CO-FIRING TECHNIQUES FOR WOOD AND COAL

Review of the various co-firing concepts in Europe

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Business from technology

What is co-firing

- Simultaneous combustion of different fuels in the same boiler, provides one alternative to achieve emission reductions. Why?

- By replacing fossil fuel with biomass
- Also as a result of the interaction of fuel reactants of different origin, e.g. biomass and coal.

- Utilisation of solid biofuels and wastes
  - sets new demands for boiler process control and boiler design
  - as well as for combustion technologies
  - fuel blend control
  - and fuel handling systems.

Why co-firing

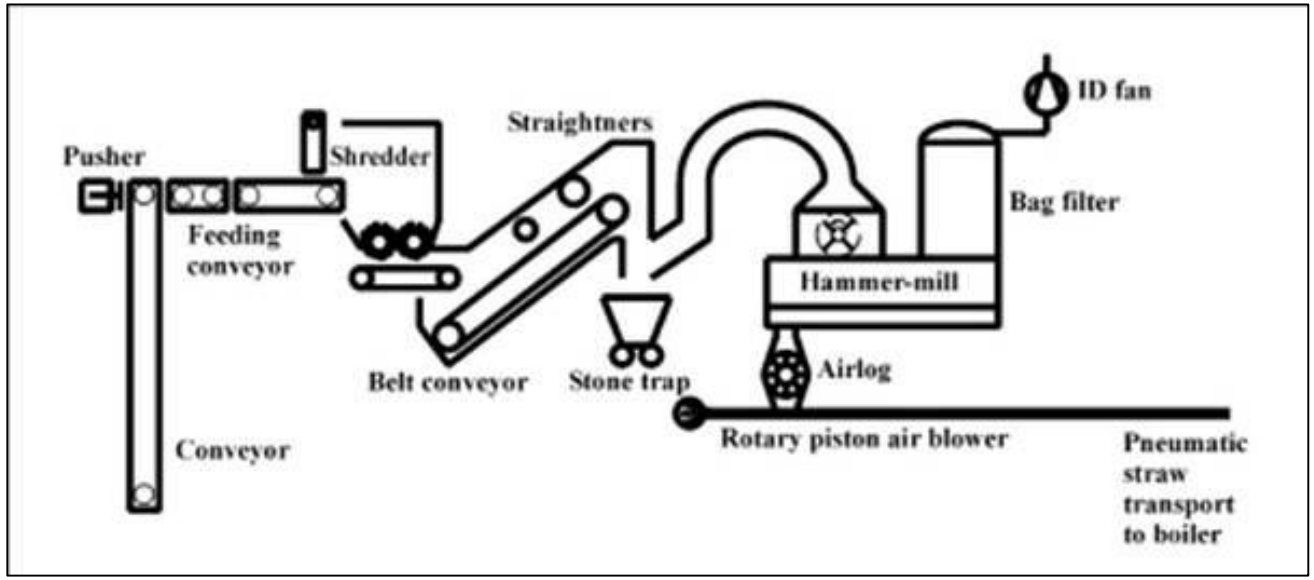
- Co-firing in existing boilers provides one alternative to achieve emission reductions.
- CO_2-emissions will lower because biomass fuels are CO_2-neutral
- Sulphur dioxide (SO_2) emissions will lower, because biomass fuels have low sulphur
- Nitrogen oxide (NO_x) emissions will lower, because biomass fuels have lower nitrogen content than coal
- Co-firing is a way to start biomass use with low investment costs

Pulverised coal-fired boilers

- Biomass co-firing is commonly slightly more expensive than dedicated coal systems.
- If there are no motivations to reduce CO_2 emissions, the motivation for co-firing is difficult to establish.
- Operating costs are typically higher for biomass than for coal.
- The most sensitive factor is the cost of fuel.
- Biomass transportation, preparation, and on-site handling increase its total costs (sometimes significantly).

The Danish Studstrup power plant

- 150 MW_e pulverised coal fired boiler
- co-firing of coal and straw
- straw is fired through the centerpipe of the burner.
- co-firing technology is viable at least up to 20 % straw share on energy basis
- the boiler performance has been only marginally affected
- more slagging, slightly increased corrosion



Pneumatic feeding system of straw in Studstrup power plant.

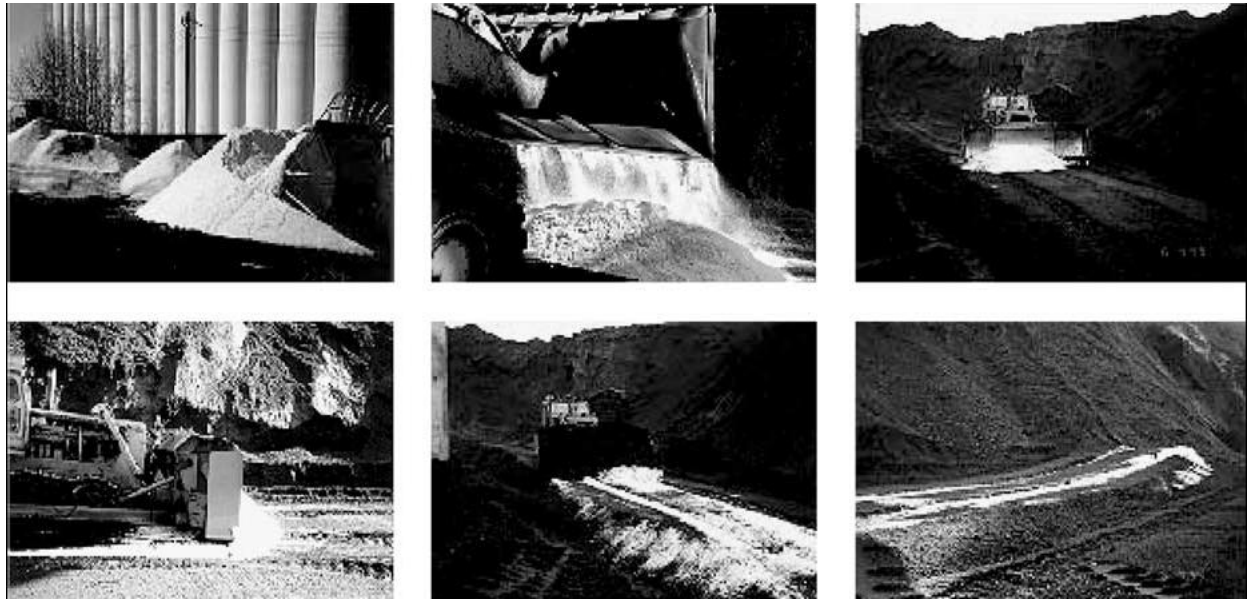
The EPON 635 MW_e power plant in the Netherlands

- co-firing pulverized wood waste with coal since 1998
- a separate handling process has been installed for the wood waste
- there are 4 separate burners for wood powder
- wood waste, consisting of forestry and demolition waste, accounts only for about 4.5 % of the total energy.
- the plant reports substantial savings in comparison to coal combustion
- reduced emissions of CO_2, SO2, NO_x and fly ash are also reported.

EPON coal power plant with co-combustion of pulverised waste wood.

Naantali 315 MW_e plant in in Finland

- co-firing of sawdust and coal
- coal and sawdust are blended in the coal yard and the mixture is fed into the boiler through coal mills
- sawdust's moisture, up to 65 %, do not cause any problems, if the wood fraction in fuel blend does not exceed 4 % on energy basis
- milling capacity limits wood fraction in fuel blend



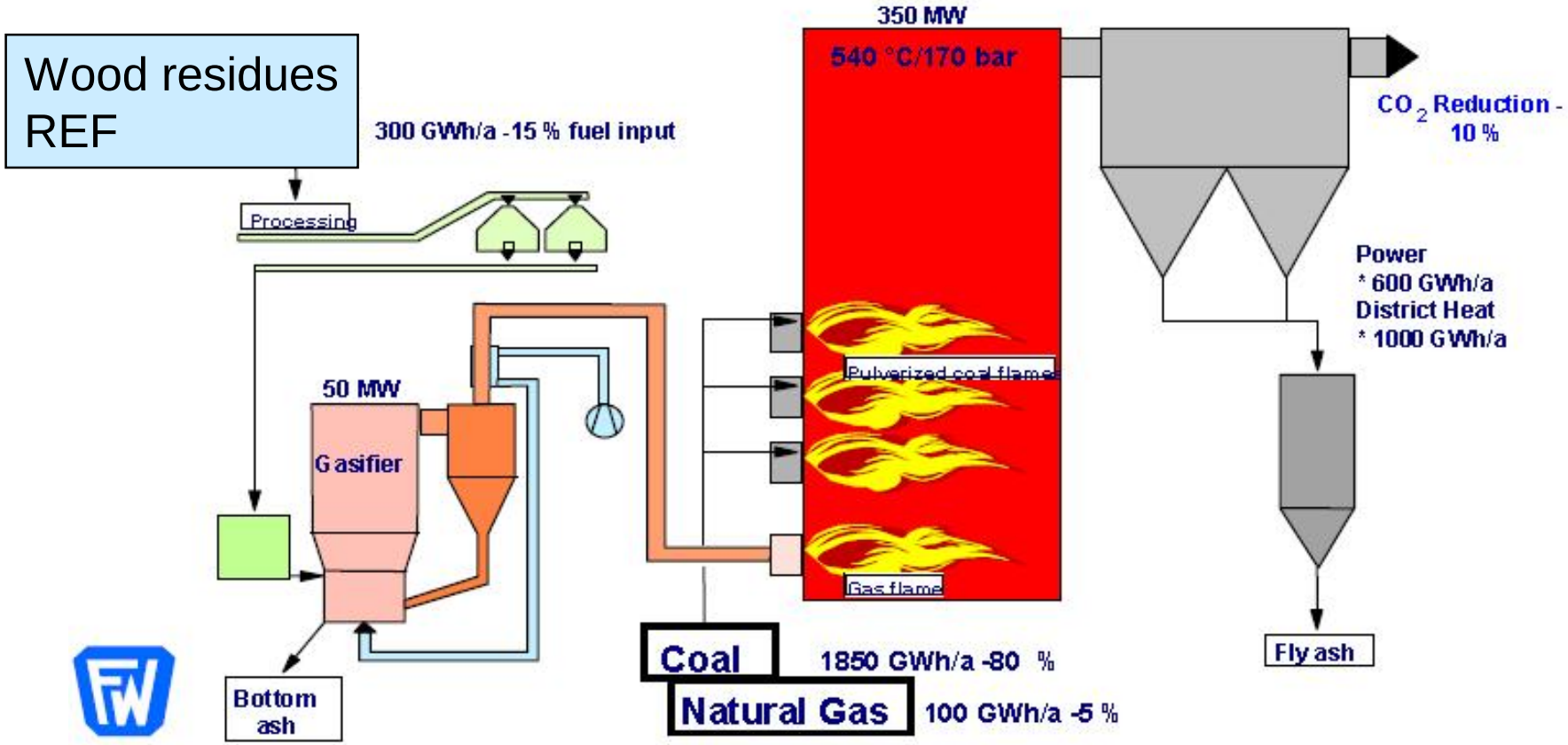
Blending of coal and sawdust in the coal yard of Naantali power plant.

Co-firing of coal and wood pellets

- Pellets are typically added to the coal prior to milling and are milled together with the coal in the coal mills.
- The produced wood dust is pneumatically transported to the power plant together with the coal dust and co-combusted in the same burners as the coal dust.
- Cofiring without burner adjustment is possible up to 20–30% on energy base
- Higher percentages, up to 70–75% on energy base are possible but require installation of so-called multi-fuel burners.
- Cofiring in standard coal fired power plants requires investments of €120/kWfuel for fuel handling and intermediate storage and requires O & M costs of 1.2 €cent/kWh$_e$.

Amer power plant of Essent in Geertruidenberg In the Netherlands

The Lahti CFB-gasifier connected to a 360 MW pulverised coal-fired boiler



Grate firing

- Traditionally used for combustion of wood fuels
- Different types of grate firing systems have been developed for various solid fuels including coal, municipal waste and biofuels:
  - stationary or moving sloping grates
  - travelling grates
  - vibrating grates
- A specific grate combustion system for straw firing has been developed in Denmark (below 15MW_{th}), in which straw bales are fed continuously into the furnace by hydraulic piston.

Grate firing

Wärtsilä BioPower plants are designed for hot water or process steam generation or combined heat and power (CHP) or condensing power production using very wet biomass fuels such as bark, sawdust, wood chips, and forest harvesting residues.

BioGrate boiler from Wärtsilä Biopower Oy. [http://www.wartsila.com/]

BioGrate

- Designed to burn very wet fuels like
  - bark
  - saw dust
  - wood chips
  - forest harvesting residues

- Benifits
  - no fuel drying needed
  - moisture content up to 60 %
  - stable burning and low emissions because of almost adiabatic combustion
  - plants run unmanned
  - proven technology

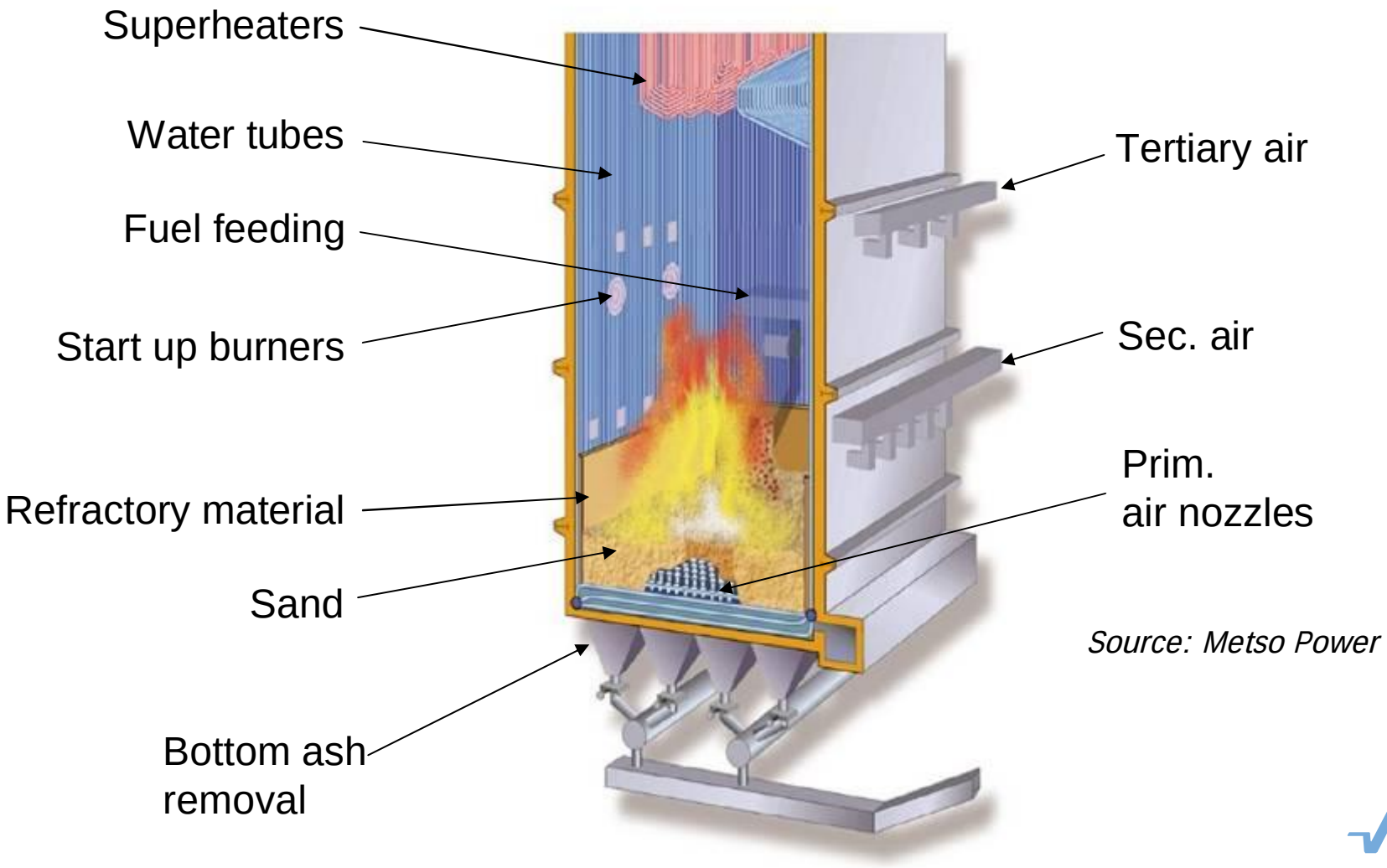
BioGrate boiler from Wärtsilä Biopower Oy. [http://www.wartsila.com/]

15 MW$_{th}$

Fluidised bed combustion

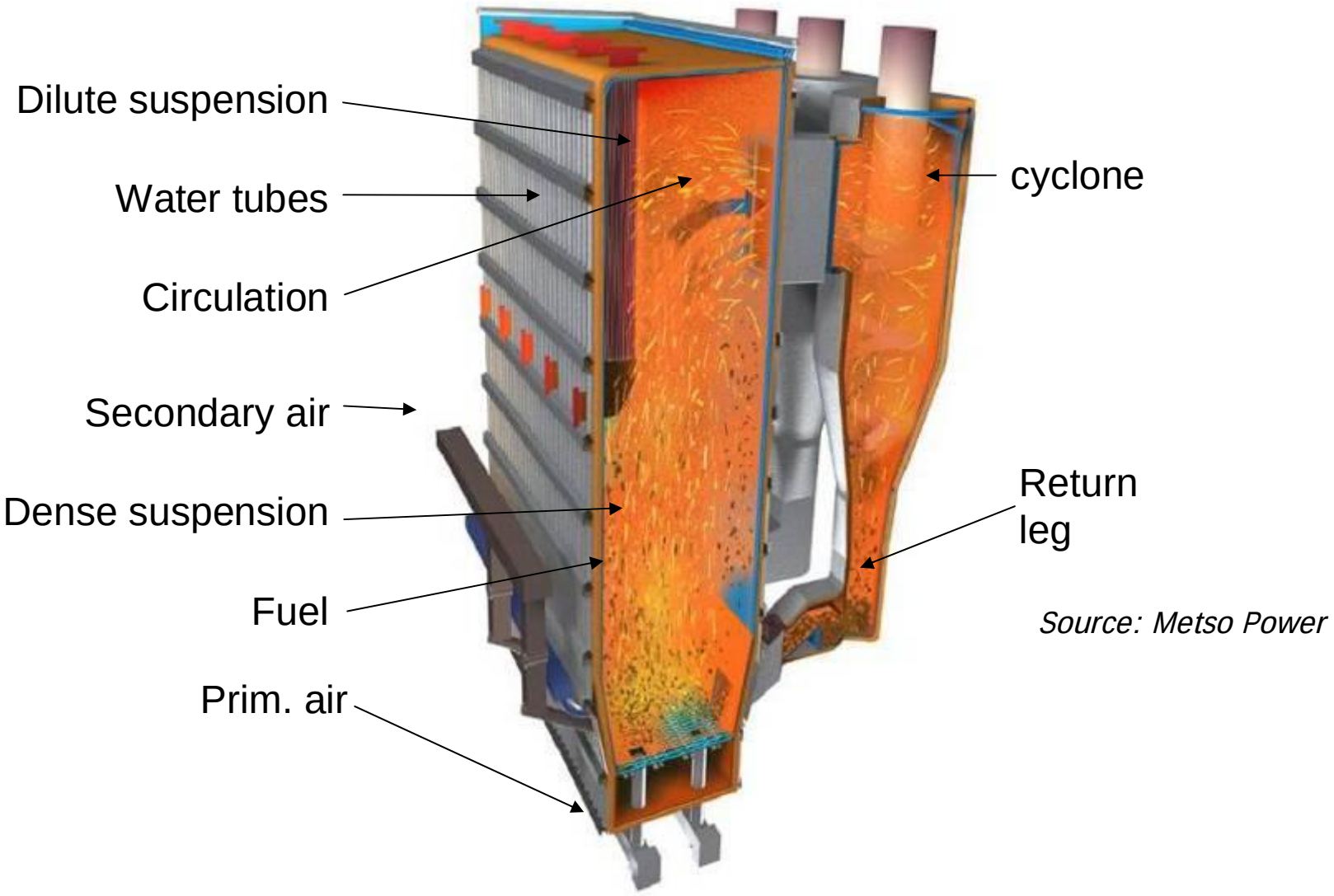
2 principles

Bubbling Fluidized Bed (BFB)



Source: Metso Power

Circulating Fluidized Bed (CFB)



Source: Metso Power

Fluidised Bed Combustion

- Bubbling (BFB) fluidised-bed units are offered up to 300 MW_{th}

  More common for biomass fuels (high volatiles)

- Circulating (CFB) fluidised-bed units up to 1000 MW_{th}.

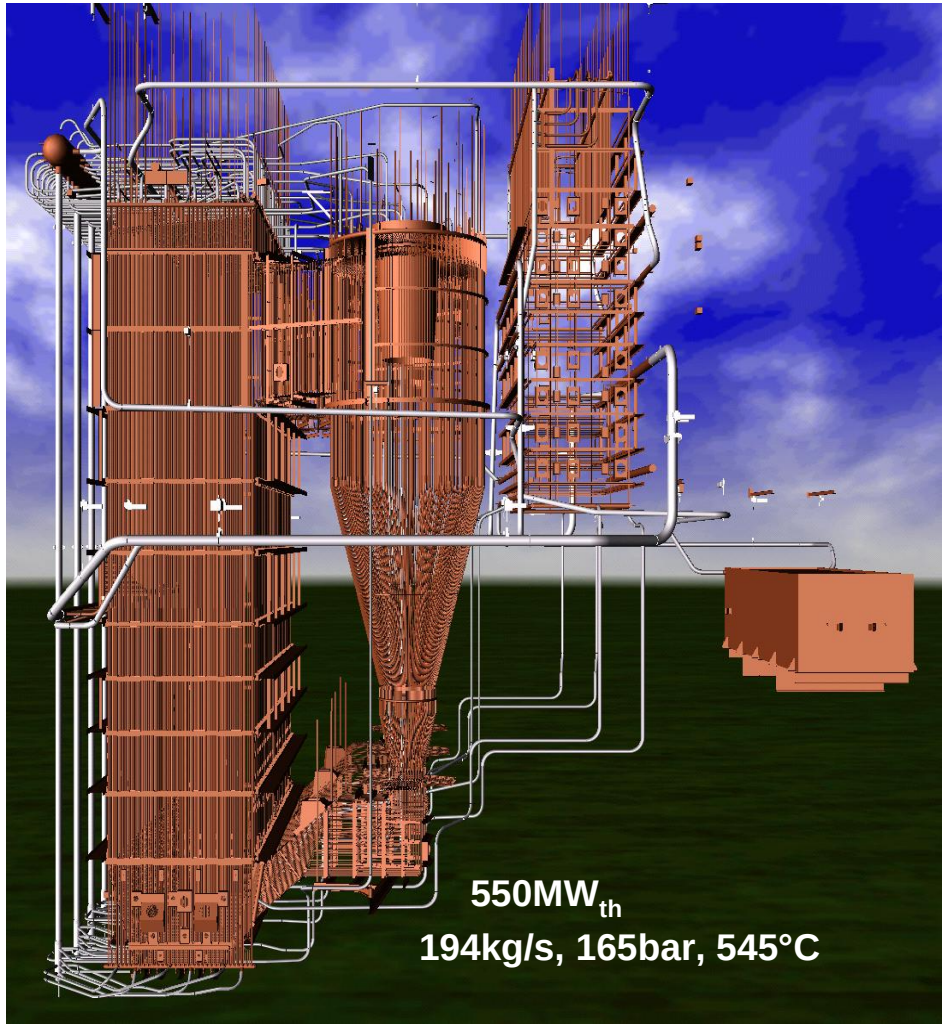
  More suitable for coal (low volatiles)

Fluidised Bed Combustion

Principal advantages:

- high flexibility for use with different ranks of coal, including those with high contents of sulphur and/or ash
- possibility to burn other low grade fuels, such as biomass, RDF and other waste substances
- “in situ” desulphurisation during combustion
- limited nitrogen oxide emissions
- compact boiler arrangement
- use of crushed fuel with relatively large particles, leading to reduced milling cost
- relatively small installation, because flue gas desulphurization and pulverizing facilities are not required

Co-firing experiences in Europe



Alholmens Kraft,
Pietarsaari, **Finland** (start-up 2001)

World's largest biofuelled boiler applying CFB technology:

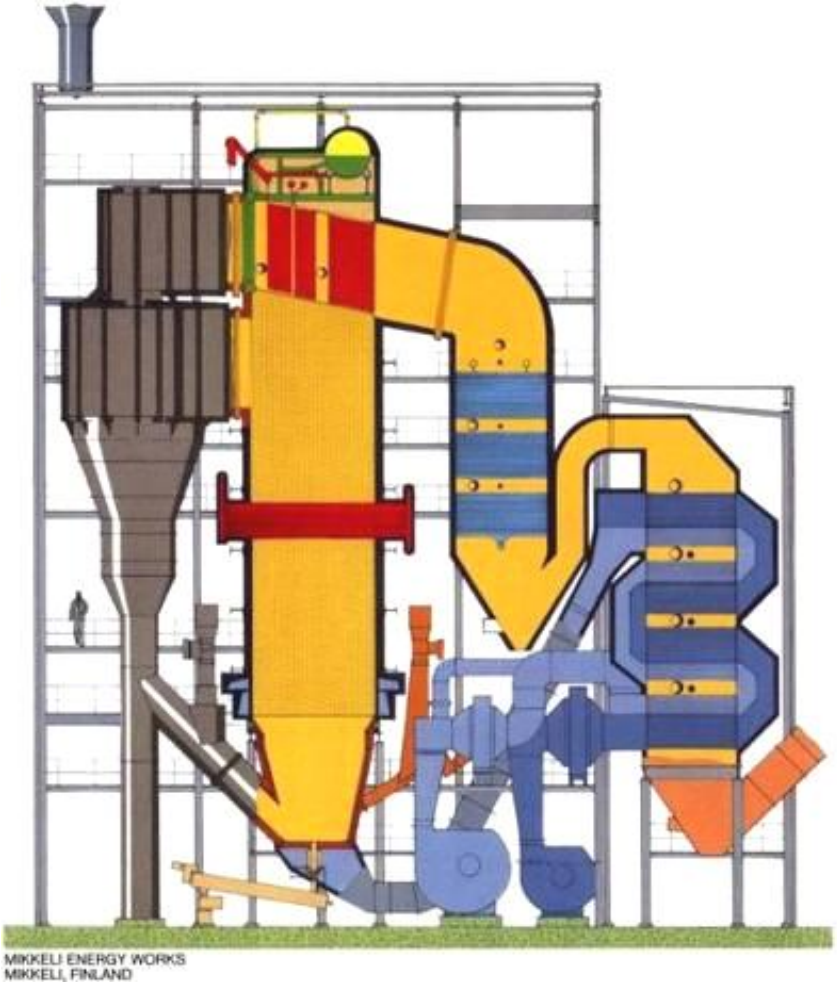
- Uses 45 % peat, 10 % forest residues, 35 % industrial wood and bark residues, and 10 % heavy fuel oil or coal as fuel. Also reed canary grass is used.
- The design of the plant allows great fuel flexibility, the boiler will be able to burn all mixtures of wood and coal from 100 % wood to 100 % coal.
- Consumes a truck load (110 m^3) of peat in 7 minutes

Grenå CHP Plant in Denmark

- Main boiler is a 85 MW_{th} CFB-boiler
- Capable of using coal and straw in a mixture with up to 60 % straw or coal alone
- Shredded straw is induced to the boiler by blowing it into the loop seal
- In the beginning of the operation corrosion was observed in some parts of the superheaters.

Mikkeli plant in Finland

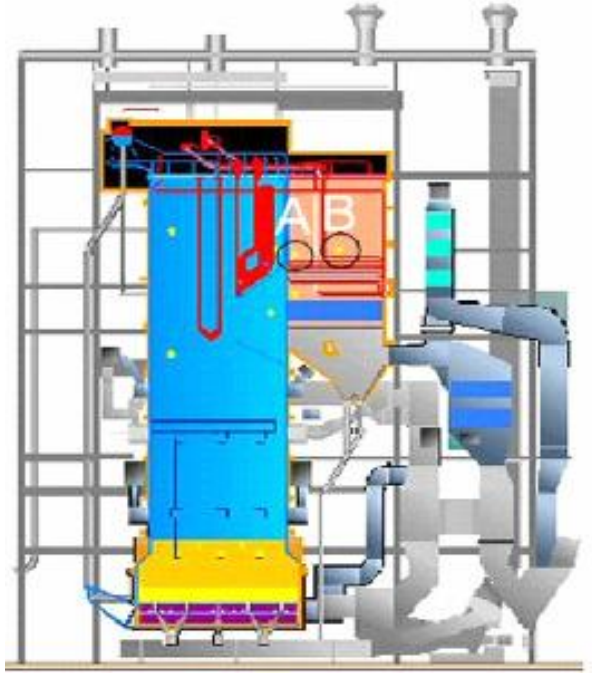
- The CFB boiler of Mikkeli plant in Finland was commissioned by Foster Wheeler Oy in 1990.
- 84 MW_{th}, 33 kg/s, 535 ºC, 114 bar
- Maximum district heat capacity is 54.4 MW, maximum electric output is 28.7 MW.
- The main fuels are currently wood-derived biomass and peat.
- Wood fuels are by-products of the mechanical forest industries, forest residues and sorted construction waste.



The Rauhalahti plant in Finland

- Was originally equipped with pulverised fuel boiler (commissioned in 1986). In 1993 new BFB boiler retrofit was installed by Metso Power.
- The main fuels are currently peat, by-products from sawmills and forest residues (wood chips, stumps). Also reed canary grass is used.

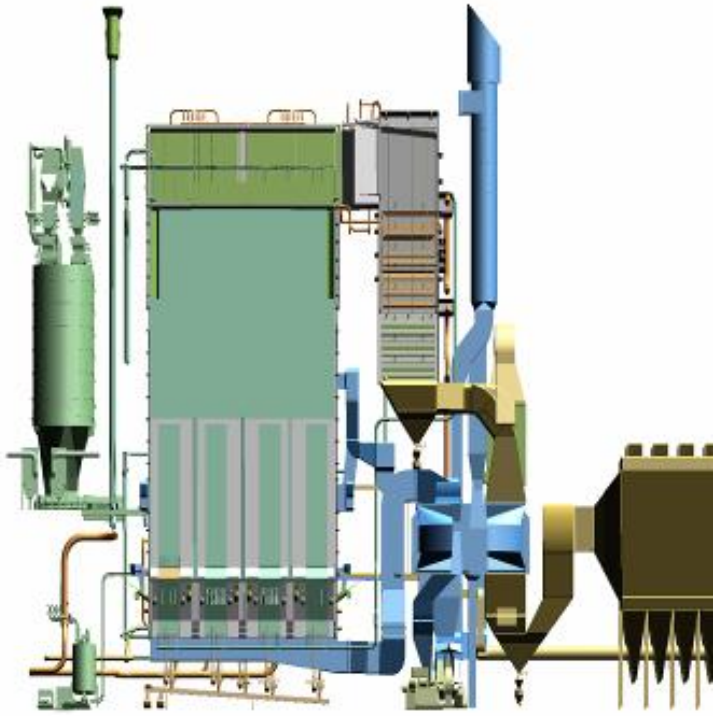
- Boiler capacity 295 MW_{th}
  - Electrical output 87 MW_e
  - District heat output 140 MW_{th}
  - Process steam output 40 MW_{th} (max. 65 MW).
  - Steam data: 110 kg/s, 135 bar, 533 °C.



Next generation fluidized bed technology - boiler applying the supercritical steam values: LAGISZA power plant with 460 MW_e in Poland

Technology:

- Higher efficiency compared to traditional CFB technology (net ~43 $\%_{el}$)→ lower fuel consumption → lower emissions
- Extremely high fuel flexibility – coal, peat, biomass together



Fuel flexibility:

- Coal from 10 different coal mines
- Burns also coal slurry
- Option to burn 10% biomass in the future

Source: Foster Wheeler Energia

Technical barriers in co-firing

- Co-firing biomass, waste wood and recycled fuels causes many challenges to power plant operators. It is very challenging compared to conventional coal firing.

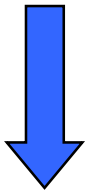
- Poor usability of the fuel mainly results from problems in the fuel feed, unstable combustion process or harmful behaviour of the ashes.

- Chemical composition of the ashes (i.e alkalis, chlorine) change ash reactivity and melting behaviour → fouling and corrosion related problems usually increase

- It is not necessarily economical to use the cheapest fuel available, if the effects on the boiler operation are significant.

Fluidised bed boilers: problems in co-firing biomass fuels

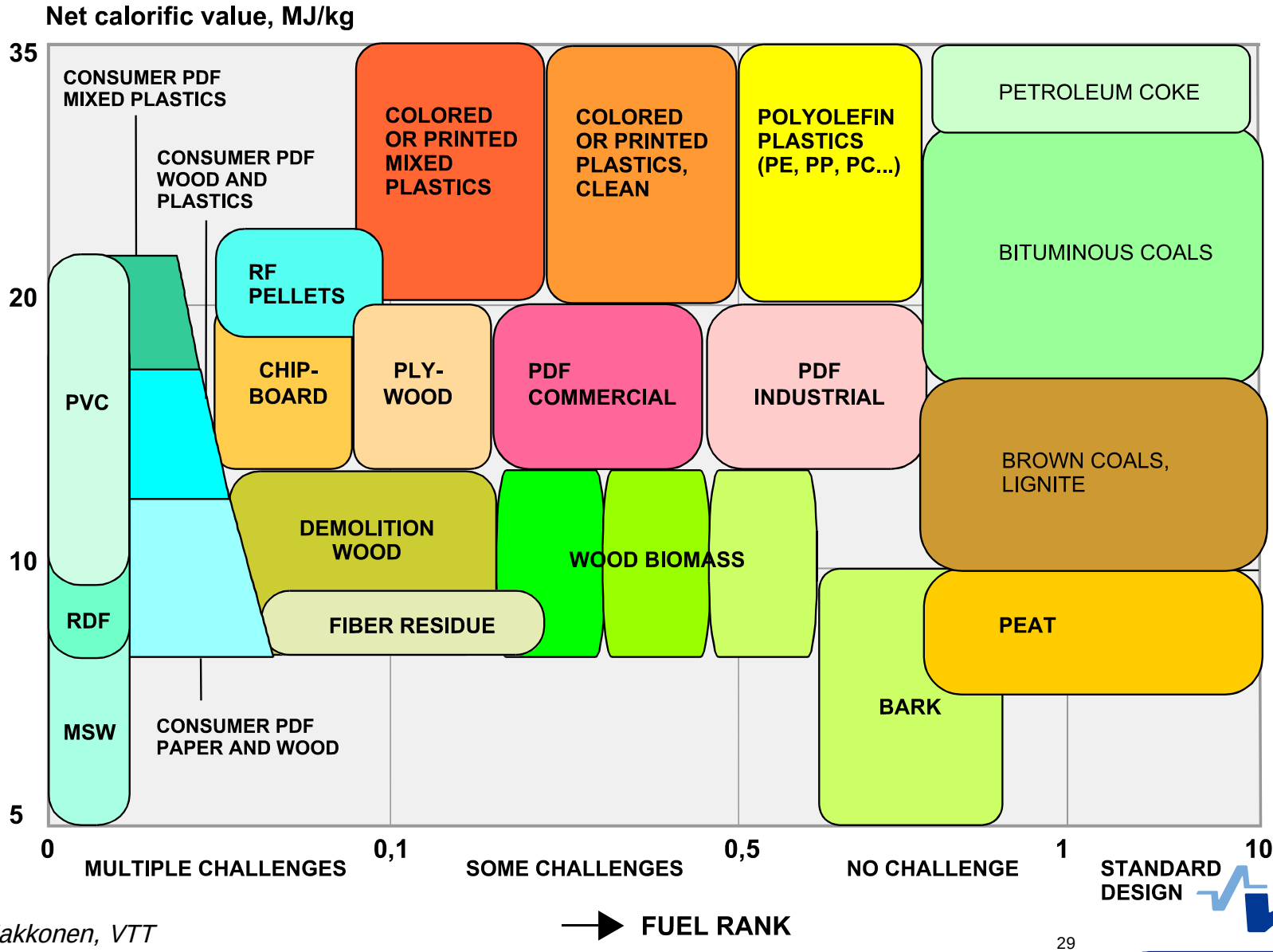
- Deposit formation on heat transfer surfaces
- Bed material agglomeration
- High temperature corrosion
- Disturbances in combustion process
- Operation of the boiler auxiliary equipment (e.g. flue gas fans)



- Increase of operational and maintenance costs (shut-down, furnace cleanning)
- Reduction of boiler efficiency
- Negative influence on boiler lifetime

Fuel Blend

Fuel properties



Source: P. Makkonen, VTT

Feasibility study of the boiler retrofit at Elektrocieplownia power plant in Poland

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Business from technology

Feasibility study of the boiler retrofit at Elektrocieplownia power plant in Poland

Background

- Preliminary plans for biomass utilisation at the plant had been made prior our this study
- Two options were compared: co-firing of biomass with coal in the existing boiler(s), and retrofitting of an existing boiler for biomass use
- The results indicated that the first of these options was not viable, since biomass could never account for more than a small fraction of the total fuel consumption, and the related costs are high

Objectives

- To calculate the amount of available wood fuel and it's price at the power plant
- To evaluate the feasibility of the retrofit for one of the boilers at the Bialystok CHP plant where coal would be replaced with wood
- To calculate the effect on energy production costs
- The effect of wood boiler investment on greenhouse gas emissions and other emissions
- Overall feasibility evaluation touching on all relevant factors

Bialystok case study

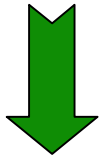
- The aim of the study was to evaluate the possibilities and economy of modern forest fuel harvesting in Polish conditions
- The studied forest fuel materials were:
  - logging residues from final fellings
  - small trees from thinnings.
- Three methods were studied
  - Chipping at roadside
  - Crushing at plant
  - Baling of the residues

Harvesting methods

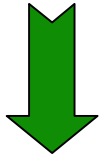
- Small private companies, manual methods widely in use
- Low productivity and limited capacity
- Large scale utilization of forest chips requires modernization of supply chains

Implementation of the study

Costs and productivity for each machine were defined



Optimal machine combinations (harvesting chains) were selected



Costs and productivity data was combined with forest fuel accumulation data

Result: Costs of biomass fuel at the plant were obtained

12 €/MWh compared to coal 8 €/MWh

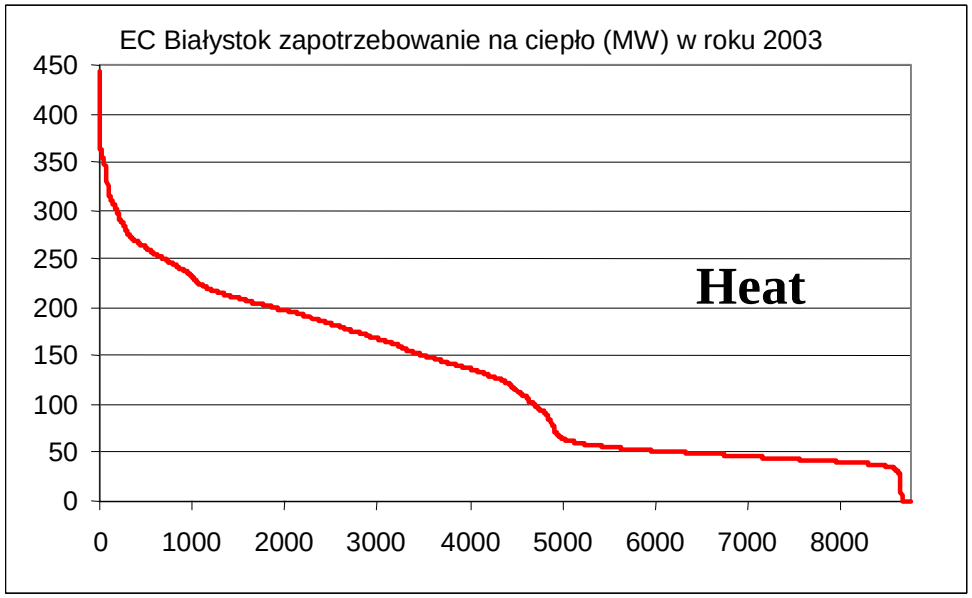
K-5 boiler of the Bialystok power plant

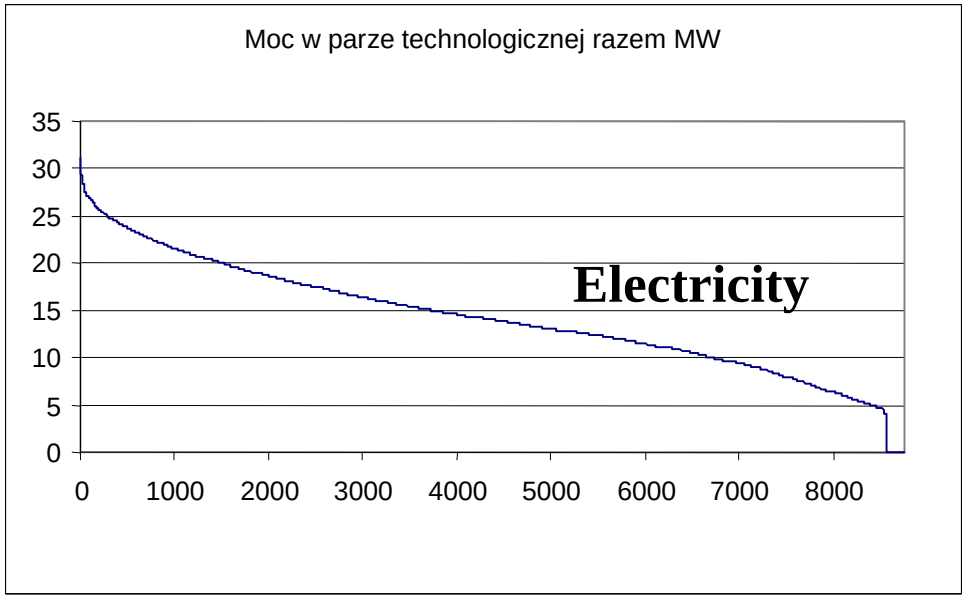
- Annual production of the K-5 boiler is
  - 910 TJ of district heat
  - and process steam together
  - and 270 TJ of electricity

- Annual fuel comsumption: coal 57 400 tons/year (1 340 TJ), oil 132 tons/year (5.7 TJ)

Duration graphs of heat and electricity of the whole power plant (6 boilers)

Source: Kozlowski, W., 2005





- Maximum outputs of the retrofitted K-5 boiler: heat 62 MW, electricity 20 MW
- Retrofitted boiler can be run at maximum output almost 7000 hours/year

Fuel characteristics of wood chips

Fuel characteristic	Design value	Design range
Moisture, %	40	35 - 55
Lower heat value, MJ/kg	18.5	18 - 21
Bulk density, kg/m3	300	250 - 350

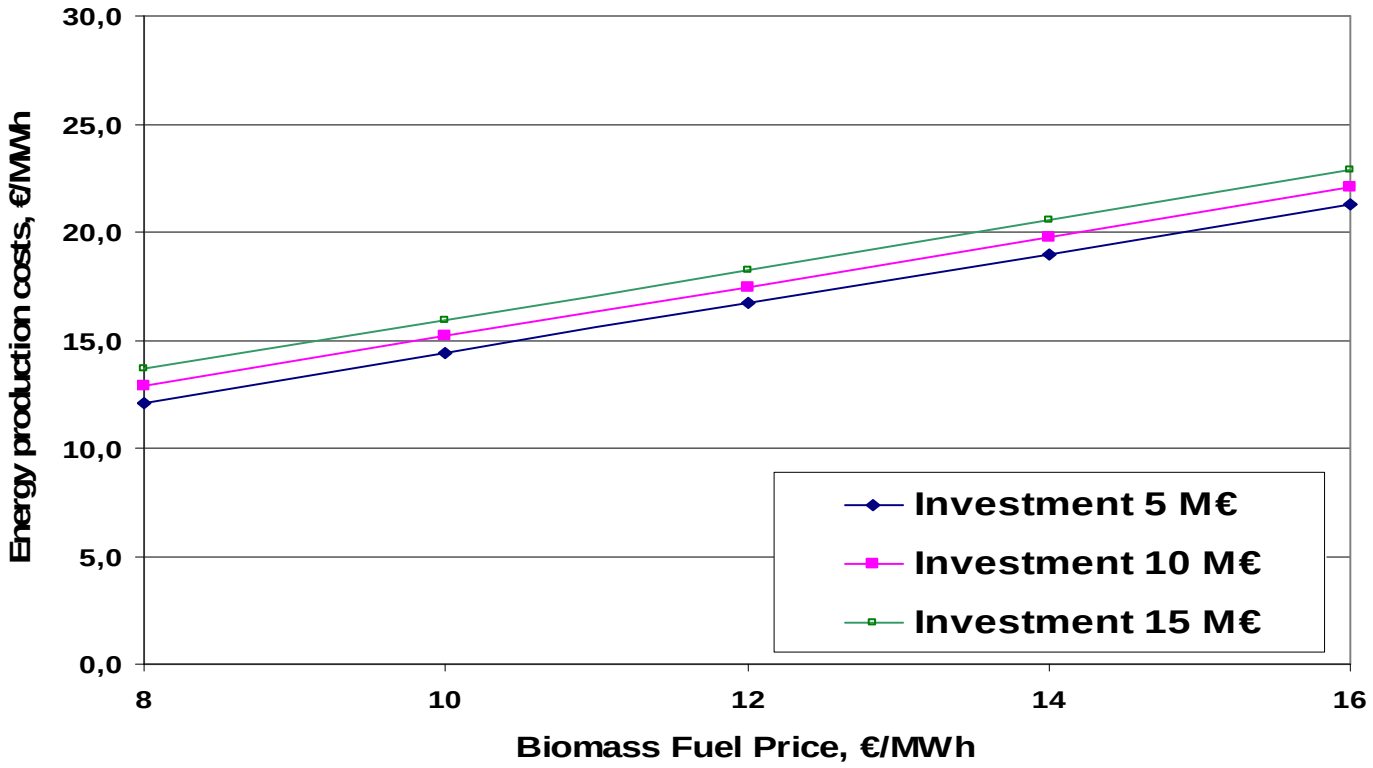
Fuel	Heat value, MJ/kg (on wet basis)	Annual consumption, tonnes	Fuel input, TJ
Wood fuel	10.1	230 000	2320
Oil	42.9	132	5.7

Energy production costs

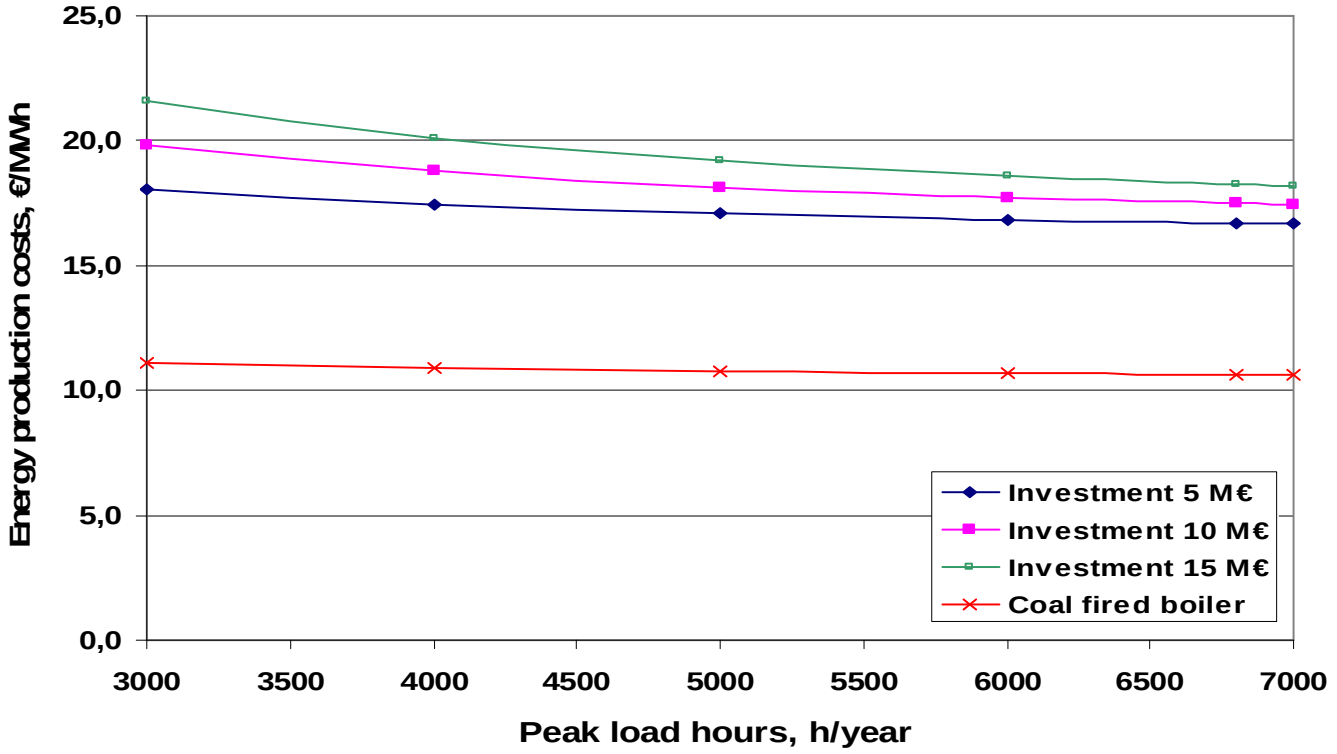
The following parameters were fixed in the calculations:

- retrofit investment: € 5 million
- labour costs: same for biomass and present coal use
- maintenance: 2% of the investment cost for biomass, present costs for coal
- electricity costs as using the current € 33/MWh at the site: for biomass 25 kWh/MWh (in steam), for coal 10 kWh/MWh
- other costs for biomass: € 1/MWh including bed sand and ash handling
- fuel prices: biomass € 12/MWh, coal € 8/MWh
- interest rate 8%
- investment pay-back period 15 years

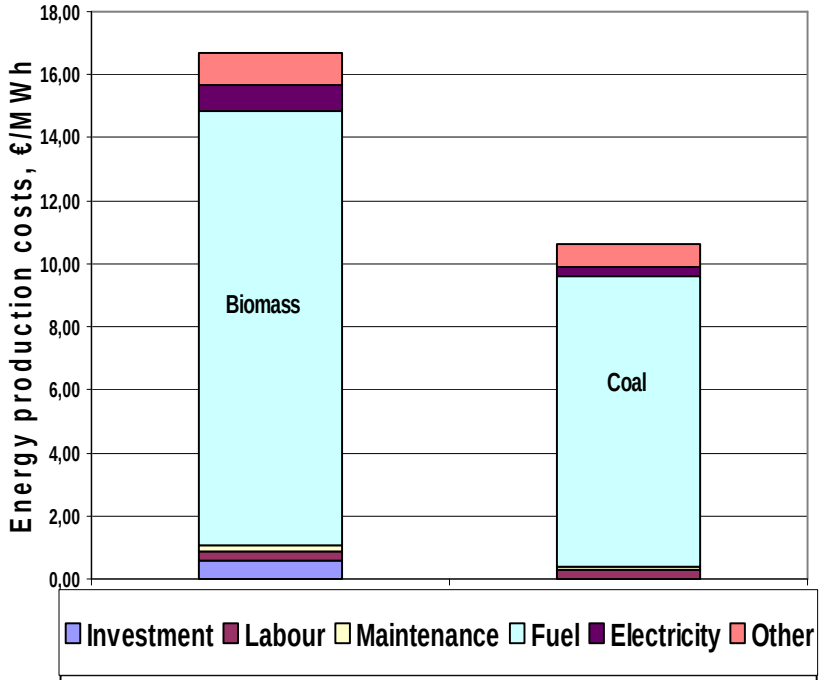
Energy production costs as a function of fuel price



Energy production costs as a function of peak load hours



Feasibility study of the boiler retrofit at Elektrocieplownia power plant



Breakdown of energy production costs

- Fuel cost of biomass accounts for about 85% of the total production costs
- The investment cost does not affect significantly:

  € 5 million to 15 million -→

  increase in the production costs less than € 2/MWh
- Biofuel option can not compete with coal on a direct cost basis
- Offsetting factors are required

Three compensating factors

- greenhouse gas emissions trading
- higher electricity price for “green power”
- penalty fee in Poland to be levied on coal use if biomass accounts for less than 3.1% in 2005 and less than 9% in 2010 of the plant’s energy production

Cost-effectiveness of the retrofitted boiler

The following assumptions were made:

- electricity rates
  - "black electricity": € 28.4/MWh (115 zl/MWh)
  - co-generation electricity: € 33.3/MWh (135 zl/MWh)
  - "green electricity": € 67.9/MWh (275 zl/MWh)

- "waived additional fee"; € 59.3/MWh (240 zl/MWh)

Cost-effectiveness of the retrofitted boiler

- Replacing 370 TJ/year of “black electricity” with “green”

  ----> additional revenue of € 4.1 million/year

- Over 29% of the total energy produced at the plant will be from biomass

  ----> the plant will be able to avoid the penalty fee of € 3.5 million/year before the year 2010, and € 10.2 million/year after 2010

Conclusions

- Price of the biomass fuel is the crucial factor in the total energy production costs; almost 85 % of the total costs
- Biomass fuel option cannot compete with coal directly, but

  ----> three sources of revenue make the investment highly profitable: emission allowance trading, higher electricity price for “green power”, and penalty fees that can be avoided in the biomass option
- Investment will decrease greenhouse gas emissions by 260 000 tonnes/year
- Retrofit investment is made and construction started this year by the Finnish company Metso Power