Particulate emissions from residential wood combustion
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PARTICULATE EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION: IMPROVING ESTIMATIONS IN DENMARK AND PORTUGAL

INTERNATIONAL CONFERENCE ON CARBONACEOUS PARTICLES
BERKELEY, USA

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How to improve PM emission estimations from RWC in Europe?

Over 240 million people is relying on heating fireplaces and inefficient WBSs and boilers in the cold season.

Global health risk

- Household heating is a major cause of premature deaths in Europe, North America and China.
- **Fireplaces and wood-burning stoves** (WBSs) in more than 20% of the European households.
- Secondary heating systems in areas with developed district heating grids.
HOUSEHOLD HEATING AND PM EMISSIONS IN WESTERN EUROPE (two case studies and new methods in the EU28)

Heating typical a single family house with NG
Costs 10% more
In 2015 than in 2008 (ERSE, 2015)

High fuel loads & low tightness

- Local resilience...
- Up to 100% of wood heat
- RWC units per dwelling

Portugal
10,4 Mo (40% rural)
92,212 km²

Low fuel loads & high tightness

- Well developed heating grid
- So, part of culture...
- 20-50% of wood heat
- Secondary energy for cozyness
  (low wattage and mechanical vent.)

Denmark
5,6 Mo (12% rural)
42,916 km²

43% of people (<10% rural)
32% of area (of California)
OLD TRADITIONAL WBSs

Fireplace in Europe
Open fire, 2014

Closed stove in Spain
Carvalho, 2015
NEW & NEW MODERN WBS

Wood stove (NEW, before 2008) in Portugal
Carvalho, 2014

Swan labelled stove (NEW MODERN, after 2008) in Denmark
Carvalho, 2014
BOILERS AND COOKERS

Residential wood boiler in Denmark
Perthshire biofuels, 2015

Wood cooking boiler in Portugal
Lareiras Pacinha, 2015
RWC in Denmark/Nordic region

~1.6Mo users per ~3.0Mo dwellings

~770,850 installations

21.920 TJ


RWC in Portugal/Mediterranean region

~3.6 Mo users
Over ~3.4 Mo dwellings

34% Users
66% Non-users

~1.2 Mo installations
35.342 TJ
+60% than DK!

AVAILABLE EMISSION INVENTORIES AND GAPS (PHONE SURVEYS)

\[ E_{PM} = \sum_{i=0}^{n} W_c \cdot EFs \]

**Denmark**

- Survey (2015) for ONLY 2133 people and 4 types of stoves…
- Average Efs on condensed particles with a controlled pressure chimney draft (Norwegian method)
- Spatial distribution from housing registration system (BBR)

**Portugal**

- Survey (2012) for ONLY 2400 people and 2 types of systems…
- Standard Efs on condensed particles but with uncontrolled pressure chimney draft (prEN4711)
- Spatial distribution from one single study [1]

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DANISH VS. PORTUGUESE PM2.5 EMISSION FACTORS?
(FIREPLACES, WOOD-LOG AND PELLET STOVES)

\[ E_{PM} = \sum_{i=0}^{n} W_{ci} \cdot EF_{si} \]

**T1: Lab to field studies, 2015**

- **fireplace**
- **old**
- **new**
- **modern**
- **new modern**

**Used in the inventory**


[18] EMEP, 2013
MAIN GAPS ON OFFICIAL EMISSION FACTORS?

\[ E_{PM} = \sum_{i=0}^{n} W_c \cdot EFs \]

- Wet wood used in real-life NOT CONSIDERED…
- Typical fuel loads vary from mean values…

**Denmark**

- Approaches to mainstream emissions, not representing:
  - Uncontrolled stove venting and household ventilation (underpressure in real world)?

**Portugal**

- Lab tests under ideal conditions do not represent situations where:
  - Uncontrolled stove venting and household ventilation (under or over pressure in real world)?

---


**Recalculations of Annual PM2.5 Emissions?**

\[ E_{PM} = \sum_{i=0}^{n} W_C \cdot EFs \]

<table>
<thead>
<tr>
<th>PM2.5 emissions</th>
<th>kton PM2.5 year-1</th>
<th>kg PM2.5 per capita</th>
<th>kton PM2.5 year-1</th>
<th>Share</th>
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</thead>
<tbody>
<tr>
<td><strong>Countries</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>17,3?</td>
<td>3,1?</td>
<td>28,3</td>
<td>61%?</td>
</tr>
<tr>
<td>Portugal</td>
<td>11,0?</td>
<td>1,1</td>
<td>36,3</td>
<td>30%?</td>
</tr>
</tbody>
</table>

*Underestimated emissions for Portuguese fireplaces?*

*Overestimated emissions for new Danish stoves?*

---


SPATIAL DISTRIBUTION OF PM2.5 EMISSIONS PER CASE

\[ E_{PM} = \sum_{i=0}^{n} W_C \cdot EFs \]


T1a. A PIONEER LAB-TO-FIELD TEST ON EFs IN DANISH DWELLINGS
(by Glausius et al., DCE, Aarhus University, 2005)

(real-life measurements in 13 houses in Denmark)

Users behaviours can be the main reason of variations on the PM2.5 Efs!

WOODUSE: Slagslunde: 400 houses, 201 with wood stoves or boilers

**T1b:** TEOM measured [PM$_{2.5}$] increment due to wood combustion during the 6-weeks period


*TEOM (tapered element oscillating microbalance) is a continuous measurement method of atmospheric particles*
**T1: WOODUSE** computated increment due to wood combustion for an average for 6-week period

**Average at the monitor:**
- Measured: 1.97 µg/m³
- Modelled (OML): 4.2 µg/m³

\[
\text{correction factor} = \frac{\text{measured av}}{\text{modelled av}} = \frac{[1.97]\text{av}}{[4.2]\text{av}} = 0.47
\]

(experiments carried out in 2006/07)
OML is an atmospheric dispersion model
**T1b WOODUSE: LAB-TO-FIELD AIR QUALITY STUDY IN A DANISH VILLAGE**  
*(DCE, Aarhus University, 2007/12)*

\[ \text{corr. av. } EF = 0.47 \cdot 935 \sim 440 \text{ gPM/GJ} \]

Dilution tunnel and dust-track  Testing convection installation

For the **dry softwood** *Pinus Pinaster* (wood type on RWC in **Portugal**):
- Variations on fuel load may increase particulate emissions by more than 3 times comparing to official emission factors used in previous inventories ”5.2±4.3 g/kgF”
- These variations might be even larger if we consider a common bottom ignition during lightning!

For the **dry hardwood** *Fagus Sylvatica* (typical fuel in **Spain**):
- Such operating practices did not change significantly…

**IAQ TEST:** indoor [PM$_{2.5}$] during one week in the Autumn when testing a wood stove (*CESAM, Aveiro University, 2014*).

Indoor particulates increase due to underpressure:

- Transport of particulates from outdoors to indoors
- Indoor emissions when lightning (insufficient draft)…

Conclusions and recommendations

• The current estimations are rather uncertain due to:
  • Few available surveys with few respondents...
  • Little knowledge of representative Efs...
  • Limited knowledge on the spatial distribution...

• Improve activity data in conjunction with national chimney sweepers associations
• New testing methods and studies to determine real emissions, especially for old types of appliances (larger uncertainties) by:
  Bringing the lab to field (quite expensive…)
  Bringing the field to lab (economic, deep investigation on burning practices)
  Modelling real-life household savings and mitigation effects
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WBS use in Denmark and Portugal

Denmark

- 21.920 TJ
- Old closed: 31%
- New closed: 42%
- Modern: 27%

Portugal

- 35.342 TJ
- Fireplace: 53%
- Old closed: 24%
- New closed: 23%

References:


SURVEYS (2012/13): REAL WOOD CONSUMPTION AND TRANSITIONS (T)?

\[
E_{PM} = \sum_{i=0}^{n} Wci \cdot EFsi
\]

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</thead>
<tbody>
<tr>
<td>Countries</td>
<td>All</td>
<td>All</td>
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<td>All</td>
<td>All</td>
<td>Users</td>
<td>Fireplace Old closed</td>
<td>New closed</td>
<td>Modern</td>
<td>All</td>
<td>All</td>
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<tr>
<td>Denmark 2013</td>
<td>Number (Mo)</td>
<td>2.133 x10^3</td>
<td>(3,0/10,4) x10^6</td>
<td>0,8x10^6</td>
<td>27%</td>
<td>1,5x10^6</td>
<td>-</td>
<td>202.500</td>
<td>315.000</td>
<td>232.500</td>
<td>750.000</td>
</tr>
<tr>
<td>Portugal 2012</td>
<td>Number (Mo)</td>
<td>2.387</td>
<td>(3,4/5,6) x10^6</td>
<td>1.5x10^6</td>
<td>34%</td>
<td>3,6x10^6</td>
<td>645.818</td>
<td>282.903</td>
<td>294.333</td>
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