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BB-CLEAN

European Regional Development Fund

BOOKLET ON POLLUTION ABATEMENT SYSTEMS

to reduce the environmental impact of biomass burning

BB-CLEAN project is co-financed by the European Regional Development Fund through the Interreg Alpine Space programme.

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The combustion of biomass causes emissions of harmful flue gases and particulate matter into the atmosphere, which is mainly due to the incomplete combustion of these materials. When it comes to increasing efficiencies and reducing pollution, non-technical measures such as consumer behaviour and fuel quality play a significant role. However, those primary measures are not enough to reduce the particulate matter emissions sufficiently.

End-of-pipe technologies are used to decrease the amount of particulate matter released into the atmosphere. This deliverable focuses solely on secondary measures and aims to explain the most common abatement technologies. In the first chapter, the difference between primary and secondary abatement measures is described. This part is followed by a section on cyclones, fabric filters and electrostatic precipitators. Exhaust condensers and flue gas scrubbers are included as well.

The explanation of the technologies is followed by a chapter on existing abatement systems from different companies on the market. This section aims to give an overview of the implementation of the different technologies as well as the cost and application ranges.

CONTENT

01 PRIMARY AND SECONDARY MEASURES

Primary measures include improving the combustion technology and combustion chamber geometry. Additionally, operator failure has to be avoided through process and sensor guided combustion regulators with a controlled circulation of combustion air [1].

Secondary measures focus on reducing particulate matter emissions through end-of-pipe technology such as flue gas scrubber, electrostatic precipitator or post-combustion. Catalysts, as well as fabric and particle filters, are further technologies for particulate matter abatement [1].

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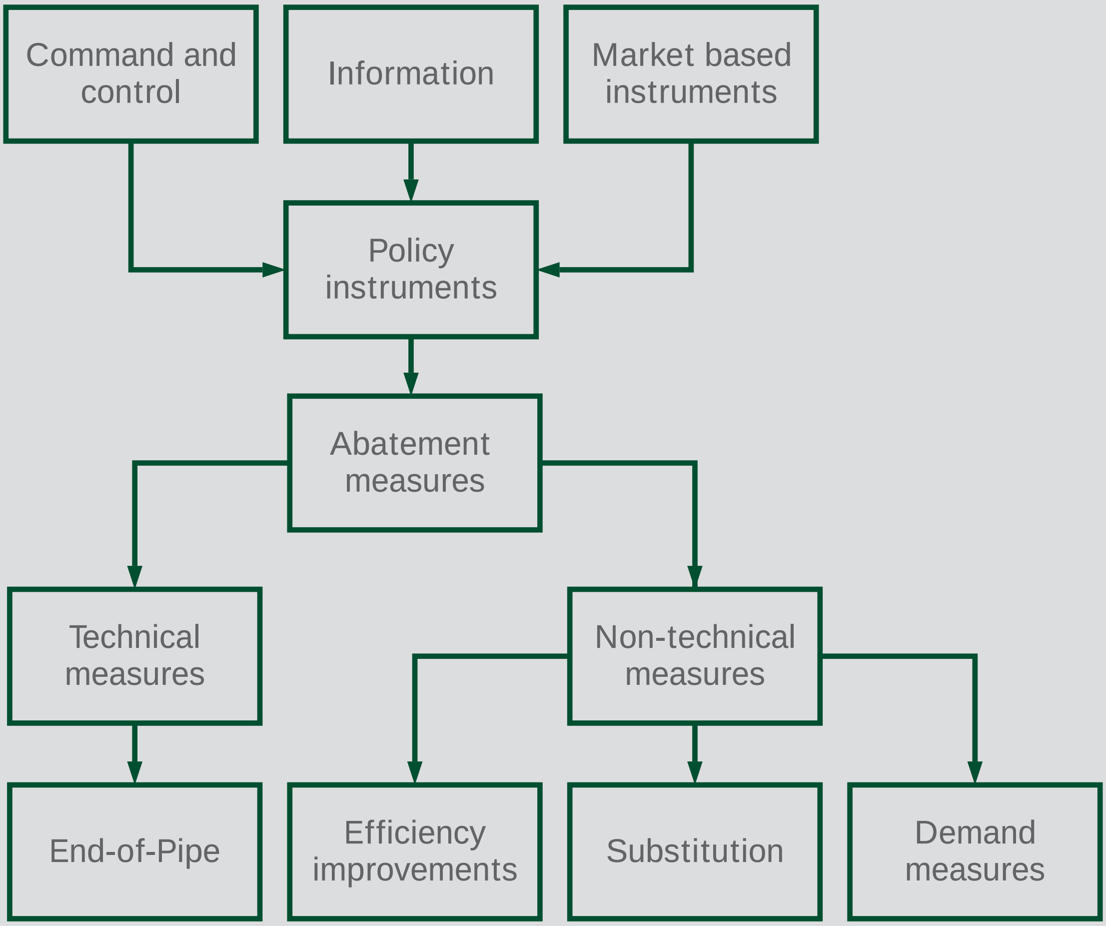

Figure 1: Abatement measures [2]

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02 SECONDARY ABATEMENT MEASURES

For small-scale furnace system there are different abatement technologies available which are listed below. Figure 2 shows the efficiencies of various systems for different particle sizes.

- Cyclone
- Fabric filter
- Exhaust condenser
- Electrostatic precipitator
- Flue gas scrubber
- Exhaust gas catalytic converter

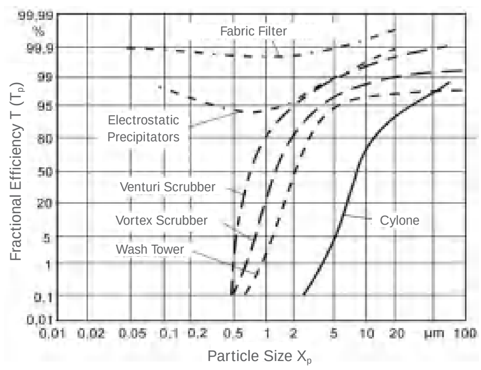

Figure 2: Efficiencies of different abatement measures [3]

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CYCLONE

A cyclone separator uses centrifugal forces to remove the dust from the flue gas. The geometry of the chamber causes a spinning motion of the gas stream. The gas enters tangentially at the upper part of the cyclone and spins in an inner vortex before it exits axially at the top. The particles are transported towards the outer walls and collected at the bottom. The most traditional type is the reverse-flow cyclone [4].

Advantages

- Low investment and operational costs
- Temperature resistant [1]
- Low maintenance
- High temperature tolerance
- High efficiency for larger particles [4]

Disadvantages

- Low separation efficiency for very small particles
- Separation efficiency dependent on velocity [1]
- Sensitive to variable flows and dust concentration
- Tar condensation possible [4]

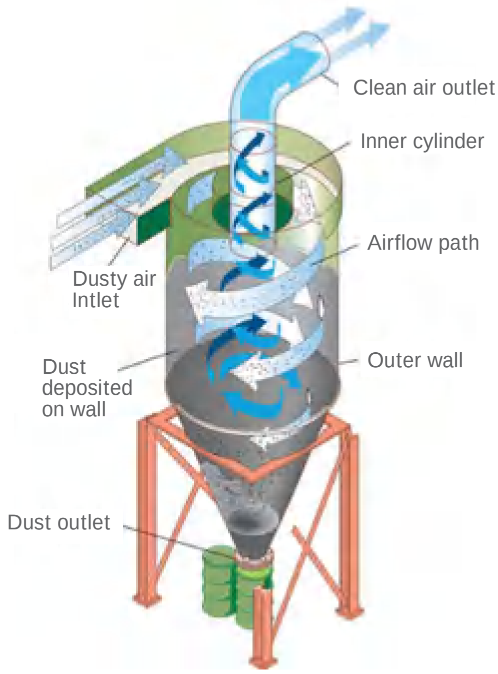

Figure 3: Cyclone [5]

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FABRIC FILTER

In filtering separators, the flue gas stream flows through a filter material which catches particles with a larger diameter than the spaces of the material (fabric) of the filter. The particles start to accumulate and the resulting layer act as a pre-filter. This leads to an increased efficiency and pressure drop. The dust has to be removed periodically either through vibration, by scraping the fabric or reversing the fluid. Fabric filters include woven or felted materials (cotton, wool, polypropylene, nylon) [6].

Advantages

- Separation efficiency up to 99%
- High separation efficiency for small particles [6]

Disadvantages

- High investment and operational costs
- High pressure drops
- Partly requires heating [1]
- Only possible for temperatures up to 250°C
- Ignited ash can severely damage the filter materials
- Filter replacement every three to five years [6]

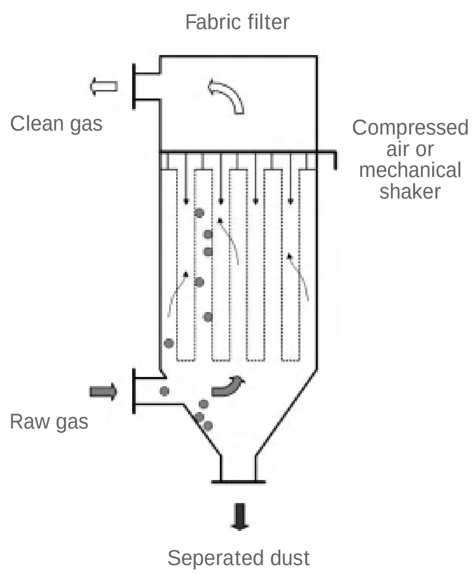

Figure 4: Fabric filter [7]

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ELECTROSTATIC PRECIPITATOR (ESP)

An ESP consists of a negatively charged, high-voltage discharge electrode and a grounded collection pipe or plate. The gas is ionized due to the potential difference of the discharge and the collection electrode. The produced ions collide with the dust particles leading to a negative charge of the particles. As a result, the particles are attracted to the collection surface which is oriented parallel to the flow. The velocity of this motion is dependent of the strength of the electric field. The gas stream moves the particles further along as they approach the collection surface which has to be considered when sizing the collection surfaces. The collector plates periodically have to be cleaned of the dust. The removed dust is collected in a hopper and either manually or automatically removed [8].

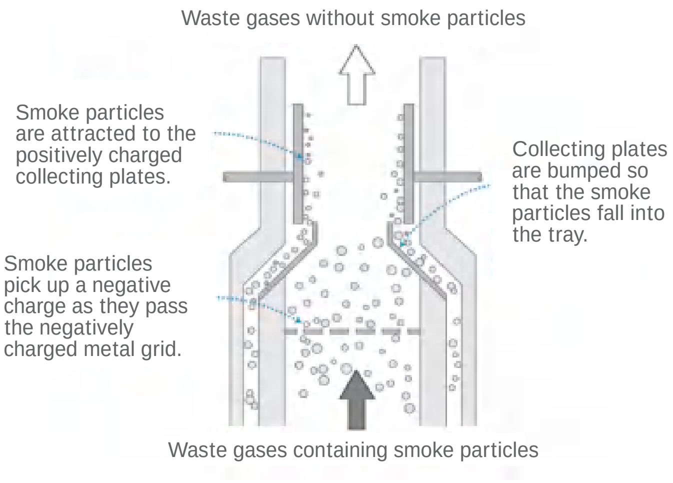

Figure 5: Electrostatic precipitator [9]

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Advantages

- High separation efficiency for small particles
- Low pressure drops
- Low power requirement
- High durability [4]

Disadvantages

- High investment costs
- High maintenance costs
- High voltage
- Large unit size [4]

Electrostatic precipitators can be separated into two categories, namely wet ESP and dry ESP. The difference lies in the cleaning mechanism as Figure 6 shows.

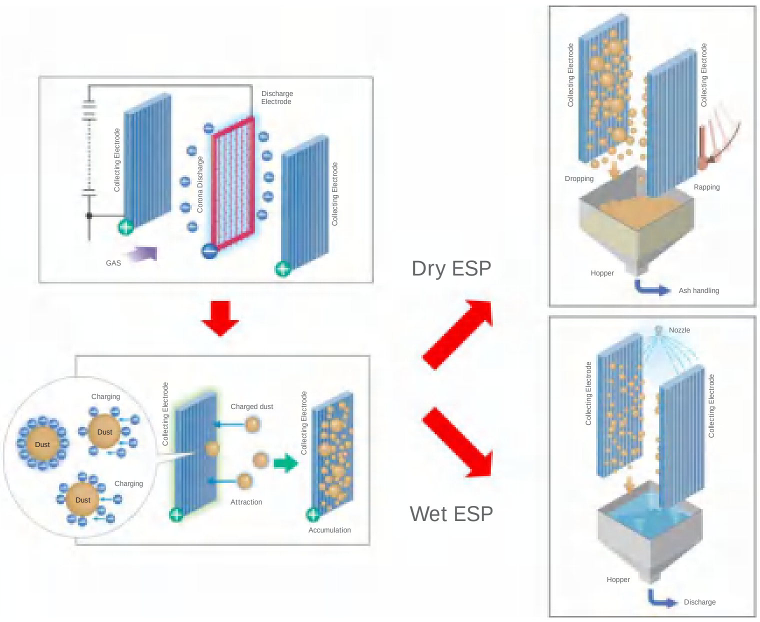

Figure 6: Working principle of dry and wet ESP [10]

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Wet electro filter

The wet electro filter includes a metallic filter that catches the charged particles until the pressure drop reaches a level that triggers an automatic cleaning system that uses a water jet. At the bottom of the chamber the water-dust mix is collected. This system is especially beneficial for the removal of tar and other sticky particles [4].

Dry electro filter

In contrast to the wet ESP the dry electro filter does not use any water for cleaning. Dry cleaning mechanisms include scraping, brushing or vibrations [8].

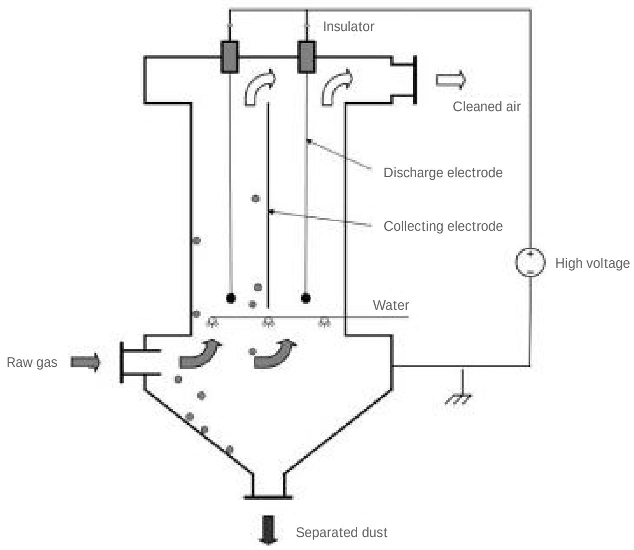

Figure 7: Dry electro filter [11]

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EXHAUST CONDENSER

This technology has two functions; namely heat recovery from the flue gas, which can then be used to supply the heating network, and separating solids from the flue gas. If the flue gas is cooled below the dew point, the water in the flue gas condenses. The heat from the flue gas is absorbed by the water droplets and the sum of those equals a large heat exchanger surface resulting in a high heat recovery rate.

The particles are trapped in the condensed water droplets and transported in the process water. This is filtered prior to its release into the sewage system. The system basically utilizes the same principle as a flue gas scrubber but without the chemicals. As a result, the exhaust condenser is less efficient in extracting particles from the flue gas [12]. The combination with another removal technology can increase the removal efficiency of the whole system [13].

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Advantages

- Low investment and operational costs
- Temperature resistant [1]
- Low maintenance
- High temperature tolerance
- High efficiency for larger particles [4]

Disadvantages

- Low separation efficiency for very small particles
- Separation efficiency dependent on velocity [1]
- Sensitive to variable flows and dust concentration
- Tar condensation possible [4]

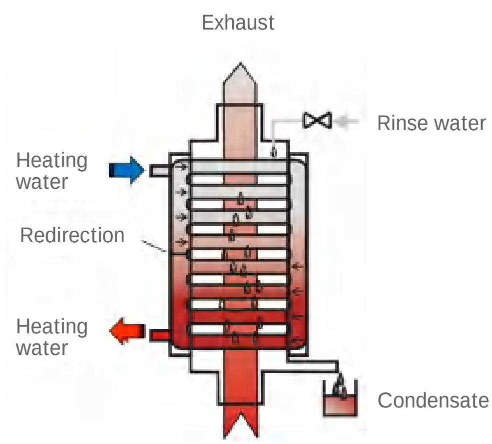

Figure 8: Exhaust condenser [1]

FLUE GAS SCRUBBER

In wet flue gas scrubbers, dust particles are removed by absorption through a liquid. Those systems can also remove heavy metals, NOx, carbon monoxide and carbon dioxide. Flue gas scrubbers can be divided into two categories: spray scrubbers and surface scrubbers. The first category includes spray towers and venturi scrubbers. Those spray the liquid through nozzles into the upward flue gas stream. Any water droplets contained in the clean gas are removed by a mist eliminator and drop back into the chamber. The second category which comprises plate and pack towers, uses a wet surface as collecting medium [8].

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Advantages

- Reduction of further emissions (HCl, SO3, etc.)
- Savings due to heat recovery [1]
- Removal of sticky particles
- Usable for very hot and moist gases [4]

Disadvantages

- High operational costs
- Low efficiency for very small particles
- Complex appliance [1]
- Costly disposal of condensate [14]
- Sensitive to low temperatures
- Corrosion [4]

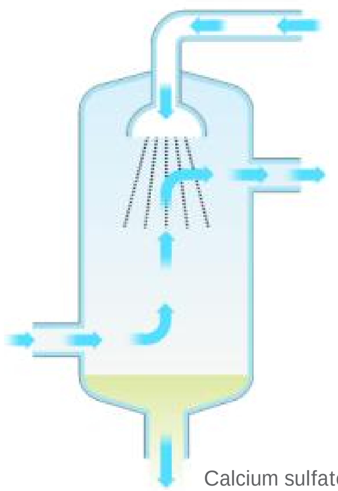

Figure 9: Flue gas scrubber [14]

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03 PARTICULATE MATTER ABATEMENT SYSTEMS

In the following chapter different available abatement systems of various companies on the market are listed. Included technologies are mainly electrostatic precipitators but also a pellet condensing boiler and a system for heat recovery.

OEKOTUBE

The OekoTube is produced by the Oekosolve AG in Switzerland and by Schräder Abgastechnologie in Germany [1]. The OekoTube is an electrostatic precipitator which is used for single room heating and automatically fed furnaces. OekoTube is installed in the chimney [15].

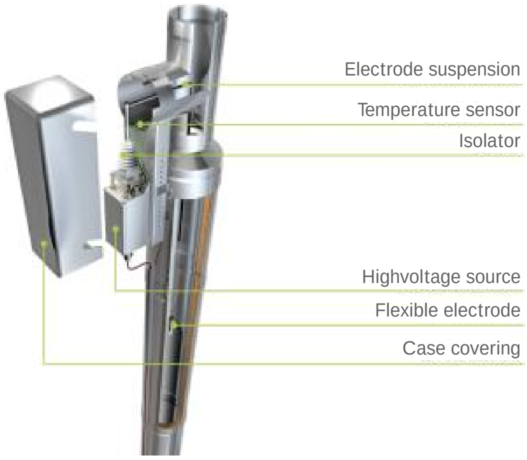

Figure 10: OekoTube [1]

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Separation efficiency	80–85% [16]
Capacity	Up to 50kW [15]
Costs	€ 1.633–1.748 [16] Low operational and maintenance costs [15]
In use since	2010 [16]
Distribution	< 1.000 on the market [16]
Characteristics	Retrofittable [15]

OekoTube-Inside

In contrast to the normal OekoTube the OekoTube-Inside is installed in the boiler [15]

Separation efficiency	80–85% [16]
Capacity	10–70kW [16]
Application	Boiler systems [16]
Distribution	~ 1.000 on the market [16]

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RUFF-KAT

The RUFF-KAT was produced by the company RUFTEC (The company does not exist anymore) in Germany. It uses electrostatic precipitation and is applied for (wood) furnaces [1].

Capacity	30kW [1]
Characteristics	Retrofittable [1]

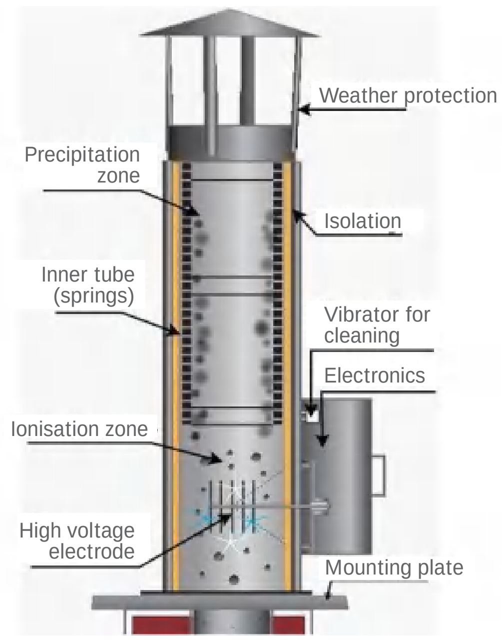

Figure 11: Ruff-KAT

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AL-TOP

The AL-TOP electrostatic precipitator is a product of Schräder Abgastechnologie in Germany [1].

Separation efficiency	75–80% [16]
Capacity	50–300kW [16]
Costs	€ 9.950–17.900 [16] Low operational and maintenance costs [15]
In use since	< 2009 [16]
Distribution	~ 100 [16]
Characteristics	Retrofittable Average electricity consumption < 25W [15]

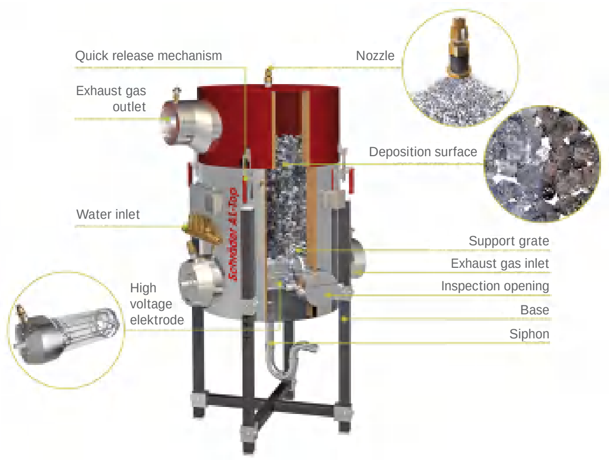

Figure 12: AL-Top

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AWT-TOP

The AWT-TOP is a system for heat recovery and calorific technology of Schräder Abgastechnologie in Germany. It is used in the industry but can also be applied in private households [1].

Efficiency increase	Up to 20% [1]
Capacity	15–2.000kW [19]
Costs	€ 50 / kW furnace capacity [20] Low operational costs [19]
In use for	Multiple years [21]
Characteristics	Retrofittable [19] Adapted for biomass [1]

Figure 13: Heat exchanger [22]

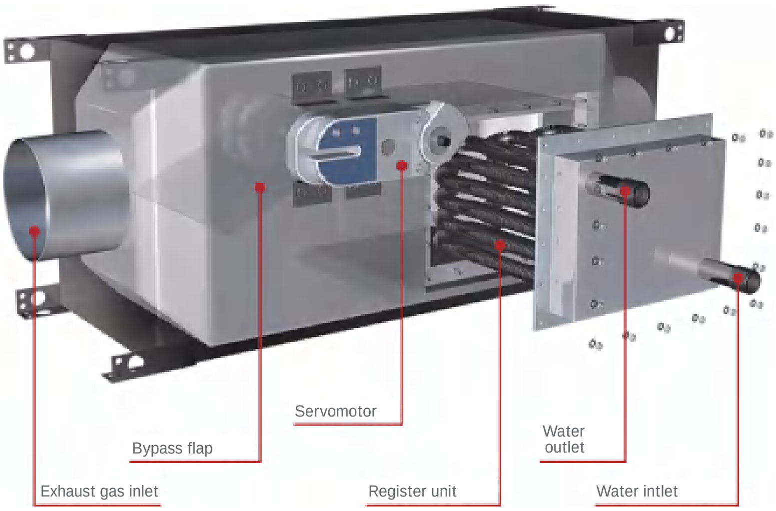

Figure 14: AWT-Top [23]

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ÖKOCARBONIZER

The ÖkoCarbonizer is produced by the Bschor GmbH in Germany. This exhaust condenser is useable for oil, gas and biomass (pellets, wood chips, wood logs) [1]. It can be applied in private households, for central heating stations and for multiple households [24].

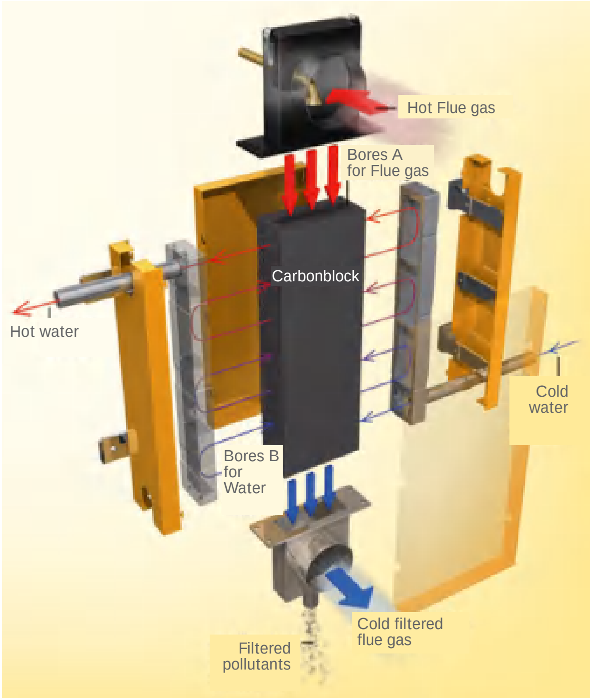

Figure 15: ÖkoCarbonizer [1]

Efficiency	Up to 86% [25]
Capacity	20–450kW [24]
Costs	€ 1.000–20.000 [24] € 50–80 / kW furnace capacity [20]
In use since	~ 2004 [24]
Characteristics	Retrofittable [20] Self-cleaning through condensate [1] Energy savings through heat recovery [1]

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ÖKOFEN

ÖkoFEN is a company in Austria and Germany that produces pellet condensing boilers [1]. They are used in private households, apartment buildings and public buildings. In public buildings they are often realized as cascade system. The particulate matter emissions of those boilers are below the regulatory emission limits without an additional separator [26].

Heat recovery	10–15% [1]
Capacity	10–64kW [27] Up to 512kW in public buildings [26]
Costs boiler **Total costs (incl. installation etc.)**	€ 12.000–14.000 [28] € 18.000–25.000 [28]
In use since	2004 [26]

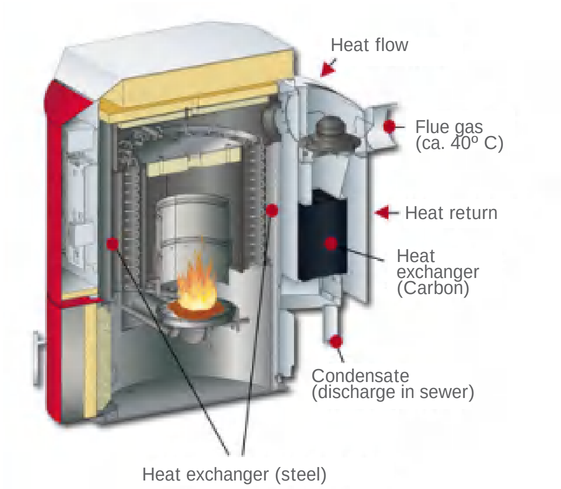

Figure 16: ÖkoFen [1]

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CYCLOJEKT

The Cyclojekt is a combination of cyclone and electrostatic precipitator and is produced by Kutzner + Weber in Germany [29]. It is available for private households, apartment buildings and public buildings [30].

Separation efficiency	90% [29]
Capacity	160, 240 and 320kW [30]
Application	Private households, apartment buildings, public buildings [30]
Costs	€ 13.233,75–21.633,37 [31]
In use since	~2017 [30]
Distribution	~50 on the market [30]
Characteristics	Retrofittable [29]

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AIRJEKT

The Airjekt is an electrostatic precipitator, the successor of Zumikron, and is produced by Kutzner + Weber in Germany [30].

Separation efficiency	95% [30]
Capacity	25–100kW [30]
Costs	€ 1.527,69–4.072,73 [31] Low operational costs [32]
In use since	~2009 [30]
Distribution	~10.000 on the market [30]
Characteristics	Retrofittable [29]

ECOPLUS

HARK Ecoplus in Germany equips fireplaces with a ceramic filter for particulate matter. Those filters should be self-cleaning but can also be rinsed with water [33].

Capacity	11kW [33]
Cost	€ 2.200–4.400 [34]
In use since	2007 [33]

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04 CONCLUSION

The rise in wood and coal usage in single ovens that are not state-of-the-art anymore lead to a significant increase of particulate matter emissions.

Modern wood carburettors and pellet boilers are not the problem in the discussion of particulate matter. Older appliances, however, cause significant amounts of particulate matter emissions that have to be considered. Retrofittable abatement measures are one possibility to reduce those.

The impacts on human health of biomass combustion emissions are still insufficiently studied but are not estimated to be neglectable.

The biggest potential of particulate matter reduction lies in changing old combustion appliances for modern low-emission pellet boilers and wood carburettors.

In order to reduce the emissions of particulate matter, the further development of primary and secondary abatement technologies is a necessity. Additionally, the offer and implementation on the market has to be enforced [1].

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