FLUIDIZED BED CONVERSION OF BIOMASS AND BIOMASS WASTE IN AUSTRIA

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ABSTRACT: In Austria the utilization of biomass and biomass waste has a long history. At the moment eleven fluidized bed combustors and three fluidized bed gasifiers utilizing biomass or biomass waste operate with a thermal capacity of around 640 megawatts (MW) and 33 MW, respectively. Around two third of the installed capacity, coming from eight fluidized bed combustors (FBC), use the circulating fluidized bed technology. In general, the FBC plants can be assigned to two industries: the electricity and heat producing industry and the pulp and paper industry. Here, biomass is utilized by the electricity and heat producing industry, whilst the pulp and paper industry utilizes biomass waste in form of bark, waste wood and rejects. The three biomass gasifiers utilize biomass and can be related to the electricity and heat producing industry.

This work aims to give an overview of the existing FBC plants and the employed technology in Austria with a special focus on the fuel processing and flue gas treatment. In addition, differences in the fuel processing as well as in the flue gas cleaning process of biomass and biomass waste plants are analyzed. This also addresses the specific needs of the different fuels on the basis of fuel properties.

For this purpose, the existing FBC plants are categorized according to their related industry, bed type, fuel processing and flue gas cleaning. The insights gained are used to deduce the differences in fuel processing and flue gas treatment systems of the two different types of fuel. Moreover, selected systems are examined in more detail in order to obtain the state-of-the-art fuel processing and flue gas treatment systems of FBCs utilizing biomass and biomass waste in Austria.

Keywords: fluidized bed, biomass, gas cleaning, pretreatment

1 INTRODUCTION

Fluidized bed conversion of biomass and biomass waste fuels is very common due to the possibility to use heterogeneous fuels with varying calorific values and moisture contents. In Austria fluidized bed combustors (FBC) are employed for different purposes: thermal treatment of municipal solid waste and municipal sewage sludge and generation of heat and power for public or internal heat and power supply [1–3]. At the moment more than 20 FBC plants having a capacity of over 1,000 MW_{th} are under operation. Additional, three fluidized bed gasifiers (FBG) having a capacity of 33 MW_{th} exist.

This work focuses on the fuel pre-processing and flue gas treatment systems of Austrian FBCs and FBGs utilizing mainly biomass and biomass waste fuels. Thus, in a first step the plants utilizing biomass fuels are identified. Furthermore, plant details like the related industry, utilized fuels, bed type and their flue gas treatment system configuration are investigated. Furthermore, the fuel specific pre-processing steps are analyzed by investigating the employed pre-processing steps of the different plants. Based on the analysis, the difference between biomass and biomass waste fuels are deduced.

Furthermore, two selected plants are investigated in more detail to obtain the Austrian state-of-the-art of fuel pre-processing and flue gas treatment systems.

2 FLUIDIZED BED PLANTS UTILIZING BIOMASS AND BIOMASS WASTE FUELS

Eleven of the more than 20 FBC plants, having a total capacity of 640 MW_{th}, utilize biomass and biomass waste fuels. Additionally, all three FBG utilize biomass as a fuel. In this work biomass and biomass wastes fuels do not include municipal sewage sludge. The FBC and FBG plants can be related to two different industries according to their purpose. Plants related to the pulp and paper industry were designed for internal heat and power supply, whereas plants related to the heat and power industry were designed for public heat and power supply.

Table I shows the identified FBC and FBG plants, their bed type, thermal capacity and related industry.

Table I: Plants utilizing biomass and biomass waste fuels in Austria, Sources: [1–5]

location	bed type[a]	capacity [MW_{th}]	related industry[b]
Bruck	BFBC	15	PP
Frantschach	CFBC	61	PP
Gratkorn 1	CFBC	25	PP
Gratkorn 2	CFBC	133	PP
Güssing	FBG	8	HP
Hallein	BFBC	30	PP
Heiligenkreuz	BFBC	43	HP
Lenzing	CFBC	108	PP
Oberwart	FBG	10	HP
Pitten	BFBC	60	PP
Steyrermühl	CFBC	48	PP
Timelkam	BFBC	49	HP
Villach	FBG	15	HP
Simmering	CFBC	66	HP

[a] BFBC: bubbling bed
CFBC: circulating bed,
FBG: fluidized bed gasifier

[b] PP: pulp and paper industry
HP: heat and power industry

The utilized fuels differ from plant to plant and depend on the availability and operating efficiency. In order to investigate the difference of the fuel pre-processing and flue gas treatment systems between high and low quality biomass fuels, an insight to the utilized fuels is needed. The utilized biomass fuels differ widely and include bark, waste wood, residual wood, wood chips, sawdust, sludges and rejects.

In this context sludges are fiber sludges from the production process and internal accrued sludges from waste water treatment. The difference between waste wood, wood chips and residual wood is defined as follows:

- Waste wood: wood which was used for a specific purpose, e.g. furniture or timber.
- Wood chips: chopped wood logs
- Residual wood: includes the wood of the whole tree.

Rejects are production wastes, which occur in the waste paper recycling process. They can include high amounts of impurities and synthetics.

Table II gives an overview of the utilized biomass fuels for each FBC and FBG plant.

Table II: Utilized fuels and flue gas treatment system configurations of the selected FBC and FBG plants, Sources: [5–8]

location	utilized biomass fuels
Bruck	bark, sludge, rejects
Frantschach	bark, sludges
Gratkorn 1	bark, sludges
Gratkorn 2	bark, sludges
Güssing	wood chips
Hallein	waste wood, rejects, residual wood, sludges
Heiligenkreuz	residual wood
Lenzing	bark, waste wood, sludges, rejects
Oberwart	wood chips
Pitten	sludges
Steyrermühl	bark, waste wood, wood, sludges, rejects
Timelkam	bark, waste wood, wood, sawdust
Villach	wood chips
Simmering	residual wood

3 PRE-PROCESSING SYSTEM AND FLUE GAS TREATMENT SYSTEM CHARACTERIZATION

3.1 Investigation of the fuel pre-processing systems

In this section, the fuel pre-treatment systems for the different fuels are investigated. For this purpose, the fuel pre-processing systems of the selected FBC and FBG plants are investigated. The pre-processing steps are condensed to four categories, since different equipment and processes are employed at different sites. The categories are: shredding, sieving, metal separation and drying. In this work shredding is defined as all measures to decrease the fuel size. Sieving includes all measures, which change the fuel size distribution by removing particular fuel size fractions. Metal separation includes all measures to remove ferrous- or non-ferrous metals from the fuel. Drying includes all measures to decrease the moisture content of the fuel, like mechanical or thermal drying.

Table III shows the applied pre-processing steps for the different fuels. The steps for the different fuels represent a combination of the applied steps of all plants for the specific fuel.

The analysis shows that sawdust is the only fuel which is utilized without any pre-treatment. All other fuels have to be pre-treated before utilization. In general, the complexity of the pre-treatment depends on the quality of the fuel. High quality fuels like wood chips and residual wood are only chopped. However, in case of external chopping, delivered forest wood is sieved and metals are separated. FBG plants dry the wood chips before gasification. Bark is either utilized as delivered or in some cases bark is shred, dried and metals are separated. Since rejects are already shred, depending on the quality, they are sieved, dried and metals are removed. The pre-treatment of sludges is limited to drying.

Table III: Applied fuel pre-processing steps, Sources: [6–10]

fuel	shredding	sieving	metal separation	drying
bark	X		X	X
rejects		X	X	X
residual wood	X	X	X	
sawdust				
sludges				X
waste wood	X	X	X	
wood chips	X			X[1]

[1] in case of gasification

3.2 Investigation of the flue gas treatment systems

In this section, the flue gas treatment systems of the different FBC and FBG plants are investigated. The common flue gas cleaning actions for FBC plants include a de-acidification with limestone or similar additives in the fluidized bed. NO_X is reduced by either a selective non-catalytic (SNCR) or a selective catalytic reduction (SCR) with urea or ammonia water. Furthermore, gravity and/or centrifugal separators, a dry flue gas cleaning using an adsorbent like active carbon and fabric and/or electrostatic filters are employed for dust and heavy metal removal. Figure 1 shows the principle assembly of the different cleaning devices in the flue gas treatment system.

None of the investigated plants employs all cleaning technologies. Since during gasification most impurities degas to the product gas, the subsequent combustion of the gasification residues releases minor pollutant amounts [11]. Thus, the flue gas cleaning system FBG plants consists of fabric filters only.

All FBC plants employ at least gravity separators and fabric filters for the flue gas cleaning. Furthermore, many FBC plants employ de-acidification for the reduction of sulfur oxides emissions. FBC plants with more complex flue gas cleaning systems were permitted and constructed between 2000 and 2010 and generally have lower legal emission limits than the plants commissioned earlier. Thus, the flue gas cleaning systems consist of additional components: dry flue gas cleaning for organic compounds and heavy metals and SNCR or SCR DE-NO_X systems.

Table IV shows the flue gas treatment system configuration of all selected FBC and FBG plants.

Table IV: Flue gas treatment system configurations of the selected FBC and FBG plants, Sources: [6,8–10,12]

location	flue gas treatment system[1]
Bruck	C, F
Frantschach	C, F
Gratkorn 1	C, F
Gratkorn 2	C, E, F
Güssing	F
Hallein	B, C, E, F
Heiligenkreuz	B, C, E, F
Lenzing	A, C, E, F
Oberwart	F
Pitten	A, B, C, E, F
Steyrermühl	A, C, E, F
Timelkam	A, B, C, E, F
Villach	F
Simmering	A, C, D, E, F

[a] A: de-acidification
B: SNCR
C: gravity and/or centrifugal separator
D: SCR high-dust mode
E: dry flue gas cleaning
F: electrostatic and/or fabric filter

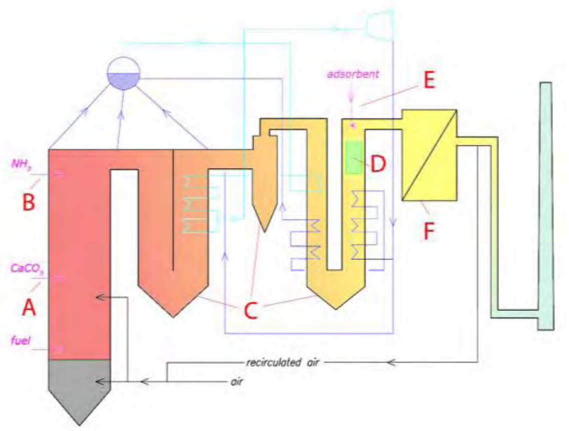

Figure 1: General system configuration of flue gas treatment systems of fluidized bed combustors and gasifiers. A) de-acidification B) selective non-catalytic reduction (SNCR) C) gravity and optional centrifugal separator D) selective catalytic reduction (SCR) in high dust mode E) dry flue gas cleaning system F) electrostatic and/or fabric filter, based on [1]

Since the legal emission limits depend on the plant license, the investigated plants have to comply with different emission limits for sulfur oxides, nitrous gases and others [6,12]. Thus, it is difficult to deduce the influence of the fuel type to the flue gas treatment system design from the gathered data.

However, by assuming that the different fuels are mono-combusted in the same plant and taking into account the impurity concentrations of the different fuels, influences can be determined. Furthermore, by neglecting any effect that reduces the pollutant concentration in the flue gas, e.g. air staging or desulfurization and dechlorination by alkaline and earth alkaline compounds [13] and taking into account the impurity contents of sulfur, nitrogen and chlorine from Table IV, following influences of the utilized fuel to the flue gas treatment system may be determined.

Since the lower quality fuels have higher impurity contents, the capacity and efficiency of the flue gas treatment system has to be higher than for higher quality fuels. If the cleaning capacity of the employed treatment systems is exceeded, cleaning systems having higher capacities and efficiencies like wet flue gas cleaning systems have to be employed [14].

Table V: Sulfur, nitrogen and chlorine contents of the utilized biomass and biomass waste fuels, Sources: [15,16]

	sulfur [wt-% daf]		nitrogen [wt-% daf]		chlorine [mg/kg DM]	
fuel	min	max	min	max	min	max
bark	-	0.3	0.4	2.0	124	421
rejects	0.1	0.1	0.2	0.3	2709	8045
residual wood	-	0.3	0.1	1.2	34	1368
sawdust	-	-	0.1	0.2	336	336
sewage sludge	1.1	2.4	2.3	8.5	500	4000
fiber sludge	-	2.0	0.2	1.9	455	2326
waste wood	0.6	0.6	0.2	1.8	126	9800
wood chips	-	0.4	0.1	2.2	-	1100

3 FUEL PRE-PROCESSING AND FLUE GAS TREATMENT SYSTEMS OF SELECTED FBC PLANTS

In order to deduce the state-of-the-art of fuel processing and flue gas cleaning in Austria, the plants Hallein and Simmering are investigated. The plants were chosen because they were commissioned recently and one utilizes exclusively biomass and the other utilizes a mixture of biomass and biomass waste.

Table II and Table IV show the utilized fuels and the flue gas cleaning system configuration of both plants. The fuel pre-processing systems are described in this section.

Since the plant at Hallein can utilize both, biomass and biomass waste fuels, the fuel pre-processing system consists of a pre-processing line for each fuel. Bark, residual wood and wood chips are pre-processed by a drum chipper, while waste wood is chopped using a shredder. Sludges are mechanically dried employing a belt thickener and an angle press. Rejects are drained with a screw press. The fuels are transported to the boiler by different transportation systems.

Since the FBC plant Simmering utilizes only residual wood, the pre-processing system is simpler than the system of the FBC plant Hallein. The residual wood is shred externally, thus, there is no shredding system at the site. However, outsizes and potential metal impurities are removed by a sieving plant and a metal separation system, respectively. The pre-processed fuel is stored in a fuel silo and fed to the combustion chamber passing a dispenser.

The differences in the fuel pre-processing systems show that the complexity of the system increases with number of different fuels utilized. Moreover, the importance of removing impurities is evident from the application of sieving systems and metal separators. A crucial step is the removal of metal and oversized parts from the fuel because they may disturb bed fluidization or plug the ash handling [13]. Thus, state-of-the-art fuel pre-processing systems aim to maximize the operation time between planed shutdowns and to reduce the number of emergency shutdowns.

The flue gas treatment systems of both plants are very similar. The differences are that the Simmering plant has a de-acidification system and a SCR in high dust mode instead of a SNCR. Considering both flue gas cleaning systems the Austrian state-of-the-art for biomass and biomass waste fuels is defined as follows: if necessary a de-acidification of the flue gas is performed by adding limestone to the combustion process, while nitrous gases are reduced by SCR or SNCR. Dust is removed by gravity and/or centrifugal separators and fabric and/or electric filters. Furthermore, calcium hydroxide and hearth furnace coke are employed for removing acidic gases, heavy metals and organic compounds [14]. The adsorbent end-up in the filter system.

The de-acidification in the fuel bed reduces the acidic components in the flue gas system and, thus, reduces the corrosion potential. Moreover, deposit formation depends, among other compounds, on sulfur and chlorine compound concentrations in the flue gas. Therefore, the de-acidification may has a significant impact on deposit formation and agglomeration [14,17]. Since gravity and centrifugal separators reduce the dust concentrations in the flue gas between the combustion zone and the first super heaters or evaporators, they also reduce the formation and agglomeration of deposits [17]. Basically, the dry flue gas cleaning system, the filter system and the $DeNO_X$ system are employed for complying with legal emission limits.

4 SUMMARY AND CONCLUSION

In this work, the fuel pre-processing and flue gas treatment systems of Austrian FBC and FBG plants utilizing mainly biomass and biomass waste fuels was investigated. Moreover, the utilized fuels were ascertained and the influence of the fuel type to the pre-processing and flue gas treatment system was investigated. In addition, two plants were investigated in more detail to derive the state-of-the-art of fuel pre-preprocessing and flue gas treatment systems of FBC plants in Austria.

The results show that fuel pre-processing system complex if different fuels are utilized. Moreover, the quality of the fuel influences the elaborateness of the pre-processing system: low quality fuels like waste wood and rejects usually are freed from impurities, whereas high quality fuels like wood chips or residual wood are usually utilized without pre-treatment (except of chopping).

Since the legal emission limits of the investigated plants are specified in the plant license, the emission limits vary among the investigated plants [6,12] and no direct derivation of the fuel type influence on the flue gas treatment system is possible. However, by taking into account the impurity concentrations of the different fuels, influences can be determined. Low quality fuels have higher impurity contents and, thus, require flue gas treatment systems with higher cleaning capacities compared to high quality fuels. If the employed flue gas treatment sub-systems described in Figure 1 are insufficient cleaning systems with higher capacities and efficiencies, like wet flue gas cleaning systems, have to be employed.

The state-of-the-art of fuel pre-processing systems includes measures for the removal of impurities in order to maximize the plant’s lifetime. State-of-the-art flue gas treatment systems consist of diverse sub-systems for different pollutants. Acidic gases are removed by either dosing limestone to the fluidized bed or dry adsorption with calcium hydroxide in the flue gas or a combination of both. Heavy metals and organic compounds are removed by dry adsorption with hearth furnace coke. In both cases, the loaded adsorbent is removed from the flue gas with filter systems. Furthermore, the filter systems and gravity and centrifugal separators are employed for dust removal. NO_X is removed with either SNCR or SCR systems.

5 ACKNOWLEDGEMENTS

The IEA FBC Implementing Agreement is kindly thanked for fruitful discussions and the BMVIT for the financial support.

6 REFERENCES

[1] A. Purgar, F. Winter, Chemie Ingenieur Technik 85 (2013) 303–307.

[2] A. Purgar, Technologien Österreichischer Wirbelschichtverbrennungsanlagen. Master thesis, Vienna, 2012.

[3] F. Winter, P. Szentannai, IEA Fluidized Bed Conversion Programme: Status Report 2010, 2010.

[4] F. Winter, IEA Wirbelschichttechnologie (FBC) Arbeitsperiode 2009 – 2013, 2014.

[5] F. Winter, P. Friebert, P. Szentannai, in: IFSA 2008 Industrial Fluidization South Africa, 2008.

[6] J. Stubenvoll, Technische Maßnahmen zur Minderung der Staub- und NO_X-Emissionen bei Wirbelschicht- und Laugenverbrennungskesseln, Umweltbundesamt, Wien, 2007.

[7] Josef Kendlbacher, Plant visit. oral, Hallein, 2012.

[8] Wien Energie GmbH, Biomassekraftwerk, 2015, http://www.wienenergie.at/biomassekraftwerk, accessed 27 May 2015.

[9] Energie AG, Umwelterklärung: Für das Kraftwerk Timelkam, 2013.

[10] Energie Burgenland GmbH, Biomassevergasung, 2015, http://www.energieburgenland.at/oekoenergie/biomasse/innovation/biomassevergasung.html, accessed 27 May 2015.

[11] M. Kaltschmitt (Ed.), Energie aus Biomasse: Grundlagen, Techniken und Verfahren, 2nd ed., Springer, Dordrecht, Heidelberg, London, New York, NY, 2009.

[12] H. Stoiber, Stand der Umsetzung der Abfallverbrennungsverordnung: Erhebung von Anlagen, die mit 28.12.2005 der Abfallverbrennungsverordnung entsprechen müssen, sowie deren Anpassungsbedarf hinsichtlich Luftemissionen ; Endbericht, Umweltbundesamt, Wien, 2007.

[13] Handbook of combustion, Wiley-VCH-Verl, Weinheim, 2010.

[14] R. Karpf, emissions - related energy indicators, TK-Vlg, Nietwerder, 2014.

[15] Energy research Centre of the Netherlands, Phyllis2: database for biomass and waste, 2012.

[16] K. Reisinger, C. Haslinger, M. Herger, H. Hofbauer, BIOBIB: A database for biofuels.

[17] A. Zbogar, F. Frandsen, P.A. Jensen, P. Glarborg, Progress in Energy and Combustion Science 35 (2009) 31–56.