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USC TECHNOLOGY IN CCT BOILERS APPLYING BIOMASS COFIRING

by

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Introduction

Previously BWE has been reporting about the USC boiler technology in Denmark that was developed in the 1990s as a CCT technology operating at high steam parameters to reach high overall efficiencies. Two of these plants NVV3 (Nordjyllandsværket) and AVV 2 (Avedøreværket) have been operating succesfully since 1998 and 2001 respectively reaching 50.000 and 25.000 operation hours with high availabilities.

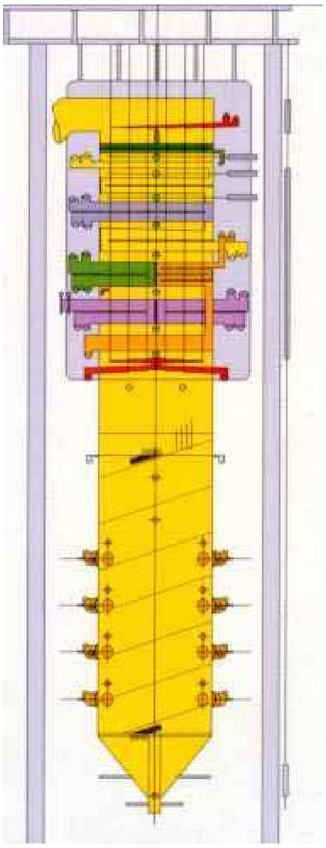

Figure 1. NVV3 boiler.
T-firing. Double reheat system.
Boiler house roof level 85m.

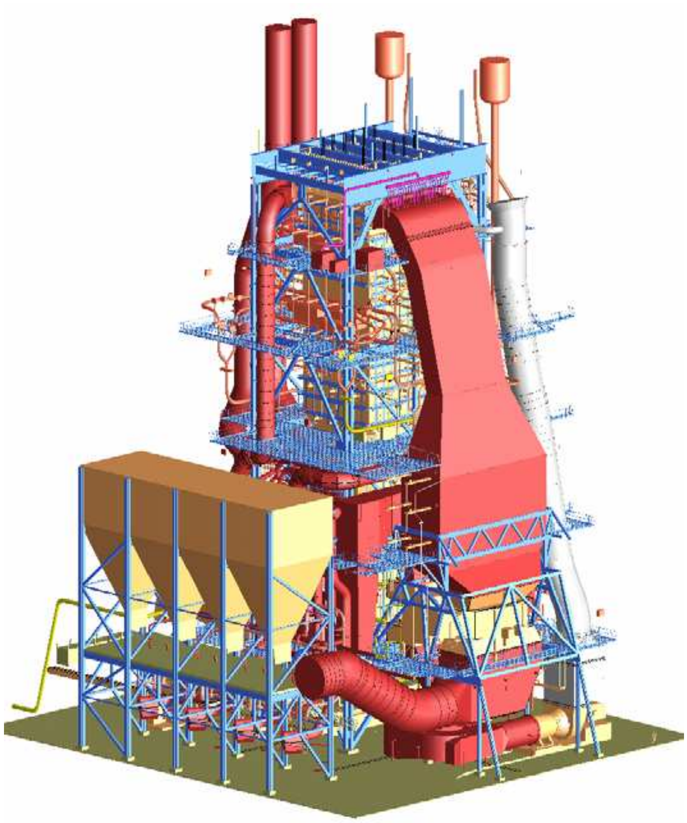

Figure 2. AVV2 boiler.
T-firing. Single reheat system.
Boiler house roof level 90 m.

Both of these boilers are designed for coalfiring and NVV 3 has always been running on coal while AVV 2 as fossil fuels has been using HFO (Heavy Fuel Oil) and NG (Natural Gas). In 2002 BWE installed the complete firing plant for coal firing on AVV 2, however also to serve the purpose of applying cofiring of biomass fuel in combination with HFO and NG. Steam data and overall efficiencies can be seen in table 1.

Plant Name	NVV3	AVV2
Plant size MW(e)	400	400
Fossil fuel	C/HFO	NG/HFO
HP steam bar	290	305
- - ºC	582	582
IP1 steam bar	80	74
- - ºC	580	600
IP2 steam bar	23	
- - ºC	580	
Efficiency	47	49

Table 1. Steam data and efficiencies.

Figure 3. Openings for burners and over burner air in a furnace corner.

These boilers are designed as tower type boilers having tangential firing systems with circular burners. The total combustion system is designed for staged combustion and contains following components:

- Mills
- Burners
- Over Burner Air system
- Over Fire Air system

The circular burners have axially concentric channels for primary, secondary and tertiary air - PA, SA and TA respectively. PA is also transport air for the pulverised fuel PF. The SA is swirled for stabilising the ignition front together with the flame holder. The TA is unswirled to improve its possibility to delay oxygen access for the long Low NOx flame. In the first combustion zone before the injection of the OBA the air ratio is slightly substoichiometric and then the OBA raises the value a little higher than 1.0. This procedure is repeated at each burner level. Finally the OFA is injected over the top burner level completing the combustion.

These 5 amounts of combustion air are giving very good staging possibilities providing a high degree of flexibility related to the fuel type. In figure 4 you can see the burners for AVV 2 before and after the modification to include also pulverised fuel. As can be seen it was relatively simple to make this modification and the burners are now capable of handling following types of fuel: HFO, NG, PF(coal), PF(biomass) . The following reporting of biomass co-firing will be referring to AVV 2.

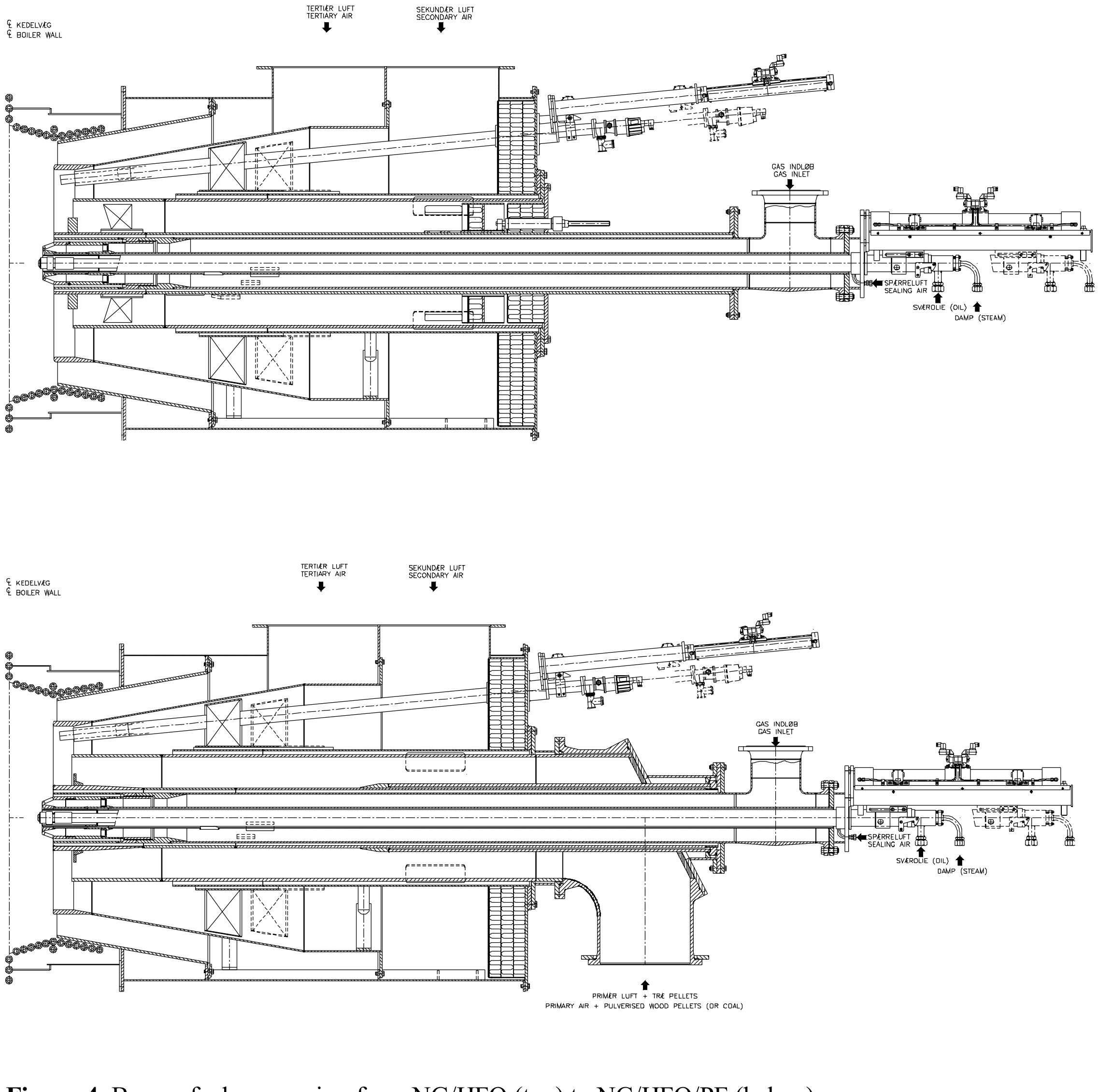

Figure 4. Burner fuel conversion from NG/HFO (top) to NG/HFO/PF (below).

Biomass firing in Denmark

In Denmark it has been agreed between the government and the main power generators that about 1.4 mill. tons/year of biomass must be used as a fuel for power generation. This has caused the installation of a number of stand-alone steam power units firing biomass on different grate systems. These units have been of a size between 2.5 and 35 MW(e) and they have been based on a principle of very little preparation of the fuel. Over a period of around 5 years they have reached a satisfactory mode of CHP operation, but the electrical efficiency is moderate, meaning not higher than 30 % and the plant size cannot be much larger than 35 MW(e). The total price for the plant is rather high, around 2000 Euro/kW. Also such units will typically be optimised for one type of fuel. This could mean a rather poor performance on other fuels, especially by varying moisture content.

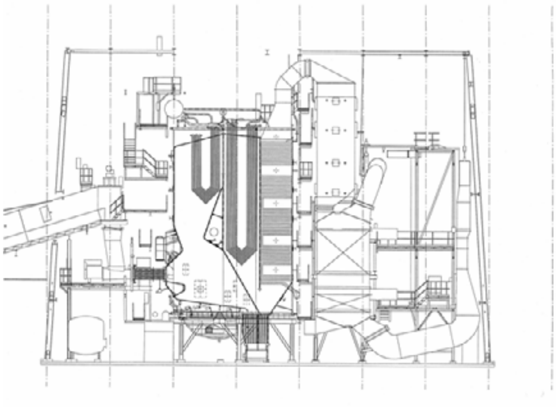

Figure 5. Biomass boiler for straw firing.

Figure 6. Biomass burning on a vibration grate.

By the Power Generators it has then been an increasing demand to have a higher flexibility in firing biomass fuels in terms of as well fuel as load flexibility while maintaining a high efficiency. This is where the principle of cofiring in USC boilers becomes interesting. If the biomass could be fired in a fossil fuel fired high efficiency boiler together with the basic fuel in the plant, then the high efficiency could also be achieved for the biomass component. We would then have reached additional fuel flexibility in the plant; however the existing load flexibility should simultaneously be maintained. Consequential measures will be some degree of fuel preparation for the biomass. These problems have been investigated and solved in Denmark in recent years in cooperation between power plant owner and boiler supplier.

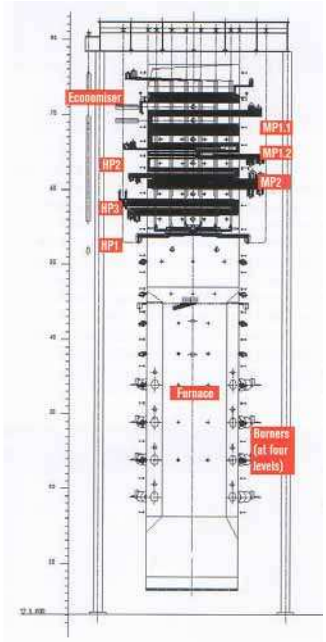

Figure 7. AVV Power Station. Unit 2 is the far one.

Figure 8. AVV2 USC boiler.

This development has taken place on the Avedøreværket unit 2 (AVV 2) in a joint operation between plant owner (Energi E2) and boiler supplier (Burmeister & Wain Energy). AVV2 is for the main system a USC CCT plant. The boiler plant is designed and now fully equipped for coal firing, however not yet approved to run on coal. In the meantime the fossil fuels at disposal have been Heavy Fuel Oil (HFO) and Natural Gas (NG).

Firing biomass in the AVV 2 boiler means the fuel must be prepared as a pulverised fuel before being injected into the furnace. In Denmark the biomass fuel can be any kind of wood waste or straw from the agricultural fields. To make these materials grindable it is necessary first to transform them into pellets. This may sound expensive, but it contains a very efficient split of the problems in handling biomass fuels into 2 groups: Collection, Pelletising and Storage, Combustion. The first group can be established where convenient for the collection and will lead to a product which is well adapted for transport to and storage at the power station, because the pelletising will provide a volume reduction by a factor of 2.5 to 5 dependent on the fuel. See table 2.

At the power station only a normal fuel handling like storing and transporting locally to the fuel silo will be necessary. From the silo the remaining preparation will be done in the normal coal handling system like feeders, mills, PA-systems and burners.

Biomass	LHV MJ/kg	Density kg/m3	Ash % (dry)	Price €/GJ	Price €/ton
Straw	14.5	130	5	4.7	68
Straw pellets	15.0	600	5	6.7	100
Wood chips	10.5	250	0.5	3.4	35
Wood pellets	17.5	650	0.5	5.4	94

Table 2. Key figures for biomass in Denmark

The pellets must be stored under cover. Otherwise there will be no special requirements. The lifetime of the pellets will then be at least 1 year, which is sufficient. A pelletising station can be established for wood waste or straw. Energy E2 has established one large station having 2 lines, one for wood and one for straw. The distance between the power station and the pelletizing unit is about 50 km, but with convenient transport communication by sea.

Wood Pellets

The wood will enter the pelletising line in form of wood chips. The moisture content can be as high as 45 % which requires a drying unit in the line. The drying is performed by superheated steam in a closed loop where the heat is regained. The chips are ground to a size of 2 mm before entering the drier. After drying the product is processed in a pelletising mill where the material is pressed through a matrix where 8mm pellets are produced in lengths of 25 to 40 mm. Capacity of this line: 180.000 tons per year.

Figure 9. Waste wood as received at the pelletising plant.

Figure 10. Wood chips made from waste wood.

Figure 11. Wood pellets. Made of wood chips after grinding, drying and compression.

Figure 12. Pelletising mill.

Figure 13. Pelletising mill, rotor and matrix.

Straw pellets

The straw is arriving at the pelletising station in Hesston bales of 500 kg. After being loosened - cutting of strings – the straw is separated from rocks and metallic items and ground in hammer mills to same sizes as the wood product and then pelletised. Capacity: 110.000 tons per year.

Combustion

The combustion system on the AVV 2 USC boiler is a tangential fired system having circular burners mounted in the corners on 4 levels. The burners were in 2002 modified to be multi-fuel burners.

Figure 14. Multi fuel circular burner for tangential firing at AVV2.

Figure 14 shows the burner for 4 different fuels. The pipe for NG is in the front and further back is the PF pipe (large diameter). The PF can be coal or wood . Below you will see the hoses for HFO. The system is sized for making up to 70% of full load on wood from pellets. This capacity has been verified and the boiler is operating on wood without problems.

The deposits as shown in figure 15 are stable in size and doesn't give problems for the operation. Also the wide spacing of the bundles coming from design for a wide range of coals is a good measure for wood firing.

The ash content is low as seen in table 2. It is anyway advantageous to fire a little HFO together with the wood. It makes the deposits easy to handle by soot blowing and it is also improving the conditions for the SCR catalyst. A small addition of fly ash from coal also has a positive effect.

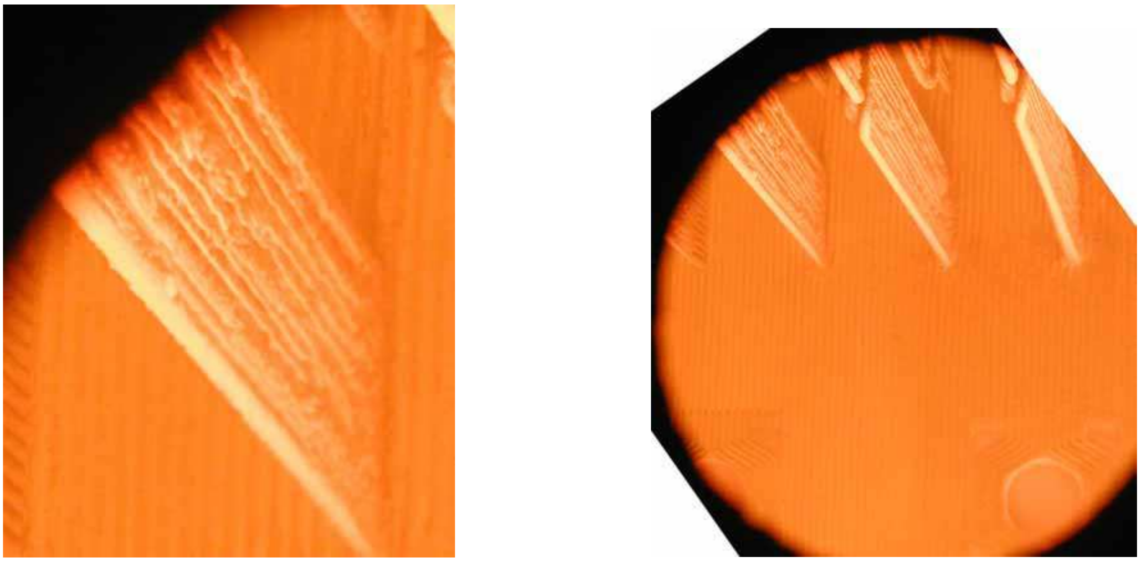

Figure 15. Superheater bundles above the furnace showing deposits from wood PF fuel.

Fuel flexibility

In figure 16 you will see an example of the high fuel flexibility in the plant. In the recorded period the unit has simultaneously been running on the fuels HFO, NG and Wood. Most of the period the load has been around 75%, however the fuels have varied frequently in their contribution. It can be observed that quantities for all 3 fuels can vary a lot relatively and that also the wood load can be changed quite fast. Altogether the cost of electricity has been maintained within relatively narrow limits around 20 øre/kWh (1 øre = 0.13 € cent).

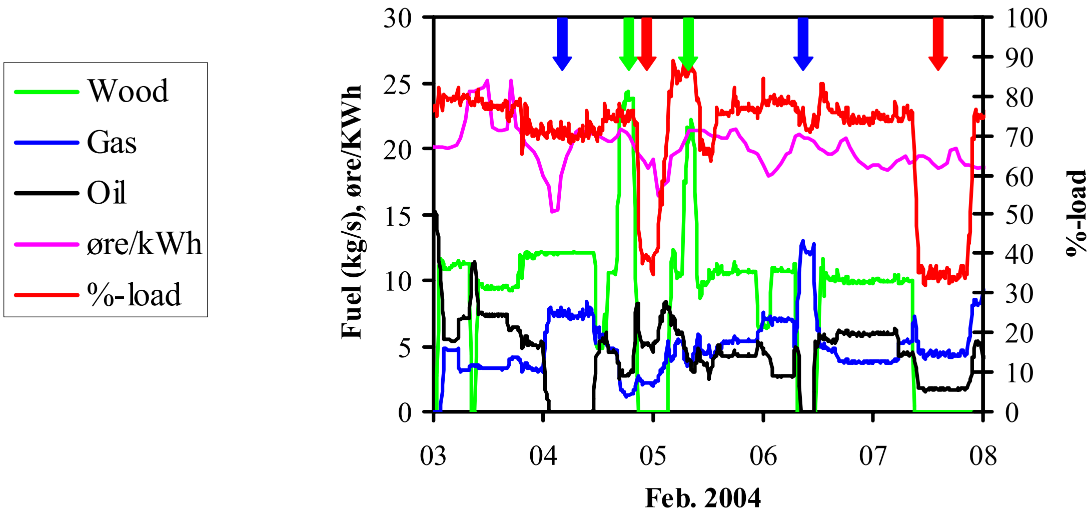

Figure 16. Fuel flexibility from the plant record.

Corrosion

There are a lot of difficult substances in biomass fuels and they can be very complicated to handle in grate firing systems. But, in a PF system it is quite easy to use additives for abatement of harmful matter. Such additives will be loaded in the pelletising mill or in the pulverising mill to be mixed and injected with the fuel. In figure 17 there is an example of compounds in the ash from wood pellets (yellow columns). As additive is simply used coal ash, and HFO is used as cofired fossil fuel. It follows from the resulting fly ash mix (red columns) that all the harmful substances have been very much reduced by this simple and cheap method.

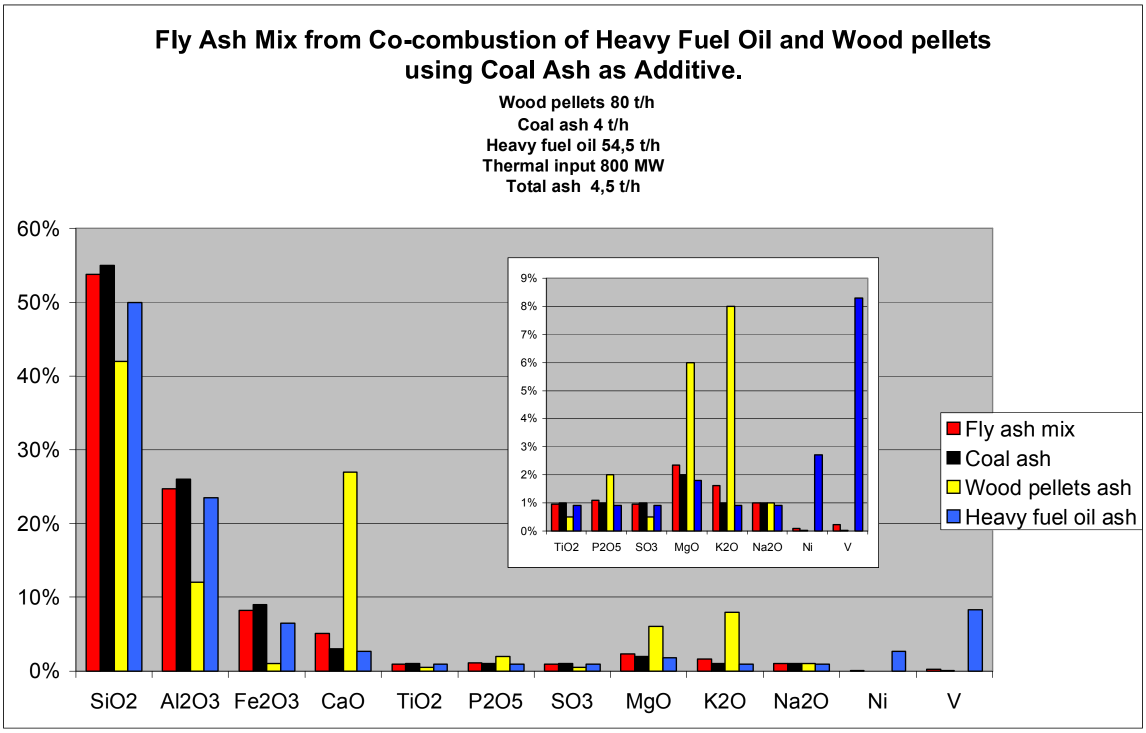

Figure 17. Restructuring of the ash from biomass fuel by a cheap additive.

Another example is Chlorine, which can be rather dangerous especially in flue gas from combustion of straw. In figure 18 you can see when the plant is running on NG and wood there will be formation of KCl which is a corrosive substance in the boiler. However, as soon as a part of the NG is replaced with HFO the KCl will disappear. Instead of KCl the Potassium will combine with Sulphur from the HFO to form K_2SO_4 which is much less harmful and easier to remove by soot blowing.

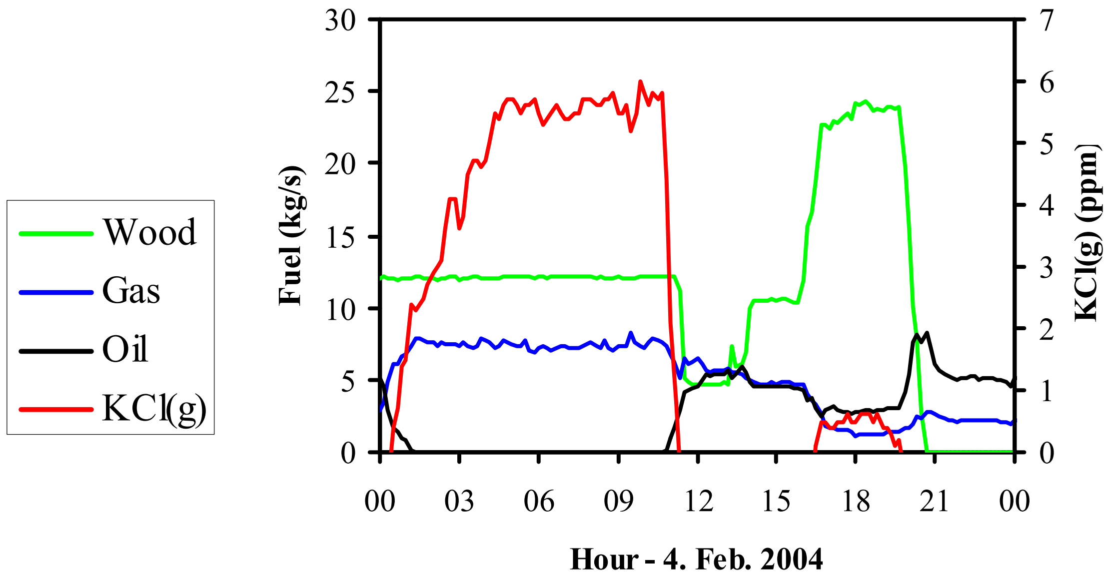

Figure 18. Abatement of KCl formation by means of HFO together with the biomass fuel

CO2 Performance

In figure 19 there's a diagram indicating the amount of CO2 emission from coal fired units having biomass cofiring. In a unit with the current European average efficiency of 37 % the emission is 930 g/kWh. A top modern USC plant with 47 % efficiency will emit 700 g/kWh, however having some of the thermal energy coming from biomass can bring down the emission to very low values, like 350 g/kWh by 50 % biomass cofiring. At AVV 2 P.S. up to 70 % of full load can be generated by biomass.

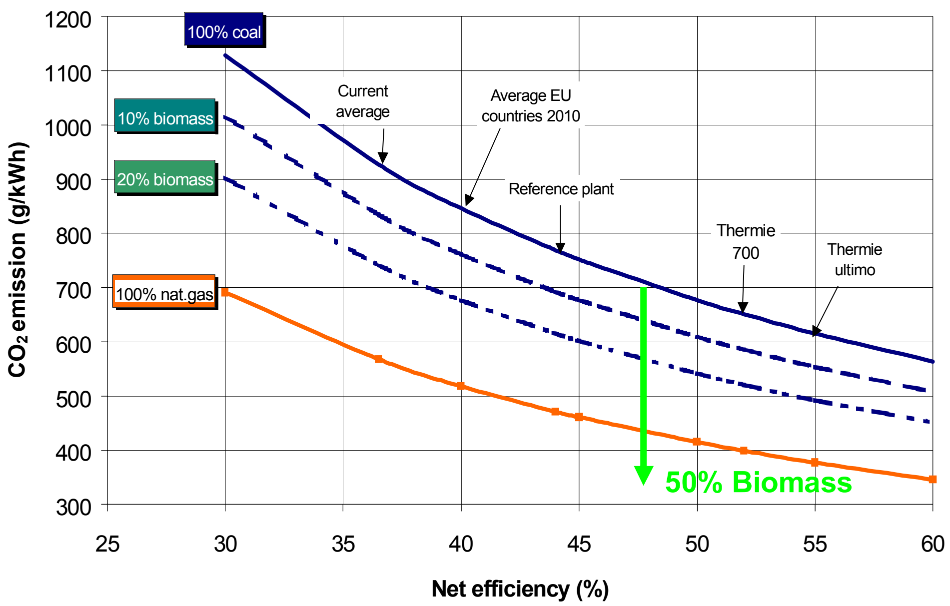

Figure 19. CO2 emission from a coalfired unit with biomass cofiring.

Conclusion

Over the last 20 years there has been a growing interest for using biomass as a fuel for power and heat generation. Biomass was at the beginning of this period seen as a waste product, something to dispose of. Historically seen biomass has always in limited amounts been used for heat generation and with the growing demand for handling of wastes without contamination of the environment it became a must to establish more sophisticated and higher capacity methods for the conversion of biomass to non-reactive substances of small volume. This brought forward the political interest for generation of power from biomass. Fossil fuels have been the tradition in power generation and to do the same with biomass fuels would mean to design boilers for generating steam power from the thermal energy in the biomass. Different methods have been developed, however in recent years there has been an interest for the possible simultaneous use of the 2 fuel types. The initiative came from the power generators who normally from the political side are wanted as partners in the development.

This turned out to be cofiring of biomass in modern power generating units basically designed for coalfiring. Such methods have been tested in several countries and also in Denmark. The technical results in recent years have been so promising that there is basis for some conclusions and basis for formulation of leads for further development.

- A utility boiler designed for coal firing will normally be adaptable for cofiring.
- The modern high efficiency USC boilers are especially interesting.
- Such boilers will be based on firing pulverised fuel, and the biomass fuel must have the necessary preparation to meet this requirement.
- From the stand-alone biomass fired units it is well known that biomass fuel can be difficult to handle due to substances not observed in fossil fuels.
- The experience now from cofiring is that some of these problems will disappear in the cofiring, or become easier to handle.
- The combustion system for PF-firing makes it easy to reach high capacities and to use cheap additives for the biomass fuel.
- The high capacity for the cofired fuel can be applied for reducing the amount of CO_2 emission.

And for the future development:

- Some systematic testing of combinations of specific fuels fossil/bio can be necessary.
- The sites for power stations are selected after criteria like access to cooling water and easy connection to the grid.
- Collection and preparation of biomass fuels must be organised after quite different criteria like many sources for biomass in the area, a good infrastructure for collection and transport, possible customers for process heat from a pelletising plant.
- After the biomass has been pelletised it can with good efficiency because of the volume reduction be transported over longer distances to power stations.

To optimise such development it can be necessary with political measures to make it interesting for investors. The benefit for the society will be a high quality handling and processing of biomass products giving electrical power without any harm to the environment.