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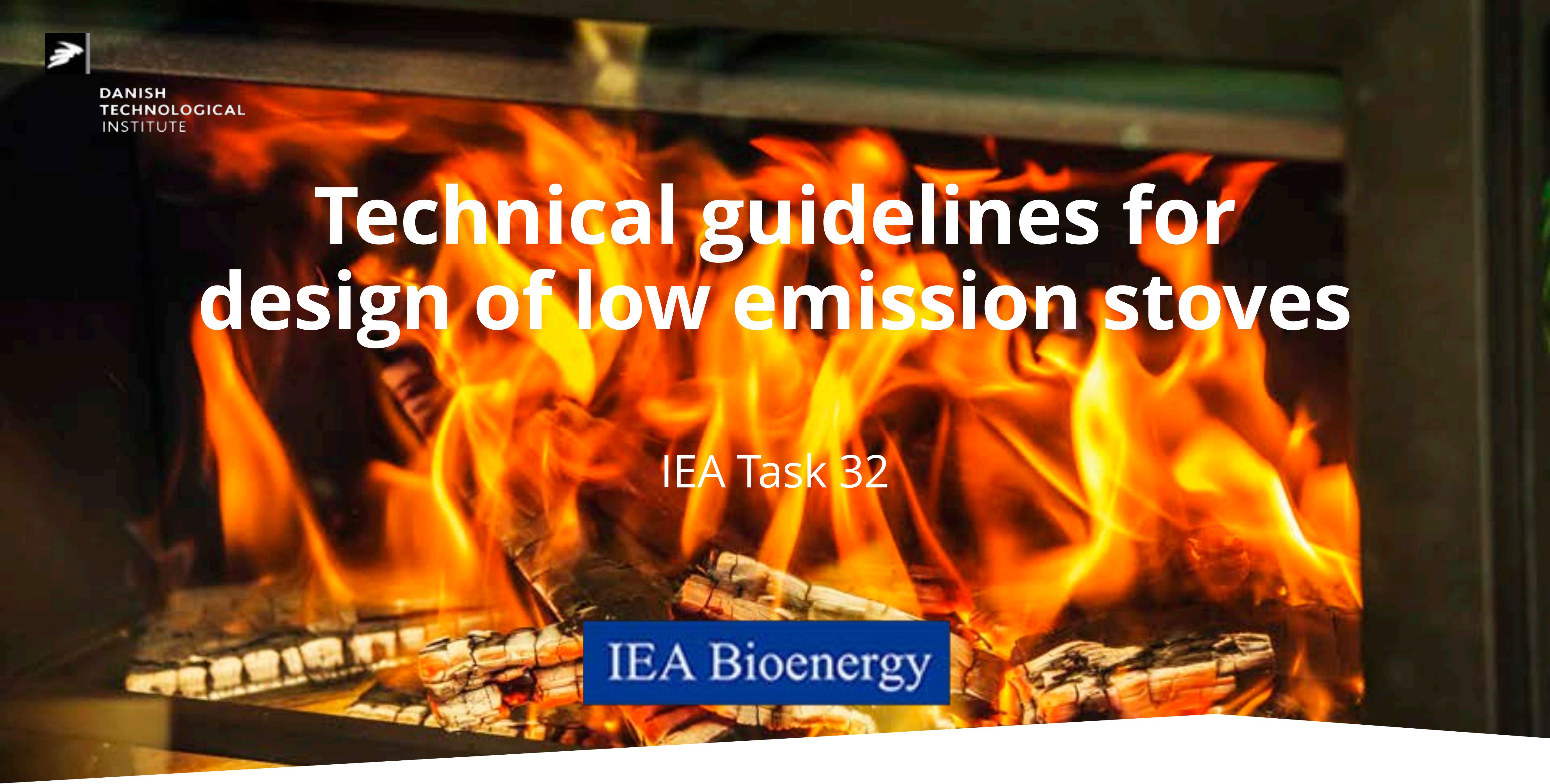

Technical guidelines for design of low emission stoves

IEA Task 32

IEA Bioenergy

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Technical guidelines for design of low emission stoves

Prepared for

IEA Bioenergy

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Why are we introducing guidelines?

- Reducing emissions in general for wood stoves
- Sharing of knowledge from European research projects
- Balance between design and combustion

Source: Danish Technological Institute

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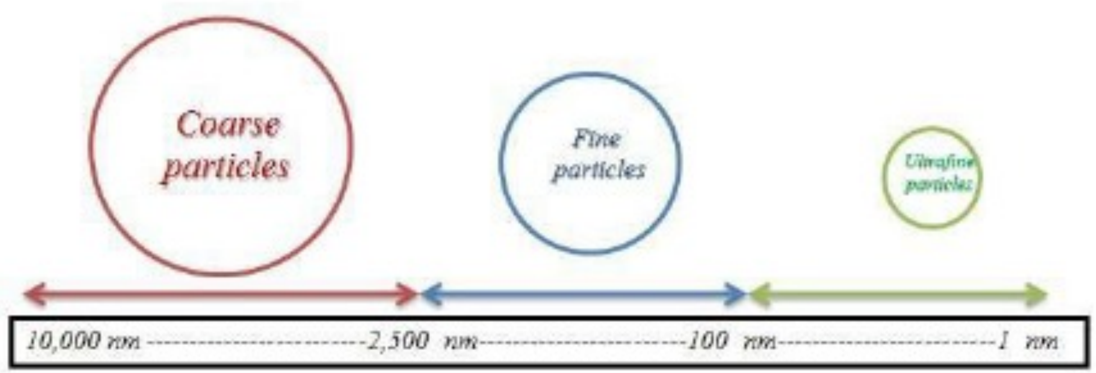
Main emissions categories to minimize



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

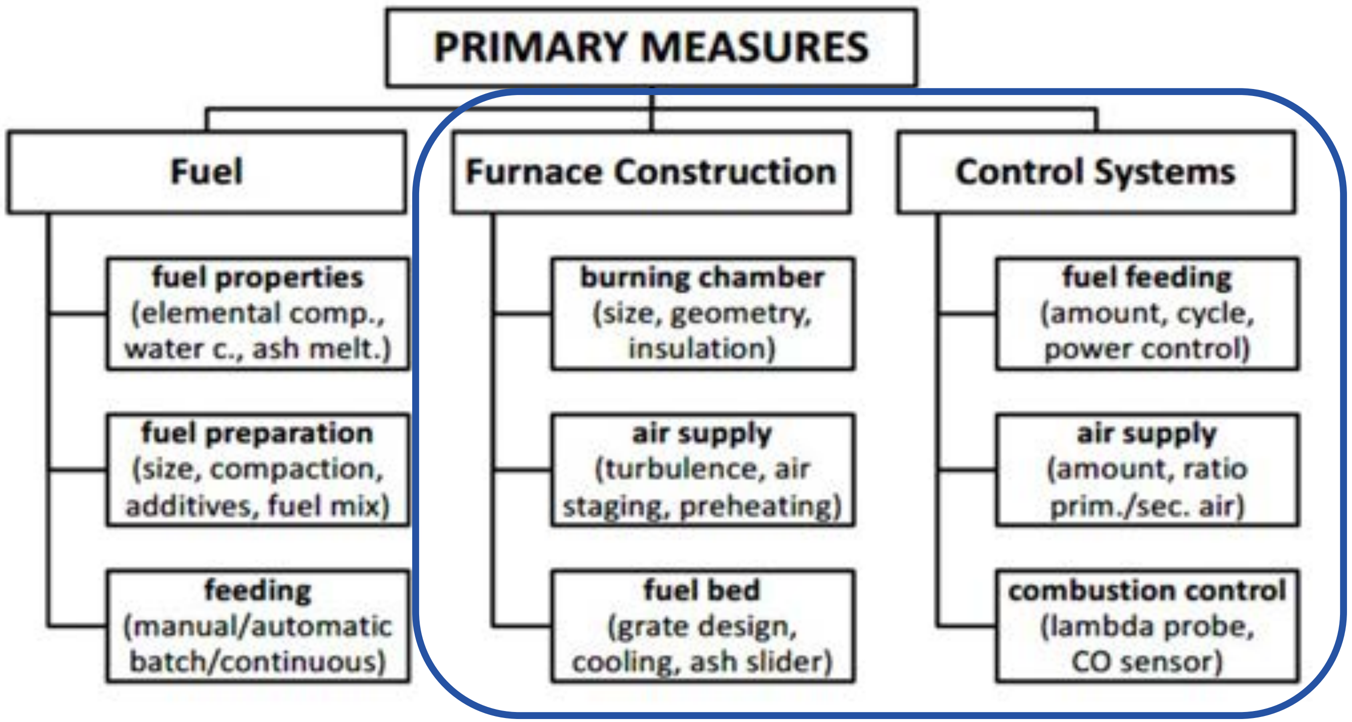
Black Carbon

CO

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

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/

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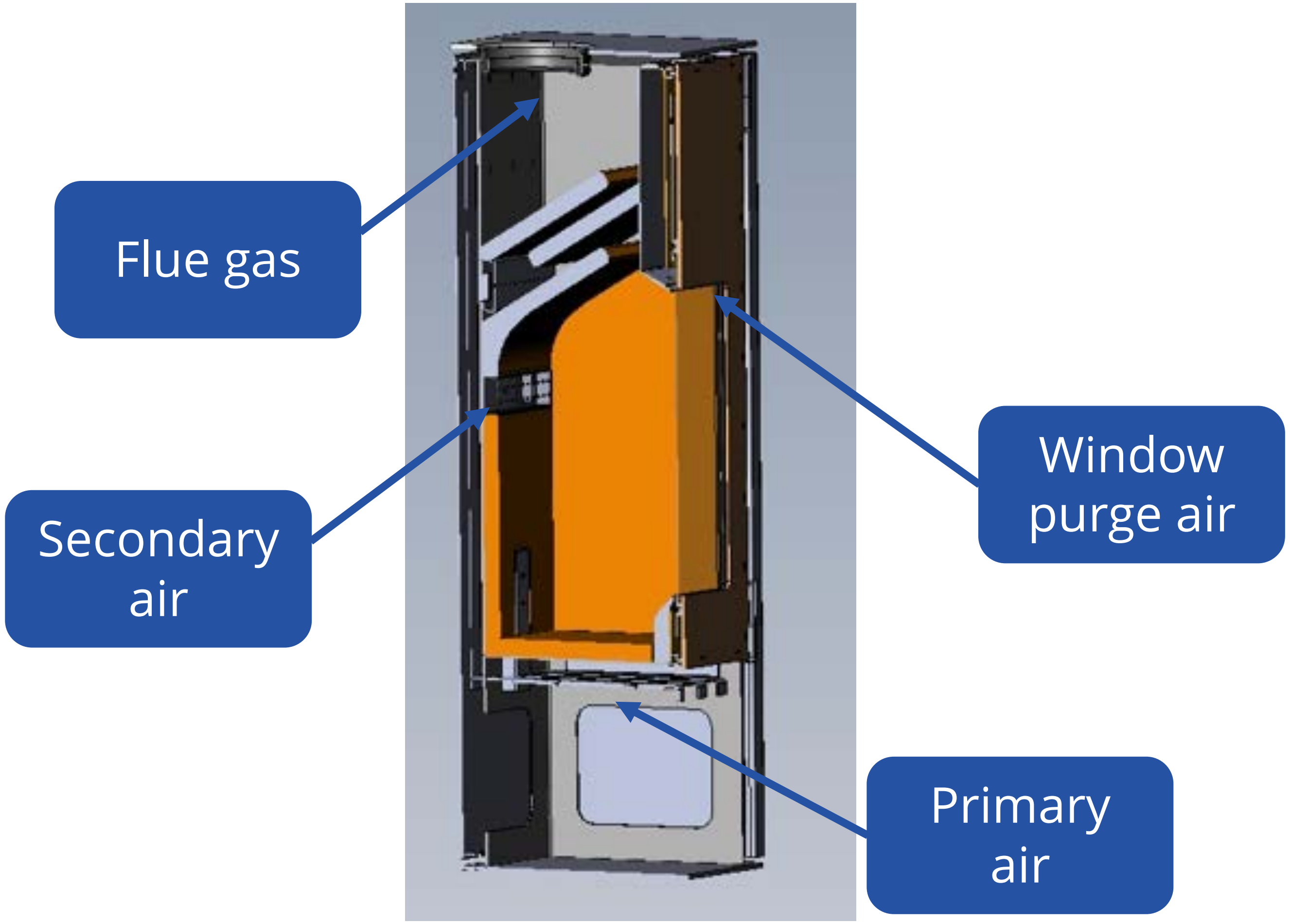
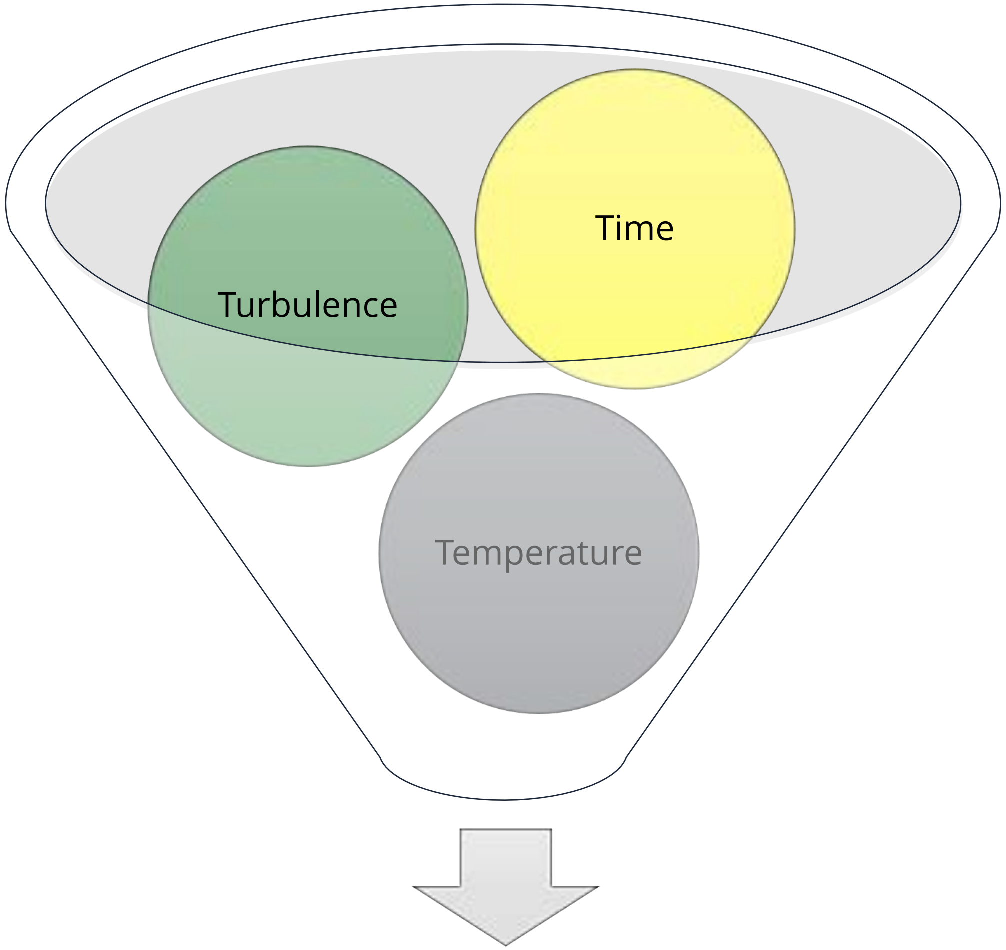
Definition of terminology regarding airflows



Source: Danish Technological Institute

Combustion chamber optimization

Source: Danish Technological Institute



Ecodesign or better

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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

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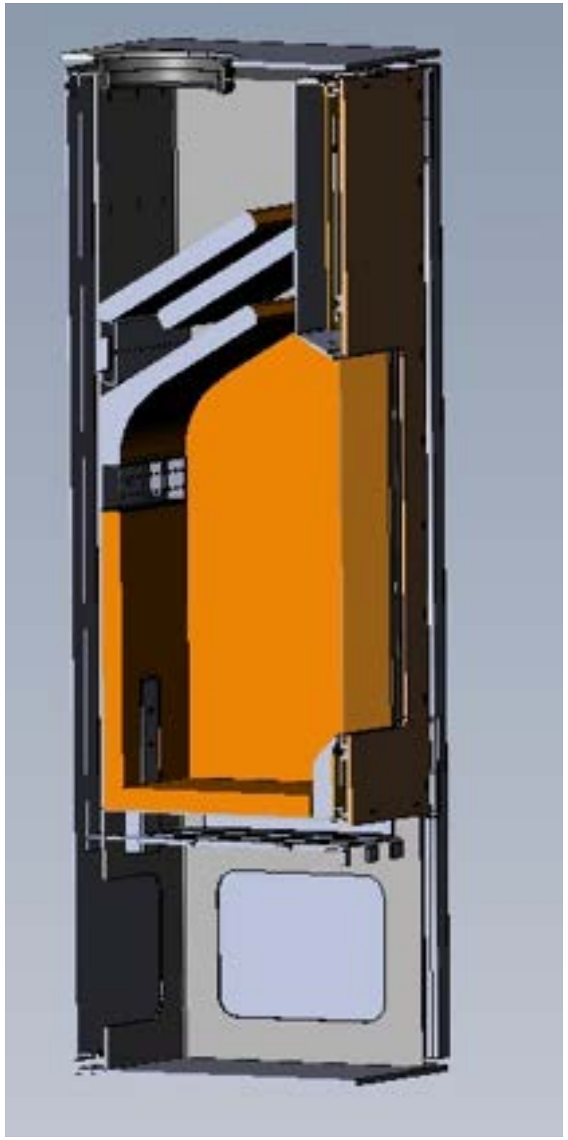
Residence time

- 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



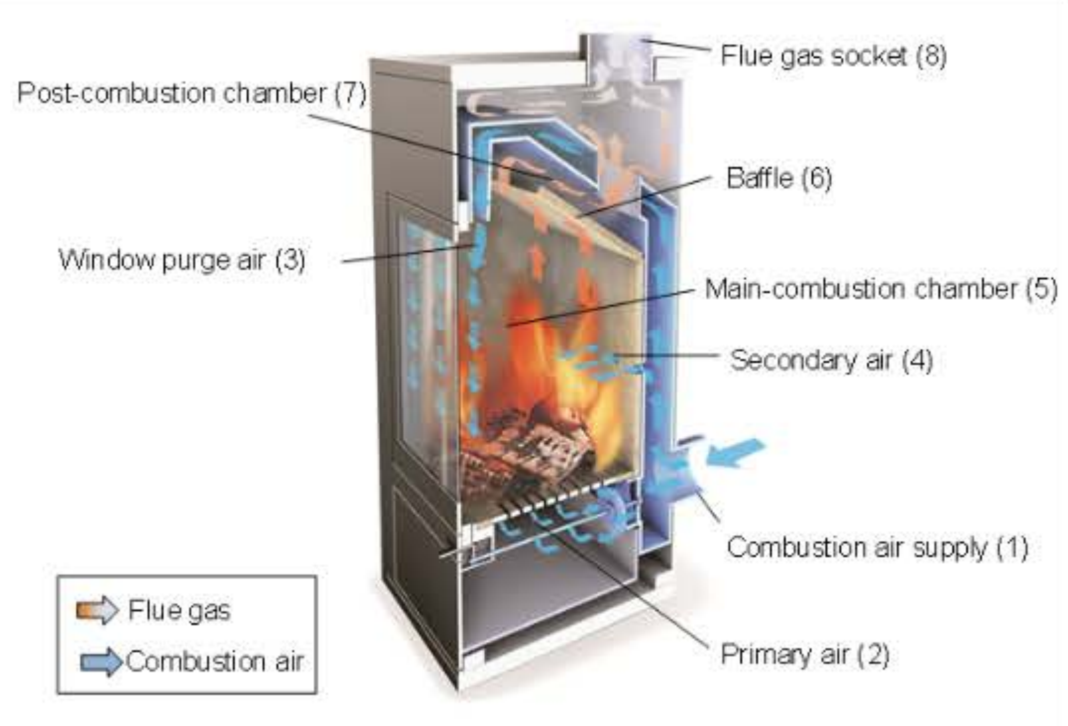
Source: Danish Technological Institute

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



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

- 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

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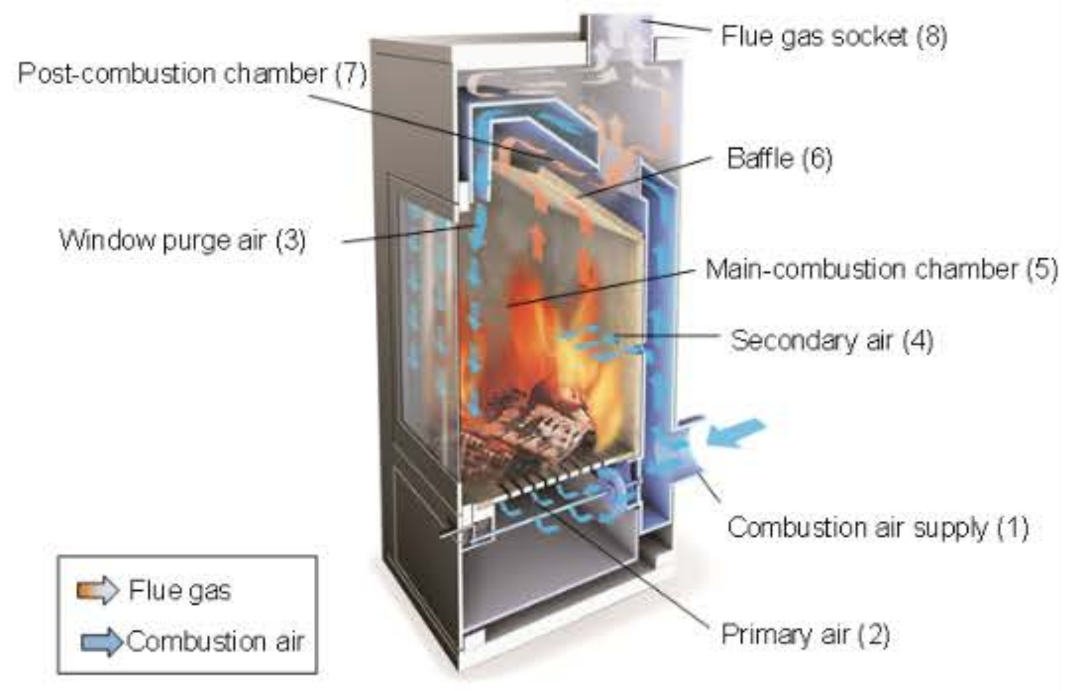
Air supply and air staging

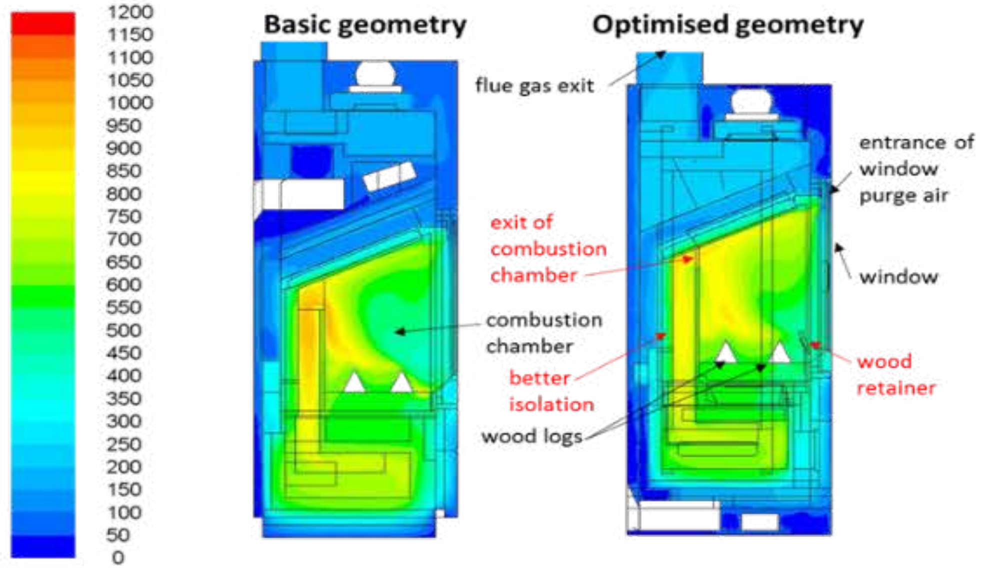


Source: http://www.tfz.bayern.de/mam/cms08/en/dateien/stoves2020-guidelines_low_emission_concepts.pdf

- 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

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

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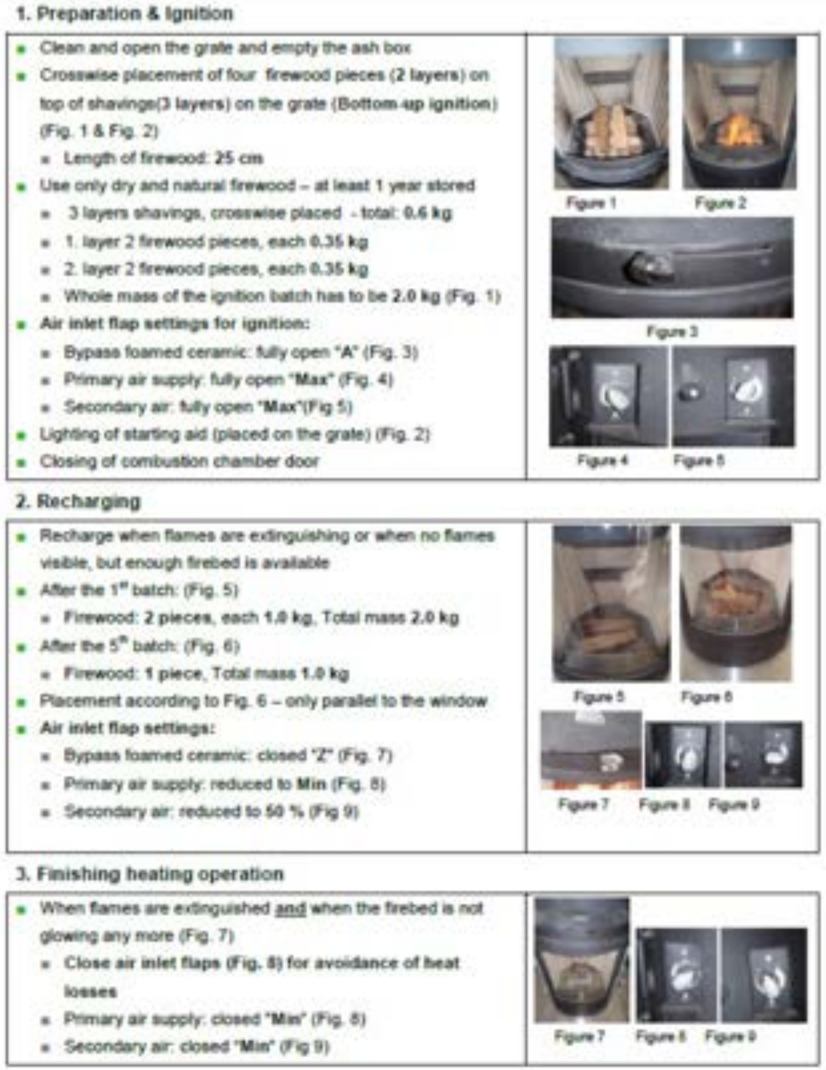
Reduced impact from user behavior

- 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

QUQ from BeReal project

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

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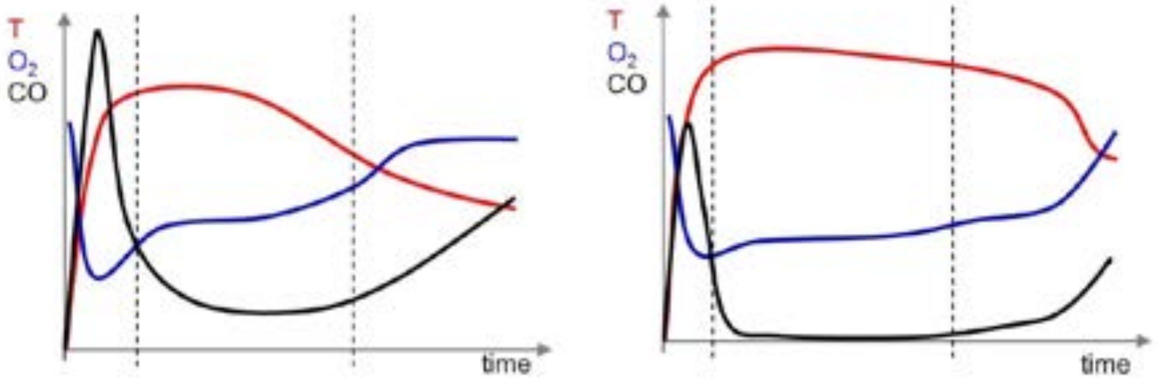
Automated Control Systems

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

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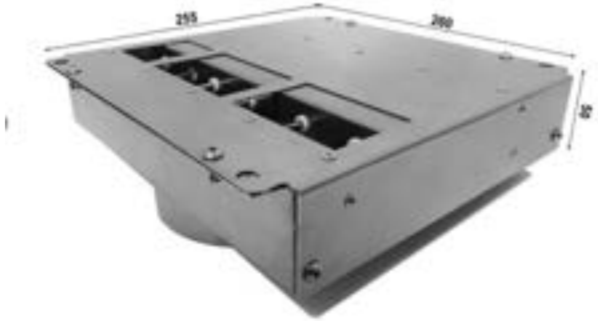
Types of Automated Control Systems

- 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

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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

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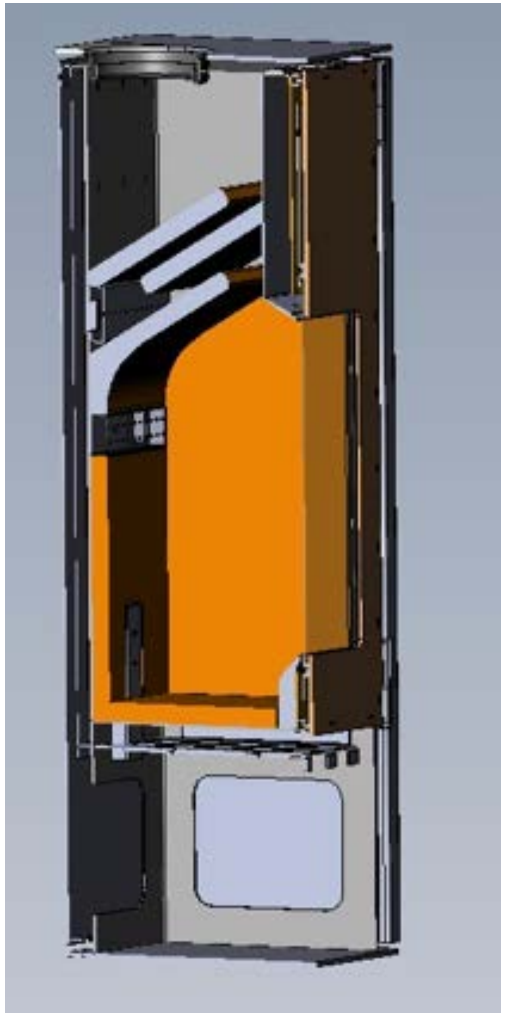
Summary

- 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



Source: Danish Technological Institute

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Final report

- Will be publised on
  - http://task32.ieabioenergy.com/

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Thank you

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