# Nordic SLCP project –
## improved emission inventories

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

- 2015-2017: Emission factors for SLCP emissions from residential wood combustion in the Nordic countries (TN2017:570).
  - http://norden.diva-portal.org/smash/record.jsf?pid=diva2:1174670
- 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)

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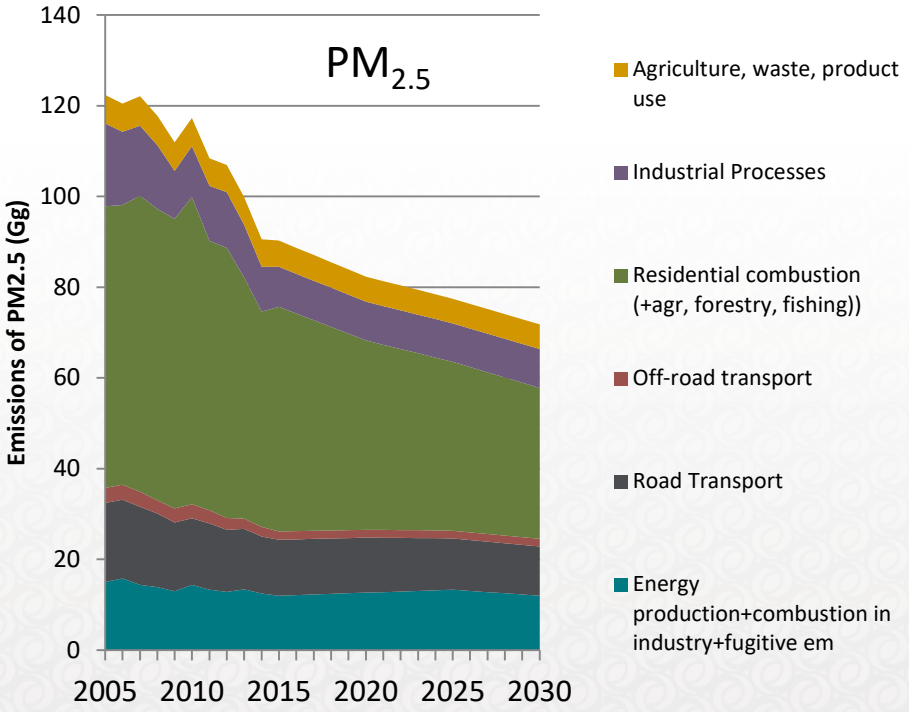
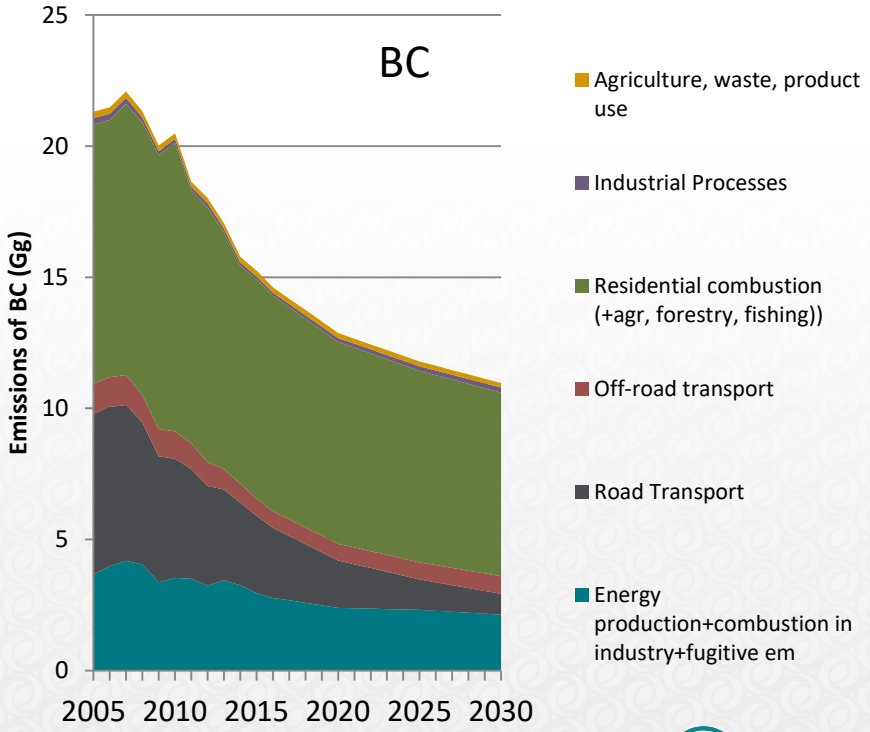
# Nordic emission inventories

- Residential wood combustion is a major source of $PM_{2.5}$ and SLCP in the Nordic countries (green in figures)
- Emission factors uncertain, need for better knowledge



# Measurement program
# Residential wood combustion (TN2017:570)

- 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 303-5
  - Room heaters: EN 16510 series, including part load (according to proposed revision)
  - Norwegian standard NS 3058
- Sampling: Dilution tunnel
- Test cases to simulate ”bad combustion behaviour”
  - Part load, high load, moist fuel, drier fuel
- Technologies grouped for emission factors

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# 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

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A1 Simple

A2 Modern

A3 State-of-the-art

A9 Sauna

A4 Cast iron stove

A5 Tiled stove

A6 Slow heat release

A8 Pellets

# Emission factors, technology groups: boilers

| | Nominal load: Standard fuel (N:S) | Nominal load: Moist fuel (N:M) | Nominal load: Dry fuel (N:D) | Part load: Standard fuel (P:S) | Part load: Moist fuel (P:M) | Ratio N:M/N:S | Ratio N:D/N:S | Ratio P:S/N:S |
|---|---|---|---|---|---|---|---|---|
| Modern log wood boilers | (6) | (3) | (2) | | | | | |
| $PM_{2.5}$ (mg/MJ) | 32 (24–45) | 43 (32–50) | 61 (32–89) | | | 1.3 | 1.9 | |
| EC (mg/MJ) | 6 (2–15) | 4 (2–5) | 6 (3–9) | | | 0.6 | 1.1 | |
| OC (mg/MJ) | 12 (10–19) | 12 (8–14) | 24 (12–36) | | | 0.9 | 1.9 | |
| $CH_4$ (mg/MJ) | 15 (4–32) | 18 (2–35) | 35 (8–62) | | | 1.2 | 2.4 | |
| NMVOC (mg/MJ) | 86 (32–141) | 124 (13–212) | 168 (56–279) | | | 1.4 | 2.0 | |
| CO (mg/MJ) | 1160 (233–2036) | 1136 (178–1894) | 1957 (754–3160) | | | 1.0 | 1.7 | |
| Traditional log wood boilers | (2) | (1) | | (3) | | | | |
| $PM_{2.5}$ (mg/MJ) | 318 (317–320) | 524 | | 1162 (373–1975) | | 1.6 | | 3.7 |
| EC (mg/MJ) | 23 (19–27) | >31 | | 24 (15–35) | | >1.3 | | 1.0 |
| OC (mg/MJ) | 117 (96–138) | >143 | | 461 (181–776) | | >1.2 | | 3.9 |
| $CH_4$ (mg/MJ) | 75 (47–103) | >28 | | 158 (35–259) | | >0.4 | | 2.1 |
| NMVOC (mg/MJ) | 470 (462–477) | >272 | | >1059 (551–>1332) | | >0.6 | | >2.3 |
| CO (mg/MJ) | 3271 (2963–3578) | 4748 | | 6274 (3437–8978) | | 1.5 | | 1.9 |
| Pellet-fired boilers | (3) | | | (3) | | | | |
| $PM_{2.5}$ (mg/MJ) | 36 (15–57) | | | 96 (14–182) | | | | 2.6 |
| EC (mg/MJ) | 6 (1–14) | | | 10 (6–17) | | | | 1.6 |
| OC (mg/MJ) | 10 (6–11) | | | 34 (16–54) | | | | 3.5 |
| $CH_4$ (mg/MJ) | 2 (1–4) | | | 11 (1–26) | | | | 5.1 |
| NMVOC (mg/MJ) | 15 (9–22) | | | 95 (10–218) | | | | 6.2 |
| CO (mg/MJ) | 295 (120–631) | | | 1249 (250–2273) | | | | 4.2 |
| Wood chip boilers | (1) | (1) | | (1) | (1) | | | |
| $PM_{2.5}$ (mg/MJ) | 48 | 61 | | 227 | 883 | 1.3 | | 4.7 |
| EC (mg/MJ) | 1 | 6 | | 7 | 16 | 4.8 | | 6.0 |
| OC (mg/MJ) | 20 | 25 | | 98 | 367 | 1.2 | | 4.8 |
| $CH_4$ (mg/MJ) | 4 | 11 | | 64 | 97 | 2.7 | | 16.0 |
| NMVOC (mg/MJ) | 47 | 94 | | 627 | 1160 | 2.0 | | 13.3 |
| CO (mg/MJ) | 366 | 1894 | | 4479 | 6780 | 5.2 | | 12.2 |

# Emission factors technology groups: stoves

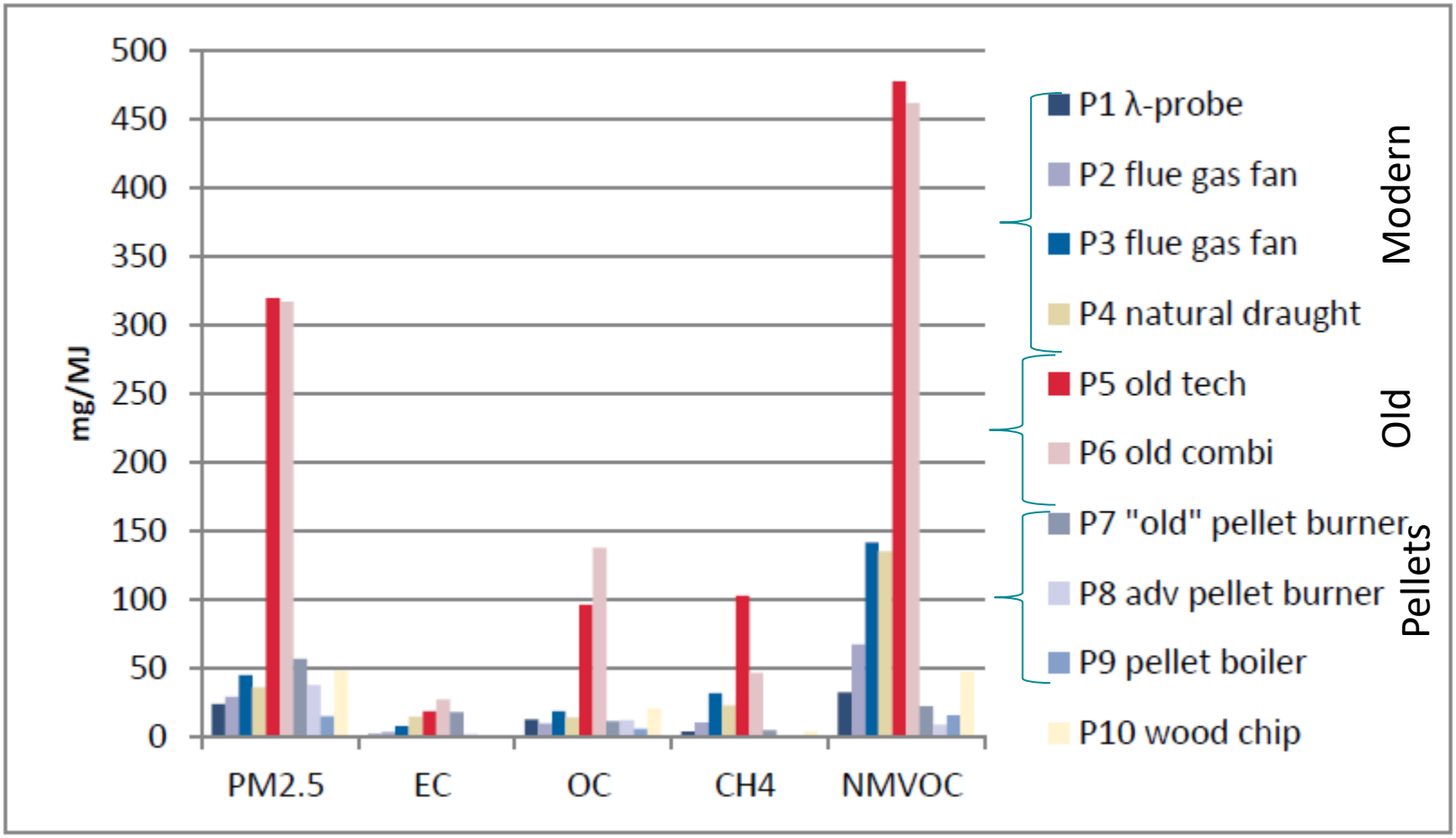
| | Nominal load: Standard fuel (N:S) | Nominal load: Moist fuel (N:M) | Part load: Standard fuel (P:S) | Ratio N:M/N:S | Ratio P:S/N:S |
|---|---|---|---|---|---|
| Modern stoves (incl. state-of-the-art) | (8) | (3) | (5) | | |
| $PM_{2.5}$ (mg/MJ) | 84 (53–106) | 423 (100–821) | 145 (74–458) | 5.0 | 1.7 |
| EC (mg/MJ) | 20 (3–42) | 10 (4–18) | 14 (4–27) | 0.5 | 0.7 |
| OC (mg/MJ) | 24 (6–39) | 202 (25–441) | 62 (7–191) | 8.4 | 2.5 |
| $CH_4$ (mg/MJ) | 90 (31–153) | 152 (80–368) | 113 (11–245) | 1.7 | 1.3 |
| NMVOC (mg/MJ) | 76 (19–144) | 370 (71–772) | 148 (1–495) | 4.8 | 1.9 |
| CO (mg/MJ) | 1582 (919–2287) | 2802 (1490–3839) | 2406 (1386–3084) | 1.8 | 1.5 |
| Older stove | (1) | | (1) | | |
| $PM_{2.5}$ (mg/MJ) | 147 | | 330 | | 2.2 |
| EC (mg/MJ) | 13 | | 15 | | 1.1 |
| OC (mg/MJ) | 47 | | 155 | | 3.3 |
| $CH_4$ (mg/MJ) | 49 | | 140 | | 2.9 |
| NMVOC (mg/MJ) | 132 | | 322 | | 2.4 |
| CO (mg/MJ) | 1165 | | 2194 | | 1.9 |
| Tiled and masonry stove* | (2) | (1) | (1) | | |
| $PM_{2.5}$ (mg/MJ) | 140 (82–198) | 78 | 285 | 0.6 | 2.0 |
| EC (mg/MJ) | 72 (22–122) | 7 | 110 | 0.1 | 1.5 |
| OC (mg/MJ) | 51 (31–70) | 24 | 100 | 0.5 | 2.0 |
| $CH_4$ (mg/MJ) | 114 (61–167) | 49 | 204 | 0.4 | 1.8 |
| NMVOC (mg/MJ) | 181 (133–229) | 75 | 154 | 0.4 | 0.9 |
| CO (mg/MJ) | 2365 (1585–3145) | 1175 | 2751 | 0.5 | 1.2 |
| Pellet stove | (1) | | (1) | | |
| $PM_{2.5}$ (mg/MJ) | 100 | | 153 | | 1.5 |
| EC (mg/MJ) | 10 | | 7 | | 0.7 |
| OC (mg/MJ) | 6 | | 3 | | 0.4 |
| $CH_4$ (mg/MJ) | 1 | | 3 | | 2.6 |
| NMVOC (mg/MJ) | 4 | | 14 | | 3.3 |
| CO (mg/MJ) | 189 | | 447 | | 2.4 |
| Sauna stove | (1) | (1) | | | |
| $PM_{2.5}$ (mg/MJ) | 104 | 120 | | 1.2 | |
| EC (mg/MJ) | 52 | 51 | | 1.0 | |
| OC (mg/MJ) | 15 | 32 | | 2.1 | |
| $CH_4$ (mg/MJ) | 43 | 80 | | 1.9 | |
| NMVOC (mg/MJ) | 85 | 180 | | 2.1 | |
| CO (mg/MJ) | 1405 | 2030 | | 1.4 | |

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

# Technology important!

## Emission factors from measurements:

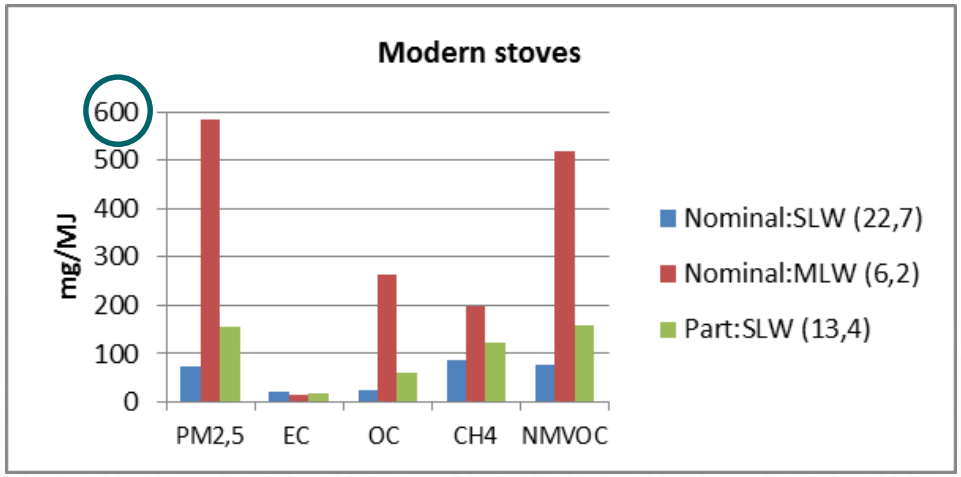
## Individual boilers, standard conditions

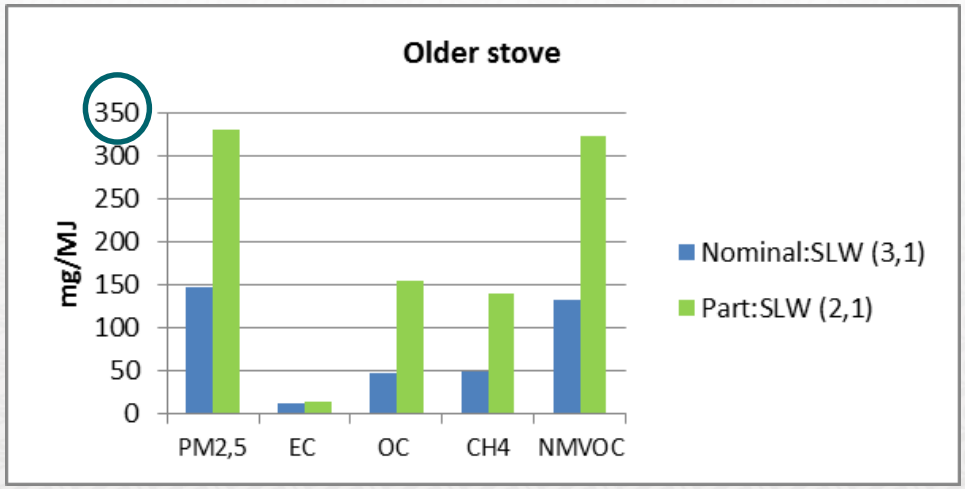


# Firing habits important!

## Emission factors from measurements:

## Technology groups stoves, different combustion conditions




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

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# 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 consideration 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”

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# Scenarios using new emission factors

## (TN2018:530)

- Technology specific activity data projections
- Technology specific emission factors (from TN2017:570)
- Scenario definitions:

| | Scenario | Early scrapping | Behaviour | Share of bad combustion |
|---|---|---|---|---|
| Adapted baseline | SC1 | No | expected | 10% |
| -"- | SC2 | No | worse than expected | 20% |
| Modern technologies | SC4 | Yes | expected | 10% |
| -"- | SC6 | yes | good | 0% |
| | | | | |

# Activity data projections (DK, FI, SE)

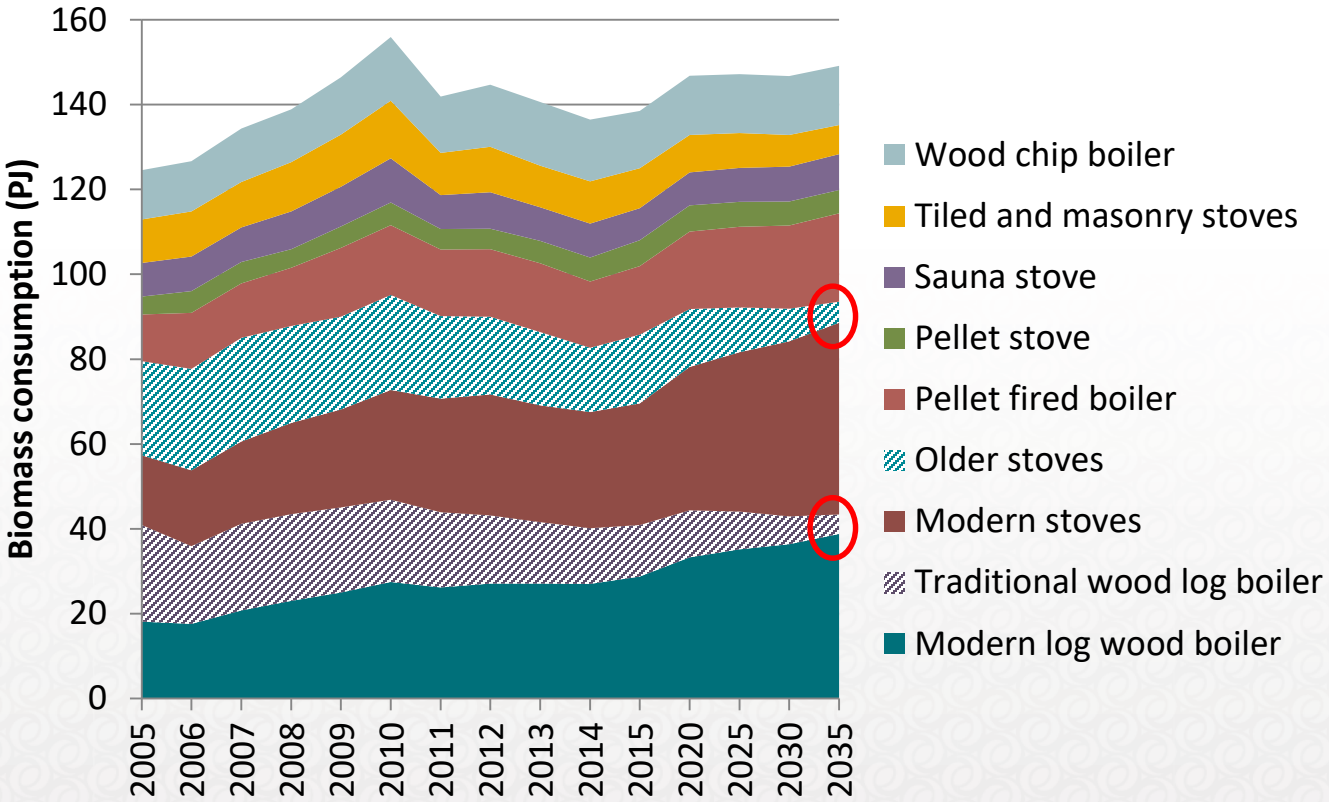
## (adapted from national projections - Denmark (10), Finland (13) and Sweden (6) technology categories)

Total biomass fuel use ~150 PJ in 2035

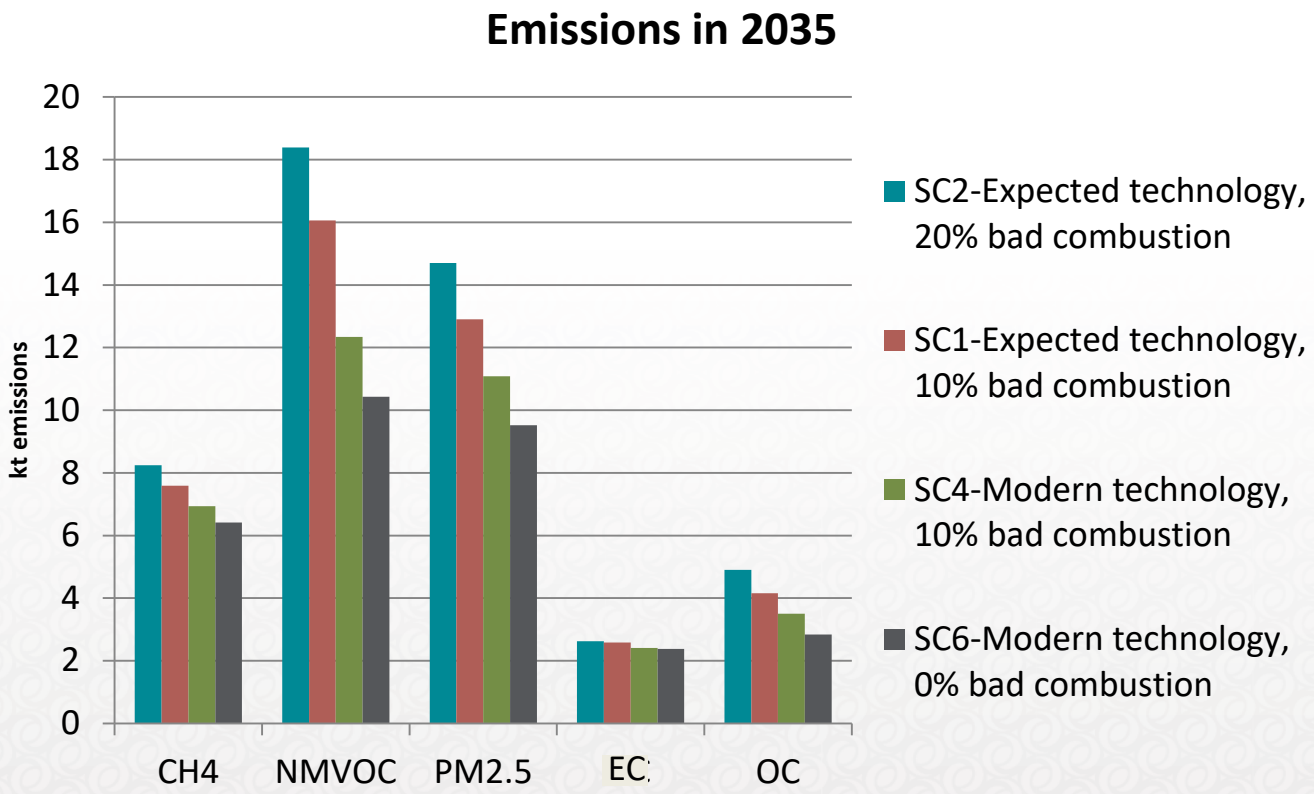
Already large share of modern equipment in national projections

Early scrapping scenarios- small change in 2035.

- 5 PJ from traditional to modern boilers,
- 5 PJ from older to modern stoves



# Scenario emissions in 2035, RWC in Denmark, Finland and Sweden



# Scenario results (TN2018:530)

- Early scrapping (only 10 PJ out of 150 PJ) and good combustion behaviour (from 90% to 100%), reduces emissions by 35% for NMVOC, 32% for OC, 26% for $PM_{2.5,}$ 15% for $CH_4$ and 8% for BC
- Technology and user behaviour important

# Measures to reduce BC (TN2018:533)

- Residential wood combustion should be prioritized– in particular, replacement of older boilers and heating stoves with new appliances, installation of ESP (electrostatic precipitator) and high-efficiency dedusters, and fuel switch from wood logs to pellets.
- A nordic analysis shows that technical measures aimed at residential combustion can reduce BC emissions in 2030 by 3.7 kt – or about 79% of the estimated total technical BC emission reduction potential in the Nordic countries. (combined SLCP analysis using the GAINS model and based on the ECLIPSE project results for the Nordic countries)
- Additional emission reduction possibilities:
  - e.g. increased energy efficiency, improved insulation of buildings
  - behavioural changes such as improved user practices in residential wood combustion