



Air Pollution from Biomass Energy

Burning Wood Is Not Clean!

Despite the frequent depiction of biomass as “clean” energy, data from air permit applications and real smokestack tests demonstrate quite clearly that biomass is a heavily polluting technology.

Burning wood and other biological materials for energy emits as much or more pollution than burning fossil fuels, including coal. Emissions are function of the fuel type, combustion temperature, and pollution controls, but in PFPI’s analysis of air pollution permits in 7 states, we have found that biomass burners are always more polluting than natural gas and are similar to coal – admittedly better for some pollutants like sulfur and mercury, but the same or worse for particulates and nitrogen oxides. Being similar to coal hardly qualifies as clean, green energy.

Biomass electricity generation facilities are major air polluters, and in many cases will significantly worsen air quality in the communities and regions where they are constructed. Yet in most cases biomass gets a break because it is (inaccurately) considered [renewable and carbon neutral](#).

Sanctioning and subsidizing major new sources of potentially lethal air pollution is not what anyone had in mind when establishing renewable energy standards. Regulators should take a clear-eyed, fact-based approach to evaluating whether or not these facilities should operate given the significant air pollution that they cause. In our view, biomass burners should not be allowed to operate until they can

show that they are dramatically cleaner than all fossil fuel alternatives, if they are to qualify as renewable energy under state policies.

(Click [here](#) for a 2011 whitepaper on Air Pollution from Biomass, or read below for a summary of air pollutants produced by biomass energy.)

What kind of pollution does a biomass burner emit?

Burning biomass emits large amounts of pollutants, just like burning other solid fuels such as coal. Burning organic material emits particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), sulfur dioxide (SO₂), lead, mercury, and other hazardous air pollutants (HAPs).

Hazardous air pollutants are a group of [187 toxics](#) that [according to EPA](#) “are known or suspected to cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental effects”. EPA has recently released the newest [National Air Toxics Assessment](#), which characterizes emissions and ambient air concentrations of toxics around the country.

The HAPs emitted in the greatest quantities by burning biomass include the organic HAPs styrene, acrolein, and formaldehyde, and the acid gases hydrofluoric acid and hydrochloric acid. Biomass burners commonly emit ten tons or more of the acid gases and from one to five tons of organics each year. Even “clean wood” – that is, forestry-derived wood, as opposed to construction and demolition debris – emits these chemicals when burned. Burning clean wood also emits non-negligible amounts of heavy metals. Burning “urban wood” – a friendly term for construction and demolition debris (CDD) – significantly increases emissions of arsenic, chromium, copper, lead, and mercury, as well as dioxins/furans and pentachlorophenol (PCPs). Biomass developers sometimes claim that sorting out the contaminated wood from CDD produces a “clean” and safe fuel stream, but it is virtually impossible (and not cost effective) to remove the contaminated wood using visual inspection and hand sorting. Even one or two percent contaminated wood can lead to significant emissions of metals when this material is burned (see [a letter](#) documenting the inadequacy of CDD sorting for a proposed CDD-burner in Massachusetts, and a [letter from the MA Department of Environmental Health](#) expressing concerns about emissions of metals and other air toxics in the environmental justice

community of Springfield, MA, where childhood asthma rates and incidence of high blood lead levels are already twice the State average).


Fine Particulate Matter (PM)

Fine particle emissions arise from both direct ash emissions from combustion at energy plants, but [also](#) from emissions of sulfur dioxide, nitrogen oxides, ammonia, and volatile organic compounds. Particulate air pollution has long been known to be associated with increased cardiopulmonary symptoms, asthma attacks, days lost from work due to respiratory disease, emergency room visits, hospitalization rates, and mortality. Two size classes are recognized in regulatory schemes: PM10 and PM2.5, with the numeric value referring to the particle size in microns (a micron is one millionth of a meter). There is no current health standard for PM10; EPA's 24-hour and annual exposure standards for PM2.5 are 35 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) and 15 $\mu\text{g}/\text{m}^3$. EPA's 2022 [risk assessment](#) for PM acknowledges that the standards are insufficiently protective and indicates that the agency will be lowering the National Ambient Air Quality Standards (NAAQS) for PM2.5 once more.

The classes of particulate matter classed as "black carbon" are implicated in a [recent study](#) as having up to 60% of the climate warming effect of CO₂, by both creating "brown clouds" and darkening and thus increasing the heat absorption of snow and ice in polar regions. Controlling soot emissions and thus lessening albedo effects may thus be [an even faster way](#) to mitigate sea ice melting than controlling greenhouse gas emissions. A [recent UN report](#) found that controlling black carbon emissions and ozone could dramatically reduce global warming and improve human health.

Nitrogen Dioxide

Nitrogen dioxide (NO₂) is the indicator species for the NO_x group of gases, which includes nitrous acid and nitric acid. It primarily forms when fuels are burned at high temperatures. These acidic gases directly impact respiratory health, and also contribute to formation of ozone and condensable particulate matter. Nationwide, the majority of NO₂ is from the transportation sector, but utilities and other sources of combustion [account for about 34% of total emissions](#).

As of January 2010, EPA set a new 1-hour standard for NO₂ of 100 ppb in ambient air, and  retained the annual average pollution standard of 53 ppb.

Ozone

A principle component of smog, ground level ozone is formed when nitrogen oxides (NO_x), volatile organic compounds (VOCs), carbon monoxide (CO), and methane react, energized by UV light. The main sources of NO_x and VOCs are industrial facilities, electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents. As a highly reactive oxidant gas, ozone aggravates the airways, causing respiratory distress and exacerbating asthma. It also damages vegetation and is increasingly recognized as a threat to forest health.

In 2015, [EPA revised its eight-hour standard for ozone](#) from 0.075 ppm to 0.07 ppm, acknowledging that the ozone standards set in 2008 were not as protective as recommended by EPA's panel of science advisors, the Clean Air Scientific Advisory Committee (CASAC). EPA retained that standard upon further review in 2020, but is [reconsidering that decision](#).

Sulfur dioxide (SO₂)

Sulfur dioxide (SO₂) exposure causes breathing difficulty for people with asthma, and is also implicated in regional haze and acid rain formation. In 2008, an EPA risk assessment for SO₂ concluded that definite health risks to asthmatics occur at concentrations significantly lower than the prior 24-hour health standard for SO₂. The document further noted that "over 20 million people in the U.S. have asthma, and therefore, exposure to SO₂ likely represents a significant health issue." The main sources of SO₂ are fossil fuel combustion at power plants and industrial facilities. Along with its direct effects, SO₂ also contributes to the formation of fine particulate matter. EPA concluded that a new SO₂ standard with a 1-hour averaging time would be more protective. As of June 2, 2010, EPA strengthened the NAAQS for SO₂ by adding a 1-hour standard set at 75 ppb. The standard for SO₂ has been [retained](#) with 2012 and 2019 reviews.

Lead

Lead exposure primarily occurs from paint that has not been remediated. Lead exposure in children is linked to a variety of developmental and neurological problems. A [recent study](#) concluded that



“long-term trends in population exposure to gasoline lead were found to be remarkably consistent with subsequent changes in violent crime and unwed pregnancy. Long-term trends in paint and gasoline lead exposure are also strongly associated with subsequent trends in murder rates going back to 1900. The findings on violent crime and unwed pregnancy are consistent with published data describing the relationship between IQ and social behavior. The findings with respect to violent crime are also consistent with studies indicating that children with higher bone lead tend to display more aggressive and delinquent behavior. This analysis demonstrates that widespread exposure to lead is likely to have profound implications for a wide array of socially undesirable outcomes.”

EPA recently dropped the NAAQS for lead from 1.5 $\mu\text{g}/\text{m}^3$ to 0.15 $\mu\text{g}/\text{m}^3$.

Carbon monoxide (CO)

Carbon monoxide is a product of incomplete combustion that when inhaled, interferes with oxygen absorption in the blood. Emissions of CO from biomass boilers generally increase with fuel moisture; “good combustion practices” are frequently cited as the best control for CO emissions. Carbon monoxide can accumulate in closed spaces and could be a problem in the vicinity of improperly ventilated combustion sources. Carbon monoxide is treated under EPA’s [“boiler rule”](#) as a proxy for certain organic toxics that are assumed to increase as CO emissions increase.

Hazardous air pollutants

Hazardous air pollutants (HAPs) is the group name for 187 compounds which are known to have highly harmful health or environmental effects. The list includes metals like chromium, lead, and mercury, as well as compounds like dioxins (products of combustion that are widely considered to be among the most toxic chemicals known), benzene (a constituent of gasoline) and formaldehyde. EPA has classified two HAPs as human carcinogens (arsenic and the hexavalent form of chromium, CrVI) and four as probable human carcinogens (cadmium, lead, dioxins/furans, and nickel). All of these HAPs, as well as others, can be emitted in significant amounts by biomass energy facilities that burn “urban wood” as fuel, which contains lead-painted wood, wood treated with copper chromium arsenate, and non-wood materials that exacerbate dioxin/furan formation. Monitoring for these pollutants is rare, but emission levels can be high in the vicinity of specific emitters.



Arsenic

Considered a human carcinogen by EPA, arsenic is highly toxic, and is a principle component of copper-chromium-arsenate (CCA) mixture that was used for pressure-treating lumber. Facilities that proposed to burn waste wood generally rely on visual sorting techniques to remove arsenic-containing pressure-treated wood from the CDD that it burns. However, such detection can be difficult, as noted by the Massachusetts Department of Environmental Protection [website](#), which states

“You can usually recognize pressure treated wood by its greenish tint, especially on the cut end, and staple-sized slits that line the wood. However, the greenish tint fades with time, and not all pressure treated wood has the slits”.

Chromium

Chromium is also a constituent of pressure-treated wood, and is toxic, particularly in the hexavalent form (CR VI). EPA’s [website](#) states: “The respiratory tract is the major target organ for chromium (VI) toxicity, for acute (short-term) and chronic (long-term) inhalation exposures. Shortness of breath, coughing, and wheezing were reported from a case of acute exposure to chromium (VI), while perforations and ulcerations of the septum, bronchitis, decreased pulmonary function, pneumonia, and other respiratory effects have been noted from chronic exposure. Human studies have clearly established that inhaled chromium (VI) is a human carcinogen, resulting in an increased risk of lung cancer. Animal studies have shown hexavalent chromium to cause lung tumors via inhalation exposure.” EPA’s [conversion constant](#) for the proportion of total chromium from biomass burning that is emitted in the hexavalent form is 56%.

Mercury

Mercury is a significant and dangerous contaminant that damages neurological development and other organ functions. It accumulates up food chains, presenting the greatest threat to humans and fish-eating birds like loons. Mercury is transported in the atmosphere but a significant amount from a point source can be deposited nearby, contaminating soils and water bodies. Biomass burning can emit surprisingly high amounts of mercury; for instance, the 21.5 MW Hu Honua facility planned in Hawaii [would emit](#) about 10 lb of mercury per year. This [emissions rate](#) is about 0.053 lb/kWh, more than 21 times the 0.0025 lb/kWh emissions rate at the Mount Tom coal plant in Holyoke,

Massachusetts. To be sure, the rate at the coal plant is this low because the facility has installed expensive emissions control equipment – equipment that biomass developers refuse to install because it is not “cost effective”.

Dioxins/furans

Dioxins/furans are “[persistent, bioaccumulative, and toxic](#)” (PBT) compounds that are created as by-products of chemical manufacturing, and also from combustion. Dioxins/furans are known to affect hormone levels and functions, as well as affecting fetal development, the immune system, and reproduction. They are toxic at levels that already exist in the environment. EPA [states](#) that dioxins, a group “are not created intentionally but are produced as a result of human activities like the backyard burning of trash.” Earlier EPA materials [note](#) that “[b]ecause dioxins are widely distributed throughout the environment in low concentrations, are persistent and bioaccumulated, most people have detectable levels of dioxins in their tissues. These levels, in the low parts per trillion, have accumulated over a lifetime and will persist for years, even if no additional exposure were to occur. This background exposure is likely to result in an increased risk of cancer and is uncomfortably close to levels that can cause subtle adverse non-cancer effects in animals and humans.”

How much pollution do biomass-burning facilities emit?

Most biomass plants do not use the most effective pollution controls, and small-scale biomass burners, like those being installed to provide heat to schools around the country, typically only have minimal controls. Utility-scale biomass plants emit tens to hundreds of tons of particulates, nitrogen oxides, carbon monoxide, and and hazardous air pollutants each year.

Emissions are typically expressed in air permits as pounds of pollution per million btu of heat input (as fuel). The problem with this approach is that it hides differences in efficiency that exist between facilities. Converting these rates so they are expressed in terms of emissions per unit energy delivered to the grid is a more accurate way of evaluating the impact of different technologies and fuels. [Read more in PFPI's 2011 whitepaper.](#)

Control of particulate matter



Particulate matter emissions are implicated in a wide range of health impacts, from asthma and heart disease to diabetes. Even when the most sophisticated emissions controls are used, biomass burning produces large amounts of the fine particulate matter that penetrates deeply into the lungs. There are a number of technologies for reducing emissions of filterable particulate matter, but three main technologies are often used with biomass burners. None is truly effective at removing fine particulates.

Cyclone and multicyclone systems rely on centrifugal force to spin particulates out of the flue gas. Cyclonic systems are not effective at removing the fine particulate matter that has the greatest impact on air quality and health, although [according to EPA](#), some high efficiency systems show removal of 60 to 95% for PM10 and 20 to 70% for PM2.5. Cyclone systems are often found as the sole means of PM control at small-scale burners like those installed in schools around the country.

Emissions data from the Wyalusing air permit, above, show that a typical school burner may emit around 9 tons of particulate matter a year. These emissions occur from low stacks and impinge directly on children in playgrounds and as they sit in class.

Electrostatic precipitators (ESPs) use an electric field to remove particles from the flue stream. They can remove up to 99% of fine particles (PM2.5) from the flue gas, although their efficacy in removing ultrafine particles is not well quantified. ESPs are expensive and are not typically installed in building-scale biomass burners.

Additionally, with all these control technologies, we are talking about removal of filterable particulate matter, which is just one component of total particulate matter. The other component is known as “condensable” particulate matter, and it consists of the fine and ultra-fine particles derived from sulfur, nitrogen, and VOC emissions that condense in the atmosphere after the flue gas has left the stack. Because the actual formation of condensable particulate matter depends both on emissions and atmospheric chemistry, it is not well characterized, therefore most air permitting agencies make some assumption about the ratio of condensable to filterable particulate matter when they are writing a permit for the amount of total particulate matter (filterable plus condensable) emitted by a facility. Such assumptions may or may not be well-justified.



Fabric filters or baghouses are generally considered the most effective means of emissions control for filterable particulates. They can show control efficiencies upwards of 99%. They are installed at some mid-sized facilities and many utility-scale facilities.

The amount of particulate matter emitted from a biomass burner is highly sensitive to small differences in control efficiency. The following table shows how much filterable PM₁₀ is emitted in four different scenarios. Note that the first scenario combusts a much smaller amount of wood than the other three – this is meant to represent the operation, for instance, of a biomass burner at a mill that is generating power and heat for its own operation. Despite the relatively small amount of wood burned, the average control efficiency of 80% for the multiclone system means that PM emissions are quite high.

Small-scale biomass emissions compared to wood stove emissions

Biomass proponents will sometimes claim that biomass burners “emit less pollution than a woodstove”. For well controlled facilities, per unit wood burned, this is true, because baghouses and other pollution control equipment reduce the amount of pollution emitted. However, the sheer amount of material burned in a utility-scale facility or even at a medium-sized sawmill means that pollution emissions massively exceed those from a residential wood-burner. And the emissions are no less harmful. The size distribution of the particulate matter that escapes control by a baghouse or ESP is shifted toward the smallest size fractions – and in the case of particulates (not to mention all the other pollutants) what you can't see can definitely can hurt you.

But what about a school-sized facility, compared to a woodstove? Estimates of the amount of particulate matter emitted by a residential woodstove vary by a factor of ten or more, but assuming an average PM emission rate of 30 grams per hour (a value between old woodstoves and EPA-certified woodstoves), and assuming 6 months of stove operation at 18 hours per day, the average woodstove emits about 214 lb of particulate matter over the heating season. Assuming 6 months of operation for a school sized boiler of about 4 mmbtu, such a facility might emit around 1.9 tons of particulate matter. This would then be about the equivalent of PM emissions from about 18 residential woodstoves.



Biomass and the Clean Air Act

Large-scale biomass burners are subject to Clean Air Act regulation and permitting like other emitters, with one crucial difference. The Clean Air Act requires “Prevention of Significant Deterioration” (PSD) review for air quality when a new “major source” facility is built or when an existing facility undergoes major modification in an area that is either classed as in attainment, or unclassifiable, with regard to the National Ambient Air Quality Standards (NAAQS). PSD review [requires](#) installation of the Best Available Control Technology (BACT, a standard that takes into consideration the cost of air pollution controls, and allows rejection of some controls as too expensive), air quality analysis, an additional impacts analysis, and public involvement. However, while the threshold for triggering PSD review for a fossil-fueled boiler 250 mmBtu/hr or greater is emission of 100 tons of a criteria pollutant, the threshold for triggering PSD review for a biomass burning facility is 250 tons. This means that a facility burning biomass can emit two and a half times the amount of pollution that a fossil-fueled facility emits before it is subjected to a similar level of scrutiny and emissions control.

Biomass, Hazardous Air Pollutants, and EPA’s “boiler rule”

To reduce the amount of hazardous air pollutants emitted by commercial and industrial boilers, EPA sets limits for certain pollutants under the “boiler rule”, which is part of the Clean Air Act. The boiler rule is especially significant for biomass burners because although the boiler rule regulates fossil-fueled boilers only up to 25 MW in size, it regulates all biomass boilers, no matter how large.

The boiler rule sets the maximum allowable emission limits for just five pollutants, although there are 187 different HAPs recognized by EPA. Setting emissions limits for each one would be difficult, so instead, EPA regulates the majority of pollutants by dividing them into classes and using proxies to estimate how well their emissions are controlled. Under the boiler rule, particulate matter (PM) serves as a proxy for metallic HAPs like arsenic and lead, and carbon monoxide (CO) is regulated as a proxy for organic HAPs like formaldehyde and acrolein. The boiler rule regulates dioxins/furans, mercury, and hydrochloric acid (HCl) directly, with HCl also acting as a proxy for other acid gases (like hydrogen fluoride).

To control emissions of these pollutants, EPA sets maximum emissions rates for different kinds of boilers and different fuels. These emission rates are based on the “best performing” (lowest emitting)



units that already exist. To set emissions rates for existing boilers, EPA essentially averages the best performing 12% of boilers, using their emission rates as the standard that all existing units are supposed to achieve. For new as-yet-unbuilt boilers, EPA expects those to achieve the same emission rate as the single best performer (lowest emitter) that already exists. These standards are referred to as Maximum Achievable Control Technology (MACT), and are set for coal, biomass, gas, and other liquid fuels boilers.

EPA further identifies two categories of emission sources under the boiler rule – “major” and “area” sources. A major source is one which emits 25 tons or more of total HAPs, and 10 tons or more of any single HAP (for biomass, the HAP usually emitted in the greatest quantities is hydrochloric acid, or HCl). An “area” source is one which emits HAPs below these thresholds.

Since the emission rules for major sources are considerably more stringent than for area sources, there is a great incentive for facilities to characterize themselves as area sources. Below is a summary of the allowable emission rates for major and area sources. Emission rates for biomass under the major source rule are the same as for coal, except for emission rates of carbon monoxide and dioxins/furans, which are generally higher than for coal.

Boiler rule emission rates for major sources.



Boiler rule emission rates for “area” sources.



From the range of heat input values in the above table, we can see that EPA had in mind regulating relatively small boilers with the area source rule. A 10 mmbtu/hr boiler is representative of the size being installed in some school districts, as it is capable of heating more than one building. A 30 mmbtu boiler is the size used by a small sawmill. However, many of the extremely large boilers being built currently are classified as “area” sources. For instance, the Gainesville Renewable Energy Center, a 116 MW (gross; 100 MW net) biomass burner with a 1,359 mmbtu boiler, is considered to be an “area” source, because the project claims it will emit less than 25 tons of hazardous air pollutants (the exact value in the permit is 24.7 tons of HAPs). This massive project, which will burn well over a

million tons of wood a year, will therefore not be held to the stricter standards of the “major” source boiler rule.

An important thing to notice about the area source rule is that while EPA set limits for mercury and carbon monoxide for existing and new coal boilers, to which it adds the regulation of PM for new coal boilers, new biomass boilers are only required to meet PM standards, and there are no standards at all for existing biomass boilers.



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