External note

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Department ECN Policy Studies
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Subject Biomass co-firing in coal power plants in the Netherlands: effects on performance and air pollutant emissions

1 Introduction and rationale

This note is intended for use in the UNECE-EGTEI work related to cost of emission reduction technologies for large combustion plants (LCP). This work is coordinated by KIT (Karlsruhe) and CITEPA (Paris).

As the Netherlands is considered to be a valuable country for data regarding biomass co-firing in large coal fired power plants, EGTEI expressed its interest on data ECN has available. For this purpose, based on available data from annual environmental reports of power plants, ECN has looked into the relationship between the percentage of co-firing and the plant performance. It should be noted that the evaluation has been based on annual data, not on real-time simultaneous measurements of the different parameters mentioned in this note. Cumulative annual data give no insights in e.g. the effects of the load factor, of start-ups or shut-downs, seasonal circumstances, fuel qualities, etc. Therefore, the findings below should be treated with due care and not be generalised.

2 Available data

The available basic data from environmental reports of 6 coal and 3 gas/oil plants on plant basis cover the years 2000 to 2009 and consist of

- Capacity.
- Electricity production.
- Heat production.
- Fuel input.
- NO_x and SO_2 emissions.

It should be noted that not for all plants all annual data are available from the reports. No effort has been undertaken to fill these data gaps. Also lack of means prevented ECN to disclose more recent data, although plans exist to do so in the future.

Based on these data, the following data used for the evaluation have been derived:

- Full load hours (production/capacity).
- Electric efficiency (production/fuel input).
- Heat efficiency (production/fuel input).

- Total efficiency (electric + heat efficiency).
- Biomass co-firing percentage[1] (biomass input/ total fuel input).
- Specific NO_x and SO_2 emissions (per kWh output and per GJ fuel input).

Out of confidentiality, the plant names or locations are not mentioned in this note. For the same reason an aggregation of the plants into plant type data has been performed. Three types are distinguished: older coal plant, construction years 1970-1980 with +/-37% electric efficiency, new coal power plants (from 1990s with over 40% electric efficiency) and mixed gas and oil power plants. The coal plants' capacity is 510 MWe on average, ranging between 250 and 645 MW_e. The oil/gas plants' capacity ranges from 350 to 640 MW_e with an average of 543MW_e. No information about the age or operating conditions (cooling system, flue gas treatment) of the individual plants is available. However from some emission profile it could be deducted that de-SO_x installations have been installed or operated. Also, most data covers 2000 to 2007, few plants have data for 2008 and 2009. No data for more recent years is yet available at ECN.

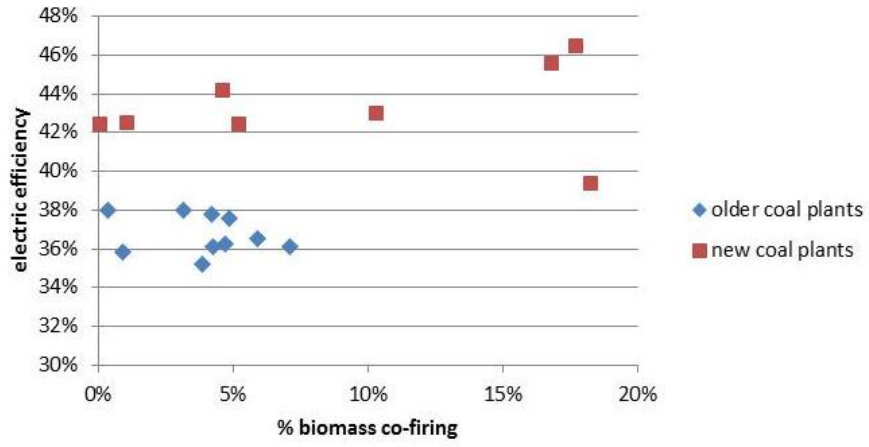
3 Analysis and conclusions

3.1 Co-firing in coal plants

From the data analysed, the following conclusions can be drawn:

- Previously biomass co-firing in pulverised coal plants was said to have an efficiency lowering effect compared to full coal fuelling, up to 5 or more per cent. Available data shows that there is no such clear relation between the amount of co-firing and efficiency reduction. A more robust statement would be that efficiency can be assumed to remain constant for co-firing percentages up to 20 per cent. (Figure 1 and 2)
- However, there seems to be a clearer relation between the load factor of the coal plants (relative amount of full load hours on annual basis) and electric efficiency. Increasing load factors (more regular operation during the year) has an efficiency increasing effect. (Figure 3)

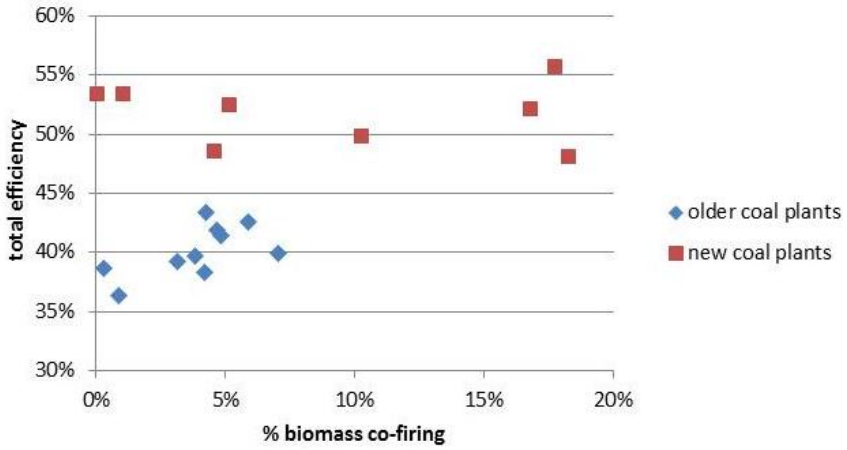
Figure 1: Relation between co-firing percentage and electric efficiency of coal plants



[1] The co-firing percentage is based on energy content.

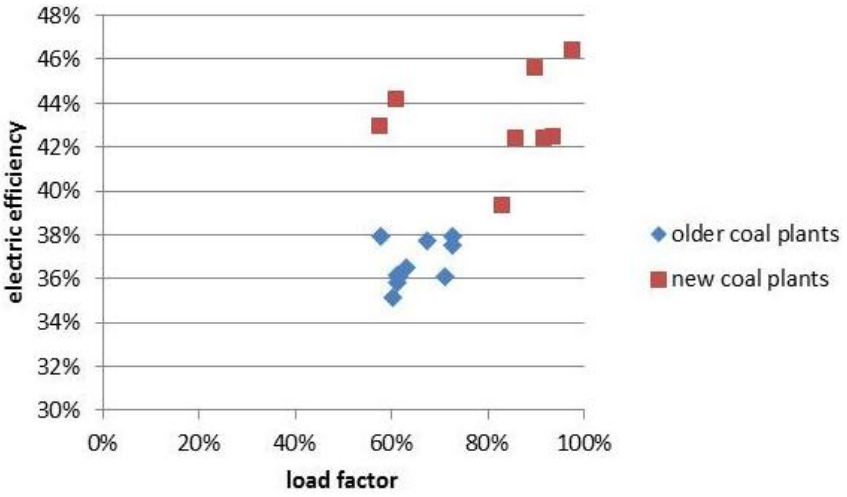
The coal power plants in the Netherlands mostly also produce heat (low temperature heat or district heating). The figure below illustrates the relationship between biomass co-firing percentages and the overall plant efficiency. Again, there is too little evidence to state that biomass co-firing lowers the plant efficiency substantially, at least not up to 20 per cent co-firing. Available data even show the highest efficiencies with higher percentages biomass co-firing.

Figure 2: Relation between co-firing percentage and total efficiency (electric + heat)



What does seem to be having an effect on the efficiency, is the annual load factor. With an increasing number of full load hours (shown relative to a full year in the figure) electric efficiency is also showing an increasing trend. As no details on operating conditions are known, care should be observed in generalising this effect.

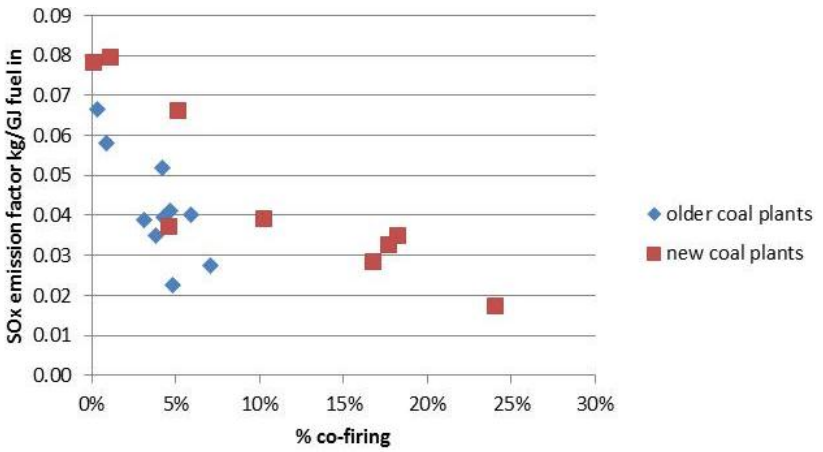
Figure 3: Relation between load factor (relative full load hours per year 8760 h =100 %) and the electric efficiency



The conclusion for the highly relevant corresponding NO_x and SO_2 emissions from co-firing, absolute or specific to output or input, is less clear. To assess these properly, much more information would be needed about the operation and performance of existing flue gas treatment systems during the years covered, and also the fuel characteristics (S-content). Moreover, the reported time series on

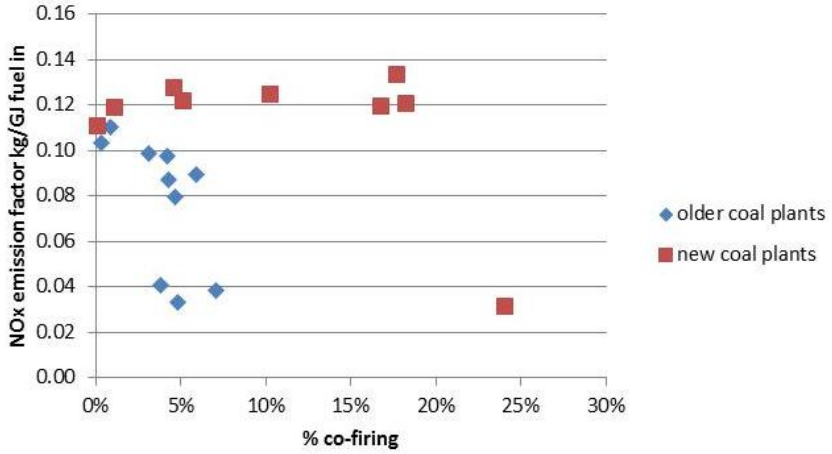
emissions are less complete than those of the energy data. Based on the incomplete information, no conclusions are drawn. Although it can be observed that there is an effect that increasing shares of biomass co-firing lower the specific SO_2 emissions. The figure below may seem to indicate such a trend, but when looking at the time scale of the annual data (see annex), most of the reduction is caused by other effects than the co-firing share (such as the use of low S-content coal or the operation of a de-SOx installation).

Figure 4: Specific SO_2 emissions (g/GJ fuel input)



For NO_x, the picture is even more indecisive: also here the lower emission factors (as observed in the later years) seem more to be caused by system changes (de-NO_x measures) than by the percentage of co-firing, see the figure below and the data in the annex.

Figure 5: Specific NO_x emissions (kg/GJ fuel input)

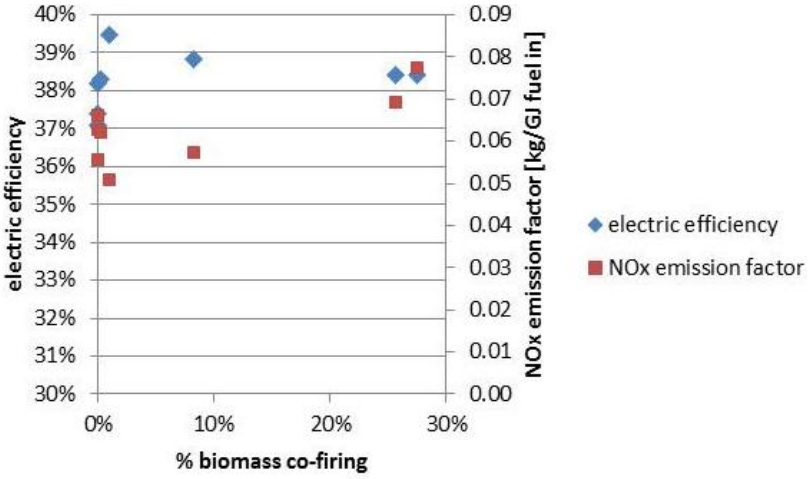


3.2 Co-firing in oil and gas plants

For the gas and oil plants in which co-firing occurred, less data is available and these plants do not have an additional thermal output like most of the coal plants. These plants also report biomass co-firing only in the period 2003-2007. From the data, again no hard conclusions on efficiency detoriation due to biomass co-firing can be drawn. The figure below represents the available data (electric

efficiency and specific NO_x emissions) related to the percentage of co-firing. The data suggest that NO_x emissions may increase with increasing biomass co-firing. Compared to the highest emissions with more than 25 per cent co-firing, somewhat lower emissions are also generated with no biomass co-firing.

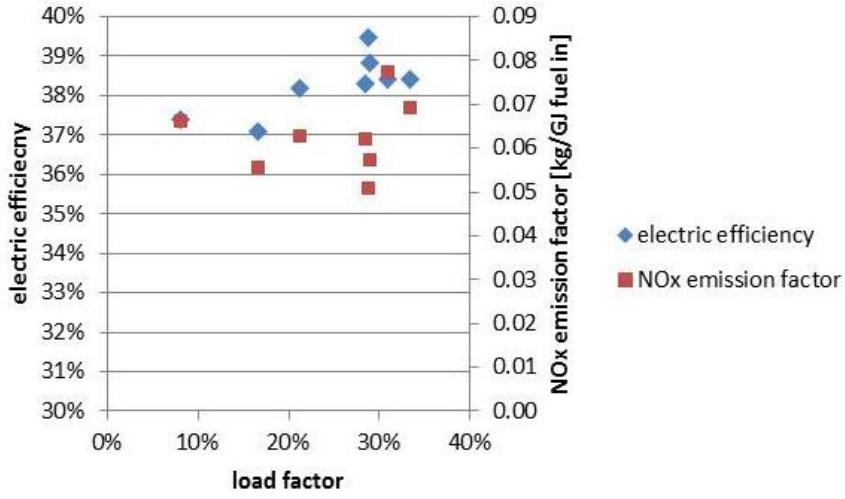
Figure 6: Relation between co-firing percentage and electric efficiency and specific NO_x emissions of oil/gas plants



The data available show that oil and gas plants concerned have a lower load factor than the coal plants. But similarly, a higher load factor indicates also a higher electric efficiency, as shown below. The picture for specific NO_x emissions is less clear, indicating that more information is needed then this annual load factor. Frequent start-ups and stops, the duration of partial and peak load operation, the available de-NO_x measures all have an expected influence on the emission factor which could not be retrieved from the available annual data.

Although some SO_2 emission data is also available for these plants, they are not considered as representative and have thus not been included in the analysis.

Figure 7: Relation between the annual load factor and electric efficiency and specific NO_x emissions of oil/gas plants



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Annex A Plant type based data used for this note

Table 1: plant type based data

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Older coal plants	**Electric efficiency [%]**	38.0%	35.9%	37.8%	38.0%	36.1%	36.5%	36.2%	35.2%	37.6%	36.1%
	Heat efficiency [%]	0.6%	0.5%	0.6%	1.3%	7.2%	6.0%	5.7%	4.6%	3.8%	3.8%
	Load factor [%]	57.7%	61.0%	67.3%	72.5%	71.9%	63.7%	61.9%	60.9%	75.1%	64.0%
	Biomass co-firing percentage [%]	0.3%	0.9%	4.2%	3.2%	4.3%	5.9%	4.7%	3.8%	4.8%	7.1%
	Specific NOx emissions [kg/GJ]	0.103	0.110	0.097	0.099	0.087	0.090	0.080	0.041	0.033	0.039
	Specific SO2 emissions [kg/GJ]	0.067	0.058	0.052	0.039	0.039	0.040	0.041	0.035	0.023	0.027
Newer coal plants	**Electric efficiency [%]**	42.4%	42.5%	42.4%	44.2%	43.0%	45.6%	39.3%	46.4%		
	Heat efficiency [%]	11.0%	10.9%	10.1%	4.4%	6.9%	6.6%	8.8%	9.2%		
	Load factor [%]	85.7%	93.4%	91.5%	60.7%	57.4%	89.6%	82.9%	97.4%		
	Biomass co-firing percentage [%]	0.1%	1.1%	5.2%	4.6%	10.3%	16.8%	18.3%	17.7%		24.0%
	Specific NOx emissions [kg/GJ]	0.111	0.119	0.122	0.128	0.125	0.119	0.121	0.133		0.032
	Specific SO2 emissions [kg/GJ]	0.078	0.080	0.066	0.037	0.039	0.028	0.035	0.033		0.017
Gas/oil plants	**Electric efficiency [%]**	37.4%	37.1%	38.2%	38.3%	38.8%	38.4%	38.4%	39.5%		
	Heat efficiency [%]	-	-	-	-	-	-	-	-		
	Load factor [%]	8.0%	16.7%	21.2%	28.4%	29.0%	30.9%	33.4%	28.8%		
	Biomass co-firing percentage [%]	0.0%	0.0%	0.0%	0.2%	8.2%	27.5%	25.7%	1.0%		
	Specific NOx emissions [kg/GJ]	0.066	0.056	0.063	0.062	0.057	0.077	0.069	0.051		
	Specific SO2 emissions [kg/GJ]	0.001	0.016	0.006	0.009	0.006	0.000	0.000	0.000		