Co-firing Biomass with Coal for Power Generation

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Power Generation

Coal

Used extensively to generate electricity and process heat for industrial applications.

Poses significant world environmental problems:

global warming (CO_2)

acid gases (NO_x and SO_2)

Presentation Objectives

1) What is co-combustion of biomass?
2) Which technologies we can use?
3) What generally fuel is and its problem?
4) Why we shod use – or not, co-combustion of biomass ?

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Power Generation

Biomass: as a fuel source.

Steadily increasing

- Biomass fuels are CO_2-neutral, hence reduce global warming effects.
- The sulphur and nitrogen contents are often lower.

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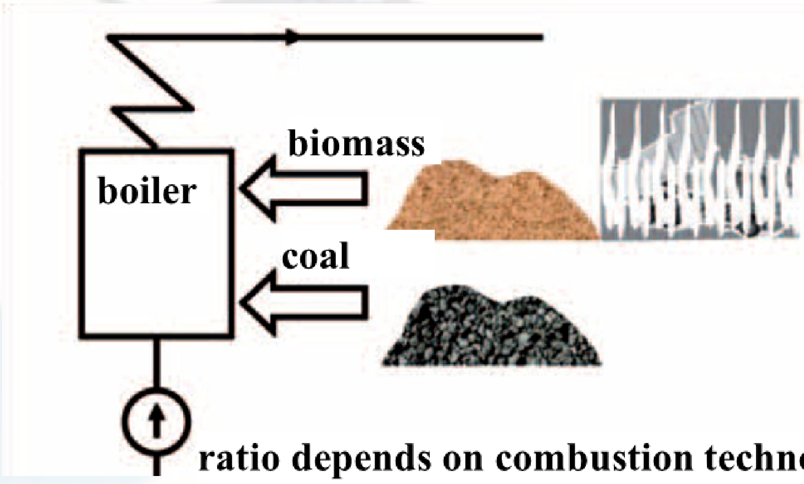
Basic technology principle of co-combustion



ratio depends on combustion technology:
powder 0 – 20 %
fluid 80-100 %

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Co-firing

Definition: simultaneous combustion of different fuels in the same boiler.

Objective: to achieve emission reductions.
This is

- not only accomplished by replacing fossil fuel with biomass,
- but also as a result of the interaction of fuel reactants of different origin, e.g. biomass and coal.

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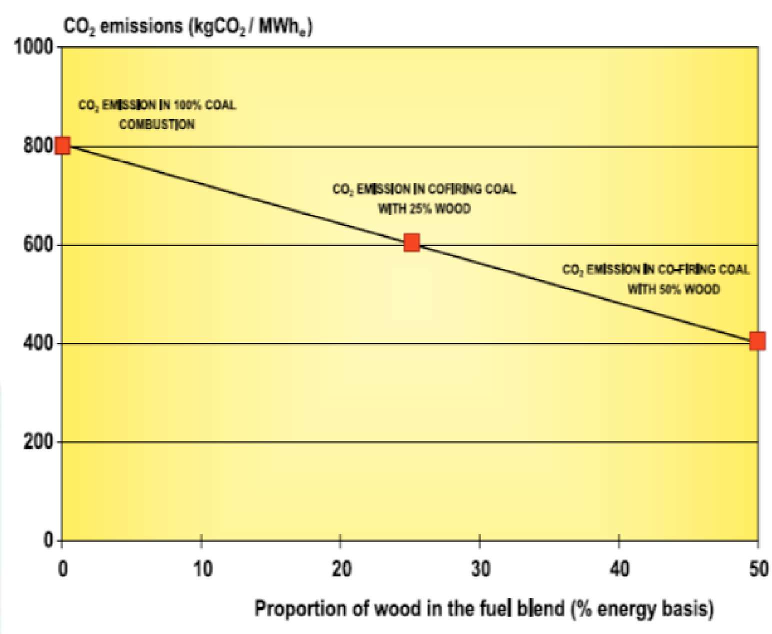
Emission reduction



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Co-firing: merits

- **Fuel feed-stocks may be available locally, reducing transport costs.**
- **Replacement of part of the coal feed can reduce dependence on imported fuels and help maintain strategic national reserves of coal.**
- **Reduced emissions of main classes of pollutants through reduction in amount of coal burnt. This can occur through simple dilution or via synergistic reactions between biomass feedstocks and coal.**

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Co-firing: demerits

- Feedstock pre-preparation may be required. For instance, wood requires chipping, straw may require chopping up, etc. resulting in increased energy requirements.
- Some biomass materials have low bulk density (e.g. straw), this resulting in the handling and storage of large quantities of materials.
- Moisture content may be high, reducing overall plant efficiency.
- Depending on the feedstock, the complexity of fuel feeding requirements may be increased; some materials can be co-fed using a single feed system whereas others require a separate, dedicated system.

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Co-firing: merits

- Several types of combustion and gasification technology may be applicable to a particular combination of feed-stocks.
- These may include:
  - pulverised fuel,
  - bubbling fluidised bed combustion
  - circulating fluidised bed combustion.

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Biomass co-firing (technology)

- Direct co-combustion in coal fired power plant
- Indirect co-combustion with pre-gasification
- Indirect co-combustion in gas-fired power plant
- Parallel co-combustion (steam side coupling)

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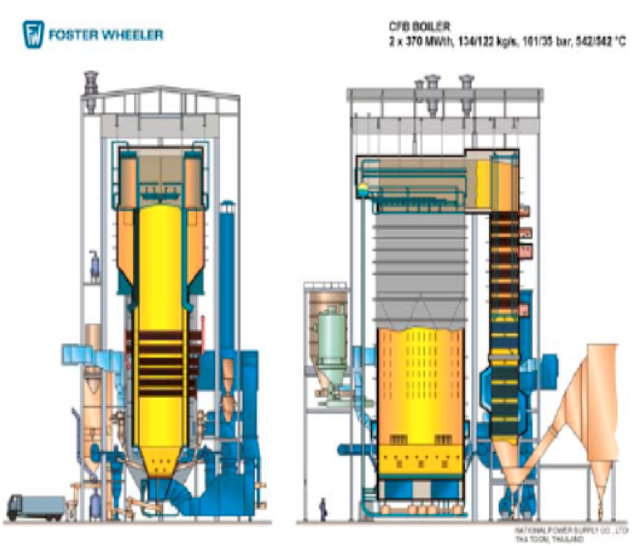
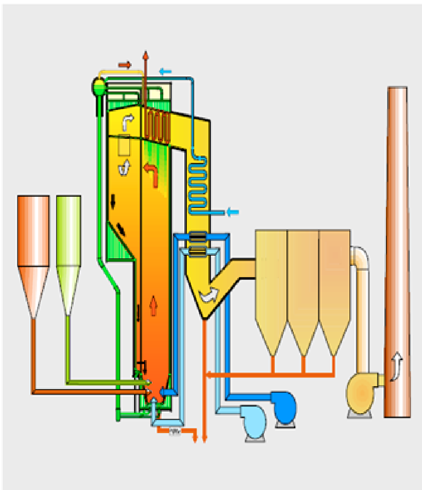
Direct co-firing



Direct co-combustion in CFB furnace



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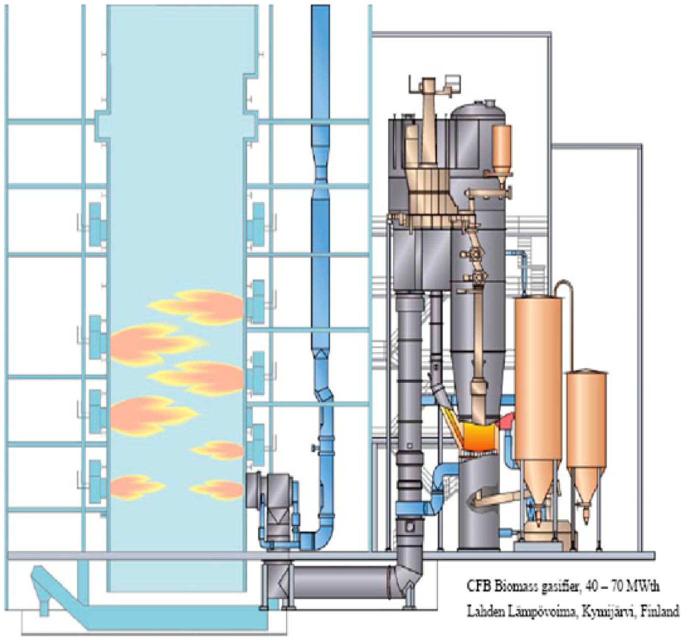
Biomass co-firing via pre-gasification (Indirect)



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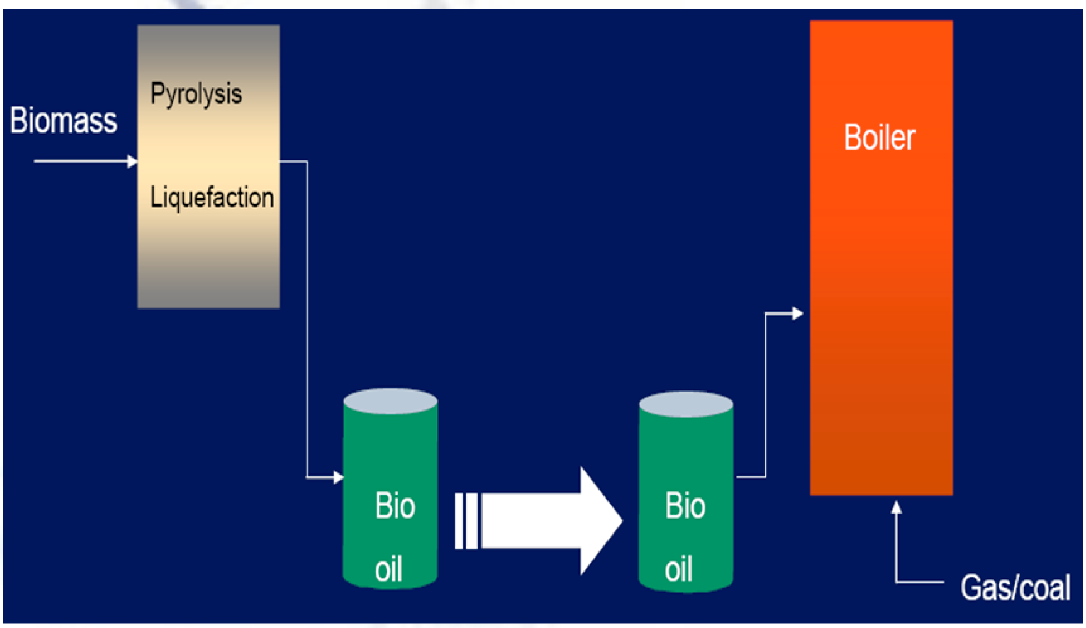
Indirect co-firing for gas-fired boilers



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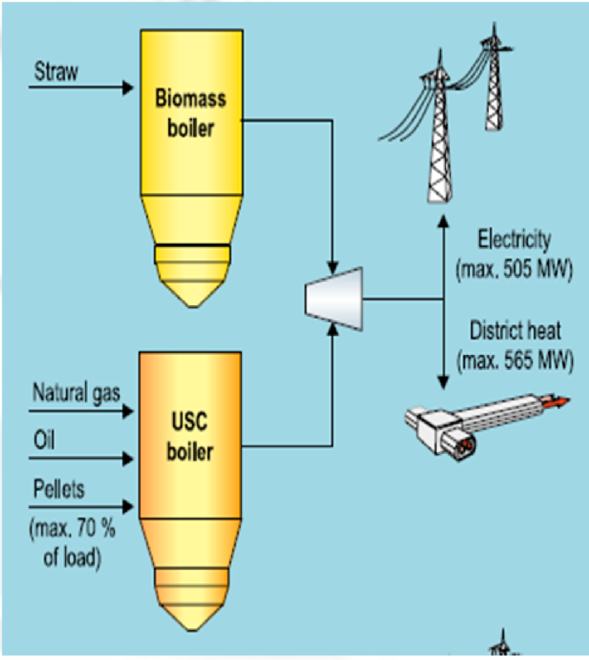
Parallel co-combustion (steam-side coupling)



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Drivers of co-firing biomass

- Reduces the emissions of greenhouse gases and other pollutants
- Co-firing in coal plants would strongly increase biomass use
- Lowest capital cost option for increasing the use of biomass to produce electricity
- Co-firing biomass and coal takes advantage of the high efficiencies obtainable in large coal-fired power plants
- Improves combustion due to the biomass higher volatile content
- Jobs creation

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Technical barriers

- Thermal behavior and efficiency
- Fouling and corrosion of the boiler (alkalis, chlorine)
- Environmental constraints - emissions

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Direct co-combustion

- Direct co-combustion is the least expensive, simplest and most frequently used approach.
- Biomass and coal are burned in the furnace coal boiler.
- During combustion, in pulverized boilers, are used together or separately existing mills and burners, which basically depends on the nature of biomass co-combustion, the design of the boiler and the fuel supply system.
- This way , by far the most commonly used arrangement of biomass co-combustion allows up to approximately 3% of the energy content of the fuel without significant additional investment costs.

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What is fuel?

- **The combustible substances which on burning in air produces large amount of heat that can be used economically for domestic and industrial purposes are called fuels.**
  Eg. Wood ,Coal etc

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Energy balance of fuels

- **Inferior calorific value**
  - Q_i, H_i (i - inferior – bottom energy value)
- **Gross calorific value**
  - Q_s, H_s (s - superior – uper energy value)

Fuels are transformed into energy forms = heat through their combustion, therefore, also called fuel. Technologically, it means the transformation of chemical energy contained in the fuel to heat by oxidation of elements contained in the fuel, which chemically react with oxygen

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Hess's law

$$2H_2 + O_2 \rightarrow 2H_2O + 285{,}7\ kJ/mol = 120580\ \ kJ/kg$$
$$C + O_2 \rightarrow CO_2 + 393{,}5\ kJ/mol = 33910\ \ kJ/kg$$
$$S + O_2 \rightarrow SO_2 + 29{,}6\ kJ/mol = 10470\ \ kJ/kg$$

In the case of chemical reaction equation of hydrogen with oxygen equation implies that two moles of hydrogen are reacted with 1 mole of oxygen to form two moles of water
Mass balance and energy linkages with two moles of hydrogen and one mole of oxygen is equal to the energy of binding of two moles of water plus the relaxed the heat of reaction.

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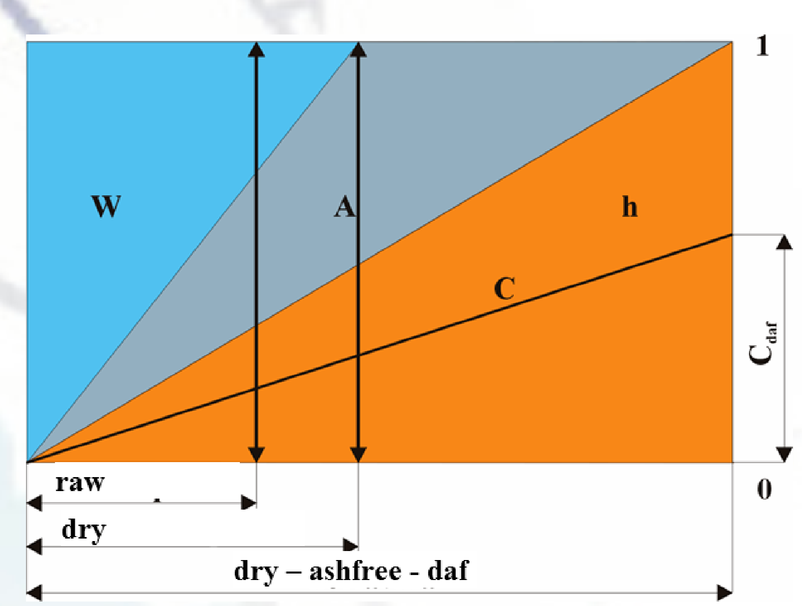
Fuel composition



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Liner dependence of fuel parts

$$h_r + A_r + W_r = C_r + H_r + S_r + N_r + O_r + A_r + W_r = 1$$

$$A_r = A_d .(1-W_r)$$

A_d = ash in dry matter

$$C_r = C_{daf} .\ (1- A_r - W_r\ )$$

$$H_r = H_{daf} .\ (1- A_r - W_r\ ),\ etc.$$

Water in fuels

$$Q^{H}_{H20} = 2453 \cdot water\ amount\ after\ combustion\ of\ 1kg\ fuel =$$

$$= 2453.\frac{molar\ hdrogen\ weight}{2} Hydrogen\ amount\ in\ 1\ kg\ fuel = 2453.\frac{18}{2} =$$

$$= 2453.9.H\ [kJ / kg]$$

$$Q^{W}_{H20} = 2453.W\ [KJ / kg]$$

$$Q_{H20} = Q^{W}_{H20} + Q^{H}_{H20}\ [KJ / kg]$$

Biomass characteristics

- Lower density
- Higher moisture content, often up to 50%
- Lower calorific value
- Broader size distribution, unless pre-conditioned by screening, crushing or palletising
- The variability of the material as a fuel will be greater

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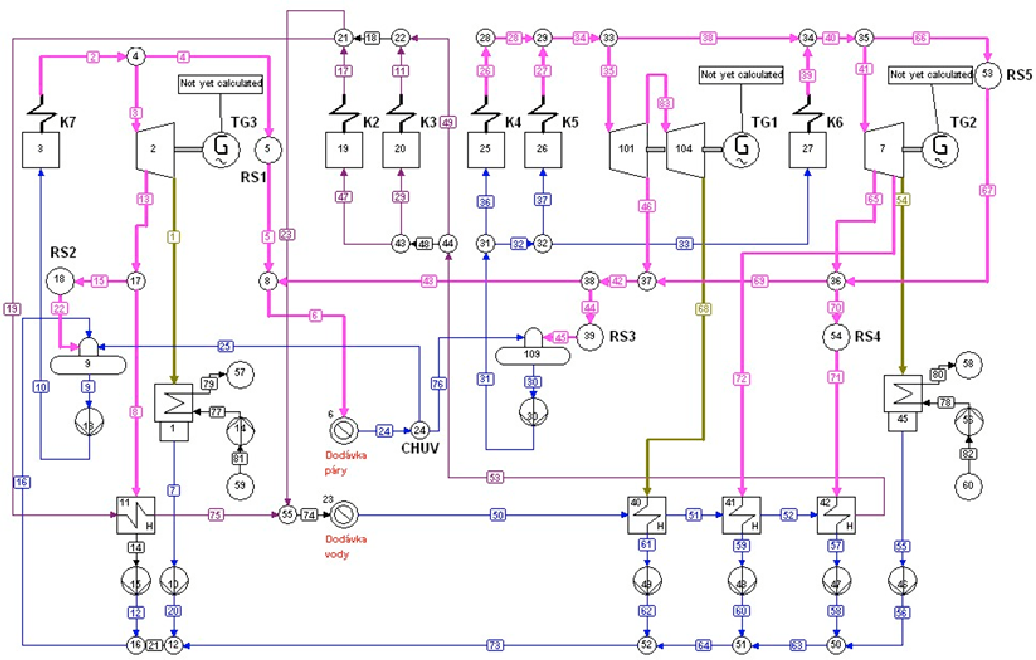
Central power heating station Plzeň



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Wood chips drying

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Route pellets to the boiler K4, K5

Transportation pellet screw conveyors

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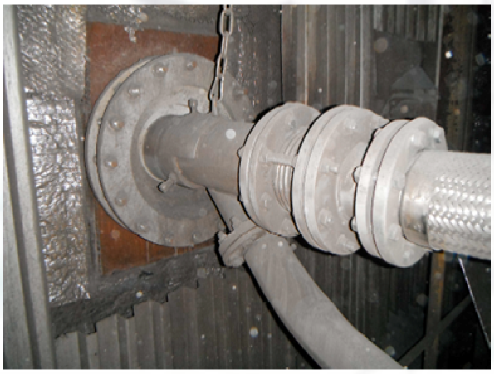
The biomass co-firing with brown coal boilers

základní palivo	base fuel	sokolovské hnědé uhlí	brown coal
doplňkové palivo	biomass	peletky	pellets
parní výkon	stem output	185t/hod	
tepelný výkon	heat output	128 MW_t	
teplota páry		540°C	
tlak páry		13,53 MPa	
účinnost kotle		84 až 86%	

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Combined emissions of air pollutants

Polutant	Jednotky	Coal	Biomasa	Rozdíl
Tuhé látky	t/r	9,30	1,72	-7,58
SO2	t/r	298,89	51,63	-247,26
NOX	t/r	484,03	344,22	-139,81
CO	t/r	40,34	114,74	74,40
CO2	t/r	111297,84	0,00	-111297,84

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Economic benefits of biomass burning

- Support of electricity production from renewable energy sources takes the form:
  - purchase tariffs
  - green bonuses

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Price comparasion

Datum uvedení do provozu	Výkupní ceny elektřiny dodané do sítě v Kč/MWh	Zelené bonusy v Kč/MWh
Výroba elektřiny spalováním čisté biomasy kategorie O1 v nových výrobnách elektřiny nebo zdrojích od 1. ledna 2008 do 31. prosince 2012	4580	3530
Výroba elektřiny spalováním čisté biomasy kategorie O2 v nových výrobnách elektřiny nebo zdrojích od 1. ledna 2008 do 31. prosince 2012	3530	2480
Výroba elektřiny společným spalováním palivových směsí biomasy kategorie S1 a fosilních paliv	-	1370
Výroba elektřiny společným spalováním palivových směsí biomasy kategorie S2 a fosilních paliv	-	700

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Co-firing provides means for emissions reduction

- **Reducing NOx emissions**
- **Biomass blending decreases SO2 emissions**
- **Trace organic compounds**
- **Particulates**

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