SUMMARY: COST ANALYSIS OF REDUCING FLUE GAS EMISSIONS TO ACHIEVE BAT ASSOCIATED EMISSION LEVELS IN EXISTING BOILERS USING BIOMASS AND PEAT IN FINLAND

Approximately 60 existing boilers in Finland using biomass and/or peat as a main fuel will be subject to European Union BAT conclusions for Large Combustion Plants (LCP). Total fuel power of these boilers is almost 10 000 MW. In total, more than 250 existing boilers in Finland will be subject to LCP BAT conclusions.

Investments and emission reduction costs to achieve the future requirements regarding flue gas emissions in existing boilers using biomass and/or peat are studied based on the LCP BREF draft available in October 2015. The current emission level of the boilers is assumed to be based on the emission limit values set in EU Directive on Industrial Emissions. Also impacts of split views submitted by Finland are studied.

1 TOTAL INVESTMENT COSTS TO ACHIEVE BAT EMISSION LEVELS

To achieve the LCP BREF emission levels, additional costs are expected to 98 % of the boilers. Additional costs are due to investments to new flue gas emission reduction measures or improving the efficiency of existing processes for example by increasing the amount of chemical injection. New investments are estimated to be needed in more than 80 % of the boilers and total investment costs are estimated to be approximately 430 MEUR. Summary of the results is presented in table 1. In addition, annually about 31 million euros of additional operation and maintenance costs will occur.

If utilizing the split views submitted by Finland, new investments would be needed in about 60 % of the boilers. However, the total investment costs would be approximately 130 MEUR, presenting only about 30 % of the investment costs to achieve the draft BAT emission levels. The additional annual operation and maintenance costs are estimated to be 10 million euros.

In this study, the investment cost is calculated to annual capital costs by dividing cost over 10 years with a 5 % interest rate.

Table 1. Total investment costs related to emission levels based on draft BAT conclusions and split views submitted by Finland.

	Total number of boilers	Investment costs in total	
		Draft BAT emission levels	Split views
		[MEUR]	[MEUR]
Total	***59***	**431**	**129**
Less than 100 MW	*21*	82	14
100-300 MW	*32*	313	104
More than 300 MW	6	36	12

The emission reduction costs are presented in tables 2 and 3 and described in more detail in the following chapters. The annual emission reduction costs including required investment costs as well as operation and maintenance costs are presented in table 2 separately for boilers with new investment and for boilers with no new investments.

Table 2. Emission reduction costs to achieve BAT associated emission levels in existing boilers using biomass and/or peat in Finland.

	Boilers, with new investments required		
	SO_2	NO_X	HCl
	[EUR/t_{SO2}]	[EUR/t_{NOX}]	[EUR/t_{HCl}]
All boilers in average	24 600 (6200...309700)	12 700 (1000...151100)	359 000 (91900...1353900)
Less than 100 MW	20 300 (9700...48500)	11 200 (1000...66700)	587 000 (244000...1353900)
100-300 MW	27 700 (6200...309700)	13 900 (1600...151100)	238 900 (91900...397700)
More than 300 MW	18 900 (11100...26600)	8 800 (3200...14400)	360 200 (196700...523600)

	Boilers, with no investments required		
	SO_2	NO_X	HCl
	[EUR/t_{SO2}]	[EUR/t_{NOX}]	[EUR/t_{HCl}]
All boilers in average	1 100 (500...1400)	500 (470...470)	1 400 (100...2200)
Less than 100 MW	1 200 (900...1400)	500 (470...470)	1 400 (800...2200)
100-300 MW	1 200 (500...1400)	470 (470...470)	1 700 (400...2200)
More than 300 MW	460 (460...460)	470 (470...470)	270 (150...390)

Table 3. Emission reduction cost levels in boilers with new investments required.

Emission reduction costs in boilers with new investments			
Boilers less than 100 MW			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0 % (0 boiler(s))	12 % (2 boiler(s))	0 % (0 boiler(s))
2 500 - 5 000	0 % (0 boiler(s))	53 % (9 boiler(s))	0 % (0 boiler(s))
5 000 - 10 000	8 % (1 boiler(s))	12 % (2 boiler(s))	0 % (0 boiler(s))
10 000 - 15 000	42 % (5 boiler(s))	6 % (1 boiler(s))	0 % (0 boiler(s))
15 000 - 50 000	50 % (6 boiler(s))	12 % (2 boiler(s))	0 % (0 boiler(s))
50 000 - 100 000	0 % (0 boiler(s))	6 % (1 boiler(s))	0 % (0 boiler(s))
100 000 - 300 000	0 % (0 boiler(s))	0 % (0 boiler(s))	30 % (3 boiler(s))
> 300 000	0 % (0 boiler(s))	0 % (0 boiler(s))	70 % (7 boiler(s))
Boilers 100-300 MW			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0 % (0 boiler(s))	21 % (6 boiler(s))	0 % (0 boiler(s))
2 500 - 5 000	0 % (0 boiler(s))	18 % (5 boiler(s))	0 % (0 boiler(s))
5 000 - 10 000	30 % (6 boiler(s))	14 % (4 boiler(s))	0 % (0 boiler(s))
10 000 - 15 000	35 % (7 boiler(s))	29 % (8 boiler(s))	0 % (0 boiler(s))
15 000 - 50 000	30 % (6 boiler(s))	14 % (4 boiler(s))	0 % (0 boiler(s))
50 000 - 100 000	0 % (0 boiler(s))	0 % (0 boiler(s))	11 % (2 boiler(s))
100 000 - 300 000	0 % (0 boiler(s))	4 % (1 boiler(s))	63 % (12 boiler(s))
> 300 000	5 % (1 boiler(s))	0 % (0 boiler(s))	26 % (5 boiler(s))
Boilers more than 300 MW			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0 % (0 boiler(s))	0 % (0 boiler(s))	0 % (0 boiler(s))
2 500 - 5 000	0 % (0 boiler(s))	50 % (1 boiler(s))	0 % (0 boiler(s))
5 000 - 10 000	0 % (0 boiler(s))	0 % (0 boiler(s))	0 % (0 boiler(s))
10 000 - 15 000	50 % (1 boiler(s))	50 % (1 boiler(s))	0 % (0 boiler(s))
15 000 - 50 000	50 % (1 boiler(s))	0 % (0 boiler(s))	0 % (0 boiler(s))
50 000 - 100 000	0 % (0 boiler(s))	0 % (0 boiler(s))	0 % (0 boiler(s))
100 000 - 300 000	0 % (0 boiler(s))	0 % (0 boiler(s))	50 % (1 boiler(s))
> 300 000	0 % (0 boiler(s))	0 % (0 boiler(s))	50 % (1 boiler(s))

Emission reduction measures and cost levels differ in different boiler types. Almost all boilers studied are bubbling fluidised bed (BFB) or circulating fluidised bed (CFB) boilers. Numbers of BFB and CFB boilers in difference emission reduction cost levels are presented in table 4. Only boilers with new investments required to achieve the LCP BREF emission levels are included in the figures.

Table 4. Emission reduction costs in BFB- and CFB-boilers.

Emission reduction costs in BFB-boilers with new investments			
Boilers less than 100 MW [number of boilers]			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0	2	0
2 500 - 5 000	0	5	0
5 000 - 10 000	1	2	0
10 000 - 15 000	4	0	0
15 000 - 50 000	4	2	0
50 000 - 100 000	0	1	0
100 000 - 300 000	0	0	2
> 300 000	0	0	6
Boilers 100-300 MW [number of boilers]			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0	3	0
2 500 - 5 000	0	3	0
5 000 - 10 000	4	3	0
10 000 - 15 000	6	7	0
15 000 - 50 000	4	4	0
50 000 - 100 000	0	0	1
100 000 - 300 000	0	0	8
> 300 000	0	0	5
Boilers more than 300 MW [number of boilers]			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0	0	0
2 500 - 5 000	0	0	0
5 000 - 10 000	0	0	0
10 000 - 15 000	0	0	0
15 000 - 50 000	0	0	0
50 000 - 100 000	0	0	0
100 000 - 300 000	0	0	0
> 300 000	0	0	0

Emission reduction costs in CFB-boilers with new investments			
Boilers less than 100 MW [number of boilers]			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0	0	0
2 500 - 5 000	0	3	0
5 000 - 10 000	0	0	0
10 000 - 15 000	1	0	0
15 000 - 50 000	1	0	0
50 000 - 100 000	0	0	0
100 000 - 300 000	0	0	1
> 300 000	0	0	0
Boilers more than 300 MW [number of boilers]			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0	3	0
2 500 - 5 000	0	2	0
5 000 - 10 000	2	1	0
10 000 - 15 000	1	0	0
15 000 - 50 000	2	0	0
50 000 - 100 000	0	0	1
100 000 - 300 000	0	0	4
> 300 000	0	0	0
Boilers more than 300 MW [number of boilers]			
[EUR/t]	SO_2	NO_X	HCl
< 2500	0	0	0
2 500 - 5 000	0	1	0
5 000 - 10 000	0	0	0
10 000 - 15 000	1	1	0
15 000 - 50 000	1	0	0
50 000 - 100 000	0	0	0
100 000 - 300 000	0	0	1
> 300 000	0	0	1

2 COST OF REDUCING SO_2 EMISSIONS

The most common way to achieve the BAT emission levels for sulphur dioxide is assumed to be investment in flue gas scrubber. In some boilers, increasing the injection rate of absorbent will be sufficient. It's estimated that in more than 90 % of the boilers will need some modifications (investments in 60 % of the boilers) and the total annual additional costs to achieve the SO_2 emission level will be 59 MEUR/a. The average cost of reducing SO_2 emissions is about 24 600 euros per ton SO_2 in boilers with new investments required. In boilers, where new emission levels can be achieved with existing reduction measures with increasing absorbent injection, the emission reduction costs are approximately 1 100 euros per ton SO_2.

To achieve the emission levels based on split views submitted by Finland, modifications would be needed to about 50 % of the boilers and the additional annual costs would be 18 MEUR/a. The additional costs would be 70 % lower compared to the costs of related to draft BAT emission levels.

3 COST OF REDUCING NO_X EMISSIONS

Regarding nitrogen oxides emissions, the actions to achieve the BAT requirements vary depending on the combustion technology, biomass-peat ratio in the fuel mix and required emission level. Additional costs are assumed to be realized for more than 90 % of the boilers (investments in 80 % of the boilers) and the total additional annual costs in Finland will be 27 MEUR/a. The average cost of reducing NO_X emissions is in boilers with new investments required about 12 700 euros per ton NO_X.

To achieve the NO_X emission levels based on split view, modifications would be needed to about 40 % of the boilers. The additional annual costs would be 7 MEUR/a; approximately 74 % lower than the costs of related to draft BAT emission levels.

4 COST OF REDUCING DUST EMISSIONS

The BAT emission levels for dust will be achieved mainly with the same reduction measures as needed for SO_2 and HCl emissions. In about 10 % of the boilers, sufficient SO_2 and HCl abatement systems already exist and the BAT emission levels may be achieved with improvements to the existing electrostatic precipitator. The average dust emission reduction cost in boilers with new investments specific for dust emission reduction is about 54 900 euros per ton dust.

Costs related to emission level based on split views are not included in this study.

5 COST OF REDUCING HCl EMISSIONS

Currently hydrogen chloride (HCl) emission levels are not typically monitored in boilers using biomass and/or peat. Based on the information available from flue gas emission measurements, it's estimated that the HCl emission level in studied boilers is typically about 1-60 mg/Nm^3. HCl emissions are reduced with same processes with SO_2 emissions. The average emission reduction cost for HCl emissions to achieve LCP BREF emission level is about 360 000 euros per ton HCl in boilers, where new investments are made. The emission reduction cost is high due to small amount of emissions reduced and that investment costs made mainly also due to SO_2 and partly due to dust emission removal are allocated as a whole to HCl.