

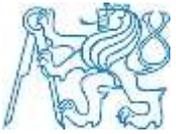


self-study

Biomass - combustion

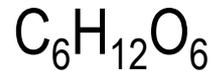
- combustion proces
- combustion equipment
- emission
- designing
- economy



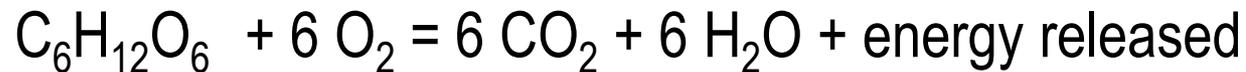


Direct combustion of phytomass

- combustion = oxidation



+ **energy released**





Direct combustion of phytomass

- **Phytomass ... high O₂ content**
 - lower calorific value *than fossil fuels* (=carbonization, hydrocarbons, high calorific value), phytomass: **higher fuel consumption, higher fuel volumes**
 - high **volatile** content (70-80% in dry matter), release at temperatures > 200 ° C **multistage combustion: gasification + combustion of gases**
 - large quantities of combustion **gases** = considerably longer flames, longer burning time: **greater space for burning gases**
 - Difficult **penetration** of combustion **air** into flames, increased need for air supply for combustion: : **Higher combustion air excess ratio λ**



Direct combustion of phytomass

- **Phytomass ... low ash content** (excluding stalks)



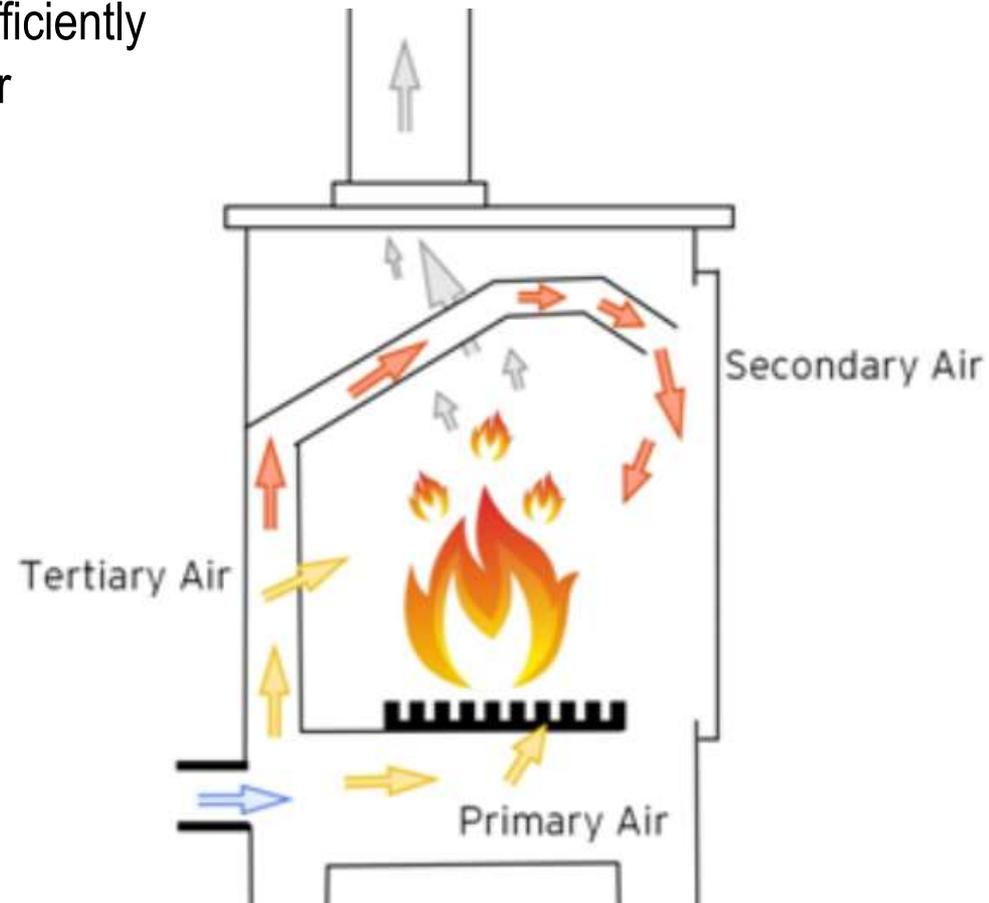


Combustion (fireplace stove)

Primary Air - comes in through the ash pan when you first start the stove
- going and up to operating temperature

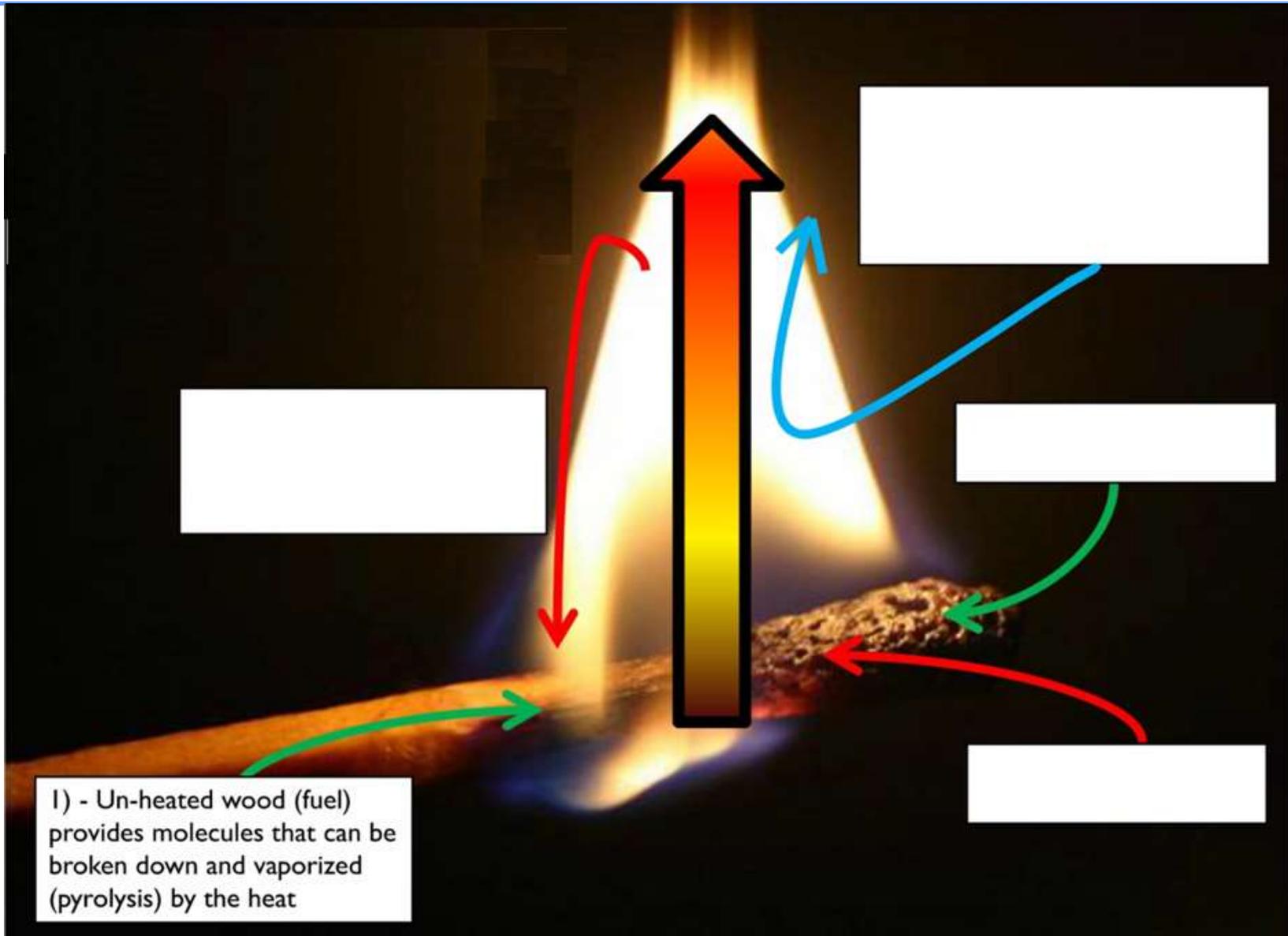
Secondary Air - pre heated air, enters the chamber around the top of door,
- after start up to keep the stove operating efficiently
- flushes down over the glass it keeps it clear

Tertiary Air - comes in through air bars
on the back of the stove,
- not controllable
- inject more oxygen/air into the chamber
- improve the efficiency ... the gases from the primary combustion are re-ignited for a cleaner and more efficient burn



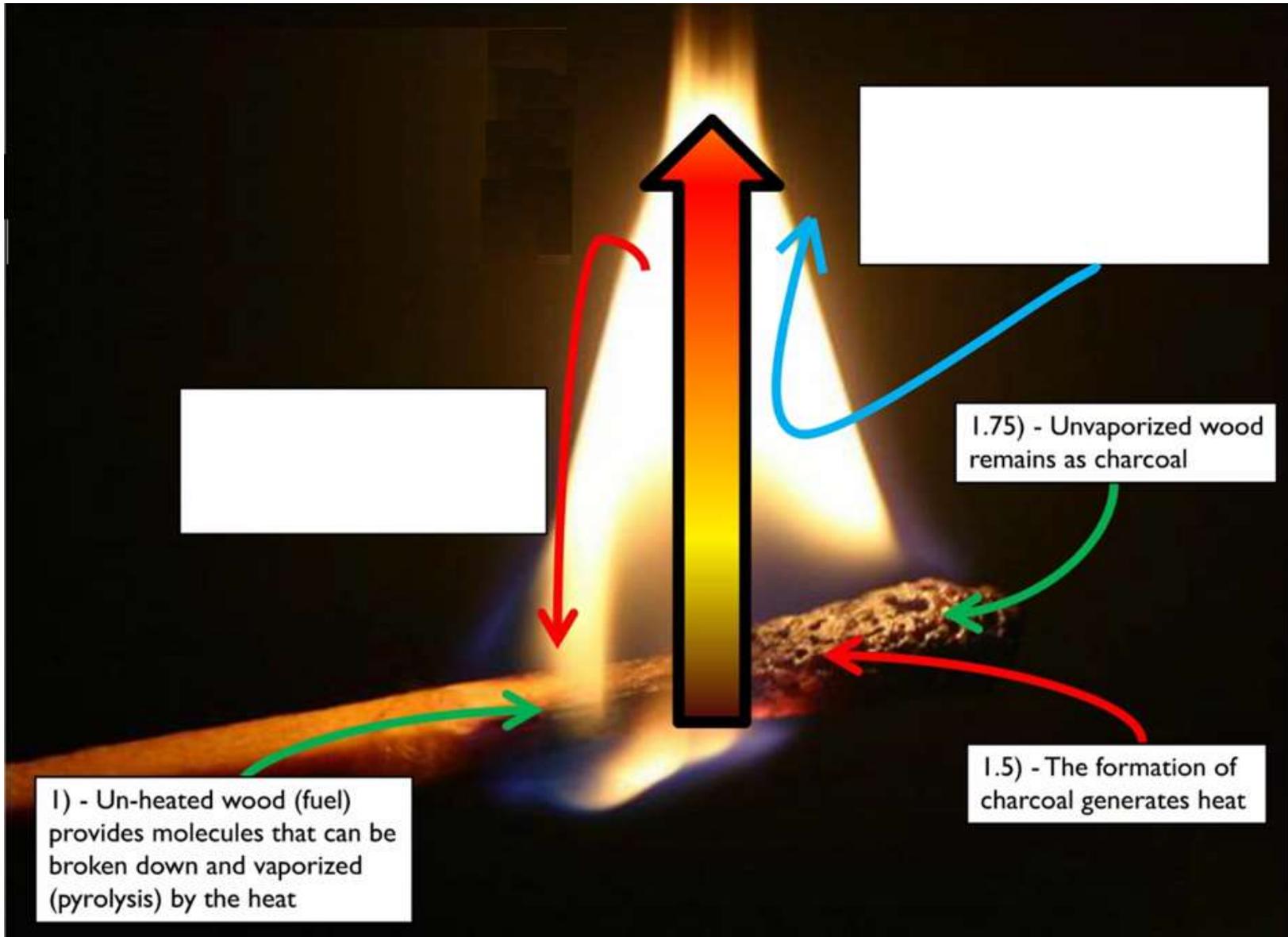


Combustion: stage I)



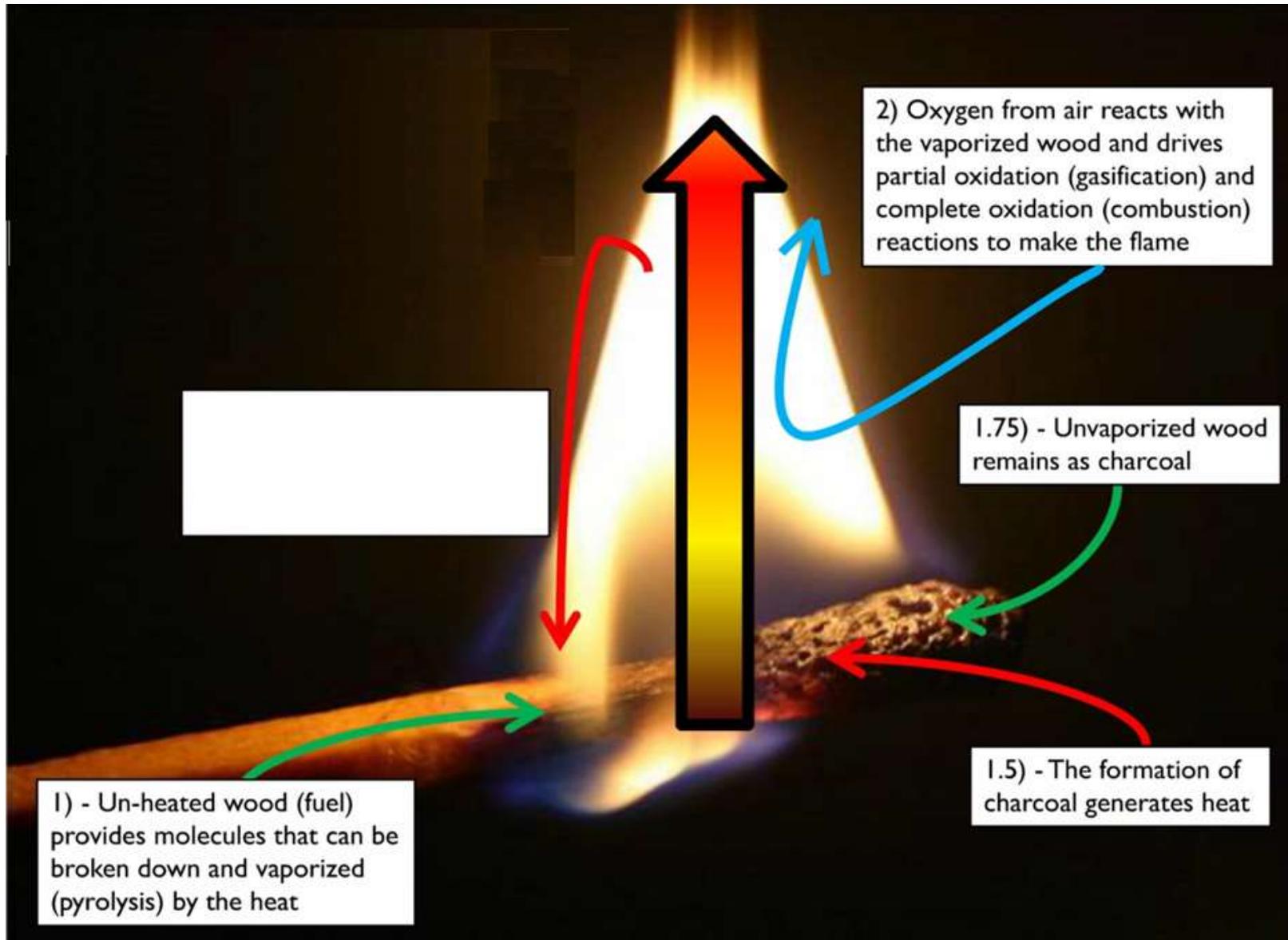


Combustion: stage I) ...



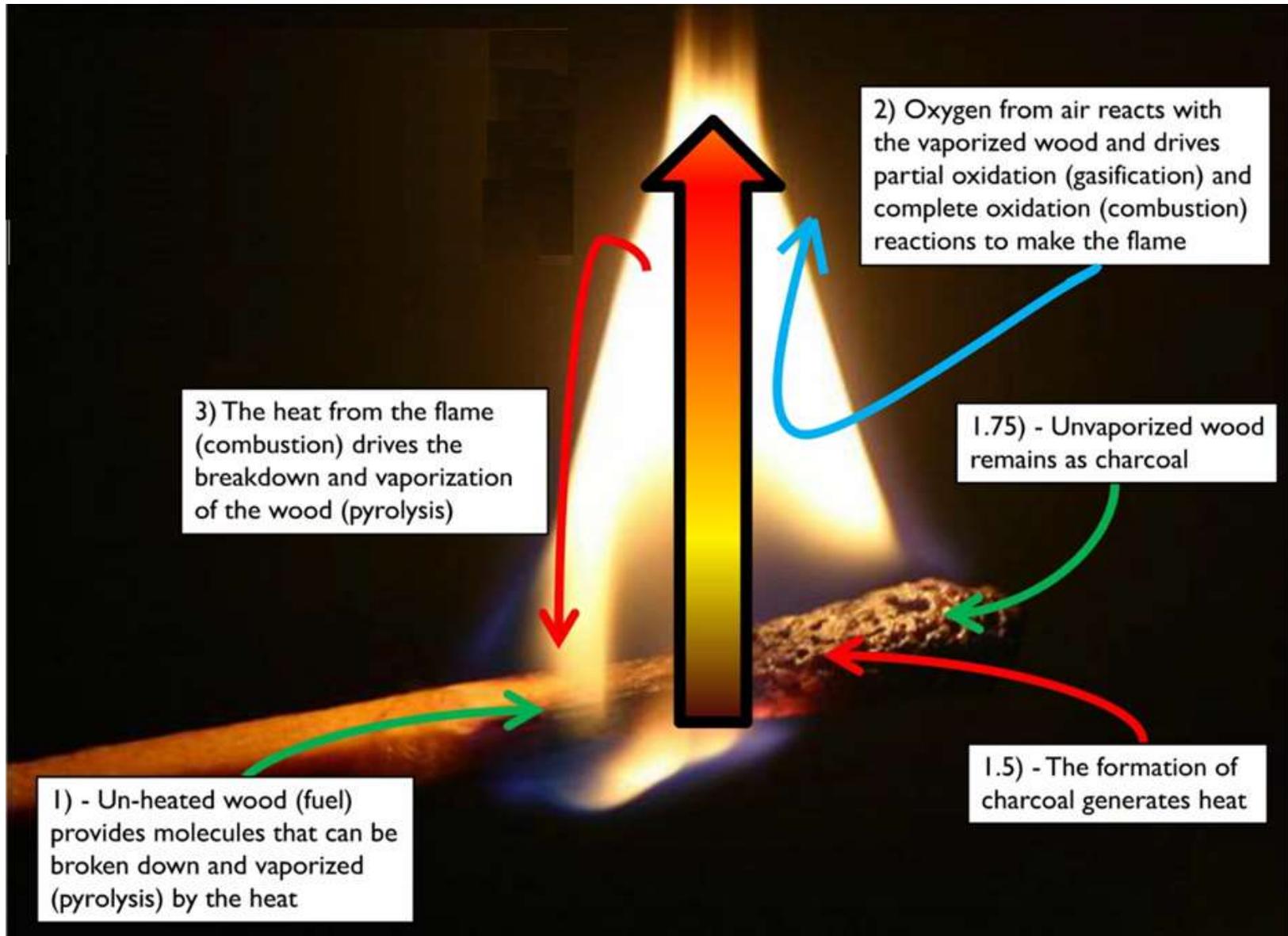


Combustion: stage 2)



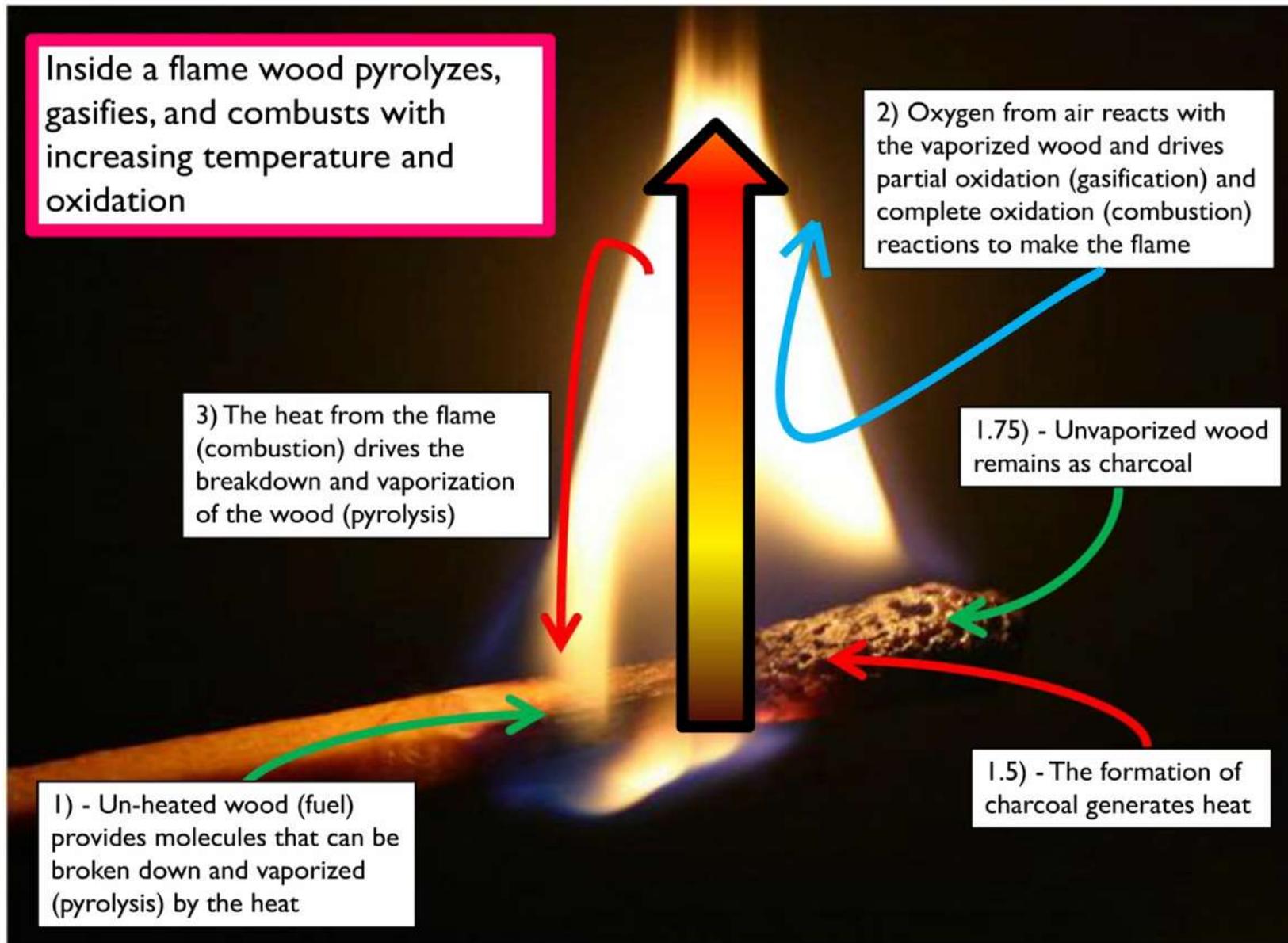


Combustion: stage 3)





Direct combustion of phytomass





Direct combustion of phytomass (endothermic)

1. **fuel heating (up to 100° C)**
 - heat from the burning fuel, increasing its temperature

2. **drying of fuel (100 to 150 ° C)**
 - evaporation of water bound in fuel, leaves as water vapor

3. **pyrolytic decomposition (150 - 230°C) - no oxygen access**
 - complex hydrocarbon chains degrade to simpler: gaseous hydrocarbons, CO
 - Pyrolytic decomposition **does not require the presence of oxygen**



Direct combustion of phytomass (exothermic)

4. dry gasification (230 to 500°C) - with oxygen access

- thermal decomposition of the fuel above the ignition temperature (230 ° C) in the furnace, oxygen supplied in **the primary combustion air**, releasing heat
- effects on solid and liquid products of pyrolysis (carbon, tar) - oxidation

5. solid carbon gasification (500 to 700°C)

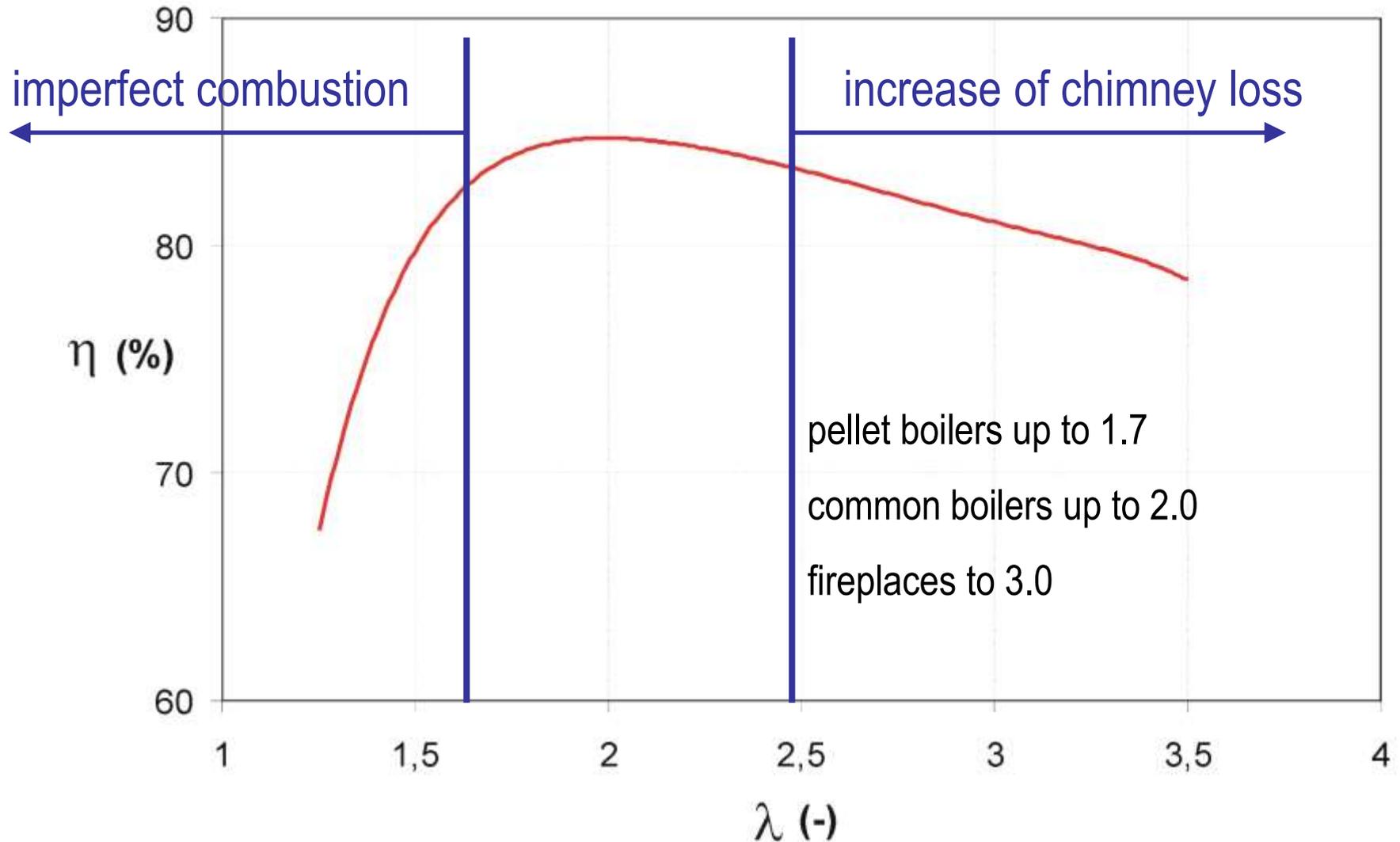
- with the contribution of CO_2 , H_2O , O_2 , combustible CO is formed: visible flame

6. oxidation of combustible gases (700 to 1400°C), optimum 900°C

- combustion of gases generated in the previous phases - supply **of secondary combustion air** for perfect combustion
- temperatures above 1200°C: load of the furnace and exchanger structure, **NOx formation**,



combustion air excess ratio λ





Combustion equipment - requirements

- simple operation and easy maintenance
 - fuel loading, ash removal
- high quality combustion, low emissions
 - CO , C_xH_y , NO_x
- high efficiency
- wide range of performance control while maintaining burning quality
- long life
- traffic safety
- low costs - investment, operational



Combustion equipment - types

- **small family-run facilities**
 - piece wood, briquettes - fireplaces, stoves, gasification boilers
 - pellets - automatic operation

- **middle appliances (schools, retirement homes, ...)**
 - necessary individual assessment: pellets x chips

- **large appliances (heating plants)**
 - hot water, steam boilers
 - possibility of combustion of lower quality fuels with a humidity above 30%, bulk material
 - the low price x the heat losses in the distribution system



Local Biomass Combustion (family houses)

- **open fireplaces**

- high combustion air consumption, low efficiency <20%



- **fireplace inserts**

- closed furnace, low temperature in the furnace
 - low efficiency <40%



- **stoves**

- stand-alone interior heaters
 - fans, storage pads, pellet burners
 - efficiency (for pellet stoves) up to 80%



- **tiled stove**

- accumulation mass in flue gas path, delayed heat transfer





Local Biomass Combustion (family houses)



wood
fireplace stove



pellet
fireplace stove



ceramic glazed tile accumulating
(ceramic glazed tile) stoves



Central biomass combustion device

(family houses)

- **classic solid fuel boilers (wood)**
- **gasifying boilers for piece wood**
- **automatic pellet boilers (chips)**



Central biomass combustion device

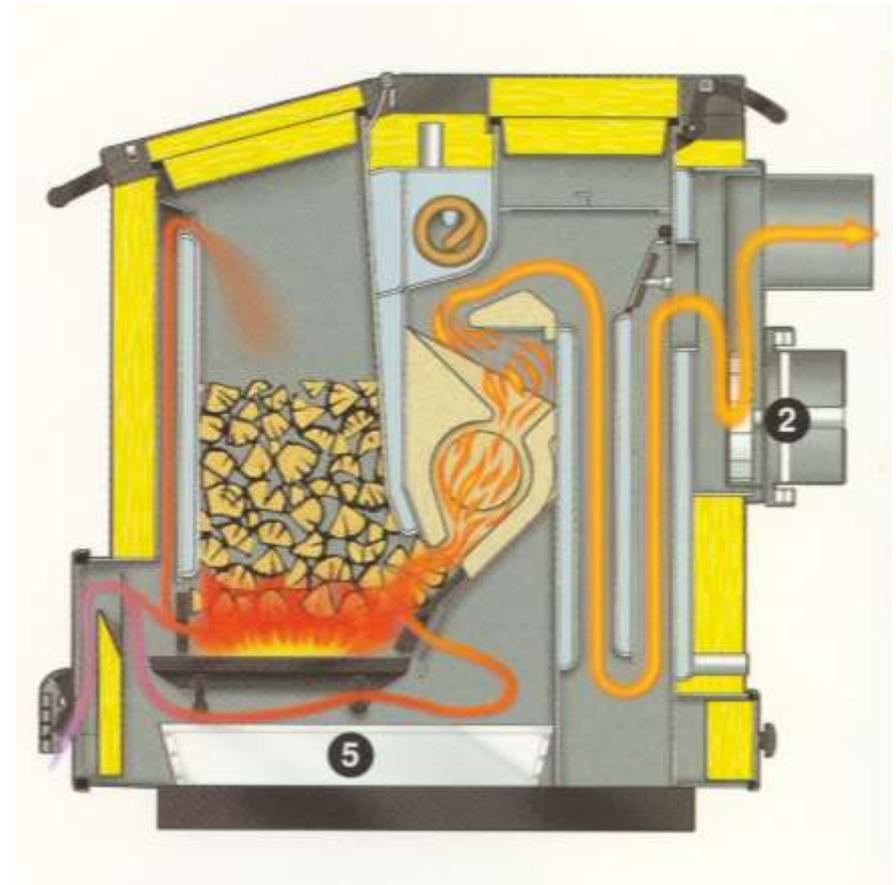
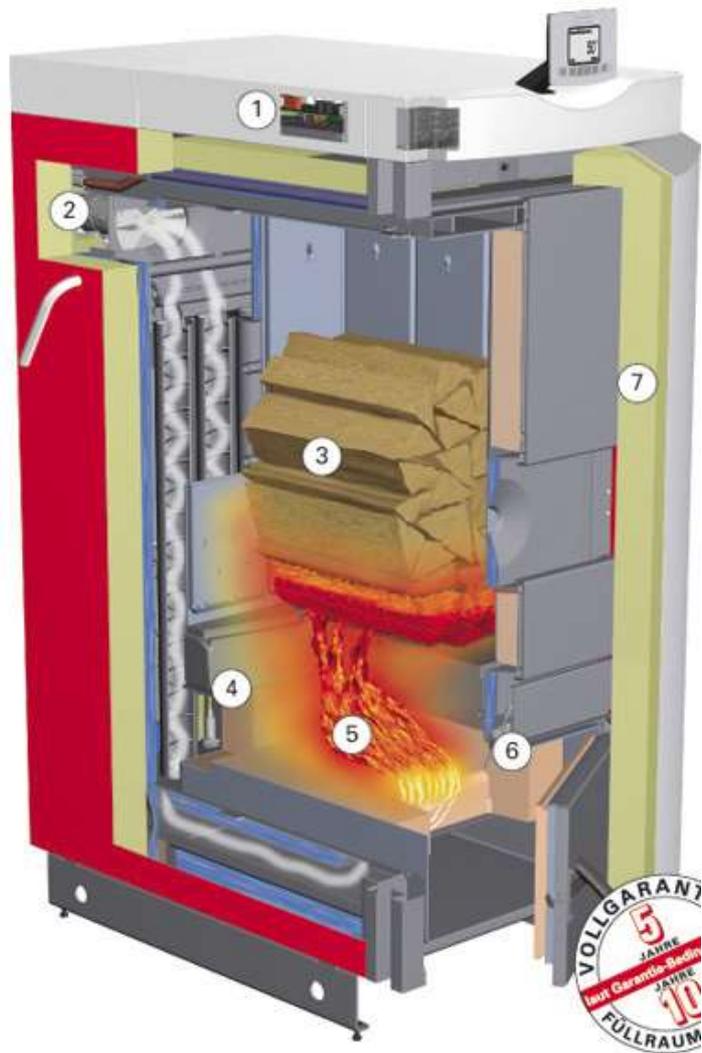
(family houses)

20/66

- **classic solid fuel boilers (wood)**
 - fuel burned directly in the furnace - burning on the grate
 - regulation with limited air supply, limited power control, efficiency 65 - 70%



classic solid fuel boilers (wood)



storage requirement
difficult regulation, emissions



Central biomass combustion device

22/66

(family houses)

- **gasifying boilers for piece wood**
 - gasification in the furnace, then combustion of gases in the combustion chamber
 - power regulation 50 - 100% (primary air supply), efficiency 80 - 90% (at nominal power)



Central biomass combustion device

23/66

(family houses)

- **automatic pellet boilers (chips)**
 - gasification in the furnace, combustion of gases in the combustion chamber
 - free operation, feeder, burner
 - power regulation 25 - 100%, efficiency 85 - 92% in the control range



automatic pellet boilers

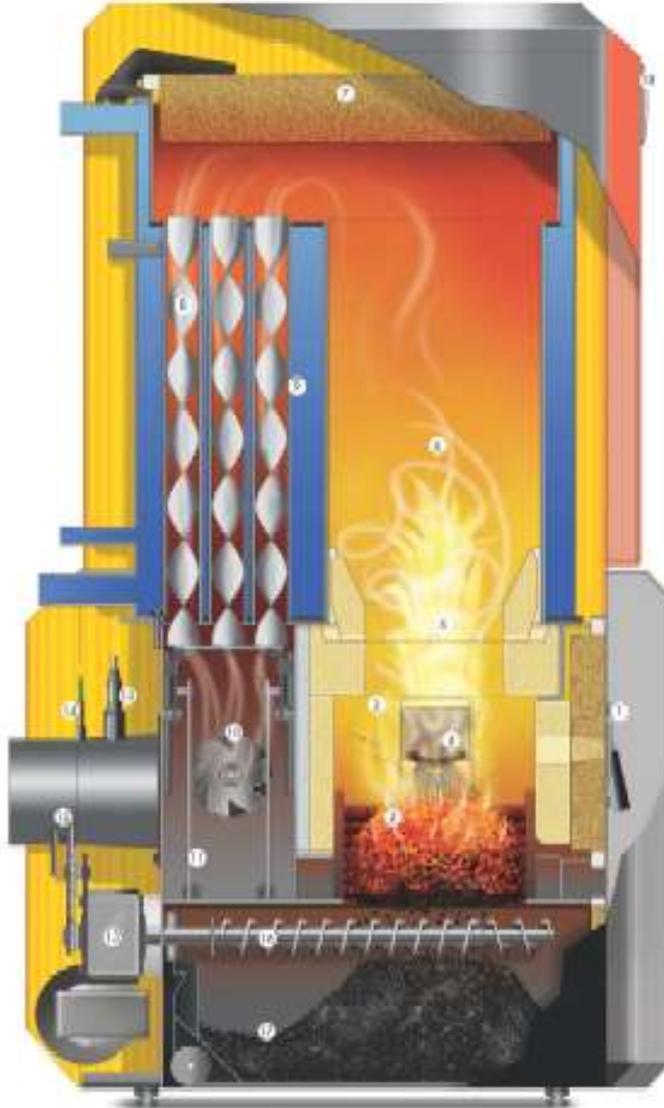


fuel tank
supply pellets from the top





automatic pellet boilers

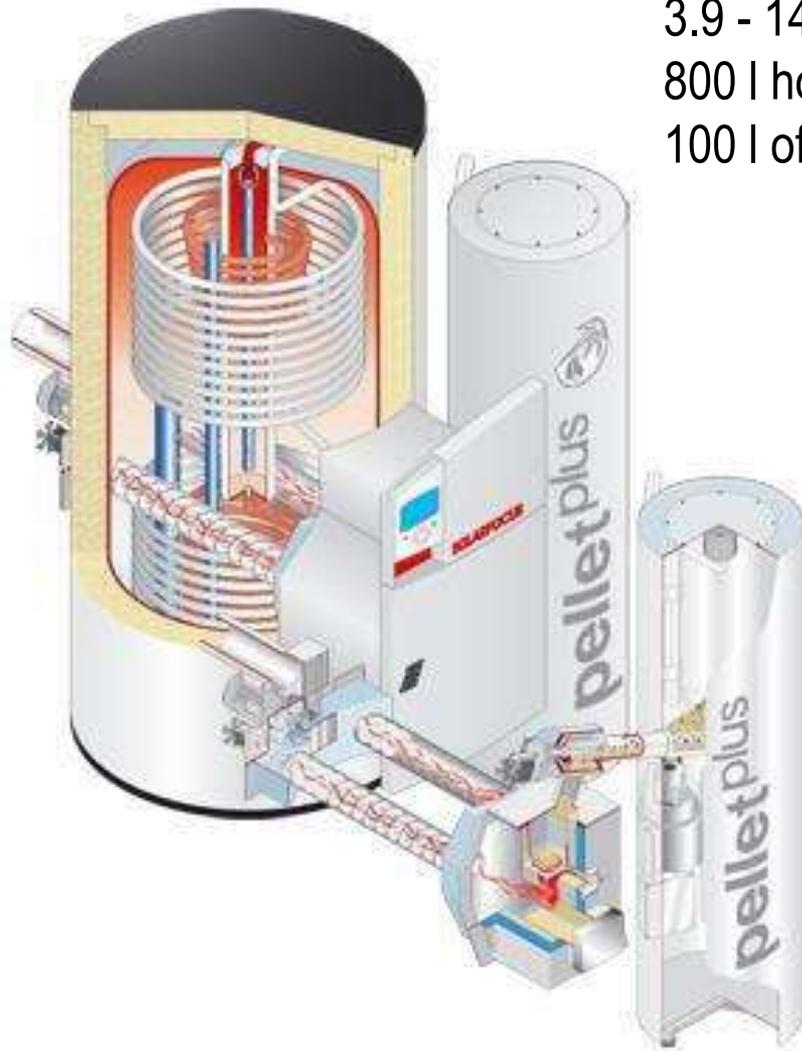


automatic fuel supply
automatic ash extraction





Integration of pellet burner in boiler



3.9 - 14 kW

800 l hot water container

100 l of pellets





Combustion equipment for chips



not suitable for small performances

storage,

drying

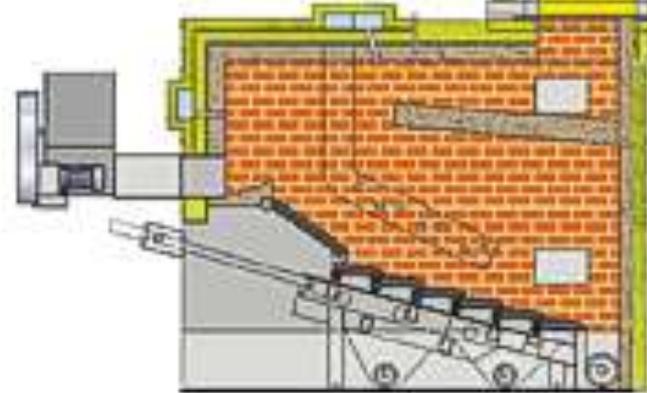
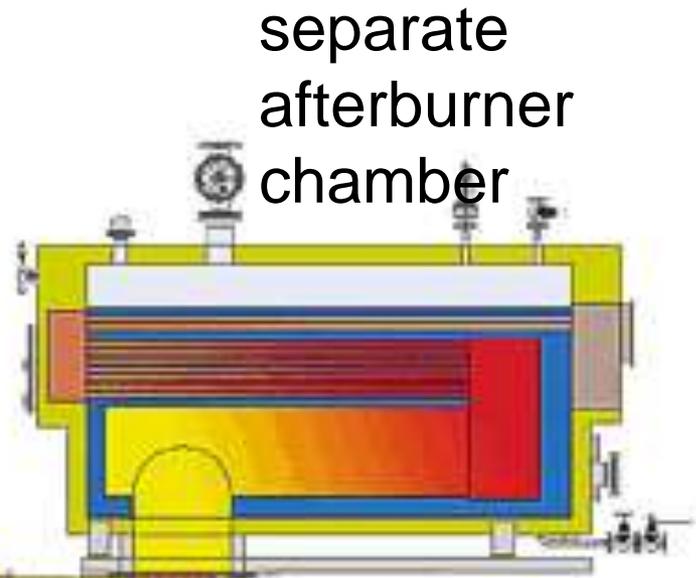
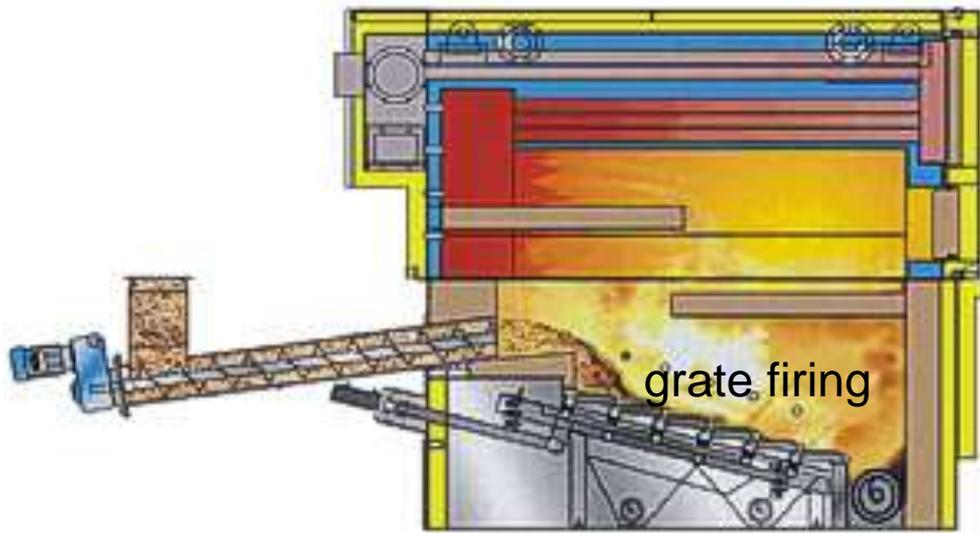


Biomass combustion devices (large appliances)

- **combustion on the grate (in the layer)**
 - fuel with high humidity > 40%, outputs up to 50 MW, efficiency up to 85%
 - multiple air supply (optimization), multistage combustion



Grate boilers for wood chips, sawdust up to 10 MW



Big combustion and afterburner chamber

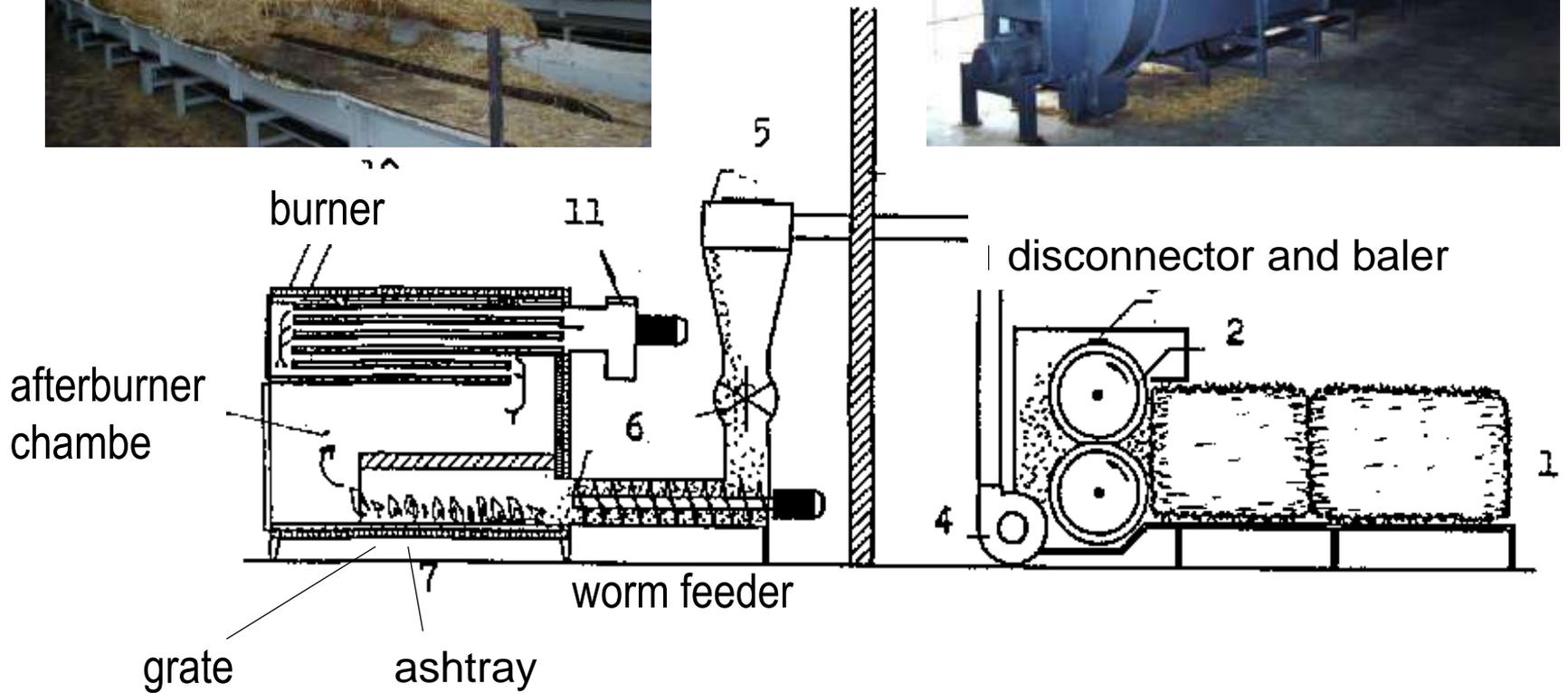
big accumulation – fireclay

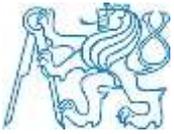
tertiary air

separate combustion chamber



Straw burning equipment





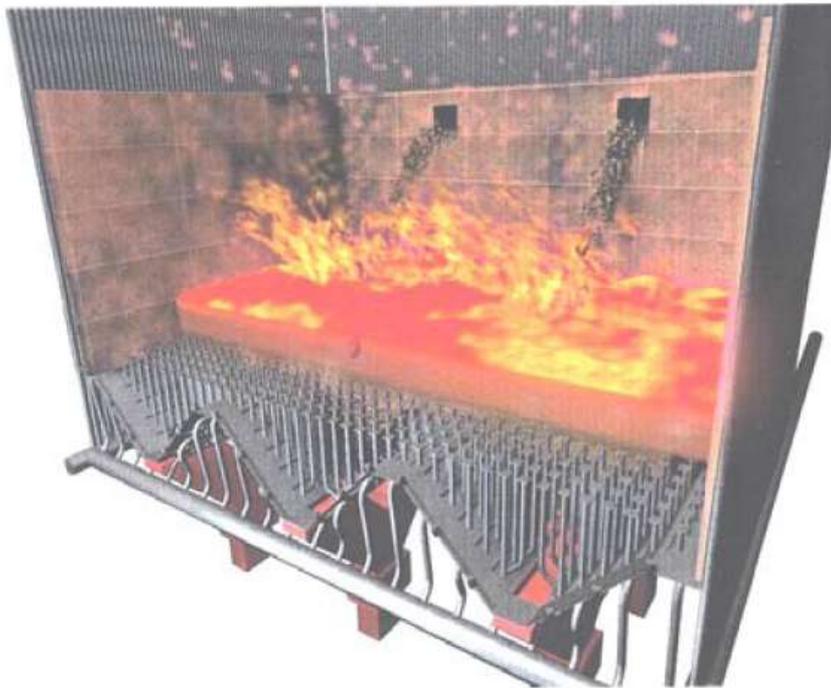
Biomass combustion devices (large appliances)

- **fluidized bed combustion**
 - uptake of fuel particles by flue gas and air, high heat transfer and substance, circulation layer, efficiency 85-88%
 - only 700 to 900 ° C, lower NO_x production, rapid combustion, wet biomass
 - cyclone separators



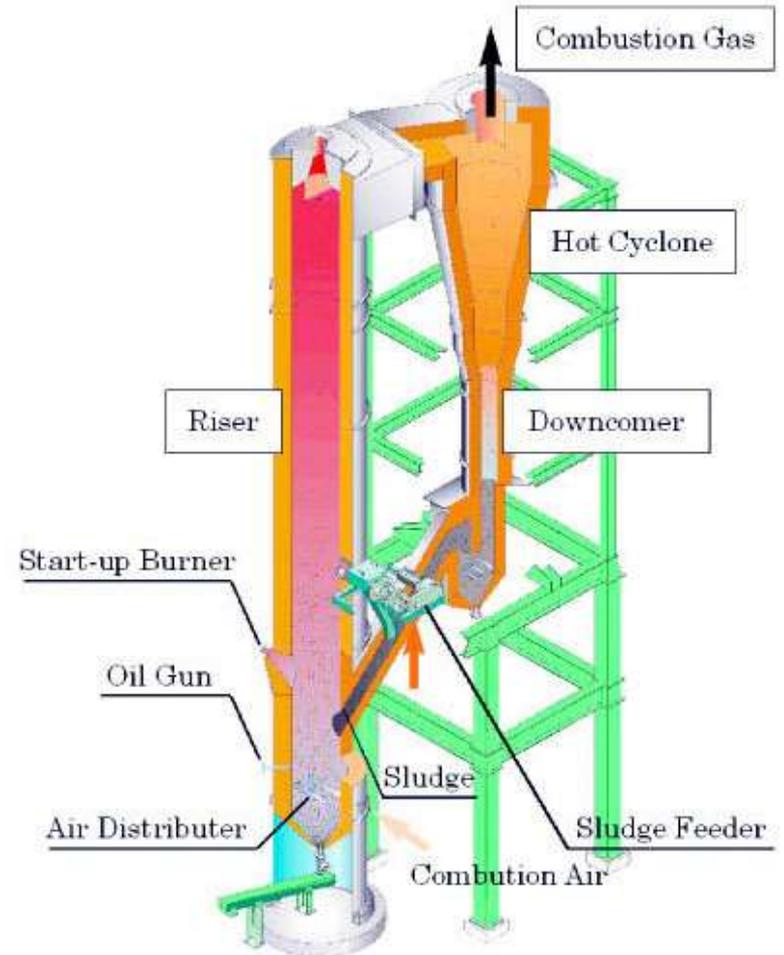
Fluidized bed boilers - fluidized bed combustion

stationary fluidized bed grate



smaller output boilers

circulating fluidized bed, cyclone



burning less valuable fuels



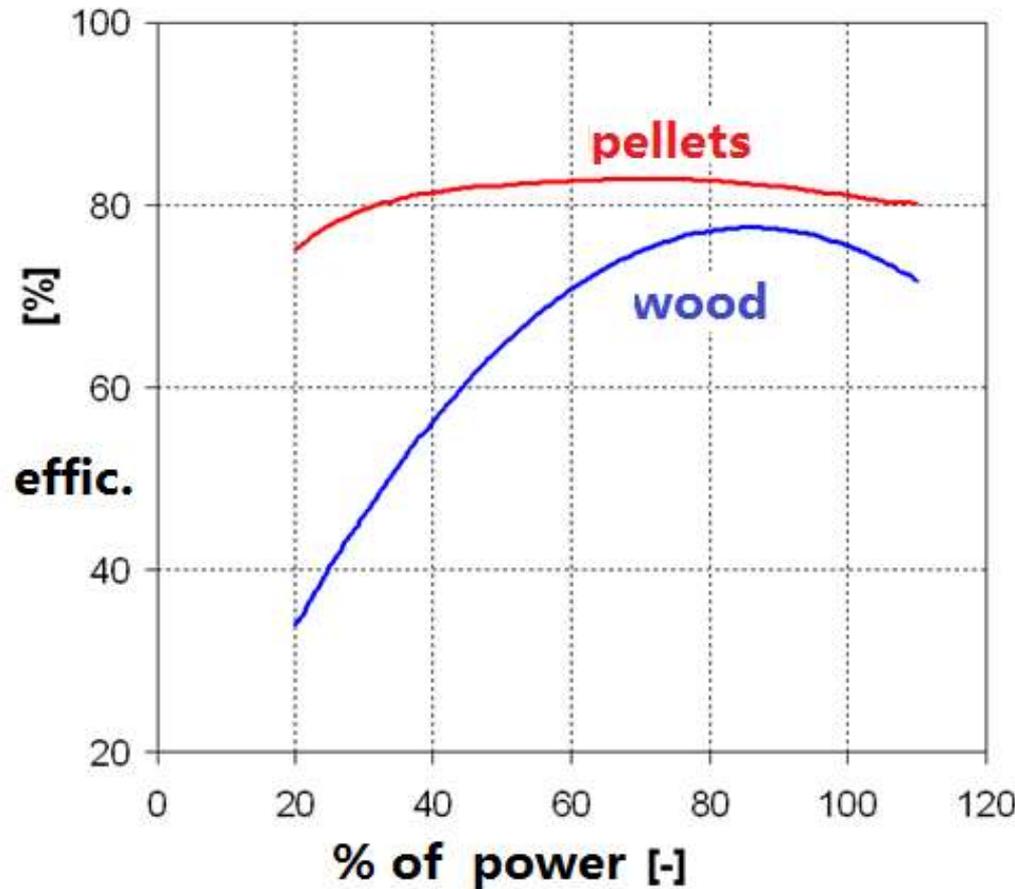
Efficiency x Power Regulation

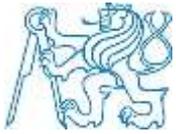
- **Power regulation by limiting the combustion air supply**

- manual stoking the boilers
- incomplete combustion
- CO emissions
- reduction in efficiency

- **Power regulation by limiting fuel supply**

- automatic boilers on pellets, chips





Principles of proper combustion of biomass

■ wood burning

- 2-3 degree: wood gasification + combustion of generated gases (wood gas)
- furnace **gasification**, partial air supply (primary air), > 200°C
- **combustion** in post-combustion (afterburner) chamber, air supply (secondary, eventually tertiary)
- heat transfer for further use (exchanger), flue gas temperature 150°C (chimney loss x chimney draft)

■ requirements for efficient combustion

- sufficient air supply (excess air $I = 1.5$ to 2.5)
- low fuel humidity (10 to 20%)
- sufficiently high combustion temperatures (800 to 900 ° C)
- stability of temperature conditions in boiler (accumulation lining, low heat loss)
- stability of pressure conditions in boiler (suitable dimensioning of flue gas path)
- constant operating conditions



Poor combustion

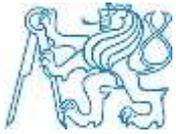
- **non-compliance with proper combustion principles**
 - biofuel with inappropriate properties (high humidity)
 - inappropriate device (eg coal-fired boiler used for wood burning) without power control
- **result**
 - low efficiency
 - short boiler life
 - high pollutant emissions





Phytomass combustion emissions

- **carbon dioxide (CO₂)**
 - neutral balance, optimal combustion: CO₂ content about 12%
- **nitrogen oxides (NO_x)**
 - nitrogen content in phytomass 0.1 to 0.5% (for comparison: coal has 1.4%)
 - oxidation of nitrogen in combustion air dependent on combustion temperature (keep up to 1200°C !)
- **solid particles (dust)**
 - ash, unburned soot - depends mainly on fuel humidity
 - the ash: content of wood is a small,
significant component in straw



Phytomass combustion emissions

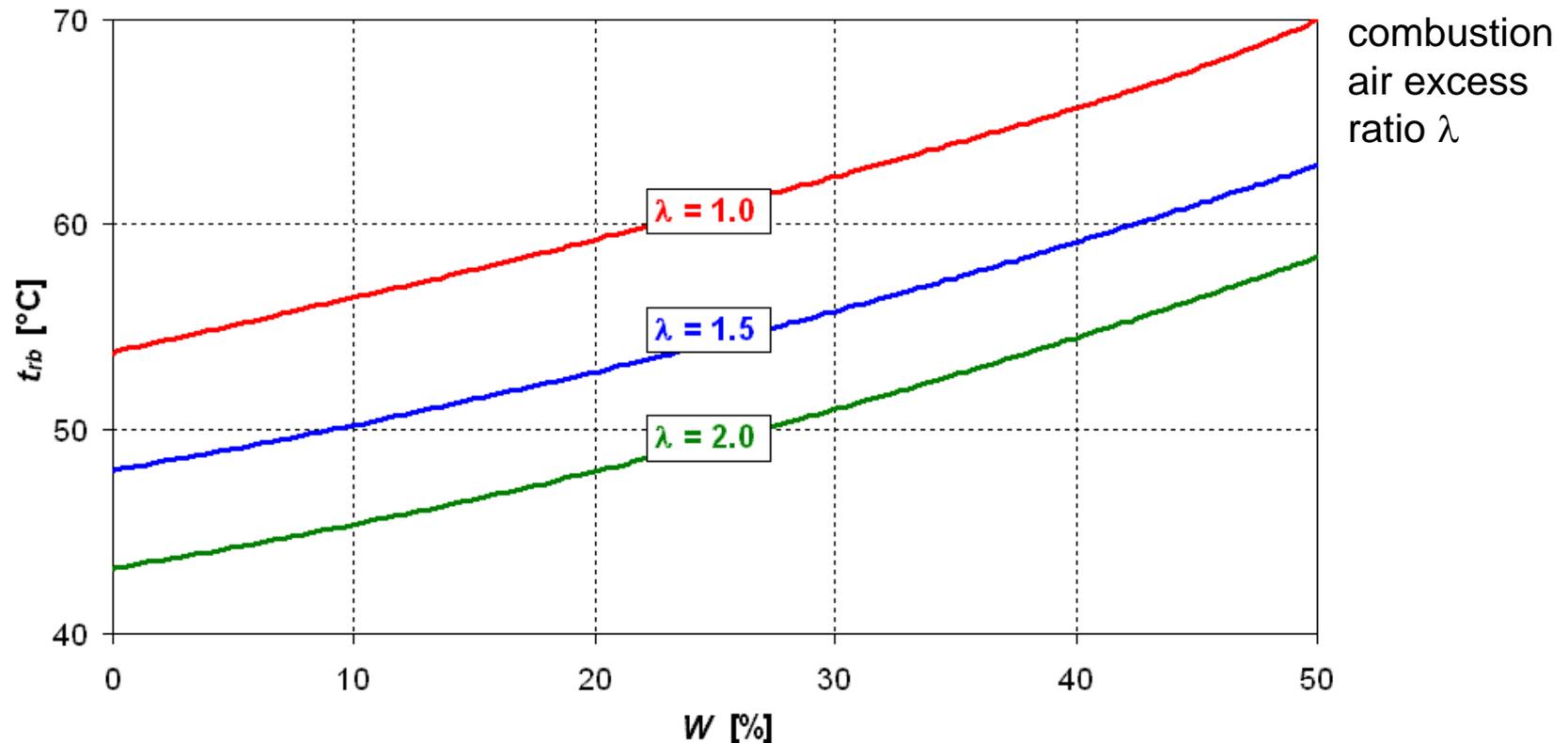
- **carbon monoxide (CO)**
 - product of incomplete combustion, wet fuel, insufficient air supply
 - CO is rich in energy ... high CO content in flue gas = low efficiency
 - combustion quality indicator, recommended: concentration CO below 0.1%
- **hydrocarbons (C_xH_y)**
 - due to pyrolytic decomposition
 - especially when start firing (below 600 °C), manifested by smoke
- **sulfur oxides (SO_x)**
 - very small amount in straw 0.1% (for comparison: browncoal has 1%)



Principles of connection of boilers to systems

- **flue gas dew point (condensation)**

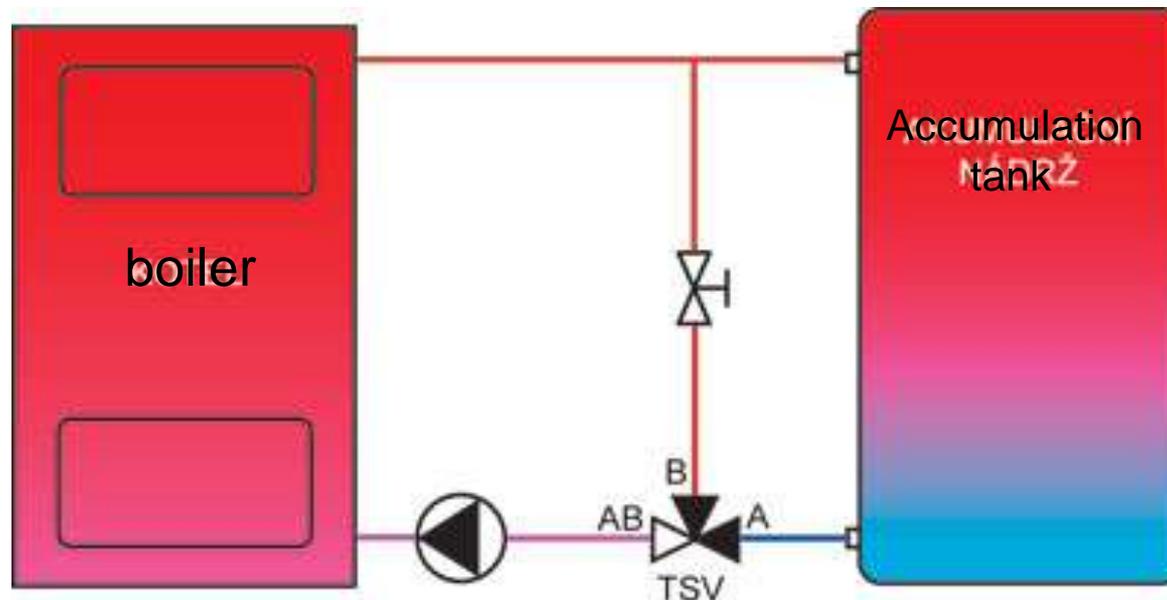
- flue gas condensation, flue gas dew point temperature $t_{rb} = 50$ to 60 °C
- aggressive condensate, **corrosion of boiler**





Principles of connection of boilers to systems

- **three-way thermostatic mixing valve**
 - boiler inlet water temperature $> 65^{\circ}\text{C}$
 - preheating the return water to the boiler
 - fireplace (high combustion air excess): no protection required, low dew point



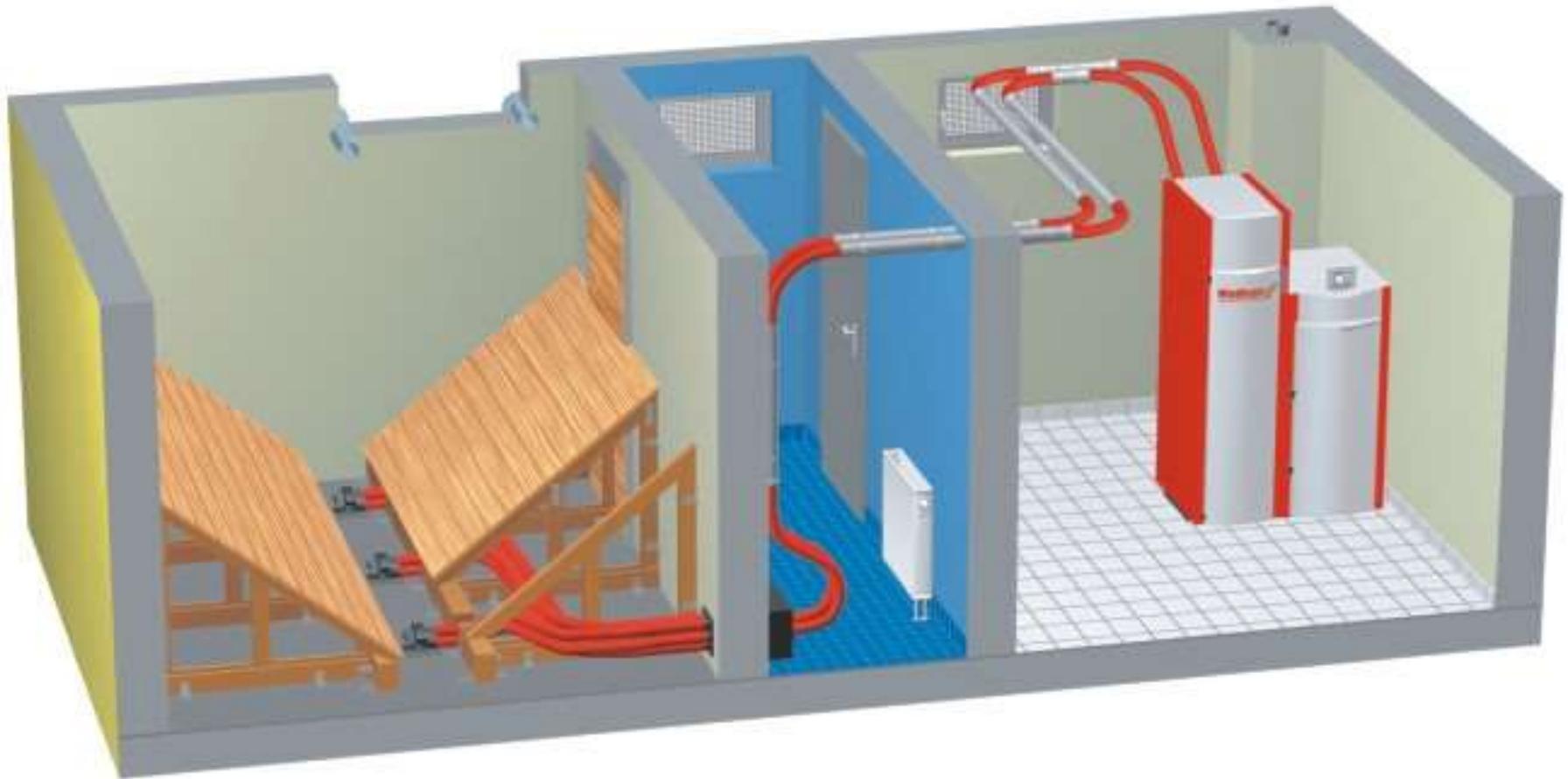


Fuel tank





Pellet storage facilities



pneumatic fuel transport, suction head in the warehouse, emergency tank at the boiler with filling sensor



Pellet storage facilities





Chips storage facilities





Chips storage facilities



worm feeder from the cointainer



Chips storage facilities

