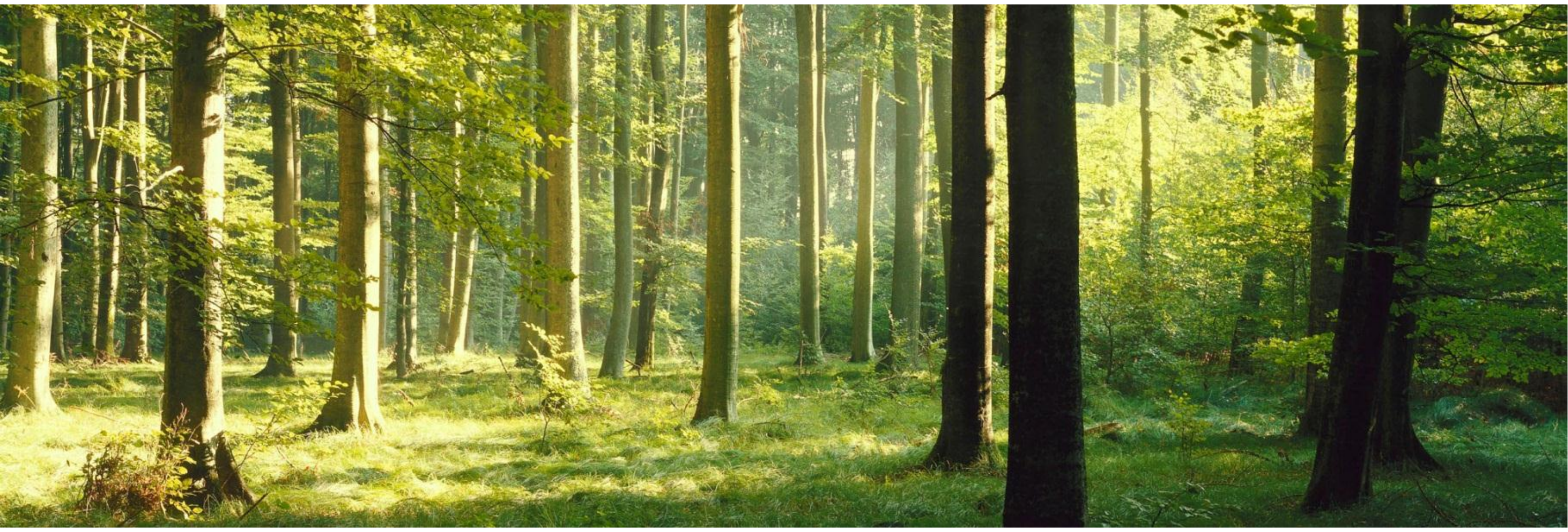
June 2014

Particle Emission Reduction

Cost Analysis for Existing 1-20 MW_{fuel} Solid Biofuel Plants in Finland



Innovation by experience

13 June 2014

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Cost Analysis for Existing 1-20 MW_{fuel} Solid Biofuel Plants in Finland

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1 EXECUTIVE SUMMARY

ÅF-Consult Ltd (Consultant) prepared the cost analysis for particle emission reduction in solid biofuel plants with a size range of 1-20 MW_{fuel}. The main focus of this report is on the solid biofuels and technologies that are used in Finland.

Main Conclusions

- In general, for small biofuel combustion plants the emission levels of 20-45 mg/Nm^3 are achieved mainly with fabric filter and ESP, with some solid biofuels (e.g. pellets) these emission levels might be achieved also with scrubber. Typically scrubber technology in these plant sizes can achieve an emission level 50 mg/Nm^3. Heat recovery scrubber investment can be profitable investment due to the additional heat production, if there is need for low temperature heat.
- The cost of particle ton reduced increases rapidly when the size of the boiler decreases (5 000 - 22 000 EUR/t operating hours 5000 h/a).
- The case specific costs, such as flue gas ducts, can play a significant role in the total investment cost of the particle reduction system. Especially with small boilers and sites where the space is limited.
- Investment cost for particle reduction differs from 200 000 - 1 200 000 EUR depending on particle reduction technology and plant size. The site specific costs are not included.

The costs of particle emissions were estimated based on existing plants, cost estimations in literature, and the information received from equipment suppliers. The main results are shown in the figure below. The cost estimates in this study are generally higher than in similar studies. The cost of particle reduction in the plants operating 5000 hour per year differs from 5 000 – 22 000 EUR/t. If the operating hours decrease the cost of particle reduction increases rapidly e.g. from 10 000 EUR/t to 35 000 EUR/t when the operating hours decrease from 5000 h/a to 1000 h/a.

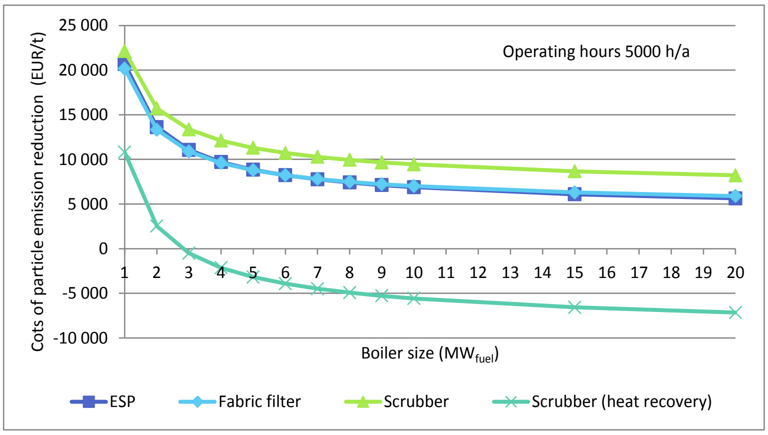


Figure 5.1 from page 15

2 INTRODUCTION

In December 2013 European Commission released a clean air policy package. A part of the package is **a proposal for new Directive to control emissions from medium-sized combustion installations (MCP-directive)**, such as energy plants for street blocks or large buildings, and small industry installations.

The emission limits for the particulate matter in the MCP-directive proposal are:

Fuel input	MCP directive	Current legislation in Finland
Existing solid biomass combustion plants		
10-50 MW_{fuel} solid biomass	30 mg/Nm^3	50 mg/Nm^3
5-10 MW_{fuel} solid biomass		150 mg/Nm^3
1-5 MW_{fuel} solid biomass	45 mg/Nm^3	200 mg/Nm^3
New solid biofuel combustion plants		
10-50 MW_{fuel} solid biomass	20 mg/Nm^3	40 mg/Nm^3
5-10 MW_{fuel} solid biomass		50 mg/Nm^3
1-5 MW_{fuel} solid biomass	25 mg/Nm^3	200 mg/Nm^3

The cost effect of lowering the particle emission limits from the current levels to the MCP-directive proposal limits for solid biomass is studied in this report. An overview of Finnish 1-20 MW_{fuel} plants is presented in the chapter 3.

3 SOLID BIOFUEL COMBUSTION IN FINLAND

The energy produced in a small scale solid biofuel combustion plants (1-20 MW_{fuel}) in Finland is typically used for production of district heat or heat for industry. There are also few small scale combined heat and power production plants. At the moment electricity production from renewable energy sources is subsidized in Finland.

The annual operating time for the plants depends on the heat demand. A small solid biomass combustion plant can be e.g. a base load district heat producer in a small district heating network with operating hours over 7500 hours per year, or a short period heat producer for a greenhouse with operating hours less than 3000 hours per year.

3.1 SOLID BIOFUELS FUELS

Solid biofuels are produced from wood, plants, and/or fruits. Solid biofuels include fuels such as wood chips, bark, saw dust, briquettes, pellets, cutter chips, fuel wood, straw, grain hull etc.

In Finland especially forest residues and by products from forest industry are used as a fuel in solid biofuel combustion plants. CHP-plants and stationary heating plants in Finland and the fuel mix in district heating are shown in the Appendix 1.

In the following table is presented some of the basic properties of forest residues, bark and saw dust used in Finland.

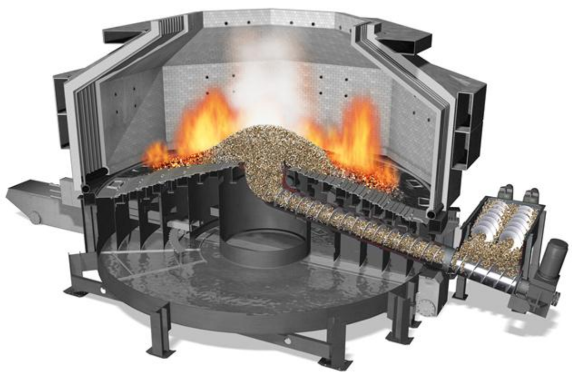
Table 3.1. Typical Fuel Properties in Finland (VTT, 2000; Suomessa käytettävien polttoaineiden ominaisuuksia; http://www.vtt.fi/inf/pdf/tiedotteet/2000/T2045.pdf)

Fuel	Forest residues	Bark (pine)	Saw dust (pine, no bark)
LHV (lower heat value) MJ/kg (db) (dry base)	19,3	20,0	19,0
Moisture m-% (mass-%)	50-60	40-85*	5-15**
Ash m-% (db)	1,3	1,7	0,08
S m-% (db)	0,02	0,03	0

* 40-50 % after dry debarking, 60-70 % after wet debarking, 70-85 % after wet storing
** Saw dust from dried lumber

3.2 BOILER AND PARTICLE EMISSION CONTROL TECHNOLOGY (PLANTS 1-20 MW_{FUEL})

Solid biofuel boiler technology depends mainly on the size of the plant. Although both grate and bubbling fluidized bed (BFB) combustion technologies can be used nearly for the entire size range of 1-20 MW_{fuel}, grate boiler is more typical when the boiler size is less than 10 MW_{fuel}.



Picture 3.1. Grate boiler furnace (KPA Unicon Ltd)

Picture 3.2. BFB boiler furnace (Valmet Ltd)

Particle emission limits in Finland require a particle emission control system after solid biofuel boilers. The particle emission limits and control technology used depends on the size of the plant.

Currently in most of the plants with size less than 10 MW_{fuel} the particle emission control technology is based on a multicyclone. With multicyclone particle emissions can be reduced to 100-300 mg/Nm^3 depending on the fuel properties. The result in the particle emission measurements can vary significantly depending on the combustion conditions and fuel properties at the moment of the measurement.

In some cases a scrubber is placed after the multicyclone and an emission level of 45 mg/Nm^3 can be achieved. However, typically the emission level for scrubber in particle emission reduction for this size of plants is 50-150 mg/Nm^3.

When the plant size is over 10 MW_{fuel} the most common particle emission control technology used in existing plants is electrostatic precipitator (ESP). In most of the plants with ESP the emission limit 30 mg/Nm^3 is already achieved.

The particle emission after the boiler, cyclone, scrubber, ESP, and fabric filter are summarized in the following figure. The values used for the particle emissions after the boiler are at the high end of the range presented in a Ohlström (1998) study[1]. The emission level after fabric filter is a rough estimate. For cyclone, scrubber, and ESP the results from a particle emission measurements[2] were used. The emission levels (mg/Nm^3) are presented in a logarithmic scale. The reduction is presented in a regular scale.

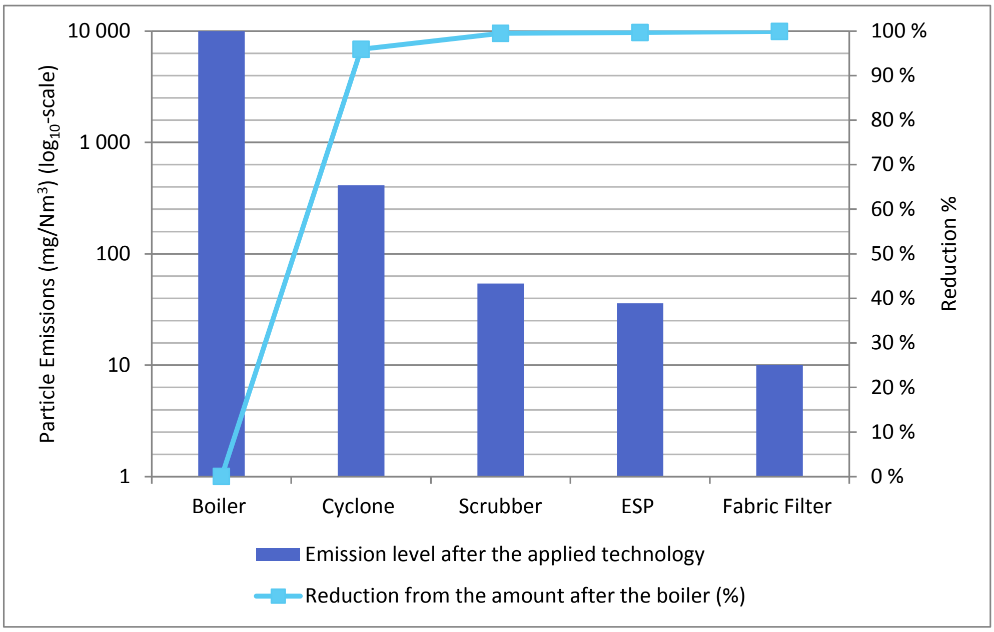


Figure 3.1. Particle emission levels and reduction level

[1] Ohlström, 1998, Energiantuotannon pienhiukkaspäästöt Suomessa, VTT, http://www.vtt.fi/inf/pdf/tiedotteet-/1998/T1934.pdf, in Finnish
[2] Sippula, 2010, Fine Particle Formation and Emissions in Biomass Combustion, University of Eastern Finland, http://www.atm.helsinki.fi/faar/reportseries/rs-108.pdf, in English

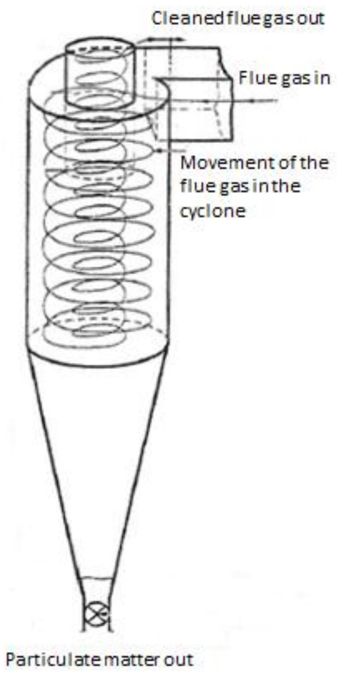
4 PARTICLE EMISSION REDUCTION

The commonly used particle emission control technologies currently on the market are cyclone/multicyclone, ESP, fabric filter, and scrubber. Based on information received from the equipment suppliers and literature, the particle emission limits in the MCP-directive proposal can only be achieved with ESP or fabric filter.

4.1 MULTICYCLONE

Cyclone and multicyclone are widely used particle emission controls systems in Finland. The cyclone separates particles by centrifugal force. Multicyclone consists of several cyclones. The flue gas is fed to the multicyclone from the side and the spread evenly to the top of the cyclones. The clean gas exits from the top of the multicyclone and the separated particles fall off to the bottom of the multicyclone.

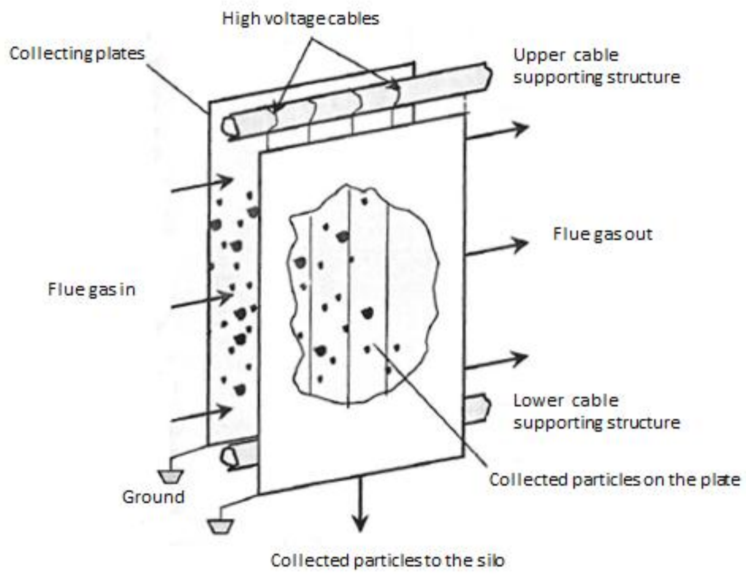
Cyclone and multicyclone are simple technology, and the investment and the operating and maintenance costs are low.



Picture 4.1. Cyclone (Oksanen, 2007, Air Pollution Control course material, Tampere University of Technology)

4.2 ELECTROSTATIC PRECIPITATOR (ESP)

The basic particle separating principle for ESP is similar to cyclones. As in cyclone the particles are collected to the wall of the device.



Picture 4.2. Simplified ESP with two plates, four high voltage cables, and one flue gas path. In practice there is always several of these units. (Oksanen, 2007)

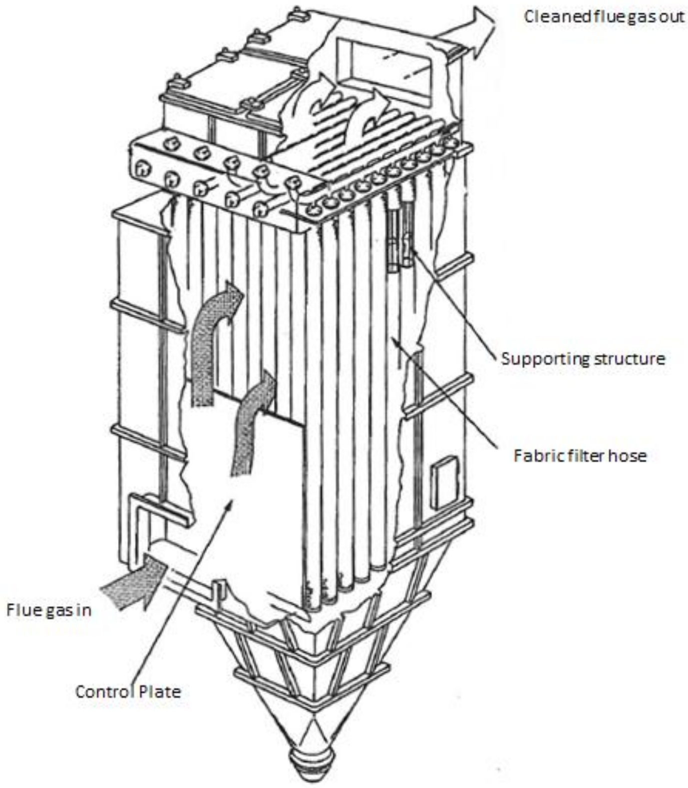
In the ESP the particles are first electrically charged, and the taken to electric field. In the electric field the particles are drawn to the walls. On the walls the particles lose their electrical charge, and form a “filter cake”. The “filter cakes” are removed by shaking the walls in regular basis, when the particles fall to the bottom of the ESP.

The charging phase is rapid, thus the size of the ESP mainly depends on the required collection area. The separation efficiency of the ESP increases when the size of the ESP increases, because the particle spends a longer time in the electric field. Gas mixing is important in ESP to assure that all the flue gas passes through an electric field where the separation efficiency is good.

4.3 FABRIC FILTER

In fabric filter the particles are separated by directing the flue gas through the filter bag. The particles are collected on the surface of the filter fabric forming a filter cake. The flue gas flows through both the filter cake and the filter fabric. The bags are cleaned in regular basis for an example by an air pulse. Depending on the fabric filter type, the cleaning either can or cannot be done during operation. The particle separation efficiency is lower right after the cleaning compared to the efficiency before cleaning due to the fact that filter cake improves separation efficiency.

The investment cost of the fabric filter is in the same magnitude with the ESP, but the operating and maintenance costs are higher. In general, the bags have to be changed to new ones in every 2-4 years. Also pressure loss and adhesive particles cause operating and maintenance costs.

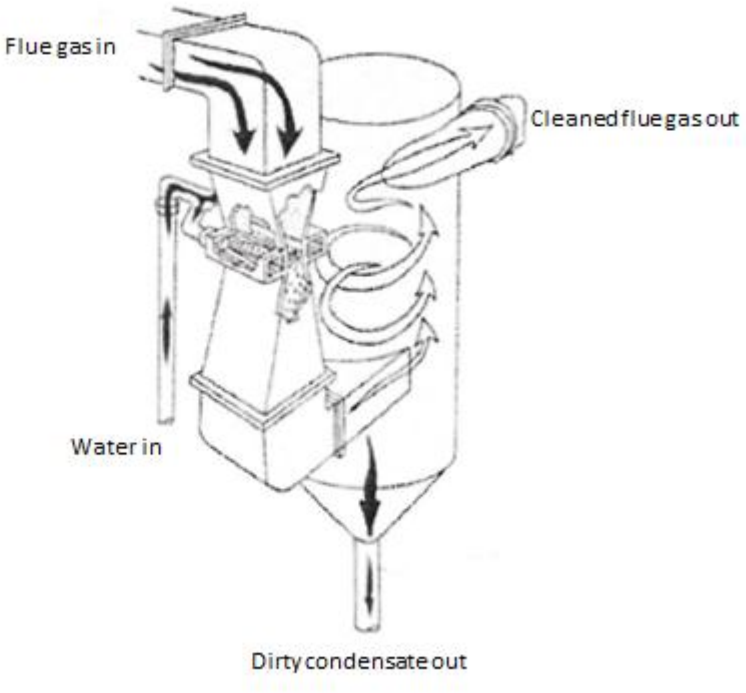


Picture 4.3. Fabric filter (Oksanen, 2007)

4.4 SCRUBBER

Scrubber particle separations are based on water drop injection to the flue gas stream. The particles are mixed into the water that circulates in the scrubber. The separation efficiency increases when the size of the water drops decreases and the velocity difference between the flue gas and the water drops increases. The particle suppression is based on the collision of the water drop and the particle, and diffusion (small particles). The efficiency increases if the water vapor condensates on the small particles, as in venturi scrubbers. Also the amount of the particles in the flue gases effects to the separation efficiency. If the amount of particles is high, a pre-particle separator, e.g. cyclone, might be required.

There are many different scrubber technologies, and the investment cost can differ significantly. The operation and maintenance cost are high due to the treatment of the dirty condensate. If there is demand for low temperature heat, such as district heating, the scrubber can also work as a heat recovery system. The heat recovery scrubber is more expensive than a regular scrubber, but the heat recovery can be significant and the payback time for the whole scrubber investment can be short. At many sites there is no need for the low temperature heat, such as industrial site where the processes produce low temperature heat as a by-product.



Picture 4.4. Scrubber (Oksanen, 2007)

5 COST ANALYSIS

The cost of particle emission reduction is presented in this chapter.

5.1 ASSUMPTIONS

In this study the emission levels achieved are assumed to be fixed for the different technologies. The values are presented in the following table. It is assumed that these emission levels can be achieved with different fuels and boiler technologies. The emission level achieved with ESP depends on the fuel used. Thus, to achieve the same emission levels with different kind of biofuels, the investment cost of an ESP might be higher for forest residue, saw dust, and bark than for pellets.

Table 5.1. Emission levels with different technologies for solid biofuels such as forest residue, bark, and saw dust

Technology	Achievable Emission Level	Emission Level Used In Calculations
Multicyclone	~200 mg/Nm³	-
ESP (two fields)	< 30 mg/Nm³	30 mg/nm³
Fabric filter	< 20 mg/Nm³	30 mg/nm³
Cyclone/Multicyclone + Scrubber	~45 mg/Nm³	50 mg/Nm³

The current emission level is assumed to be 200 mg/Nm³ for existing bio boilers, and the technology used is cyclone/multicyclone. The emission levels after the investment to ESP or fabric filter would be as required in the MCP directive. The emission level after scrubber investment would be 50 mg/Nm³.

5.2 INVESTMENT COSTS

It is assumed that all the solid bio fuel plants in Finland with sizes over 1 MW_{fuel} have at least cyclone as a particle reduction system. The additional investment for particle reduction depends on the efficiency of the existing system.

5.2.1 Equipment

The required emission levels in the directive proposal cannot be achieved with the cyclone/multicyclone. The required investment in these cases is either ESP or fabric filter. Also the scrubber investment is analyzed, even though the emission level that can be achieved is 50 mg/Nm³. The investment cost of a heat recovery scrubber is estimated to be 30 % more than for the scrubber without heat recovery system. Scrubber investment includes a new stack.

If the required emission levels are not achieved with the existing ESP, the required investment comes from adding a field to the ESP. The investment cost of an ESP (two fields) achieving 30 mg/Nm³ emission level is approximately 30 % more than the investment cost of an ESP (one field) achieving 50 mg/Nm³ emission level.

The investment cost estimates are based on the ÅF cost knowledge base, information received from equipment suppliers, and literature.

5.2.2 Additional Investment Cost Factors

Besides the particle reduction equipment several other factors influences to the investment cost. In this study, estimates for foundation and project management costs are included in the investment cost, but the costs of integration of automation and flue gas ducts and other connections are not included to the investment cost estimate.

Investment costs, which are included to the investment cost estimate, are

- Equipment (55 000 – 1 000 000 EUR)
    - ESP (72 000 - 790 000 EUR)
    - Fabric filter (55 000 - 610 000 EUR)
    - Scrubber with heat recovery (88 000 - 1 000 000 EUR)
- foundations (50 000 - 100 000 EUR),
- project management and other costs (70 000 - 100 000 EUR).

Additional highly site specific investment costs, which are difficult to estimate in general and therefore **not included** in the investment cost estimate, comes from

- integration of automation to existing system,
- a new ID fan (if the pressure drop increases significantly),
- flue gas ducts (especially, if there is no space near the current particle reduction system) (20 000 - 200 000 EUR), and
- demolition work for the old system.

However, it should be noted that in some cases these costs might have an important role. Especially in cases, where there is limited space for the equipment at the site. The site specific costs can double the investment cost of the particle reduction system.

5.2.3 Investment Cost Estimates

The investment options and the costs are presented in the following table. The estimates are indicative and for information only. It is assumed that the existing particle reduction system is cyclone/multicyclone. The new investment would be placed after the existing system.

Table 5.2. Investment costs (the site specific costs are ***not included****)*

Plant size	New system	Equipment, foundations and project and other costs*
1-2 MW_{fuel}	ESP (two fields) / fabric filter / scrubber (heat recovery)	190 000 - 250 000 / 170 000 - 220 000 / 200 000 - 260 000
2-5 MW_{fuel}	ESP (two fields) / fabric filter / scrubber (heat recovery)	250 000 - 400 000 / 220 000 - 340 000 / 260 000 - 470 000
5-10 MW_{fuel}	ESP (two fields) / fabric filter / scrubber (heat recovery)	400 000 - 610 000 / 340 000 - 510 000 / 470 000 - 650 000
10-20 MW_{fuel}	ESP (two fields) / fabric filter / scrubber (heat recovery)	610 000 - 990 000 / 510 000 - 810 000 / 650 000 – 1 170 000

*Excluding the site specific costs such as flue gas ducts. These costs can be 5-100 % of the equipment investment cost.

5.3 OPERATION AND MAINTENANCE COSTS

Operation and maintenance cost (O&M costs) for different particle reduction systems are presented in the following table. The estimates are indicative and for information only.

The operating cost include the consumption of electricity and other consumables, increased electricity consumption in flue gas fan due to the increased pressure loss. The main factors that influences on the operating and maintenance costs are electricity consumption for ESP, frequency of bag changes for fabric filter, and amount of waste water for scrubber.

Table 5.3. O&M Costs

Particle reduction	O&M cost
ESP	0,1 EUR/MWh_{fuel}
Fabric Filter	0,4 EUR/MWh_{fuel}
Scrubber	2 EUR/MWh_{fuel} *

* Based on the assumption that the waste water treatment cost is 4 EUR/t.

5.3.1 Operating Income – Low Temperature Heat From Scrubber

Scrubber can also work as a flue gas condenser and heat recovery system. If there is use for low temperature heat at the site, the flue gas condenser can be a profitable investment because of the value of the heat recovered.

In this report, the value of the heat is assumed to be 20 EUR/MWh based on decreased usage of wood chips (Price of Forest energy: 19.73 EUR/MWh, 13.5.2014 / FOEX).

The heat available from the scrubber is calculated for flue gas moisture 28 v-% at inlet, and flue gas temperature 55 °C at outlet. It is assumed that all the heat recovered can be used.

5.4 SENSITIVITY ANALYSIS

The sensitivity of the cost of particle reduction to the operation hours, to the boiler size, and to the emission level are presented in this chapter. An example of the particle reduction costs calculations for a 10 MW_{fuel} plant is presented in the appendix 1. The interest rate used is 5 % and the calculation period 10 years. Site specific costs are excluded from the investment cost estimate. If these costs are 50 % of the equipment investment cost it can increase the cost of particle reduction by 20-40 %, and even more in the case of the heat recovery scrubber.

5.4.1 Boiler Size

The sensitivity of the cost of particle reduction in relation to the boiler size is presented in the following figure. As can be seen from figure, the cost of particle emission reduction per ton of particles reduced is significantly more for smaller boilers than for the boilers larger than 10 MW_{fuel}.

The emission reduction cost for the heat recovery scrubber is negative, which indicates that the income from heat is more than the total costs. The economy of heat recovery scrubber depends on many factors. From particle reduction point of view, it should be noticed that the emission level of ~50 mg/Nm^3 might be possible to achieve with a technology that can be feasible investment in some cases from the heat production point of view.

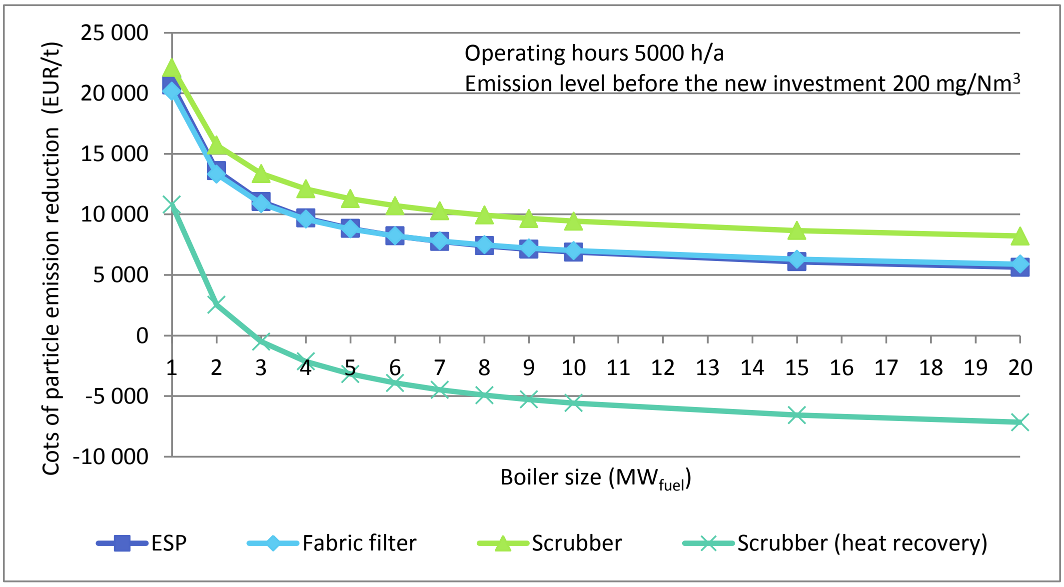


Figure 5.1. Sensitivity of the Costs to Boiler Size (site specific costs are excluded from the investment cost estimate) (Lower end of the costs range presented in the table 5.2 is used for the lower end in the size range, and the higher cost for the larger size in the range.)

5.4.2 Operating Hours

The sensitivity of the cost of particle reduction in relation to the operation hours of the boiler is presented in the following figure. As can be seen from figure, the cost of particle emission reduction increases rapidly from under 10 000 EUR/t to over 50 000 EUR/t when the operating hours of the boiler decreases.

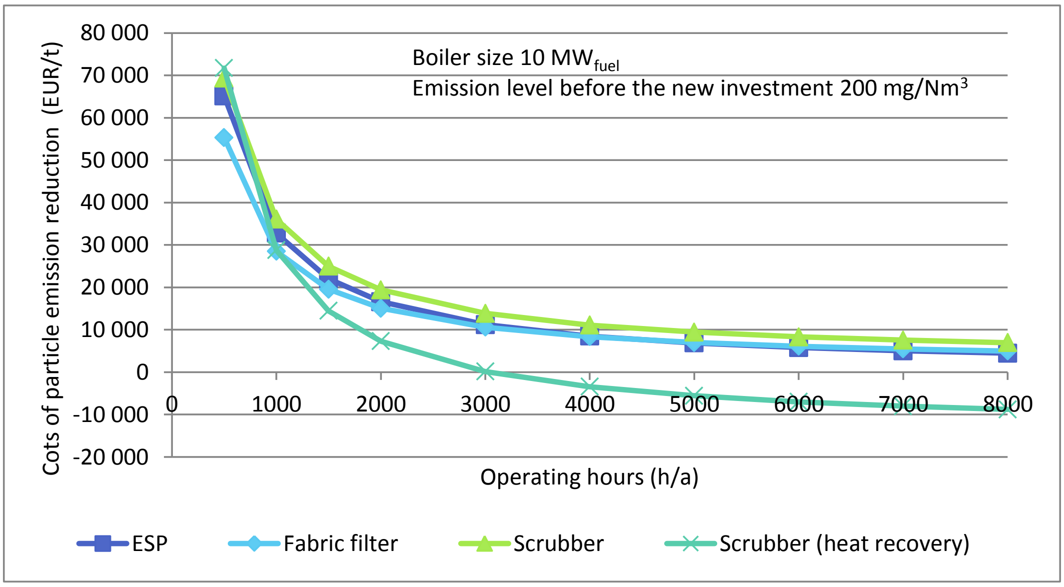


Figure 5.2. Sensitivity of the Costs to Operation Hours (site specific costs are excluded from the investment cost estimate)

5.4.3 Investment Cost

As mentioned in the previous chapter the site specific costs can be high. In the following figure the investment of the site specific cost is added to the investment cost estimate. The amount of the site specific costs is specified as a percentage of the equipment investment cost.

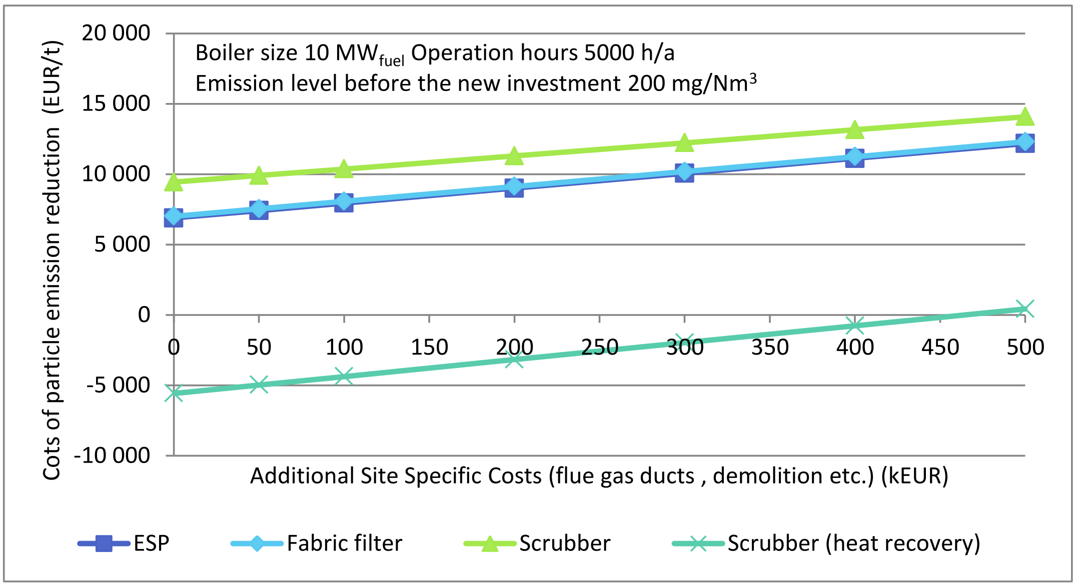


Figure 5.3. *Sensitivity of the Reduction Costs to Investment Costs (site specific costs included)*

5.4.4 Emission Level

The investment cost of an ESP is less if the required emission level can be achieved with one field ESP. As discussed in the investment costs chapter, the investment cost can be roughly 30 % less for ESP with one field compared to the ESP with two fields. If it is assumed that the emission level 50 mg/Nm^3 can be achieved with ESP with one field, the reduction in the cost of particle emission reduction would be 17-20 % in EUR/t.

5.5 COMPARISON TO OTHER PARTICLE EMISSION REDUCTION COST EFFECT STUDIES

In this chapter the results from this study are compared to the results from the following studies:

- **Amec:** Amec Environment & Infrastructure UK Ltd.; February 2014; Analysis of the impacts of various options to control emission from the combustion of fuels in installations with a total rated thermal input below 50 MW
- **Nussbaumer**: Nussbaumer, Thomas; June 2010; Overview on Technologies for Biomass Combustion and Emission Levels of Particulate Matter

5.5.1 Amec Study

In the Amec study, the cost for fabric filter and cyclone are estimated. It was also indicated that the emission level below 45 mg/Nm^3 cannot be achieved with cyclone. The total annual costs for fabric filter in the Amec study are presented in the following table. The interest rate used is 4 % and the calculation period 10 year. The operating hours related to the costs in the previous table were not clearly mentioned in the study. It is here assumed that the operating hours given on the page 22 in the Amec study, are also applicable for the costs mentioned in the appendix 1.

Table 5.5. Total Annual Costs in Amec Study

Case	Total Annual Costs (Amec, 2014, Appendix 1)	Operating hours (Amec, 2014, p.22)
1-5 MW_{th} LOW	2 768 EUR/a	1847 h/a
1-5 MW_{th} HIGH	6 617 EUR/a	
5-20 MW_{th} LOW	13 838 EUR/a	2945 h/a
5-20 MW_{th} HIGH	30 077 EUR/a	

The inlet particle emissions were 300 mg/Nm^3 for size 1-5 MW_{th}, and 250 mg/Nm^3 for size 5-20 MW_{th}. However, in the following comparison the amount of reduced particle emission is calculated from the same assumption as in this study 200 mg/Nm^3.

In the following figures the results from Amec study are compared to the results in this study. The flue gas amount was estimated for the Amec study.

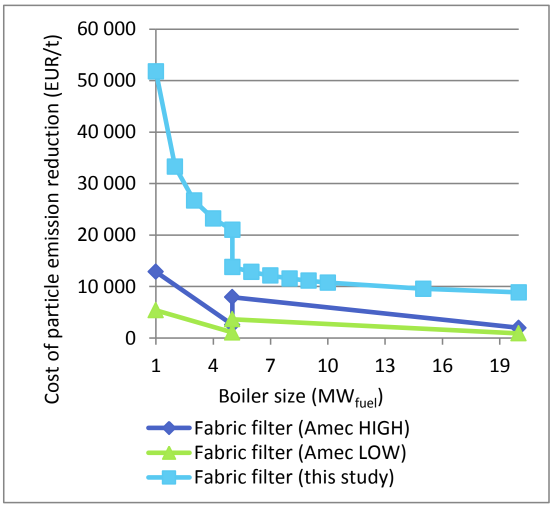


Figure 5.3. Boiler size

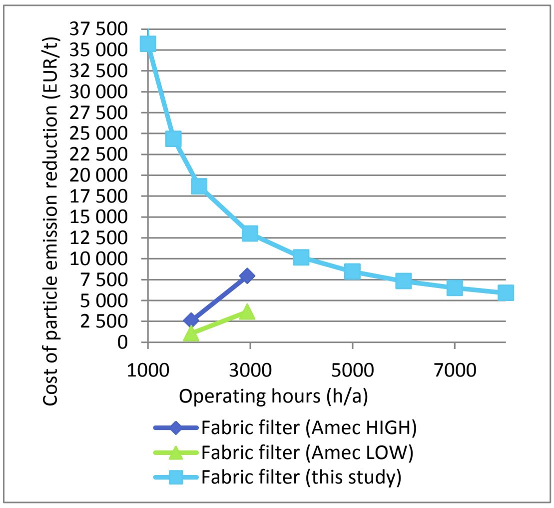


Figure 5.4. Operating hours

As can be seen from the figures, the assumption of the operating hours used in Amec study might be incorrect. Despite of this inconsistence, it can be conducted from the figures that the cost estimates in this study are in the high end of the Amec study. The difference is significant, especially with low operating hours and small boilers.

The Amec study has used the same literature sources for the cost estimates, as used in this study. The cost division is not show in the study. Thus, it cannot be indicated whether the difference is in operating cost or in investment cost.

5.5.2 Nussbaumer Study

The increase of the heat production cost by ESP and fabric filter are researched in the Nussbaumer study. These results are presented in the following table. The interest rate for capital cost is 5 %, payback time 15 years for equipment and 30 years for buildings, operating hours 2000 h/a, and lifetime of filters for fabric filters 5 years. The comparable figures calculated using the assumptions made in this study and the same operation hours and payback time as in Nussbaumer study.

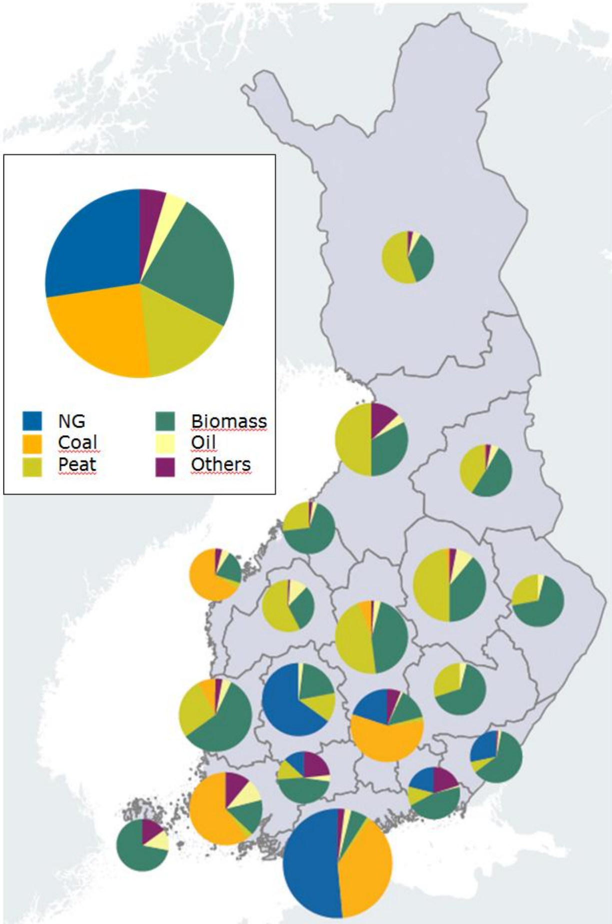
Table 5.6. Increase of heat production cost

Boiler Size	ESP	Fabric filter
Increase of heat production cost (Nussbaumer, 2010, pp.44-45)		
1 MW_{th}	0,7 ₵ (EUR cents) / kWh	0,6 ₵/kWh
2 MW_{th}	0,5 ₵/kWh	0,4 ₵/kWh
Increase of heat production cost in this study		
1 MW_{th}	1,1 ₵/kWh	1,0 ₵/kWh
2 MW_{th}	0,7 ₵/kWh	0,7 ₵/kWh

As can be seen from the previous table, the cost estimate in the Nussbaumer study is 29-36 % less for ESP and 40-43% less for fabric filter. The life time of fabric filters in Nussbaumer study is longer than assumed in this study. Thus, the operating cost for fabric filter might be lower in the Nussbaumer study. In the Nussbaumer study the assumptions for investment and operation cost for automatic wood combustion plants without ESP or fabric filters were based on experiences from more than 30 existing plants. In addition, investment cost on ESP and fabric filters for the size range between 100 kW and 2 MW were collected from five different manufacturers from Switzerland, Germany, and Austria.

APPENDIX 1: CHP-PLANTS AND STATIONARY HEATING PLANTS IN FINLAND AND FUEL MIX IN DISTRICT HEATING

CHP-plants and stationary heating plants in Finland



Fuel mix in district heating in Finland

APPENDIX 2: AN EXAMPLE OF THE CALCULATION OF THE COST OF PARTICLE EMISSION REDUCTION IN A 10 MW_{FUEL} PLANT

The summary of the costs for particle emission reductions indicated in the report are presented in the following table for a 10 MW_{fuel} plant. The emission level before the investment is 200 mg/Nm^3. For this case, as can be seen from the table, the lowest cost for particle emission reductions is for ESP. The particle emission reduction costs increases the heat production cost by 2 EUR/MWh, which can be 10 % of the total heat production costs.

Cost of the particle emission reduction					
Assumptions					
Calculation period				10	a
Interest rate				5 %	
Boiler size				10	MW_{fuel}
Operation hours				5000	h/a
Particle emission before the new investment (dry, 6 % O_2)				200	mg/Nm^3
Amount of flue gases (dry, 6 % O_2)				14 400	Nm^3/h
Technology	ESP	Fabric filter	Scrubber	Scrubber (heat recovery)	
Investment cost	612 000	508 000	555 000	716 000	EUR
	79 000	66 000	72 000	93 000	EUR/a
O&M costs	5 000	20 000	30 000	50 000	EUR/a
Income from low temperature heat	0	0	0	203 000	EUR/a
Cost of particle emission reduction	**84 000**	**86 000**	**102 000**	**-60 000**	**EUR/a**
Particle emissions	30	30	50	50	mg/Nm^3
Particle emission reduced	170	170	150	150	mg/Nm^3
	12,2	12,2	10,8	10,8	t/a
Cost of particle emission reduction	**6 900**	**7 000**	**9 400**	**-5 600**	**EUR/t**
Effect to the cost of heat produced (boiler efficiency 0,85)	2,0	2,0	2,4	-1,4	EUR/MWh_{th}

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