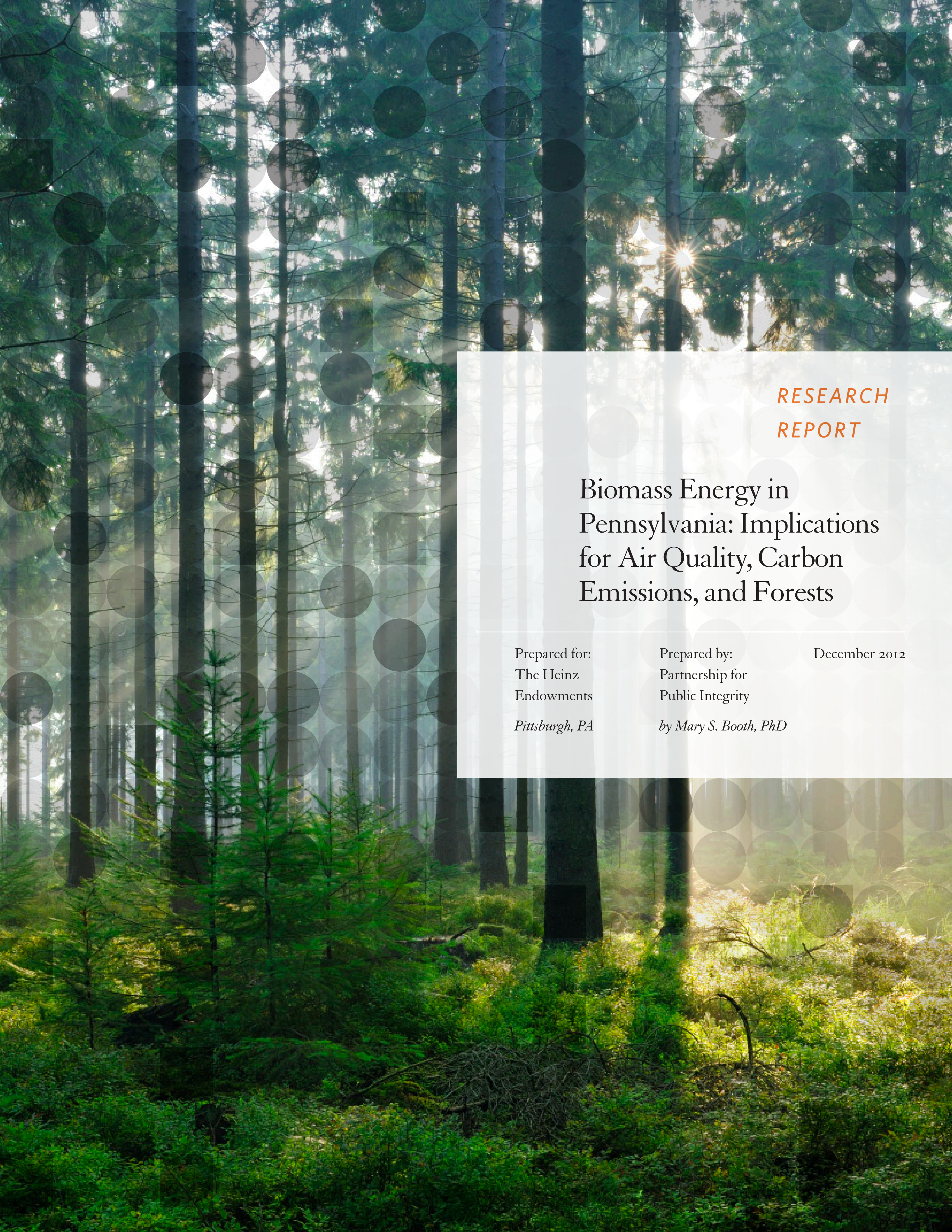

RESEARCH REPORT

Biomass Energy in Pennsylvania: Implications for Air Quality, Carbon Emissions, and Forests

Prepared for:
The Heinz Endowments

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PURPOSE OF ASSESSMENT

In Pennsylvania and across the country, burning wood and other biological materials for "biomass energy" is widely promoted as a cleaner and low-carbon alternative to fossil fuels. Supported by an array of renewable energy incentives and widely marketed as sustainable and environmentally sound, biomass energy facilities ranging in size from institutional heating boilers to 100 megawatt (MW) electrical plants are being built at an unprecedented rate across the United States. Often missing in the rush to take advantage of renewable energy grants and subsidies, however, is discussion of how biomass combustion may affect air quality, greenhouse gas emissions and forests. Air quality regulators know that biomass boilers emit as much or more key air pollutants as fossil fuel boilers, giving them the potential to affect air quality. Scientists increasingly recognize that biomass energy, which is chiefly fueled with wood, is a significant source of greenhouse gases that could put large new demands on forests if growth continues unchecked. Still, the federal government and many states, including Pennsylvania, have prioritized rapid expansion of biomass energy capacity with little consideration of potential impacts. While pollutant emissions, greenhouse gases, and forest impacts from biomass energy are recognized by many scientists and regulators, they are only beginning to be considered at a policy level.

This report focuses on Pennsylvania's growing biomass energy sector and its current and potential impacts on air quality, greenhouse gas emissions and forests. By compiling information on these considerations in one document, it attempts to identify gaps in policy that, if filled, could mitigate potential impacts.

CENTRAL FINDINGS

Pennsylvania's biomass energy sector

Pennsylvania's existing biomass energy sector consists of dozens of sawmills and wood-related enterprises that burn wood scraps and sawdust from mill operations, as well as green chips from forestry operations and land-clearing. In recent years, the state has strongly promoted bioenergy development, providing funding for new installations of biomass boilers to heat schools, commercial facilities, and other institutions. Grants and loans are also being made to wood pellet manufacturing facilities.

Findings

- Use and production of "energy wood" is widespread in Pennsylvania. More than 60 mills and wood-related enterprises have permits to burn wood. The state is home to 35 recent and proposed institutional and commercial biomass burners, including 12 "Fuels for Schools and Beyond" projects. There are also approximately 20 wood pellet manufacturing mills in Pennsylvania, with several more proposed.
- The Pennsylvania Alternative Energy Portfolio Standard (AEPS) provides alternative energy credits and revenue to a variety of combustion technologies for electricity generation, including biomass and waste combustion.

- Four industrial-scale biopower facilities in Pennsylvania burn a variety of fuels besides woody biomass, including fossil fuels and black liquor from the paper-making process. The Evergreen Community Power plant in Reading burns treated wood and other waste.
- Pennsylvania has allocated more than $30 million in grants and loans to the biomass energy and biomass fuel sectors in recent years. With some important exceptions, the emphasis of state-level funding has been on small-scale biomass boiler installations for heat and on wood pellet manufacturing. Grants incentivize use of a variety of fuels, including animal wastes and construction and demolition-derived waste wood.
- State-level policies and reports in Pennsylvania have usually promoted biomass energy without examining its potential impacts on air quality and greenhouse gas emissions, although some consideration has been given to forest impacts. The assumption that biomass energy is carbon neutral is common.

Pollutant emissions from biomass energy

Although it is frequently described as "clean" energy, burning biomass emits large amounts of particulate matter (PM), nitrogen oxides (NO_X), volatile organic compounds (VOCs) and carbon monoxide (CO). The amount of pollution that a facility emits, however, depends greatly on the combustion design and sophistication of the emissions controls. The growing use of construction and demolition waste as biomass fuel presents an additional concern, since contaminants in this fuel are not well controlled even when advanced emissions controls are used. Pennsylvania already has a number of facilities that currently burn contaminated wood, and new Environmental Protection Agency rules appear to be loosening restrictions on use of this material as fuel, increasing the prospect that it may be burned in small biomass boilers that have only minimal emissions controls.

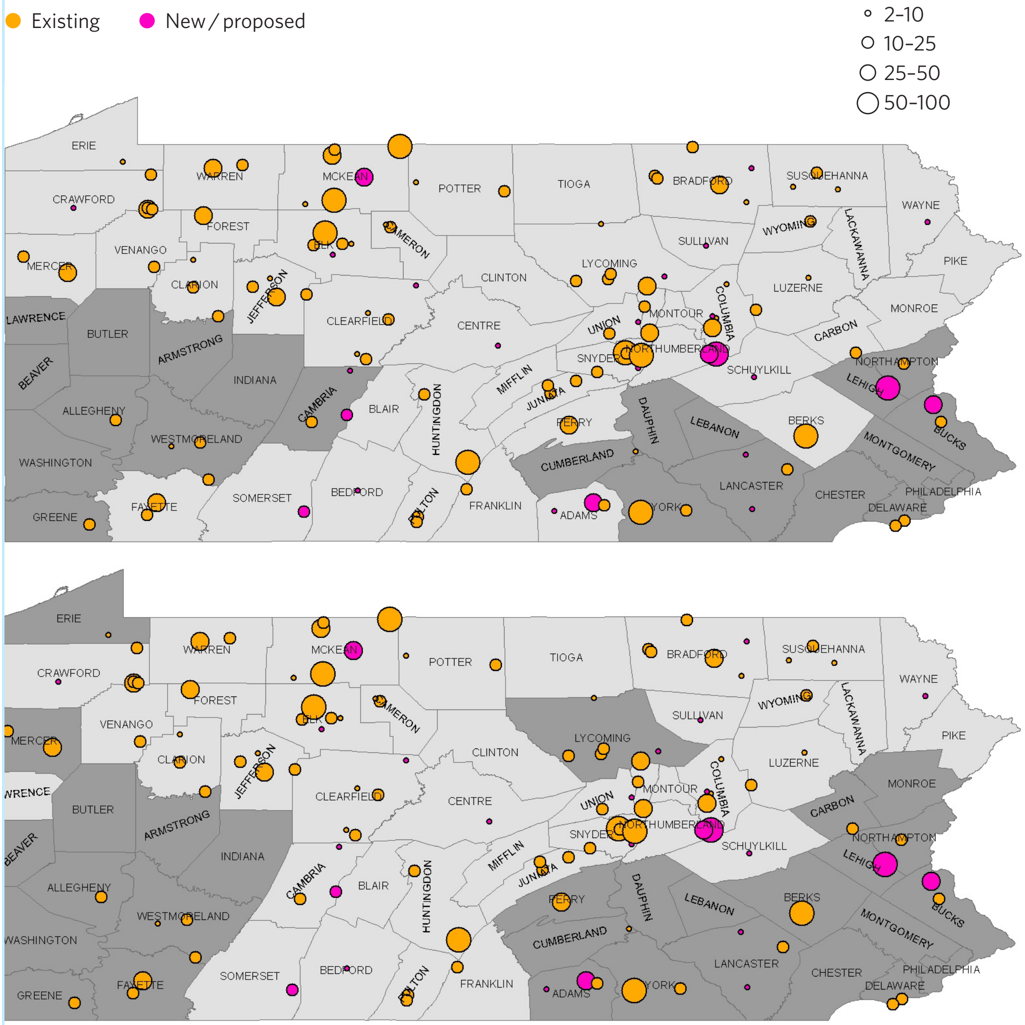
Evaluating the impact of emissions from biomass energy facilities is difficult because Pennsylvania's Department of Environmental Protection (DEP) does not require modeling or monitoring to determine impacts of small biomass burners on air quality. However, the potential impacts of biomass burners can be evaluated by putting facilities in context of what is already known about air quality and other regional emissions sources. For example, a number of commercial and industrial biomass burning facilities in Pennsylvania are located in counties that are in non-attainment with EPA health standards for particulate matter and ozone (Figure 1).

The multiple wood pellet manufacturing and other wood processing plants in Pennsylvania that burn biomass for process heat can be significant local sources of air pollution, emitting tens of tons of PM, NO_X, CO and VOCs per year. Schools and other institutions that replace oil or gas heating systems with biomass will likely experience significant increases in local air pollution. For instance, comparing permitted emissions rates from a new biomass boiler and a new oil boiler installed at a school reveals that biomass PM emissions exceed oil emissions by a factor of seven, biomass NO_X emissions are 1.5 times oil emissions, and biomass CO emissions are four times oil emissions. Particulate matter emission rates from the biomass burners being installed at schools and other institutions range from 0.2 to 0.25 lb/MMBtu, considerably higher than the EPA-mandated "boiler rule" rate of 0.07 lb/MMBtu for boilers 10–30 MMBtu/hr. But because the boilers installed at schools and other institutions are typically smaller than 10 MMBtu/hr, PM emissions are unregulated under the federal standard.

EXECUTIVE SUMMARY

(CONTINUED)

Figure 1. **Biomass Facilities (with PM emssions in tons per year) in the Context of $PM_{2.5}$ and Ozone Attainment Status (dark grey indicates non-attainment with EPA air quality standards)**



As residential wood smoke is increasingly recognized as a major contributor to air pollution in some regions, comparisons of emissions from commercial, industrial and institutional biomass boilers with residential wood burning are inevitable. Although small biomass boilers usually have lower PM emission rates than conventional woodstoves, total PM emissions are around 10 to 15 times greater, due to the larger amount of wood that is burned (Table 9). The cumulative effect can be significant—summed estimates of PM emissions from commercial and institutional biomass burners in some Pennsylvania counties are similar in magnitude to emissions from domestic wood-burning at the county level (Figure 6).

Findings

- While particulate matter, or PM, emission rates of institutional biomass burners are lower than those of domestic woodstoves, the amount of wood burned at these facilities is much greater. The impact of a typical school-sized boiler using a multicyclone for PM control is equivalent to having 10 to 15 non-EPA-certified woodstoves venting out of one stack.
- Small biomass boilers like those promoted by Pennsylvania's "Fuels for Schools" program not only emit significantly more PM than the oil and gas boilers they replace, but also carbon monoxide (CO). Federal law does not limit PM emissions from most institutional biomass boilers, and state-level requirements in Pennsylvania fall far short of what is achievable with modern emissions technology, especially for PM.
- In some Pennsylvania counties, PM emissions from industrial, commercial and institutional biomass boilers are similar in magnitude to emissions from residential wood-burning, which is widely recognized as a significant threat to air quality.

Greenhouse gas and forest impacts from biomass energy

With several combustion-based power generation technologies eligible for ratepayer-funded subsidies, Pennsylvania's alternative energy credit program is not greatly focused on reducing greenhouse gas emissions. Along with biomass combustion, Pennsylvania's Alternative Energy Portfolio Standard (AEPS) includes coal mine methane, waste coal combustion and municipal waste incineration. Pennsylvania's four existing industrial-scale heat and power biomass facilities burn a diversity of fuels, including black liquor from the paper-making process, construction and demolition waste, and railroad ties. Although forest harvesting is recognized as a significant source of greenhouse gas emissions worldwide, Pennsylvania's "Climate Action Plan" adopts the position that burning wood for energy reduces emissions and advocates a role for biomass electricity generation in the state. However, incentives have mostly favored using biomass for heating.

While Pennsylvania has no shortage of trees, existing forest management issues increase the likelihood that biomass harvesting could harm forests. The state Department of Conservation and Natural Resources (DCNR) has issued guidelines for biomass harvesting that recommend leaving 15 to 30 percent of pre-harvest biomass on site as tops and branches to maintain soil fertility and other ecological values, but such guidance is not enforceable. Increased harvesting could also contribute to an existing problem with deer overbrowse that is compromising forest regeneration. DCNR has warned that disturbances that exacerbate this situation, including timber harvest, could put forest regrowth at risk in fully one-half of Pennsylvania's forests. Pressure to increase harvesting could come from facilities within Pennsylvania, or from out of state; for instance, Ohio state officials have approved about 2,000 MW of biomass power, mostly as co-firing at coal plants, although these projects currently appear to be on hold.

Findings

- Although often considered “carbon neutral,” biomass facilities emit more carbon dioxide (CO_2) per unit of energy generated than fossil fuel facilities, generating a “carbon debt.” It requires decades to regrow forests to resequester equivalent carbon and repay the carbon debt created by harvesting whole trees for fuel. Burning biomass sourced from forestry residuals can also generate a carbon debt that persists for long periods.
- Cumulative demand for forest-derived biomass fuel and wood for pellet manufacturing in Pennsylvania (4.3 million green tons per year) is similar in magnitude to the amount of roundwood converted to lumber (~5 million green tons per year). However, even combined, these uses do not sum to the amount of wood (12.8 million green tons per year) that would be required to replace just 10 percent of Pennsylvania’s coal use by co-firing biomass in coal plants.
- The amount of “low-grade” wood that can be cut for energy production in Pennsylvania’s forests is limited. Deer overbrowse is already a significant problem in preventing forest regeneration, and increased forest harvesting for biomass fuel could exacerbate this problem.

RECOMMENDATIONS

While the number of biomass facilities and other “energy wood” facilities is increasing in Pennsylvania, there is still relatively little scrutiny of their potential impacts. The need for evaluation is especially great with small-scale biomass burners, which combine low stack heights, high pollutant emission rates, and proximity to high-sensitivity populations. Impacts of energy wood harvesting on forests and greenhouse gas emissions also need to be examined in light of increased threats to forests from climate change and disturbance. The following recommendations constitute the outline of a general “no regrets” policy for continued development of the biomass energy and pellet manufacturing sectors. Such recommendations could be implemented relatively inexpensively.

- The Pennsylvania Department of Environmental Protection should require that all institutional biomass burners, and especially those at schools, achieve an emission rate at least as low as that at the Evangelical Community Hospital biomass boiler in Lewisburg, which is required to install a baghouse for PM control.
- The state should require air quality monitoring in the vicinity of biomass burners at schools and other institutions to determine if small burners are causing local air pollution. All new facilities should be subjected to air quality modeling to explore what their impact on air quality may be.
- When permitting new biomass facilities, PA DEP should ensure that they are not located in environmental justice areas or areas with existing air quality problems.
- Strict policies should be put in place immediately to ensure that materials that emit elevated levels of hazardous air pollutants, such as construction and demolition-derived wood, are kept out of the biomass fuel stream, particularly at institutional burners that have minimal emissions controls. There should also be a rigorous testing program to ensure that contaminated wood is not used for pellet manufacture.

- The conditions required to ensure that lifecycle carbon debts from biomass energy are "repaid" in a time frame meaningful for addressing climate change should be rigorous. Pennsylvania policymakers should reevaluate the role of biomass energy in the state's alternative energy portfolio in light of new science concerning carbon emissions from biomass energy.
- Large electricity-only biomass facilities are highly inefficient and polluting. Pennsylvania policymakers should withhold state-funded grants and loans from such facilities, and should reform Pennsylvania's Alternative Energy Portfolio Standard to restrict eligibility for alternative energy credits to higher efficiency combined heat and power facilities, as Massachusetts has done. State grants and loans should be restricted to small facilities that employ the best emissions controls available.
- Forests are most valuable when managed for both high-value products and carbon sequestration. Policymakers should ensure that forests are protected from intensified harvesting for energy wood, which not only liquidates forest carbon stocks, but may exacerbate an existing problem with deer overbrowse that is currently inhibiting regeneration of Pennsylvania forests.
- The widespread marketing and perception of biomass energy as "clean" and "carbon neutral" is itself a barrier to mitigation of air quality, greenhouse gas and forest impacts. Policymakers should reserve these words for renewable energy technologies that do not rely on fuel and have no emissions.

CHAPTER 1:
BIOMASS ENERGY — THE NATIONAL CONTEXT

> In Pennsylvania and around the country, biomass energy, the burning of biological materials in commercial and industrial boilers to produce heat and electricity is promoted as "clean" and carbon neutral, and receives similar subsidies as other types of renewable energy.

> The existing biomass power industry is relatively small and largely used to produce heat and power for the wood and paper industries. However, driven by renewable energy incentives, there are now more than 150 utility-scale facilities being proposed and built in the United States as well as multiple biomass co-firing projects at coal plants. Numerous small biomass boilers are also being installed around the country to provide heat at schools and other institutions.

> Nationally, emerging demand for forest wood by biomass energy facilities, wood pellet plants, and cellulosic ethanol production is approximately 90 million tons a year, far exceeding available logging residues that are usually cited as the primary source of "energy wood." The European market for wood imported from North America is also growing.

> New biomass energy ventures have stated that logging residues are insufficient, and that whole tree harvesting is needed to meet emerging demand.

> A number of biomass plants propose to use construction and demolition debris as fuel, but such materials must be sorted to remove contaminated wood, and supplies are limited.

In Pennsylvania, as across the country, biomass energy[1]—the combustion of biological materials of recent origin to generate heat and power—is promoted as an affordable, local, and renewable substitute for fossil fuels. Promoted as "clean" and "green," electricity generated at biomass power plants is eligible for most of the same renewable energy policy and financial incentives as wind and solar power, and an increasing number of incentives exist for installing smaller biomass boilers operated solely for heat. In response to incentives, the number of biomass energy facilities, both large and small, has expanded enormously around the country, with a particularly large increase in state-supported institutional sized thermal biomass boiler installations in Pennsylvania.

However, unlike other renewable energy technologies, burning biomass produces large amounts of greenhouse gas emissions and conventional air pollution, including particulate matter and precursors of ground-level ozone. Additionally, since most biomass burners use wood for fuel, a growing biomass energy sector will likely increase forest harvesting,[2] which is generally acknowledged as unfriendly to climate. What is the current capacity of the biomass energy sector in Pennsylvania, and how is it developing? How much fossil fuel use could biomass energy displace, and what does biomass energy mean for air quality, greenhouse gas emissions, and forest cutting in the state? This report addresses these questions, first examining national trends in the biomass industry and investigating the forest, carbon, and air pollution impacts of biomass energy in general, and then investigating the current and emerging biomass energy sector in Pennsylvania.

THE EMERGING BIOMASS POWER INDUSTRY

The surge in new biomass energy development now under way nationally represents the first significant growth in decades for an industry dominated by aging infrastructure. As of 2008, the Energy Information Administration reports approximately 300 operating biomass plants producing an estimated 7,173 megawatts (MW), with 1981 as the median year of construction.[3] The oldest facilities in the United States have been operating since the 1930s. Most biomass burners are industrial boilers, meaning boilers located at a mill or pulp or paper plant that provide heat and sometimes power to that facility. About half use wood as their primary fuel, with the balance using wood liquors from the paper and pulp industry as their primary fuel, and most use unprocessed wood as a secondary fuel. This infrastructure generated about 37 million megawatt hours (MWh) in 2010, or about 0.9 percent of the electricity generated in the United States that year. “Other” biomass, defined by the Energy Information Administration (EIA) as consisting mostly of the biogenic portion of municipal waste, was responsible for 0.46 percent of U.S. electricity generation in 2010.[4]

The size of the biomass power industry has been stable for the last few decades. However, the industry is now in a period of dramatic growth, driven by state-level renewable energy mandates and federal tax incentives. Across the country there are more than 150 proposals to build new utility-scale biomass plants and to “co-fire” or “re-fire” coal plants with biomass, a process in which biomass either supplements or replaces coal in existing power plants. These new projects tend to be larger than the existing fleet of biomass power plants, and many are stand-alone commercial enterprises with the primary goal of delivering electricity to the grid, rather than providing heat and electricity to an associated industrial facility. At more than 5,000 MW,[5] the amount of biopower capacity currently in planning and permitting nationally is approximately equivalent to the current capacity of the biomass power industry.

In addition to the surge in utility-scale biomass electricity generation, numerous smaller heat-only or combined heat and power (CHP) biomass burners are being installed around the country to replace oil, gas, and coal boilers at schools and other institutions. A relatively rare example of a campus-sized CHP plant is the 2 MW facility at Middlebury College in Vermont, which burns about 20,000 tons of wood a year. Institutional-sized biomass boilers typically burn around 1,000 tons of fuel per year for a school-sized facility, in contrast to the hundreds of thousands of tons of fuel that industrial and utility-scale burners require. Because of their small size, these institutional facilities often trigger minimal oversight at the state level, making it difficult to track the number being installed. Just as utility-scale biomass installations receive financial support from taxpayer- and ratepayer-funded subsidies for renewable power generation, a number of state and federal grant and loan programs cover initial installation costs for smaller-scale institutional boilers.

CUMULATIVE DEMAND FOR “ENERGY WOOD” NATIONALLY

Many different materials can be burned for energy generation. The main categories of biomass fuel are forest wood, mill residues, “urban wood,” which usually includes construction and demolition waste, energy crops including switchgrass and willow, and crop residues, such as corn stover. Given this variety of materials, industry data[6] still show that, nationally, the overwhelming majority of biomass facilities and co-firing projects now in planning and permitting will use forest wood as fuel.

Until recently, industry assurances that waste wood, sawmill residues, and pulping wastes constitute the primary fuel source for the biomass industry have been widely accepted as sufficient evidence for biomass energy to be considered "carbon neutral." This conclusion is based on the assumption that burning waste material, including forestry residues,[7] emits no more greenhouse gases than letting them decompose naturally. However, the current rapid expansion of biomass facilities across the country raises serious questions about the ability of "waste" materials to meet the demand for fuel,[8] and with no clear line between forestry residues and "low value" trees that are frequently harvested for biomass, the emerging demand for biomass has real potential to significantly accelerate forest harvesting in some regions of the country. Such increased harvesting is likely to reduce carbon storage in forests, invalidating the claim that biomass energy is carbon neutral (see Chapter 2 for a fuller examination of forest carbon dynamics.)

In addition to providing green wood chips for combustion biomass facilities, forests are also being harvested for other kinds of "energy wood." The wood pellet industry is undergoing a dramatic surge in growth, supported by demand from pellet-only biomass burners and an emerging, potentially large international market for wood fuels. Cellulosic ethanol facilities that use wood as feedstock comprise a smaller demand, but this demand is also likely to grow significantly as technology to digest wood into ethanol or other fuels develops. Excluding demand from existing facilities, the combined new demand by proposed biomass power facilities and coal plant co-firing and re-firing projects is about 65 million tons of green wood per year nationally, while proposed pellet facilities and currently proposed ethanol facilities would require about 25 million tons per year.[9] Together they total to about 90 million tons per year of new demand for energy wood in the United States. The European market for wood fuel imported from the United States is also growing. According to an industry source,[10] European demand for wood fuels will increase to around 72 million green tons a year by 2014, with much of this demand met by wood pellet exports from the United States and Canada.

While developers of some new biomass energy facilities claim that wood from forestry residues, land-clearing, and other "waste" wood sources are sufficient to meet emerging demand for biomass fuel, it is increasingly clear that forest harvesting will have to increase significantly to meet the rapidly expanding demand for wood fuel and feedstock. According to U.S. Forest Service data,[11] the total number of forestry residues generated each year is about 100 million green tons. However, maintenance of forest soil fertility, erosion prevention, and other considerations of sustainable forestry call for leaving at least 50 percent of logging residues on most logging sites. Logistics and accessibility further restrict the amount of sites where logging residues can be collected. The actual availability of forestry residues for fuel is thus certainly far less than 50 million green tons, falling considerably short of emerging demand. Even if the entire 50 million tons were available for biomass fuel, co-firing all this material in coal plants would generate enough energy to displace only about 2.3 percent of the nation's coal use in 2010.[12]

Demand for biomass fuel is already intense in some regions. A 2010 editorial[13] in the leading industry publication on the wood market explains:

> Hungry for large volumes of wood, and frequently armed with government subsidies, the nascent operations have triggered wood price spikes and cross-grade competition in the tightest markets. The oft-repeated assumption that forests and sawmills are littered with waste wood, just waiting for a cheap home, is proving largely erroneous.

Energy companies themselves have been straightforward regarding the need for increased forest harvesting to provide fuel. The air permit for the 70 MW Laidlaw biomass plant proposed in Berlin, N.H., states that the plant will burn 113 tons of "whole logs" per hour. The website[14] for the Frontier Kinross ethanol plant in Michigan states that the facility will require one million tons of "surplus" forest growth a year, largely consisting of whole trees. In North Carolina, Duke Energy won a case in front of the Utilities Commission and in state court to allow whole trees to be defined as "waste wood" under the biomass provisions of the state's alternative energy regulations. In Duke's pre-trial testimony, the company emphasized the undesirability of logging residues as a source of fuel and its preference for whole-tree harvesting, stating that "wood waste" is limited and that there is "simply not enough 'wood waste' fuel available" to meet the company's needs:

> In today's marketplace, only approximately 6 percent of forest residues are collected within our service area. Most are left at the harvest site because they are considered uneconomic to transport and have low quality for utilization due to size, dirt, and bark content.

Beyond forest wood, a number of biomass facilities are proposing to burn construction and demolition debris (C&D) and other sources of "waste" wood, including used shipping pallets, as biomass fuel. Facilities burning this material can sometimes generate extra revenue by collecting part of the "tipping fee" that generators of such waste often pay for its disposal. However, construction and demolition waste contains a mix of pressure treated, painted, and laminated wood, along with untreated wood. Removing contaminated wood, particularly wood treated with copper chromium arsenate (CCA), is required so that heavy metals and other air toxics are not released at unacceptably high levels when this material is burned. It is unclear how effectively such separation can be performed, and how much "clean" fuel can be generated cost-effectively from these sources of "urban" wood.

CHAPTER 2:
CARBON EMISSIONS FROM BIOMASS POWER

- The idea that biomass energy is carbon neutral is largely based on the assumption that biomass fuels are derived from waste materials that would decompose and emit carbon dioxide anyway, thus burning them for energy results in no net increase in emissions.
- Even when fueled by waste wood, however, biomass power plants emit significantly more CO_2 than fossil fuel power plants, due to their low efficiency and the low energy density of biomass.
- The Manomet Study was commissioned by the State of Massachusetts to determine the net carbon impacts of biomass energy. The model compares net carbon emissions from biomass energy and the "business as usual" fossil fuel scenario, taking current forest sequestration of CO_2 from energy generation into account in both scenarios. Biomass combustion emits more CO_2 than fossil fuels, creating an initial "carbon debt." It takes forests decades to recapture the extra CO_2 emitted under the biomass scenario when whole trees are harvested for fuel. Other studies have since confirmed this conclusion.
- Responding to new science on bioenergy carbon emissions, the State of Massachusetts drafted a policy restricting eligibility of biomass power for renewable energy credits.
- At the federal level, EPA has been slow to recognize the significant potential for biomass energy to act as a net source of carbon, but is devising a system for biogenic carbon accounting.

The surge in bioenergy development occurring around the United States and internationally is chiefly driven by the treatment of biomass as a "renewable" fuel and the subsidies that accompany that designation. At least by implication, a desirable attribute of renewable energy is that it emits less greenhouse gases than fossil-fueled energy, and, until recently, the assumption that biomass energy was equally entitled to this assumption as wind or solar power has rarely been questioned. To the extent that power sector carbon emissions are counted in the United States, for instance in the Northeast's Regional Greenhouse Gas Initiative (RGGI) cap and trade system for CO_2 emissions from power plants, CO_2 emissions from bioenergy are usually ignored.

As long as the biomass industry consisted chiefly of industrial facilities burning mill waste or pulping liquors, the assumption of carbon neutrality did not attract much attention, since net carbon dioxide emissions from combustion of these wastes were considered equivalent to the emissions that would occur if they were simply left to decompose, and because the industry as a whole was relatively small. However, the surge in proposals for large-scale bioenergy facilities around the country has brought new scrutiny to the biomass power industry and its potential effects on forest cutting and greenhouse gas emissions. These new facilities tend to be larger than the existing fleet of industrial boilers, and they overwhelmingly propose to use forest wood for fuel, rather than mill wastes. Burning one ton of green woodchips emits almost exactly one ton of CO_2, and the low efficiency of biomass facilities combined with the low energy density of wood means that, per MWh, carbon emissions from biomass facilities exceed those from fossil-fueled plants (Table 1). Partly because biomass tends to have a high moisture content, utility-scale biomass power facilities are at best about 24 percent efficient at converting fuel into electricity, compared to higher efficiencies at fossil fuel plants. Because stack emissions of CO_2 from a biomass plant are about 150 percent those of a coal plant, and 250–350 percent those of a natural gas plant, displacing fossil-fueled power with biopower immediately increases the rate of emissions. Whether those emissions "net out" over time, and how long this takes, depends on the source of fuel. When trees are harvested for fuel, this quickly moves forest carbon that would not otherwise have been emitted into the atmosphere in a short time frame. Regrowing trees to resequester an equivalent amount of carbon released by burning, which is what is required to achieve "carbon neutrality"—that is, no increase in atmospheric carbon above what would have occurred anyway—requires decades to centuries.

Table 1. **Modeled Carbon Dioxide Emissions per Megawatt-Hour from Utility-Scale Gas, Coal, and Biomass Facilities**

	Fuel C per MMBtu (lb)	Facility Efficiency	Fuel MMBtu Required to Generate 1 MWh	Lb CO_2 / MWh
Gas combined cycle	31.9	0.45	7.54	883
Gas steam turbine	31.9	0.33	10.40	1,218
Coal steam turbine	56.1	0.34	10.15	2,086
Biomass steam turbine	58.1	0.24	14.22	3,029

Note: Efficiency rates for fossil fuel facilities calculated using EIA heat rate data; Biomass efficiency value is common value for utility-scale facilities.[15]

THE MANOMET STUDY

As more biopower plants have been proposed around the country, a growing number of studies have increasingly recognized that far from being carbon neutral, harvesting trees and burning them for power moves significant amounts of forest carbon into the atmosphere, while simultaneously diminishing forest carbon sequestration. The carbon impact of biomass energy was examined in detail by what has become known as "the Manomet Study,"[16] which was commissioned by the State of Massachusetts in response to growing concerns about the impacts of three large biomass energy facilities proposed in Western Massachusetts. The study was conducted by the Manomet Center for Conservation Sciences, along with Vermont's Biomass Energy Resource Center, the Pinchot Institute, and the Forest Guild. The Manomet Study explored different scenarios to evaluate net carbon emissions from wood energy, utilizing a Forest Service model of forest growth to track how quickly forests harvested for fuel would grow back.

The Manomet model assumed a modified but conventional treatment of burning of "waste wood," treating CO_2 emissions from forestry residues as if they would be equivalent to decomposition emissions after about 10 years if that material had been left on site to decompose. However, recognizing that the amount of wood required to fuel biomass development in Massachusetts far exceeded the amount available as forestry residues, the Manomet team also calculated the net carbon emissions when new trees are cut to provide biomass fuel. The model compared CO_2 emissions from biomass with CO_2 emissions from fossil fuels by examining two scenarios: a "business-as-usual" scenario in which forests are cut for sawtimber only and power is generated from fossil fuels; and a "biomass" scenario in which some biomass power replaces fossil fueled power. Under this scenario, forests are cut for sawtimber and then additional "low value" trees are harvested for biomass fuel, along with partial collection of the tops and branches generated in the harvest.

A key element of the Manomet model was the acknowledgment that forests are currently growing and currently sequestering carbon, and this baseline level of carbon sequestration must be taken into account when calculating net CO_2 emissions from energy generation. Thus in both the biomass and the business-as-usual scenarios, the CO_2 emitted by energy generation is taken up by forests as they regrow after cutting. Since biomass combustion emits more CO_2 than fossil fuels, its combustion creates an initial "carbon debt." Eventually, after a period of several years or even decades, enough of the additional carbon emitted by burning biomass has been recaptured by new forest growth so that net emissions for the biomass scenario are reduced to the same level as net emissions in the fossil-fuel, business-as-usual scenario. Only after this threshold has been reached—which may take decades—can biomass begin to show a lower net emission of CO_2 than fossil fuels.

Manomet's calculations of the time required for biomass energy to show equivalent emissions with fossil-fueled energy are presented below. As expected, the carbon "payback" times are much shorter when biomass fuels are confined to "residues that would decompose anyway," as opposed to mixed wood, which is a combination of residues and additional whole tree harvesting. In the mixed wood scenario, it would take biomass emissions 15–30 years to achieve parity with emissions from oil. It is important to note that this is not "carbon neutrality"—it is simply an equivalence with fossil fuels. When replacing a gas thermal system, the switch to biomass represents greater net carbon emissions for 60–90 years.

Table 2. **Estimates of Time Parity with Fossil Fuels, asCalculated by the Manomet Model**[17]

Years to Achieve Equal Flux with Fossil Fuels

	Fossil Fuel Technology			
Harvest Scenario	**Oil (#6)/Thermal**	**Gas/Thermal**	**Coal/Electric**	**Gas/Electric**
Mixed wood	15–30	60–90	45–75	>90
Logging residues only	<5	10	10	30

Since Manomet, other studies have come to similar conclusions about the several-decades long "payback" times for biomass carbon to be resequestered. A recent study[18] on the carbon implications of harvesting managed Southeastern forests for fuel found that using biomass for energy would increase net CO_2 emissions for more than five decades, even taking into account the high growth rates and intensive management of Southeastern plantation forests.

In the context of the urgent need to reduce greenhouse gas emissions, the finding that net CO_2 emissions from utility-scale biomass exceed those from fossil fuels is enormously consequential, especially for states like Massachusetts where legislation (the Global Warming Solutions Act) mandates percentage reductions in greenhouse gas emissions by a certain date, in this case 2020. In response to the findings of the Manomet Study, the State of Massachusetts proposed new regulations designed to constrain biomass power eligibility for renewable energy credits to those facilities that meet certain efficiency and fuel-sourcing criteria. This policy is unique in the country, and even the world, in recognizing that biomass power can be a net source of greenhouse gases if not developed under certain quite narrow conditions.

Meanwhile, federal action regulating biogenic CO_2 emissions has not been decisive. Despite initially proposing to regulate biogenic carbon emissions under the "Tailoring Rule," which adapts Clean Air Act regulatory thresholds to the regulation of greenhouse gases, the EPA almost as quickly proposed a three-year moratorium on permitting requirements for biogenic carbon emissions sources. In July 2011, EPA suspended applicability of the Tailoring Rule to sources of biogenic CO_2, and later convened a Science Advisory Board to help the agency construct an accounting system for CO_2 emissions from biogenic sources that would take the dynamic nature of the biogenic carbon cycle into account.

CHAPTER 3:
POLLUTANT EMISSIONS FROM BIOMASS COMBUSTION

> While actual emissions depend on the type of pollution controls employed, biomass combustion emits as much or more particulate matter (PM), nitrogen oxides (NO_X), volatile organic compounds (VOCs), and carbon monoxide (CO) as other solid fuels.

> PM emissions from biomass combustion depends on the quality of the material burned. In general, the cleanest burning material is debarked trunkwood from trees; combustion of green wood and bark can significantly increase emissions. However, "clean burning" wood pellets have a heavy lifecycle carbon footprint, since the highest-quality pellets require harvesting more than two tons of trees to make one ton of pellets.

> A large proportion of the PM emitted by biomass combustion is in the smallest particle size fractions, which present the most danger to health, as this material is difficult to eliminate once it enters the lungs.

> Small biomass boilers such as those used for heat at schools generally employ cyclonic devices for emissions control that use centrifugal force to spin out PM in the larger particle size classes, but do little to control fine particulates. Relatively few units use electrostatic precipitators (ESP), which are more effective in controlling fine PM, but which add tens of thousands of dollars to facility costs.

> Utility-scale and industrial biomass energy facilities nearly always employ an ESP or a baghouse for PM control, which are capable of capturing well above 90 percent of PM. However, because of provisions in the Clean Air Act, these facilities are generally held to less stringent emission standards than are coal-burning facilities.

> Nearly all new large-scale biomass facilities now being built employ "add-on" controls for NO_X. Add-on emission controls for CO, the pollutant generally emitted in the greatest quantity from biomass combustion, are more rare. Control of acid gases, including HCl, requires injection of large amounts of neutralizing agents.

While biomass energy is often portrayed as "clean," combusting wood and other biological materials actually emits similar amounts of PM, NO_X, VOCs, and CO as other solid fuels, and dramatically more of key pollutants than oil and gas (the appendix contains information on the main pollutants emitted by biomass burning). Post-combustion controls can effectively limit emissions, but emissions from boilers that do not employ the most sophisticated controls can vary considerably, depending in great part on the type of fuel burned. Common fuels can show considerable variability. Including bark in the fuel stream can significantly increase fine PM[19] and NO_X emissions compared to burning only trunkwood,[20] and burning energy crops and agricultural wastes can generate higher filterable PM, NO_X, sulfur dioxide (SO_2) and hydrogen chloride (HCl) emissions than woody fuels.[21] Phosphate (PO_4) is also frequently elevated in particulate matter from agricultural materials,[22] and use of animal manure as fuel can also significantly increase nitrogen and phosphorus emissions. As a low-sulfur material, biomass generally emits less sulfur than coal, though sulfur emissions can be relatively high from combustion of construction and demolition waste that contains dust and "fines" from gypsum-based wallboard. Combustion of construction and demolition-derived wood and other wastes like railroad ties and telephone poles can also emit a number of toxic pollutants, including heavy metals, dioxins, and organic toxics like benzene and formaldehyde. While emissions of most pollutants can be reduced by post-combustion emission controls and "good combustion practices" that provide adequate oxygen and a hot flame to oxidize carbon compounds to CO_2, there are no emission controls for carbon dioxide itself, and the "cleaner burning" a facility is, the more CO_2 it emits, by definition.

PARTICULATE MATTER

Particulate matter, a combination of ash, carbon and other constituents, is one of the most important and closely monitored pollutants from biomass combustion. Particulate matter emissions are generally considered as being divided into the filterable fraction, which is largely a function of ash content, and the condensable fraction, which forms in the atmosphere from the cooling and condensation of gaseous pollutants emitted during combustion. Straight combustion of biomass with no emission controls produces much more filterable PM than natural gas or oil, but generally less than coal.[23] However, actual PM emission rates from any particular unit depend on the efficiency of the controls used, and the generally tighter regulation of coal-burning units means that post-control PM emissions from coal burners can be lower than from biomass burners, even though pre-controls, emissions are higher.

A distinguishing characteristic of biomass emissions overall is the large proportion of particulate matter that is emitted in the 2.5 micron ($PM_{2.5}$) size class and below. Particulate emissions of the larger size fractions are derived from ash entrained into the flue gas, but a substantial fraction and often the majority of the particulate matter emitted from biomass combustion is less than one micron in diameter,[24] the hardest size fraction to capture and one that has special implications for health, due to its ability to penetrate deep into the lungs. This size fraction includes aerosols, particles with a diameter less than 0.1 micron. Particles and aerosols emitted during combustion are considered "primary" particles; aerosols that form in the diluting exhaust plume or later in the atmosphere are considered "secondary" particles, and constitute the condensable fraction of PM. Emissions of NO_X, SO_2, and VOCs from biomass combustion contribute to this secondary particulate formation and can contribute to regional haze and ground-level ozone.

The kinds of fuel burned can influence PM emissions due to inherent content of ash-forming inorganic compounds. Bark has a higher concentration of inorganic ash-forming elements (ash content of 5–8 percent) than woodchips without bark, which have an ash content of 0.8–1.4 percent.[25] Bark has also been found to have significantly elevated mercury concentrations relative to trunkwood over a range of sites.[26] Agricultural material has a higher ash content than wood (4–12 percent, for straws and cereals[27]). Wood pellets, which are generally made from debarked and thus cleaner and more homogenous wood, and are also drier, are the cleanest burning form of wood fuel, although the pellet production itself can be a highly polluting process (see next page).

Compared to residential wood smoke, which tends to be dominated by poorly combusted organic carbon compounds, the hotter and more reliable combustion conditions of well-operated biomass boilers tend to produce emissions composed of salts and oxides of K, Cl, S, Ca, Na, Si, P, Fe, and Al.[28] These alkali metal vapors produced by combustion (primarily potassium and sodium) can condense and re-emerge in the fine particle fraction,[29] and are also notorious for causing buildup of difficult-to-remove residues in boilers and on emissions control equipment.[30]

PARTICULATE MATTER EMISSIONS FROM SMALL BOILERS

Depending on the control technology used, particulate emissions rates from small biomass burners can be highly variable, with reported rates of PM emissions from some "controlled" units reaching levels similar to combustion with no external emission controls. A survey[31] of small, institutional-size biomass boilers found operating emission rates ranging from 0.06 lb/MMBtu[32] to 0.506 lb/MMBtu, similar to EPA uncontrolled emission values[33] for wet wood (0.29 lb/MMBtu), dry wood (0.36 lb/MMBtu), and bark combined with wet wood (0.5 lb/MMBtu). Some European units are reported to be better controlled; summarizing a number of European emissions tests, a study commissioned by the New York State Energy Research and Development Authority (NYSERDA)[34] found PM emission rates at European units burning woody fuels to range between 0.023 and 0.116 lb/MMBtu. A U.S. study[35] of three high-efficiency institutional boilers using cyclonic systems for PM control found $PM_{2.5}$ emission rates of around 0.06 lb/MMBtu for two boilers burning wood pellets, while the boiler burning wood chips had an emission rate of around 0.095 lb/MMBtu. The study found that particulate matter was heavily shifted toward the smallest size classes, with 80–95 percent of PM at less than 1 μm in diameter.

Regulation of emissions from small biomass burners in the United States is minimal. The EPA's "area source"[36] boiler rule does not set any emission standard for biomass boilers smaller than 10 MMBtu/hr, and therefore misses the majority of "school-sized" units. Under EPA's rule,[37] new units 10–30 MMBtu/hr in capacity are supposed to meet a filterable PM standard of 0.07 lb/MMBtu, while the limit for boilers larger than 30 MMBtu/hr is much lower, at 0.03 lb/MMBtu. However, as "area" sources, the vast majority of existing biomass boilers in the U.S. are not held to any federal emission standard because the area source boiler rule applies only to new units, not existing units.

Smaller institutional biomass burners, such as those employed to heat schools and other institutions, generally control PM emissions with cyclones, multicyclones, or core separators, mechanical collectors that employ centrifugal force to pull PM out of the exhaust. These devices remove some coarse particles but are considered relatively ineffective at removing fine particles,[38] which are of the greatest health concern. Some institutional units employ electrostatic precipitators or baghouses, which capture both a greater proportion of total PM and are considered the most effective means for capturing fine PM, but correct operation is essential.[39]

While the use of "ultra-low emissions" technologies from Europe is often advocated for small-scale burners in the United States,[40] many of these European burners in fact achieve their low emissions rates using ESPs for PM control,[41] a technology equally available in the United States and Europe. Still, while dry electrostatic precipitators for small biomass units are capable of removal efficiencies of 90 percent or greater overall,[42] a European study found that they are least effective in removing particles in the size range 0.2–1 microns, the very small size fractions that most effectively penetrate into the lungs.[43] Theoretically, equipping small biomass combustors with electrostatic precipitators can reduce biomass PM emissions to approximately the same level as from an oil burner, which for American units is as little as 0.0012 lb/MMBtu,[44] but such rates are rarely achieved in practice.[45] The combination of cleaner burning fuels and emissions controls is required to really reduce rates; a survey of Austrian and Germany biomass burners found small burners with ESPs to be best controlled, but also that burners combusting pellets, rather than whole logs or chips, had the lowest emissions. Particulate matter emission rates as low as 0.003 lb/MMBtu were reported for the survey, though specific control technologies associated with the lowest emission rates were not specified.[46]

Using gasification instead of direct combustion is another way to reduce PM emissions. With gasification, fuel is combusted under low-temperature and low-oxygen conditions to drive off volatiles (carbon compounds in a gaseous state), and then this gas is combusted separately from the fuel material. Small gasification units simply employ "staged combustion" with a separate chamber above the fuel bed for gas combustion and heat transfer; utility-scale gasification facilities collect the "syngas" and use it to drive a gas-powered turbine to generate electricity. In a U.S. study of small wood-fired units, gasifiers had the lowest levels of emissions,[47] and some of the best-performing European boilers available in the United States use gasification. For instance, the imported Viessmann "Pyrot" pellet burner is advertised as employing gasification and having a PM emission rate of 0.06 lb/MMBtu,[48] and Hamont boilers imported and manufactured by ACT Bioenergy have been reported to achieve $PM_{2.5}$ emission rates of around 0.06 lb/MMBtu when burning pellets.[49] However, achieving this emissions rate comes not only at the cost of the boiler, but also involves an ongoing commitment to purchasing pellet fuel rather than green wood chips. Prices of $200–$250/ton are not uncommon for wood pellets,[50] though bulk delivery may result in a lower price. (Green woodchips, which have a lower heating value, are $20–$40 per ton. Even taking into account the greater heating value of dried pellets, the cost difference is significant.)

While effective PM emissions controls for small burners are available, installing them has appeared to be prohibitively expensive for some small institutions using biomass heating. For a 10 MMBtu/h boiler, which is the size of some school biomass boilers, PM emissions control systems range from $50,000 to more than $150,000, depending on the technology.[51] Even with state and federal grants, the costs may prove too much for some schools hoping to install a biomass boiler. For instance, a "Fuels for Schools" boiler installation project in Missouri that had received $370,000 in federal stimulus funds was abandoned when the school district was told by EPA that an electrostatic precipitator costing an additional $60,000 was required for emissions control.[52] A 2010 review[53] of small wood-fired facilities in the United States did not find any ESPs currently in use, though some are in line to be constructed.

USE OF PELLETS TO REDUCE EMISSIONS AND THE CARBON DILEMMA

Burning "cleaner" and drier fuels such as high-quality wood pellets can reduce PM emissions, particularly from small-scale burners. However, the gain comes with a significant cost in terms of carbon emissions, since when the full lifecycle emissions of wood pellets are taken into account, it is clear that emissions of both conventional pollutants and CO_2 are similar or higher than emissions from green wood chips. The industry standard estimate is that it takes about two tons of green wood to manufacture a ton of pellets.[54] Even accounting for the difference in moisture content (green wood generally has a moisture content of around 45 percent; pellets are dried down to a moisture content of 6–10 percent), manufacture of high-quality pellets requires that bark and low-diameter material be rejected and that only white, interior trunkwood be utilized. This material is chipped, pulverized, cooked, extracted, and dried, a process that itself emits high levels of volatile organic compounds[55] and uses large amounts of energy. The low-diameter material and bark generated during this process is often used to generate process heat for pellet manufacturing, and burning that material itself produces large amounts of PM, VOCs, CO, and NO_X.

The energy and fossil fuels expended during pellet manufacture and drying can be considerable. In one study, use of fossil fuels during production and drying of pellets required about 13 percent of the energy inherent in the pellet product itself.[56] While using waste wood and fossil fuels to generate heat to dry the pellets makes the final product burn more efficiently, pellet production ultimately involves harvesting and burning much excess wood, which increases the overall carbon footprint of pellet manufacture, as well as emissions of conventional pollutants.

PARTICULATE MATTER CONTROLS FOR LARGE BOILERS

Utility-scale and industrial biomass energy facilities usually employ an ESP or a fabric filter baghouse to control PM emissions. In some cases, a cyclonic device may be used first, with emissions then passed through to an ESP or a baghouse to remove fine particulates. Both ESPs and fabric filters employed at industrial and commercial biomass power facilities are capable of achieving greater than 99 percent removal of particulates from the exhaust stream, but fabric filters are generally considered to be the most effective in removing fine PM.

Given that uncontrolled PM emissions from coal combustion tend to be greater than emissions from biomass combustion, large-scale biomass burners using ESPs and baghouses should be able to achieve PM emission rates at least as low as those achieved at coal-burning facilities. However, the air permits for many if not most large-scale biomass plants do not usually contain maximally stringent emissions limits for PM, because of various loopholes in the Clean Air Act, including a higher threshold for biomass (250 tons of a criteria pollutant) than coal (100 tons) to trigger a mandatory "best available control technology" analysis. EPA's "boiler rule," the part of the Clean Air Act concerned with reducing emissions of HAPs, sets less stringent PM emission standards for biomass facilities than coal-burning facilities.[57] Thus, most large-scale biomass facilities have higher PM emission rates than coal plants that are currently being permitted.[58]

CONTROLS FOR OTHER POLLUTANTS

Nitrogen oxide emissions from combustion are a function both of fuel nitrogen content and the formation of "thermal" NO_X from oxidation of atmospheric nitrogen, which is partly controlled by combustion temperature. Small institutional-scale biomass boilers do not have add-on controls for NO_X, and typical NO_X emission rates are similar to or greater than emissions from natural gas and fuel oil burners.[59] Most existing industrial biomass boilers also do not have add-on controls for NO_X, meaning that their rates are more than twice those at a plant with NO_X controls. However, add-on controls for NO_X are common for the new large-scale biomass facilities now being built, resulting in NO_X emission rates similar to those at coal facilities. Nitrogen oxide emissions can be reduced by low-NO_X burners, which optimize combustion to reduce NO_X formation, and also with pollution control devices that employ selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR), or derivations of these technologies. SCR and SNCR both use added ammonia to transform NO_X in the exhaust stream to dinitrogen (N2), the form of nitrogen found in the atmosphere. Both technologies result in some release of un-reacted ammonia from the emission control device, known as "ammonia slip."

Carbon monoxide is a pollutant of significance not only for its own sake but also because the conditions of "incomplete combustion" that lead to its formation are the same conditions that in part govern formation of organic HAPs such as acrolein and formaldehyde. Carbon monoxide emissions generally increase with fuel moisture, thus burning green wood chips, as is common in biomass facilities, is generally more polluting than burning drier material. Carbon monoxide formation can be controlled using "good combustion practices" that maximize oxidation of fuel carbon to CO_2. However, many biomass facilities burn a variety of fuels at a variety of moisture contents, making consistent combustion conditions difficult to achieve. For instance, a study of CO emissions from an institutional boiler burning wood chips in New York found that hourly rates varied from 10 ppm to 1,500 ppm, and that the CO rate did not relate to load or changes in boiler operation.[60] Operation does affect CO emissions greatly, however, as shown in another combustion test that found a hundred-fold increase in CO emissions over an eight-minute period upon shutdown of a small woodchip boiler.[61] Such spikes can produce hazardous conditions of indoor air pollution if boiler exhaust systems are leaking or not vented properly. Maximizing oxygen in combustion is not a straightforward solution for controlling CO formation, since increasing burn temperature accelerates formation of thermal NO_X, making NO_X emission limits harder to meet. Add-on controls for CO consist of oxidation catalysts that convert carbon monoxide to carbon dioxide, and that also reduce emission of volatile organic compounds and organic HAPs. However, catalysts are expensive and, while some of the new large-scale facilities being proposed around the country will include them, they are infrequently employed on the existing fleet of biomass burners.

The acid gases hydrochloric acid, hydrofluoric acid and sulfuric acid are also emitted by biomass combustion and can be controlled by injecting neutralizing sorbents like limestone or trona to the boiler process or exhaust stream. Adequate neutralization can require significant amounts of these agents; industrial biomass facilities typically inject from one-half ton to 12 tons of sorbent per hour.

CHAPTER 4:
BIOMASS COMBUSTION IMPACTS ON HUMAN HEALTH

> Certain characteristics make biomass emissions a special concern from a human health perspective, including the heavy concentration of biomass PM in the smallest particle size fractions, which penetrate deeply into the lungs. Emissions controls typically employed on institutional biomass burners do little to control emissions of fine PM.

> "Good combustion practices" that ensure complete combustion of fuels in institutional burners can shift the composition of emitted PM toward alkali metals and reduce the partially combusted carbon that characterizes residential wood smoke.

> Some biomass facilities are proposing to burn waste or "urban" wood, such as construction and demolition debris, which contains dioxins, heavy metals, and other hazardous air pollutants. New EPA rules may make use of contaminated materials for fuel more common, increasing the threat from small biomass burners with minimal emissions controls. Some pellet fuels can contain high concentrations of heavy metals.

> The significant amount of diesel fuel necessary to harvest and transport wood fuel for biomass burners — about 2.1 gallons per green ton of chips — is itself a major source of particulate matter and other pollutants.

> The American Lung Association "does not support biomass combustion for electricity production" and "strongly opposes the combustion of wood and other biomass sources at schools and institutions with vulnerable populations." The Massachusetts Medical Society opposes construction of large-scale biomass energy plants, stating that they pose an "unacceptable risk to the public's health."

Despite its frequent portrayal as "clean," biomass combustion is a major source of particulate matter, making it of concern from a public health perspective. The effects of particulate pollution on respiratory and cardiac health are well documented and are characterized by a linear response that extends below the current EPA health threshold. "Natural experiments," such as the well known example of how traffic restrictions during the Atlanta Olympics led to decreased particulate levels and lower hospitalization rates for asthma,[62] confirm that reducing pollution pays dividends virtually immediately in improved health and reduced medical costs. Hundreds of studies have confirmed the link between air quality and respiratory and cardiac health, but new relationships between air pollution and health are still emerging, including connections with seemingly unrelated conditions like diabetes.[63]

Health organizations have recognized the air quality impacts of biomass combustion. The 2011 Energy Policy of the American Lung Association states that the ALA "does not support biomass combustion for electricity production" and "strongly opposes the combustion of wood and other biomass sources at schools and institutions with vulnerable populations."[64] The Massachusetts Medical Society has also adopted a resolution opposing construction of large-scale biomass energy plants in Massachusetts on the grounds that they pose an "unacceptable risk to the public's health."[65]

SPECIAL CHARACTERISTICS OF BIOMASS EMISSIONS

Beyond acting as an ordinarily harmful source of PM and other pollutants, including NO_X, VOCs, CO, and HAPs, certain characteristics make biomass emissions a special concern from a human health perspective. In particular, although emissions controls can reduce the overall amount of PM emitted, the PM that does get past emission controls—even advanced systems like ESPs—is heavily shifted toward the finest particle size fractions of one micron and even 0.1 micron and below, which are the most difficult to clear from the lungs. Cylconic systems that are installed on many institutional biomass burners do very little to reduce fine particle emissions.

To some degree, the toxicity of biomass emissions depends on boiler operation and how completely fuels are combusted. Wood smoke contains polycyclic aromatic hydrocarbons, transition metals, acids, and elemental and organic carbon, all of which exhibit varying levels of toxicity. With proper boiler operation at a high temperature leading to complete combustion, particulate emissions from small and medium-sized facilities are dominated by alkali compounds, with a smaller percentage of PM composed of particulate organic matter that has higher toxicity. However, poor operation of commercial-sized burners shifts the emissions profile to resemble that of residential wood-burning, where incomplete combustion produces emissions that can be even more toxic than diesel particulate matter. A survey of operational emissions from several of Vermont's small boilers revealed problems at many facilities that increased emissions,[67] suggesting that maintenance of these facilities can be a challenge.

Emissions of metals from biomass burning can also be of concern. Research in Finland found that even when green, "clean" wood is burned, some elements such as magnesium tend to accumulate in bottom ash, while certain more toxic elements, including zinc, lead, cadmium, copper, arsenic, and thallium, tend to concentrate in the fine particulate fraction emitted from the stack.[68] The high surface area of particulate matter means that when PM containing these metals is inhaled, a transfer of metals to the lungs can occur. Burning waste or so-called "urban" wood, especially construction and demolition wood (C&D), can lead to significant emissions of arsenic, chromium, mercury, and lead, as well as dioxins/furans and other hazardous air pollutants that result from burning glues, stains, and trace plastics. While construction and demolition wood is supposed to be sorted so that the more toxic pieces, including pressure-treated wood, are removed from the fuel stream, in practice such separation is difficult to perform, and is an essentially unregulated process left to the discretion of the sorting facility operator. The potential for construction and demolition fuel to emit toxics has been taken seriously by EPA; for instance, in 2010 an ethanol company in Minnesota was fined $120,000 for burning wood contaminated with lead-based paint and arsenic preservatives in its biomass gasification unit.[69] However, proposed rules from the EPA indicate a loosening of the standard that the agency uses to determine whether fuels are contaminated, meaning that more C&D wood will likely be approved for use as biomass fuel in the future.[70]

Construction and demolition wood also appears to be making its way into the pellet fuels manufacturing process. Pellet fuels are widely marketed as "clean burning" and are required for use in certain biomass boilers in order to achieve reduced PM emission rates that are impossible to achieve when burning green woodchips. However, a recent study from New York found elevated levels of arsenic, chromium, cadmium, lead, mercury, nickel, copper and zinc in 15 percent of a selection of 100 different brands of pellet fuels purchased in the state. In some cases, metals concentrations were thousands of times higher than in the low-concentration, presumably uncontaminated samples.[71] While the Pellet Fuels Institute has voluntary standards for pellet quality, there is no regulatory pellet fuel standard in the United States, though the EPA is expected to propose regulations.

DIESEL EMISSIONS FROM BIOMASS HARVESTING AND TRANSPORT

Biomass has greater volume and lower energy density than other fuels, thus emissions of diesel particulate matter (DPM), NO_X, and air toxics associated with fuel harvesting and transport can represent a significant additional source of toxic emissions. Biomass harvesting and transport requires one to two gallons of diesel fuel per ton of material delivered to a biomass power plant, with one recent and credible estimate at 2.1 gallons per green ton.[72] Thus, a 50 MW plant that burns around 650,000 tons of wood a year will require approximately 1.365 million gallons of diesel fuel to provide that wood.[73] Diesel particulate matter from trucks is recognized as an especially toxic form of fine particulates,[74] and is a significant contributor to air quality problems, particularly in urban areas and near heavily traveled roadways. Diesel NO_X emissions from transport alone can be equivalent to about 30 percent of stack emissions for a typical stand-alone biomass plant,[75] and for certain air toxics, emissions from mobile sources and fugitive sources can be as high as stack emissions.[76]

CHAPTER 5:
POLICY DRIVERS FOR BIOMASS POWER IN PENNSYLVANIA

> A variety of policies and entities both drive and constrain biomass energy development in Pennsylvania, including the state's Alternative Energy Standard. State-commissioned efforts to promote biomass use include provisions under the Climate Action Plan (CAP), the Biomass Energy Center at Pennsylvania State University, and the "Fuels for Schools" program.

> Pennsylvania's Alternative Energy Portfolio Standard (AEPS) includes not only conventional renewables like wind and solar, but also fuels like coal mine methane and waste coal. In 2011, 54 percent of generation capacity eligible to receive alternative energy credits in Pennsylvania was fueled by combustion of various materials. Prices for both Tier I and Tier II credits under the AEPS are low, which may limit construction of new large biomass power plants. Biomass power facilities burning waste that existed when the AEPS was enacted are eligible for the more lucrative Tier I alternative energy credits, but new facilities appear to be eligible only if burning clean wood.

> Pennsylvania's Climate Action Plan (CAP) concluded that about 6 million tons of "low use" wood would be harvestable in the state each year, for allocation to the biomass electricity generation, biomass thermal, and biofuels sectors. However, the CAP appears to favor small-scale bioenergy development and recognizes that large-scale development would intensify demands on forests.

> Ongoing financial incentives for biomass power generation include Pennsylvania alternative energy credits and the federal renewable energy tax credit program. A federal program that awards a cash grant worth 30 percent of construction costs has been a major driver for biomass power proposals around the country. The United Corrstack/Evergreen Community Power plant in Reading, which burns construction and demolition waste, received $39 million under this program.

> The State of Pennsylvania has also awarded grants and loans to a number of biomass energy facilities at schools and other institutions, including institutional biomass burners that would otherwise not be affordable. The Pennsylvania "Fuels for Schools" program provides support and promotes these installations.

> None of Pennsylvania's programs and policies deal in any substantive way with the environmental or health impacts of biomass combustion. The CAP and other programs and policies assume that biomass combustion is carbon neutral, an assumption challenged by scientific analysis (see the June 2010 "Manomet Report.")

As one of the most forested states in the country, and one with a robust agricultural economy, Pennsylvania is often seen as having great potential for bioenergy development. State initiatives to increase bioenergy production in Pennsylvania focus on both combustion-based biomass energy and on cellulosic biofuels production.[77] While agricultural residues and energy crops are anticipated to play a large role in the state's bioenergy future, pending development of an infrastructure for collecting and pelletizing these materials, forest wood will continue to be the largest source of biomass for both biomass energy and biofuels applications. The use of wood as biofuel feedstock has a particularly significant potential for expansion. For instance, a woody cellulosic ethanol demonstration plant planned in Curwensville, Clearfield County, received $2 million from the state's Redevelopment Capital Assistance Program, and the developer has spoken of plans for 10 to 30 additional plants across Pennsylvania, pending investor interest.[78]

The following are some of the main influences in Pennsylvania both promoting biomass energy and holding its development in check.

BIOENERGY IN PENNSYLVANIA'S ALTERNATIVE ENERGY PORTFOLIO STANDARD

As in other states, biomass power is seen in Pennsylvania as an important tool for reaching renewable energy goals, but unlike in most other states, Pennsylvania's renewable energy goals are specified in a broadly defined AEPS that includes a wide variety of technologies and fuels, including non-renewables such as coal mine methane and waste coal. The AEPS mandates that by 2021[79] at least 8 percent of electricity sold to consumers be generated from Tier I sources, which according to the state's Public Utilities Commission, include "solar photovoltaic and solar thermal energy, wind power, low-impact hydropower, geothermal energy, biologically derived methane gas, fuel cells, biomass energy (including generation located inside Pennsylvania from byproducts of the pulping process and wood manufacturing process such as bark, wood chips, sawdust and lignin in spent pulping liquors) and coal mine methane."[80] Solar power has a "carve out" and is mandated to provide 0.5 percent within the overall 8 percent to be provided by Tier I sources. A further 10 percent of electricity must be supplied from Tier II resources, which include "waste coal, distributed generation systems, demand-side management, large-scale hydropower, municipal solid waste, generation of electricity outside of Pennsylvania utilizing byproducts of the pulping process and wood manufacturing process, such as bark, wood chips, sawdust and lignin in spent pulping liquors and integrated combined coal gasification technology."[81] As of late 2011, 54 percent of the 6,816 MW of generation capacity eligible to receive alternative energy credits in Pennsylvania was fueled by combustion of various forms of gas, municipal waste, biomass, waste coal, residual fuel oil, and other wastes.[82]

Because renewable energy can be expensive to produce, energy producers sell renewable energy credits or, in the case of Pennsylvania, alternative energy credits (AECs), to help recoup the costs. An AEC serves as a certificate that one MWh of power has been generated from alternative sources as defined under Pennsylvania statute. Under the state's mandatory compliance program, utilities purchase AECs from power generators, and the extra costs are then passed through to the consumer. The price of these AECs reflects not only legislative mandates but also market influences. Prices for Tier I credits in Pennsylvania have fallen from initial levels of around $25 per megawatt-hour as significant new wind capacity has been brought online, saturating Tier I requirements;[83] in 2010, the weighted average price for Tier I credits was $4.77 per megawatt-hour.[84] The Tier II requirement has been oversubscribed[85] from the day the AEPS was signed in 2004, and the weighted average price for Tier II credits in 2010 was only $0.32 per megawatt-hour. Tier I credits are worth less than the value of the federal renewable energy production tax credit (PTC), which, at $0.022 per kilowatt-hour for wind power and $0.011 for biomass energy, is worth many times the value of alternative energy credits. Facilities are eligible for the PTC for 10 years following construction.

The low prices currently offered for AECs in Pennsylvania are likely one reason that there are not more utility-scale biomass facilities currently proposed in the state. The Alternative Energy Credit Program currently recognizes[86] four biomass facilities in Pennsylvania as qualified to receive credits: the Domtar Johnsonburg Mill, which burns black liquor, a byproduct of the papermaking process; the P. H. Glatfelter plant at Spring Grove, which burns wood and black liquor; Viking Energy of Northumberland, which burns wood; and the Koppers Susquehanna plant in Montgomery, which burns railroad ties and other waste wood (in-state biomass facilities that burn byproducts of the pulping process and wood manufacturing process became eligible for Tier I credits through a 2008 amendment, but it was only extended to existing facilities). The newer 30 MW United Corrstack/Evergreen Community Power facility in Reading, which burns a variety of waste wood, has not yet applied for eligibility for AECs in Pennsylvania, possibly because the Tier II credits for which it qualifies are worth so little. It is not yet clear whether the 100 MW tire-burning "Crawford Renewable Energy" power plant proposed in Crawford County, which would combust 330,000 tons of tires a year, will qualify as a renewable power source under Pennsylvania rules.

According to the annual report published by the Pennsylvania Public Utility Commission,[87] there is sufficient generation, transmission, and distribution capacity to "reasonably meet the demands of Pennsylvania's electricity consumers for the near future." All utilities in Pennsylvania have been required to meet the prescribed alternative energy generation obligations since January 2011. However, as of early 2012, the list of power plants either proposed or under construction in Pennsylvania does not include any biomass-powered facilities; proposed energy projects consist of a number of large natural gas facilities, along with smaller wind and solar power projects.[88]

PENNSYLVANIA'S CLIMATE ACTION PLAN

Pennsylvania's Climate Action Plan (CAP), prepared to fulfill the requirements of the Pennsylvania Climate Change Act of 2008, envisions a relatively moderate role for biomass power generation in the state. However, even this moderate role would require significant and likely unsustainable increases in forest harvesting. For instance, the "Wood to Electricity" component of the CAP's forestry plan, informed by analysis of the state's "Low-Use Wood" study (discussed below) states that between 3 million and 6 million dry tons of wood (or 6–11 million green tons) could be harvested from Pennsylvania's forests each year. This figure would more than double the annual commercial timber harvest for the state, which was reported at approximately 5 million tons in 2006.[89] The goal of the wood-to-electricity initiative in the CAP is to "increase wood utilization for sustainably generated electricity to 0.8025 million metric tons a year by 2020," which translates to a fuel requirement of about 885,000 tons of wood per year just for biomass electricity. (The projection reduces the assumed availability of the initially large estimate of harvestable wood based on physical access and the ecological sustainability of harvesting, then splits the remaining amount into thirds to account for demands from electricity generation, small-scale thermal applications, and cellulosic biofuels. Some of the assumptions behind these calculations are discussed below in the section on forestry.)

The state's climate action plan makes the common but fundamentally incorrect assumption that burning wood to generate electricity does not result in any net emission of carbon dioxide, noting that "co-utilization of biomass with coal represents a least-cost option for reducing CO_2 emissions" and citing a projection that if 3 percent of coal-fired capacity in Pennsylvania were co-fired, it would offset CO_2

emissions by almost 3.3 million tons per year. However, the climate plan also includes a cautionary statement about the large amount of wood that is required to replace even a small amount of coal:

> Data suggest that if all Pennsylvania coal plants were to co-fire biomass at a 10 percent rate (thermal basis), it would double the current total demand for Pennsylvania woody biomass. This level of demand may impact woody biomass availability, existing wood industries, and potential wood energy projects with higher efficiency of conversion, such as district/industrial CHP projects. However, co-firing of these facilities would potentially produce positive benefits to these alternative biomass markets, and forest management opportunities, if constrained to a more moderate level, in the range of 2–4 percent by thermal input.

Given these caveats, the CAP therefore primarily favors "community-based and district-scale energy initiatives that reduce net carbon emissions through utilization of forested wood biomass and other clean wood material" and recommends state financing and assistance for small-scale projects. The state has been aggressive about providing funding for development of a number of small biomass projects, as discussed below.

BLUE RIBBON TASK FORCE ON THE LOW-USE WOOD RESOURCE

The Governor's Task Force on Low-Use Wood, initiated by Governor Rendell in 2004, was assembled to contemplate the future of Pennsylvania's forests. The panel was comprised almost exclusively of representatives from the wood products industry, thus it was not surprising that it recommended increased harvesting of low-grade trees as a remedy for past cutting practices, which left low-grade wood standing and removed high-grade wood excessively. The task force report clearly saw biomass fuel harvesting as the solution to the problem, uncritically accepting the idea that biomass energy is carbon neutral:[90]

> The only apparent way to significantly and controllably reverse the trend of increasing forest inventory of low-use wood is through the expansion of wood-based energy production and development of a Pennsylvania regional hub in bio-refinery competency and production. Wood consumed for energy is clearly accepted as a carbon neutral concept when based on harvesting from well-managed forests, as is done in Pennsylvania. Governor Rendell's announced goal of one billion gallons a year of bio-based transportation fuels is certainly a major step in projecting an economic basis for developing our internal energy-wood based ethanol production facilities.
>
> The harvesting of our low-use wood would be both sustainable in perpetuity and environmentally sound from a standpoint of carbon neutrality. Conversion of the Commonwealth's stocks of low-use wood to energy and bio-refinery products at a sustainable rate is the most socially responsible and ecologically sensible strategy for this vast, yet vastly underutilized, natural forest resource.
>
> This Task Force, in the process of examining the over-abundance of so-called "Low-Use Wood" in the state, and its potential best utilization, has discovered a literal energy gold mine on the forestlands of Pennsylvania, one that will renew itself into perpetuity with proper, sustainable management and clear, consistent policy, legislation, and funding.

The study concluded that about 6 million tons of this low-use wood could be harvested annually to provide fuel and feedstock, a figure that was further used to inform forestry projections in the State's Climate Action Plan.[91] This amount of harvesting would exceed the state's annual harvest of commercial timber, which is estimated to be around 5 million tons per year.[92] The estimate contrasts somewhat with one from the Cary Institute of Ecosystem Studies, which defined the sustainable harvest of biomass as the amount of wood that can be cut in working forestlands without having harvest rates exceed growth rates. The analysis removes reserved lands like parks from the analysis, eliminating the possibility that growth on reserved lands can "compensate" for harvesting on working forestland in the net harvesting-growth equation. Using this approach, the Cary Institute study determined that the total sustainable yearly harvest in Pennsylvania would be around 4 million green tons. The Cary Institute study did not, however, equate "sustainability" with "carbon neutrality."

FINANCIAL INCENTIVES FOR BIOMASS AND PELLET FACILITIES

A variety of financial incentives exist for biopower development. As renewable energy providers, biomass power plants and coal plants co-firing biomass are eligible to sell alternative energy credits, which can generate millions of dollars a year for a single facility. The federal renewable energy production tax credit (PTC) for biomass power grants facilities 1.1 cents per kilowatt-hour or about $96,360 annually for every MW of generation for facilities fueled with "open loop" biomass, which is sourced from waste wood, forest thinning or agricultural residues. The credit doubles for facilities powered by "closed loop" biomass, which is composed of crops or trees grown specifically for energy production,[94] although few if any facilities around the country have taken advantage of this aspect of the program. Facilities are eligible for the PTC for a period of 10 years.

Instead of taking the PTC, biomass facilities have been eligible for a program initiated under the 2009 American Reinvestment and Recovery Act (ARRA, or Stimulus Act), which reimburses 30 percent of plant development costs (the 1603 program that enables this converts the incentive tax credit into a cash grant). While relatively few of these grants have been allocated for utility-scale biomass power plants, the largest grant allocated to date, for $39 million, was to the United Corrstack/Evergreen Community Power facility located in Reading, Pa., which burns construction and demolition debris and other waste. There has also been money available for biomass power development though programs like the United States Department of Agriculture's "Rural Energy for America Program," the Forest Service's "Woody Biomass Utilization Grants" and also the "Biomass Crop Assistance Program" (BCAP).[95]

Pennsylvania has allocated a significant amount of state-level funding to small-scale biomass energy development, much of which is ultimately derived from federal funds. Pennsylvania's "Energy Harvest" funds are part of a yearly base grant from the Department of Energy,[96] which was supplemented with Stimulus Act funding. The Pennsylvania Energy Development Authority (PEDA) has also provided up to $500,000 per project in loans for alternative energy development, including biomass power and pellet manufacture. A number of facilities have received grants under these programs, as listed in Chapter 7, Table 4.

PENNSYLVANIA'S "FUELS FOR SCHOOLS AND BEYOND" PROGRAM

The Pennsylvania "Fuels for Schools and Beyond" program[97] has promoted installation of a number of biomass boilers in schools as well as in other institutions across the state, replacing oil and gas boilers with wood boilers. The state has allocated funding to cover the upfront costs of such installations, which would otherwise be prohibitive. These projects have proved attractive to some school districts because of the potential savings in fuel costs, which have ranged from $60,000 to $190,000 a year, depending on the size of the facility. The Clearfield School District replacement of one of two boilers designed to burn oil or gas with biomass provides an example of the economics of these biomass projects that school districts have found it so difficult to resist. By burning 640 tons of biomass in a season at $35 per ton, the district saved almost $89,000 over the cost of heating with liquid fossil fuels for a year.[98]

Larger facilities in Pennsylvania have also received state and federal grants for wood boiler installation that would otherwise be cost-prohibitive. For instance, the Elk Regional Health Center received $1,775,000 from the USDA Rural Development program, a $500,000 grant from the Pennsylvania Energy Development Authority, a $250,000 USDA Forest Service Woody Biomass Utilization grant, and a $300,000 Community Facilities loan from the Rural Development program[99] for conversion of its heating system from natural gas to biomass. However, certain factors may combine to slow the pace of new bioenergy installations in Pennsylvania. The recent surge in natural gas exploration in the region and the abundance of natural gas is likely decreasing the relative financial benefit of switching to biomass heat. Further, nearly all the new biomass energy projects going forward in Pennsylvania have received some kind of governmental financial support, much of this derived from Stimulus funds. As these funds become less available, the pace of new project announcements is likely to slow.

PENN STATE UNIVERSITY'S BIOMASS ENERGY CENTER

It is difficult to summarize the number and scope of biomass energy-related projects and activities at Penn State, they are so numerous, although much of the research being conducted focuses on biofuels, not biomass power. Penn State's status as a leader in biofuels research was consolidated with receipt of a $21 million Department of Energy grant in 2009 to study biopolymers in plant cell walls and improve methods for converting plants into fuel.

The University's Biomass Energy Center[100] coordinates and facilitates much of the research and outreach on biomass energy. However, while some of the research at the center focuses on issues such as sustainability, the materials on the Center's website have been almost uniformly uncritical of biomass energy. The site provides factsheets on various aspects of biomass energy both for biofuels and biomass power, but there is no discussion of the controversy surrounding claims that biomass is carbon neutral, and no discussion of potential air quality impacts from biomass power.[101] The "Wood Tech" website[102] administered by Dr. Charles Ray of the Penn State School of Forest Resources is a valuable source of information, but contains little serious discussion of the net greenhouse gas implications of moving already sequestered forest carbon into the atmosphere, nor any substantive discussion of pollutant emissions from bioenergy.

From an economic perspective, biomass energy and co-firing in particular are seen by some as an efficient way to create a market for agricultural products. An article in *Hay and Forage Grower* from April 2010[103] quotes an extension agent from the Penn State College of Agriculture saying that if 5 percent of Pennsylvania's coal use were replaced with agricultural biomass, it would require 4.4 million tons of biomass per year, and that providing fuel for just 5 percent of the power at a single 1,000 MW coal plant would require about 50,000 acres of high-yield agricultural production.

Promotion of biomass in the academic realm in Pennsylvania is not confined to the university level. Amendments to the academic standards put forward by the State Board of Education specify goals for different age groups. By seventh grade students are expected to be able to "define and describe how fuels and energy can be generated through the process of biomass conversion."[104]

CHAPTER 6:
BIOMASS SUPPLY AND HARVESTING IN PENNSYLVANIA

- There are five major categories of biomass fuel: mill residues, agricultural residues, energy crops, "urban" wood, which may include construction and demolition waste, and forest wood.
- Mill residues are already mostly allocated in Pennsylvania, and thus do not exist in quantities to support new demand for biomass fuel.
- Agricultural residues may be available in limited amounts as fuel for bioenergy, but are also considered important feedstocks for cellulosic ethanol production. The time window for collection of these materials is limited, and spoiling over long-term storage is a problem. To be usable as fuel for combustion-based biopower, agricultural residues require processing and in some cases pelletization, requiring creation of a parallel processing infrastructure.
- Energy crops grown in the future could include switchgrass and fast-growing trees. However, replacing 5 percent Pennsylvania's fossil-fueled power with switchgrass would require harvesting about 1.3 million acres per year. A five-year study of actual production costs for switchgrass concluded that costs per ton were $50–$60 at the farm gate, even before pelletizing and transport costs, higher than the $20–$30 per ton commonly paid for wood chips. These materials will likely be most cost-effective as feedstock for ethanol production.
- "Urban wood," which mostly consists of construction and demolition (C&D) waste, is already used as fuel by the United Corrstack/Evergreen Community Power facility in Reading. This material contains arsenic, chromium, lead, mercury, dioxins, and other toxins.
- Forestry residues, the tops and branches left over after commercial harvesting, are limited, and plans to expand the biopower industry in Pennsylvania depend on accelerating harvesting of "low-value" trees. Burning this material for energy, however, will increase CO_2 emissions relative to the fossil fuels being replaced.
- Aside from being a major source of greenhouse gas emissions, increased forest harvesting to provide biomass fuel has implications for long-term forest sustainability. Pennsylvania's Department of Conservation and Natural Resources (DCNR) has issued guidelines for biomass harvesting that mandate retention of a percentage of tops and limbs on the forest floor.
- The DCNR states that the Low-Use Wood Task Force's estimates that 6 million tons of biomass could be harvested annually "are overly optimistic and do not adequately consider the many ecological, social, and practical concerns associated with procuring biomass."
- Increased biomass harvesting may also exacerbate Pennsylvania's existing problem with deer overbrowse, which is already a significant threat to forest regeneration.

Pennsylvania's seemingly abundant forest and agricultural resources, as well as waste wood supplies, are frequently invoked as the foundation for a new biopower industry. Five major categories of potential fuels are generally considered: mill residues, which are the waste materials left over at sawmills and other wood processing facilities, including pulping liquor residue from pulp and paper mills; agricultural residues, such as the corn stover left over after harvesting; energy crops such as switchgrass or fast-growing trees like willow; "urban wood," which can include tree trimmings and yard waste but is generally understood to chiefly consist of pallets and construction and demolition debris; and forest wood. The forest wood category is in some cases assessed as the amount of collectable "waste" or "residues" left over after commercial timber harvesting, and in others as "available net growth" on the landscape after current harvesting levels are taken into account.

ESTIMATES OF BIOMASS AVAILABILITY

Estimates of the true availability of materials in these categories vary, but an often-cited reference for state-level estimates of residues and waste materials is a report from the National Renewable Energy Laboratory (NREL).[105] Despite the variety of fuels described by the NREL report, it is important to note that the overwhelming majority of biomass energy facilities currently being proposed and built both in Pennsylvania and the country as a whole intend to use forest wood as fuel.

MILL RESIDUES

Wood mill residues include bark, coarse residues (chunks and slabs), and fine residues (shavings and sawdust). Forest Service data indicate that nationally, about 42 percent of mill wastes are used for energy generation, with only about 1.5 percent of mill residues going unused,[106] and this appears to be the case in Pennsylvania, as well. For instance, a biomass availability report for the Southern Alleghenies Region[107] concluded that mill residues for this region were mostly allocated to existing uses. A review of air permit applications conducted for this report indicates that there are as many as 70 sawmills and other businesses using wood for heat and sometimes power in the state, with a number of those having switched to burning wood within the last decade, suggesting that there is probably little unused mill waste available. The estimate from NREL for Pennsylvania is that, of about 1.36 million tons of mill residues generated in the state, only about 144,000 tons go unused. Since the NREL report was published in 2005 and thus predates the recent increase in the number of biomass and pellet facilities in Pennsylvania that use mill wastes, it is certain that only negligible amounts of mill waste are currently available.

AGRICULTURAL RESIDUES

The NREL report estimates that, because some portion of crop residues needs to be retained in place to maintain soil fertility, only about 35 percent of total residues generated each year, or about 810,000 tons of material, are available in Pennsylvania for biomass fuel. Availability of these materials for biomass power generation is likely to be limited, as demand for agricultural residues as feedstock for cellulosic biofuels is likely to grow, particularly under federal mandates for cellulosic biofuels production. Storage of large amounts of agricultural residues is a challenge for the biopower industry, since unlike wood, agricultural materials can only be collected during the growing season and must be stockpiled for the rest of the year. Further, material that is over 15 percent in moisture content cannot be stored for very long without spoiling,[108] thus storage of agricultural materials may present even greater challenges for the biopower industry than the biofuels industry, where fermentation is actually part of the process. Making agricultural residues useful as biomass fuel on a meaningful scale will also require creation of a parallel infrastructure for collecting, processing, and drying materials. Pelletizing agricultural materials creates the best fuel product with ideal moisture content and homogeneity, but this requires still more infrastructure.

ENERGY CROPS

Energy crops grown in the future could include switchgrass and fast-growing trees like willow and poplar. However, as is the case for agricultural residues, these hypothetical crops are being claimed by both the biofuels and the biomass power industries. The state allocated a significant grant to Ernst Biomass, a switchgrass pelletization facility, and other efforts to make energy crops a reality are under way. However, a number of factors still make it likely that energy crops will be chiefly used as feedstock for biofuels, rather than as fuel for biomass power generation, including the strong federal mandate for cellulosic ethanol production. The USDA estimates that about 27 million acres of switchgrass will be required to meet biofuels mandates nationally;[109] similarly, EIA estimates that it would require harvesting between 20 and 30 million acres of energy crops to meet renewable electricity generation goals by 2030.[110] The acreage required to provide fuel for even a single biopower facility is substantial—for instance, powering a 50 MW biomass plant with switchgrass requires about 61,000 acres harvested at six tons of fuel per year. Replacing just 5 percent of Pennsylvania's fossil-fueled power with switchgrass would require harvesting about 1.3 million acres per year. Scaling up could prove expensive. A five-year study of actual production costs for switchgrass concluded that costs per ton were $50–$60 at the farm gate, even before pelletizing and transport costs.[111] This is much higher than the $20–$30 per ton commonly paid for wood chips by utility-scale biomass plants, so it seems unlikely that large amounts of land will be allocated to growing switchgrass or other energy crops for biomass electricity generation, though small amounts could be economically grown to meet fuel needs at certain small facilities that are able to pay more per ton than a utility-scale plant.

URBAN WOOD

"Urban wood" refers to waste wood and other materials generated in the urban environment. This can include materials like utility line trimmings and yard waste, but the main source of urban wood is from construction and demolition debris (C&D). Wood contained in this waste stream must undergo sorting to at least remove pressure-treated lumber, which contains the EPA-recognized carcinogens arsenic and chromium. It is common, however, for painted, stained and glued wood to be passed through to the fuel supply; thus, common contaminants in C&D are lead paint, glues, mercury waste, dioxins/furans, and pentachlorophenol, which was used as a preservative in telephone poles. Non-wood waste, such as plastic, can increase chlorine content of the burned waste stream and exacerbate post-combustion formation of dioxins/furans.

Sorting C&D material to generate a "clean" waste stream is expensive and never completely effective, since sorting is done visually and it is difficult to remove 100 percent of pressure-treated wood, and painted, stained and glued wood is generally considered burnable and is allowed to pass though. Even when expensive emissions controls are employed by the combustion facility, emissions of metals and emissions of other HAPs can be significant. One proposal[112] to burn "clean, sorted" C&D wood for energy in Springfield, Mass., would have resulted in arsenic, chromium, and dioxin emissions that would increase ambient air levels of these contaminants to around 50 percent of state-established health thresholds in the vicinity of the plant, assuming zero background concentration.[113]

Estimates of urban wood/C&D availability in Pennsylvania vary. The NREL report estimates that there are about 1,238,000 tons generated in the state per year; a dataset from the Oak Ridge National Laboratory, which is used as an input into Energy Information Administration projections of biomass power build-out, takes price into consideration and estimates that 400,000 to 667,000 tons of urban wood may be available in the state annually.[114] However, these estimates appear to assume that a very high percentage of construction and demolition wood is burnable as fuel, disregarding the significant portion of the fuel stream that is made up of pressure-treated and otherwise contaminated material.

It is sometimes argued that C&D wood is a carbon neutral fuel because burning it emits less greenhouse gases than landfilling it, which can lead to emissions of methane, a greenhouse gas many times more powerful than carbon dioxide. However, EPA's own estimates of landfill gas generation reflect the assumption that significant amounts of waste wood, as well as even more decomposable materials like food waste, are buried so thoroughly in landfills that they actually represent carbon sequestration, rather than a net source of emissions.[115] A separate multi-study review[116] of methane evolution from landfilled wood estimated that only about 0–3 percent of the carbon from wood is ever emitted as landfill gas, concluding that the majority of wood in landfills actually represents relatively long-term carbon sequestration. EPA also has determined that recycling construction and demolition waste is the most effective greenhouse gas mitigation strategy.[117] Re-use of wood further reduces the amount of forest harvesting required for wood products, yielding additional greenhouse gas benefits.

FORESTRY RESIDUES

Commercial logging operations in Pennsylvania generate around 3 million green tons of logging residues per year.[118] However, actual availability of logging residues in Pennsylvania is limited by accessibility and the need to leave material in the forest to maintain nutrient stocks that are contained in tops and branches; as a precaution, the Pennsylvania DCNR recommends leaving 15–30 percent of pre-harvest biomass on the forest floor following a harvest.[119] An independent evaluation of biomass availability carried out for the Southern Alleghenies region[120] (including counties in Maryland) also concludes that less than 50 percent of harvest residues are actually available as fuel. A realistic assessment of logging residue availability depends on a variety of factors, but it is clear that actual availability of this material is limited as a significant source of fuel.

BIOMASS HARVESTING IMPACTS ON PENNSYLVANIA'S FORESTS

As of the 2006 United States Forest Service inventory,[121] Pennsylvania has 16.57 million acres of forest-land, constituting 58 percent of the state's total area. Of this, the majority—15.25 million acres—are of natural origin. The state's roundwood harvest was around 5 million green tons in 2006. The "Wood to Electricity" initiative, a component of Pennsylvania's Climate Action Plan, assumes that between 3 million and 6 million dry tons of forest wood could be harvested each year for energy use (6–11 million green tons). Given limited availability of logging residues, the majority of this supply would need to come from trees cut specifically for fuel.

The report from the Task Force on Low-Use Wood estimates that a large proportion of the 468 million tons of standing low-use wood in Pennsylvania forests is available for biomass harvesting.[122] The plan does not say that all low-use wood should be harvested, but instead that annual growth in this class of wood can be continuously harvested to provide an ongoing and sustainable source of fuel. However, this approach fails to take into account the actual way that biomass harvesting is conducted, which is not by traveling with light impact through the forest, selectively harvesting non-merchantable trees, but by increasing harvesting intensity in areas already being cut for commercial timber. Citing similar concerns, the Pennsylvania DCNR has also objected to the task force's estimate that 6 million tons are available annually, stating that the estimates are "overly optimistic and do not adequately consider the many ecological, social, and practical concerns associated with procuring biomass."[123]

FOREST MANAGEMENT CONSIDERATIONS FOR WOODY BIOMASS HARVESTING

While support for wood energy is strong in the Pennsylvania Department of Conservation and Natural Resources, the DCNR does appear to have grappled with the real limitations to wood availability in the state. The DCNR's Carbon Management Advisory Group final report (May 2008) recommends consideration of "using local wood for small-scale local district combined heat and power and liquid fuel production, etc." but also recommends paying "close attention to biomass supply":

> Under the most optimistic available projections for annual sustainable biomass supply (6 million tons/year statewide), if all of that supply was harvested (ignoring availability and accessibility issues) and was used for electricity production, using in-state biomass for this option will offset 13 percent of existing electricity demand in PA. Similarly, if all of the estimated sustainable biomass supply (6 million tons/year) was used for cellulosic ethanol production, 6 percent of PA's annual transportation fuel demand would likely be met with ethanol produced in-state.

Charged with administering public lands in the state, the DCNR expresses considerable concern that biomass harvesting can influence long-term forest sustainability, listing impacts to wildlife and soil fertility among potential threats. The agency's biomass harvesting guidance provides that, on state lands, at least 15–30 percent of pre-harvest biomass (tops, limbs and other unmerchantable material) should be left on site to maintain soil fertility and other ecological values, or the equivalent of one out of every three to six trees removed, and that the best opportunities for biomass harvest may be natural-event driven, such as disturbance from ice storms or insect damage. To the extent that the DCNR appears to favor biomass power development, a preference is expressed for small-scale projects such as "Fuels for Schools" projects, rather than larger projects that require greater amounts of fuel.

A parallel concern for the future of Pennsylvania's forests is the existing problem of deer over-browse, which kills seedlings and inhibits forest regeneration. Increased biomass harvesting could exacerbate this problem by increasing harvesting intensity, thus opening the forest canopy to light and further stimulating brushy growth of the light-loving early successional plant species that increase deer browse and population growth. DCNR's "State of the Forest" report[124] states that (italics added):

> …only 50 percent of the study sites had sufficient seedlings and saplings to replace the existing forest with a similar tree composition. In other words, if disturbed, such as through a windstorm, insect or disease outbreak, or *timber harvest*, half of Pennsylvania's forests are at risk of failing to regenerate! If this analysis includes stands with closed canopies, the outlook is even more negative. These results paint a troublesome picture for the future of Pennsylvania's forests, and could have serious economic and ecological implications. It is appropriate to say that, based on available evidence, although some variation exists across the Commonwealth, the regeneration problem is ubiquitous and is not specific to a particular region, owner, or forest type. Forestry experts strongly recommend that tree seedlings be in place before harvesting in order to establish a new forest.

Currently, the Pennsylvania DCNR spends millions of dollars each year fencing off portions of state forests so that seedling regeneration can occur and trees can reach a height where they can no longer be killed by deer browse. DCNR's inclusion of timber harvesting as a disturbance from which forests may not recover suggests that plans to increase biomass harvesting for fuel need to be reconciled with long term forest management concerns.

Forest thinning to reduce the risk of fire, which predominantly occurs in forests of the Western United States but is sometimes advocated in Pennsylvania, is also relevant to biomass harvesting. Thinning advocates claim a double benefit from projects that ostensibly reduce the risk of forest fire and provide "carbon neutral" fuel for biomass energy. However, fire does not appear to present an unusually severe threat to Pennsylvania forests. From 2003 to 2009, there were about 1,100 to 8,000 acres burned in the state each year, or about 0. 0.006 percent to 0.048 percent of the 16.5 million acres of Pennsylvania forest.[125] Thinning forests to reduce fire danger thus represents a much greater net movement of forest carbon into the atmosphere than do forest fires themselves, given the low risk of any particular area burning.

CHAPTER 7:
BIOMASS ENERGY FACILITIES IN PENNSYLVANIA

> Pennsylvania is home to more than 100 biomass-burning facilities. The majority of biomass energy generation is occurring at industrial sites and pellet mills; electricity generation from biomass is limited, with just 0.29 percent of the 219,496,144 MWh of power generated in 2010 coming from "wood and wood-derived fuels" and 0.74 percent from other biomass, including biogenic municipal solid waste.

> The Energy Information Administration lists three industrial-scale power generating facilities in Pennsylvania, which burn a variety of fuels, including fossil fuels, treated wood, and black liquor from the paper-making process. The new United Corrstack/Evergreen Community Power facility in Reading also burns treated wood and other waste.

> Use of "energy wood" is widespread. There are eight industrial-scale facilities that use wood as fuel, and more than 65 existing mills and wood-related enterprises have permits to burn wood as fuel. There are 35 recent and proposed institutional and commercial biomass burners, including 12 "Fuels for Schools" projects. There are approximately 20 existing and seven proposed pellet manufacturing mills in Pennsylvania, several of which have received grants or loans from the state. One cellulosic ethanol plant uses wood as feedstock, but potential for growth in this industry is significant.

> The state has allocated over $30 million in grants and loans to more than 40 biomass energy and wood pellet manufacturing enterprises. Most of these grants are to schools and commercial enterprises for installation of biomass burners for thermal energy.

> Cumulative demand for "energy" wood in Pennsylvania (4.3 million green tons) is similar in magnitude to the commercial wood harvest (5 million green tons). Replacing 10 percent of Pennsylvania's coal use by co-firing biomass in coal plants would require more than 12.8 million green tons per year. The State of Ohio has approved about 2,000 MW of biomass power, mostly as co-firing at coal plants, increasing the possibility that Pennsylvania's forests may be harvested to meet that demand.

> While most facilities rely on wood for fuel, several new/proposed facilities in Pennsylvania plan to burn animal wastes for fuel.

Most use of wood for energy in Pennsylvania currently occurs at wood mills and other commercial facilities, while electricity generation for distribution on the grid has been limited. In 2010, data from the Energy Information Administration indicate that just 0.29 percent of the 219,496,144 MWh of power generated in the state came from "wood and wood-derived fuels" (i.e., pulping liquors) and that

0.74 percent was generated from "other" biomass, which includes biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, other biomass solids, other biomass liquids, and other biomass gases (including digester gases and methane).[126] Total generating capacity was 108 MW for facilities fueled by wood and wood-derived fuels, and 424 MW for facilities fueled by "other" biomass, representing 0.24 percent and 0.93 percent of the total state nameplate capacity of 45,575 MW respectively.[127]

EXISTING AND PROPOSED BIOPOWER, PELLET, AND ETHANOL PLANTS USING WOOD

Figure 2 and Table 3 provide a list of existing and proposed users of "energy wood," including biomass-burning facilities, pellet plants, and cellulosic ethanol plants. Data were assembled from news stories, the federal Energy Information Administration, Pennsylvania's Alternative Energy Credit Program, and permits and statements of operating conditions listed in the *Pennsylvania Bulletin*. There are some sources of potential error in the data. Existing facilities—mostly mills—consist of facilities listed as applying in the *Pennsylvania Bulletin* for a permit to operate a wood boiler in the last decade, meaning that some of these facilities may no longer be in operation, or might not have pursued installation of a wood boiler even after applying. The current status of a few proposed biomass boiler installations is also uncertain; however, many proposed projects have received state grants and loans, increasing the likelihood that they will be completed.

FIGURE 2. **Existing and Proposed Burners, Pellet Plants, and Ethanol Facilities Using Biomass as Fuel and Feedstock in Pennsylvania**

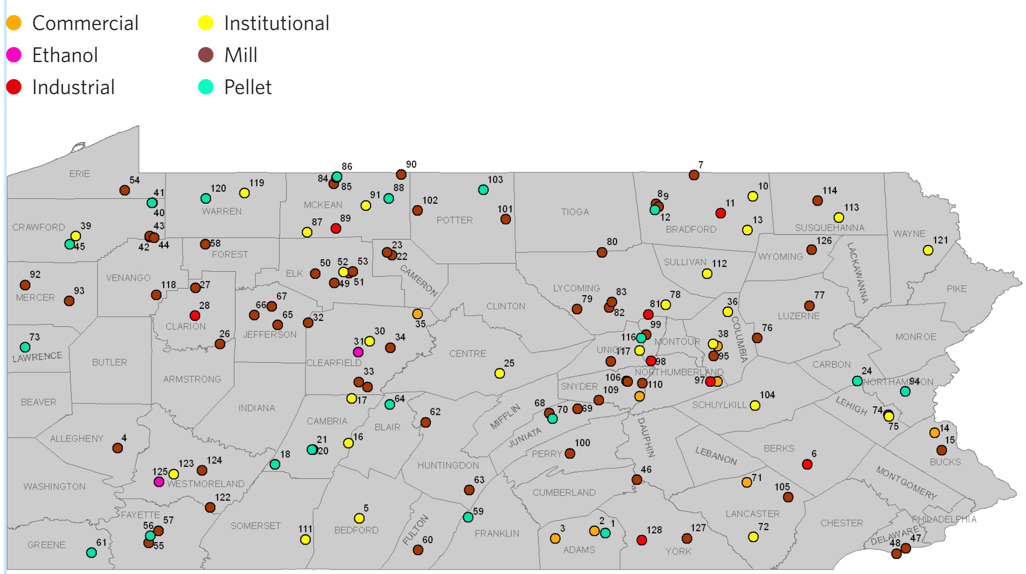


TABLE 3. **Existing and Proposed Biopower, Pellet Manufacturing, and Cellulosic Ethanol Facilities in Pennsylvania**

Label	County	Town	Facility	Type	Existing or Proposed
1	Adams	East Berlin	Penn Wood Products, Inc.	Pellet	Existing
2	Adams	Heidlersburg	EnergyWorks Biopower/ Hillandale Farms	Commercial	Proposed
3	Adams	Orrtanna	Twin Springs Fruit Farm	Commercial	Proposed
4	Allegheny	Pittsburgh	Babcock Lumber	Mill	Existing
5	Bedford	Loysburg	Northern Bedford County School District	Institutional	Proposed
6	Berks	Reading	Evergreen Community Power and United Corrsstack	Industrial	Existing
7	Bradford	Sayre	Mill's Pride	Mill	Existing
8	Bradford	Troy	Oak Hill Veneer	Mill	Existing
9	Bradford	Troy	Cummings Lumber Co., Inc.	Mill	Existing
10	Bradford	Le Raysville	Northeast Bradford School District	Institutional	Proposed
11	Bradford	Towanda	Craftmaster	Industrial	Existing
12	Bradford	Troy	Barefoot Pellet Company	Pellet	Existing
13	Bradford	Wyalusing	Wyalusing School District	Institutional	Existing
14	Bucks	Kintnersville	Peace Tree Farms	Commercial	Proposed
15	Bucks	Plumsteadville	Jenbrooke Properties, Inc.	Mill	Existing
16	Cambria	Cresson Township	State Correctional Facility at Cresson	Institutional	Proposed
17	Cambria	Flinton	Glendale School District	Institutional	Proposed
18	Cambria	Johnstown	Tinst National Pellet	Pellet	Proposed
19	Cambria	Johnstown	First Nation Wood Pellet	Pellet	Proposed
20	Cambria	Summerhill	C&C Smith Lumber Co., Inc.	Mill	Existing
21	Cambria	Summerhill	Wood Pellets Co.	Pellet	Existing
22	Cameron	Emporium	Lewis and Hockenberry, Rich Valley	Mill	Existing
23	Cameron	Emporium	Lewis and Hockenberry, Clear Creek	Mill	Existing
24	Carbon	Palmerton	Great American Pellet/ Keystone	Pellet	Proposed
25	Centre	Spring Mills	Penns Valley Area School District	Institutional	Proposed
26	Clarion	Fairmount City	OEM Enterprise, Inc.	Mill	Existing

CHAPTER 7:
BIOMASS ENERGY FACILITIES
IN PENNSYLVANIA
(CONTINUED)

Table 3 *(continued)*

Label	County	Town	Facility	Type	Existing or Proposed
27	Clarion	Marble	Allegheny Wood Products	Mill	Existing
28	Clarion	Piney Creek Township	Piney Creek Limited Partnership	Industrial	Existing
29	Clearfield	Beccaria	K & F Wood Products, Inc.	Mill	Existing
30	Clearfield	Clearfield	Clearfield Area School District	Institutional	Existing
31	Clearfield	Curwensville	Helios Scientific LLC	Ethanol	Proposed
32	Clearfield	Dubios	The Burke Parsons Bowlby Corp.	Mill	Existing
33	Clearfield	Glen Hope	Kitko Wood Products	Mill	Existing
34	Clearfield	Woodland	Walker Lumber, Inc.	Mill	Existing
35	Clearfield	Karthaus	Nydree Flooring	Commercial	Proposed
36	Columbia	Benton	Benton Area School District	Institutional	Existing
37	Columbia	Bloomsberg	Dillon Floral Corporation	Commercial	Existing
38	Columbia	Bloomsberg	Bloomsberg University	Institutional	Proposed
39	Crawford	Meadville	Crawford Central School District	Institutional	Proposed
40	Crawford	Spartansburg	Clear Lake Lumber, Inc.	Mill	Existing
41	Crawford	Spartansburg	Log Hard Pellets	Pellet	Existing
42	Crawford	Titusville	Baillie Lumber Co.	Mill	Existing
43	Crawford	Titusville	Weyerhaeuser Choice Wood	Mill	Existing
44	Crawford	Titusville	Taylor-Ramsey Corp.	Mill	Existing
45	Crawford	Union Township	Ernst Biomass LLC	Pellet	Existing
46	Cumberland	Lemoyne	Lafferty & Co, Inc.	Mill	Existing
47	Delaware	Chester	Kimberly-Clark of PA, LLC	Mill	Existing
48	Delaware	Marcus Hook	Alan McIlvain Co.	Mill	Existing
49	Elk	Kersey	Horizon Wood Products	Mill	Proposed
50	Elk	Ridgway	Buehler Lumber	Mill	Existing
51	Elk	Saint Mary's	Babcock Lumber	Mill	Existing
52	Elk	Saint Mary's	Elk Regional Health System	Institutional	Existing
53	Elk	Saint Mary's	Penn Pallet	Mill	Existing
54	Erie	Union City	Noram Seating, Inc.	Mill	Existing
55	Fayette	Hopwood	Coastal Lumber / Hopewood Sawmill	Mill	Existing
56	Fayette	Lemont Furnace	Tri State Biofuels	Pellet	Existing
57	Fayette	North Union Township	Holt & Bugbee Hardwoods, Inc.	Mill	Existing

Table 3 *(continued)*

CHAPTER 7: BIOMASS ENERGY FACILITIES IN PENNSYLVANIA (CONTINUED)

Label	County	Town	Facility	Type	Existing or Proposed
58	Forest	Endeavor	Industrial Timber & Lumber Co.— Endeavor Lumber Plant	Mill	Existing
59	Franklin	Fort Loudon	Gish Logging, Inc.	Pellet	Existing
60	Fulton	Needmore	Mellott Wood Preserving Co., Inc.	Mill	Existing
61	Greene	Garards Fort	Greene Team Pellet Fuel Company	Pellet	Existing
62	Huntington	Alexandria	The Walter McIlvain Co.	Mill	Existing
63	Huntington	Shade Gap	Interforest Lumber Corp.	Mill	Existing
64	Huntington	Tyrone	Bald Eagle Pellet Co.	Pellet	Existing
65	Jefferson	Brookville	Matson Lumber Co.	Mill	Existing
66	Jefferson	Brookville	PW Hardwood, LLC	Mill	Existing
67	Jefferson	Brookville	Brownlee Lumber, Inc.	Mill	Existing
68	Juniata	Fermanagh Township	Tammy Kay Realty, Inc.	Mill	Existing
69	Juniata	McAlisterville	Stella-Jones Corp.	Mill	Existing
70	Juniata	Mifflintown	Energex Pellet Fuel, Inc.	Pellet	Existing
71	Lancaster	Lititz	Esbenshades Greenhouses, Inc.	Commercial	Proposed
72	Lancaster	Providence Township	Providence Township Municipal Building	Institutional	Proposed
73	Lauwrence	Newcastle	Stein-David Hardwood	Pellet	Proposed
74	Lehigh	Allentown	American Atelier, Inc.	Mill	Existing
75	Lehigh	Allentown	City of Allentown / Delta Thermo Energy	Institutional	Proposed
76	Luzerne	Nescopeck	RAD Woodwork Co., Inc.	Mill	Existing
77	Luzerne	Wilkes-Barre	Toledo Furniture	Mill	Existing
78	Lycoming	Hughesville	East Lycoming School District	Institutional	Proposed
79	Lycoming	Jersey Shore	RP's Machinery Sales, Inc.	Mill	Existing
80	Lycoming	Liberty	Wheeland Lumber Co., Inc.	Mill	Existing
81	Lycoming	Montgomery	Koppers Inc. – Susquehanna	Industrial	Existing
82	Lycoming	Williamsport	David R. Webb Co., Inc.	Mill	Existing
83	Lycoming	Williamsport	Eastern Wood Products	Mill	Existing
84	McKean	Bradford	Bradford Forest, Inc.	Mill	Existing
85	McKean	Bradford	Werzalit of America, Inc.	Mill	Existing
86	McKean	Bradford	American Refining and Biochemical	Pellet	Proposed
87	McKean	Kane	Kane Area School District	Institutional	Existing

TABLE 3 *(continued)*

Label	County	Town	Facility	Type	Existing or Proposed
88	McKean	Liberty Township	Postlewait Logging Company	Pellet	Proposed
89	McKean	Mount Jewett	Temple Inland	Industrial	Existing
90	McKean	Shinglehouse	Ram Forest Products	Mill	Existing
91	McKean	Smethport	Smethport	Institutional	Proposed
92	Mercer	Greenville	Woodcraft Industries, Inc.	Mill	Existing
93	Mercer	Jackson Center	International Timber & Veneer, LLC	Mill	Existing
94	Northampton	Nazareth	Treecycle	Pellet	Proposed
95	Northumberland	Catawissa	Catawissa Lumber & Specialty Co., Inc.	Mill	Existing
96	Northumberland	Mount Carmel	Kurt Weiss Greenhouses of PA Inc.	Commercial	Proposed
97	Northumberland	Mount Carmel Township/ Coal Township	IntelliWatt Renewable Energy	Industrial	Proposed
98	Northumberland	Northumberland	Viking Energy Corp/ GDF Suez	Industrial	Existing
99	Northumberland	Watsontown	Sensenig Milling Services, Inc.	Mill	Existing
100	Perry	Elliotsburg	Tuscarora Hardwoods, Inc.	Mill	Existing
101	Potter	Galeton	Patterson Lumber Co.	Mill	Existing
102	Potter	Roulette	C.A. Elliott Lumber Co., Inc.	Mill	Existing
103	Potter	Ulysses	PA Pellets, LLC	Pellet	Existing
104	Schuylkill	Pottsville	Schuylkill County Agricultural Facility	Institutional	Proposed
105	Snyder	East Earl	Conestoga Wood Specialties Corp.	Mill	Existing
106	Snyder	Kreamer	Wood-Mode, Inc.	Mill	Existing
107	Snyder	Kreamer	Bingaman & Son Lumber, Inc.	Mill	Existing
108	Snyder	Port Trevorton	Windview Farm	Commercial	Proposed
109	Snyder	Richfield	Cherry Hill Hardwoods	Mill	Existing
110	Snyder	Selinsgrove	Modular Structures of PA, Inc.	Mill	Existing
111	Somerset	Fairhope Township	International Conservation Center	Institutional	Proposed
112	Sullivan	LaPort e	Sullivan County School District	Institutional	Proposed
113	Susquehanna	Kingsley	Mountain View School District	Institutional	Existing
114	Susquehanna	Montrose	Donald Dean & Sons, Inc.	Mill	Existing

Table 3 *(continued)*

Label	County	Town	Facility	Type	Existing or Proposed
115	Union	Lewisburg	Evangelical Community Hospital	Institutional	Proposed
116	Union	Lewisburg	Biomass Fuel Stocks of PA, Inc.	Pellet	Existing
117	Union	Mifflinburg	Yorktowne, Inc.	Mill	Existing
118	Venango	Cranberry	Seneca Hardwood Lumber Co., Inc.	Mill	Existing
119	Warren	Warren	Warren State Hospital	Institutional	Existing
120	Warren	Youngsville	Allegheny Pellet Corporation	Pellet	Existing
121	Wayne	Texas Township	McCanna Cooperage Building	Institutional	Proposed
122	Westmoreland	Champion	Babcock Lumber	Mill	Existing
123	Westmoreland	Greensburg	Greensburg Thermal, LLC	Institutional	Existing
124	Westmoreland	Latrobe	Gutchess Hardwoods, Inc.	Mill	Existing
125	Westmoreland	Madison	Coskata	Ethanol	Existing
126	Wyoming	Tunkhannock	Deer Park Lumber, Inc.	Mill	Existing
127	York	Red Lion	David Edward Ltd.	Mill	Existing
128	York	Spring Grove	P. H. Glatfelter Co.	Industrial	Existing

LARGE-SCALE BIOMASS POWER FACILITIES

The EIA's list of existing larger-scale biomass generating facilities includes three industrial direct-fired plants in Pennsylvania, with a combined capacity of 70 MW: the Koppers plant in Lycoming County, the P. H. Glatfelter plant in York County, and the Viking plant in Northumberland County. Not on EIA's list is the new United Corrstack/Evergreen Community Power facility in Reading, which at approximately 33 MW gross/30 MW net has a substantial fuel demand that is apparently being met mostly with construction and demolition wood and other waste wood.[128] The facility received $39 million in federal Stimulus funds.

Recent data on biomass co-firing does not show large coal plants currently utilizing biomass. Although the Shawville coal plant in Clearfield County and the Seward plant in Westmoreland County have both tested co-firing in the past, neither appears to be co-firing biomass now. Certain smaller facilities burn a variety of fuels besides wood, including materials like waste coal that qualify for Pennsylvania's alternative energy standard. The Energy Information Administration's 2009 list[129] of energy-producing facilities burning biomass and other materials includes the Koppers Susquehanna plant (wood solids), the P. H. Glatfelter plant (coal, black liquor, distillate fuel oil, residual [bunker] fuel oil, sludge, and wood), Viking Energy of Northumberland (natural gas and wood), Northampton Generating Company (petroleum coke, tires, waste coal, wood, and waste oil), Piney Creek (distillate fuel oil, "other" solids—including nonbiogenic municipal solid waste—waste coal, and wood), and the Johnsonburg Mill (coal, black liquor, distillate fuel oil, and natural gas).

The 33 MW Piney Creek L.P. facility in Clarion County is an example of a plant filling the niche created by the broad definition of renewable energy under the Pennsylvania definition. The plant burns waste wood, including railroad ties that are treated with creosote and telephone poles that can contain pentachlorophenol, a carcinogenic chemical used as a wood preservative. The plant experienced a large fire in the woodpile in 2009. The plant has received over $400,000 in grants and loans to supplement a portion of its waste coal with biomass fuel.

SMALL-SCALE BIOMASS FOR THERMAL ENERGY AND COMBINED HEAT AND POWER

There are more than 60 mills and other wood-related enterprises in Pennsylvania that have applied to the Pennsylvania Department of Environmental Protection for permission to use wood as fuel, but the actual amount of wood-burning now occurring is difficult to quantify precisely. A number of these businesses have applied for permits in the last few years, possibly in response to increasing fossil fuel costs. There are now 12 existing and proposed institutional "Fuels for Schools" projects, and at least 12 other institutional biomass installations, including greenhouses, farms, a hospital, and a correctional institution, almost all of which received grants and loans.

PELLET FACILITIES

Several new pellet mills have been added to the existing pellet industry in Pennsylvania with the assistance of Stimulus funds. There are approximately 20 pellet manufacturing facilities in the state, about half of which received state funding. Many of these facilities themselves incorporate a wood-fired boiler to generate process heat for pellet drying. Pellet manufacturing facilities generally demand much more wood than small-scale biomass energy facilities, requiring between 50,000 and 200,000 tons of wood a year.

CELLULOSIC ETHANOL PLANTS USING WOOD AS FUEL

There is presently one existing cellulosic ethanol plant in Pennsylvania that uses wood as feedstock (the Coskata plant in Westmoreland County) and one proposed plant that will use wood as feedstock (the Helios Scientific plant in Clearfield County). The Helios plant received a $2 million grant from the state.

GRANTS AND LOANS TO PENNSYLVANIA BIOENERGY FACILITIES

The State of Pennsylvania and the federal government have awarded a substantial number of grants and loans to commercial and institutional biomass energy and pellet manufacturing facilities. Most of the money allocated to these projects is derived from federal Stimulus dollars. The total for grants and loans given to facilities on this list is about $73.2 million, which includes a $39 million federal grant to the United Corrstack/Evergreen Community Power facility.

Table 4. **List of Pennsylvania Biomass and Pellet Manufacture Facilities Receiving Grants and Loans**

County	Facility	Federal and State Grants and Loans	Total
Ethanol			
Clearfield	Helios Scientific LLC	$2 million from Redevelopment Capital Assistance Program	$2,000,000
Commercial			
Adams	Twin Springs Fruit Farm	$326,273 from Pennsylvania Department of Community and Economic Development	$326,273
Bucks	Peace Tree Farms	$230,000 from Alternative and Clean Energy Program; $100,000 from REAP	$330,000
Clearfield	Nydree Flooring	$270,000 from PEDA	$270,000
Columbia	Dillon Floral Corp	$207,000 Energy Harvest Grant	$207,000
Lancaster	Esbenshade's Greenhouses, Inc	$474,502 Energy Harvest funds	$474,502
Northumberland	Kurt Weiss Greenhouses of PA Inc	$959,500 loan from Alternative and Clean Energy Program	$959,500
Snyder	Windview Farm	$61,356 from Energy Harvest and Alternative Fuels Incentive Grant program	$61,356
Industrial			
Berks	Evergreen Comm Power/ United Corrsstack	$39 million in Stimulus funds; $250,000 from PEDA	$39,250,000
Bradford	Craftmaster	$1.358 million in Stimulus funds	$1,358,868
Clarion	Piney Creek Limited Partnership	$429,599 (ARRA)	$429,599
Northumberland	IntelliWatt Renewable Energy	$4.98 million loan from Alternative and Clean Energy Program; PEDA grant of $150,000	$5,130,000
Institutional			
Bedford	Northern Bedford County School District	$746,192 from Alternative and Clean Energy Program	$746,192
Bradford	Wyalusing School District	$310,000 Energy Harvest grant	$310,000
Bradford	Northeast Bradford School District	$905,000 loan from Alternative Energy Investment Fund	$905,000
Cambria	Glendale School District	$350,000 from Energy Harvest and Alternative Fuels Incentive grant program	$350,000
Centre	Penns Valley Area School District	$788,956 in Stimulus funds; $868,959 grant from PEDA	$1,657,915

Table 4 *(continued)*

County	Facility	Federal and State Grants and Loans	Total
Institutional (cont.)			
Clearfield	Clearfield Area School District	$600,000 in federal funds some years ago	$600,000
Columbia	Benton Area School District	Two PEDA grants, each $350,000	$700,000
Columbia	Bloomsburg University	$500,000 Energy Harvest grant	$500,000
Crawford	Crawford Central School District	$500,000 Energy Harvest grant from state	$500,000
Elk	Elk Regional Health System	$300,000 USDA loan; $1,475,000 rural development loan; $500,000 from PEDA; $250,000 woody biomass utilization grant	$2,525,000
Lancaster	Providence Township Municipal Building	$43,687 from Commonwealth Financing Authority	$43,687
Lehigh	City of Allentown/ Delta Thermo Energy	Alternative Energy Program grant of $2,000,000	$2,000,000
Lycoming	East Lycoming School District	PEDA grant of $915,476	$915,476
McKean	Smethport	$25,000 from Community Fund for the Alleghenies, $50,000 from Richard King Mellon Foundation	$75,000
McKean	Kane Area School District	$250,000 from USDA Woody Biomass Utilization program; $355,653 from Energy Harvest Program	$605,653
Schuylkill	Schuylkill County Agricultural Facility	$346,822 Energy Harvest grant	$346,822
Somerset	International Conservation Center	$267,000 Clean Energy Grant from Dept. of Community and Economic Development; $375,000 from Richard King Mellon Foundation	$267,000
Sullivan	Sullivan County School District	$630,000 from PEDA; $200,000 USDA state and private forestry grant	$830,000
Union	Evangelical Community Hospital	$800,000 grant from Alternative and Clean Energy Program	$800,000
Wayne	McCanna Cooperage Building	$35,430 from Alternative and Clean Energy Program	$35,430
Pellet			
Adams	Penn Wood Products, Inc.	$973,035 from the Adams County Economic Development Corporation	$973,035
Bradford	Barefoot Pellet Company	$469,200 from PEDA	$469,200
Carbon	Great American Pellet/ Keystone	$770,000 in loans; $220,000 alternative energy grants; $80,850 job training funds	$1,000,850
Crawford	Ernst Biomass LLC	PEDA grant of $900,000; total assistance $1,336,929	$1,336,929

TABLE 4 *(continued)*

County	Facility	Federal and State Grants and Loans	Total
Pellet (cont.)			
Fayette	TriState Biofuels	$716,500 loan and $360,000 grant	$1,076,500
Juniata	Energex Pellet Fuel, Inc.	$525,000 loan; $150,000 grant from Alternative and Clean Energy fund	$675,000
McKean	American Refining & Biochemical	$1 million from PEDA	$1,000,000
McKean	Postlewait Logging Company	$180,000 from Commonwealth Financing Authority	$180,000
Potter	PA Pellets, LLC	PEDA grant of $325,000	$325,000
Somerset	First Nation Wood Pellet	$500,000 from PEDA	$500,000
Union	Biomass Fuel Stocks of PA Inc.	$152,000 from PEDA	$152,000

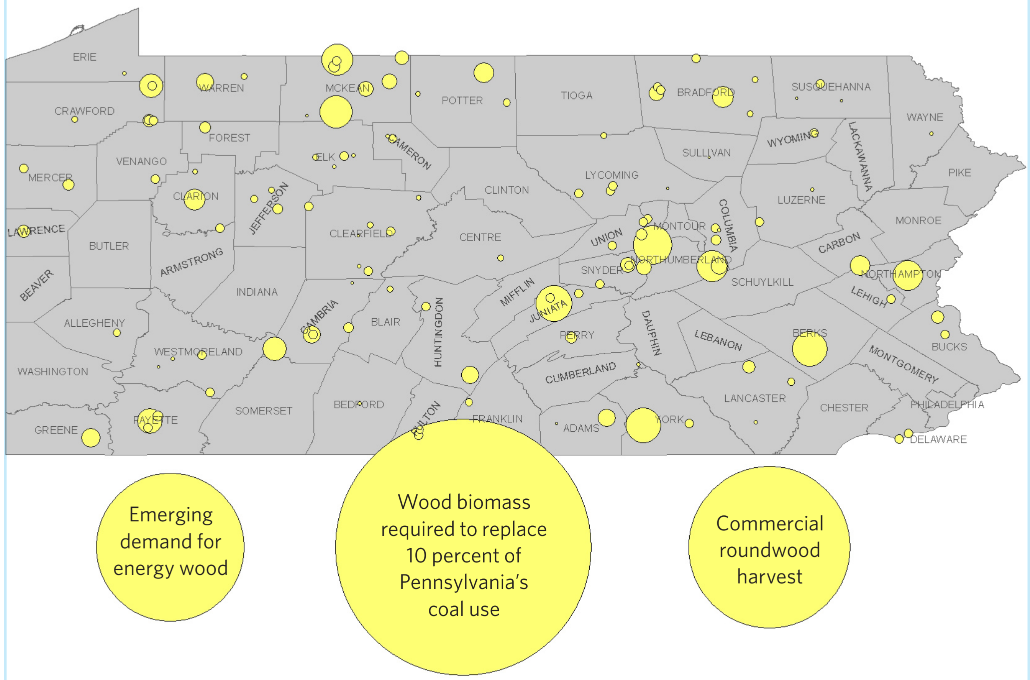
The promise of "energy independence" and reductions in fuel costs compared to purchase of oil and gas is repeatedly cited as an important rationale for the grants and loans awarded to new biopower facilities, but it is important to note that the assumption of carbon neutrality of biomass energy is used to justify these awards, as well. For instance, the report of the Commonwealth Financing Authority on funding under the Alternative Energy Program describes a grant to Keystone Pellet,[130] stating "Keystone Pellet expects to manufacture 35,000 tons per year of hardwood pellets for home heating use in pellet stoves and furnaces. The capital invested will result in 35,000 tons of alternative fuel that will replace 4,025,000 gallons of heating oil per year and prevent the emission of over 33 million pounds of carbon dioxide."

CUMULATIVE WOOD DEMAND FROM WOOD ENERGY FACILITIES IN PENNSYLVANIA

Although the majority of wood energy facilities in Pennsylvania are small to medium-sized, the emerging cumulative demand for "energy" wood shown in Figure 3 (at about 4.3 million green tons) is similar in magnitude to the commercial wood harvest (at about 5 million green tons), with demand chiefly driven by a smaller number of larger biomass energy and pellet manufacturing facilities. Replacing 10 percent of Pennsylvania's coal use by co-firing biomass in coal plants would require more than 12.8 million green tons per year. Figure 3 shows the equivalent area of land that would be required to supply fuel for existing and proposed facilities over a 10-year period, assuming that forests were harvested for energy wood at 25 tons per acre.[131] Fuel and pellet feedstock wood demand from new/proposed facilities represents about 30 percent of mapped demand; about 70 percent of demand at these new/proposed facilities comes from four pellet plants and one 10 MW power plant.

Figure 3 is not meant to imply that this amount of forest harvesting is actually occurring at this time, but is presented as an "apples to apples" comparison of the amount of wood potentially burned for energy assuming that proposed projects go forward, the amount that would be required to replace 10 percent of coal use with wood,[132] and the amount currently harvested for commercial sawtimber.[133] Only wood demand that is currently met or will be met with forest biomass was included on the map; wood demand at facilities using construction and demolition debris and other waste wood sources was not included. Current biomass fuel demand is met by a variety of means. Most mills burning biomass for heat and power burn sawdust and trimmings from commercial sawtimber processing for fuel; some facilities may acquire fuel from other states (for instance, the Viking Energy plant in Northumberland gets the bulk of its wood from land clearing in adjacent states).[134] Some facilities are burning construction and demolition debris and other waste wood, demand that is not represented on this map. However, a portion of emerging demand is being met with new whole-tree harvesting conducted specifically to produce "energy wood," especially new pellet manufacturing facilities that require trunkwood to produce high-quality pellets.

Figure 3. **Equivalent Area of Forest Harvesting Required (at 25 tons per acre) to Provide a 10-Year Supply of Woody Biomass for Pennsylvania's Biomass Energy, Pellet, and Ethanol Facilities**



The estimate of harvesting to support replacing a portion of coal with wood is provided because co-firing biomass with coal is more efficient than burning it in stand-alone biomass power facilities, and is also the fastest way to increase the amount of biopower generated since coal infrastructure exists and many plants can handle 5–10 percent biomass fuel with few changes in operation. Pennsylvania's 2010 coal consumption was fifth in the nation after Texas, Indiana, Illinois, and Ohio.[135] Putting potential co-firing projects in Pennsylvania into perspective, it would take about more than 12 million tons of green wood per year to replace 10 percent of coal-fired electricity in Pennsylvania with co-firing.[136]

While there has not been a significant initiative to co-fire biomass with coal in Pennsylvania as of yet, demand for wood fuel may also come from adjoining states. The Ohio Public Utilities Commission (PUCO) has approved an unprecedented increase in biomass power generation, mostly as co-firing with coal and full conversion of coal plants to biomass. The PUCO has approved co-firing plans at Conesville Generating Station, Killen Generating Station, the Bay Shore plant, the Beckjord plant, and the Picway Generating Station, as well as at the 200-MW stand-alone South Point biomass plant. With over 2,000 MW of biomass power already approved by the PUCO, most of it to be fueled with wood, even energy companies have acknowledged that demand may be formidable. In response to a motion by environmental groups and the Ohio Consumers Council to intervene in the Public Utilities approval process, a representative of the Beckjord coal plant offered testimony before the PUCO that the "most likely" source of biomass for co-firing will be "whole tree chipping" from sources in Ohio.[137] American Electric Power in Ohio estimates in its 2010 resource plan that it would require cutting 730,000 acres of forest on a 40-year rotation to power a single 200 MW biomass facility.[138] In the face of such demand, it is not surprising that the status of many of these projects is currently uncertain. Other than the South Point facility, which if it goes forward will be the largest biomass project in the country, many of the proposals currently face difficulty in securing fuel supplies.[139]

AN EMERGING TREND: FACILITIES BURNING ANIMAL WASTE AND SLUDGE AS FUEL

Although biomass energy facilities in Pennsylvania predominantly use wood for fuel, Pennsylvania currently has several small facilities that burn or plan to burn sludge and animal wastes. The City of Allentown has received $2,000,000 from the Commonwealth Financing Authority to build a 3 MW facility that will burn both municipal waste and sewage sludge. The farm-scale Windview boiler in Snyder County is currently burning turkey litter as fuel, and a poultry-waste-burning facility to be located at the Schuylkill Agricultural Facility received an Energy Harvest grant of $346,822. The Esbenshade's Greenhouses in Lancaster County have also discussed using chicken litter as fuel and were granted $474,502 in state funds. Another manure-burning project will be at the Pittsburgh Zoo International Conservation Center, which announced plans to heat the elephant house by burning elephant dung and switchgrass. The Zoo received a $267,000 "clean energy" grant from the state and a $375,000 grant from the Richard King Mellon Foundation. Also contemplating using animal waste as fuel is the 10 MW IntelliWatt plant proposed in Northumberland County, which has proposed burning chicken litter and received a $4.98 million loan.[140] Finally, plans have been announced for an expansion of an egg layer operation at Hillandale Farms in Adams County, from three million to five million birds, which will provide chicken litter as fuel for a new 2.5 MW gasification facility. The plant will burn at least 13,000 tons of manure annually and is being promoted as a way to reduce manure applications on fields and thus nutrient-loading to the Chesapeake Bay Watershed. A Pennsylvania-based company, Fibrowatt, is attempting to build very large utility-scale plants that burn chicken litter in North Carolina and other states, although they have been met with strong citizen opposition due to the potential emissions from these facilities. However, the increased use of manure as fuel at small facilities in Pennsylvania may presage proposals for larger facilities by Fibrowatt and others.

CHAPTER 8:
EMISSIONS FROM BIOMASS ENERGY FACILITIES IN PENNSYLVANIA

> Evaluating the impact of emissions from biomass energy facilities is difficult, because air quality modeling is rarely performed, and few monitoring studies are conducted.

> A number of biomass energy facilities in Pennsylvania are located in counties that are in non-attainment with EPA health standards for particulate matter and ozone. These non-attainment areas tend to coincide with counties that have the highest asthma rates.

> Some facilities appear to have been sited with little regard for existing air quality. The 33 MW Byproducts United Corrstack/Evergreen Community Power facility is located in Reading, Berks County, which is in non-attainment with EPA's ozone and lead standards and has one of the highest asthma rates in the state. The plant burns up to 1,000 tons per day of construction and demolition waste as well as "significant amounts of paper, plastic, and other foreign debris," and generates 70,000 tons of toxic ash per year that requires special landfill disposal.

> Wood pellet manufacturing and other wood processing plants that burn biomass for process heat emit tens of tons of PM, NO_X, CO, and VOCs. One new pellet facility is permitted to emit 78 tons of PM per year.

> PM emission rates at biomass burners being installed at schools and other institutions range from 0.2 to 0.25 lb/MMBtu. Only one recently permitted facility, at a hospital, has been required to use a baghouse and thus reduce its permitted PM emission rate to 0.03 lb/MMBtu. Most biomass burners installed at schools are too small to trigger EPA's "boiler rule" emissions limit of 0.07 lb/MMBtu.

> Schools and other institutions that replace oil or gas heating systems with biomass will likely experience significant increases in local air pollution. A comparison of emissions rates from a new biomass boiler and a new oil boiler reveals that biomass emissions are more than seven times greater than oil emissions for PM, 1.5 times greater for NO_X, and four times greater for CO.

> Although institutional biomass boilers have lower PM emission rates than woodstoves, total emissions are around 10 times greater, due to the larger amount of wood that is burned.

> Summed estimates of PM emissions from commercial and institutional biomass burners suggest that emissions from this sector are similar in magnitude to emissions from domestic wood-burning in some Pennsylvania counties.

Although wood combustion is recognized as an important source of particulate matter and other pollutants, evaluating air quality impacts from institutional and commercial biomass burners in Pennsylvania is not straightforward. Pennsylvania already has a significant problem with air pollution generated both in and out of the state. A number of counties are out of attainment with EPA standards for PM and ozone (Figure 4). One county (Armstrong) is out of attainment for SO_2, and parts of Berks and Beaver counties are out of attainment with EPA's lead standard of 0.15 $\mu g/m^3$. Challenges to improving air quality in the state are substantial. Pennsylvania received about 48 percent of its power from coal in 2010,[141] making the energy sector a major in-state source of pollution, but transportation is also an important source of air pollution in urban areas. Some of the problem comes from out of state; polluted air entering from the south and west that is at or near the eight-hour ozone health standard[142] also impedes progress toward attainment of standards. Poor air quality may be linked to asthma rates in Pennsylvania, which continue to rise; the state's lifetime asthma rate for school children increased from 6.6 percent in 1997–98 to 11.3 percent in 2008–09.

In this context, do biomass energy facilities represent only a marginal addition to existing air pollution, involving a small trade-off in air quality for a shift to local fuels that is favored by many communities, or do such facilities represent a significant source of air quality impairment, where the risks outweigh the benefits? These questions can be explored by conducting air quality modeling that considers the types of emissions, pollution dispersion, ambient levels of pollutants, and other nearby sources of pollution. However, the Pennsylvania Department of Environmental Protection does not perform emissions modeling for any emissions source that does not meet "prevention of significant deterioration" (PSD) requirements under the Clean Air Act, which are triggered when a facility emits 100 tons of a criteria pollutant in a non-attainment area. Since most of the institutional and commercial biomass burners being installed in Pennsylvania do not trigger this threshold, air quality modeling is not required.

Not only is there a lack of air quality modeling, but there are also few if any monitoring studies that evaluate the impact of small sources. In the absence of such data, it is difficult to evaluate the impact of the growing number of biomass burners around the state on a site-specific basis. The lack of air quality modeling for small biomass burners is a particularly notable data gap given the increasing number of "Fuels for Schools" biomass burners, where low stack heights, active children with high respiratory rates, and the lack of anything but rudimentary emissions controls on biomass boilers increase potential exposure to air pollution in a vulnerable group.

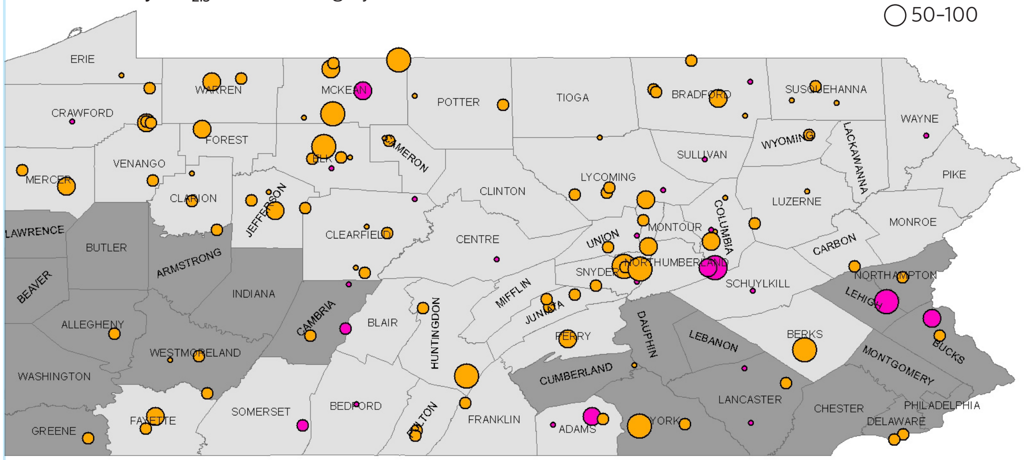
Lacking site-level modeling, it is still possible to evaluate emissions in terms of information on ambient air quality, and the magnitude of emissions relative to other emission sources, and known impacts from better-characterized emissions sources, such as residential wood-burning. Figure 4 places emissions from new and existing biomass burners in Pennsylvania in the context of attainment for EPA's particulate matter standard, the ozone standard, and patterns of asthma incidence in the state (age-adjusted hospitalization rates for asthma from 2007[143]), which correspond well with PM and ozone non-attainment regions. A number of proposed and existing facilities are located in areas with existing air quality impairment and high asthma rates.

FIGURE 4. **Biomass Facility PM_{10} Emissions and County-Level Air Quality in Pennsylvania**

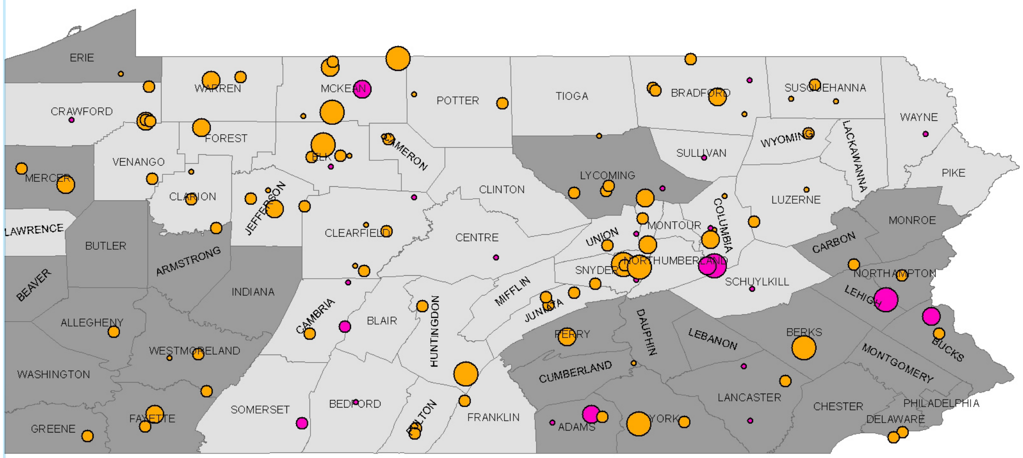
Existing   New / proposed

2–10
10–25
25–50
50–100

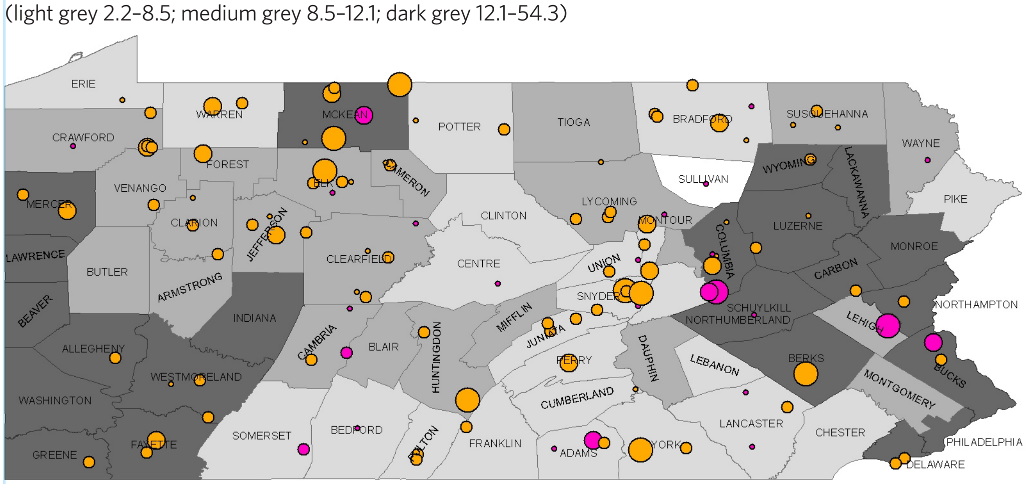
Tons Per Year by $PM_{2.5}$ Status (dark grey indicates non-attainment)



Tons Per Year by Ozone Status (dark grey indicates non-attainment)



Tons Per Year by Age-Adjusted Hospitalization Rate for Asthma Per 10,000 in 2007
(light grey 2.2–8.5; medium grey 8.5–12.1; dark grey 12.1–54.3)



BIOMASS ENERGY IN NON-ATTAINMENT, HIGH ASTHMA, AND ENVIRONMENTAL JUSTICE AREAS

Large facilities with significant emissions trigger air quality modeling in non-attainment areas, but small facilities do not. This does not mean, however, that emissions from these "minor source" facilities are inconsequential, since minor sources are generally allowed to emit pollution at higher rates and can be prone to spikes in emissions, for instance during startup and shutdown, that can seriously degrade local air quality. However, the lack of an air quality assessment for these sources means that these effects are never considered by the state, which may explain why a number of biomass energy facilities located in non-attainment areas and counties with high asthma rates have been proposed and built in Pennsylvania (Figure 4). Some are also located in or near communities identified by the state as environmental justice areas,[144] defined as census tracts with at least a 20 percent poverty rate and/or at least a 30 percent minority population.[145] Many of these facilities have received loans or grants of government money. Some examples of larger installations include:

- **The 33 MW[146] United Corrstack / Evergreen Community Power facility in Reading, Berks County**. Berks County is not only designated as out of attainment with EPA's health standard for ozone but also lead, is in the highest of the three terciles for asthma, and is an environmental justice area. The plant burns up to 1,000 tons per day of construction and demolition waste as well as "significant amounts of paper, plastic, and other foreign debris" imported from New England and New Jersey (and Pennsylvania); it generates 70,000 tons of toxic ash per year that requires special landfill disposal. As a "synthetic minor" emissions source, the facility did not go through "Best Available Control Technology" permitting and is operating only under a state air pollution permit, and no EPA permit. The facility got $39 million in stimulus funds, but is currently operating at a loss of $15,000,000 annually.[148]
- **Bloomsburg University and Dillon Floral in Columbia County.** These facilities received a combined total of $707,000 from the state to install biomass boilers in a region in the highest category of asthma incidence. The facilities are located on two sides of an environmental justice community.
- **Piney Creek in Clarion County.** This facility is near an environmental justice community. The plant burns creosote-treated railroad ties and received a total of $872,427 in funding.
- **TriState Biofuels in Fayette County.** This facility is in a non-attainment area for ozone that is in the highest tercile for asthma, is located in an environmental justice community, and is within close proximity to two other wood-burning facilities. The company received $1,076,500 in grants and loans from the state.
- **American Refining and Biochemical, Inc., in McKean County.** This county is in the highest tercile for asthma incidence. The facility is located close to an environmental justice community, as are at least two other wood-burning facilities. The company received $1 million in energy funding from the state for a facility that will "annually convert up to 180,000 tons of biomass into more than 60,000 tons of a coal-like product."[149]
- **A poultry-manure burner at the Agricultural Facility in Schuylkill County.** This region is in the highest tercile for asthma incidence, and the facility is located near an environmental justice community in Pottsville. The facility was awarded an Energy Harvest grant of $346,822.

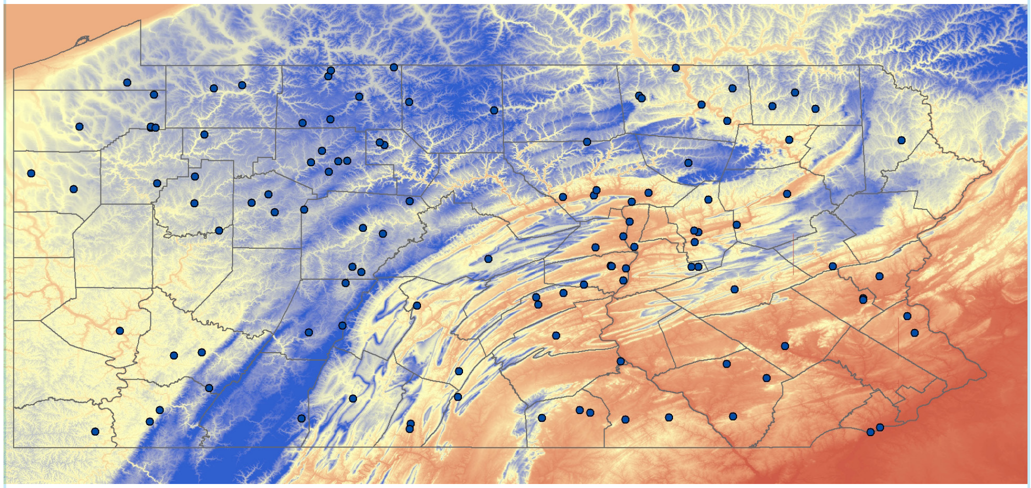
TOPOGRAPHICAL POSITION OF BIOMASS ENERGY FACILITIES

While air pollution is often seen as an urban problem, rural areas can also have high local levels of air pollution due to pollution transport, and also because local sources, especially residential wood smoke, can contribute significant amounts of particulates. Characterization of PM sources in different regions of New York[150] found that, while mobile sources, especially diesel engines, contribute about 58 percent of emissions in urban areas, residential wood combustion represents about 92 percent of total carbonaceous $PM_{2.5}$ emissions in rural areas.

Rural air quality problems can be exacerbated by topography as valleys trap emissions and experience inversions, and pollutants such as wood smoke spread long distances as air moves down hydrological drainages.[151] As is the case for most sources of air pollution, commercial biomass energy facilities tend to be located in population centers in river valleys, increasing the potential for air pollution accumulation in inversion layers (Figure 5).

FIGURE 5. **Biomass Energy and Wood Pellet Faciilities Shown in Terms of Relative Position in the Landscape**

Higher elevations Lower elevations



ASSESSING EMISSIONS FROM COMMERCIAL AND INDUSTRIAL WOOD ENERGY FACILITIES

Although the health impacts of residential wood smoke are increasingly acknowledged, it is still rare to see anything beyond the most basic controls for PM installed on biomass burners, even though total exposures of workers or schoolchildren to emissions from commercial and institutional burners are potentially significant. For areas in attainment with EPA's ambient air quality standards, Pennsylvania's regulations require that burners of 2.5–50 MMBtu/hr and above emit no more than 0.4 lb/MMBtu PM.[152] When more stringent emissions controls are required, Pennsylvania Department of Environmental Protection requires a Best Available Technology determination, which consists of developers presenting two or three options for boilers with different levels of emissions control. Typical determinations are for PM emission rates around 0.22 lb/MMBtu.

Pellet plants and other wood-processing mills that burn biomass for process heat or on-site electricity generation are relatively large sources of air emissions. Table 5 shows permitted emissions from a commercial burner at a greenhouse, as well as pellet plants and wood mills, which may employ baghouses for wood processing but not for the biomass burner on site. Emissions of VOCs from pellet drying and kiln-drying sawtimber can also be large, as shown by the total tons of VOCs at pellet plants, where total VOCs reflect both pellet drying and biomass burning.

The permit for the facility with the largest emissions in Table 5, Tri-State Bio Fuels, provides specifics that convey the magnitude of emissions associated with different processes. The permit specifies that the facility can process up to 77,376 tons of raw sawdust, of which 14,976 tons can be burned for process heat. The amount of wood used for pellet production indicates that this is a fairly small plant[153]; nevertheless, it is required to have two baghouses, in addition to the cyclone and multicyclone, and even with these controls, its emissions are permitted at 46.6 tons per year of PM (as well as 29.8 tons per year of NO_X and 30.1 tons per year of carbon monoxide; VOCs were not specified in this permit).[154] The permit for the Tree Cycle pellet facility with just a 54 MMBtu boiler limits PM emissions to 78 tons per year, which is comparable to PM emissions from a utility-scale biomass electricity plant with a boiler several times that size.[155]

Table 5. **Representative Examples of Boiler Capacity and Yearly Facility Emissions, including Process Emissions**

Facility	Type	MMBtu	PM rate	NO_X rate	CO rate	VOC rate	SO_X rate	PM tons	NO_X tons	CO tons	VOC tons	SO_X tons	HAP tons	PM Control
Esbenshade's Greenhouses	Comm.							21.6	46.2	28.2	1.6	2.4		Multicyclone
Tree Cycle	Pellet							78	86		36			Cyclone, air filters
PA Pellets	Pellet	54						36.53	22.78		29.91			Multicyclone
Allegheny Pellet Corp.	Pellet	22						15.7	24.1	57.8	16.4	2.4		Multicyclone
Tri-State Bio Fuels	Pellet	50						46.6	29.8	30.1	13		6.6	Multicyclone, baghouses
Tuscarora Hardwoods	Mill	27.4						18	22	61	2	3		None specified
Wheeland Lumber Co., Inc	Mill	6.2						10.42	11.47	26.06	0.68	0.52		Multitube mechanical collector
C.A. Elliott Lumber Co., Inc	Mill	4.8						10.44	10.3	12.62	0.5	0.53	0.4	Cyclone collector, fabric after-filter

Data primarily taken from *Pennsylvania Bulletin*; most facility summaries do not include emission rates, just total tons of pollutant emitted.

EMISSIONS FROM INSTITUTIONAL BIOMASS BURNERS

New institutional biomass burners currently being installed in Pennsylvania (Table 6) typically employ cyclone and multicyclone systems for PM control, with emission rates of 0.2–0.3 lb/MMBtu, one to two orders of magnitude higher than emission rates that can be achieved with a baghouse or an electrostatic precipitator. Thus far, it appears that none of the new biomass burners being installed at schools use the low-emissions burners or cleaner fuels; all appear to be burning green wood chips.

Since all are 10 MMBtu/hr and below, none of the biomass burners installed at schools trigger EPA's area source boiler rule threshold, which is 0.07 lb/MMBtu for new boilers of 10–30 MMBtu/hr. EPA's standard makes a significant difference to facility emissions. Filterable PM emissions from a 9 MMBtu/hr burner permitted at 0.22 lb/MMBtu, at 8.67 tons, are almost three times those from a 10 MMBtu/hr burner permitted at EPA's rate of 0.07 lb/MMBtu, which has emissions of 3.07 tons.

Table 6. **Boiler Capacity, Emission Rates (in lb/MMBtu), and Total Permitted Emissions (in tons per year) for Some Institutional Biomass Burners in Pennsylvania**

Facility	Type	MM Btu	PM rate	NO_X rate	CO rate	VOC rate	SO_X rate	PM tons	NOx tons	CO tons	VOC tons	SO_X tons	HAP tons	PM Control
Sullivan Cty School DIstrict	Instit.	4	0.23	0.22	0.84	0.017	0.025	3.01	2.88	2.1	0.23	0.33		Cyclone
Clearfield Area School DIstrict	Instit.	10	0.3					9.86	5.98	5.39	0.13	0.07		Cyclone
Northeast Bradford School DIstrict	Instit.	8.5	0.2	0.25	0.16	0.02	0.025	7.45	9.31	5.96	0.74	0.93		Multi-cyclone
East Lycoming School DIstrict	Instit.	6.43	0.22	0.22	0.16			6.7	6.2	4.5	0.5	0.7	0.7	Multi-cyclone
Wyalusing School DIstrict	Instit.	12	0.22					8.68	7.18	6.48	0.16	0.08	0.1	Multi-cyclone
Crawford Area School DIstrict	Instit.	9.5	0.25					7.84	10.21	18.7	0.53	0.78		Multi-cyclone
Penns Valley Area School DIstrict	Instit.	9.7	0.2	0.25	0.16			8.5	10.62	6.8	0.7	1.1		Multi-cyclone
Cresson State Correctional Institution	Instit.	28.7	0.2					25.14	6.31	75.4				Multi-cyclone
Bloomsburg University	Instit.	22.2	0.2	0.25	0.4	0.02	0.025	19.44	24.31	38.89	1.65	2.42		Multi-cyclone
Elk Regional Health Center	Instit.	18.5	0.24	0.36	0.6	0.017	0.025	19.04	28.77	48.62	1.38	2.03		Multi-cyclone
Evangelical Community Hospital	Instit.	24.7	0.03	0.22	0.33	0.017	0.025	3.25	23.8	35.7	1.84	2.71		Baghouse

Data primarily taken from *Pennsylvania Bulletin*

The only institutional facility recently permitted in Pennsylvania that meets EPA's PM emission standard of 0.03 lb/MMBtu for boilers greater than 30 MMBtu/hr is the burner at Evangelical Community Hospital. This boiler shows significantly reduced PM emissions (3.25 tons per year) compared to other burners of similar size, which typically have emissions of 19–25 tons per year. The facility is using both a multicyclone and a baghouse to achieve this rate.

Permitted PM emission rates for the institutional biomass boilers like those presented in Table 6 show little variation. However, actual operating emission rates can be more variable. Table 7 exhibits a range of PM emission rates from five small biomass burners (four in Vermont, and one in Rhode Island)[156] that employ different combustion technologies, fuels, and control equipment. Of note are emissions at the Bennington College plant, which although controlled with two multicyclone systems still had PM emissions of 0.38 lb/MMBtu, higher than the permitted level for the Pennsylvania boilers. The best-controlled source, the boiler in Rhode Island, was using a multicyclone with extremely low removal efficiency, but as a gasification unit, the emissions from the boiler are relatively low to begin with.

Table 7. **Emissions Controls and Particulate Emissions for School Boilers in Vermont and Rhode Island** [157]

Location	Boiler Type	Emissions Control	Total PM (lb/hr)	PM Rate (lb/MMBtu)	Removal Efficiency, Filterable PM
Crotched Mountain Rehabilitation Center	Messersmith	Baghouse	0.22	0.078	83.2%
Brattleboro High School	Messersmith	Core separator	1.34	0.172	57.2%
Champlain Valley High School	Messersmith	Single cyclone	0.69	0.182	3.8%
Bennington College	AFS Energy Systems	Two multicyclones	4.55	0.38	61.1%
Ponaganset High School (RI)	Chiptex (gasifier)	High-efficiency multicyclone	0.20	0.058	22.5%

The cleanest burning European biomass burners are theoretically capable of achieving PM emissions rates similar to those from an oil burner, although doing so requires using very clean, dry woodchips or pellets. However, in Pennsylvania, "Fuels for Schools" projects are using green chips for fuel, and emissions rates are higher, meaning that schools that replace natural gas or oil-fired boilers with wood-fired boilers will certainly increase particulate emissions.

The emissions permit for the Wyalusing Area School District (Table 8) most clearly illustrates the difference between emissions from oil and wood burners. The school district received a permit to install a new 12 MMBtu wood boiler to be fired on virgin wood, and a new 12 MMBtu/h oil boiler to be fueled with virgin No. 2 oil. The permitted emissions rate for the wood boiler is higher for PM, NO_X, and CO; it is lower for VOCs and SO_2. The air permit additionally stipulates that hazardous air pollutants should be emitted from the wood-fired boiler at no more than 0.004 lb/MMBtu, or 0.1 tons (200 lb) per year. The ratio of wood emissions to oil emissions for the total allowable tons of PM emitted per year is greater than the ratio of the rates (in units of lb/MMBtu), suggesting that the school plans to use the wood boiler for more hours of the year than the oil burner.

TABLE 8. **Permitted Pollutant Emissions Rates (in lb/MMBtu) and Total Tons per Year for New Biomass and Fuel Oil Boilers in the Wyalusing Area School District**

	PM Rate	PM Tons	NO_X Rate	NO_X Tons	CO Rate	CO Tons	VOCs Rate	VOCs Tons	SO_X Rate	SO_X Tons
Oil	0.03	0.29	0.12	1.18	0.04	0.39	0.025	0.25	0.08	2.06
Wood	0.22	8.68	0.18	7.18	0.16	6.48	0.004	0.16	0.002	0.08
Wood/Oil ratio	7.3	29.9	1.5	6.1	4.0	16.6	0.16	0.6	0.03	0.04

COMPARING EMISSIONS FROM BIOENERGY AND RESIDENTIAL WOOD-BURNING

The impact that residential wood smoke can have on local air quality is increasingly recognized, yet in the rush to replace oil and gas boilers with biomass at schools and other institutions, there has been little acknowledgment that commercial and institutional biomass burners may also degrade air quality. Compared to residential burning, commercial and industrial biomass units generally have a higher temperature of combustion and more controlled combustion conditions, and they typically use at least a cyclone system to reduce PM, which does reduce the immediate and apparent impact from biomass burners in terms of visible emissions. Yet while emissions controls can reduce PM emissions by an order of magnitude, the amount of wood burned by even a small biomass boiler is still one to two orders of magnitude higher than in a domestic woodstove or boiler, meaning that overall emissions are far greater.

Table 9 compares $PM_{2.5}$ emission rates and total emissions between domestic and institutional/commercial wood burners. Wood use and total emissions in tons per year are estimated for the heating season for woodstoves, and to be conservative, are calculated using the highest of either the AP-42 or the "adjusted" emission factors[158] listed in a 2005 review of EPA-certified and uncertified wood and pellet stove emissions.[159] The emissions for the school boiler are based not on the capacity of the burner, but on the estimate that a typical school burner consumes about 1,000 tons of wood chips per heating season at about 45 percent moisture content. The emissions for the lumber mill are calculated assuming year-round operation at 90 percent capacity. While the woodstove data is expressed as $PM_{2.5}$ and the boiler data is expressed as PM_{10}, as the woodstove study notes, "the overwhelming majority of PM is $PM_{2.5}$" and the two size classes are frequently used interchangeably. The data show that although the wood-fired boilers have lower emissions rates than the residential woodstoves, their greater fuel demand means their total emissions exceed those from residential systems by a factor of at least ten.

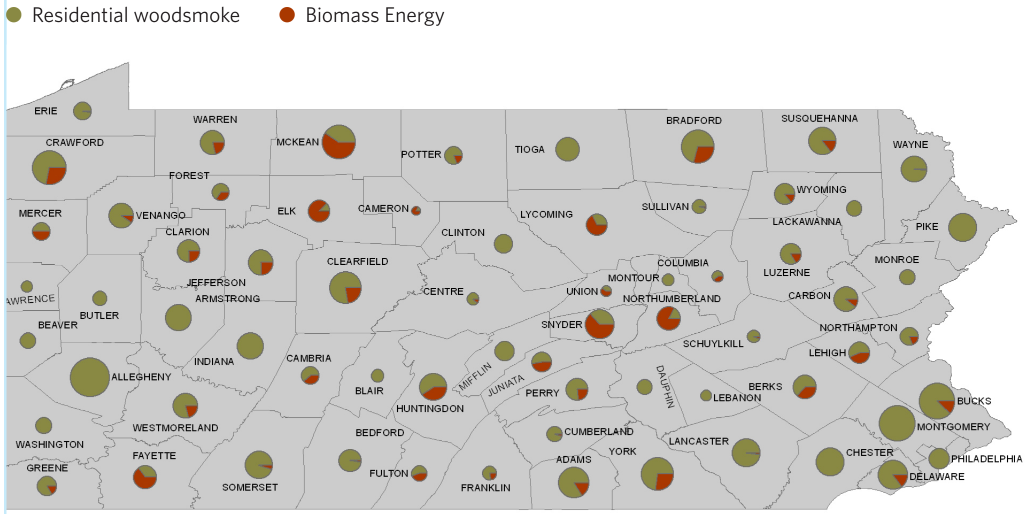
Table 9. **PM Emission Rates and Estimated Total Yearly Emissions for Representative Domestic, Institutional and Commercial Wood-Burners**

Burner Technology	$PM_{2.5}$ Emission Factor (lb/ton)	Tons Fuel (Dry)	$PM_{2.5}$ Emissions (Tons)
Conventional woodstove	66.8	2.45	0.08
Certified non-catalytic woodstove	14.6	2.1	0.02
Certified catalytic woodstove	16.2	2.1	0.02
Pellet stove	8.8	1.7	0.01
Burner Technology	**PM_{10} Emission Factor (lb/MMBtu)**	**Tons Fuel (Green)**	**PM_{10} Emissions (Tons)**
4 MMBtu / hr (school boiler)	0.22	1,000	1.0
15 MMBtu / hr (lumber mill)	0.25	12,500	14.8

Residential wood-burning is recognized as the largest contributor to particulate matter pollution in rural regions of New York, and it is likely that air quality in rural areas of Pennsylvania is similarly impacted by residential wood smoke. A study conducted in the inversion-prone region of Libby, Mont., found that a woodstove change-out program that replaced around 1,100 residential stoves with new, EPA-certified models significantly reduced both ambient $PM_{2.5}$ levels and incidence of "wheeze" and other respiratory symptoms, including cold, bronchitis, influenza, and throat infection, in children.[160] Given the obvious influence of residential wood smoke on respiratory health, and the fact that $PM_{2.5}$ emissions from even a small institutional biomass burner are equivalent to emissions from more than 12 conventional woodstoves, it is extremely likely that institutional burners represent concentrated sources of PM with significant potential to impact local air quality and respiratory health.

As a way of comparing the cumulative impact of emissions from biomass energy facilities with domestic wood-burning, Figure 6 presents county-level EPA data on particulate matter emissions from residential wood-burning, along with summed emissions for the biomass-burning facilities compiled in this report.

Figure 6. **Summed PM_{10} Emissions from Biomass Facilities Compiled for This Report Versus PM_{10} Emissions from Residential Wood-Burning in Pennsylvania from EPA's National Emissions Inventory** [161]



Biomass boiler emissions data are summed from permits included in this report.

These estimates suggest that emissions from commercial and institutional biomass facilities rival and even exceed estimates of emissions from residential wood-burning in some counties, and thus deserve to be recognized as a potentially major source of PM air pollution in some regions.

CHAPTER 9: CONCLUSIONS

At the beginning, we proposed to address the current and developing capacity of the biomass energy sector in Pennsylvania, and what increased commercial and institutional bioenergy may mean for air quality, greenhouse gas emissions, and forest cutting in the state. From this report, certain conclusions emerge. In summary, Pennsylvania's biomass energy sector is still chiefly composed of boilers associated with the wood products industry that range from around 2 MMBtu/hr to around 30 MMBtu/hr, which are mostly operated for heat, but for which burning waste wood also eliminates a disposal problem. The state has a few large bioenergy facilities that burn a variety of fuels; the 33 MW Evergreen plant in Reading has been an important recent addition to the fleet, symbolizing the state's continued willingness to tolerate burning of contaminated fuels. In recent years, however, the state has mostly promoted installation of institutional biomass burners and pellet manufacturing, providing over $30 million in grants and loans to multiple new biomass burning and wood pellet manufacturing facilities, with a significant initiative to install biomass burners at schools. Although some new boilers burn animal wastes and one grant was made to a grass pelletization facility, existing and new biomass burners in Pennsylvania mostly burn wood.

Given the surge in proposals for utility-scale biomass power facilities occurring nationally, the emphasis on small-scale biomass projects proposed in Pennsylvania has been notable. With the important exception of Evergreen Community Power, which is already operating, the 10 MW IntelliWatt facility in Mt. Carmel Township, which appears to now be on hold, and the proposed Crawford Renewable Energy plant, which is not technically a biomass burner but is a tire-burner, new biomass energy projects in Pennsylvania have consisted mainly of smaller institutional and commercial burners. The scarcity of larger biopower projects in Pennsylvania may in part be due to current low prices for Alternative Energy Credits and restrictions on eligible fuels. Currently, to be eligible for Tier I credits in Pennsylvania, new biomass power facilities would need to burn clean wood, energy crops, or crop residues as fuel, not the construction and demolition debris, pulping liquors, and other waste wood that fuel the four older facilities that were grandfathered into eligibility for Tier I credits and the new Evergreen plant, which is not qualified for the alternative portfolio standard.

However, more large-scale biomass and waste burning facilities could be proposed in Pennsylvania if recurring efforts to make waste-burning facilities eligible for Tier I credits in Pennsylvania gain traction. Currently, facilities burning waste, such as the Evergreen plant and the proposed Crawford tire burner, generate revenue from waste disposal fees that are passed through from waste generators, but this is still not necessarily enough to render a facility profitable. Even after having received $39 million in federal Stimulus funds, the Evergreen facility continues to lose $15 million a year, its business model of importing waste from other states and collecting tipping fees not having proved as lucrative as planned. If state incentives are increased for waste-burning, more facilities might be proposed; such expansion could be aided by EPA's "waste" and "boiler" rules, which as currently drafted classify a great deal of waste wood as biomass and allow it to be burned with no special emissions controls.

Given the large role that coal plays in Pennsylvania's power sector, co-firing or re-firing of coal plants with biomass may keep coming up for consideration, particularly if alternative energy credits or federal renewable energy tax credits continue to be available for such activities (the federal renewable energy production tax credit is not granted for co-firing, but completely re-firing a coal plant with biomass renders it eligible under current rules). Since co-firing requires little up-front cost for retrofitting or new construction, it is less expensive than building a stand-alone biomass power plant. Co-firing has been aggressively approved by the Public Utilities Commission in Ohio, which has approved around 2,000 MW of new capacity, meaning that even if Pennsylvania itself does not promote co-firing, demands on Pennsylvania's forests could intensify. Currently, the Ohio proposals appear to be stalled, but depending on what kind of state and federal incentives continue to be available for biomass power development, these projects could be reactivated.

The amount of fuel wood required by existing and proposed industrial and commercial biomass facilities in Pennsylvania is already significant—similar to the amount of "roundwood" converted to commercial lumber. While the majority of wood burned for energy at mills is "waste"—sawdust and mill scraps—rather than new trees harvested specifically for fuel, fuel demand at new facilities is more likely to be met by increased forest harvesting, or at least new removals of forest residues. New pellet manufacturing is assuredly increasing forest harvesting for "energy wood," since high-quality pellets require debarked roundwood of adequate diameter, rather than the mixture of branches, bark and trunkwood that can comprise green chips. With its requirement for large quantities of white trunkwood, Pennsylvania's fast-growing wood pellet sector has the clearest potential to move forest carbon quickly into the atmosphere, but the threat is little recognized, since most pellets are used for domestic heating, not power production. While still mostly in the talking stage, cellulosic ethanol using wood for feedstock also has potential to increase forest harvesting. As Pennsylvania's Climate Action Plan recognizes, any significant increase in biomass power generation will require an expansion in forest harvesting; such expansion, however, may come with a cost to forest sustainability. The Pennsylvania Department of Environmental Protection has warned that disturbance—including forest harvesting—could exacerbate the problem of deer overbrowse suppressing forest regeneration, a trend that can worsen even under "sustainable" harvesting regimes.

In the meantime, the pace of bioenergy development may be slowing in Pennsylvania. Savings on fuel costs from switching from oil or gas to wood has allowed some institutions to pay back initial costs of switching to biomass heat, but where increasingly inexpensive gas is available, this cost advantage erodes. Further, an important incentive for small institutional bioenergy projects in the state has been the availability of federal Stimulus money for new biomass energy and pellet facilities, but with this revenue source no longer available, and without a major new infusion of funds, it is not clear that these projects can pay for themselves. For institutional biomass burners in the 10–30 MMBtu/hr range, another important factor may be increasing installation costs under EPA's "area source" boiler rule limits, which limits filterable PM emissions to 0.07 lb/MMBtu. Meeting this limit is difficult to achieve without the use of an ESP or baghouse, especially for a facility burning green wood as fuel, and achieving EPA's filterable PM standard of 0.03 lb/MMBtu for boilers greater than 30 MMBtu/hr certainly requires add-on controls. In contrast, particulate matter emissions are of almost no concern for natural gas and oil burners, which do not require add-on controls for PM and thus avoid this additional expense, which for a biomass boiler amounts to tens of thousands of dollars per facility.

While any given institutional biomass burner may not itself represent a significant impact on wood demand or greenhouse gas emissions in the wider context of Pennsylvania's large forestry and energy sectors, the same can not be said for impacts of conventional pollutant emissions. Biomass burners tend to be located where people are located—in valleys—increasing the likelihood of inversions where pollution is concentrated near the ground.

With the exception of the biomass boiler at Evangelical Community Hospital, even the biomass boilers recently sited in Pennsylvania's PM non-attainment areas are permitted with PM emission rates of about 0.22 lb/MMBtu, significantly greater than the EPA "boiler rule" limit of 0.07 lb/MMBtu that applies to new burners of 10–30 MMBtu/hr. Biomass boiler emissions of PM, NO_X and CO are much greater than emissions from the oil and gas boilers that biomass boilers displace. Considering that PM emissions from small institutional boilers such as those being installed at schools are functionally equivalent to emissions from a group of 10–15 conventional, non-EPA certified woodstoves, and considering that a recent study showed a dramatic health benefit when conventional woodstoves were replaced with lower-emissions units, there can be little question that institutional biomass burners can severely degrade local air quality and threaten respiratory health. Our analysis indicates that in some Pennsylvania counties, total PM emissions from commercial and institutional biomass boilers rival or exceed PM emissions from residential wood smoke, but that significant emissions reductions could be achieved if more sophisticated emissions controls were required. However, the typically lower visible emissions from institutional biomass burners, where the bulk of PM is emitted in the finest size fraction that is the hardest to see but represents the greatest threat to health, means that emissions from these burners are sometimes taken less seriously than they should be.

Perception—both visible perception of the opacity of emissions, and the widespread marketing and perception of biomass as "clean" energy—is a real barrier to reducing emissions from biomass boilers. At the institutional level, biomass burners more frequently displace oil and natural gas burners than coal burners, almost always leading to an unambiguous increase in overall PM emissions. Pennsylvania does not require air quality modeling, or air emissions monitoring, on the small biomass burners that are being installed around the state at schools and other institutions, even though low stack heights and poor dispersion may cause unhealthy conditions to occur. In this data vacuum, the idea of biomass as "clean" energy is allowed to persist, even as residential wood smoke is increasingly recognized as a major contributor to degradation of air quality in some regions. Emissions from small-scale biomass burners could be reduced considerably using existing fuels and technologies. If the state wishes to take the potential health impacts from biomass boiler emissions seriously, there should be a commitment to both modeling and monitoring effects of biomass energy facilities on local air quality, and a commitment to transitioning to cleaner, low-emissions burners.

APPENDIX: BACKGROUND ON POLLUTANTS FROM BIOMASS BURNING

NITROGEN DIOXIDE (NO_X)

"Nitrogen oxide" is a term that refers both to the compound nitrogen oxide (NO) and to the group of several compounds that include nitrogen and oxygen, including nitrogen dioxide (NO_2), nitrous acid, nitric acid, and other more complex molecules. While stack emissions from biomass plants actually contain more NO than NO_2, subsequent atmospheric transformations occur that convert NO to NO_2, which EPA regulates as one of the criteria pollutants. Nitrogen oxides form during combustion both as a function of nitrogen content of fuels, but also as a function of the temperature of combustion, which is known as "thermal" NO_X formation. This relationship between combustion temperature and NO_X formation means that employing "good combustion practices" to minimize carbon monoxide (CO) formation may exacerbate NO_X formation. Nitrogen dioxide and other nitrogen-containing gases are respiratory irritants, and also contribute to formation of condensable particulate matter. Nitrogen oxides also drive ground-level ozone formation, and regulation of NO_X is a chief means for reducing smog formation. Nationwide, the majority of NO_2 is from the transportation sector, but utilities and other sources of combustion account for about 34 percent of total emissions.[162]

As of January 2010, EPA set a one-hour standard for NO_2 of 100 ppb, and retained the annual standard of 53 ppb. Pennsylvania counties are in attainment, but under new monitoring rules, several locations in Pennsylvania are subject to increased monitoring for NO_2, particularly in urban areas and near roads.

OZONE

A principal 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.

Many counties in Pennsylvania are currently in non-attainment for EPA's eight-hour ozone standard. EPA had proposed revising its eight-hour standard for ozone from 0.075 ppm to 0.06–0.07 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).[163] However, this proposal was shelved by the Obama administration, and implementation of the 2008 standard continues.

SULFUR DIOXIDE (SO_2)

Sulfur dioxide (SO_2) exposure causes breathing difficulty for people with asthma, and is also implicated in regional haze and acid rain formation.[164] Current air quality standards do not appear to be protective; an EPA risk assessment[165]of SO_2 concluded that clear health risks to asthmatics occur at concentrations significantly lower than the current 24-hour health standard for SO_2. The document further notes that "over 20 million people in the U.S. have asthma, and therefore, exposure to SO_2 likely represents a significant health issue." The main sources of SO_2 are fossil fuel combustion at power plants and industrial facilities. Along with its direct effects, SO_2 also contributes to the formation of fine particulate matter. Concluding that a new SO_2 standard with a one-hour averaging time would be more protective than the 24-hour standard alone, EPA strengthened the National Ambient Air Quality Standards (NAAQS) for SO_2 in June 2, 2010, by adding a one-hour standard set at 75 ppb.

Attainment status for the new one-hour standard had not yet been determined as of autumn 2012. With regard to the old standard, only six counties in the United States were in non-attainment; of these, one is Armstrong County in Pennsylvania. Areas formerly in non-attainment but that now have an EPA-approved plan to meet the standard ("maintenance" areas) include parts of Allegheny and Warren counties.[166]

PARTICULATE MATTER (PM)

Particulate matter emissions from power plants arise not only from emissions of ash during combustion, but also from secondary condensation in the atmosphere 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.[167] Two size classes of PM are recognized in regulatory schemes: PM_{10} and $PM_{2.5}$, with the numeric value referring to the particle size in microns (a micron is one millionth of a meter). PM units of concentration in air are expressed as micrograms per cubic meter ($\mu g/m^3$). "Ultra-fine" particulate matter, with particle diameters of 0.1 μg down to 0.01 μg and below, is not separately regulated from $PM_{2.5}$, but an increasing body of research indicates that this is the most dangerous size class of all. Ultra-fine PM is even more poorly controlled by emissions control technology and, in terms of particle number, is present in the millions to billions of particles per cubic centimeter of air, orders of magnitude greater in abundance than particle numbers for larger size classes.

There is no current health standard for PM_{10}. In 2006, EPA lowered the 24-hour exposure standard for $PM_{2.5}$ from 65 $\mu g/m^3$ to 35 $\mu g/m^3$. The current annual exposure standard is 15 $\mu g/m^3$. However, EPA's most recent risk assessment for PM acknowledges that the current standards are not protective enough,[168] and the agency will soon be lowering the annual standard for $PM_{2.5}$, likely to the 12–13 $\mu g/m^3$ range.

The classes of particulate matter classed as "black carbon" have also been implicated as having up to 60 percent of the climate warming effect of CO_2, by both creating "brown clouds" and darkening and thus increasing the heat absorption of snow and ice in polar regions.[171] Controlling soot emissions and thus lessening albedo effects appears to be a faster way to mitigate sea ice melting than controlling greenhouse gas emissions.[170]

Much of Pennsylvania is not in attainment with the current $PM_{2.5}$ standards. States are required to submit State Implementation Plans (SIPs) within three years of promulgation of revised NAAQS. In May of 2010, EPA notified Pennsylvania and 21 other states and the District of Columbia of failure to submit an SIP to meet the 2006 24-hour fine particulate standard.[171] Once EPA lowers the PM standards from the 2006 levels, more areas will likely be out of attainment.

LEAD

While lead exposure primarily occurs from lead paint that has not been remediated, power plant emissions, including those from burning forest biomass and construction debris, can be a source of lead to the environment. 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."[172]

EPA recently dropped the NAAQS for lead from 1.5 $\mu g/m^3$ to 0.15 $\mu g/m^3$. Parts of two Pennsylvania counties, Berks and Beaver, have not met the new standard.

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, particularly given that biomass fuel variability can cause very large changes in CO concentration in exhaust gases. Carbon monoxide is treated under EPA's boiler rule as a proxy for certain organic hazardous air pollutants that are assumed to increase as CO emissions increase, since both are products of incomplete combustion.

VOLATILE ORGANIC COMPOUNDS (VOCs)

According to the EPA, volatile organic compounds are any compound of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) that participates in atmospheric photochemical reactions[173]—in other words, a compound that is activated to change its form, or merge with other compounds, simply through light energy. VOCs are of general concern because they interact in the atmosphere with other compounds, including NO_X, to form smog. The VOCs emitted from biomass and other fuel combustion are also of concern because several of the main VOCs emitted by combustion, such as benzene and formaldehyde, are carcinogenic and can cause other health problems.[174] In some areas, ambient levels of VOC HAPs such as benzene can exceed health thresholds.

HAZARDOUS AIR POLLUTANTS (HAPs)

Hazardous air pollutants (HAPs) is the group name for 187 compounds that 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 methylene chloride, a widely used solvent. EPA has classified two HAPs as human carcinogens (arsenic and the hexavalent form of chromium, Cr(VI) 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 the copper-chromium-arsenate (CCA) mixture that was used for pressure-treating lumber. Facilities that propose to burn waste wood generally rely on visual sorting techniques to remove arsenic-containing pressure-treated wood from the C&D that they burn. 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." [175]

HEXAVALENT 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."[176] EPA's conversion constant for the proportion of total chromium from biomass burning that is emitted in the hexavalent form is 56 percent.[177]

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, though in comparison to coal as a source, biomass emissions are not significant.

DIOXINS/FURANS

Dioxins/furans are "persistent, bioaccumulative, and toxic" (PBT) compounds that are created as byproducts of chemical manufacturing, and also from combustion. Dioxins/furans are known to affect hormone levels and functions, as well as fetal development, the immune system, and reproduction. They are toxic at levels that already exist in the environment. EPA states: "Because 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."[178]

ENDNOTES

[1] The term "biomass energy" in this document means energy (either as heat, or heat and electricity) generated from the combustion of solid materials of recent biological origin, but for the purposes of this report does not include municipal waste. However, municipal waste combustion for power generation is treated as renewable energy in a number of state renewable portfolio standards.

[2] While some biomass energy facilities may use sources of wood that were previously required by a now-declining pulp and paper industry, the magnitude of growth in the industry (as well as the wood pellet industry) indicates that a net increase in forest harvesting will be required to meet emerging demand (Colnes, A. et al. Biomass supply and carbon accounting for Southeastern forests. Biomass Energy Resource Center and the Forest Guild, February, 2012. Available at www.southernenvironment.org/uploads/fck/file/biomass/biomass-carbon-study-021412-FINAL.pdf; also Abt, R. et al., 2010. The near-term market and greenhouse gas implication of forest biomass utilization in the Southeastern United States. Nikolas School of the Environment, Duke University, August 2010). A surge in biomass facilities proposed in the Northeast will significantly increase demand in those forests that are currently harvested primarily for sawtimber, and not pulpwood.

[3] Energy Information Administration. Database: Existing electric generating units by energy source, 2008. Available at www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html.

[4] Energy Information Administration. 1990–2010 Net Generation by State by Type of Producer by Energy Source (EIA 906, EIA-920 and EIA-923). Available at www.eia.gov/cneaf/electricity/epa/epa_sprdshts.html.

[5] Announced plants and co-firing projects represent about 4,950 MW; co-firing proposals are difficult to quantify, since the amount of capacity to be replaced by biomass is usually flexible. The largest co-firing proposals going forward as of early 2012 actually represent 100 percent re-firing of the coal facility with wood, like the three 51 MW facilities proposed for re-firing by Dominion Energy in Virginia. However, significant expansion could occur; for instance, the Ohio Public Utilities Commission has approved around 2,000 MW of biomass power, mostly as co-firing at coal plants.

[6] RISI North American Wood Biomass Projects Database, 2010.

[7] "Forestry residues" consist of the tops and branches left over after commercial timber harvesting, as well as other unmerchantable trees cut or knocked down during harvesting.

[8] For a detailed overview of the constraints on biomass fuel stocks nationally, see Booth, M. and Wiles, R., 2010. "Clearcut Disaster." Environmental Working Group, Washington, DC.

[9] The potential wood demand from cellulosic ethanol is massive; a single facility, such as the Frontier Kinross ethanol plant proposed in Michigan, can consume well over a million tons of wood a year: the equivalent to clearcutting about 13,000 acres of Michigan forests a year.

[10] RISI April 2010 newsletter.

[11] Smith, W.B., et al., 2007. Forest Resources of the United States, 2007. United States Forest Service, Gen.Tech Report WO-78. December 2008.

[12] Energy Information Administration. 1990–2010 Net Generation by State by Type of Producer by Energy Source (EIA-906, EIA-920 and EIA-923). Available at www.eia.gov/cneaf/electricity/epa/epa_sprdshts.html.

[13] Perritt, W.R. "Wood biomass market realities explode waste wood myth." RISI website, accessed Aug. 5, 2010.

[14] www.frontier-renewable.com/questions/#What_is_Frontier_Renewable_Resources. Accessed July 2011.

[15] Energy Information Administration, 2011. "Average heat rates by prime mover and energy source." Electric Power Annual, 2009. April 2011. Available at www.eia.gov/cneaf/electricity/epa/epat5p4.html.

[16] Manomet Center for Conservation Sciences. 2010. *Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources*. Walker, T. (Ed.). Contributors: Cardellichio, P., Colnes, A., Gunn, J., Kittler, B., Perschel, R., Recchia, C., Saah, D., and Walker, T. Natural Capital Initiative Report NCI-2010-03. Brunswick, Maine.

[17] Walker, Thomas. Manomet & Biomass: Moving Beyond the Soundbite. Presentation to USDA Bioelectricity and GHG Workshop, November 15, 2010.

[18] Colnes, A. et al. *Biomass Supply and Carbon Accounting for Southeastern Forests.* Biomass Energy Resource Center and the Forest Guild, February 2012. Available at www.southernenvironment.org/uploads/fck/file/biomass/biomass-carbon-study-021412-FINAL.pdf.

[19] Hinckley, J. and Doshi, K. *Emission controls for small wood-fired boilers*. Resource Systems Group, Inc. and Biomass Energy Resource Center. May 2010. White River Junction, Vermont.

[20] Sippula, O. 2010. *Fine particle formation and emissions in biomass combustion*. Dissertation, Department of Environmental Science, University of Eastern Finland, Kuopio, Finland.

[21] Tissari, J. et al. 2008. Fine particle and gas emissions from the combustion of agricultural fuels fired in a 20 kW burner. Energy & Fuels, 22: 2033–204; also Van Loo, S. and Koppejan, J. 2008. *The Handbook of Biomass Combustion and Co-Firing*. Earthscan, Sterling, VA.

[22] Sippula, 2010.

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[23] EPA. AP 42, Fifth Edition, Vol. 1. Chapter 1, External Combustion Sources. Available at www.epa.gov/ttn/chief/ap42/ch01/index.html.

[24] Sippula, 2010.

[25] Van Loo, S. and Koppejan, J. 2008. *The Handbook of Biomass Combustion and Co-Firing*. Earthscan, Sterling, VA.

[26] Mentz, J. et al., 2005. Potential mercury and hydrochloric acid emissions from wood fuels. *Forest Products Journal*, 55: 46–50.

[27] Van Loo, S. and Koppejan, J., 2008.

[28] Musil-Schlaffer, B. et al. 2010. European wood-heating technology survey. Prepared for the New York State Energy Research and Development Authority. Albany, NY; also Sippula, 2010; also Chandrasekaran, S. et al., 2011. Emission characterization and efficiency measurements of high-efficiency wood boilers. Energy Fuels 25(11): 5015–5021.

[29] Sippula, 2010.

[30] Tissari et al., 2008.

[31] Hinckley and Doshi, 2010.

[32] Emissions of pollutants are typically represented on a "pounds of pollutant per million BTU of boiler capacity" basis (lb/MMBtu). Expressing pollution on this basis of "heat input" to the boiler is standard practice for conventional pollutants; however, emissions of CO_2 are typically expressed on the basis of energy output, for instance as pounds of CO_2 per megawatt-hour of electrical output (lb/MWh).

[33] Environmental Protection Agency. AP 42 Compilation of Air Pollutant Emission Factors. External Combustion Sources: Wood residue combustion in boilers. Washington DC, September 2003.

[34] Data summarized in Nussbaumer, T. Biomass combustion in Europe: Overview on technologies and regulations (NYSERDA Report 08-03). Report prepared for the New York State Energy Research and Development Authority. April 2008.

[35] Chandrasekaran, S. et al., 2011. Emission characterization and efficiency measurements of high-efficiency wood boilers. Energy Fuels 25(11):5015–5021.

[36] An "area" source is one than emits less than 25 tons a year of all hazardous air pollutants (HAP), and less than 10 tons per year of any one HAP.

[37] EPA 40 CFR Part 63. National emission standards for hazardous air pollutants for area sources: industrial, commercial, and institutional boilers. Federal Register Vol. 76, No. 247, Friday, December 23, 2011.

[38] Hinckley and Doshi, 2010.

[39] For example, Gammie and Snook report PM emission tests at a 5.7 MMBtu/hr boiler in Vermont where removal efficiency for filterable PM was only 83.2 percent, even though a baghouse was in use. It was concluded that a bypass damper may not have been sealed tightly enough, allowing exhaust gases to escape without going through the baghouse (Gammie, J. and Snook, S. Air emissions test report: Small biomass energy system particulate matter emissions testing. Prepared for State of Vermont Agency of Natural Resources. GamAir Project No. 641–0712, June 2009.)

[40] The idea that European biomass power is uniformly less polluting does not appear to be well-founded. In fact, emissions from existing biomass capacity in European countries do not appear to be well-controlled; in some regions that are heavily dependent on wood for heat and power, such as Finland, many small facilities have no air pollution controls at all (Sippula, 2010).

[41] Hinckley and Doshi, 2010.

[42] Sippula, O. et al., 2009. Particle emissions from small wood-fired district heating units. Energy and Fuels 23: 2974–2982. The Hinkley and Doshi report on small boilers in the United States states that PM removal rates by ESPs are around 99 percent.

[43] Ibid.

[44] Batey, J. Technical update: air emissions from home oil burners and other sources. Oil Heat Manufacturers Association, April 2004 (www.oma-oilheat.org/PDF/airEmissions.pdf).

[45] Sippula, 2010.

[46] Musil-Schlaffer. et al., 2010.

[47] Ibid.

[48] Viessman website, accessed February 2012, at www.viessmann.ca/en/products/wood/Pyrot.html.

[49] Chandrasekaran, S. et al., 2011

[50] Wood pellet prices at www.woodpelletprice.com/.

[51] Ibid.

[52] *The Rolla Daily News*. District returns grant funds. August 9, 2010.

[53] Hinckley and Doshi, 2010.

[54] RISI North American Wood Biomass Projects Database, 2010. The figure of two tons of green wood per ton of finished pellets is likely an underestimate, considering the amount of wood in a harvested tree that is not useable for pellet manufacture.

[55] A review of air permits for pellet manufacturing plants in New York reveals that, like kiln-drying sawtimber, pellet drying is a significant source of VOCs.

[56] Katers, J. and Kaurich, J., 2007. Heating fuel life-cycle assessment. Study prepared for the Pellet Fuels Institute, February 2007. University of Wisconsin, Green Bay. 54 pp.

57 Under EPA's boiler rule as formulated on December 23, 2011, the filterable PM emission rate for a new coal stoker is 0.28 lb/MMBtu, while the rate for a new biomass stoker is 0.029 lb/MMBtu. A new coal bubbling fluidized bed boiler must achieve 0.0011 lb/MMBtu, while the rate for a new biomass bubbling fluidized bed boiler is nine times as high, at 0.0098 lb/MMBtu.

58 EPA's BACT permit "clearinghouse" shows overlap in the permitted emission rates for coal- and biomass-burning facilities for key pollutants, with the exception of sulfur, which is usually emitted at a higher rate by coal plants. The range of rates at the five lowest-emitting coal facilities and the five lowest-emitting biomass facilities as of Spring 2012 were: Filterable PM10 Coal: 0.01 to 0.12 lb/MMBtu; Biomass: 0.02 to 0.03 lb/MMBtu; NO_X Coal: 0.067 to 0.07 lb/MMBtu; Biomass: 0.065 to 0.15 lb/MMBtu; CO Coal: 0.1 to 0.135 lb/MMBtu; Biomass: 0.1 to 0.24 lb/MMBtu.

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68 Sippula et al., 2009.

69 Minn. Pollution Control Agency. Chippewa Valley Ethanol to pay $120,000 environmental penalty. April 30, 2010.

70 EPA's "waste rule," as proposed December 23, 2011, states that for the purposes of determining whether a biomass fuel meets the "legitimacy" standard for contamination, its contaminant concentration can be compared to concentrations in any other fuel that aboiler could potentially burn, even coal, whether or not that boiler is actually permitted to burn other fuels. Because, on average, coal has a higher concentration of heavy metals than "clean" biomass, this opens the door to burning of much more contaminated fuel than has occurred in the past. EPA, 2011. Commercial and industrial solid waste units: reconsideration and proposed amendments; non-hazardous secondary materials that are solid waste. 40 CFR Parts 60 and 241. Federal Register Vol. 76, No. 247. December 23, 2011.

71 Rector, L., et al. 2011. Residential wood pellets: elemental composition, market analysis and policy implications. Presentation at "Environmental Monitoring, Evaluation and Protection in New York: Linking Science and Policy" Conference hosted by New York State Energy Research and Development Authority, November 15–16, Albany, NY (available at www.nyserda.ny.gov/Page-Sections/Environmental-Research/EMEP/Conferences/2011-EMEP-Conference/~/media/Files/Events/Events%20and%20Conferences/EMEP%202011/presentations/Rector.ashx).

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74 U.S. Environmental Protection Agency (EPA), (2002). Health assessment document for diesel engine exhaust. Prepared by the National Center for Environmental Assessment, Washington, DC, for the Office of Transportation and Air Quality; EPA/600/8-90/057F. Available from: National Technical Information Service, Springfield, VA; PB2002-107661, and www.epa.gov/ncea.

75 Based on calculations for the 50 MW Russell Biomass plant, proposed in Massachusetts.

76 Referring to formaldehyde, acetaldehyde, benzene, acrolein, and 1,3-butadiene, an air modeling study for a biomass plant proposed in Springfield, Massachusetts, concluded that "maximum modeled annual average impacts of these air toxics are slightly higher for mobile and fugitive source emissions than for the project stack air emissions." (Epsilon Associates. Palmer Renewable Energy Project Notice of Project Change. Submitted to Massachusetts Executive Office of Energy and Environmental Affairs, September 2010).

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[81] Pennsylvania Public Utility Commission, 2010. 2008 and 2009 Annual Reports: Alternative Energy Portfolio Standards Act of 2004. June 2010. Harrisburg, PA. Available at www.puc.state.pa.us/electric/pdf/AEPS/AEPS_Ann_Rpt_2008-09.pdf.

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[85] Pennsylvania Public Utilities Commission. 2010 Annual Report: Alternative Energy Portfolio Standards Act of 2004. August 2011. Harrisburg, PA.

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[89] Smith et al, 2007.

[90] Pennsylvania Hardwoods Development Council. Report of the blue-ribbon task force on the low-use wood resource. September, 2008.

[91] Energy Information Administration, 1990–2008, Net generation by state by type of producer by energy source (EIA 906), available at www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html).

[92] Smith et al., 2007.

[93] Buchholz, T., et al. Forest biomass and bioenergy: opportunities and constraints in the Northeastern United States. Cary Institute of Ecosystem Studies, Millbrook, NY. February 2011.

[94] Coal plants co-firing using "open loop" biomass are not eligible for the PTC, but facilities co-firing using "closed loop" biomass — crops and trees grown specifically for the purposes of energy production — are eligible for the credit.

[95] One component of BCAP matched up to $45 per dry ton as a payment to biomass suppliers. The program paid out $243 million in 2009/2010, with over $203 million being paid for "woody resources" from federal and private lands. USDA. BCAP CHST Component Report, FY 2009 and FY 2010. Released October 19, 2010.

[96] Pennsylvania Department of Environmental Protection website: "PA State Energy Program" (www.portal.state.pa.us/portal/server.pt/community/pa_state_energy_program/10396).

[97] The Fuels for Schools website is www.pafuelsforschools.psu.edu/.

[98] From a promotional brochure for the "Pennsylvania Fuels for Schools and Beyond" program.

[99] *Tri-County Courier Express*. Elk Regional Health Center to use biomass energy. May 5, 2007.

[100] Website at www.bioenergy.psu.edu/.

[101] For instance, one factsheet from the Department of Agricultural and Biological Engineering states as a benefit of biomass energy, "improving the environment and public health."

[102] http://woodpro.cas.psu.edu/Homepage.htm.

[103] http://hayandforage.com/biofuels/co-firing-biomass-with-coal-402/.

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[112] Epsilon Associates, Inc. Beneficial use determination application to Massachusetts Department of Environmental Protection for Palmer Renewable Energy, Springfield, MA. April 17, 2009..

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[123] Pennsylvania Department of Conservation and Natural Resources, 2007.

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[127] Energy Information Administration. 1990–2010 . Existing Nameplate and Net Summer Capacity by Energy Source, Producer Type and State (EIA-860). Available at www.eia.gov/cneaf/electricity/epa/epa_sprdshts.html.

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139 Hunt, Spencer. Plan to use wood at power plants now on back burner. *The Columbus Dispatch*. December 5, 2010.

140 While emissions of NO_X from most wood-burning facilities appear to be similar in magnitude or smaller than particulate emissions, the IntelliWatt facility's projected and permitted emission limits include 23.2 tons of PM versus 46.2 tons of NO_X, double the PM emissions. (The plant's permit also specifies 2.4 tons of SO_2, 1.6 tons of VOCs and 28.2 tons of CO.) It is not clear if NO_X emissions from manure burning are consistently so high.

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142 Pennsylvania Department of Environmental Protection, 2009. Evaluation of the Pennsylvania Air Quality Program 2002–2007.

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144 Health burdens and especially asthma rates tend to be high in urban, minority, and economically disadvantaged populations. The Pennsylvania DEP has shown awareness of environmental justice issues in the past, but there appears to have been little if any discussion of the environmental justice implications of the United Corrstack facility in Reading.

145 A geospatial coverage for Pennsylvania's environmental justice areas is available from the Pennsylvania Geospatial Data Clearinghouse at www.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=eja_v.xml&dataset=255.

146 The plant delivers 30 MW to the grid. Its total capacity, accounting for parasitic load, is around 33 MW.

147 Toxic Release Inventory data for Reading indicate that, in 2008, pollutant emissions (in pounds) included HCl: 1,516,043; Hydrogen fluoride: 130,005; Sulfuric Acid: 24,005; Chromium compounds: 11,257; Arsenic: 176; Antimony: 597; Lead: 2,357; and Trichloroethylene: 87,693 (data can be obtained at http://toxmap.nlm.nih.gov/toxmap/main/startOver.do).

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