CO-FIRING LOW COST FUELS USING INDIRECT GASIFICATION

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INTRODUCTION

Indirect gasification offers the advantage of using low cost fuels in installations with strict fuel requirements. Pulverized coal boilers are using hard coal as their main fuel, but for different reasons other cheaper fuels could be acceptable as well. However, cheaper fuels typically mean more problems in downstream equipment. Indirect gasification offers the solution for many of these fuel related problems. The following paper describes tests with different types of fuel, such as lignite, demolition wood and grass as feedstock for an indirect gasifier. It will also give a comparison with direct gasification, which is already common practice for co-firing applications. The paper will outline the advantages indirect gasification has over direct gasification and will quantify the economic advantage it has over direct co-firing.

This is the main conclusion: Indirect gasification is fuel flexible, has a 100% conversion of the fuel and reduces the load of impurities to the boiler compared to direct co-firing with more than 80%. It can operate at low temperatures and still obtain full conversion of the fuel. The electricity production price with indirect co-firing is estimated at 5.1 €ct/kWh compared to 8.2 €ct/kWh for direct co-firing.

GASIFICATION OF LOW COST FUELS

Gasification of fuels offers the possibility of feeding materials to a pulverized coal gasifier that would not be possible when fed in a solid form. Gasification can be done with several technologies. A bubbling fluidized bed gasifier (BFB) being one of the simpler approaches. Circulating fluidized bed gasification (CFB) is already applied. In Geertruidenberg (NL) an 80 MW_{th} Lurgi CFB gasifier is used to convert demolition wood into a combustible gas used in a 600 MW_e PC boiler. In Ruien (B) a Foster Wheeler CFB is producing 45-70 MW_{th} producer gas for the largest fossil fuel fired plant in Belgium.

At the Energy research Centre of the Netherlands (ECN) a new innovative indirect gasifier has been developed. This indirect gasifier (MILENA) is capable of gasifying different fuels at different temperatures. The laboratory scale gasifier MILENA operates on all kind of fuels, ranging from beech wood, lignite, straw, RDF and grass [1-3].

In [3] the experiments are described in more detail and a small summary is given in table 1. This shows the load of impurities to the boiler, which is the sum of dust and gas phase components that will pass through the cyclone (see figure 3). One experiment is straw pellets gasified at 690°C and the other a mixture of beech and RDF (57 wt.%) gasified at 680°C. On average it can be concluded that for low temperature gasification the slip of impurities to the boiler is between 0 – 20 %. The reduced load to the boiler is related to the low gasification temperature in the MILENA gasifier. There is no penalty, such as decreased carbon conversion, because all remaining char is still burned in the combustor of the MILENA. Direct gasification technologies have a direct link between temperature and fuel conversion The LT-CFB is a technology especially developed for difficult fuels that can operate at low temperatures in order to minimize the load of impurities to the boiler and they report a conversion of 95% [4].

Table 1: Load of impurities to the PF boiler based on low temperature gasification experiments [3]

	Straw pellets	RDF 57 wt% Beech 43 wt%	
K	7.9	1.3	%
Na	9.2	0.5	%
Cl	12.5	12	%
P	17	3.3	%

The results of these test showed the possibility to gasify in the indirect gasifier, the change in gas composition based on input, the alkali distribution at low temperature gasification and the change in equilibrium temperature for different fuels. These results led to the idea of using indirect gasification for co-firing.

GASIFICATION OPTIONS

There are many technologies capable of gasification, but not all of them are suitable for co-firing. To identify the technologies most suited, some prerequisites are set. First of all the technology needs to be available at larger scale, secondly it should be fuel flexible and lastly there should be a freedom to the fuel size for using this technology. For these reasons fixed bed and entrained flow gasifiers are not regarded as feasible. Fixed bed gasifiers tend to be of a smaller scale and have limits to fuel size and type of fuel. Entrained flow gasifiers are available on very large scale, but have strict requirements for fuel and fuel size.

The more logical choice is fluidized bed gasification, which also comes in different setups (see figure 1). The easiest is the direct gasifier in a bubbling fluidized bed (left frame in figure 1). These gasifiers consist of a bed of sand fluidized with air (or steam/oxygen) that partly burns the fuel and provides a combustible gas. It can reach considerable scale for applying in a co-firing option and is fuel flexible. However the biggest downside is the low conversion of fuel.

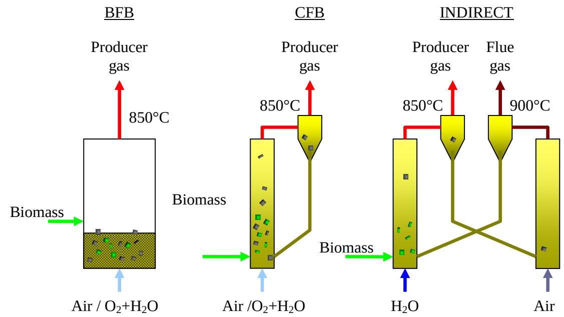

Figure 1: Schematic comparison of BFB, CFB and allothermal gasification

A CFB gasifier more or less has the same conversion as a BFB. However, because of the fast fluidizing regime this type of reactor is of a larger scale. This technology used to be popular in the pulp and paper industry to supply gas for the lime kilns and currently is used for co-firing applications. The biggest disadvantage of this technology is the limited conversion of fuel. The ashes coming from the producer gas always contain carbon and lead to a stream of waste. Sending the producer gas straight to a boiler will increase the load of impurities significantly. Secondly the gasification with air leads to a nitrogen diluted producer gas, increasing volumes and reducing the calorific value.

The approach used and developed by ECN is indirect gasification. In this process, combustion and gasification are separated in two different reactors. The heat generated by combustion is transported via bed material to the reactor where gas is produced via gasification. In figure 2 a schematic overview of the MILENA gasifier is given. It normally operates around 850°C for gasification of wood, but temperatures will need to be much lower when grass or straw are gasified. The gasifier has operated at temperatures as low as 650°C. In [3] more information on low temperature gasification is given.

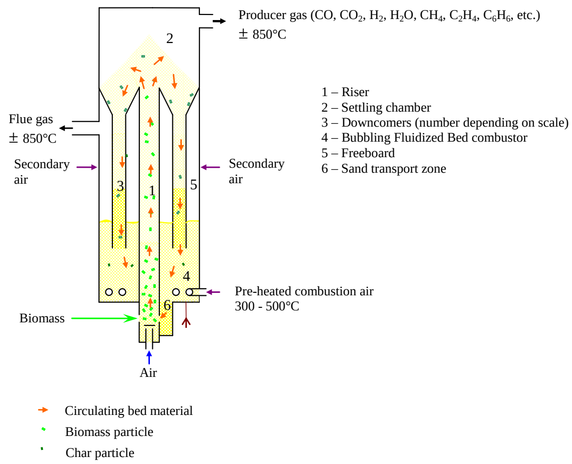

Figure 2: Schematic overview of the indirect gasifier MILENA

The decoupling of gasification and combustion leads to several advantages. First of all the producer gas is not diluted with nitrogen. Secondly the bulk of the ashes are ending up in the flue gas resulting in less ash going to the boiler. This is mainly achieved by operating at lower temperatures to keep the impurities in the solid phase. The ash from the producer gas is returned to the combustor, so that energy loss from unburned carbon is avoided. Another big advantage is that no fuel is lost, so 100% conversion can be achieved. It has the fuel flexibility of a fluidized bed gasifier and can be scaled up to more than 100 MW_{th} input.

ECONOMIC PROFITABILITY

The economic profitability will be determined by comparison with direct co-firing. Direct co-firing has the advantage of low investment costs, but needs a cleaner and thus more expensive well defined fuel. The indirect gasifier can handle cheap (more difficult) fuels, but will be more expensive to build. The assumptions for the comparison are given in table 2.

Both installations will have a 100 MW_{th} input. The availability for the direct approach is high, since these installations mainly consist of pellet mills that are directly connected to the burners. The indirect co-firing availability is chosen a little bit lower, since the technology is more complex. Because it is more complex and some cooling is required, the efficiency to electricity is slightly lower.

Table 2: Assumptions for the economic comparison

assumptions:	direct	indirect	
input capacity	100	100	MW
availability	7500	6500	h/y
efficiency	40%	38%	e/th
power income	0.10	0.10	Euro/kWh
capex	100	1050	Euro/kWe
capex	2	40	Meuro
fuel costs	9	2	Euro/GJ
fuel costs	135	30	Euro/ton
fuel costs	32	7	Euro/MWh
capital costs	15%	15%	%/y
O&M costs	5%	5%	%/y

The power income for both cases is the same and set at 0.10 €/kWh. The CAPEX for the pellet mills is about 2 M€ based on a price of 100 €/kW_e. For the MILENA this price is chosen substantially higher. It is based on in-house engineering and a reference of Metso, where a 140 MW_{th} plant was constructed for 40 M€ [5]. The feeding system, the gas cooling and gas cleaning needed in this line-up are causing the price difference between direct and indirect (see figure 3).

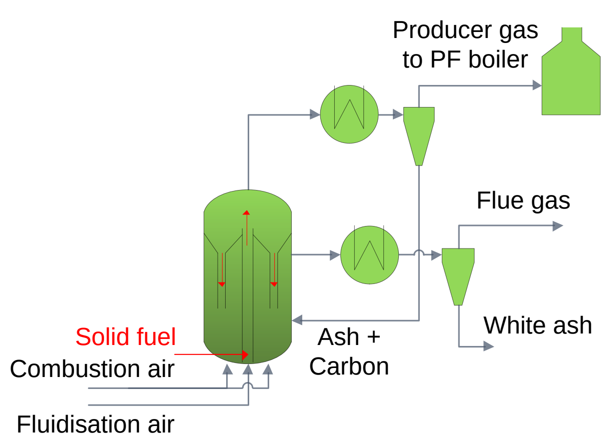

Figure 3: Schematic line-up of indirect gasification for co-firing application

The fuel price is also an important factor. The pellet mills may be relatively cheap to buy, but direct co-firing requires an expensive and clean fuel, since all impurities end up in the boiler. A pellet price of 9 €/GJ [6] is currently the standard and it is expected to be rather stable the coming years. If it changes it will probably go up. The fuel price for the indirect gasifier is different. Typical prices are 45 €/ton for clean waste wood and if it contains impurities (glass, nails, gypsum etc.) it has a price of 30 €/ton. For more contaminated waste wood (railroad ties) it is probably even cheaper. In this case 30 €/ton was used for the calculation.

For the depreciation of the capital costs a 15%/y is fixed. Based on the capital costs is also the operation and maintenance (O&M) fixed at 5%.

Table 3: Financial results for both cases

	direct	indirect	
capital costs	0.6	6.0	M€/y
O&M costs	0.2	2.0	M€/y
fuel costs	24.3	4.7	M€/y
power income	30.0	24.7	M€/y
profit	**4.9**	**12.0**	**M€/y**

The overall picture for both cases is summarized in table 3. This shows the annual profit and it shows the build-up of this profit. For direct co-firing 97% of the costs is fuel, which most likely will not really change. For indirect gasification as a means of indirect co-firing, the costs are spread a little. Roughly 50% of the costs are CAPEX, 40% is fuel and 10% is O&M. The two biggest factors can be tuned. For the indirect co-firing case the price assumption is based on in-house engineering and on one of the first plants of Metso. It is expected that the CAPEX will decrease with every next plant constructed and the fuel price can become lower if more difficult fuels are used. However, even with this case already the annual profit is 12 M€/y for the indirect gasification approach and roughly 5 M€/y for the direct approach. The CAPEX can still double for the indirect approach and still be equally profitable as direct co-firing. A fuel price increase for the indirect gasification can be allowed 2.5 times than assumed in this model.

The more interesting comparison between the two approaches is based on production price for the electricity. It is assumed that the PF boiler is excluded in the calculation and the assumptions made in table 2 still hold. However, the electricity price is varied for both cases as to reduce the profit to zero. The electricity price now is equivalent to the production price. For the direct co-firing case an 8.2 €ct/kWh is assumed and for the indirect co-firing case a production price of 5.1 €ct/kWh is assumed.

CONCLUSIONS

Indirect gasification is an advanced technology for converting low cost fuels, typically problematic fuels, into a fuel gas for pulverized coal installations.

Indirect gasification reduces the load of impurities to the boiler compared to direct co-firing due to a.o. the possibility to operate at low temperature without an efficiency penalty. Less than 20% of the impurities will end up in the boiler.

Indirect gasification has a large economic margin compared to direct co-firing. The production price of electricity via indirect co-firing is 8.2 €ct/kWh, compared to 5.1 €ct/kWh with direct co-firing. This margin allows for fuel prices to increase 2.5 times for the indirect approach or a doubling of the capital costs and still being able to compete with direct co-firing.

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