Silesian University of Technology

# ABATEMENT OF PARTICULATE MATTER EMISSION FROM SMALL COMBUSTION INSTALLATIONS FUELED WITH BIOGENIC, SOLID FUELS

## PRIMARY AND SECONDARY MEASURES

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## THE SCOPE

Tackling the dust emissions from wood combustion by residential sector:

- Secondary abatement measures
- Primary abatement measures

1 **Introduction**
PM emissions from SCIs, surces, options for emission abatement

2 **Microscale electrostatic precipitators ESPs**
Design, Laboratory and field testing

3 **Ecolabel stoves and boilers**
Laboratory and field testing

4 **Summary and conclusions**

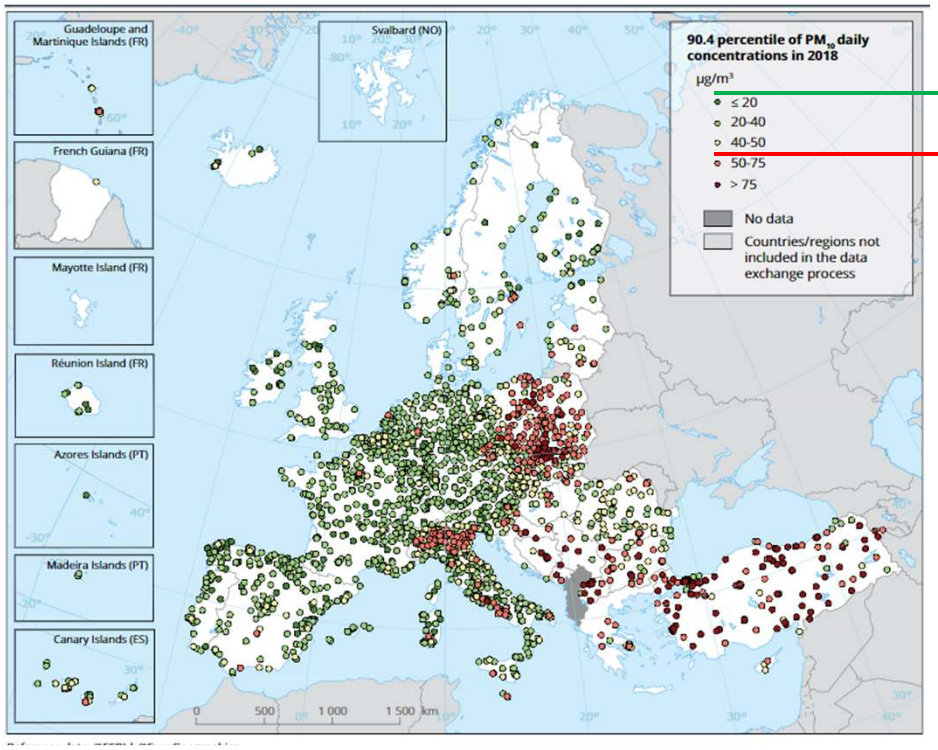
## *Introduction*

*Air quality, Particultate Matter PM*

Drivers and pressures

*We all have a right to breathe a clean air!*

Fig.1.



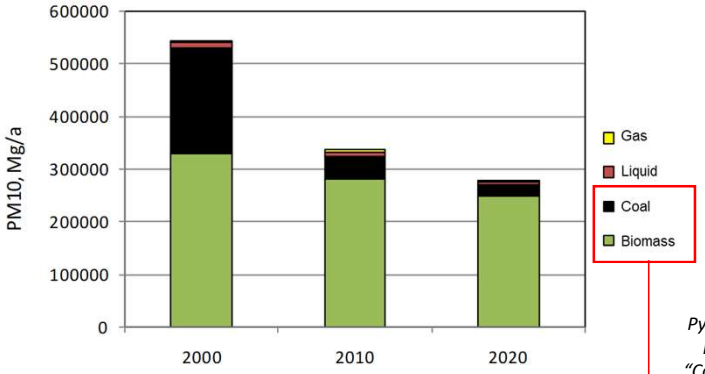

WHO

NEC Directive, EU

- Ambient air concentrations
- Exceedances of limit values – ($\mu g/m^3_n$), suggested WHO limit values as low as 20
- Hot-spots; Krakow, Silesia, Po valey (Italy) > 50 ($\mu g/m^3_{std}$)

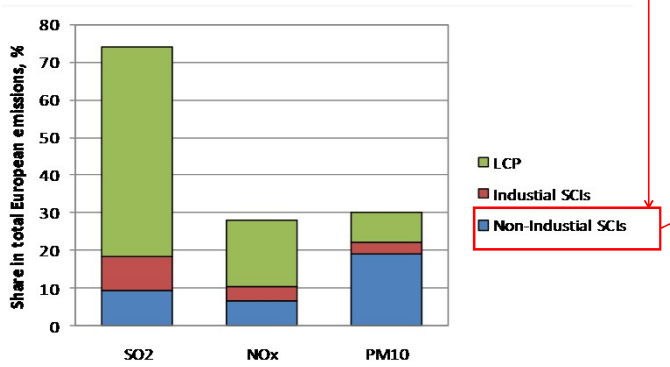
## *Introduction*

*The sources of **PM** emissions*

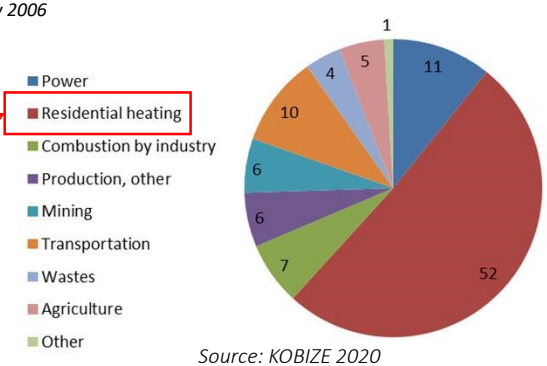



Major contribution of **solid fuels combustion** in the total emissions

*Source: KOBIZE*
*Pye S., Jones G., Stewart R., Woodfield M., Kubica K., Kubica R., Pacyna J.; "Costs and environmental effectiveness of options for reducing mercury emissions.."; AEAT/ED48706/Final report v2, January 2006*




Recognised, significant share of **Small Combustion Installations (SCIs)** in the total emissions




*Source: KOBIZE 2020*

### Anthropogenic sources

- combustion of fuels,
  - over 75% of Nox and $SO_2$, about 70% of CO
  - **over 75% of dust** and over 90% of $CO_2$
- mining and transportation of crude materials,
- the processes of chemical, petroleum, metallurgical and cement industries,
- storage of crude materials and by-products,
- transportation.

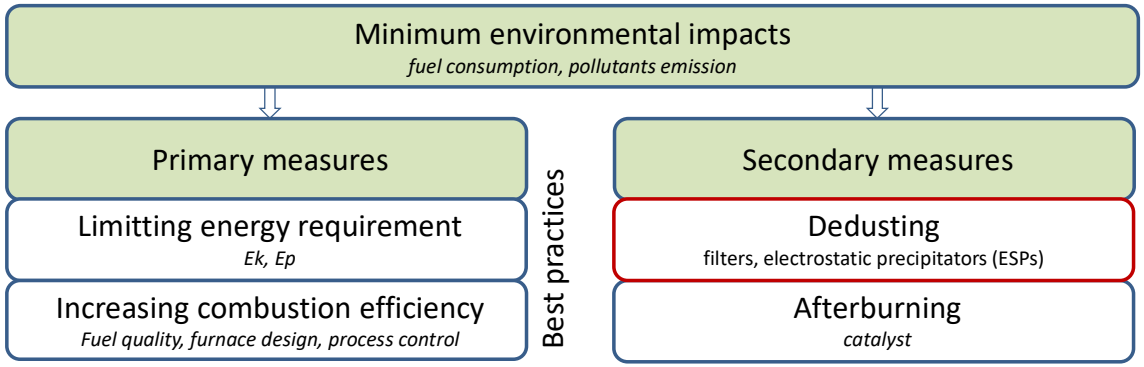
***Old, conventional stoves*** and **boilers**
Poor performance
Inneficient heat generation
highly polluting,

PM emission factors
Conventianl stove – **800 g/GJ**
Aggregated wood – **550 g/GJ**

## *Introduction*

*How to tackle/solve the problem of PM emissions?*

- Residential sector is a key field for improvement – ***clean combusiton of solid biofuels*** including wood and pelet ***by local space heaters*** *and* **boilers**




- lowered heat requirement (proper insulation of the building, **automated systems for zone heating control – above 20 % of savings,** simple payback time SPBT 2 to 6 years)
- combustion process arrangement, **ecolablel appliances**
- fuel switch, gas (**RES, modern biomass - pellet**),
- clean sources – heat pumps
- heating grid

- Micro-scale electrostatic precipitators ESPs

- Best practice - education

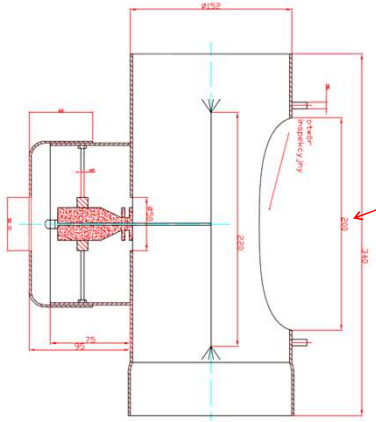
*H. Hartmann, P. Turowski, New developments in small scale ESP technology,Technology- and Support Centre (TFZ), Straubing, Germany(www.tfz.bayern.de)*

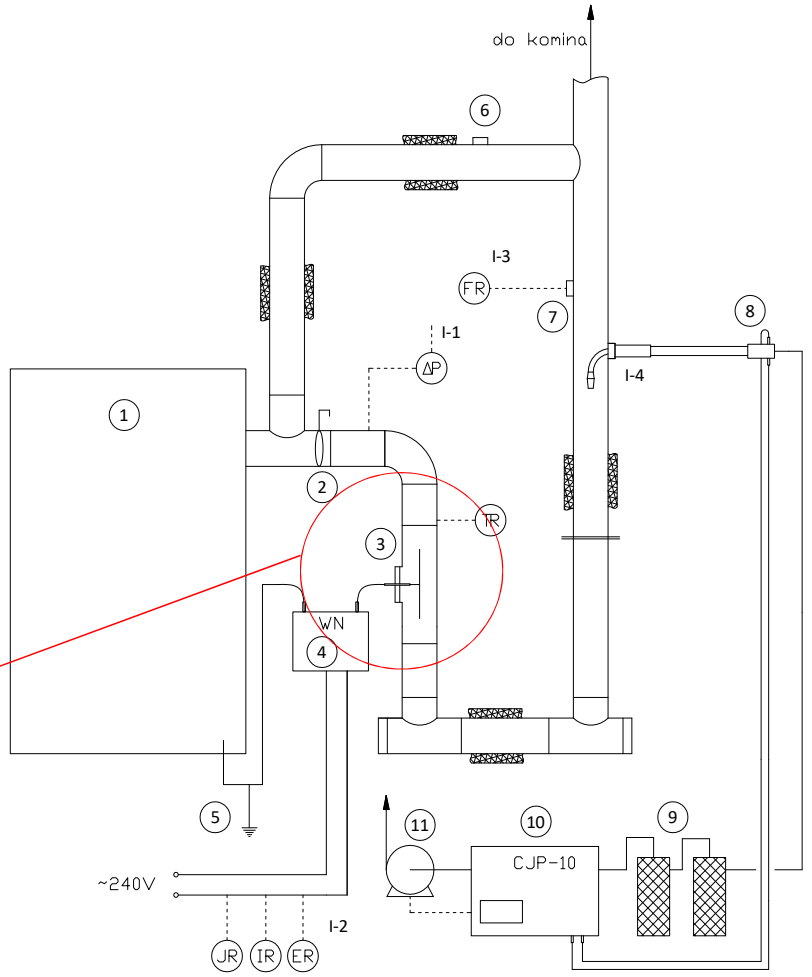
Der Partikelabscheider OekoTube-Inside für Holzfeuerungen (oekosolve.com)

***R&D***

*Prototype, tubular ESP*
*2009*

Fig.10.






Overall efficiency η ~ 70%
Outlet dust concentration ~ 30 mg/m$^3_u$

***R&D***

*Tubular ESP*
*in cooperation with TECHSTEROWNIKI*

***Installed directly at the flue outlet***

*Dedusting efficiency within the range* **60 to 90%**.

1 – *HV module*
2 – *chasis*
3 – *discharge electrode*
4 – *insulator*
13-16 – *automatic cleaning*

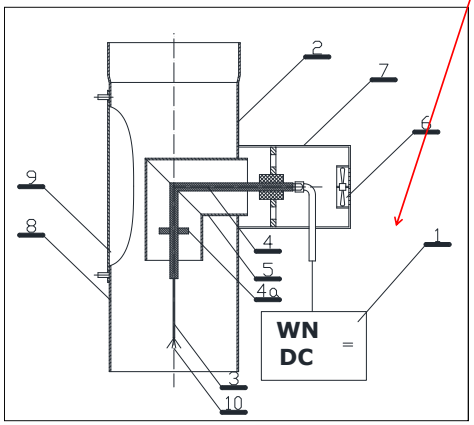



Fig.12.

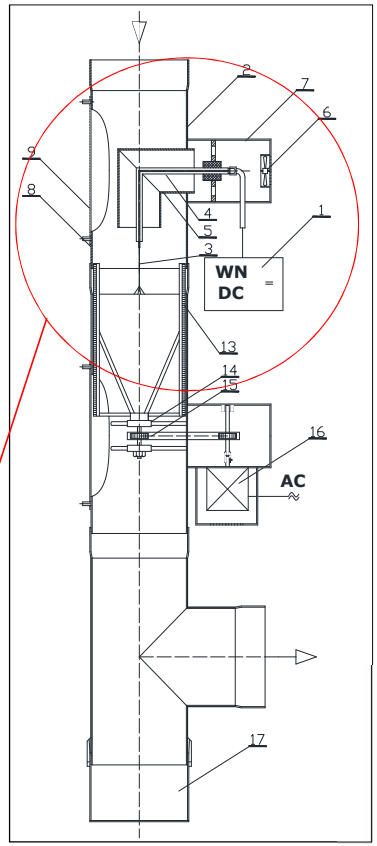



Fig.11.

- *automatic cleaning*
- ***el. (0,04 PLN/h)**, low operating costs*
- ***~ 2000-4000 PLN**, capital costs*

Fig.13.

***R&D***

*Chimney, disc ESP*

*The aim - to abate emissions at the chimney outlet*

*Difficult operating conditions (atmospheric and flue)*

*Possibility to apply for*

- *space heaters*
- *stoves*
- *fireplaces*
- *cook-stoves*

*Bigger population of appliances to be covered*

*More effective emssion abatement – condensing aerosol*

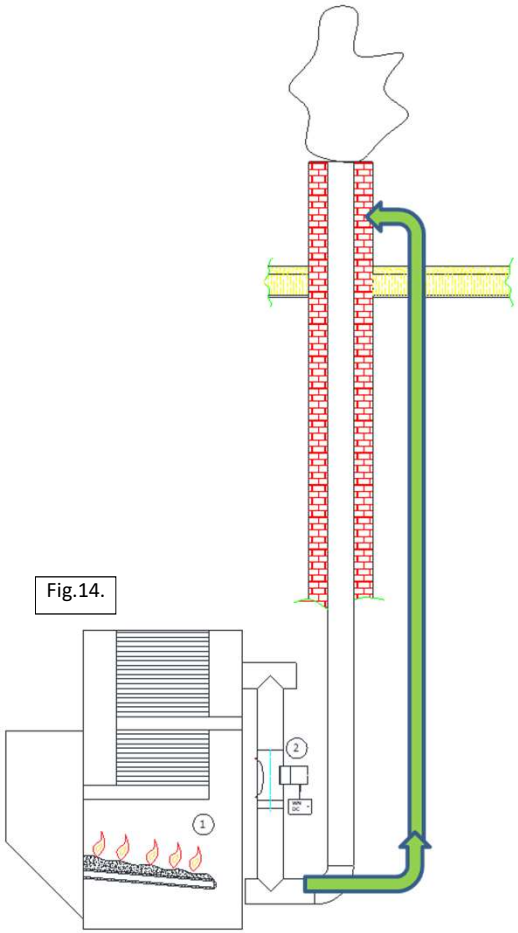


Fig.14.

## R&D

## *Chimney, disc ESP*

*Functional and compact design*

- *stainless steel*
- *aut. cleaning*
- ***el. (0,10 PLN/h)**, low operating costs*
- ***~6000 PLN**, capital costs*

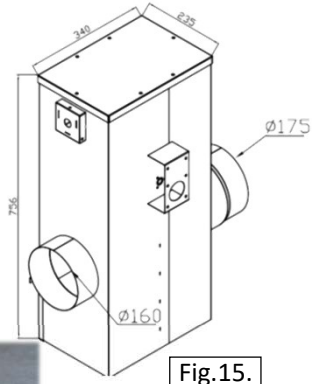
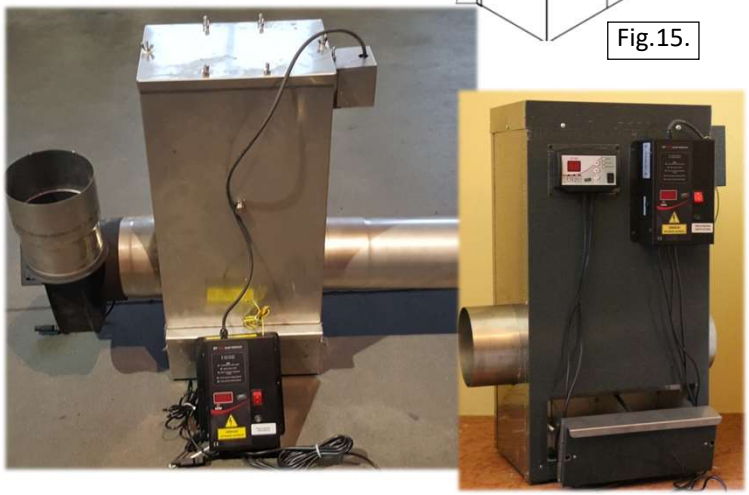



Fig.15.



1 – extraction fan
2 – flue inlet
3 – discharge electrode
4 – collecting electrode
5 – motor
6 – cleaning scrapers
7 – ash tray
9 – flue outlet

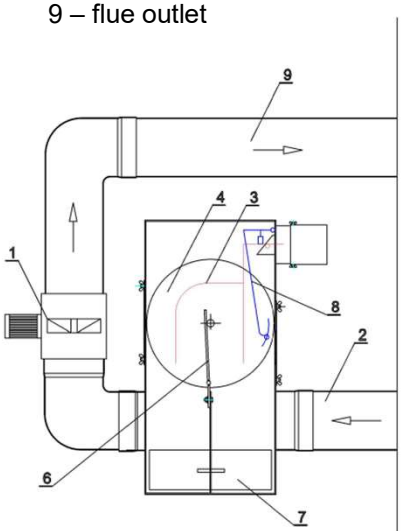
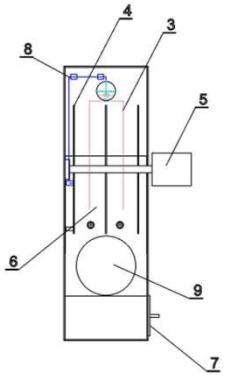



Fig.16.



***R&D***

*Laboratory testing*

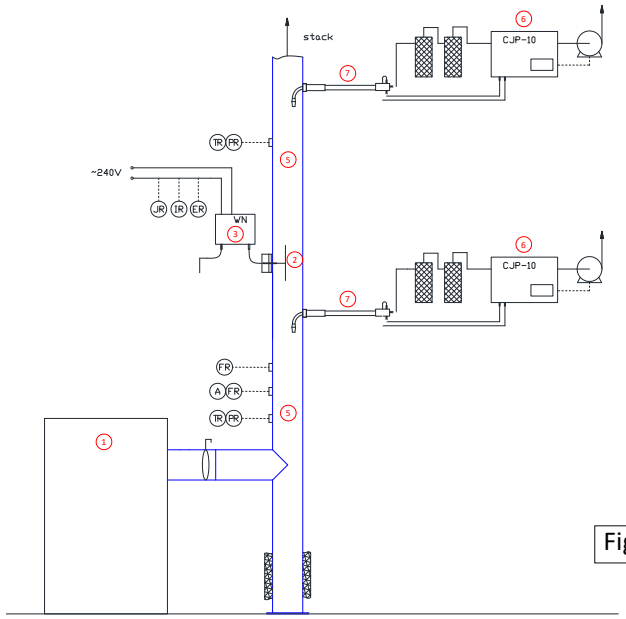



Fig.17.

Overall dedusting efficiency up to 90%
PM emission, concentration <40 mg/m$^3_u$ @10%$O_2$

$$\eta = \frac{c_{in} - c_{out}}{c_{in}} 100\%$$

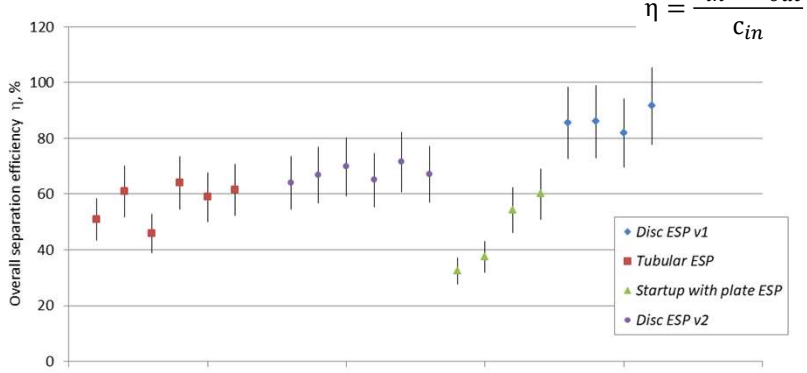



Fig.18. Measured, overall efficiency of different ESPs by laboratory testing

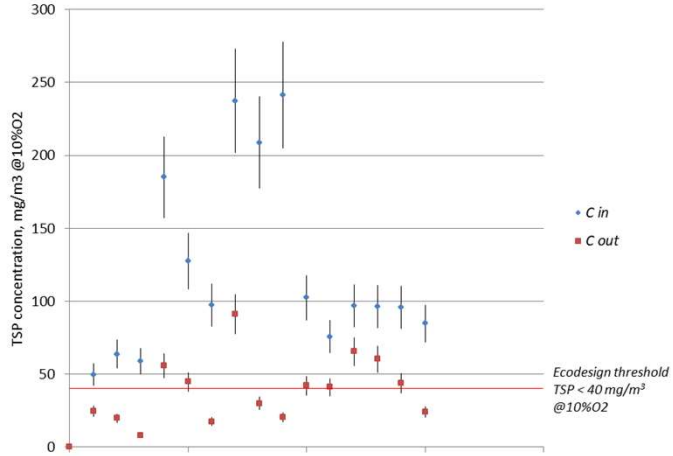



Fig.19. Inlet and outlet dust concentration measured by laboratory testing

## Microscale ESPs

***R&D***

*Field testing*




Fig.20.

Overall dedusting efficiency η 70-80%
PM emission, concentration <40 mg/m$^3_u$ @10%$O_2$

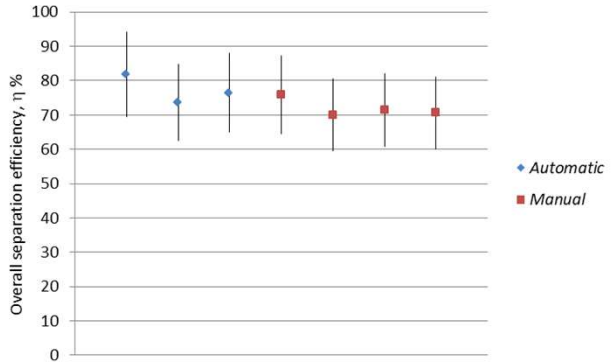



Fig.21. Measured, overall efficiency of disc ESP by field testing

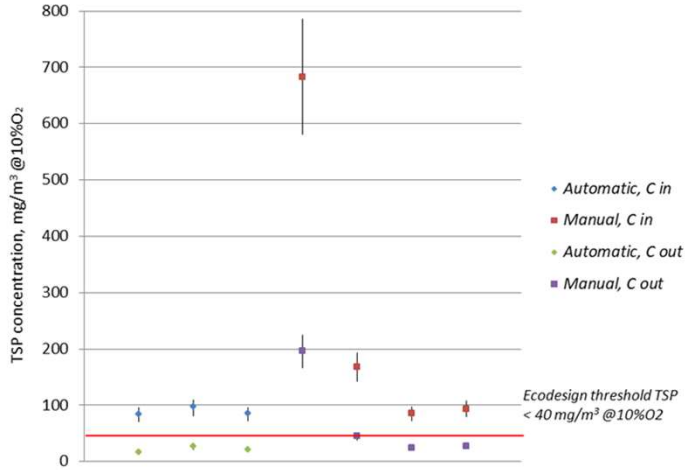



Fig.22. Inlet and outlet dust concentration measured by tubular ESP testing

***R&D***

## *Certification – fire proof testing*

*Mechanical strength*

*Leakage testing prior to and after fire testing*

- ❑ Up to do t=300°C, *Temperature proof testing*
- ❑ **t=1000°C,** *Fire proof testing, soot fire*

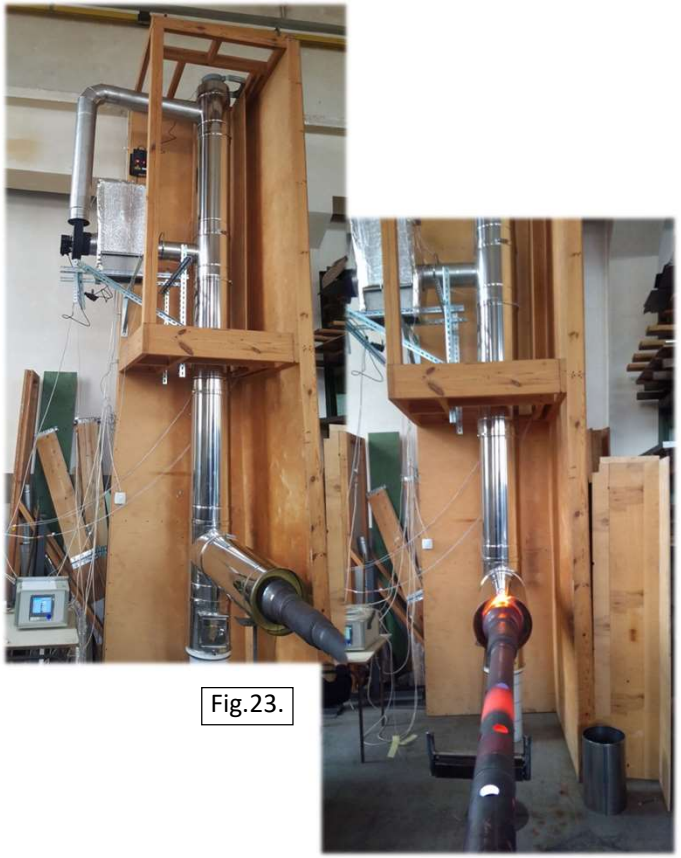
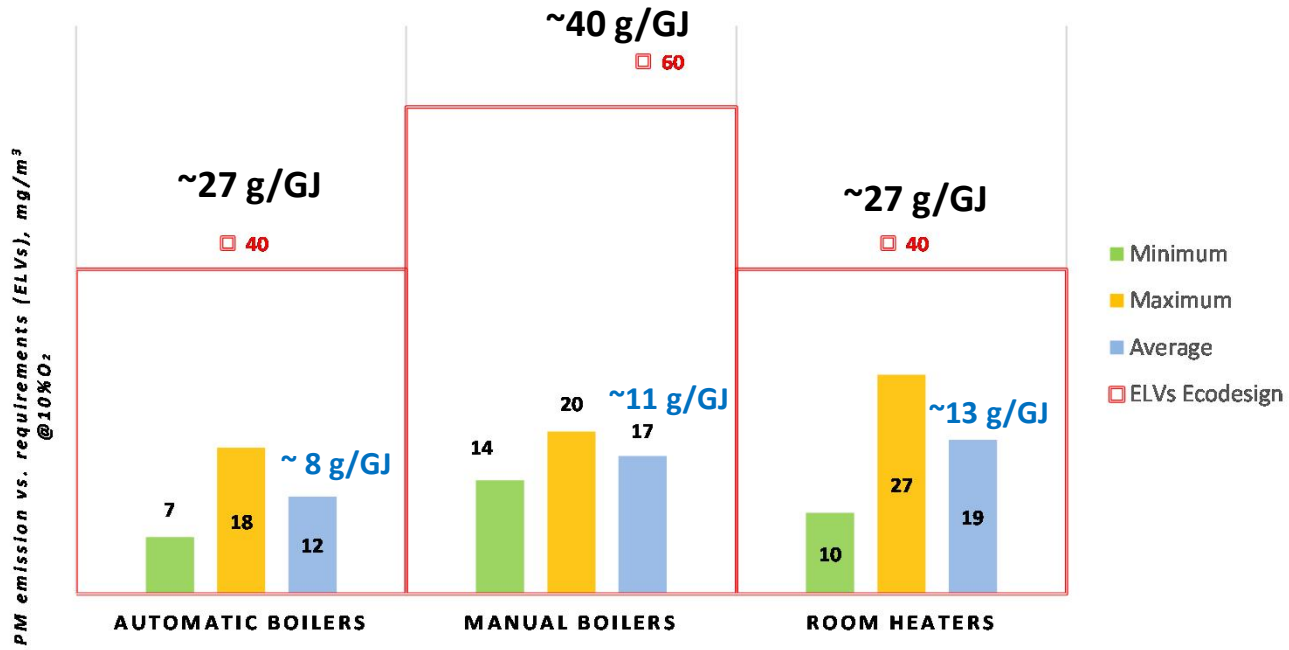


Fig.23.

*Certification testing according to the PN-EN 1856-1:2009 Chimneys*

***Primary measures*** *Ecolabel appliances, laboratory testing*

***Old, conventional stoves*** and **boilers**
PM emission factors
Conventianl stove – **800 g/GJ**
Aggregated wood – **550 g/GJ**



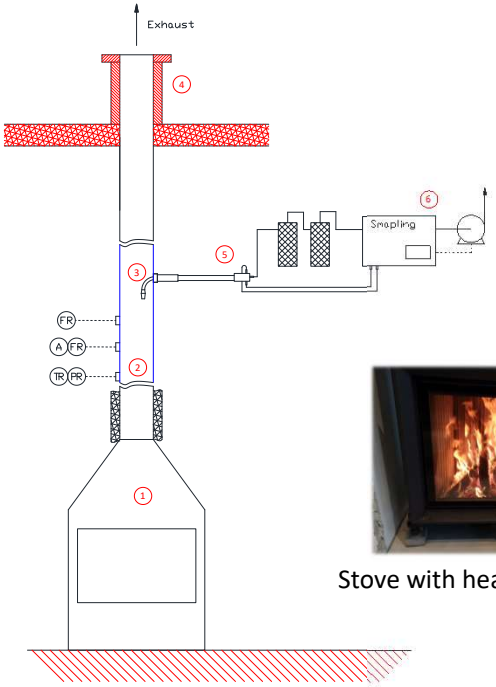

ELVs Ecodesign regulation (EU); stoves 2015/1185, boilers 2015/1189

## *Primary measures*

*Ecolabel appliances, stoves field testing*

4 systems tested:

1. Stove with accumulation + Beech wood
2. Stove with accumulation + Birch wood
3. Stove with heat exchanger (fluegas-water) + Beech wood
4. Stove with heat exchanger (fluegas-water) + Birch wood




Stove with heat exchanger

Stove with accumulation

## PM emission abatement

### ***Primary measures*** *Ecolabel appliances, stoves field testing*

| Pollutant | Emission, g/GJ [2] for all PAHs in mg/GJ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dilution tunel [1] | EIG 2019 [4] | EIG 2019 [5] Tier 1 | US EPA[6] | KOBIZE[7] Tier 1 | Stove 1 | | Stove 2 | | Average |
| | | Ecolable stove | Stoves aggregated | Conventional | Stoves aggregated | Beech/1[3] | Birch/2 [3] | Beech/3[3] | Birch/4 [3] | 1-4 |
| TSP/PM | 97,9 | 100; (20 - 250) | 800 (400-1600) | b.d. | 370 | 10,3 | 12,2 | 24,0 | 15,7 | 15,6 |
| PM.10 | 93,0 | 95; (19 - 238) | 760 (380-1520) | b.d. | 330 | 8,1 | 7,9 | 21,4 | 14,2 | 12,9 |
| PM 2.5 | 90,6 | 93; (19 – 233) | 740 (370-1480) | b.d. | 300 | 3,3 | 3,2 | 13,9 | 9,6 | 7,5 |
| OGC (VOC/LZO) | 705,8 | 250; (20 – 500) | 600; (20-3000) | b.d. | 600 | 86,9 | 221,4 | 158,7 | 72,2 | 138,4 |
| CO | 4851,8 | 2000; (500 – 5000) | 4000; (1000-10000 | b.d. | 5500 | 2 271 | 995 | 2046 | 1076 | 1597 |
| NOx | 61,9 | 95; (50 – 150) | 50; (30 – 150) | b.d. | 50 | 60,6 | 63,1 | 55,0 | 59,4 | 59,5 |
| $SO_2$ | b.d. | 11; (8 – 40) | 11; (8 – 40) | b.d. | 11 | 6,3 | 12,9 | 9,4 | 3,9 | 8,1 |
| Benzo(a)piren | 92,1 | 10; (5 – 20) | 121; (12-1210) | 176 | 250 | 0,51 | 0,55 | 0,27 | 0,55 | 0,47 |
| Benzo(b)fluoranten | 72,4 | 16; (8 – 32) | 111; (11-1110) | 235 | 240 | 0,91 | 0,73 | 0,43 | 0,96 | 0,76 |
| Benzo(k)fluoranten | 47,9 | 5; (2 – 10) | 42; (4-420) | 59 | 150 | 0,27 | 0,28 | 0,19 | 0,46 | 0,30 |
| Indeno(1,2,3-cd)piren | 61,5 | 4; (2 – 8) | 71; (7-710) | 588 | 180 | 0,31 | 0,26 | 0,24 | 0,54 | 0,34 |

[1] **NovaMetodikaEBSpalovZdrojuVDomacnostech; średnia dla kominków, pieców (ogrzewaczy pomieszczeń); T121044, uwzględniają nowe konstrukcje;**
[2] **WWA mg/GJ**
[3] test number
[4] WWA pochodza z danych literaturowych: Boman, C., Pettersson, E., Westerholm, R., Boström, D. & Nordin, A., 2011: Stove Performance and Emission Characteristics in Residential Wood Log and Pellet Combustion, Part 1: Pellet Stoves. Enery Fuels 2011, 25. (2011); Johansson, L.S., Leckner, B., Gustavsson, L., Cooper, D., Tullin, C. & Potter, A., 2004: Emissions characteristics of modern and old-type residential boilers fired with wood logs and wood pellets. Atmospheric Environment, 2004, 38. (2004)
[5] Tier 1, czyli zagregowane do wyliczenia przez ilość spalanego paliwa; takie same wartości przyjęto *dla Conventional stoves* oraz *High-efficiency stoves (stoves, fireplaces, cooking,...);* WWA pochodza z danych literaturowych: Goncalves et al. (2012); Tissari et al. (2007); Hedberg et al. (2002); Pettersson et al. (2011); Glasius et al. (2005); Paulrud et al. (2006); Johansson et al. (2003); Lamberg et al. (2011)
[6] US EPA, 1996; AP-42 Compilation of Air Pollutant Emission Factors Vol 1 Stationary Point and Area Sources, United States Environmental Protection Agency, available at http://www.epa.gov/ttn/chief/index.html; (za: John J. Todd; Wood-Smoke Handbook: Woodheaters, Firewood and Operator Practice; Eco-Energy Options, 2003, https://www.cleanairtas.com/links/woodsmoke-handbook.pdf); oryginalne dane w mg/kg, przeliczono na GJ przyjmując 17GJ/tonę;
[7] KOBIZE (opracowanie: K. Kubica; Analiza i oszacowanie trendu wskaźników emisji co, wwa, pcdd/fs oraz pcb ze spalania paliw stałych w sektorach mieszkalnictwa i usług w latach 2000-2014Warszawa marzec 2017 rok), zagregowany dla starych ogrzewaczy pomieszczeń; znikomy udział nowych konstrukcji eksploatowanych w terenie

**PM emission abatement**

***BATs***

*Summary and conclusions*

Advanced stoves and boilers (Ecodesign compliant) - the Best Available Techniques (BATs) of solid biofuels combustion, commercially available, ***guarantee*** performacne at the ***lowest required ELVs*** releavnt for ***dust*** emission.

***Effective*** primary ***measure*** to ***abate*** emissions of ***PAHs***

***Fuel quality*** must be ***assured***

Advantages of primary measures – ***cost effectiveness***

Secondary measures such as ESPs - ***Retrofitting of existing systems***

Reduction of emissions by ecolabel appliances
**EcoDESIGN** compared **to conventional**

| | |
|---|---|
| **PM** | **> 95%** |
| **PAHs** | **>> 90%** |
| **BaP** | **> 99%** |

*Cobination of primary and secondary measures (80% dedusting efficiency) provides ultra low emission of pollutants from combustion of solid biofuels!*

*Class 5/ECODESIGN* — *pellet boiler*
***TSP < 2 mg/m³*** $CO_2 = 0$ *outlet concentration of PM*

*Class 5 klasy/ECODESIGN* — *wood gasifying boiler*
***TSP < 2 mg/m³*** $CO_2 = 0$ *outlet concentration of PM*

Rational use of local renewable resources for useful heat production
Circular economy

# CONTACT

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