Particulate Matter Emissions-Control Options for Wood Boiler Systems

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Biomass Energy Resource Center

PARTICULATE MATTER EMISSIONS-CONTROL OPTIONS

for Wood Boiler Systems

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Particulate Emissions from Wood Combustion

The combustion of any fuel releases pollutants; the type and quantity of pollutants emitted varies among different fuel sources. When wood is used for fuel there are many documented benefits, but one drawback is the greater rate of particulate matter emissions.

Particulate matter (PM) is small-diameter pieces of solid matter or very fine water droplets, ranging in size from visible to invisible. Even with the installation of the most efficient wood-burning systems, there are still significantly higher PM emissions than that of similarly sized gas and oil systems.

PM and Public Health

The potential impact PM has on public health and ambient air quality is of concern to many communities. Relatively small PM, 10 microns or less in diameter, is called PM10. Small PM is of greater concern for human health than larger PM since small particles remain air-borne for longer distances and can be inhaled deeply within human lungs. Increasingly, very fine particulates (those 2.5 microns and smaller), referred to as PM2.5, are receiving more attention by health and environmental regulators for these same reasons.

Emissions-Reduction Measures

Fortunately, for communities wanting to heat with wood, steps can be taken and equipment added to mitigate these risks. Consideration should be given to sourcing quality wood fuel, installing high-efficiency boilers, implementing best management practices, installing emissions-reduction equipment, ensuring proper sizing and stack height, and proper plant siting.

What follows is a discussion of methods for reducing the impact of wood used for energy on public health and ambient air quality. BERC is actively engaged in ongoing technological and regulatory initiatives and will continue to recommend changes in combustion techniques and emission control options to reduce emissions from wood energy systems as appropriate and based on the state of the scientific information.

Best Practices for Reducing Emissions Levels

Operating a biomass boiler in the most efficient and beneficial way starts with the very basics: fuel selection, equipment selection, and equipment operation and maintenance. Each is critical to minimizing emissions levels.

From an emissions perspective, a screened, relatively dry, sawmill or bole chip that is blown directly into a trailer is the optimal fuel.

FUEL SELECTION

The quality of the fuel is an important factor in controlling the amount of PM emissions released. For woodchip systems, the moisture and mineral content of the chips can affect the emissions coming out of the stack. Using drier, "clean" woodchips with a minimum of bark and foliage content will typically yield less PM emissions than using "dirty" chips with more ash-causing bark, foliage, and grit.

There are several types of woodchips commonly used for boiler fuel, including:

- **Clean or Paper-Grade.** High-quality chips from sawmills. Commonly contain no bark and are often screened to a consistent size and shape.
- **Bole.** Medium-quality chips from roundwood. Often contain bark and therefore have higher ash content than clean chips.
- **Whole-Tree.** Low-quality chips from tops and branches of trees produced when harvesting timber. Include both bark and foliage, translating to considerably higher ash content.
- **Urban-Derived.** Lowest-quality chips from ground-up miscellaneous sources of community waste wood.

More ash-forming minerals in the fuel produces more particulates—in the form of fly ash—which is present in the exhaust gases at combustion.

Woodchips can also differ in how they are handled, and this too can impact emissions. Woodchips stored on the open ground and scooped into a trailer can be contaminated with rocks and dirt that are not present when woodchips are blown or conveyed directly into a trailer.

There are currently no clear standards for woodchip quality in the United States, though BERC has recently produced a document, *Woodchip Fuel Specifications in the Northeastern United States*, to provide better clarity on woodchip fuel quality. Generally, from an emissions perspective, a screened, relatively dry, sawmill or bole chip that is blown directly into a trailer is the optimal fuel.

Woodchip quality grades, from top left clockwise: clean or paper-grade; bole; whole-tree; and urban-derived.

Wood pellet fuel quality, like woodchips, ranges widely depending on the quality of the source fibers used and their ash content.

The Pellet Fuels Institute (PFI) has developed voluntary standards that gauge pellet fuel quality and these grades, from highest to lowest quality, include:

- Super Premium
- Premium
- Standard
- Utility

While these standards account for numerous factors, including moisture content, bulk density, and pellet durability, the greatest factor impacting PM emissions is the ash content.

Below are the maximum allowable ash content levels for PFI-graded pellet fuels:

Maximum Allowable Ash Content for PFI-Graded Pellet Fuels	
Super Premium	0.5%
Premium	1.0%
Standard	2.0%
Utility	5.0%

Selecting a high-efficiency biomass boiler with an automated fuel-feeding system is an important consideration in the reduction of emissions.

BOILER SELECTION

Any facility installing a biomass energy system should select a high-efficiency boiler with an automated feeding system. The size of the system should be based on the facility's heat energy requirements.

The boiler should have primary and secondary, and/or tertiary air systems linked to oxygen sensors in the flue, detecting oxygen levels in the flue gases. These sensors will then communicate with the system to better regulate oxygen flows to optimize combustion, thereby ensuring a more complete burn and lower particulate emissions rates.

The system should additionally be equipped with an induced fan for better combustion control.

Best Practices for Reducing Emissions Levels *(cont'd)*

Properly implemented, BMPs will optimize combustion conditions, thereby helping maximize energy efficiency and minimize emissions.

BEST MANAGEMENT PRACTICES (BMPs)

BMPs are a set of operation and maintenance practices conducted on a regular and continuous basis to keep a biomass energy system performing at its best. BMPs range from the use of physical equipment such as oxygen sensors, to operational practices such as visual observations of plume opacity. Properly implemented, BMPs will optimize combustion conditions, thereby helping maximize energy efficiency and minimize emissions.

The first step in implementing BMPs is to obtain the highest-quality fuel possible (as discussed in the fuel selection section). As important is selecting well-designed combustion equipment with advanced combustion controls, which are properly calibrated during system operation.

The operational and maintenance plan for the system is critical to minimizing PM emissions. Combustion air control is not only an equipment selection component, but also an operation and maintenance issue. Proper knowledge of running and maintaining the equipment at peak performance levels is critical.

Maintaining complete combustion at varying loads will mean less particulate matter in the air. The boiler operators should be confident with the boiler's operation and knowing what the peak flame temperature is and how to maintain it. They should receive operations training by the boiler system vendors who install the equipment. An annual tune-up by professionals is essential to ensure best performance.

Above: Modern biomass system controls help in keeping a biomass system operating at peak performance.

SMALL-DIAMETER MULTI-CYCLONE COLLECTOR

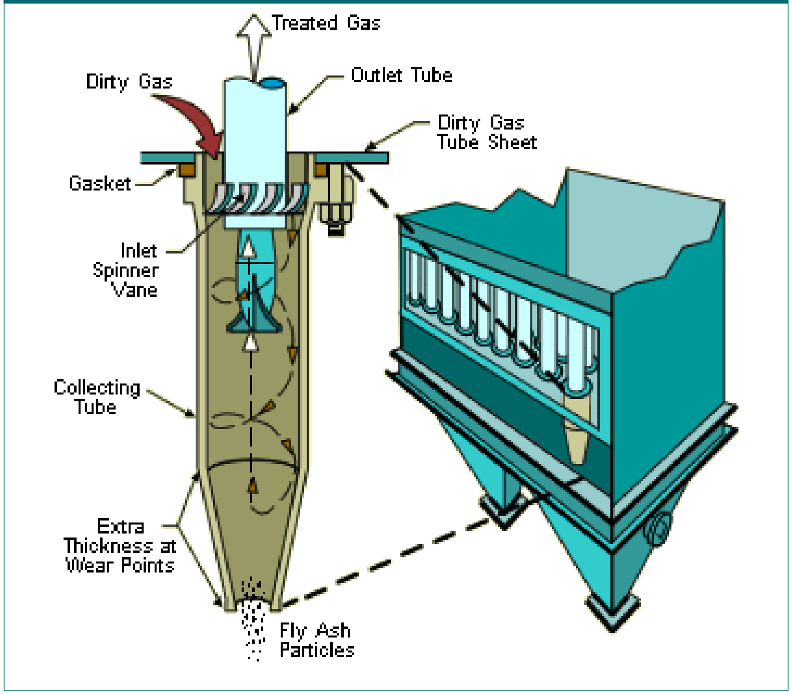


DIAGRAM COURTESY US ENVIRONMENTAL PROTECTION AGENCY

PM EMISSIONS-CONTROL EQUIPMENT

Modern emissions-control equipment can reduce total PM emissions by 50-99.9 percent. Currently, the most common technologies used on larger (>1MMBtu/hour) wood boilers are:

- **Mechanical Collectors** (cyclones, multi-cyclones, and core separators)
- **Fabric Filters** (bag houses)
- **Electrostatic Precipitators** (ESPs).

A well-known technology called a water scrubber is not normally used for wood energy systems.

The following sections present detailed descriptions of each of these technologies.

Cyclones and Multi-Cyclones

Cyclones use centrifugal force to separate particulate out of the flue gases. There are no moving parts inside a cyclone body and no filter media. The flue gases with particulate matter enter the inlet at a high velocity along the inner wall at the top of the cyclone body. The clean flue gases exit out of the top. As gravity starts pulling the spinning particulate down, the taper of the cyclone body helps keep the spinning (cyclonic) effect in motion until the particle drops out the bottom of the cyclone body and into a hopper. A multi-cyclone uses numerous smaller diameter cyclones to improve efficiency.

Single cyclones are less efficient collectors of PM than multi-cyclones. The diagram on the previous page shows a cross section of one of the smaller cyclones that make up a multi-cyclone; however, the principle is the same for a single cyclone.

Overall, the average efficiency of particulate removal with a single cyclone is approximately 50 percent; for a multi-cyclone, the efficiency ranges from 65 to 95 percent.

When making a decision on purchasing, installing, and maintaining emissions collection with cyclone technology, it is important to understand that both single and multi-cyclones' collection efficiencies decrease as particle size decreases, making them more efficient at capturing larger particles (PM10) and ineffective at capturing the finest particles (PM2.5).

Core Separators

The core separator is a mechanical collector system that functions on the same general principle as a cyclone, but the processes of separation and collection are accomplished by two different components: a core separator and a cyclone collector. The exhaust gas is cleaned as it flows through the core separator by a recirculation fan until the particles are collected in the cyclone.

The core separator has very high collection efficiency for larger particles (larger than PM10) but collection efficiency falls to below 50 percent for the smallest particles. Overall, collection efficiencies can be as high as 90 percent.

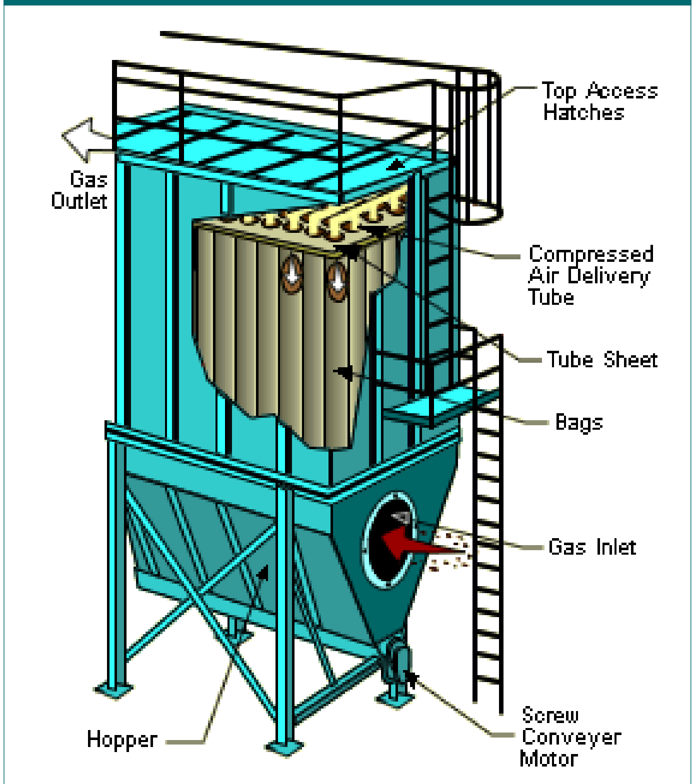
It should be noted that, at this time, core separator collection systems are not in commercial production.

Modern emissions-control equipment can reduce total PM emissions by 50-99.9 percent.

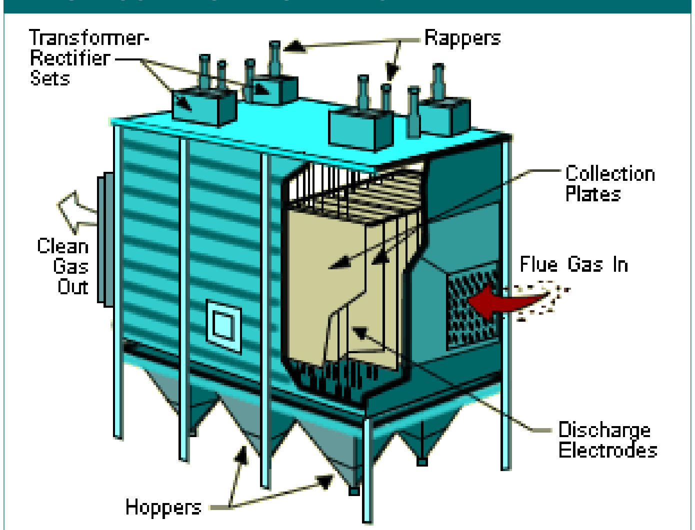
Best Practices for Reducing Emissions Levels *(cont'd)*

DIAGRAMS COURTESY US ENVIRONMENTAL PROTECTION AGENCY

FABRIC FILTER (BAGHOUSE)



ELECTROSTATIC PRECIPITATOR



Fabric Filters (Baghouses)

While mechanical separators such as cyclones and multi-cyclones have a broad range and relatively lower collection efficiency, that of fabric filters or baghouses can be higher. Depending on the design and choice of fabric, particulate control efficiencies of more than 99 percent for total PM can be achieved by fabric filters or baghouses.

Fabric filters are better able to reduce fine particular emissions when they are not overloaded with larger particulates. Therefore, the best application of a fabric filter includes a cyclone in sequence. Since the cyclone is good at removing larger particles, it complements the fabric filter well.

One downside to fabric filters—and operating experience has shown this to be true—is an increased risk of fire when burning embers are caught in the fabric. This is another reason to install a mechanical collector upstream from the fabric filter; the mechanical collector will serve to remove large burning particles of fly ash, known as sparklers. A cyclone-baghouse combination reduces the fire risk and improves particulate collection efficiencies.

Lastly, a cyclone before a baghouse can also reduce the caking of particulates on the inside of the fabric filter, allowing the fabric filter to run more effectively.

Electrostatic Precipitators (ESPs)

An ESP is a particle control device that employs electric fields to separate particles from the gas stream on to collector plates from where they can be removed.

The ESP has two components, the charging and collecting sections. In the charging section, the PM in the flue gases pass by an ionizer that imparts a positive electric charge to PM. The positively charged PM is collected on negatively charged plates in the collecting section, thereby removing PM from the flue gases. At periodic intervals, the particles from the negatively charged plates are removed by rappers or hammers or vibrators, depending on the design, and collected into the bottom hopper for removal.

In general, collection efficiencies of ESPs typically average more than 98 percent for PM10, and almost as high for PM2.5. While fabric filters are the most efficient means of collecting total PM, ESPs are almost as good as the best fabric filters without the fire risk. ESPs can handle hot flue gases at temperatures up to 572° F. Due to its low height, an ESP can usually be installed inside the boiler room or plant if there is sufficient floor space. Compared to a fabric filter, an ESP uses less energy and has both lower maintenance requirements and better separation efficiencies.

At this time, BERC recommends, at minimum, a baghouse and cyclone combination or an ESP on any new wood energy system in the size range of 5 MMBtu/hour output and larger.

Compared to a fabric filter, an ESP uses less energy and has both lower maintenance requirements and better separation efficiencies.

REDUCTIONS RATES ACHIEVABLE WITH EMISSIONS CONTROL DEVICES

The table below compares the reduction rates (or collection efficiencies) of each emissions control technology discussed here. Two types of PM are shown: PM10 (particles 10 microns or smaller) and PM2.5 (particles 2.5 microns and smaller), the latter of which are of greatest concern relative to impacts on public health.

It is important to remember that reduction rates can be improved when combined with best combustion practices, and that ground-level impacts to air quality and public health can be reduced by correctly siting and sizing the stack associated with a wood energy system.

Reductions Rates Achievable with Emissions Control Devices

	PM10	PM2.5
Single Cyclone	50%	5%
Multi-Cyclone	75%	10%
Core Separator	29-56%	72-94%
Fabric Filter (Baghouse) with Cyclone	99%	99%
Electrostatic Precipitator (ESP)	95%	90%

Source: Emission Control Technologies for Small Wood-Fired Boilers, Resource Systems Group, Inc., May 6, 2010.

Best Practices for Reducing Emissions Levels *(cont'd)*

SIZING THE STACK AND SITING THE PLANT

It is critical to properly size and site a stack that allows emissions to disperse higher into the air, thereby reducing ground-level concentrations of PM and other pollutants.

In general, stack heights should be designed with the worst-case weather conditions for that site in mind and in a way that ensures that on-the-ground air quality meets health-based standards.

One basic requirement in stack design is ensuring that it is a minimum of 1.5 times the height of the building from ground level, which minimizes plume entrapment in wakes created by obstructions in air streams.

The stack should discharge exhaust gas vertically upwards, at an exit velocity of at least 40 feet per second, and the stack heads (devices installed to prevent precipitation from entering the stack) must be installed so that they do not restrict the vertical flow of the exhaust gas stream.

Additionally, both the plant and stack should be sited in a location that allows flue gases to be carried up and away from the building and ground level. Site characteristics such as topography, neighboring buildings, and the tree line can all have an impact on air flows and should be considered when a site is chosen for the plant and stack.

Air dispersion modeling should be conducted at each site to both inform the design and siting of the stack and understand the dispersal patterns given the surrounding topography and adjacent structures.

Summary

There are many benefits that come from heating facilities with wood fuels; however, any community or facility owner considering a wood energy system should question the potential impact that system will have on air quality.

The combustion of any fuel will emit pollutants, and emissions from wood will differ from that of other fuel sources. A discussion of pollutant emissions rates from wood-fired energy systems can be found in a report prepared by BERC and RSG, Inc. entitled, *Emission Controls for Small Wood-Fired Boilers.*

It is important to first understand what those emissions are; and, second, to consider what measures can be taken to reduce impacts to ambient and on-the-ground air quality. This is especially important in the case of PM, which is a concern for public health.

There are steps that can be taken to reduce these impacts on air quality and public health. In the boiler room, PM emissions can be reduced by using quality wood fuel and optimizing combustion. Optional add-on equipment can also be used to dramatically reduce the amount of PM emitted from the stack.

Efficiencies of these equipment options can range from a 50-99 percent reduction in PM emissions. Further, stack exhaust should be emitted away from ground level, preferably via a stack that is sized and sited in a way that disperses any remaining emissions into the prevailing winds.

All of these steps combined can effectively reduce the emissions from wood combustion and will minimize impacts to ambient and on-the-ground air quality.

When combined, the recommended measures cited here can effectively reduce the emissions from wood combustion and minimize impacts to ambient and on-the-ground air quality.

For more information on community-scale biomass energy—including case studies, a biomass facilities database, fact sheets, a glossary of wood-heating terms, frequently asked questions, an image library, and links to additional resources—visit the BERC website at:

www.biomasscenter.org

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The Biomass Energy Resource Center (BERC) is an independent, national nonprofit located in Montpelier, Vermont with a Midwest office in Madison, Wisconsin, that assists communities, colleges and universities, state and local governments, businesses, utilities, schools, and others in making the most of their local biomass energy resources. BERC's particular focus is on the use of woody biomass and other pelletizable biomass fuels. Its work is funded in part by the US Department of Energy through the generous support of Senator Patrick Leahy.

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