Stove Design guide

IEA Task 32

IEA Bioenergy

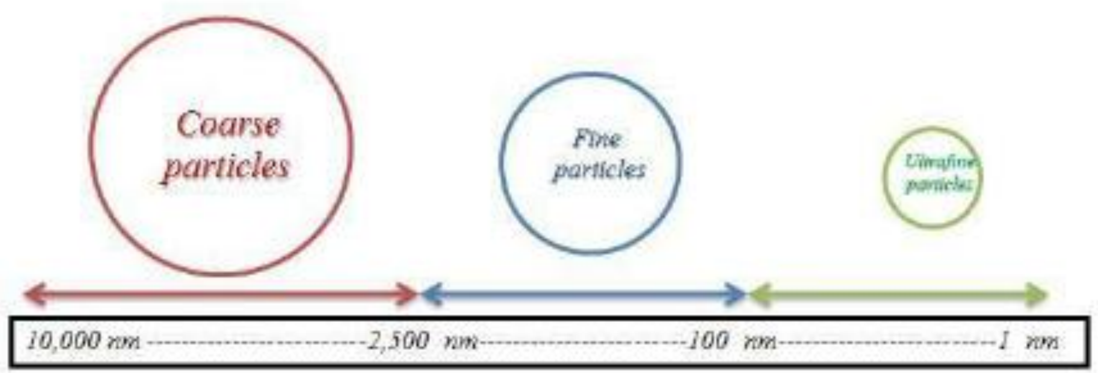
Why are we introducing guidelines?

Reducing emissions in general for wood stoves

Sharing of knowledge from European research projects

Balance between design and combustion

Main emissions categories to minimize



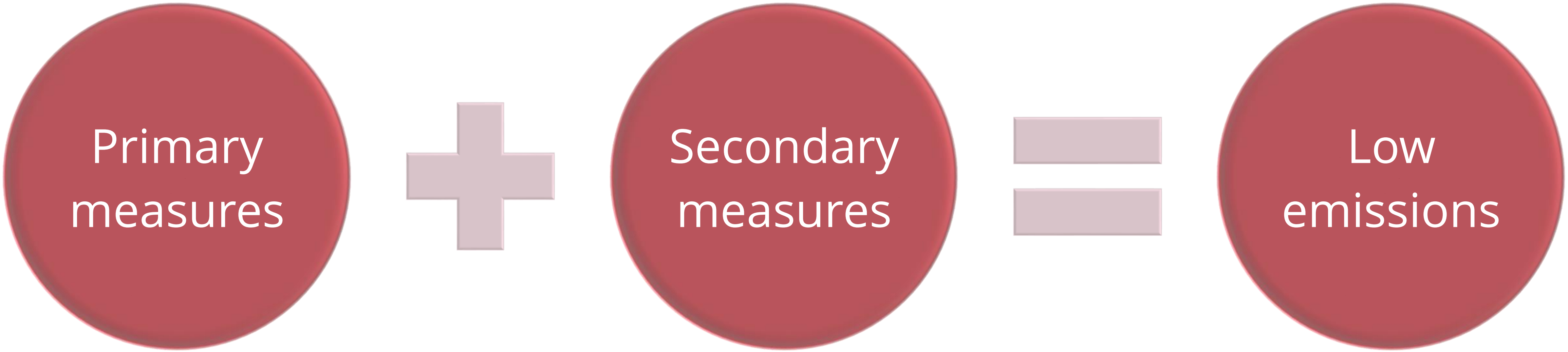
https://www.researchgate.net/profile/Hitesh_Waghwani/publication/262843669/figure/fig1/AS:296445971320833@1447689635765/Classification-of-particles-on-the-basis-of-their-size-distribution-in-the-nanometer.png

Black Carbon

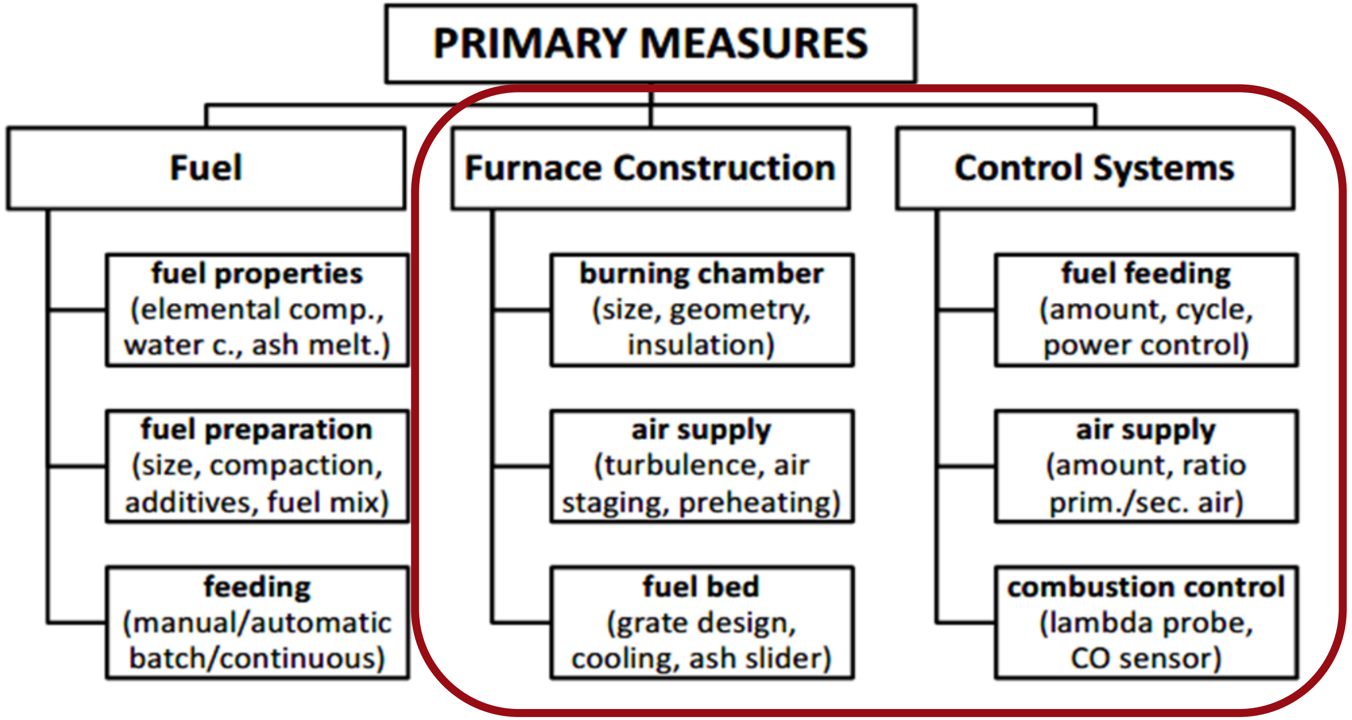
https://thumbs.dreamstime.com/z/black-ink-hand-drawing-smoke-coming-house-chimney-voc-volatile-organic-compound-air-pollution-concept-black-brush-132924878.jpg

CO

Measures to reduce emissions

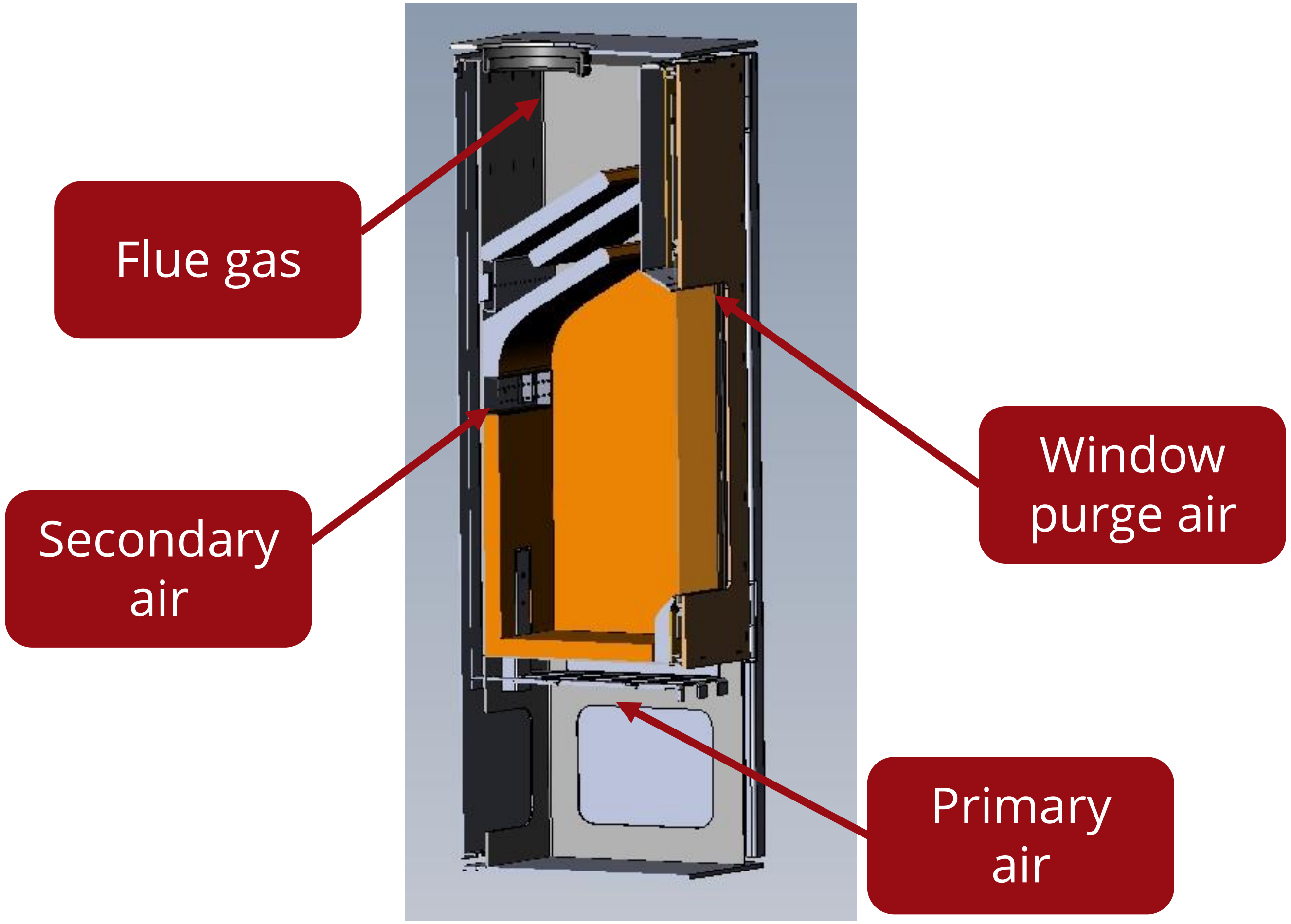


Primary design measures



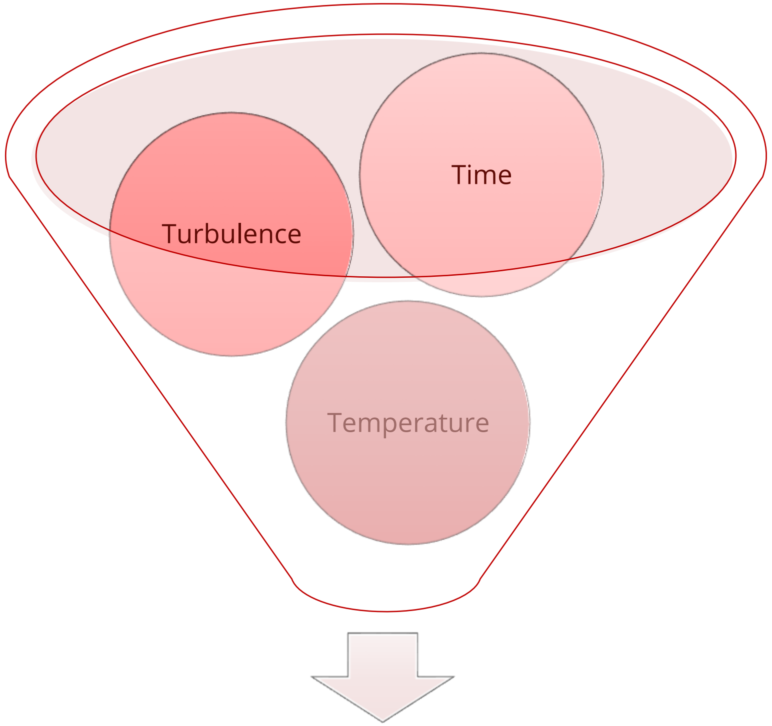
Source: http://task32.ieabioenergy.com/iea-publications/events/workshop-highly-efficient-clean-wood-log-stoves-berlin-november-2015/

Definition of terminology regarding airflows



Source: Danish Technological Institute

Combustion chamber optimization



Ecodesign or better

Source: Danish Technological Institute

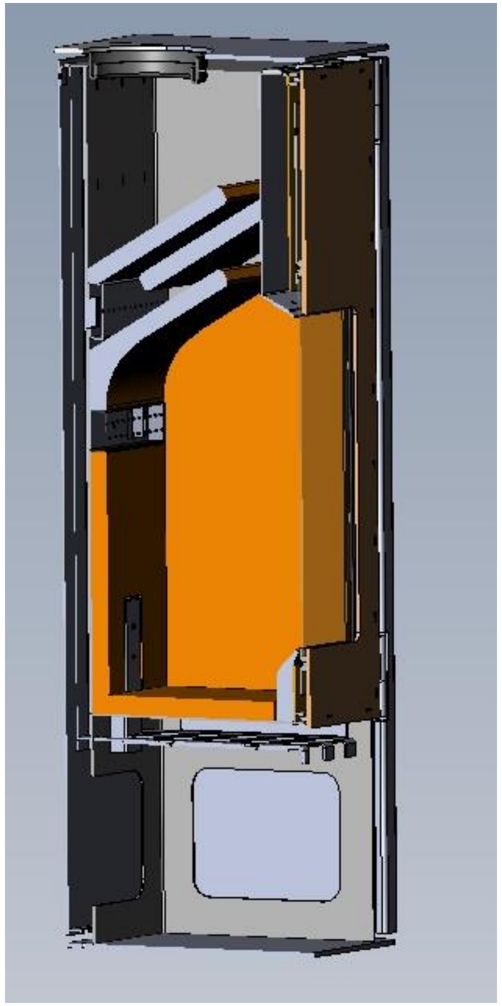
Temperatures

- Things to consider
  - Refractory lining in the combustion chamber
  - Shape and size of combustion chamber
  - Material and isolation of the door as well as size of window and its radiation coefficient or alternatively coated glasses or double/triple windows with air gap between
  - Windows should be of moderate size

Source: Danish Technological Institute

Residence time

- Sufficient residence time is needed and is influenced by the following parameters
  - Gas volume flow
  - Distribution of flue gas over combustion chamber
  - Distribution of air
  - Height of the combustion chamber



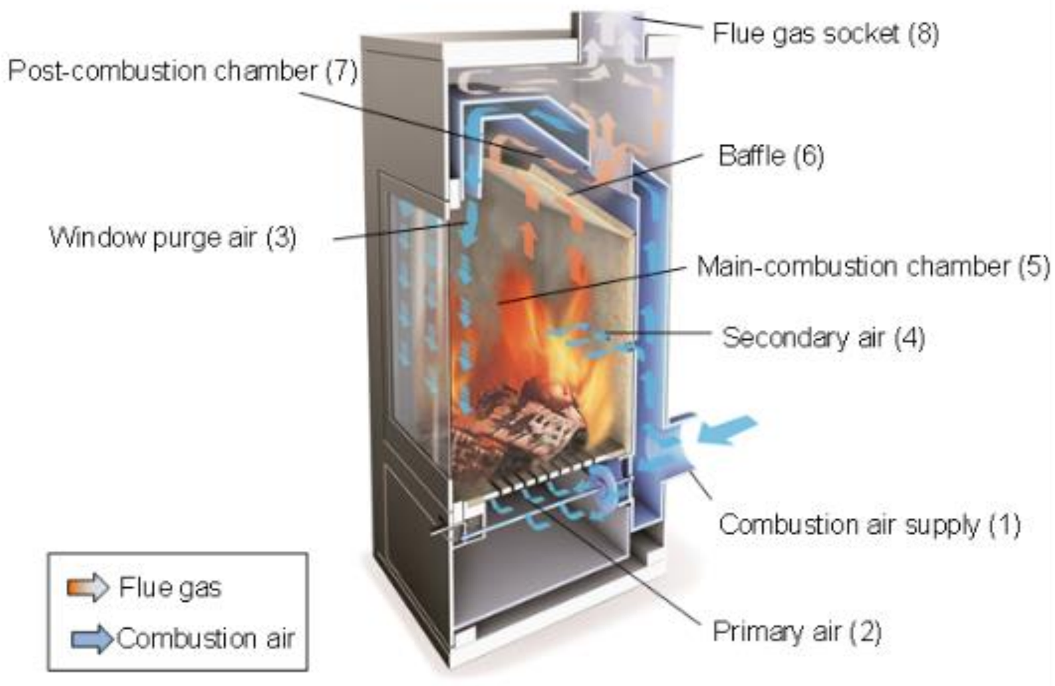
Source: Danish Technological Institute

Turbulence or mixing of flue gasses

- Distribution of window purge air
- Direction and geometry of additional air
- Velocities of flue gas and combustion air
- Geometry of main as well as post combustion chamber
- Geometry of deflection plate and the use of baffles in post combustion chamber.
- Avoidance of leakage streams (sealing)
- Avoidance of short-circuiting of the flue gas stream
- Groved surfaces

Source: Danish Technological Institute

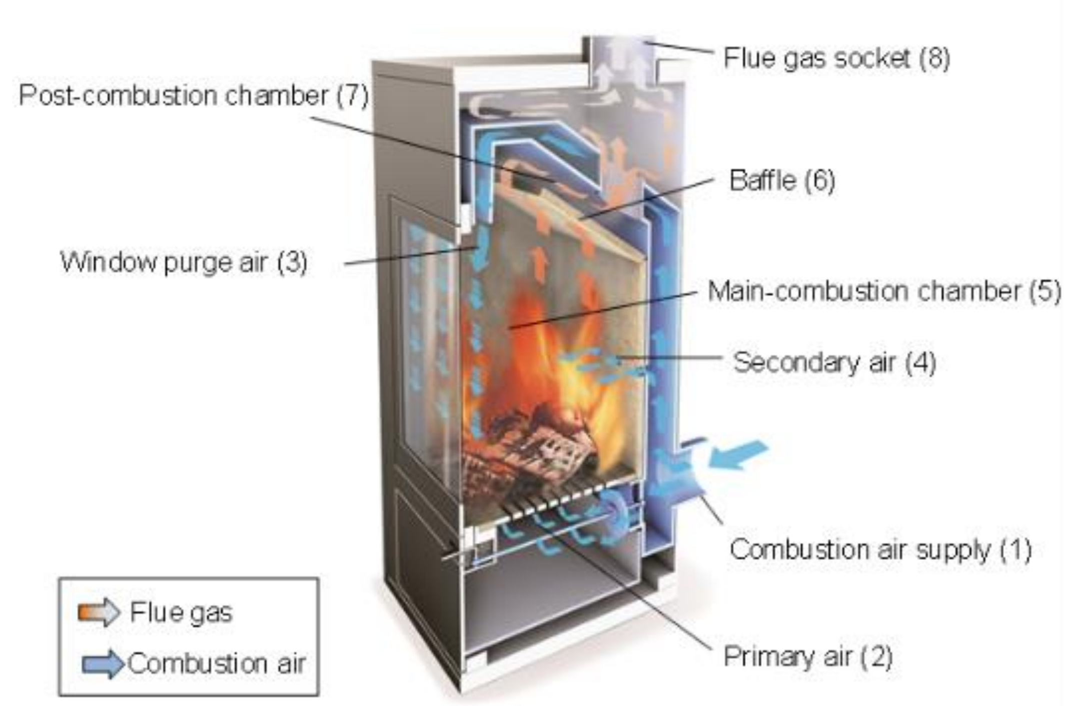
Geometry of combustion chamber



- High and slim geometry improves flame dispersion and result in more homogeneous residence pattern of pyrolysis gases in the hot zone.
- Should be dimensioned according to the desired effect
- No glass side panes
- No or limited radius or angel on front glass
- Well isolated chamber and stable and high temperatures in the combustion chamber is important.
- Airtight door and system
- Grooved surface pattern to obtain local turbulence and reduce elementary carbon emission

Source: http://www.tfz.bayern.de/mam/cms08/en/dateien/stoves2020-guidelines_low_emission_concepts.pdf

Air supply and air staging

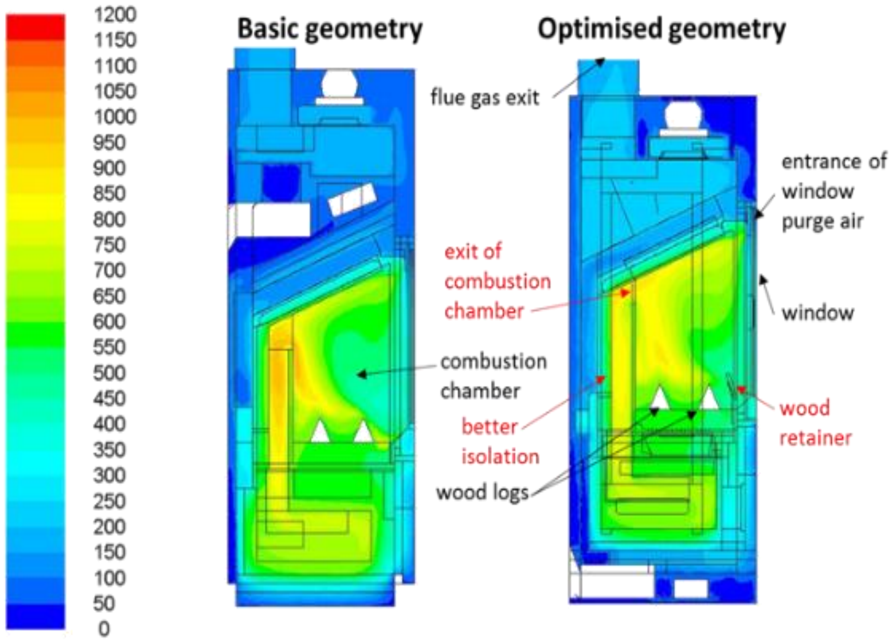


- Air staging should result in equally distributed fuel decomposition and charcoal burnout as well as almost gas phase burn out by introducing different airflows
- Minimum primary air and window purge air
- Primary air should not be preheated whereas air streams to secondary combustion chamber should be pre-heated.
- Precaution about window purge air secondary air nozzles functioning as primary air
- Secondary air should be applied in multiple levels

Source: http://www.tfz.bayern.de/mam/cms08/en/dateien/stoves2020-guidelines_low_emission_concepts.pdf

Computational Fluid Dynamics - CFD

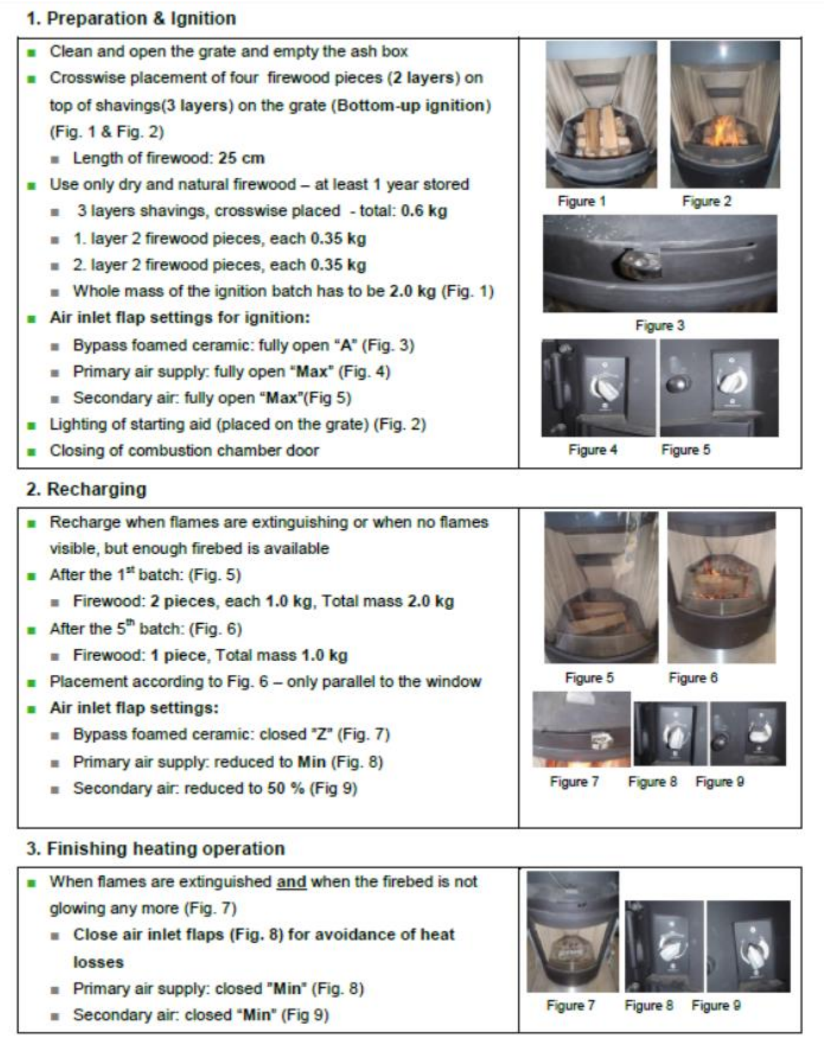
- Velocities and temperatures of the combustion air
- Convective air and flue gas
- Path lines and flue gas
- CO and O_2 concentrations in the flue gas
- Material and surface temperatures
- Heat transfer
- Efficiency
- Pressure losses



Source: http://www.tfz.bayern.de/mam/cms08/en/dateien/stoves2020-guidelines_automated_control_systems.pdf

Reduced impact from user behavior

- QUG or improved information
- Automated control systems



1. Preparation & Ignition

- Clean and open the grate and empty the ash box
- Crosswise placement of four firewood pieces (**2 layers**) on top of shavings(**3 layers**) on the grate (**Bottom-up ignition**) (Fig. 1 & Fig. 2)
  - Length of firewood: **25 cm**
- Use only dry and natural firewood – at least 1 year stored
  - 3 layers shavings, crosswise placed - total: **0.6 kg**
  - 1. layer 2 firewood pieces, each **0.35 kg**
  - 2. layer 2 firewood pieces, each **0.35 kg**
  - Whole mass of the ignition batch has to be **2.0 kg** (Fig. 1)
- **Air inlet flap settings for ignition:**
  - Bypass foamed ceramic: fully open "**A**" (Fig. 3)
  - Primary air supply: fully open "**Max**" (Fig. 4)
  - Secondary air: fully open "**Max**"(Fig 5)
- Lighting of starting aid (placed on the grate) (Fig. 2)
- Closing of combustion chamber door

Figure 1 Figure 2 Figure 3 Figure 4 Figure 5

2. Recharging

- Recharge when flames are extinguishing or when no flames visible, but enough firebed is available
- After the 1st batch: (Fig. 5)
  - Firewood: **2 pieces**, each **1.0 kg**, Total mass **2.0 kg**
- After the 5th batch: (Fig. 6)
  - Firewood: **1 piece**, Total mass **1.0 kg**
- Placement according to Fig. 6 – only parallel to the window
- **Air inlet flap settings:**
  - Bypass foamed ceramic: closed "**Z**" (Fig. 7)
  - Primary air supply: reduced to **Min** (Fig. 8)
  - Secondary air: reduced to **50 %** (Fig 9)

Figure 5 Figure 6 Figure 7 Figure 8 Figure 9

3. Finishing heating operation

- When flames are extinguished and when the firebed is not glowing any more (Fig. 7)
  - **Close air inlet flaps (Fig. 8) for avoidance of heat losses**
  - Primary air supply: closed "**Min**" (Fig. 8)
  - Secondary air: closed "**Min**" (Fig 9)

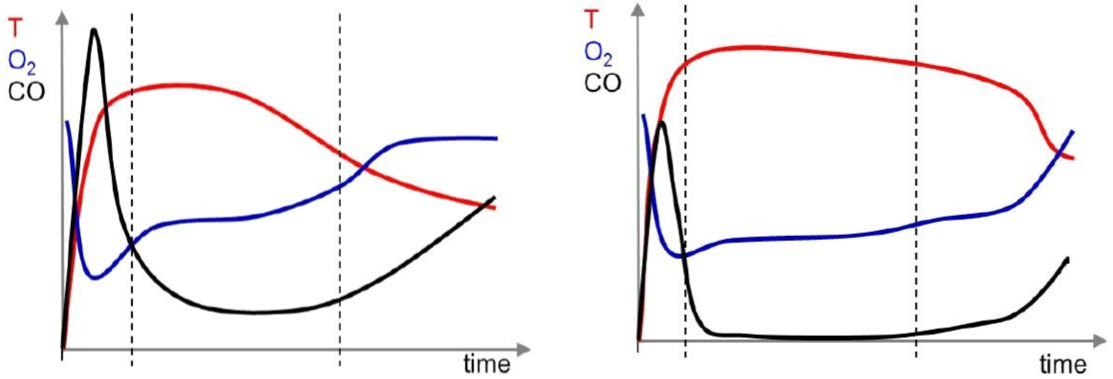
Figure 7 Figure 8 Figure 9

QUG from BeReal project

Source: http://www.bereal-project.eu/uploads/1/3/4/9/13495461/13.40_the_firewood_method_2.pdf

Automated Control Systems

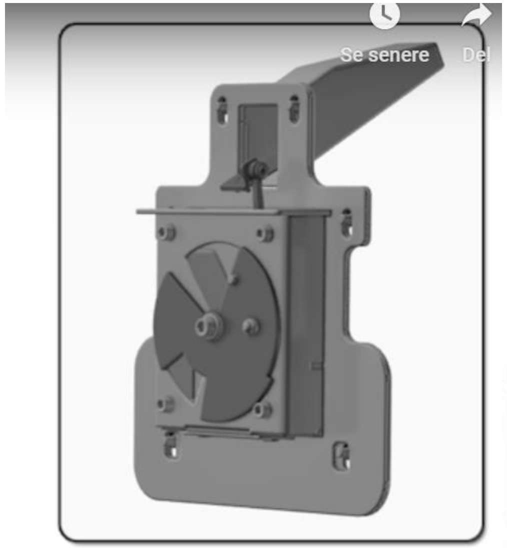
- Advantages with both integrated automatic control systems and retrofit solutions are
- Reduced user influence
- Reactions to changes throughout the batch
- Reducing emission in real life operation
- Increase thermal efficiency
- Increase operation comfort
- Reduce standing losses

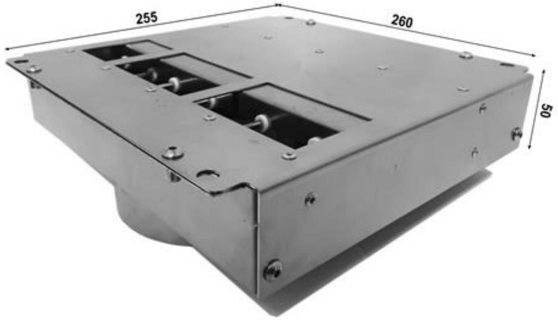


Source: http://www.tfz.bayern.de/mam/cms08/en/dateien/stoves2020-guidelines_automated_control_systems.pdf

Types of Automated Control Systems

- Thermo-mechanically operated air flaps
- Electronic sensor driven automatic control concept
  - Flue gas temperature measurements in combustion chamber
  - Oxygen measurement in exhaust gas
  - Combined temperature and oxygen measurements
- Stoves add-ons and retrofit systems
  - Chimney draught stabilizer and flue gas fans
  - Air and flue gas flaps
  - Electronic air distribution system





Sensors available

- Temperature sensors
  - The cheapest solution, also being quite robust, is thermocouples
- Gas sensors
  - Oxygen – lambda probes
  - CO_2 sensors
  - CO – normally detects CO and hydrocarbons.
  - Combination sensors for oxygen and unburnt components.
- Pressure sensors
- Other sensors of interest
  - Recognizing flames
  - Recognizing door opening

Secondary measures

Catalysts

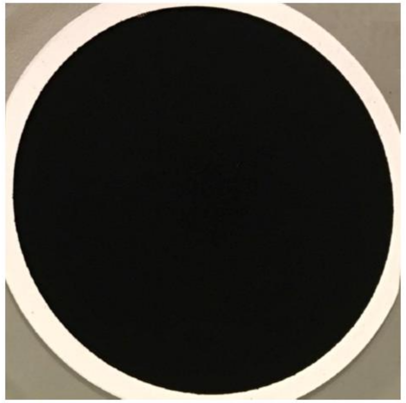
- Efficiency as catalyst has been seen to be very good for
  - CO reduction between 90%
  - 50-70% of HC's depending on the starting point for the stove
- No or limited effect documented with regards to PM/PN

- Challenges with applying an integrated catalyst in the wood stoves are
  - Flow resistance which can cause insufficient air flow
  - Flue gas backflow
  - Degradation
    - From very server within a few weeks' time, to almost no during long time or application
  - Pressure drop varies from a few Pa to double digit number.

Electrostatic precipitators

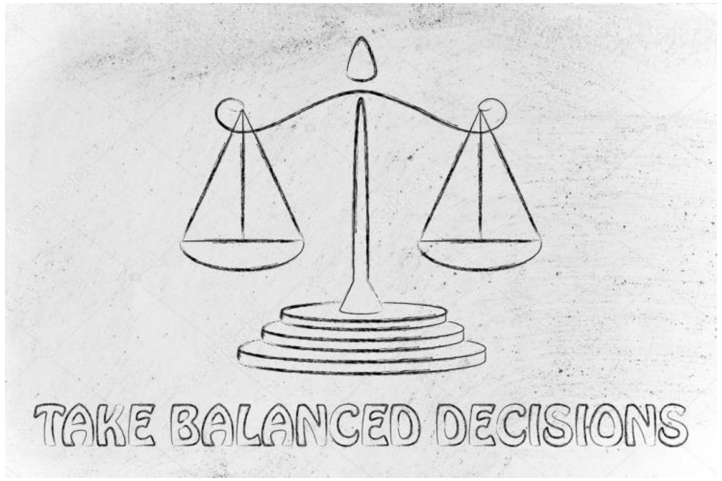
- High efficiency reached 80-95 %
  - Both PM and PN
  - Reduction potential for Black Carbon
- No effect with regards to CO, HC, NOX

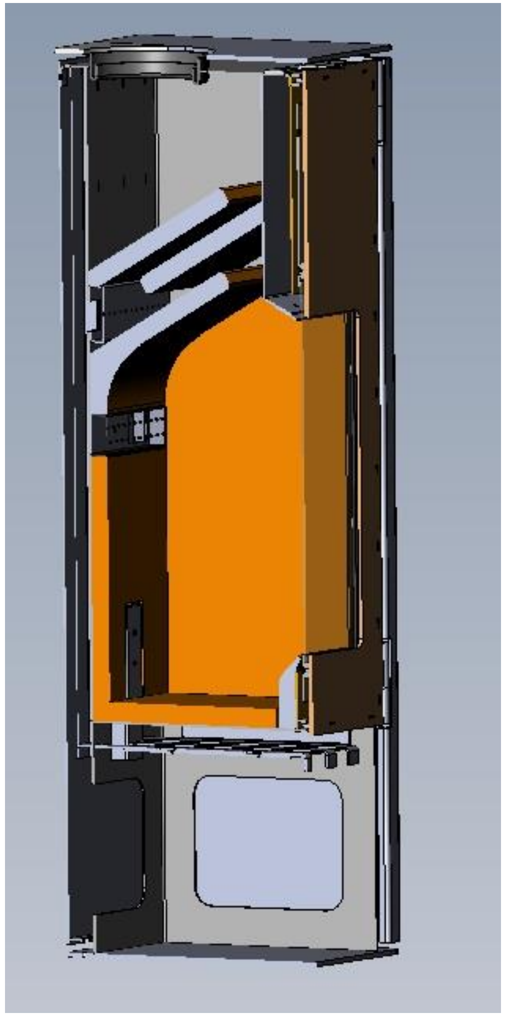
- Challenges applying an ESP in connection with wood stoves are
  - Expected lifetime and maintenance cost
  - Cleaning of the filter
  - Cost of the filter itself



Summary

- The most important aspects of stove development
  - The three T's
    - Time, temperature and Turbulence
  - Geometry of the combustion chamber
  - Air supply and air staging
  - Reduction of the user influence on the combustion – Automated systems





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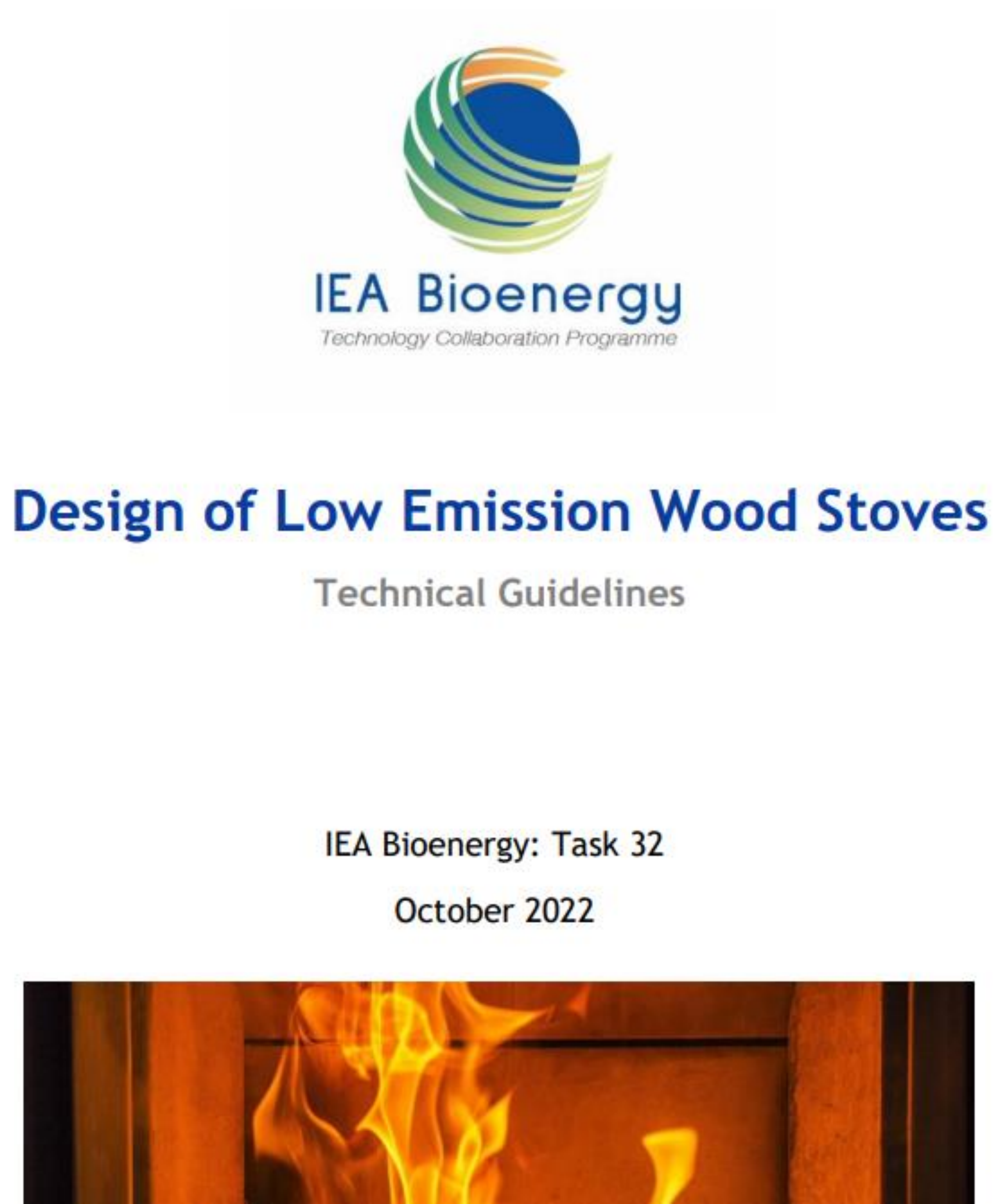
By

IEA Bioenergy

http://task32.ieabioenergy.com/


IEA Bioenergy
Technology Collaboration Programme

Design of Low Emission Wood Stoves

Technical Guidelines

IEA Bioenergy: Task 32

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Thank you

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