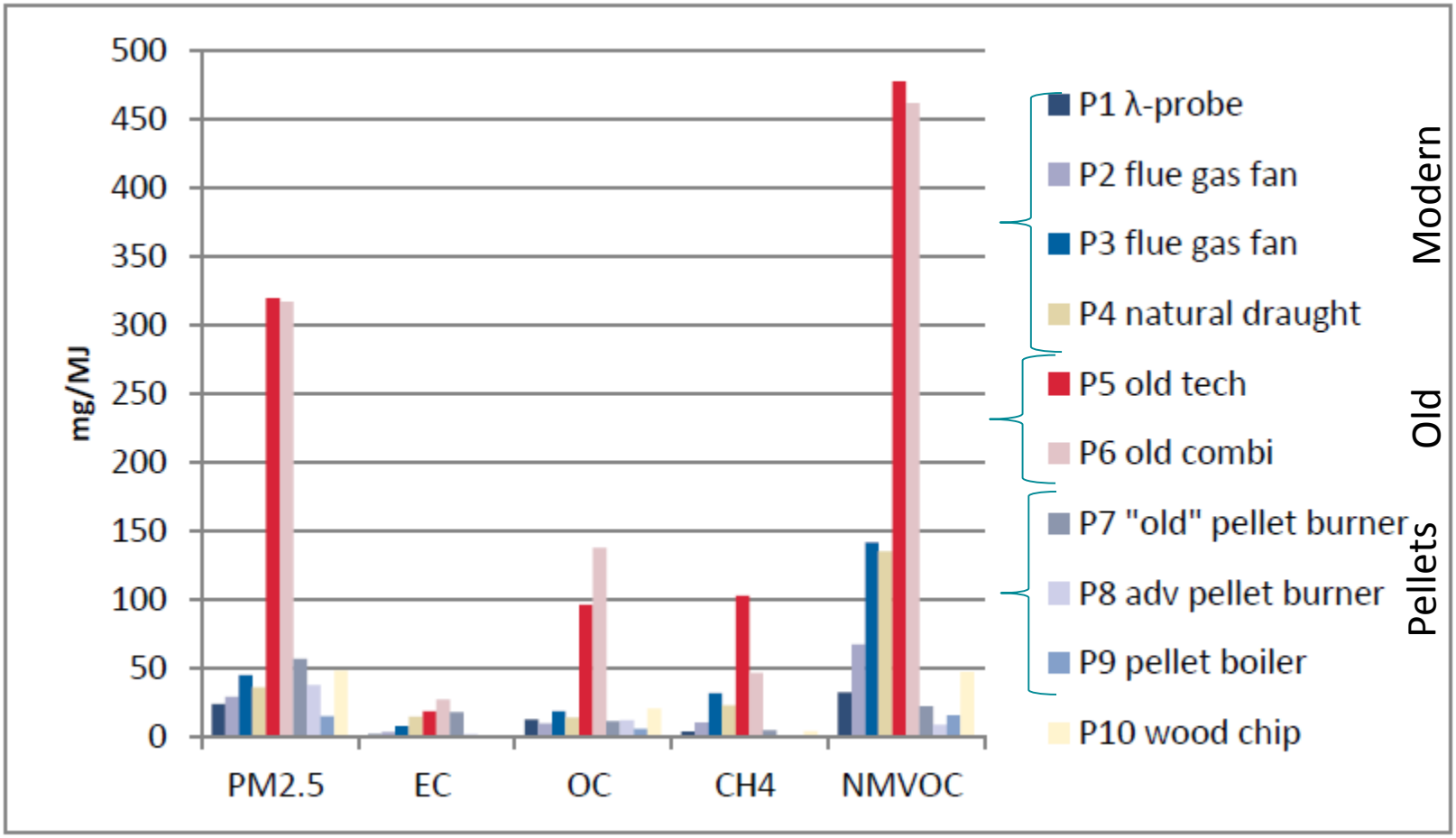
- EC and $PM_{2.5}$ do not correlate (no ”fixed” share $EC/PM_{2.5}$)
- EC least affected by ”bad combustion conditions”

ivl

Technology important!

Emission factors from measurements:

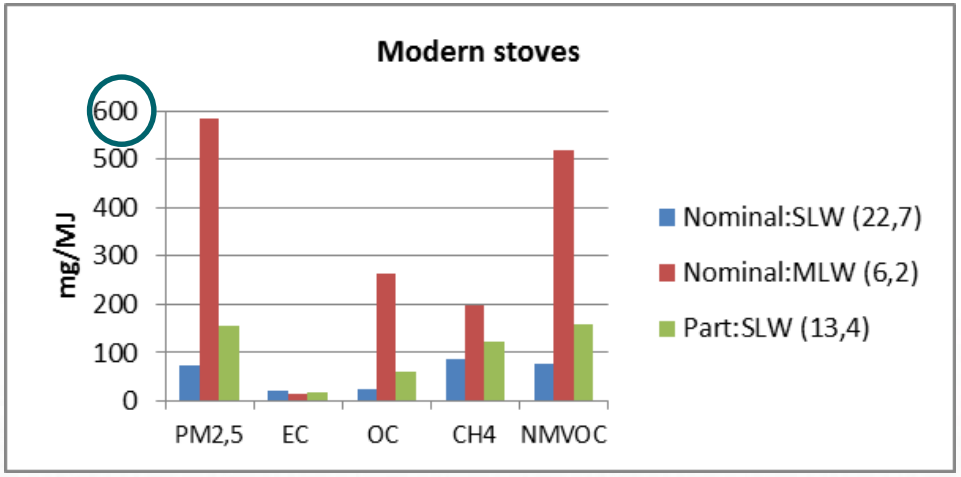
Individual boilers, standard conditions



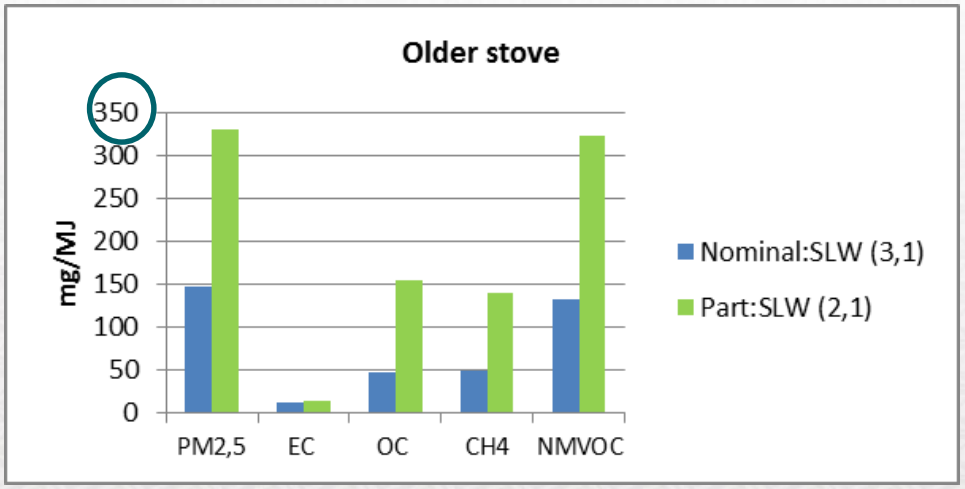
Firing habits important!

Emission factors from measurements:

Technology groups stoves, <u>different combustion conditions</u>



Blue=standard conditions
Red=moist fuel
Green=part load



SLW=standard fuel
MLW=moist fuel
Part=part load

ivl

Emission factors technology groups: STOVES

	Nominal load: Standard fuel	N:S min	N:S max	Ratio moist fuel to standard fuel N:M/N:S	Ratio part load to nominal load P:S/N:S
Modern stoves (incl state-of-the-art)	(8)				
$PM_{2.5}$ (mg/MJ)	84	60	106	5.0	2.0
EC (mg/MJ)	20	3	42	1.0	1.0
OC (mg/MJ)	24	6	39	8.0	2.5
CH_4 (mg/MJ)	90	31	153	2.0	1.5
NMVOC (mg/MJ)	76	19	144	5.0	2.0
Older stove*	(1)				
$PM_{2.5}$ (mg/MJ)	147				2.5
EC (mg/MJ)	13				1.0
OC (mg/MJ)	47				3.5
CH_4 (mg/MJ)	49				3.0
NMVOC (mg/MJ)	132				2.5
Tiled and masonry stove	(2)				
$PM_{2.5}$ (mg/MJ)	140	82	198	1.0	2.0
EC (mg/MJ)	72	22	122	1.0	1.5
OC (mg/MJ)	51	31	70	1.0	2.0
CH_4 (mg/MJ)	114	61	167	1.0	2.0
NMVOC (mg/MJ)	181	133	229	1.0	1.0
Pellet stove*	(1)				
$PM_{2.5}$ (mg/MJ)	100				1.5
EC (mg/MJ)	10				1.0
OC (mg/MJ)	6				1.0
CH_4 (mg/MJ)	1				2.5
NMVOC (mg/MJ)	4				3.5
Sauna stove*	(1)				
$PM_{2.5}$ (mg/MJ)	104			1.5	
EC (mg/MJ)	52			1.0	
OC (mg/MJ)	15			2.0	
CH_4 (mg/MJ)	43			2.0	
NMVOC (mg/MJ)	85			2.0	

N:S =
Nominal load:Standard fuel
N:M =
Nominal load:Moist fuel
P:S =
Part load:Standard fuel

”Bad combustion” in emission factors

- ***Emissions = AD * EF***
  - **AD** = fuel use in the specific technology or technology group (MJ)
  - **EF** = emission factor for a pollutant (mg/MJ)
- To take bad combustion conditions into account in the emission factor (EF), the following equation can be used (*Savolahti et al., 2016*):
- $EF = EF_{Normal} * S_{Normal} + Ratio_{Bad/Good} * EF_{Normal} * S_{Bad}$
  - **S** = share of fuel used
  - **Ratio** = factor for bad combustion

Savolahti M., Karvosenoja N., Tissari J., Kupiainen K., Sippula O. & Jokiniemi J. (2016). Atmospheric Environment 140 (2016) 495–505. https://doi.org/10.1016/j.atmosenv.2016.06.023

ivl

Activity data:
Residential wood combustion

- Combustion technologies
- Fuel consumption (type and amount for each technology)
- User behaviour (share of ”bad combustion”)

Current activity data collection in Sweden, Denmark and Finland (1)

- Combustion technology:
  - Regular or intermittent surveys/questionnaires, sometimes in combination with modelling based on expected lifetimes of equipment.
  - Depending on country, rather good understanding of present technologies, **OR** difficult to get good enough data, low response rates in surveys, questions not detailed enough/do not cover all information needed.
- Fuel consumption:
  - Regular surveys
  - Sometimes low response rates. Depending on country assignment of fuel to technology based on studies **OR** not yet done (assumptions).
  - Solid data requires surveys potentially coupled with energy demand modelling.

ivl

Current activity data collection in Sweden, Denmark and Finland (2)

- User behaviour:
  - Emission factors for “bad combustion” based on measurement data
  - Share of “bad combustion” estimated based on expert judgement, dedicated studies, interviews with chimney sweepers etc.
  - **OR** no assumptions made regarding user behaviour, the default EFs from EMEP/EEA Guidebook assumed to be representative average.

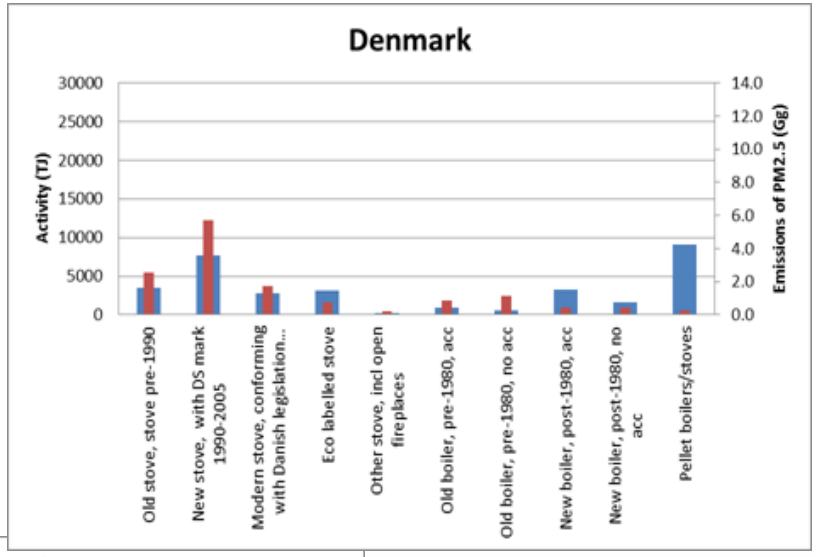
Activity data in Nordic inventories

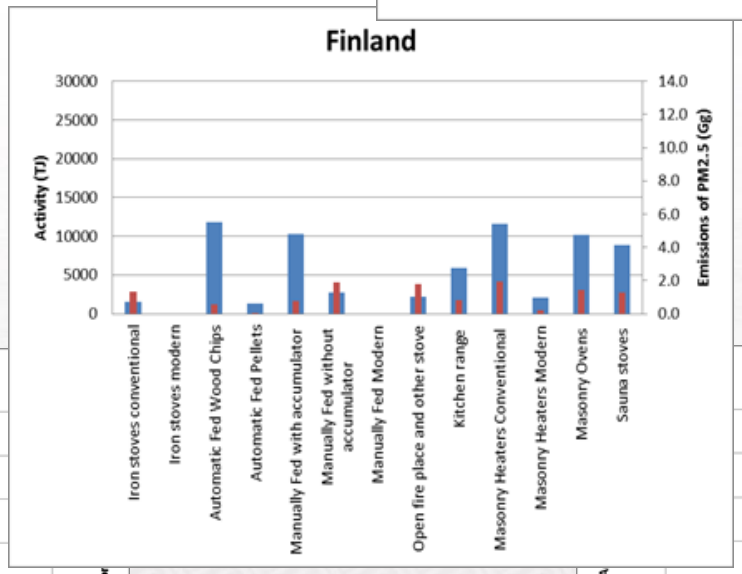
Denmark, 10 technology types. New stoves and pellet boilers/stoves use the largest quantities of biomass fuel.

Finland, 13 technology types. Biomass fuel use is more evenly distributed on several technologies.

Norway, 3 technology types. Approximately equal amounts of biomass used in old and new technology stoves.

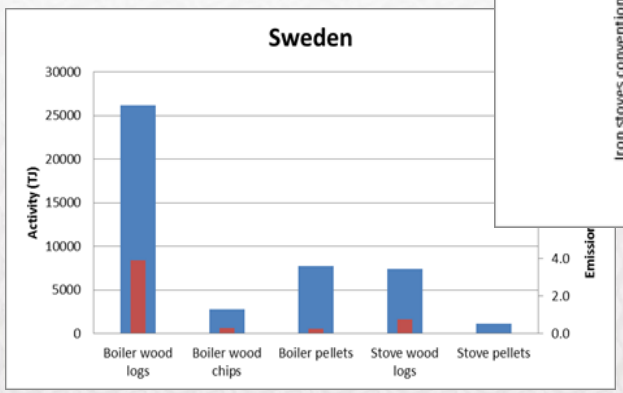
Sweden, 5 technology types. Wood boilers >50% of biomass fuel use.

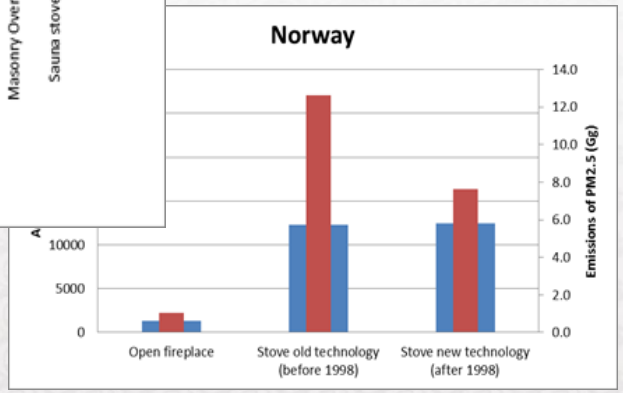




Blue=biomass fuel

Red= $PM_{2.5}$ emissions





Conclusions residential wood combustion

- Emission inventories of residential wood combustion sensitive to user behaviour and combustion technology

- Measurement program has provided SLCP and $PM_{2.5}$ emission factors for several types of residential wood combustion technologies representative for the Nordic countries
- User behaviour – important to take into account
- EC (BC) least affected by behaviour
- EC and $PM_{2.5}$ do not correlate

- Activity data collection challenging - need to combine information from different sources, and make assumptions

ivl

Thank you for your attention!

karin.kindbom@ivl.se

ivl

Emission measurement methods influences emission factors for particulate matter (PM)

- Sampling
  - In hot flue gases
  - In diluted flue gases at lower temperature
- Semivolatile organic compounds created in inefficient combustion (for example at poor user practices)
  - Exist in gas phase in hot flue gas measurements, not as PM
  - Partly condensed as additional PM in diluted sampling (lower temperatures)
- Measurement methods thus give different results regarding amount of PM
- Reported differences in the order of 2-10 times

ivl

Emission factors technology groups: BOILERS

	Nominal load: Standard fuel (N:S)	N:S min	N:S max	Ratio moist fuel to standard fuel N:M/N:S	Ratio part load to nominal load P:S/N:S
Modern log wood boilers	(6)				
$PM_{2.5}$ (mg/MJ)	35	24	45	1.5	
EC (mg/MJ)	6	2	15	1.0	
OC (mg/MJ)	15	10	19	1.0	
CH_4 (mg/MJ)	15	4	32	1.5	
NMVOC (mg/MJ)	85	32	141	1.5	
Traditional log wood boilers	(2)				
$PM_{2.5}$ (mg/MJ)	320	317	320	1.5	4.0
EC (mg/MJ)	25	19	27	>1.5	1.0
OC (mg/MJ)	120	96	138	>1.5	>4.0
CH_4 (mg/MJ)	75	47	103	>1.5	>3.0
NMVOC (mg/MJ)	470	462	477	>1.5	>3.0
Pellet-fired boilers	(3)				
$PM_{2.5}$ (mg/MJ)	35	15	57		3.0
EC (mg/MJ)	6	1	14		1.5
OC (mg/MJ)	10	6	11		3.5
CH_4 (mg/MJ)	2	1	4		5.0
NMVOC (mg/MJ)	15	9	22		6.0
Wood chip boiler*	(1)				
$PM_{2.5}$ (mg/MJ)	50			1.5	5.0
EC (mg/MJ)	2			5.0	6.0
OC (mg/MJ)	20			1.5	5.0
CH_4 (mg/MJ)	5			3.0	15.0
NMVOC (mg/MJ)	50			2.0	15.0

N:S =
Nominal load:Standard fuel
N:M =
Nominal load:Moist fuel
P:S =
Part load:Standard fuel