RELIABILITY OF RENEWABLE ENERGY: BIOMASS

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The Institute of Political Economy (IPE) at Utah State University seeks to promote a better understanding of the foundations of a free society by conducting research and disseminating findings through publications, classes, seminars, conferences, and lectures. By mentoring students and engaging them in research and writing projects, IPE creates diverse opportunities for students in graduate programs, internships, policy groups, and business.
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EXECUTIVE SUMMARY

As Americans grew more concerned with fossil fuel emissions, policymakers responded to their constituencies by mandating and subsidizing renewable energy sources. Because of these policies, the amount of electricity produced from biomass is increasing. But, producing electricity from biomass relies heavily on government assistance, is inefficient, and causes environmental damage. Currently, the biomass industry is heavily dependent on government mandates and subsidies, and without these policies the biomass industry could not sustain its current growth within the energy market. Before lawmakers enacted renewable energy policies, energy producers used biomass as a small supplement in electricity generation. Biomass fuels were generally waste products, such as crop residues and animal waste, that had few other economic uses. Burning these wastes for electricity was an efficient use of otherwise wasted resources. Newly-enacted mandates and subsidies are now making non-waste biomass resources, including lumber, economically viable as fuel. Mandates and subsidies have caused environmental damage, which undermines the purpose of using biomass as an energy source. Harvesting and burning whole trees for electricity production releases captured carbon that will not be re-captured for several decades. Fuel crops require water, land, and fertilizers, all of which have their own environmental impacts. Burning solid biomass also releases more greenhouse gases and other pollutant emissions per unit of energy produced than burning coal.

Government regulators have established a double standard for biomass pollutant emissions compared to fossil fuels. Compared to fossil fuels, solid fuel biomass power plants typically emit two and a half times more of the pollutants, such as dioxins, carcinogens, or heavy metals, specified in the Clean Air Act. Since biomass facilities are lightly regulated but heavily subsidized, they have little incentive to produce cleaner electricity and reduce emissions. Biomass-generated electricity is costly, inefficient, and environmentally degrading in many cases. Current policies are a misallocation of taxpayer dollars and cause increased environmental harm. Biomass’ viability in the nation’s energy portfolio is best decided by markets rather than government mandates or subsidies.

INTRODUCTION

As concerns over the long-term effects and viability of fossil fuels continue to grow, many Americans favor switching to renewable energy sources. Federal and state policymakers respond to their constituencies by mandating and subsidizing renewable energy sources like biomass electricity generation.1 Although biomass fuels are not as well-

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known as other renewable energy sources like wind and solar, biomass is quickly growing in prominence. From 2004 to 2013, employment in the biomass industry grew at an average rate of 8.9 percent annually and today biomass accounts for 1.7 percent of the total electricity generated in the United States.\textsuperscript{2,3} The influence of biomass on the nation’s energy portfolio will likely increase as utility companies strive to comply with government mandates that require them to provide more electricity from renewable sources. Because biomass’ share of the electricity market is so small, biomass’ impact on the overall market will not be examined in this report.

As government policies favor biomass-generated electricity, one way to determine whether these policies are beneficial is to examine the reliability of biomass as an energy source. If biomass is unreliable, then government policies that promote its growth are a misallocation of taxpayer dollars.

Utah State University’s Institute of Political Economy (IPE) designed this report to examine the reliability of biomass-generated electricity. The term “reliability” is ambiguous and goes beyond an energy source’s ability to generate power consistently. IPE explored the economic, environmental, and physical reliability of biomass-generated electricity, and defined them as follows: First, economic reliability is the ability of an energy source to be self-sustaining and affordable on the market without government mandates and subsidies; second, environmental reliability is the ability of an electricity source to have less environmental impact than fossil fuels; finally, physical reliability is the ability of an electricity source to consistently meet electricity demands without disruptions in energy supply. Electricity sources that do not meet these definitions are unreliable and an inefficient use of taxpayer dollars.

\textbf{HOW BIOMASS ENERGY PRODUCTION WORKS}

Biomass is organic matter that can be used for generating electricity or transportation fuel. The majority of biomass fuels come from plant materials. Because biomass sources are so diverse, for the purpose of this IPE report divides them into three categories: solid, gas, and liquid.

\textbf{SOLID BIOMASS}

Several widely used solid biomass fuels include lumber, wood waste from mills and forest thinning projects, crop waste, and energy crops. Solid fuels can be directly burned or concentrated into charcoal or pellets to be burned later. Solid biomass sources are burned much like coal; materials are combusted to produce heat, which boils water to spin steam-powered turbines.\textsuperscript{4}

Crop residues are also classified as solid biomass. When farmers harvest crops, they leave behind residues such as straw, vines, leaves, stubble, and other agricultural components.\textsuperscript{5} Crop residues are often used to fertilize soil and reduce erosion, but they can also be burned to generate electricity.\textsuperscript{6}

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Energy crops, in comparison, are grown strictly for energy production. These are typically low-cost and low-maintenance crops such as beetroot, corn, coppice, switchgrass, and other plants with high sugar content. Some energy crops are burned directly, but they can also be converted into bio-ethanol or biomass pellets.

**GASEOUS BIOMASS**

Gaseous biomass, or biogas, is produced when organic materials such as agricultural waste, plant material, sewage, and manure decompose. Biogas usually consists of 55-70 percent methane, 30-45 percent carbon dioxide, and traces of hydrogen, nitrogen, and carbon monoxide. Methane can be collected and used as an alternative to natural gas. Methane is emitted when organic material decays, through a process called anaerobic digestion. This process occurs naturally on farms and landfills, but material can also be placed in digesters that introduce bacteria to aid in decomposition.

**LIQUID BIOMASS**

The most common biofuels are ethanol and biodiesel, which can replace gasoline and diesel in many vehicles. Biofuels, which come from plant oil and fermented plants, can also be used in home stoves for cooking and in some generators to provide electricity. Because liquid biomass’ primary use is transportation and this report examines biomass as an electricity generating source, liquid biofuels will not be thoroughly assessed in this report.

**ECONOMIC RELIABILITY**

Because “economic reliability” is not a common academic term, in the context of this report, IPE defines economic reliability as the ability of a renewable electricity source to stand on its own in the electricity market without government mandates, subsidies, or incentives. Other academic reports may refer to economic reliability as economic viability or sustainability.

When the costs of collecting waste and residue resources for electricity generation do not exceed the value of the electricity generated, biomass energy can be economically reliable. Biomass-generated electricity is typically more expensive than coal power, so it is a less used electricity source. By subsidizing and mandating biomass electricity production, lawmakers make biomass more competitive.

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RELATIVE COST OF BIOMASS

Although biomass fuels are usually more expensive than coal on average, the two fuels can be cost-competitive in some markets, making them more economically reliable than many renewable electricity sources. In 2010, forest residues and wood waste cost anywhere from $10-50 per ton, based on how they were harvested and who they were sold to. Agricultural residues cost $20-50 per ton, and energy crops cost $39-50 per ton. Averaged, biomass in 2010 cost $34.35 per ton. In that same year, coal cost an average of $32 per ton.

These price estimates are only for fuel and do not take into account the total costs of operating biomass or coal facilities. Researchers use the term “levelized cost of electricity” (LCOE) to estimate the lifetime costs associated with generating electricity. In 2015, the Energy Information Administration estimated that the levelized cost of producing electricity from a conventional coal plant was $95.1 per megawatt-hour, and the levelized cost of producing electricity from a biomass plant was $100.5 per megawatt-hour. This a general estimate, as it does not control for the many different types of biomass fuels that can be used in electricity production.

Biomass companies can co-fire biomass material with coal in already-existing coal plants to reduce overhead costs incurred by the construction of new facilities. Co-firing is done in several different ways, and each comes with different costs. Biomass fuel can be directly fired with coal. This method is the cheapest because it requires minimal installation of new equipment. Another method indirectly fires biomass with coal by burning biomass in a separate boiler from the coal, then combining the gases from both boilers to generate electricity. This method is more expensive because it requires a separate boiler and other biomass equipment, but many of the instruments coal boilers use can also be used by biomass boilers. The final method for co-firing is called gasification. Gasification is the most expensive co-firing method because it requires separate equipment to gasify biomass material. In some cases gasification makes economic sense as it significantly increases efficiency of co-firing.

MANDATES

RENEWABLE PORTFOLIO STANDARDS

Biomass electricity generation is currently only mandated by state governments; there are no federal mandates. Renewable Portfolio Standards (RPS), the most common type of renewable energy mandate, outlines what portion of a state’s energy must come from renewable resources. Illinois’ RPS, for instance, requires 15 percent of its electricity to come from renewable sources by 2026. Some states’ RPS mandate that a specific amount of its energy come from

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a particular energy source. These mandates are called carve-outs. Maryland, for example, has a carve-out that requires two percent of the state’s electricity to come from solar sources by 2020.19

Most carve-outs are for wind or solar power, but some states have carve-outs for biomass. Minnesota’s RPS requires Xcel Energy, a large, private Midwestern utility company, to construct or contract facilities for 110 megawatts of biomass power.20 Although biomass has fewer carve-outs than wind or solar power, it is still eligible to satisfy the general renewable requirements for all twenty-nine states that have adopted RPS mandates.21 Because biomass is one of the most reliable ways to fulfill RPS, RPS drive the growth of the biomass energy industry.

CASE STUDY: NORTH CAROLINA BIOMASS

Not all RPS mandates have proven attainable. In 2007, North Carolina implemented specific biomass carve-outs in its RPS requiring by 2018, .2 percent of the state’s electricity come from swine waste and by 2014, 900,000 megawatt hours of electricity come from poultry waste. Electricity producers realized they would be unable to meet these standards of production and as a result, in 2012 the North Carolina Utilities Commission reevaluated the requirements.22 As of 2015, North Carolina RPS requires that 0.2 percent of the state’s electricity come from swine waste by 2020 and 900,000 megawatt hours of electricity come from poultry waste by 2016.23

The North Carolina Utilities Commission extended the requirements because it appeared that utility companies had made good-faith efforts to achieve the state standards, but electricity producers could not reasonably supply the mandated amounts of electricity from swine and poultry waste due to high costs of methane-to-electricity systems. Besides the costs, utility companies were hesitant to make changes because they were uncertain about which environmental regulations would pertain to their facilities. In the report from the Commission modifying North Carolina’s carve-outs, the Commission stated, “[The] costs [of installing biomass projects] are eventually borne by retail consumers, and allowing more time for the market to develop is in the public interest in that it will protect customers from the inflated cost of an undeveloped industry.” Although the committee recognized that mandating biomass power directly affects electricity consumers by increasing electricity prices in the long run, biomass carve-outs in North Carolina are still in place.24

SUBSIDIES

In addition to mandates, governments use subsidies to encourage growth in the biomass industry. Biomass subsidies redistribute wealth from taxpayers to biomass producers. Taxpayers for Common Sense, a 501(c)(3) non-profit organization that acts as a budget watchdog, listed ten subsidy programs for wood based (or “woody”) biomass in the

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In theory, subsidies can help biomass technologies get started and eventually compete with other sources of electricity. After years of subsidies, biomass facilities are unable to compete. In the United States and in Europe they continue to require subsidies.

PRODUCTION TAX CREDIT

The Production Tax Credit (PTC) is a key government subsidy for some forms of renewable energy, including most types of biomass. Biomass produced from energy crops is called closed-loop biomass. Electricity producers that use closed loop biomass receive a tax credit of 2.3 cents per kilowatt-hour, which is the same amount wind and geothermal energy producers receive. Biomass produced from farm and forest waste, landfill gas, and other forms of waste biomass is called open-loop biomass and receives a smaller tax credit of 1.1 cents per kilowatt-hour.

Although closed-loop systems receive a greater tax credit than open-loop systems, none were built in the 1992-2006 window established in the Energy Policy Act of 1992. Any plant built during that period qualified for the tax credit, but the subsidy was evidently insufficient to overcome the high costs of closed-loop systems.

Open-loop biomass material is less expensive and easier to procure than closed-loop biomass. Even without the PTC in effect, some electricity companies will use open-loop biomass to generate electricity. Bill Carlson, the former chairman of the USA Biomass Power Producers Alliance, said, "That's the model that works - taking people's waste materials and making electricity out of it." Because some facilities used waste biomass to generate electricity even before it was subsidized, incentivizing biomass provides additional profit to electricity companies that were already profiting by using waste biomass.

BIOMASS CROP ASSISTANCE PROGRAM

The Biomass Crop Assistance Program (BCAP) is another federal subsidy used to help the biomass industry. To incentivize farmers to harvest more agriculture and forest residues, the U.S. Department of Agriculture matches payments made to farmers by biomass energy companies through the BCAP. The BCAP provides matching payments up to $12.5 million per year. In 2014, the BCAP also funded the removal of 200,000 tons of biomass from federal

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lands. According to the US Forest Service, these projects helped generate energy, restored watersheds and removed dead wood that could fuel forest fires.\(^{32}\)

Many biomass energy plants have come to rely on the BCAP to stay in operation. According to Bob Cleaves, president of the Biomass Power Association, “seven of Maine’s ten biomass energy plants would have shut down without the new influx of funds.”\(^ {33}\) Along with propping up failing plants, the BCAP is one of the sole incentives for farmers to enter the biomass industry. The BCAP assists farmers with the high startup costs of developing land and devoting resources to biomass materials. Proposed BCAP cuts discourage farmers from entering the industry, showing that biomass suppliers are unconfident that the biomass industry could sustain itself if the industry were to lose government support.\(^ {34}\)

**CASE STUDY: DRAX POWER STATION**

Drax Power Station, the largest power plant in the United Kingdom, shows the reliance of large scale biomass plants on subsidies. Although Drax operates in the European energy market, it provides an example of how government subsidies affect biomass’ viability. Drax, in response to government incentives and public pressure to be more environmentally friendly, switched from using mainly coal as fuel to using biomass for electricity generation by importing millions of tons of wood from North America to burn. In 2013, Drax burned seven million metric tons of plant material, about 90 percent of which was imported primarily from the United States.\(^ {35}\)

Concerned by the volume of imported plant material from the United States, in 2014, the United Kingdom planned to remove biomass as a qualifier for most of its renewable energy incentives. As a result, Drax’s shares dropped sharply and continued to do so each time the government made any move toward removing biomass incentives.\(^ {36,37}\) The Guardian reported Liberum’s Peter Atherton saying, “Drax has bet its corporate strategy on biomass and the economics of conversion depend entirely on government subsidy.”\(^ {38}\) Only a month after the UK planned to stop subsidizing Drax, the UK turned around and provided Drax a contract for difference, which is a guaranteed payment for every unit of renewable electricity produced.\(^ {39}\) Drax shares rose almost six percent as a result.\(^ {40}\) Drax’s subsidy dependence gives credence to the conclusion that large-scale biomass is not economically reliable without government support.

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Reliability of Renewable Energy: Biomass
In July of 2015, the Office of Budget Responsibilities estimated that biomass subsidies in the UK would rise from 4.3 billion pounds in 2015 to 9.1 billion by 2021. This amount would surpass the budget set by the United Kingdom Treasury for renewable electricity by about one fifth. As a result, the Department of Energy and Climate Change cut the feed-in tariff program that allowed biomass developers to have guaranteed premium payments for the life of a project. When the policy change was announced, Drax shares fell again by 2.2 percent. Changes in biomass policies are estimated to save taxpayers in the United Kingdom about 500 million pounds per year by 2021.

CASE STUDY: BUTLER PIG FARMS

In 2011, Tom Butler, owner of Butler Farms, installed an electrical system on his farm that is powered by methane gas captured from the farm’s “hog lagoons” — pits that contain the collected waste from 6,000 pigs. Butler originally covered his lagoons to collect methane and burn it, thus reducing methane emissions. Butler installed a methane-to-electricity system, and now makes between $8,000-$10,000 every month by selling the farm’s excess electricity to the utility company.

Butler purchased his system using grants from the Farm Bureau and the North Carolina Green Business Fund. Butler acknowledges that without the grants he would be losing money from interest payments on the equipment, which initially cost over one million dollars. Other pig farmers also recognize the high installation costs that prevent entry into the electricity market. Prestage Farms, the company that employs Tom Butler and other North Carolina farmers to raise pigs, provides no investment help to any farmers interested in installing methane-to-electricity systems.

Due to noxious odors and potential water pollution from pig waste, state legislators determined that farms in North Carolina cannot raise more than 250 pigs per farm. As methane-to-electricity technology develops, widespread implementation of methane-fueled electrical systems could provide an incentive for North Carolina legislators to lift restraints on pig farm size. Farmers would be able to generate clean, renewable electricity while expanding farming operations. Capturing methane from hog lagoons will reduce odors, but it will have little effect on water pollution from pig farms. Unfortunately, methane-to-electricity systems will not become a common sight on animal farms until methane generated electricity is more developed and becomes an economically viable electricity generation method.

VERDICT ON ECONOMIC RELIABILITY

Biomass does exist in the electricity market without subsidies or mandates. Wood waste, animal waste, and other waste resources can be used to profitably generate electricity. But, energy crops are not an economical biomass fuel and only exist on the scale they do because of subsidies and mandates. The large-scale facilities that have been built in recent years, and will profit based on subsidies and tax breaks, are the biomass facilities that are economically unreliable.

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43 Ibid.
45 Ibid.
Biomass is economically reliable when it exists independent of government support, but when biomass is grown and used solely because of government intervention, as is often the case with animal waste and closed-loop biomass energy sources, biomass is not an economically reliable electricity source.

ENVIRONMENTAL RELIABILITY

Environmental reliability is the ability of an electricity source to have less environmental impact than fossil fuels. Although biomass can be environmentally beneficial, the scale at which governments mandate biomass is unsustainable and environmentally unreliable. Grid-scale biomass electricity production emits more pollutants than fossil fuels, negatively affects local water sources, and is permitted by government regulation to pollute more heavily than any fossil fuel electricity source.

Biomass fuels are harvested from various sources, including forests, grasslands, construction projects, animal waste, and landfills. The environmental implications of each form of biomass are unique to each fuel. Although some biomass fuels may be more efficient than others, increased efficiency often comes at the cost of greater environmental harm. This section analyzes the more prominent sources of biomass fuel and their environmental impacts.

WOODY BIOMASS

Wood is the principal fuel used in biomass electricity generation.47 As biomass electricity facilities increase in number and size, wood fuel consumption also increases. To meet increased demand, some biomass facilities turn from forest thinning projects and wood waste collection to logging operations specifically designed to harvest trees for electricity generation.48

FOREST THINNING AND LOGGING

Forest thinning reduces the likelihood of overly-destructive wildfires, increases the growth of remaining plants by reducing competition, and enhances pest resistance.49, 50 Thinning large sections of forest can also have detrimental effects. The equipment used to cut and transport organic growth compacts the soil, which in turn inhibits seed germination and growth, increases erosion, and limits the soil’s ability to replenish nutrients effectively.51

Local ecosystems are disturbed by forest thinning projects, and long-term effects on biodiversity are difficult for researchers to predict. Some species benefit from the open spaces left by thinning, although others do not. Thinning

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forests in patches, as opposed to large swaths of land, helps minimize widespread impacts on local biodiversity. Thinning in patches, however, greatly reduces the efficiency of gathering large quantities of woody biomass.

A single biomass plant can consume around 650,000 tons of lumber per year, which means that expansion of biomass electricity production would require a significant amount of new logging to feed new power plants. The Partnership for Policy Integrity estimated in 2011 that 55 million tons of wood (roughly 650,000 clear-cut acres of forest) would be needed each year to provide enough fuel for predicted biomass facilities coming online over the next three years. This amount was estimated to only supply new and proposed facilities. As states continually move toward fulfilling their RPS mandates, more biomass facilities will be built, necessitating vast amounts of forest thinning or clear-cutting.

In Ohio, native forests are considered “tree crops” and by state definition are eligible to be clear cut for biomass fuel. Thirty-two other states have similar inclusions of whole trees being eligible for biomass fuel, opening the door for biomass companies to pursue logging enterprises in the name of renewable energy. If whole trees were no longer considered a viable generation source, biomass users would need to obtain their fuel from other sources such as existing forest residues, grasses, or animal waste.

CLAIMS OF CARBON NEUTRALITY

The U.S. Department of Agriculture and the Environmental Protection Agency claim that the carbon released by burning plant materials is the same amount sequestered over the plant’s lifetime, resulting in total carbon neutrality. Although this logic holds to an extent, it fails to consider several implications. Organic material grows and decays over many years, but burning it releases its stored carbon almost instantaneously into the atmosphere. If governments are concerned with climate change, it is illogical for them to incentivize tree burning as a way to reduce carbon emissions. Net carbon emissions are positive in the short term because large numbers of trees that would absorb carbon dioxide in the future have been harvested and burned. By burning whole trees cut specifically for energy production, atmospheric carbon dioxide builds while carbon sequestering rates decrease.

Harvesting trees for electricity is illogical as an effort against climate change. According to a study on biomass sustainability and carbon policy by the Manomet Center for Conservation Sciences, “Forest regeneration and growth will not instantaneously recapture all the carbon released as a result of using the woody material for energy generation.” Carbon neutrality is a valid argument in the long run only if new forest growth rates consistently equal

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61 Ibid.
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deforestation rates. The outlook on attaining an equal growth-to-cutting ratio is bleak. Biomass facilities are being proposed and built at unprecedented rates due to government mandates and subsidies for renewable energy development. It will be decades before the short-term carbon emissions from burned trees are re-sequestered into new growth.

BIOMASS VS. FOSSIL FUELS

Burning biomass releases more carbon into the atmosphere per unit of power produced than coal. A study done by the Partnership for Policy Integrity finds that biomass combustion produces more carbon dioxide and nitrogen oxides than coal per megawatt-hour. In addition, the Massachusetts Environmental Energy Alliance states that biomass combustion emits 1.5 times more carbon monoxide and carbon dioxide than burning coal.

Small biomass power plants can emit more pollutants and greenhouse gases than larger fossil fuel power plants. In 2011, a report from the Partnership for Policy Integrity compared the Gainesville Renewable Energy Center (GREC), a 100 megawatt biomass power plant in Florida, to the Pioneer Valley Energy Center, a 431 megawatt fossil fuel power plant in Massachusetts. At the time, the GREC was only a proposed plant. Air permit applications from both plants show that the GREC was expected to produce 4.53 times more nitrogen oxides, 12 times more carbon monoxide, 5 times more particulate matter, 14.6 times more sulfur dioxide, and 3.25 times more volatile organic compounds than its fossil fuel counterpart, despite its smaller size. The Partnership for Policy Integrity calculated that the biomass plant would produce approximately 86 percent as much carbon dioxide as the fossil fuel plant. But considering its smaller size, the GREC would emit more carbon dioxide overall.

The GREC in 2014 used an average of 61,000 tons of biomass material per month. The plant uses forest residues, plant residues, wood waste from industry and residential areas, and whole trees as electricity generating fuel. According to the National Association of Conservation Districts, forests produce between 1-4 tons of biomass material per acre of forest. If the GREC were to solely harvest biomass material from forests, (assuming they harvest 2 tons of biomass per acre), it would be consuming 30,500 acres (around 48 square miles) of biomass material monthly. Although the GREC claims to use mostly waste products as fuel, it still uses whole trees as a fuel, meaning it still has large impacts on forests.

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70 Used online conversion tool to convert acres to square miles. (1 square mile = 640 acres) 30500 acres/640= 47.66 square miles.
Although the Pioneer Valley Energy Center uses natural gas and diesel, some of the cleanest burning fossil fuels, to generate electricity, the difference between the two plants illustrates that although biomass is renewable, it is often much dirtier than fossil fuel alternatives.

CONCLUSIONS FOR WOODY BIOMASS

In the short term, burning biomass emits more carbon dioxide per unit of power produced than burning coal and other fossil fuels. Carbon neutrality will be exceedingly difficult to achieve long term as it is nearly impossible to ensure an equilibrium of growth and harvesting rates. Healthy forest thinning practices cannot provide adequate fuel supplies for future demand. To meet demand, forests would have to be clear-cut, which increases carbon emissions. As such, woody biomass is an environmentally unreliable renewable fuel at currently incentivized levels.

GRASSES

Grasses have gained popularity in recent years as fuel for electricity generation. They are carbon neutral but require vast amounts of land to provide sufficient feedstock for a biomass facility. Grasses release toxic emissions when burned, but these can be reduced if they are co-fired with coal. Based on these variables, grasses are environmentally reliable as a supplementary fuel, but unreliable when used as an exclusive power plant fuel source.

CARBON NEUTRALITY

Unlike trees, grasses do not have a significant time lag between releasing and sequestering carbon. Burning grass that will be regrown the next year has little impact on short-term net carbon emissions. Grasses have a minimal net carbon impact on the environment.

LAND USAGE

As will be discussed in more detail in the Physical Reliability section of this report, energy crops like switchgrass require large tracts of land. The Union of Concerned Scientists suggest that if grasses are planted on a large enough scale, forestland would have to be cleared to make room for displaced food crops or grasses themselves. Clearing forests would release massive stores of carbon dioxide into the atmosphere, and if grasses replace that forest growth, they will never be able to store the same amount of carbon as the removed trees did. Ironically, this would be releasing large amounts of carbon in the name of producing electricity that is carbon neutral.

Grasses’ ability to thrive in infertile areas makes it more realistic to conclude that unless market conditions change dramatically, grasses will fill marginal farmland before farmers clear-cut forests to make room for grasses. Switchgrass, one of the main grasses used in biomass electricity production, is a fast-growing and hearty grass that thrives in many different soil types and climates, including marginally productive lands like those with steep slopes and acidic soils.

Given current market conditions, it is doubtful that grasses will displace food crops and forestland enough to have significant negative environmental impacts.

**SOIL, FERTILIZER, AND INPUTS TO GROWTH**

Switchgrass, the most common grass used as an electricity-generating feedstock, can take several years to become an established crop because of its 2-4 year seed dormancy. Farmers must weed and fertilize grass plots until the grass takes root. These added costs make it less appealing for farmers to grow switchgrass in place of row crops or forest land. Once it is established, switchgrass is low maintenance and produces large yields compared to many annual crops.

Switchgrass requires less nitrogen fertilizer than corn and other row crops, and replacing those crops with switchgrass would result in a net decrease of nutrient runoff. This practice will only reduce net fertilizer use if the existing row crop is replaced. If grasses are grown in addition to existing row crops, then it is reasonable to conclude that net fertilizer usage will actually increase proportionate to the acreage of new grass.

Increased fertilization has its own associated environmental impacts. Nitrogen fertilizers create toxic runoff that flows into and damages nearby aquatic systems. These effects are seen most prominently when nitrogen is applied before grasses are well established. Premature fertilization also encourages weed invasion. Some energy crop companies advise against fertilizing switchgrass during its first year of growth, as the grass is not capable of keeping weeds out yet. Farmers can use herbicides to keep spring weeds in check until the warm season grass comes in, but this may increase fertilizer runoff.

Once grasses are well-established, their roots help prevent erosion and fertilize runoff. Toxic runoff could be addressed by sowing multiple species of grasses throughout the growing area. Growing multiple species in one plot is called a polyculture, while plots with one species of grass are known as monocultures. The different types of grasses in a polyculture grow during different seasons (including spring, when fertilizer is first applied) so nutrient uptake is increased as toxic runoff is reduced. But polyculture plots do not yield as much biomass material as monoculture switchgrass plots. Monoculture plots emit more nitrogen oxides than polyculture plots, but they also have larger yields, meaning monoculture plots have sequestered more carbon into the plants and soil.

75 Ibid.
78 Ibid.
AIR

A study conducted by the Vermont Grass Energy Partnership found that burning dried grass pellets releases more nitrogen, sulfur, and chlorine than burning wood.\(^{82}\) Salts within plant material are difficult to combust and aid in the formation of deposits inside combustion chambers. When combusted, these nutrients create toxic emissions.\(^{83}\) To minimize toxic emissions from biomass, biomass materials can be co-fired with coal. Burning biomass materials with coal can reduce greenhouse gas emissions, particularly carbon dioxide and sulfur compounds.\(^{84}\) Leaving grass crops in fields over the winter allows nutrients from the grasses to leach back into the soil and reduces the amount of toxins produced when that grass is combusted. When grass is wintered, however, anywhere from a quarter to a third of the grass crop is unharvestable, which deters farmers from wintering their crops. The cost of wintering grass crops is too steep for the marginal benefit of slightly cleaner air.

CONCLUSIONS ON BIOMASS GRASSES

Grass biomass fuel has, so far, had little environmental impact because it is still used mainly as a supplement to coal. Biomass grasses have benefits including erosion prevention, nutrient absorption, near-carbon neutrality, and use of infertile lands, but grasses are incompatible with existing boiler technology and produce noxious emissions. In addition, the low profit margin of grasses give farmers little incentive to grow grasses in more costly, yet environmentally beneficial, ways. As such, biomass grasses can be considered economically reliable when they are used as a supplemental fuel, but when they are used as the sole fuel source for an electric plant, biomass grasses are often grown in environmentally unreliable ways.

ANIMAL WASTE

Animal farms send large amounts of methane into the atmosphere. Methane gas is the second-most emitted greenhouse gas in the United States after carbon dioxide, but methane can be burned to produce energy and is converted to carbon dioxide in the process. Carbon dioxide is by far the more abundant greenhouse gas in the atmosphere, but methane is 25 times more potent as a greenhouse gas than carbon dioxide.\(^{85}\)

Most methane is emitted from wetlands and forests, but a significant amount comes from landfills and livestock operations.\(^{86}\) Methane qualifies as a biomass fuel under most states’ Renewable Portfolio Standards (RPS).\(^{87}\) North Carolina uses its RPS mandates to address methane emissions that come from its many animal farms. As of 2015, North Carolina requires 0.2 percent of its electricity to be generated from swine waste by 2020 and 900,000 megawatt

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\(^{83}\) Ibid.


\(^{86}\) Ibid.

hours from poultry waste by 2016.88 Covering pig waste areas and burning discharged methane gas decreases greenhouse gas effects while also reducing odors for local residents.89,90

Generating electricity from poultry waste is done in two ways. First, poultry waste can go through an anaerobic digestion process, which produces methane that can be burned to produce electricity.91 Second, poultry litter can be burned directly to produce electricity, much like other solid biomass fuels.92 Poultry litter consists of bird droppings, sawdust and shavings laid down for the birds, and spilled feed. When litter is burned it releases toxic chemicals that are harmful to humans and animals. Anaerobic digestion is a relatively environmentally friendly process, whereas burning poultry litter is not.93

**CONCLUSION ON ANIMAL WASTE**

Burning methane from animal farms reduces greenhouse gas effects and odor for locals. Burning poultry litter, however, may be more harmful than helpful. Overall, burning methane to generate electricity is environmentally reliable, but the environmental costs of burning animal litter may outweigh its economic benefits.

**BIOMASS GENERAL IMPACTS**

**WATER**

The impacts of biomass are varied and dependent upon region and type of biomass used. This section examines the more common impacts that biomass electricity generation has on water.

Anaerobic digestion, the use of bacteria in processing animal waste such as manure, can destroy harmful microorganisms and prevent them from entering water sources.94 Anaerobic digestion leaves an environmentally stable filtrate which provides nitrogen in a more soluble form than is found in untreated manure.95 In this regard, biomass electricity generation is beneficial in its impact on local water quality.

Because biomass power plants use the same cooling methods and technologies as fossil fuel plants, their water needs are comparable. The cooling methods used, whether by coal or biomass plants, strain water systems above and below ground. Overtaxed aquifers are drawn on by power companies, diminishing future underground water supply.96 Surface

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95 Ibid.
water that has been used to cool facilities is returned to streams at dangerously warm temperatures (up to 30°F warmer) and negatively affects local ecosystems.⁹⁷,⁹⁸

Though water needs in biomass facilities are comparable to fossil fuel facilities, biomass material itself requires large volumes of water to grow. A University of California study shows that switchgrass and miscanthus (a genetically engineered high-yield grass) produce the greatest yield when a constant supply of water is available, which can be provided through precipitation or irrigation.⁹⁹ Miscanthus uses more water per acre than corn, so increasing the scale of miscanthus growth would greatly increase water usage, potentially reducing stream flows during critical times for aquatic organisms as farmers irrigate their crops.¹⁰⁰

Even in areas with sufficient water, potential exists for damage from tilling and nutrient runoff.¹⁰¹ Similar problems occur in forested areas where logging operations and the removal of biomass material can make the ground more susceptible to erosion.¹⁰² As great quantities of erodible materials reach waterways, they pollute and clog river systems, threatening fish and other aquatic life.¹⁰³

Biomass’ water impacts are similar to those of traditional energy sources. But since biomass requires water to grow, it impacts water in ways distinct from other energy sources. The negative impacts on water vary in severity depending on location and water availability, but, they reduce biomass’ overall environmental reliability.

REGULATORY FAVORITISM

Despite emitting more carbon per unit of power produced than fossil fuels, biomass electricity plants are not held to the same emissions standards as their fossil fuel counterparts. Fossil fuel electricity plants are heavily monitored and controlled by federal regulators to ensure minimal environmental impacts, but biomass facilities are not held to the same standards.

When fossil fuel plants emit 100 tons or more per year of pollutants specified in the Clean Air Act (such as carbon dioxide), federal regulation requires facilities to obtain a Prevention of Significant Deterioration (PSD) permit from the Environmental Protection Agency.¹⁰⁴ These permits require companies to use emission-reducing technology and air impact evaluations to reduce their emissions. Biomass facilities, compared to fossil fuel facilities, are not required to

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obtain PSD permits until they have emitted two and a half times more of the specified pollutants. Unlike fossil fuel facilities, most biomass facilities do not face restrictions regarding hazardous air pollutants such as hydrochloric acid, dioxins, carcinogens like benzene and formaldehyde, or heavy metals like arsenic, lead, and cadmium.

The EPA allows biomass facilities flexibility to use what is considered burnable “waste” as fuel. Biomass plants burn tires, plastics, and other wastes with little regulatory accountability. To make matters worse, as long as biomass facilities are not issued PSD permits, they are not legally required to use the best available technology to help reduce emissions, resulting in dangerous emissions when garbage is burned.

Energy policy favors the growth of green energy in the United States, but there is a double standard when it comes to biomass. Since biomass facilities are lightly regulated but highly subsidized, they have little incentive to produce clean electricity and reduce emissions. Policy leniency undermines the purpose of promoting cleaner energy production because biomass companies do not have to be as clean as fossil fuel companies. If the EPA’s purpose is to reduce pollution, it is illogical for the EPA to hold biomass to lower standards than other energy sources.

VERDICT ON ENVIRONMENTAL RELIABILITY

Because biomass materials are so different, their environmental impacts vary greatly. Government mandates and regulations encourage companies to harvest biomass in environmentally detrimental ways. In small-scale scenarios, biomass energy can be an efficient use of waste resources. But as the biomass industry grows, its impacts are more harmful to the environment than they are helpful. Government incentives influence harvesting forests in unsustainable ways, which increases carbon emissions by decreasing carbon stores. Additionally, biomass facilities are encouraged by subsidies to burn biomass material, but they are not held to the same pollution standards as their fossil fuel counterparts. Biomass can be environmentally reliable when waste biomass is used, but overall, government-supported biomass on a grid-scale is environmentally unreliable.

PHYSICAL RELIABILITY

An electricity source is physically reliable when it is able to consistently meet electricity demands without disruptions in energy supply. According to this definition, biomass is physically reliable and can fulfill the role of a baseload power resource, but it is inefficient and its costs outweigh its physical benefits.

BASELOAD POWER

Biomass holds an advantage over the renewable energy sources of wind and solar because its supply can be controlled. Baseload power sources are power plants that operate around the clock, providing power that can be relied upon at all times. Wind and solar cannot provide baseload power because of their intermittency.

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106 Ibid. p. 38-40.
107 Ibid. p. 57-59.
108 Ibid. p. 8.
CASE STUDY: COMBINED HEAT AND POWER HOSPITAL SYSTEMS

Biomass can be used to make small systems independent of the electric grid. The Gundersen Health System hospital campus in La Crosse County, Wisconsin, operates on a combined heat and power system, fueled by landfill-produced methane gas and wood waste from nearby lumber operations. Combined heat and power systems burn fuel to make steam, which turns an electricity producing turbine. The steam then circulates through pipes in the hospital to provide heat. In the fall of 2014, the Wisconsin hospital generated more electricity than it consumed and was able to profit from selling excess electricity back to the electric company.

Vermont’s North County Hospital has saved approximately $102,000 per year in electrical costs and $128,000 per year in heating fuel costs through the use of a combined heat and power system. The hospital was able to plan and install its system using grants from the Vermont Economic Development Authority and the federal government. Its combined heat and power system is fueled by wood chips delivered from a lumber company less than a mile away.

Having an onsite boiler allows these hospitals to operate independently of local power grids. In the case of a serious power outage, the hospitals are self-reliant and can continue to treat patients. Biomass systems allow hospitals to store enough fuel to operate for several days, allowing them to remain in operation in the case of extended emergencies.

LOW ENERGY DENSITY OF BIOMASS

Despite its benefits in small grid applications, there are physical characteristics of biomass that make it an inefficient energy source. Biomass materials have a low energy density, meaning there is less energy stored in biomass materials per unit of weight compared to other materials like coal or natural gas. The low energy density of biomass is due largely to the high water content of biological materials. Biomass materials also have low bulk density, meaning they have less weight per unit volume.

FIGURE 1. EQUIVALENT ENERGY CONTENT BY VOLUME OF UNPROCESSED MATERIALS.
The combined effect of low bulk density and low energy density means that biomass materials take up more space and weigh more per unit of energy than other fuel sources.\textsuperscript{117} Figure 1 shows that to store the same amount of energy, both wood and straw require significantly more space than coal.

Green woody biomass derives about half of its weight from water.\textsuperscript{118} Other biomass materials can be composed of up to 70 percent water by weight.\textsuperscript{119} The water within biomass cannot be burned for energy and weighs the material down, increasing transportation costs. Unless it is first processed to reduce its water content, biomass material usually cannot be profitably transported more than 50-100 miles by truck.\textsuperscript{120} Inefficiency of transportation limits the range of service for a biomass operation unless material can be treated on site before being transported or stored.

Biomass materials can be treated in several ways to increase their bulk and energy density. Material can be densified by removing water, which makes it more efficient to transport.\textsuperscript{121} The material can also be compressed into shapes like pellets and cubes to increase transportation efficiency.\textsuperscript{122} Large-scale operations can produce densified biomass at low cost, but densifying costs are prohibitive for small-scale operations (any facility producing less than 45,000 tons per year) due to the capital investment required.\textsuperscript{123}

Torrefaction is a newer method of densifying wood. By heating biomass in an oxygen-deprived environment, torrefaction increases the energy density of biomass by removing water and other compounds that decrease burning efficiency.\textsuperscript{124} Torrefied wood that is pressed into pellets becomes more energy dense than traditional biomass

\textsuperscript{117} Ibid.
pellets. Figure 2 shows that torrefied biomass has a comparable energy density to coal while having similar ash and sulfur content to wood.

**FIGURE 2. WOOD PELLETS VS. TORREFIED WOOD VS. COAL**

<table>
<thead>
<tr>
<th></th>
<th>Caloric Value (BTU/lb)</th>
<th>Bulk Density (lbs/ft³)</th>
<th>Energy Density (MMBTU/ft³)</th>
<th>Energy to Grind (kwe/MWth)</th>
<th>Ash Content (%)</th>
<th>Sulfur Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Pellets</td>
<td>8,000-8,500</td>
<td>31-41</td>
<td>0.25-0.35</td>
<td>12-25</td>
<td>&gt;1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Torrefied Pellets</td>
<td>10,000-11,000</td>
<td>40-45</td>
<td>0.4-0.5</td>
<td>1</td>
<td>&gt;1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Coal</td>
<td>8,000-10,000</td>
<td>56-62</td>
<td>0.45-0.68</td>
<td>3</td>
<td>9%</td>
<td>4-10%</td>
</tr>
</tbody>
</table>

Torrefaction requires more research and development before widespread application. Little research has been done on its wide scale applicability, but torrefaction may be an advancement that makes biomass a more physically reliable renewable energy in the future.

**ENERGY CROPS AND LAND USE**

Energy crops can enhance the long-term health of existing agricultural systems if they are properly used. On existing farms they can serve as buffer strips or wind breaks, and the roots of these energy crops can reduce erosion and increase organic content on overused soil.

Though energy crops have beneficial impacts on farmland, the amount of land necessary to produce utility-scale volumes of feedstock is enormous. Researchers at Iowa State University estimate that 1500 acres of switchgrass are required per year to produce one megawatt of electricity. For a biomass facility to reach the same capacity as an average (600 megawatt) coal power plant, this would require 900,000 acres, or approximately 1400 square miles, of land completely dedicated to switchgrass growth.

A World Resources Institute report concluded that increasing the use of energy crops would be a direct threat to the availability and sustainability of future food supply. Rising food costs would impact low-income citizens most. The report also noted that supplying 20 percent of the world’s energy demands with biomass by 2050 would require a doubling of the world’s production of all plant materials. As biomass energy is pursued on a larger scale, it becomes less physically reliable as food prices increase and forests are removed to make room for energy crops.

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129 To get these numbers, we multiplied 1500 acres by 600 megawatts, then converted acres to square miles.
UNADAPTED TECHNOLOGY FOR BURNING GRASS

Burning grasses presents several problems for biomass facilities. First, as mentioned before, biomass material contains large amounts of water which reduces the net amount of energy that power plants capture from burning grass and other materials. Even though grasses can be dried and pelletized, burning grass also creates salt residues inside combustion chambers known as “clinkers” that are difficult to remove and can decrease burning efficiency.

Most biomass boilers are designed to burn wood rather than grass, and are ill-equipped to handle residue buildups. The ash and particulate emissions from grasses also require specialized equipment and monitoring processes that conventional biomass facilities are not equipped with. Co-firing grass pellets with coal or wood at low percentages (usually less than 20 percent grass by mass) reduces deposits that coat boiler walls. Co-firing effectively uses facilities that are already in place and expands the market for grass fuels. The technology and costs of exclusively burning grass for electricity are high, but the costs, both capital and environmental, of using it as a supplemental fuel are low.

METHANE

Collecting methane from waste materials is widely considered a sustainable method of generating electricity. Waste is readily and predictably available, and biogas operations help lower the effects and costs of waste disposal. The operations also lengthen the existence of landfills and delay additional landfill needs. Animal waste can be used as fertilizer, but its only other economic use is producing methane. After manure has been processed for electricity generation, its value as fertilizer is often increased.

VERDICT ON PHYSICAL RELIABILITY

Despite its low energy density, biomass can predictably and consistently meet electricity demands, making it a physically reliable electricity source. The larger the biomass industry becomes, however, the more physical barriers it encounters, including transportation costs, excessive land usage, and facilities that are ill-equipped to burn biomass materials. Biomass can provide baseload power, but as the biomass industry grows in response to government support its physical benefits will likely be outweighed by the high costs of land use and transportation.

CONCLUSION

Policymakers have mandated and subsidized the use of biomass, but these policies have made biomass unreliable as an electricity source. Dependence on government assistance and environmental damage make biomass an unreliable electricity source.

Biomass will, and does, exist in the electricity market without subsidies or mandates. Waste can be used to generate both a profit and electricity. Energy crops, however, are not an economical biomass fuel and exist on the scale they do because of subsidies and mandates. Without these policies, the biomass industry would be unable to sustain its current growth.

Current biomass policies have caused environmental degradation, such as chopping and burning whole trees for electricity production. Burning trees releases sequestered carbon that will not be re-sequestered for several decades. Fuel crops require water, land, and fertilizers, which have environmental impacts. In addition, burning biomass produces more greenhouse gases and pollutants per unit of energy produced than traditional coal.

Although the purpose of using biomass as an alternative to fossil fuels is to be environmentally friendly, biomass is more subsidized, but its emissions are less regulated than fossil fuel emissions. Biomass facilities have little incentive to produce clean electricity and reduce emissions to receive subsidies. Considering that the goal of renewable electricity is to provide a cleaner electricity source, regulatory leniency is illogical and environmentally damaging.

In comparison to solid biomass fuels, bio-produced methane is relatively energy dense and environmentally favorable. Biomethane functions similarly to natural gas, so it can be used in many of the same energy-producing applications. Some energy producers are capturing methane from animal waste and garbage for small-scale electricity production. Burning methane also has a net environmental benefit. Methane is a more potent greenhouse gas than carbon dioxide. Collecting methane from animal waste and landfills and converting it to carbon dioxide through combustion is more favorable than releasing the methane into the atmosphere. Using biomethane may serve as a reliable form of energy production as long as it does not rely on government assistance.

Biomass can reliably provide baseload power, unlike other renewable energy sources like wind and solar, but the main drawback of biomass fuel is its inefficiency. Although biomass can be used to produce electricity to meet consumer demand, biomass contains large amounts of water per unit of weight, which means it does not contain as much energy potential as fossil fuels. Additionally, transportation costs for biomass are higher per unit of energy than fossil fuels because of its low energy density.

Biomass-generated electricity is inefficient and environmentally degrading in many cases. Mandates and subsidies that promote biomass are a misallocation of taxpayer dollars and cause increased environmental harm. Whether biomass-generated electricity will be reliable is a question best answered by markets, not government mandates or subsidies.