Forests Are Not Fuel

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Synopsis

As the world seeks solutions to climate change, and in light of the 2015 Paris Climate Agreement, attempts to decarbonize the electric power sector by 2050, a primitive form of energy generation has reemerged as a possible environmentally-friendly solution to fossil fuels. Bioenergy, defined here as the process of turning woody plant based matter into a combustible fuel used in the electric power generation sector, is perhaps the oldest source of energy that humans have known. While bioenergy has been branded as an environmentally-sound solution to the problems of power sector decarbonization and climate change, there are a number of issues with an increased global dependence on bioenergy as a replacement for fossil fuels.

We provide current trends in bioenergy in the United States and globally, with a focus on the European Union. We detail why there has been an increased interest and demand for bioenergy as a substitute for fossil fuels in the electricity sector. Then, we examine the climate impacts of burning forests as fuel. Finally, we document the troubling ecological impacts of increased bioenergy production, alongside some of the human community impacts that arise as a result of bioenergy harvesting, logging, processing, and shipping.

Keywords: biomass, bioenergy, climate change, environmental justice, renewable energy, wood pellets, carbon emissions, logging, carbon debt

Abstract

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This chapter details the current trends in bioenergy in the United States and globally, with a focus on the European Union. We detail why there has been an increased interest and demand for bioenergy as a substitute for fossil fuels in the electricity sector. Then, we examine the climate impacts of burning forests as fuel. Finally, we document the troubling ecological impacts of increased bioenergy production, alongside some of the troubling human community impacts that arise as a result of bioenergy harvesting, logging, processing, and shipping.

Introduction

As the world seeks solutions to climate change, and in light of the 2015 Paris Climate Agreement, attempts to decarbonize the electric power sector by 2050, a primitive form of energy generation has reemerged as a possible environmentally-friendly solution to fossil fuels. Bioenergy, defined here as the process of turning woody plant based matter into a combustible fuel used in the electric power generation sector, is perhaps the oldest source of energy that humans have known. Bioenergy is an energy-lite resource (8,262 Btu/lbs), compared to fossil fuels such as coal (9,507 Btu/lbs) and natural gas (19,000 Btu/lbs), meaning that it requires more mass to generate an equivalent amount of electricity ("U.S. Energy Information Administration," 2019).

Humans have been turning trees and other woody material into burnable fuels to heat our homes and cook our food for thousands of years. Like all combustion-based technologies, wood-based bioenergy (referred to alternatively as bioenergy, biomass, or wood pellets herein) has direct and potentially significant impacts to surrounding air quality through the release of local air pollutants, as well as carbon dioxide as a result of the combustion process. In addition, there are a number of local hydrological, ecological, and biodiversity impacts to ecosystems from which bioenergy is harvested. While bioenergy has been branded as an environmentally-sound solution to the problems of electric power sector decarbonization and climate change, there are a number of issues with an increased global dependence on bioenergy as a replacement for fossil fuels (Drax Group PLC, 2019).

We detail the current trends in bioenergy development in the United States and globally, with a focus on the European Union (EU), and why there has been an increased interest and demand for bioenergy as a substitute for fossil fuels in the electricity sector. Then, we examine the climate impacts of burning forests as fuel and why this will not help us turn back the rising threat of climate change nor avoid the need to invest in truly renewable energy solutions. We further discuss the troubling ecological impacts of increased bioenergy production, alongside some of the troubling human community impacts that arise as a result of bioenergy harvesting, logging, processing, and shipping. Finally, we highlight a number of environmental justice impacts, primarily within the southeastern United States, as a result of an increasing reliance of bioenergy.

Current Trends in Bioenergy Production and Demand: U.S and Globally

In the developed world, prior to the emergence of bioenergy as a possible substitute for fossil fuels in the electric power generation sector, bioenergy was and is still widely used in the residential home heating sector. According to the U.S. Energy Information Administration's (EIA) 2015 residential energy survey, wood burning stoves are the primary source of heating for 3.5 million U.S. households (roughly 3 percent of all households) and the secondary source of heating for 9.2 million households("Residential Energy Consumption Survey (RECS) - Data," 2019) . In the European Union, an estimated 40 percent of all wood consumed in 2015 was in the residential heating sector, representing the largest portion of bioenergy consumption(Birdlife et al., 2017). However, over the last 15 years, there has been a marked increase in the use of bioenergy in the non-residential sector, in order to produce electricity and thermal energy for commercial and industrial processes. According to the EIA, biomass electricity generation increased 18 percent between 2005 and 2015, with biomass accounting for almost one percent of all U.S. electricity generation. In 2018, it accounted for around 0.5 percent of all U.S. electricity generation ("U.S. Energy Information Administration," 2019) (Figure 1).

While in the U.S., the role of bioenergy in the electric power sector remains small, it has ballooned in the European Union (EU). Over 44 percent of renewable energy in the EU comes from bioenergy or waste wood, with bioenergy accounting for 7.5 percent of EU-wide gross final energy consumption in 2016 (Brack et al., 2018). EU demand for bioenergy is substantial and growing, and while European nations are able to produce a significant amount of bioenergy, it is not enough to meet regional demand.

Much of this growth in European demand for bioenergy is being met by increasing global imports. In 2016, it is estimated that 40 percent of overall wood pellet consumption in the EU was from imports.(Brack et al., 2018) In the U.S., bioenergy export production and capacity has increased rapidly over the last few years. In 2012, the United States exported 1.9 million metric tonnes of densified biomass fuel. By 2018, that number had jumped to 6.1 million metric tonnes, more than a 300 percent increase in just six years(U.S. Census Bureau, 2019) (Figure 2).

The southeastern United States has been the largest source of this expanded global demand for biomass fuels, and each pellet-producing mill has a 120km sourcing radius (Figure 3). Since 2012, the US Southeast has been responsible for over 98% of wood pellet exports. This demand eclipses pre-existing demand for other forest products, primarily pulpwood, from the region. From 2012 to 2015, pulpwood generation in the US Southeast decreased by 6.8 million metric tonnes, about 4.5%; in the same time period, the equivalent amount of wood pellet production increased by 5.6 million metric tonnes, or 249% (Table 1). Although the demand for bioenergy still represents a relatively small portion of the pulpwood market in the U.S., it is growing steadily and may present supply problems in the near future for non-wood pellet US forest products companies.

Policy Drivers of Bioenergy Demand

Much of the increased demand for densified bioenergy fuel results from recent changes in international and national policies. We identify two potential reasons for the increased reliance on bioenergy in the electric power sector around the world. First, the rise in global demand for bioenergy has been spurred by a number of national and international climate and energy policies aimed at encouraging a low-carbon transition and tackling climate change. Second, some countries, such as the United Kingdom subsidize bioenergy use as an alternative to fossil fuels. And finally, subsidizing existing coal-fired powered plants to burn bioenergy is a political win because transforming coal-fired power plants to co-firing plants is a fairly easy process that extends the useful life of an otherwise stranded generation asset.

National and International Climate & Energy Drivers

First, worldwide climate treaties have created perverse incentives to rely on bioenergy to meet climate goals. International climate treaties like the 1997 Kyoto Protocol establish that carbon emissions from direct combustion (excluding harvest, production and transportation of woody material) are counted under the country of origin's Land Use / Land Use Change (LULUC) emissions category (Grubb et al., 1997). However, the United States never ratified the Kyoto Protocol, meaning that bioenergy exported from the U.S. to other countries is not subject to the accounting procedures demanded by the Kyoto Protocol (Hovi et al., 2003). In practice, this means that imports from North America to countries that are parties to the Kyoto Protocol, treaty countries, such as the European Union, are considered "carbon neutral" by the Kyoto Protocol without accounting for the carbon emissions from the combustion process anywhere within the accounting system. This accounting loophole has created a perverse incentive for treaty countries to import bioenergy from non-treaty countries and only account for a fraction of the associated carbon emissions. In addition, the European Union, which established a renewable energy target of 20 percent by 2020 in 2009 and increased it to 32 percent by 2030, classifies most woody bioenergy as carbon neutral (Klessmann et al., 2011).

Fuel Switching and Existing Infrastructure

With large and increasing renewable energy targets, countries subject to those targets must consider the cost and extent of switching from coal and other fossil fuels to renewable energies. With many operational coal power plants being potentially phased out in favor of renewable and low carbon energy production options, there has been continued interest in repurposing coal power plants through either co-firing biomass with coal, or conversion to complete biomass combustion (Demirbaş, 2003; Hughes, 2000). In contrast to other renewable energies, biomass presents an opportunity to reuse or improve existing infrastructure instead of needing to build new plants, windmills, or solar panel fields. As a result, many countries party to renewable energy goals, like the Kyoto Protocol, have promoted the use of bioenergy through subsidies and credits.

National Subsidies and Support for Bioenergy

In planning for climate change mitigation, many countries created pathways that rely heavily on the adoption of bioenergy as a pathway to transition away from fossil fuels. As a result, several countries have created substantial subsidy programs to encourage the adoption of co-firing biomass with coal, or transitioning coal-powered plants entirely to wood pellet fuel. In 2012, twelve EU member countries contributed 8.3 billion Euros (9.4 billion USD) in subsidies to biomass usage (Alberici et al., 2014) (Figure 3).

In the United Kingdom (UK), the largest importer of US wood pellets, renewable energy from biomass and other sources is subsidized through the Renewable Obligation Certificates system, where the government rewards companies with credits for producing renewable energy, which can then be sold to energy delivery companies. The UK’s largest power producer, Drax, reported 468 million pounds in profits from Renewable Obligation Certificates, equivalent to just over 593 million USD in 2018(Drax Group PLC, 2019).

As the use and subsidization of bioenergy rises rapidly in the international economy, many scientists have expressed worry about the longevity and feasibility of bioenergy as a widely adopted renewable technology(Duffy et al., 2016; Editorial Board, 2016; Söderberg and Eckerberg, 2013). There are potentially major impacts to forest biodiversity, resilience, ecosystem services, and carbon balance, as well as impacts to air and water quality, equity, and quality of life in nearby human communities.

Climate Impacts of Forests as Fuel

The extraction of timber for wood pellet production creates direct and indirect greenhouse gas (GHG) emissions into the atmosphere. GHG emissions come not only from pellet burning, but also from the production and transportation processes as well. Furthermore, forest operations can impact soils, altering physical, biological, and chemical properties due to the use of agrochemicals, heavy machinery, and the correlated requirements of lubricants and fuels (Cambi et al., 2015). A suitable way to evaluate the environmental performance and climate impact of the wood pellet industry in terms of pollutant emissions and energy consumptions is through a life cycle assessment (LCA). LCAs assess the extraction and consumption of resources including GHG emissions throughout the entire lifecycle of production extraction and creation (Campbell et al., 2011).

Comparing GWP from Bioenergy to Other Renewable Energies

With many possible GHG emissions from different chemical compounds, it is often necessary to standardize the impact of those chemicals on the global carbon cycle. The Global Warming Potential (GWP), defined by the U.S. Environmental Protection Agency (EPA) as a measure of how much energy the emissions of 1 ton of a greenhouse gas will absorb over a given period of time (commonly 100 years), relative to the emissions of 1 ton of carbon dioxide (CO_2), is one such measure("Understanding Global Warming Potentials," 2017). This potential depends on the radiative efficiency of the gaseous species and its atmospheric lifetime.

A study conducted in British Columbia, Canada found that the GWP for the production of wood pellets and overseas transportation is 723 kg CO_2 e/tonne or 0.15 kg CO_2 e/KWh of wood pellets when using natural gas as fuel, and 532 kg CO_2 e/tonne or 0.11 kg CO_2 e/KWh when using sawdust as fuel in the production process, with an additional 916 kg Co_2e/tonne, or 0.19 CO_2 e/KWh stored in the wood and combusted during electricity generation(Magelli et al., 2009).[4] Together, this means a GWP range of 0.30 - 0.34 kg CO_2e/KWh for wood pellet electricity generation, assuming combustion at 100% efficiency. However, electricity generation from biomass fuel combustion is still only 20-25% efficient (*Biomass Energy: Efficiency, Scale, and Sustainability*, 2009), and so a final, more realistic calculation would be 1.35 - 1.53 kg CO_2e/KWh for wood pellet electricity generation.

On the other hand, similar LCA studies for wind turbines reported GWP values of approximately 0.06 kg of CO_2 e/KWh (Bayindir et al., 2018) and 0.029 kg of CO_2 e/KWh (Tazi et al., 2018). A study made on photovoltaic power systems used in the production of solar energy assets GWP values of 1 kg of CO_2 e/KWh (Frischknecht et al., 2015). In terms of GWP, both photovoltaic power systems (solar) and wind turbines have lower GWP than wood pellets used to generate electricity.

In 2018, the United States exported six million metric tonnes of wood pellets which likely released approximately nine million tonnes of CO_2e into the atmosphere. If industries continue to invest aggressively in bioenergy and the demand increases by 20% (conservative, based on previous years' expansion rates), in the next five years, carbon released into the atmosphere from wood pellet consumption could rise to 22 million metric tonnes of CO_2e per annum, equivalent to an addition 4.7 million vehicles on the road each year.

The Inaccuracies and Assumptions of Carbon Neutrality

Many analyses of wood pellet GHG emissions automatically exclude the carbon stored in the fuel (former trees) itself (Brack et al., 2018; Hoefnagels et al., 2014; Magelli et al., 2009). This is

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[4] Because this paper produced numbers by tonne instead of kilowatts, there is some conversion that needs to take place in order to compare between technologies. We estimate that there are 4,800 KWh per tonne of wood pellets, and divided accordingly.

based on the net-growth theory -- in short, that because forests are continuing to grow in a given region (predominantly the US Southeast), one can assume that the landscape is automatically absorbing new carbon to replace the carbon in wood pellets that will be burned internationally. Although this is both simple and convenient, this net-growth theory fails to account for the lost growth potential of acres harvested for bioenergy. That is, regional acres will continue to grow whether or not bioenergy harvests occur. There is no additionality to replace the carbon lost during bioenergy harvest.

Instead, consider the acres on which the bioenergy harvest occurs. After harvest there will be a "carbon debt" (C Debt) on those acres until they regrow enough to restore the carbon lost during harvest, and exceed the carbon benefits from previous fossil-fuel based power generation (Mitchell et al., 2012; Walker et al., 2010). Estimates of carbon debt vary widely and are based on variables that primarily include the type of harvest (tops and limbs, large residues, or whole trees) and pre-existing land cover (natural or artificial stands). One study indicates that even just removing harvest residues (tops, limbs) from a harvested site can reduce the mitigation potential by 10-40% (Zanchi et al., 2010). Modeling a coal plant conversion to wood pellets in Ontario, Canada revealed that the carbon debt repayment for their source would not occur until a full 91 years after operation if harvesting specifically for bioenergy (Ter-Mikaelian et al., 2015). The oft-termed "Manoment study" reveals a carbon debt repayment period between 20 and 90 years (Walker et al., 2010). Finally, if a natural forest is replaced with a plantation for bioenergy, carbon debt repayment may take 150-200 years (Zanchi et al., 2010).

The Reality of Bioenergy Production In The US

Carbon debt repayment and GHG emission estimates often make assumptions about the source of wood for pellets that may be inaccurate in the lived reality of the wood pellet market. For example, when studies consider only small residues harvested additionally from sites where other forest products are being sourced from, their relative impact is small (Walker et al., 2010; Zanchi et al., 2010). However, in practice, a large portion of harvested materials in the United States for bioenergy production comes from whole trees and large residues. The standard harvest method in the United States, and especially the US Southeast, is clearcutting. The best wood may go to lumber production, but the bulk of it will go to pulpwood production: paper products and wood pellets.

Enviva, the largest US-based wood pellet export company, reports that less than 18% of their input material is from "Sawdust, shavings, residuals from wood manufacturing, or arboricultural sources" ("Track & Trace," 2017). The remaining 82% of input material comes from pine plantations (38%), mixed pine and hardwood forests (40%), and other hardwood forests (5%). Under current conditions, carbon debt repayment is on a timescale much longer than the time currently available to address carbon emissions and prevent the worst impacts of climate change from occurring. Finally, these practices contribute to wide scale impacts on the carbon balance of forests in the US Southeast and nationally.

Ecological Impacts of Forests As Fuel

There are many similarities between traditional forest harvest and forest harvest for bioenergy. As a result, it is necessary to discuss the general impacts of anthropogenic forest disturbance through forest harvest, as well as the additional impacts that demand for bioenergy has brought into natural ecosystems.

Impacts of Harvest on Forest Ecosystems

The United States Leads In Forest Harvest Rates

The US, and predominantly the US Southeast, is the second largest producer of pulp and paper products in the world (Food and Agriculture Organization, 2018). As a result, the US Southeast has one of the highest forest turnover rates in the world, four times higher than the rate of South American rainforests (Hansen et al., 2013). Less than half of the forest stands in the US Southeast are older than 40 years (Oswalt et al., 2014).

Impacts on Carbon Balance of US Forests

Although forests in the United States are considered a net sink, not a net source of carbon, this was not always the case. Widespread logging from the 1700 to 1935 released 42,000 Tg (4.2 Billion Metric Tonnes) of carbon into the atmosphere. From 1935 to 2010, just 15,000 Tg (1.5 Billion Metric Tonnes) had been recovered by US forests (McKinley et al., 2011).

Despite current successes in net growth of US forests, modern forest harvests still significantly reduce the growth rate of the terrestrial carbon sink. A joint study between scientists at nonprofit institutions and the US Forest Service revealed that forest harvest activities account for 85% of the carbon emissions from US forests, more than insects, drought, disease, wind, and conversion combined (Harris et al., 2016).

Impacts on Rare Species

Forest harvest also reduces the frequency of valuable habitat for rare species. The Fish & Wildlife Service found that 56% of all wetland losses in the United States from 2004-2009 were attributable to silvicultural activities (Dahl, 2011). Wetlands and wetland forests in particular are reserves of remarkable biodiversity (Junk et al., 2006; Thiere et al., 2009).

Logging activities can impact biodiversity for decades after a forest harvest occurs. In the Mississippi Alluvial Valley, two species of concern, prothonotary warbler *(Protonotaria citrea*) and Acadian flycatcher (*Empidonax virescens*), were impacted by the opening of gaps in the forest canopy from harvest activities, and differences in species composition between stands were found for up to 35 years after a forest harvest (Heltzel and Leberg, 2006). Historically, logging has been implicated in the decline of several species, including *Pieris virginiensis*, a rare butterfly native to the eastern US (Davis and Cipollini, 2016). Additional logging impacts are documented in the Pacific Northwest region of the US (DellaSala et al., 2015), nationally (Heilman et al., 2002), and across the world (Benkman, 1993; Czech et al., 2000; Mackey et al., 2015).

Impacts on Water Quality In Riparian Forest Systems

During forest harvest, it is often necessary to install temporary or permanent roads, which include temporary or permanent stream crossings for the transport of equipment and logs. Even temporary stream crossings have impacts on temperature, sediment load, and pH(Aust et al., 2011). Even abandoned roads contribute to sediment loads in forest streams (Reid and Dunne, 1984). Although there are voluntary standards ("Best Management Practices") to prevent the worst impacts to water quality during forest harvest operations, compliance is not always 100%, and compliance rates during biomass harvest has been documented as significantly less than compliance during traditional forest harvest (Barrett et al., 2016). In addition to sediment, high nitrate runoff has been documented from clearcut and patchcut forests for three to five years after the harvesting event (Mupepele and Dormann, 2016).

Logging & Salvage Activities Reduce Resilience to Extreme Events

As climate change increases the frequency of extreme events and natural disasters, the desire to engage in "salvage logging" of disturbed ecosystems increases. Often a highly political or economic move, salvage logging could be a significant source of fuel for bioenergy production in the near future (Lindenmayer et al., 2008). However, evidence tends to show that post-disturbance clearcut logging compacts soils, kills seedlings and shrubs associated with forest renewal, increases fine fuels that aid the spread of fire in wildfire prone habitat, and degrades fish and wildlife habitat (Lindenmayer et al., 2008).

Intensive Harvest Practices Harm Soil Structure & Carbon

Nearly 70% of the biosphere's carbon is stored below the ground, in forest soils, around the world (Karsenty et al., 2003). Global soils hold 2400 Petagrams of carbon, about three times the amount of atmospheric carbon currently warming the planet (Paustian et al., 2016). However, forest harvest and especially intensive forest harvest for biomass damages the soil carbon in forests. One study found that over half of the extractable soil carbon was lost in a temperate forest after clear cutting (Lacroix et al., 2016). A meta-analysis showed that biomass harvests reduce soil carbon 15% more than traditional logging, and soils could lose up to 60% of their carbon sink potential after intensive biomass harvest (Achat et al., 2015).

Additional Impacts of Bioenergy Demand on Forest Ecosystems

Bioenergy impacts more acres than solar photovoltaic fields

Converting wood energy in to usable electric or thermal energy is also less efficient than solar photovoltaic generation. A 50MW biomass-only electricity generating station with 55.4% efficiency(5 year average from ("U.S. Energy Information Administration," 2019)) would produce 242,650 MWh per year in usable electric energy under normal operating circumstances in the United States, and use approximately 6,300 acres per year of harvested wood and residues(Phillips, 2016). In contrast, a solar photovoltaic field of equivalent MWh would take up roughly 124 acres. In addition, whereas the solar photovoltaic field has a productive life of 25 years, to produce a comparable amount of energy from forest bioenergy would require annual harvest of thousands of acres each year.

Demand for Unmerchantable Wood

Wood product processing facilities often have strict specifications for accepting incoming wood products. Trunks that are too large, curved, or hollowed can be rejected in favor of better quality of wood. This unmerchantable wood, e.g., curved or hollowed trunks, is accepted and processed by wood pellet plants, and represent a substantial resource for the forest products industry (Hoefnagels et al., 2014). However, these mostly untapped resources also serve as reserves for both carbon and biodiversity (Davis and Cipollini, 2014; Heltzel and Leberg, 2006; Pacific Northwest Research Station, 2003; Rudolphi et al., 2014). Deadwood legacies, in particular -- the type of unmerchantable wood used for bioenergy -- accounts for 20-25% of carbon stores in a forest even 62 years after the initial harvest (Schaedel et al., 2017). Expansion of the forest products industry into previously unharvestable areas means that, across the landscape, forest stand age, and therefore, carbon sequestered, will decrease.

Large increases in bioenergy production could impact food security

The pending impacts of climate change include the potential for food insecurity in light of growing populations, increasing frequency and scale of natural disasters, and changes in water availability (Bohle et al., 1994; Brown and Funk, 2008). In addition to these stressors on arable land, the increasing use of wood pellets for electricity and heat generation represents another market pressure on the availability of land for food. Models demonstrating the possibility of major increases in the use of biomass for electricity generation assume massive increases in efficiency of food production coinciding with subsequent decreases in meat consumption (Strapasson et al., 2017). In the US, if domestic combustion for electricity begins to increase, the U.S. Energy Information Agency estimates an additional 18 percent increase in US forest harvest is required for every 1% added to current energy production (Duffy et al., 2016).

Community Impacts of Forests as Fuel

The environmental and health impacts to the communities in which bioenergy wood pellets are logged, harvested, processed, and shipped is significant. In the US Southeast, where the bioenergy economy has grown substantially over the last decade, there are 35 wood pellet facilities with a total annual capacity of 9 million dry tons per year ("U.S. Energy Information Administration," 2019). Due to the economics of harvesting and transporting whole logs to wood pellet processing facilities, most of the timber harvested to produce wood pellets is sourced within a 120 km radius of a facility, which creates a new and substantial burden on roads within the sourcing radius of the pellet facility (Magelli et al., 2009; NRDC, 2015).

Woody biomass and fossil fuels are often burned on-site at wood pellet processing facilities in order to generate thermal energy to dry and process the pellets, which causes an increase in noise and ambient air pollutants such as volatile organic compounds (VOCs) in the immediate vicinity of the wood pellet plant (Anderson and Powell, 2018). The 21 US wood pellet mills exporting to Europe emit a total of 14,500 tonnes of air pollutants per year, including particulate matter, nitrogen oxides, carbon monoxide, and organic compounds. These plants also release 2.8 million tonnes of GHG emissions annually (Anderson and Powell, 2018).

Wood pellet processing tends to have disproportionate impacts on the communities in which pellet facilities and ports are located. According to the National Association for the Advancement of Colored People (NAACP), African-Americans who live within close proximity to a biomass power plant are more likely than any other racial group in the United States to suffer from increased exposure to smog, asbestos, sulfur dioxide, and other air pollutants (Wilson et al., 2011). Finally, there may be other sources of air and water pollution located in communities that have wood pellet facilities, such as meat and poultry farms, industrial and chemical manufacturing, and rail yards and other transportation infrastructure. For example, one county in North Carolina with a large wood pellet processing plant is also home to a freight train station, natural gas pipeline, chicken processing facility, and natural-gas fired power plant, all sources of local and global air pollutants (Koester and Davis, 2018).

"Environmental justice" was a term that originated in the 1980s and has its roots in the social-environmental justice struggles in the southeastern U.S. The famous 1982 PCB contamination case of Warren County, North Carolina, a community that was 84 percent black with per capita incomes 25 percent below the state median, represents a quintessential example of environmental justice. This case led many poor people of color to demand that their communities not become dumping grounds for toxic waste and harmful industrial and chemical manufacturing (McGurty, 2007). The communities in which wood pellet production facilities are located also tend to be designated environmental justice communities. One study found that poor (above the state median poverty level) communities of color (over 25% percent nonwhite population) in the US Southeast are 50 percent more likely to have a wood pellet facility sited in their county than wealthier, majority white counties(Koester and Davis, 2018). This trend illustrates the potential environmental justice concerns at play with the expansion of the bioenergy economy in the United States and the increasing global demand for wood pellets.

One recent example illustrates the community and environmental justice concerns of the growing bioenergy industry in the US Southeast. In Hamlet, North Carolina, Enviva, the world's largest producer of bioenergy wood pellets, opened a 480,000 tonne-per-year capacity bioenergy processing facility. Hamlet, NC is in the 70th to 90th percentile for Superfund-site proximity, traffixty, ozone, PM 2.5, air toxics and cancer risk(US Environmental Protection Agency, 2014). The median poverty level in Hamlet, NC is 27.3 percent, 7 percentage-points higher than the state overall ("Census of Housing - Housing Characteristics In The U.S. - Tables," n.d.). The nonwhite population of the Richmond County is 37.5 percent, roughly 16 percentage points higher than the state average ("Census of Housing - Housing Characteristics In The U.S. - Tables," n.d.). In 2019, Enviva was granted an air quality permit from the state's Division of Air Quality to increase annual production by 16 percent to 570,000 tonnes of dry pellets annually, and then was subsequently challenged in court by three environmental groups, and agreed to install additional air pollution controls to prevent further harm to the overburdened community (Stone, 2019).

Conclusions

Although bioenergy is a "renewable" energy source, it comes with significant costs and impacts to the global climate situations, as well as regional and local ecological and human community impacts. Bioenergy may have a place in the world's current energy portfolio, however, it should be limited and phased out as quickly as possible. The lifespan, footprint, and climate impacts of other energies are much more attractive than bioenergy as a renewable fuel source.

Figures, Tables, and Captions

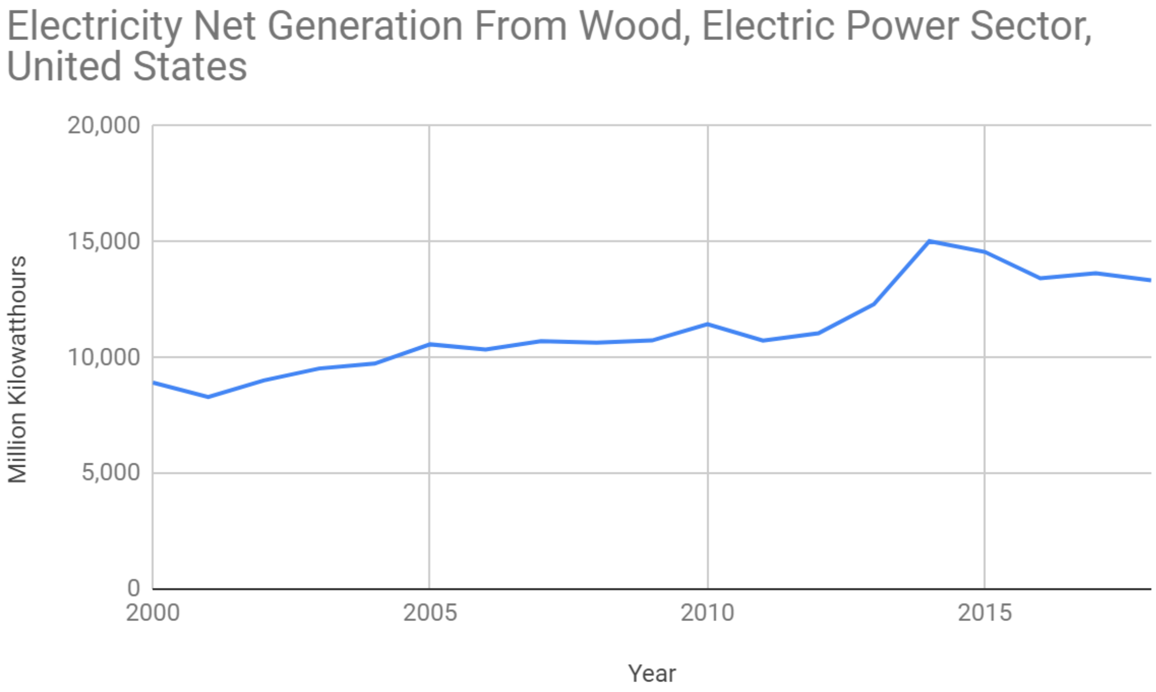

Figure 1. Electricity (million kilowatthours) generated from wood, 2000-2018, in the United States.

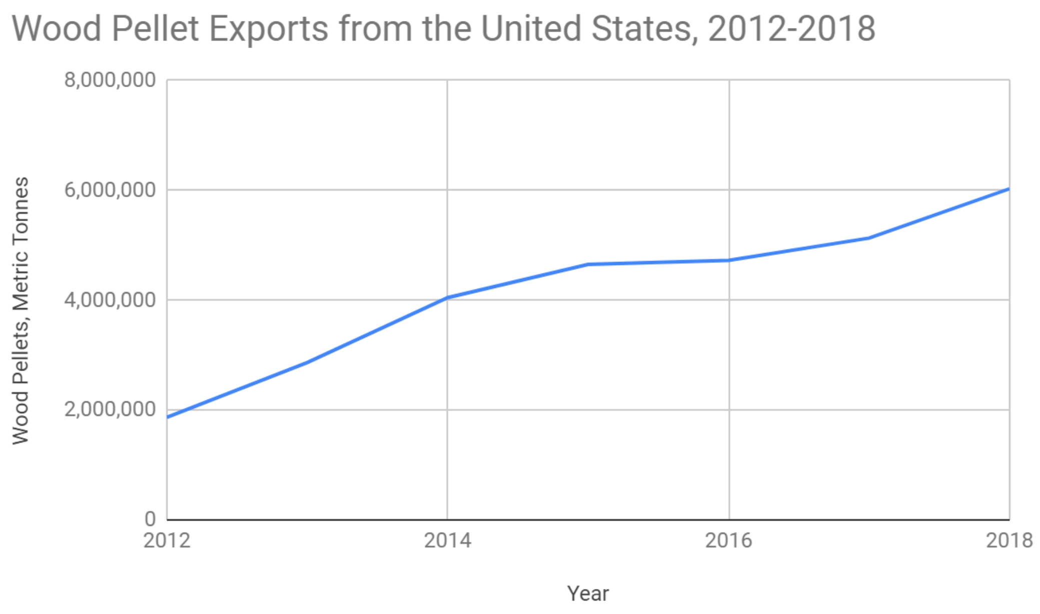

Figure 2. Wood pellet exports from the United States, 2012-2018. Exports tripled in just six years, with nearly all wood pellets (> 98%) coming from the US Southeast.

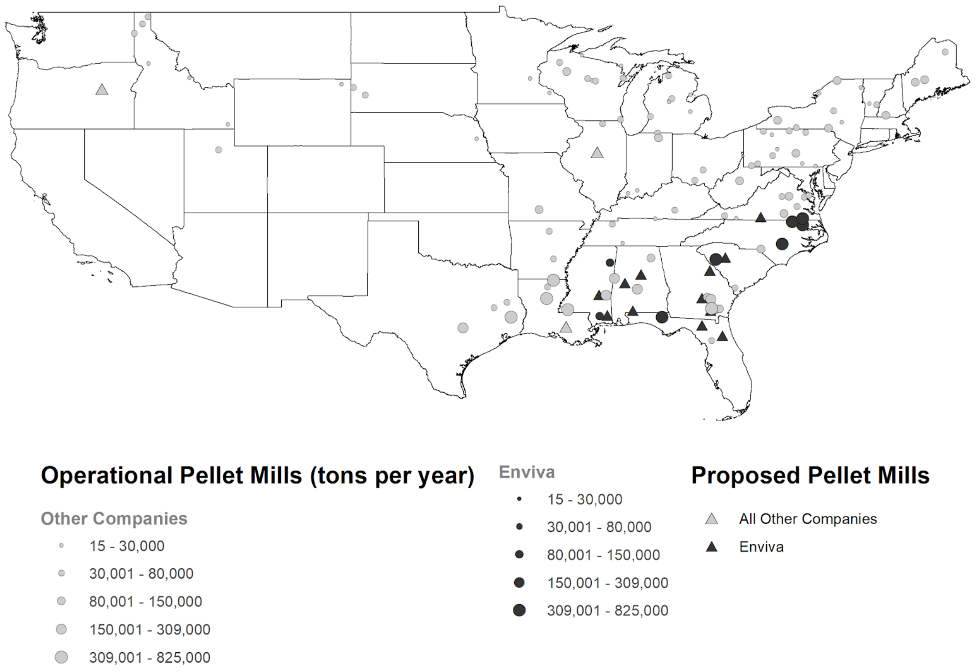

Figure 3. The locations and operating capacities of current pellet production facilities in the United States.

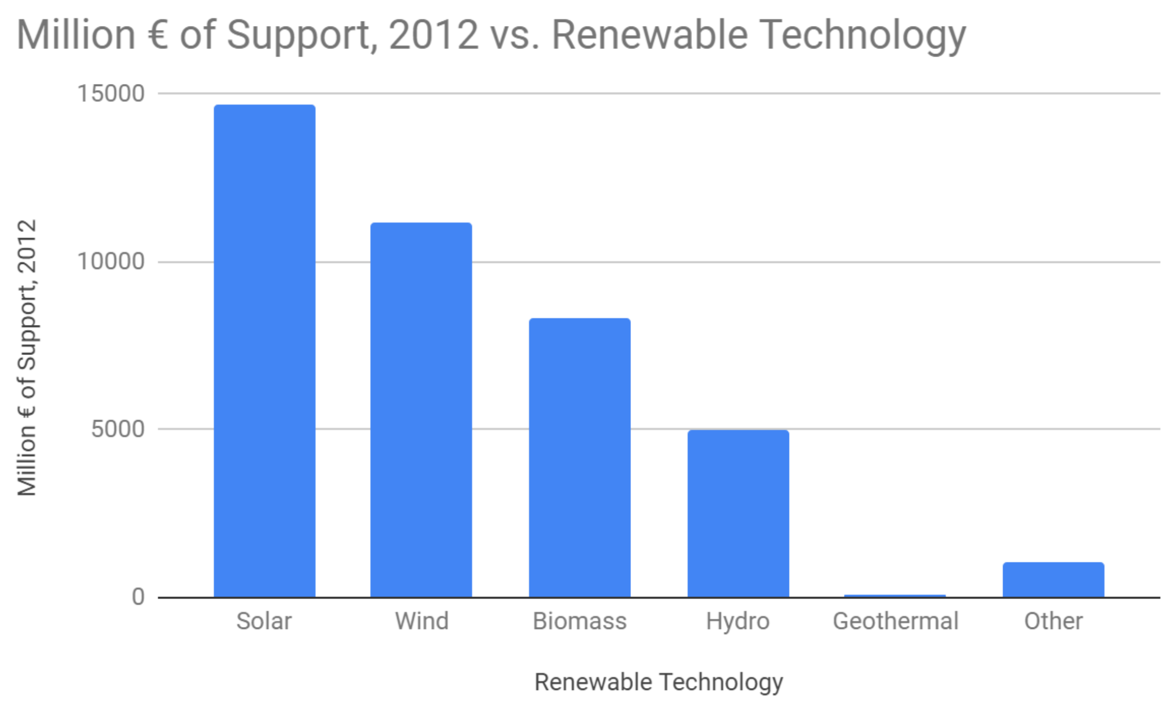

Figure 4. Financial support from EU member countries to renewable technologies, 2012. Data from (Alberici et al., 2014).

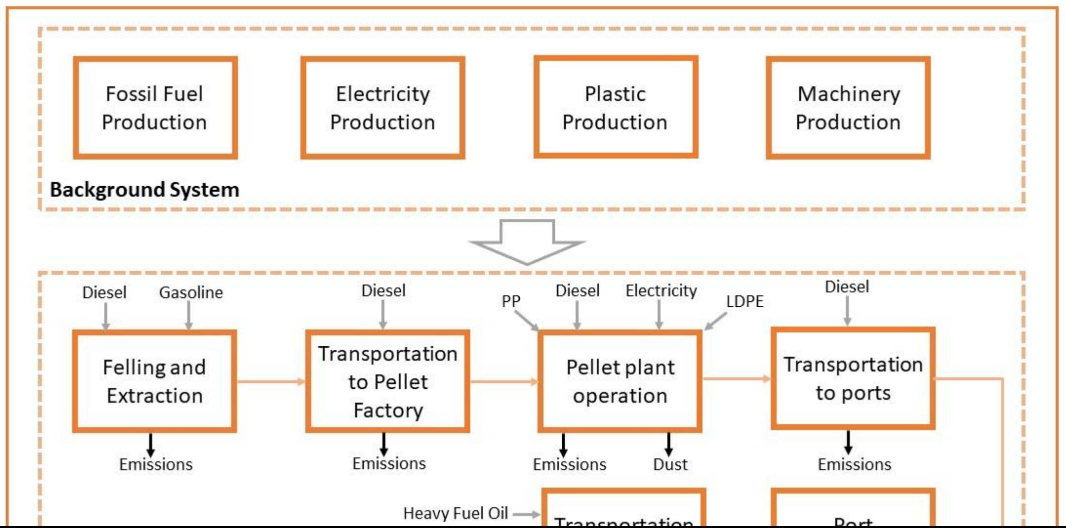

Figure 5. A model Life Cycle Analysis for wood pellet production. It displays the system boundaries, identifying the different processing stages involved in the LCA for wood pellet production. Additionally, it includes the types of energy used and the emissions associated with the production and transportation.

Table 1. Pulpwood and Wood Pellet Production, 2012-2015, US Southeast.
Pulpwood green tons retrieved from (Gray et al., 2016) and previous years of reports, converted to metric tonnes. Wood pellet dry tons retrieved from (U.S. Census Bureau, 2019) and converted to green metric tonnes, assuming a standard 50% water content.

Year	Pulpwood, Green Tonnes	Wood Pellets, Green Tonnes
2012	153,591,595	3,730,472
2013	151,816,980	5,711,590
2014	149,411,769	7,981,178
2015	146,740,931	9,289,367
% Change	4.46%	249.01%
Total Change	-6,850,664	5,558,896

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