

**Co-firing of fossil fuel with biomass**

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# Introduction

Current EU policy is aimed to increase the share of renewables in the energy mix to a clean and efficient use of traditional resources and to reduce greenhouse gas emissions. This forces us to think about alternative ways of energy production. Co-firing of fossil fuel with biomass could be partly solution to realize 2020 goals.

We chose the topic of co-firing of biomass in coal fired power plants, because in our opinion it’s important to consider all possibilities for reaching a sustainable energy system. It is absolutely necessary to have an overall look at every technology which could help us to cope with the big problems of resource scarcity and human made climate change. Therefore we wanted to widen and deepen our knowledge in the case of co-firing biomass to be able to judge this technology due to technical, economical and ecological aspects. We want to see if it is a noteworthy technology for reducing the emissions of coal-fired power and heating plants. Moreover we want to see if the resource need of coal can be significantly minimized through co-firing biomass and eventually make the plants „greener“.

# Legislation

In the current EU legislation in the field of energetic set the direction mainly climate and energy package and the third energy package. Their requirements are or will be transposed to the national legislation of each EU member. The aim of climate and energy package is to:

* cut emissions in EU by at least 20 % of 1990 levels by 2020,
* improve energy efficiency by at least 20 % by 2020,
* achieve a 20 % share of energy from renewable sources in it’s gross final consumption by 2020.

The instruments to reach these goals are i. a. EU ETS directive (2003/87/ES) and directive on the promotion of the energy from renewable sources (2009/28/ES).

The Member States are to establish national action plans which set the share of energy from renewable sources consumed in transport, as well as in the production of electricity and heating, for 2020.

Czech Republic has to reach 13 %, Austria 34 % share of energy from renewable sources. Co-firing could be the partly way to realize these requirements.

#  Co-firing in world

Experiences with co-firing have lots of countries all over the world. The main representations have USA, Germany, Poland, Finland or Great Britain.

More than 190 energy sources have experiences with co-firing. Operation of these sources bring up to now these conclusions: [2]

* co-firing brings mainly reduction of $CO\_{2}$, which combination with EU ETS and subsidies makes the fundamental role on the economics of the operation mode,
* there is a cut emissions $NO\_{x}$ and $SO\_{2}$, volume depends on the kind of co-fired biofuel,
* possible amount of co-fired biofuel depends mainly on the kind of firing system,
* there arew effeciency losses on the order of percent,
* depending up to the kind of biofuel, there is possible to happen sedimentation, slagging or corrosion.
* investment cost depends first of all on the inevitable alterations of biolers and fuel transport tracks

##  Co-firing in Czech Republic

The history of co-firing in Czech Republic could be divided to several phases. In the first phase (1993 – 1998) it happened to installation of fluidized bed-combustion systems of ČEZ, a. s., the combustion tests became since 1999. [3]

In the period 2002 – 2004 was the purchase price same for co-firing and combustion of pure biofuel. It meant a great impulse for the development of co-firing. [3]

Diversifiing bonuses for co-firing and combustion of pure biofuel from 2005 correspond with logical reduction of interest. [3]

Since 2007, there was a further diversification of subsidies. There are mainly supported combustion of power plants and waste from agriculture and forest. [3]

In Czech Republic have emerged three main groups of power producers co-firing biofuels: [3]

* ČEZ, a. s. which is dominant - 4 power plants, 1 cogeneration plant,
* Pulp and paper industry Štětí, Paskov (waste production)
* Cogeneration plants – Pilsen, Krnov, Olomouc, Otrokovice…

Co-firing involves in electricity production from biofuels for more than 50 %. Time evolution of gross electricity production from biofuels and its contribution to meet the indicative targets are seen in the following table: [4]

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 |
|  | GWh | GWh | GWh | GWh | GWh | GWh |
| Biomass in sum  | 564,5 | 560,2 | 731,0 | 968,1 | 1170,5 | 1396,2 |
| Wood chips etc. | 265,2 | 222,5 | 272,7 | 427,5 | 603,0 | 650,0 |
| Cellulose extracts | 272,8 | 280,5 | 350,0 | 474,5 | 458,5 | 500,5 |
| Plant materials | 20,8 | 53,7 | 84,4 | 26,4 | 23,1 | 72,9 |
| Pellets a briquettes | 2,6 | 4,4 | 23,8 | 39,2 | 84,5 | 164,1 |
| Other biomass |  - | 0 | 0 | 0 | 1,4 | 8,6 |
|  | **%** | **%** | **%** | **%** | **%** | **%** |
| Share RES in sum on gross consumption | 4,0 | 4,4 | 4,9 | 4,7 | 5,1 | 6,7 |
| Share biomass on gross consumption | 0,8 |  0,8 | 1,0 | 1,3 | 1,6 | 2,0 |

Eletricity generation of biofuels, where a large share goes to co-firing significantly contributes to the indicative target of 8 % share of renewable electricity I n gross domestic consumption in Czech Republic in 2010.Biofuel consumption increased from 681 354 t in 2007 to 1 073 926 in 2010. That confirms the growing role of biofuels in the energy field.The maximum biomass share on gross consumption depends also on the potential of biomass production. The most used in Czech Republic are wood chips. But their potential is almost abandoned. The biggest potential is so in short totation woody crops and herbaceous biomass fuels. [6]

## Co-combustion plants in Austria at the example of St. Andrä and Zeltweg

The pulverized coal firing plant of St. Andrä is an interesting example where the co-combustion of diverse biomass has been tested. In January 2000 the test cycle became authorised till January 2002. The goal was on the one hand to find out about suitable sizes of the derived fuels, as well as to find out about the optimal fuel mix , storage and availability. On the other hand the impacts on the emissions, quality of the residual material and on the operating system in general were aimed to be found out. [[1]](#footnote-1)

Amongst others bark, wood waste, waste paper, sewage sludge, carcass meal and even synthetics have been co-fired. The test showed that the co-firing of different substances is possible without any greater adoptions of the plant. Moreover it resulted that the co-fired amount is depending on the chemical composition of the fuels and on the capacity of the plant.

The different fuels were stored depending on the group they belonged. For example the wood waste, the bark and the sewage sludge were stored at the regular coal storage, whereas the carcass meal was kept in a special silo.

All in all the combustion process worked very well with all derived fuels, except of animalistic fats and waste oil. In this case, especially in greater amounts, there had been problems with scorification.

In general it had positive effects if some mixtures between the derived fuels have been made. So was it for example better for the combustion performance of wood waste, if bark was mixed into. Furthermore the size of the fed fuel was of importance

The measured emissions were at any time significantly under the defined emission limit values and moreover there has been a reduction of the CO2 emissions. But nevertheless the co-combustion had impacts on the quality of the residual material. To avoid economic losses through a worse quality of the residual waste there should thus be paid special attention to the co-fired amount of some derived fuels. At the end of the first testing cycle the quality of the residuals has been worse than before, but they were still usable. But due to the previous knowledge, the co-fired amount should not be increased in terms of the residuals. [[2]](#footnote-2)

Another example for a pilot project of co-firing of biomass and waste is the pulverized coal firing plant in Zeltweg. There biomass and waste have been gassed for the co-combustion with coal. In the first testing period different kinds of biomass, like bark, woodcut or sawdust were used for co-firing. In the second period also sewage sludge was used. But due to economic reasons the plant was shut down.[[3]](#footnote-3)

# Technological aspects of co-firing

The great majority of biomass co-firing worldwide is carried out in large pulverized coal power boilers, and the focus in this section is very much on this type of plant. The basic cofiring options relevant to pulverized coal-fired power plants can be categorized as follows:

1. direct co-firing, which involves the direct feeding of the biomass to the coal firing system or the furnace;
2. indirect co-firing, which involves the gasification of the biomass and the combustion of the product fuel gas in the furnace;
3. Parallel combustion, which involves the combustion of the biomass in a separate combustor and boiler and the utilization of the steam produced within the coal plan steam and power generation systems.

**4.1 . Direct cofiring**

The direct co-firing approach can be implemented in a number of ways. The first option involves the mixing of the bio-fuel with the coal upstream of the coal feeders, and generally within the coal conveying system. The mixed fuel is then processed through the installed coal milling and firing system. This is the simplest option and involves the lowest capital cost. This approach has been applied widely for co-firing biomass materials in granular, pelletized and dust forms, generally at relatively low co-firing ratios.

The second option involves separate handling, metering, and comminution of the biofuel and injection into the pulverized fuel pipework upstream of the burners or at the burners. This option can permit co-firing at elevated levels.

The third option involves the separate handling and comminution of the bio-fuel with combustion through a number of dedicated burners. This approach involves significant modification of the combustion equipment and the furnace, and represents the highest capital cost direct co-firing option. It is, in principle, possible to inject the pre-milled biomass into the upper furnace as a reburn fuel for NOx emission control; however this option needs significant further development prior to full scale implementation. Some testwork has been carried out in small scale test facilities.

**4.2 Indirect co-firing**

The indirect co-firing approach is based on the gasification of biomass, with the product fuel gas being combusted directly in the coal-fired furnace. The main product of the gasification process is a low calorific value fuel gas, with the calorific value depending principally on the moisture content of the fuel. The other major products are:

• all of the biomass ash materials, including the alkali metals and trace metals;

• the tars and other condensable organic species;

• the Cl, N and S species.

In terms of the nature and cost of the installed equipment, the indirect co-firing is equivalent to the replacement of the comminution equipment by a gasifier, i.e. the gasifier can be regarded as being a form of bio-fuel pre-processing. On the scale of operation relevant to most utility boiler co-firing projects, the preferred systems for biomass gasification are airblown, atmospheric pressure, circulating fluidized beds. There are a number of gasification technologies of this type, from a number of suppliers, in demonstration or commercial operation.

One of the key issues with indirect co-firing approach is the degree of the fuel gas

cleaning prior to co-combustion in the coal-fired furnace.

**4.3 Parallel co-firing**

Parallel firing involves the installation of a separate combustor and boiler for the biomass to produce steam which, in turn, is used in the coal-fired power plant steam circuit.

Although parallel firing installations involve significantly higher capital investment than direct co-combustion systems, they may have advantages such as the possibility to use relatively difficult fuels with high alkali metal and chlorine contents and the production of separate coal and biomass ash streams.

# Ecological aspects of co-firing

 In this chapter the impacts of co-fired biomass on the emissions and the ash, which occurs during the combustion process, are discussed. In the first paragraph the emissions which arise in a combustion process and their effects on the environment are explained in general. Afterwards the influence of the co-combusted biomass on the emissions and the ash of a coal-firing plant are depicted, with a special view at the different types of plants.

**Classical air pollutants and their impacts**

To the classical air pollutants count SO2, NOX, CO, HCl and dust particles.

SO2 occurs when burning sulphurous fuels.[[4]](#footnote-4) It is one of the main causes for acid rain which damages trees, waters and buildings. Moreover it affects humans health through harming the lunges when it oxidizes. [[5]](#footnote-5)

Under the term NOx, the gases NO2 and NO are summarized.[[6]](#footnote-6) It is also one of the gases which are responsible for acid rain. Further it causes, together with other emissions like O3, smog.[[7]](#footnote-7) Because of the fat solubility of nitrogen oxides, they infiltrate very deep in the lungs and therefore can harm them seriously.[[8]](#footnote-8)

Another classical air pollutant is CO. It is produced through incomplete combustion.[[9]](#footnote-9) This gas is Iethal when breathed in big amounts. In this case the blood starts to absorb CO instead of O2 and so one is going to suffocate.[[10]](#footnote-10)

Hydrogen chloride is mainly produced when burning biomass. It is very acid and leads to the creation of hydrochloric acid on the surface of the respiration passages.[[11]](#footnote-11)

Another group of emissions that occur when coal or biomass are combusted are dust particles. Depending on the size of the particle they can cause smog and harm the respiration system. [[12]](#footnote-12) One important group of dust particles is the so called fine dust (PM10). Under this definition fall all particles with a diameter smaller than 10µm. These particles are especially dangerous for human health, because due to their small size they get over all protection mechanism of the human respiration system and can thus even get into the blood circulation.[[13]](#footnote-13)

**Carbon dioxide and its impacts**

Beneath the classical air pollutants and their obvious impacts also the greenhouse gas CO2, which is produced by burning fossil fuels like coal, has to be considered.

Unlike to the classical air pollutants CO2 does neither immediately cause damages for the human health nor are its impacts on the environment visible over a short period of time, but over the long run CO2 and other greenhouse gas emissions are changing our climate and thus cause tremendous changes of the environment and also of living conditions for humans and other species. Nevertheless a certain amount of greenhouse gases are necessary for keeping the temperature on earth stable and liveable. But through emission of CO2 and other greenhouse gases in atmosphere the natural concentration increases and so climate change is caused.[[14]](#footnote-14)

**Influence of co-fired biomass at the ecological aspects of a pulverized coal firing plant**

Most of the used coal-firing power plants are pulverized coal firing plants, for this reason the ecological aspects will be treated more in detail than in case of fluidized-bed combustion coal firing plants.[[15]](#footnote-15)

In general the co-combustion of wooden or straw shaped biomass has a positive effect on the emissions of pulverized coal firing plants. The SO2 emissions are reduced, because biomass has a lower sulphur concentration than coal and further some part of sulphur is bond in the ash. The NOx level of the emission also reduces due to advantages in combustion kinetics of biomass, although the total amount of nitrogen oxides in the fuel itself doesn’t change. In general the CO emissions don’t increase either, if the biomass is enough pulverized. In the case that straw is co-fired an increase of the hydrogen chloride rate has to be considered.[[16]](#footnote-16)

If sewage sludge is co-fired the impacts are not for every emission as positive as for wooden and straw shaped biomass. So leads co-firing of sewage sludge to a higher concentration of SO2, NOx and volatile heavy metals. As consequence it may be necessary to install additional exhaust cleaner.[[17]](#footnote-17)

In view of the carbon dioxide emission, co-firing of biomass has very positive effects, because biomass is seen as CO2 neutral.[[18]](#footnote-18) This results from the fact that all the CO2 which is released during the combustion was absorbed by the plants during photosynthesis.

The co-combustion of biomass has also impacts in term of the exhaust cleaners. In general a low-dust cleaner for the denitrification system should be favoured compared with a high-dust cleaner. That is because in case of a low-dust cleaner there are already some exhaust cleaners connected upstream. A high-dust cleaner in contrast bears the risk that the catalyser collapses.

However the co-firing of wooden and straw shaped biomass releases the exhaust-desulphurisation system through the lower concentration of sulphur.[[19]](#footnote-19)

If wooden or straw shaped biomass is burned, the filter for the ash is less strained, because of the smaller amount of ash, than in case of the sole coal firing. On the contrary when sewage sludge is burned the amount of ash increases and can even lead to an overload of the filter.

If the ash should be used for cement or recultivating of surface mining, it should be kept in mind that the composition of the ash changes when biomass is co-fired. Especially in the case of sewage sludge there can be a higher percentage of toxic components.[[20]](#footnote-20)

**Influences at the ecological aspects of a fluidized-bed combustion firing plant**

The impact on the emissions in fluidized-bed combustion coal firing plants is quite the same than in pulverized coal firing plants. If wooden or straw shaped biomass is co-combusted there are reductions in the SO2 and the NOx emissions. There has to be paid attention to the percentage of hydrogen chloride, if straw is co-fired.

Also if sewage sludge is co-combusted the emissions are within the regular limits of variation, but the higher amounts of ash should be considered.[[21]](#footnote-21)

#### Economical aspects of co-firing

The majority influence on the economic point of view of co-firing have green bonuses, cost of emissions allowance and the cost of biofuel. By co-firing are collected green bonuses for each generated MWh. The co-firing reduce CO2 emissions. The measure depends on the share of biofuels in the burning mixture. The amount of saved CO2 emission essentially affects to the economy of operation. On the one hand, the value of saved emission allowances, the price of saved coal, the revenues from green bonuses and cost savings for lower emissions. On the other hand, there are costs of biofuel, specific investment costs, costs incurred not sold electricity or change of income tax.
Investment costs affects mainly by the need of revision of routes and boilers [6]:
•The reconstractuon of existing fluidized-bed coal boilers to biomass boilers;
•The modification the existing grate-shaped boilers to biomass boilers;
•The building new fluidized-bed boilers to biomass boilers;
•The modification storing space tens of millions of CZK;
•The construction of new routes for fuel;
•The construction of dryers for biomass.
The price of biofuels is also an important factor. Since the price is higher than the price of coal it is need to support of co-firing.
On the basis of calculations [5] is a small co-heating plant with a fluidized-bed boilers economically advantageous for a 10% share of biofuel in the heat. It is always depends mainly on the specific situation, the need of technological changes, the price and availability of biofuels.

#### Summary

Increasing concerns about the environmental impacts of power generation from fossil fuels have prompted the development of more sustainable means of generating power. These have included increasing the fraction of renewable and sustainable energy in the national energy supply. Historically, renewable energy sources have struggled to compete with fossil energy, due to their relatively high costs, and high technical risk.

The co-firing of biomass with coal in conventional coal-fired boilers can provide a

reasonably attractive option for the utilization of biomass for the generation of power, and in some cases heat. Co-firing makes use of the extensive infrastructure associated with the existing fossil fuel-based power systems, and requires only relatively modest additional capital investment. In most countries, the co-firingof biomass is one of the most economic technologies available for providing significant CO2 reductions.

Overall, therefore, the principal driver for the increasing demand for the capability to co-fire biomass materials in new and existing coal boiler plants is that co-firing is regarded as representing a very attractive option for biomass utilization, and for the delivery of renewable energy, in terms of the capital investment requirement, security of supply, power generation efficiency and generation cost. This is recognized in the EC Biomass Action Plan (2005), and by a number of member state and other governments, who have introduced specific financial instruments to encourage biomass utilization and co-firing activities at existing and future coal-fired power plants.

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18. (Bachhiesl, et al. 2001, 62) [↑](#footnote-ref-18)
19. (Nussbaumer, et al. 2009, 591-592) [↑](#footnote-ref-19)
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21. (Nussbaumer, et al. 2009, 597-598) [↑](#footnote-ref-21)