Advantages and Limitations

of

Biomass Co-combustion

in

Fossil Fired Power Plants

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1 Introduction

The aim of the European Commission is to increase the share of the renewable energy sources in overall energy consumption to 20% by 2020. This was set as a binding target by the European Commission in its energy package in spring 2007. At the end of 2006, renewable energy sources accounted for 6.5% of overall energy consumption. In order to meet the most challenging requirements the share of electricity generation from renewable energy sources must increase from 15% in 2005 to around 34% in 2020. An increase from 9% to around 18% in 2020 is required for direct heat utilization and for cooling purposes. The use of wind energy and biomass in particular should make a significant contribution to this. In addition within the Biomass Action Plan, which was published at the end of 2005, the European Commission encourages the EU member States to harness the potential of all cost effective forms of electricity generation from biomass. Co-combustion of biomass is one of the promising technologies.

Co-combustion of biomass is an important technology for CO_2-neutral electricity generation. In many countries biomass co-combustion is one of the most economic ways to save CO_2. In addition it can be motivated by saving of CO_2 taxes. Co-combustion of biomass is practiced in numerous plants, especially in Denmark, Belgium, The Netherlands, Poland, Italy and United Kingdom.

Different government subsidy schemes as well as other financial instruments provide various national incentives for biomass co-combustion within the European Union. In Germany biomass co-combustion is excluded from special electricity refunds for renewable energy sources. As co-combustion to a certain extent competes with stand-alone biomass plants for the limited biomass resources, the position towards biomass co-combustion is controversial. This paper demonstrates the advantages and limitations for biomass co-combustion.

2 Co-combustion

Typical co-combustion plants in the power plant sector are in the electrical output range of 50 MW to 700 MW. The majority of the plants are equipped with pulverized coal firing systems. However, biomass co-combustion is also implemented in fluidized bed systems (bubbling and circulated) and in other boiler designs. Basically, it is possible to distinguish the use of biomass in fossil fired power plants in three different biomass co-combustion concepts, which are as follows:

- Direct co-combustion: Biomass and coal are burned in the same boiler or gasifier, using the same or separate mills and burners, depending principally on the biomass fuel characteristics. Coal and biomass can be mixed before milling (e.g. formerly Schwandorf plant, e.on), or coal and biomass are fed and milled by separated supply chains. The latter approach is applied e.g. in the Amer 9 power plant in The Netherlands and Avedøre Unit 2 in Denmark.
- Indirect co-combustion: In a gasifier the solid biomass is converted into a fuel gas, which after cooling and cleaning can be burned in the coal boiler furnace. This approach is applied, for instance, in the Amer gasifier in The Netherlands. As an alternative the produced syngas can also directly be burnt in a joint steam boiler without further cooling or cleaning. This is realized in the power plant in Lahti (Finland) and in Ruien (Belgium).
- Parallel co-combustion: It is also possible to install a completely separate biomass boiler including flue gas cleaning and utilize the steam produced in the coal power plant steam system. This approach e.g. is applied in the straw-fired boiler of the Avedøre Unit 2 power plant in Denmark.

3 Advantages of biomass co-combustion

The major advantages of co-combustion are the common utilization of existing plants, the fuel flexibility, a wide range of usable fuels and the attainment of higher overall efficiencies for power generation from biomass. Therefore, co-combustion in large thermal power stations can lead to an overall saving of fuels in comparison to independent fossil and biomass fired plants. Further, use is made of existing flue gas cleaning facilities present in such large-scale facilities. The technical as well as the economical advantages can be described as follows:

- Technical
  - The electrical efficiency is higher compared to the use of biomass in small stand alone plants.

– Fuel flexibility: The availability of the substitute is not important because the main fuel remains coal or gas. There exists a wide range of usable biomass fuels. Varying qualities and quantities of fuels can be partially compensated by adjusting the co-firing rate.

– Higher ratio of sulfur to chlorine reduces risk of corrosion.

- Economical

  – The additional investments of the co-combustion equipment are significantly lower (for pulverized coal-fired plants in some examples as low as 300 Euro/kW_{el}; the investments of stand alone biomass plants amount from 2,500 to 3,000 Euro/kW_{el}).

  – Due to lower additional investment and higher electric efficiencies with biomass co-combustion the sensitivity on feedstock prices is lower and higher prices than in small stand-alone plants are tolerable for the fuel at the same electricity refund. This might open up new, more expensive biomass potentials for energetic utilization or on the other hand reduce the cost for the utilization of the already available biomass.

  – The reduction of specific CO_2 emissions is significantly larger for biomass co-combustion because of the higher efficiencies. As a result additional CO_2 certificates can be generated and the CO_2-reduction costs are also lower.

- Environmental

  – Reduction of CO_2-emissions by saving of fossil fuels.

  – Lower NO_x, because the content of fuel nitrogen in most types of biomass is lower and large plants are typically equipped with deNOx installations. NOx is better controlled in PF-fired than in grate-fired boilers.

  – Lower SO_x, because most types of biomass contain much less S than coal.

  – An improved combustion because of the higher volatile matter content of the biomass, resulting in a better burn out and lower unburned carbon in the ash.

– In case of (limited) co-combustion the fly ash can be valorized in cement and concrete. Moreover, due to the abovementioned high temperatures in the combustion chamber, the fly ash particles have an amorphous structure (glass), improving the puzzolanic properties.

4 Limitations of biomass co-combustion

Biomass co-combustion is on the other hand limited by technological, economic and environmental problems.

Technical:

- A combustion system is always designed for a certain fuel. The burners are designed for certain volatile components and ash. The fuel handling system is designed for water content, size distribution, dust etc. When Co-firing biomass it is necessary to adapt the existing or even build a new combustion system for that fuel. The same is valid for storage and conveying.
- Co-firing in PF-fired boilers requires milling. Therefore the biomass has regularly to be dried and sometimes pelletized, that it can be milled to sufficient fine particles. This does not apply to fluidized bed boilers.
- Additional cost for fuel preparation e.g. increased amount of fuel to be milled or pelletizing for pulverized coal fired plants.
- Corrosion
  - Higher corrosion risk due to increased HCl formation in case of substitution of fuels with higher chlorine content (sewage sludge, some cereals).
  - Increased corrosion rates of the high temperature components (superheater) due to the higher temperature in comparison to stand- alone facilities.
  - Many biomass fuels contain large amounts of alkalines, especially potassium, which may aggravate the fouling problems.
  - Biomass fuels can be high in chlorine, but typically have low sulphur and ash content.
- Additional slagging, accelerated by reducing atmosphere (Due to primary low NO_x measures).

- SCR DeNOx catalyst can be blocked by ash particles or deactivated by potassium, chlorine, and in case of sewage sludge also poisoned by some heavy metals (As, Zn).

Economical:

- Operating costs are typically higher for biomass than for coal. The most sensitive factor is the fuel cost. Even if the fuel is nominally free at the point of its generation (as many residues are), its transportation, preparation and on-site handling typically increase its effective cost per unit energy such that it rivals and sometimes exceeds that of coal.
- Competition with monovalent plants on the fuel market, if market conditions are changed (e.g. Germany: up to now only monovalent firing receives feeding-in tariffs for bioenergy).

Environmental:

- For the utilization of the ash in the cement and concrete industry the concentrations of alkali metals, P_2O_5, SO_3, Cl and unburned carbon in the ash are the critical parameters. The proportion of ash operating from biogenic fuels should not exceed 10% of the total ash. Main criterion is that the ash has to meet the physical and chemical requirements given in the standards EN 197 (cement) and EN 450 (concrete).
- Ash management: In case of substitute fuels with high ash content combined with a high co-combustion rate there can arise problems with the fly ash quality
- Reduced ESP efficiency. Because most biomass contains less S than coal, the fly ash conductivity will decrease.

Many problems connected to co-firing can be meliorated or solved. Some problems and their respective solution measures for technology and market are presented in Annex 1 and Annex 2.

Annex 1

Balance of Process	
TECHNICAL CONSTRAINT	**HOW TO OVERCOME THE CONSTRAINT**
Additional fuel storage	Fuel preparation, which allows open-pit storage (e.g. TOP-pellet) or by subcontracting the fuel preparation
Longer transport distances than with small, decentralized plants	Development of decentralized pretreatment to reduce transport effort
Fuel quality varies with seasons	Pre-treatment of the fuel
Additional equipment requires additional investment and operating costs	Direct blending of coal and biomass before milling – this is only valid for small particles or pellets or with fluidized bed boilers or after burner grate in PC-firing
Special, more expensive fuel preparation (pelletizing for milling in dust firing systems) or adapted firing system (e.g. fluidized bed, afterburner grate in PC-firing) required	Utilization of fluidized bed boilers and pre-treatment of fuels (TOP-pellet, fast pyrolysis, torrefaction)
Ash characterization: qualities are changed and might not be in the required quality range any more, new channel for ash utilization required	- Characterization of new qualities, - New utilization paths
Poisoning or faster deactivation of catalysts might occur	Limitation of co-combustion rate
Striated flows	- Burner configuration - Fluid flow

Annex 2

Market and Economic Impacts	
TECHNICAL CONSTRAINT	**HOW TO OVERCOME THE CONSTRAINT**
At present fuel price levels for biomass are higher and more volatile than for coal. Also operating costs are typically higher for biomass than for coal. Therefore electricity from biomass co-combustion is more expensive than from coal combustion	- Government subsidies - Other financial instruments - Consideration of long term security for investments
Competition on biomass fuel market might increase prices and endanger the economic basis of smaller stand-alone biomass plants (especially in Germany when opening subsidies also for biomass co-combustion)	- Open subsidies for new biomass potentials only, which are not yet used (e.g. straw) - Relating the biomass potential and the potential of applications in co-combustion: co-combustion is technically limited and therefore in competition
The total cogeneration potential is smaller than with small, decentralized plants	Primary concentration on district heat applications
The organisation of fuel supply is more individual than for fossil fuel and requires more labour and capital investment	Creating a biomass fuel market