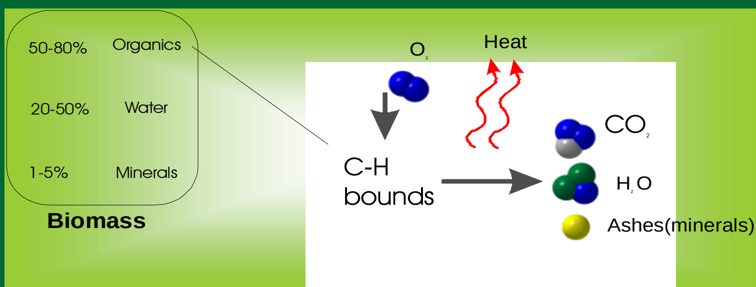
Module 2e

Combustion

Combustion basics

> Fuel Characteristics:
- Ash content
- Volatile matter content
- Elemental composition
- Calorific value
- Moisture content
- Bulk density
- Ash properties
- Combustion conditions
- Fouling



Combustion theory

> Combustion stages
  - Drying
  - Size reduction
  - Devolatilization
  - Combusiton of volatiles
  - Combusiton of char

> Capacity of the fire
  - the amount of heat released from a unit of fuel per unit of time

> When heating water, combustion efficiency is defined as:
  - heat absorbed by the water divided by the heat released during combustion

Process parameters

> Particle size (pretreatment)

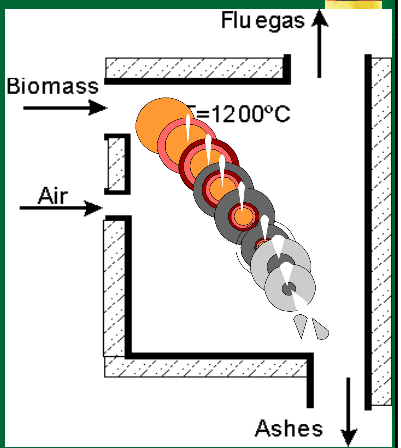
> Moisture content (pretreatment)

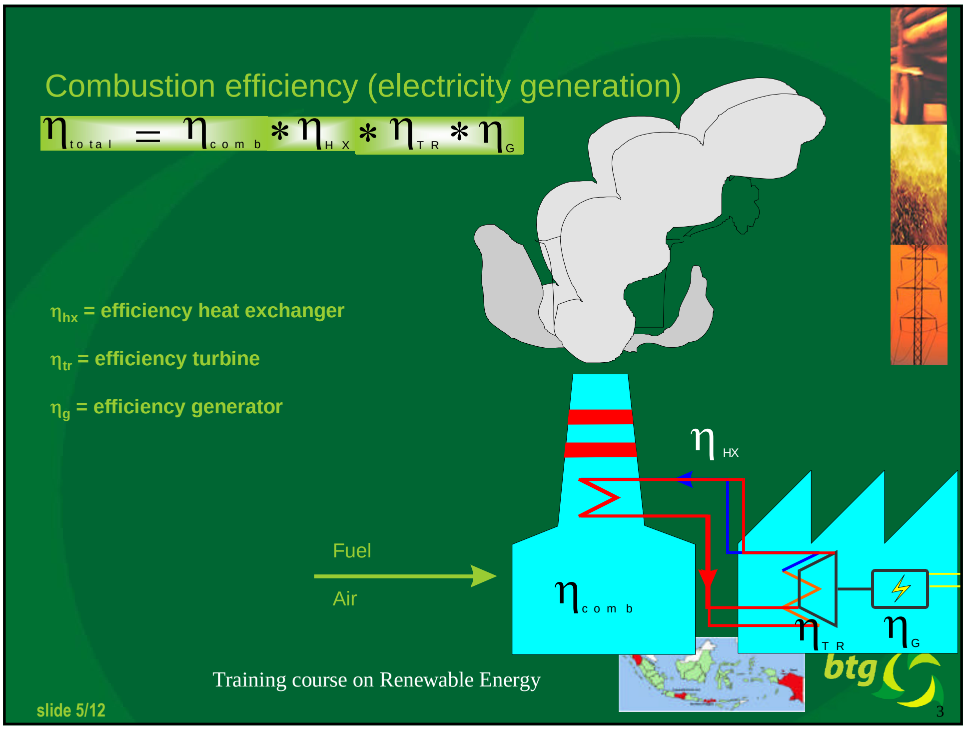
> Lambda (air/fuel ratio)

> Residence time in the furnace (distribution)

> Temperature (and heat distribution)

> Mixing / turbulence




Combustion efficiency (electricity generation)
$\eta_{total} = \eta_{comb} * \eta_{HX} * \eta_{TR} * \eta_{G}$
η_{hx} = efficiency heat exchanger
η_{tr} = efficiency turbine
η_{g} = efficiency generator
η_{HX}
Fuel
Air
η_{comb}
η_{TR}
η_{G}
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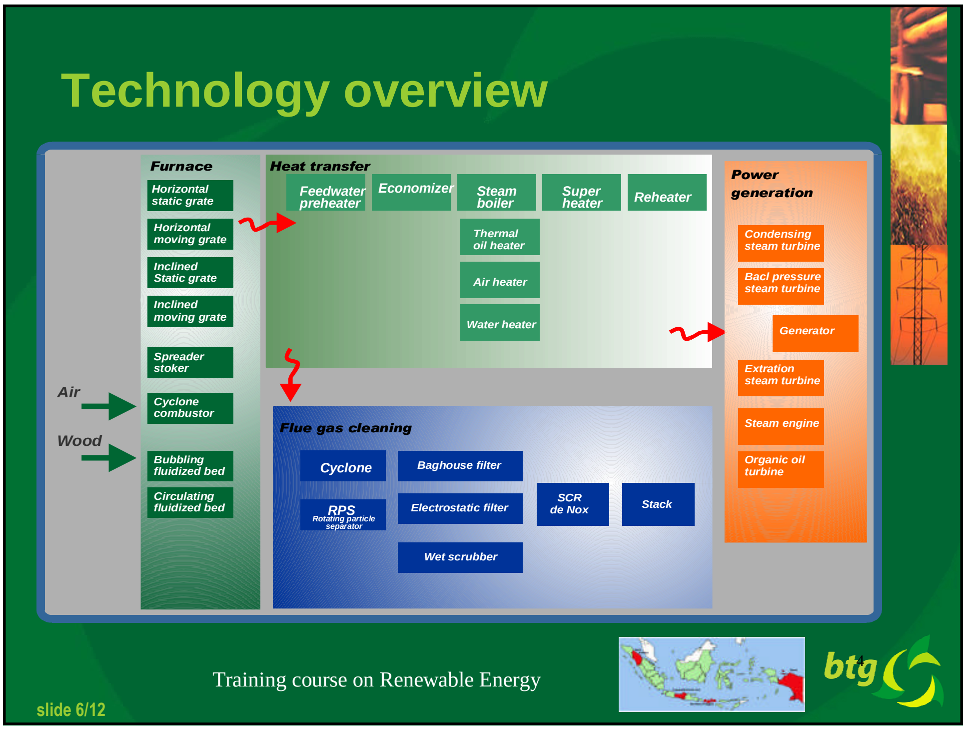
slide 5/12
3


Technology overview
Furnace
Horizontal static grate
Horizontal moving grate
Inclined Static grate
Inclined moving grate
Spreader stoker
Cyclone combustor
Bubbling fluidized bed
Circulating fluidized bed
Air
Wood
Heat transfer
Feedwater preheater
Economizer
Steam boiler
Super heater
Reheater
Thermal oil heater
Air heater
Water heater
Flue gas cleaning
Cyclone
Baghouse filter
RPS Rotating particle separator
Electrostatic filter
SCR de Nox
Stack
Wet scrubber
Power generation
Condensing steam turbine
Bacl pressure steam turbine
Generator
Extration steam turbine
Steam engine
Organic oil turbine
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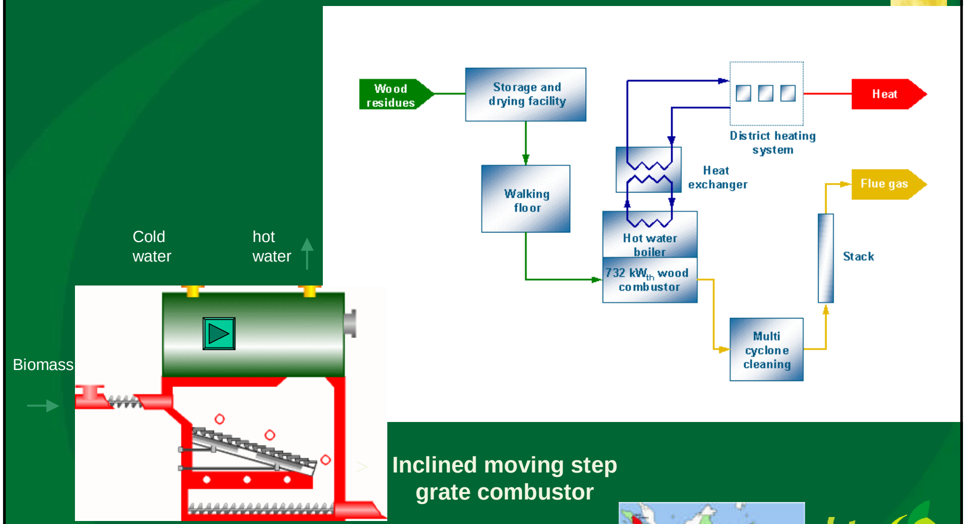
Example: system lay-out of 730 kWth biomass heat boiler in Hostetin, Czech Republic



Inclined moving step grate combustor

What is the amount of air needed for combustion of 1 kg dry (moisture content is 0 %) rice husk, given that:

- excess air factor = 1.6
- ultimate analysis:
  - C = 0.404 kg/kg fuel
  - H = 0.055 kg/kg fuel
  - O = 0.343 kg/kg fuel
  - ash = 0.198 kg/kg fuel
- proximate analysis:
  - charcoal = 0.161 kg/kg fuel
  - volatiles = 0.641 kg/kg fuel
  - ash = 0.198 kg/kg fuel
- composition of air by volume:
  - 21 % O_2
  - 79 % N_2
- composition of air by weight:
  - 23.3 % O_2
  - 76.7 % N_2

Primary air: 1 mol C + 1 mol O_2 = 1 mol CO_2

Amount of oxygen needed

$$0.161 \times \frac{32}{12} = 0.429 \quad kg \quad O_2$$

Stoichiometric amount of air needed

$$0.161 \times \frac{32}{12} \times \frac{100.0}{23.3} = 1.843 \quad kg \quad air$$

Including excess air factor:

$$1.6 \times 0.161 \times \frac{32}{12} \times \frac{100.0}{23.3} = 2.948 \quad kg \quad air$$

btg 8

Secondary air:

- burning volatiles above the fuel bed (1st reaction)
- burning of charcoal in the fuel bed (2nd reaction)

1st reaction: 2 mol H_2 + 1 mol O_2 = 2 mol H_2O (CO is neglected)

Amount of oxygen needed: $0.055 \times \frac{32}{4} = 0.44 \quad kg \quad O_2$

Oxygen present in biomass also takes part at combustion, therefore oxygen needed from the air:

$$0.44 - 0.343 = 0.097 \quad kg \quad O_2$$

Stoichiometric amount of air needed: $\frac{100.0}{23.3} \times 0.097 = 0.416 \quad kg \quad air$

Including excess air factor: $1.6 \times 0.416 = 0.666 \quad kg \quad air$

btg 9

2e reaction: 1 mol C + 1 mol O_2

total amount of air needed:

$$1.6 \times (0.404 - 0.161) \times \frac{32}{12} \times \frac{100.0}{23.3} = 4.450 \quad kg \quad air$$

So total secondary air needed:

$$0.666 + 4.450 = 5.115 \quad kg \quad air$$

The combustion products then become:

- CO2: 1.481 kg
- O2: 0.704 kg
- H2O: 0.495 kg
- N2: 6.185 kg