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Effects of Increased Biomass Power in the South on Forest Resources, 2001–2015

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Cover photos are biomass fuel in yards at a biomass power plant.

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Abstract

This research analyzed two datasets to determine the effects of increased installations of biomass power plants on forest resources with a specific focus on the South, the region in the United States that experienced the largest growth in biomass power capacity using wood solids between 2001 and 2015. Using data from the U.S. Energy Information Administration and the U.S. Department of Agriculture Forest Service, effects on timber harvest and residue production and utilization relative to the increased need for wood fiber from new biomass power plants were assessed. The study found a negative correlation between installed biomass power capacity and total forest removals ($r_s = -.452$, $p = .006$) and mill residues produced ($r_s = -.452$, $p = .260$) over the 15-year period. Timber harvest and residue figures across the South were flat prior to the Great Recession in 2008 with modest (19-percent) growth during the latter half of the study period. In contrast, biomass power experienced 186-percent growth from 2001 to 2015, the majority of which occurred after the Great Recession. Using a case study in Virginia, the State with the largest increase in installed biomass power capacity, it was found that newly installed biomass power plants were using exclusively waste wood, such as logging residues, which are not directly captured in Timber Product Output data. Political, ecological, and climatic considerations of biomass energy are also discussed, as well as further research needs on biomass utilization for power production.

Keywords: Biomass, biomass power, forest harvest, Timber Products Output, wood utilization.

INTRODUCTION

Prior to the widespread availability of fossil fuels brought on by the Industrial and Technological Revolutions, biomass was the dominant source of energy (Fernandes and others 2007). During the 18th and 19th centuries, widespread practices of clearing forests for conversion to other land uses supplied large amounts of fuelwood in North America, resulting in deforestation, environmental degradation, and carbon emissions (Houghton and Hackler 2000). In 1850, energy from biomass fuel sources comprised over 90 percent of total energy consumption; by the mid-20th century that figure had dropped to < 3 percent (Schurr and Netschert 1960), primarily due to a diversification of fuel sources that included an increasing proportion of fossil fuels.

Post-1950, the energy mix diversified even more to include nuclear, geothermal, solar, wind, and a newly increasing amount of biomass energy. From 1950 to 2000, annual biomass energy production in the United States went from 1.562 to 3.006 quadrillion British thermal units (BTU), an increase of almost 50 percent (USEIA 2012). A subset of the biomass energy sector, biomass electricity generation, which includes combustion and gasification technologies using feedstocks such as wood and wood-derived fuels, wood waste liquids, black liquor, sludge waste, agricultural byproducts, and other biomass solids, liquids, and gases, grew a further 28 percent from 2001 to 2015 nationally. Recent U.S. Energy Information Administration (EIA) projections indicate that biomass electricity generation will continue to increase an average of 3.1 percent per year (USEIA 2015).

An understanding of the role played by increasing anthropogenic emissions of carbon dioxide (CO_2) and other greenhouse gases (GHGs) in increasing tropospheric warming (e.g., Allen and others 2009; IPCC 2007, 2014; Knutti and Rogelj 2015; Matthews and others 2009) has led to efforts to increase carbon-neutral renewable energy sources and decrease GHG emissions. In the 21st century, renewable biomass power from forest resources continues to play an increasing role in the energy mix of the United States. When compared to piling and burning forest residues generated during harvest, utilization of residues in biomass power plants significantly reduces emissions of fine particulate matter, carbon monoxide (CO), and volatile organic compounds (VOCs), with smaller reductions in nitrogen oxides (NO_X) and CO_2 (Jones and others 2010; Lee and others 2010; Springsteen and others 2011, 2015). Biomass power may have the potential to reduce CO_2 from the electric grid when it displaces power produced by fossil fuels (Gustavsson and others 2007); however, there are varying methodologies and approaches to calculating and understanding the carbon balance of power produced from forest resources (McKechnie and others 2011). Some studies show a carbon

debt (e.g., Czeskleba-Dupont 2012, Manomet 2010) and others show biomass power as carbon-neutral or providing a carbon dividend (e.g., Daigneault and others 2012, Springsteen and others 2011).

The differences hinge on a number of factors, including the technology used to turn the fuel into electricity, site productivity and rotation cycles, and feedstock sources. Lamers and Junginger (2013) provide a comprehensive synthesis of the varying carbon accounting methodologies used in understanding biomass power's carbon emissions. They identify that the most immediate net carbon benefits come from feedstocks that utilize: (i) harvesting or processing residues, (ii) cull wood from insect- and pathogen-infected sites, and (iii) new forest land or forest plantations on previously unproductive land, thereby increasing biogenic carbon sequestration from land use. The authors also highlight the importance of viewing carbon balances with respect to regional wood fiber markets in determining future energy policies.

Much of the concern surrounding the increase of biomass power in the electrical sector is the role that forests play not only in the carbon cycle, but also in water, soil quality, and soil nutrient cycles, ecological biodiversity, as well as economic and public health considerations (Karvonen and others 2017). The Intergovernmental Panel on Climate Change (2014) estimates that land use change (primarily in the form of deforestation) accounts for approximately 25 percent of global anthropogenic GHG emissions, but in the United States, the Environmental Protection Agency (EPA) recognizes Land Use, Land-Use Change, and Forestry (LULUCF) as a net carbon sink (USEPA 2017). Nevertheless, there is public concern regarding the utilization of forest resources for energy production given the value placed on the ecosystem services that forests provide.

Potential impacts on ecosystem services could be realized in changes in soil nutrients, timber productivity, erosion, and water quality as a result of tree harvesting and removal of logging residues. There are many studies that assess these impacts, especially in the fields of soil nutrients and site productivity. Such studies compare impacts after the removal of logging residues, commonly known as whole tree harvest (WTH), with harvest operations where only the bole is removed, referred to as conventional harvest (CH). The results demonstrate the importance of site selection when using WTH and indicate high variability in negative impacts found in different soil types and tree species, with some soils and species experiencing no negative effects from WTH and others experiencing significant reductions in soil nutrients and growth rates (e.g., Curzon and others 2014, Helmisaari and others 2011, Hendrickson and others 1989, Nave and others 2010, Peng and others 2002). Generally, it appears that sandy soils are more affected by WTH than clay or loam soils, and sites that are more productive in terms of tree growth rates have a lower risk of impact on their productivity. Overall, there is sufficient evidence to consider WTH on sites with good buffering capacity, low clay content, sufficient water holding capacity, and deep regolith (Bailey 2008).

For ecosystem services related to water and erosion, a Virginia-based study comparing CH and integrated biomass harvesting where roundwood and fuel chips were produced synchronously, there was no significant difference found in erosion rates or implementation of best management practices to protect water quality post-harvest (Barrett 2013). A comprehensive review of impacts in various forested regions ultimately recommended longitudinal studies spanning an entire rotation to understand the conditions for which WTH will have negative effects. Their review also concluded that there are "no consistent, unequivocal and universal effects of forest biomass harvesting on soil productivity" (Thiffault and others 2011). Due to the site specificity indicated in existing literature, it is clear that assessing ecological impacts should be done on a case-by-case basis with regional guidance determining suitability for biomass utilization.

As bioenergy grows within the energy sector and issues such as carbon emissions, ecosystem services, and land use changes are meaningful to society, it is important to analyze what the growth of biomass power entails for forest resources. This research assesses changes in timber harvest, mill residue, and logging residue production in the Southern United States over a 15-year time period alongside changes in installed biomass power plants using wood solids as fuel. The correlation between increased biomass power generation in the South and impacts on wood fiber extraction from southern forests is calculated to try to understand effects, if any, of one forest resource utilization pathway. Given the varying dynamics in markets and policy in an area as broad as the U.S. South, the analysis also investigates feedstock sourcing and biomass energy politics, using Virginia as a case study, to provide a more comprehensive understanding of the factors influencing forest biomass utilization for energy.

METHODOLOGY

Before investigating the effects of biomass power on forest resources, it is necessary to define "biomass power" for the purposes of this research within a broad industry. The conversion of biomass to electricity uses various feedstocks; this research focuses on biomass power generated from woody material, which is further divided into two primary categories: wood solids and wood waste liquids. Wood solids may be sourced from various places, including logging residues, mill residues, bole chips from primary roundwood harvest, as well as other nonforest sources such as wood generated from orchards, landscape and utility corridor tree trimmings, urban wood waste, and construction and demolition debris. Wood waste liquids are byproducts, such as black liquor produced during the kraft pulping process for manufacturing paper. These two feedstocks, wood solids and wood waste liquids, constitute the types of biomass power that utilize forest resources.

This research will focus on biomass power plants using wood solids as their primary fuel, hereafter referred to simply as biomass power. It is noteworthy that biomass power plants fueled by wood waste liquids represented the majority (μ = 78 percent) of the installed capacity of biomass plants in the South (fig. 1) between 2001 and 2015 (USEIA 2016a). Biomass power plants that burn wood waste liquids utilize a residue produced in the pulp and paper manufacturing process which otherwise has very little value. Wood waste liquids are typically combusted in a recovery boiler to produce energy at the facility where they were produced (Gavrilescu 2008), making paper production more economical by generating onsite electricity and reducing effluent. As such, biomass power plants using wood waste liquids as their main fuel source do not represent a primary driver of timber harvest and fall outside the scope of this analysis.

In order to establish the growth of biomass power, an analysis of EIA data (USEIA 2016a) is of particular use. Power generating facilities of all types that have a nameplate capacity of >1 megawatt (MW) report to the EIA on an annual basis, giving details of location, technology used, nameplate capacity and power factor of the generator(s), primary, secondary, etc. fuel sources, and many other details. These data allow for an analysis of the

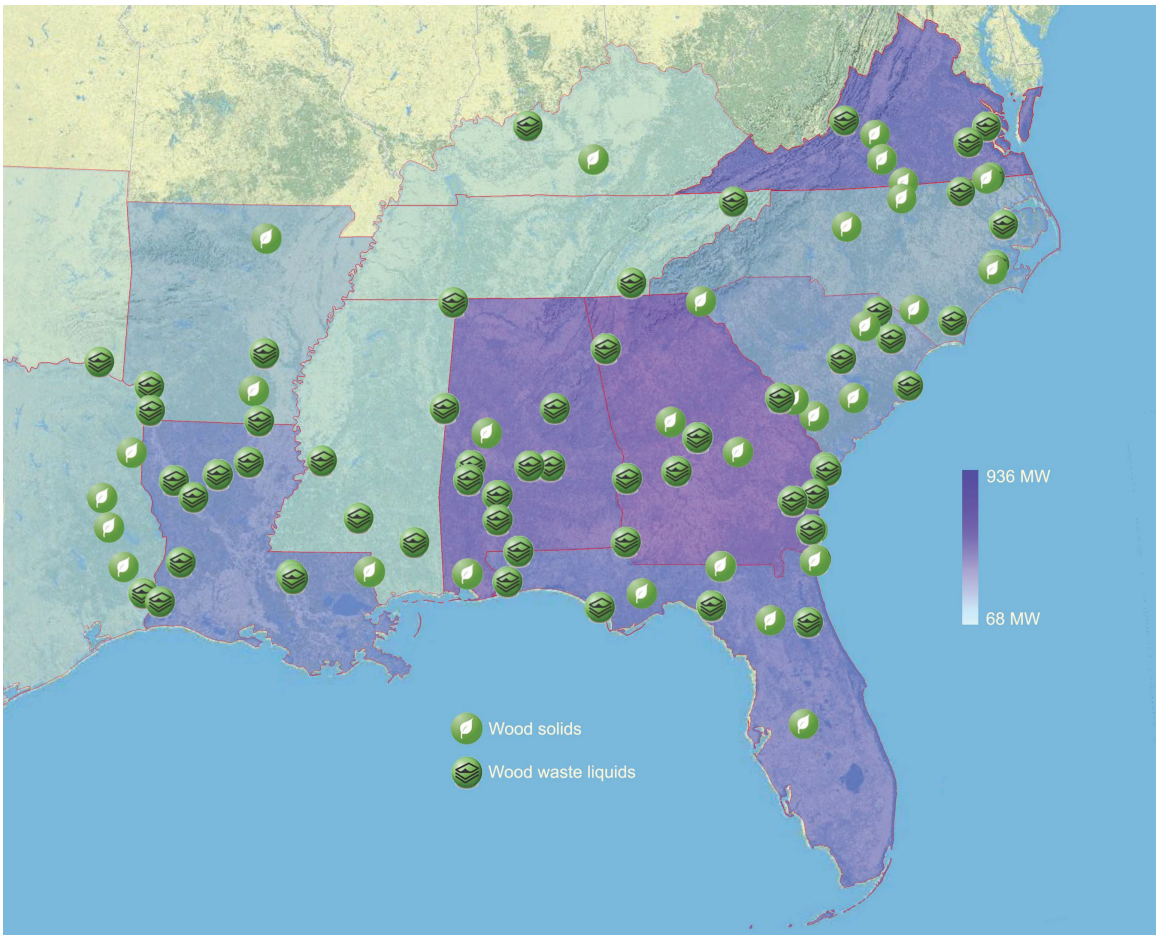

Figure 1—Biomass power plants in the South by primary fuel and installed, operating capacity in megawatts (MW) by State in 2015 (USEIA 2016a).

growth of power production over time, allowing for the aggregation of individual power plants with a geographic focus by fuel source. What one finds from the data is that the greatest growth in biomass power since 2001 can be found in Southern States, which include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia (fig. 2).

With the regional focus of the South and an ability to analyze the growth of power production, there is the additional need to understand the change in forest harvest over a similar timeframe in the same geographic region. The Forest Service, U.S. Department of Agriculture (USFS) provides extensive datasets through their Forest Inventory and Analysis (FIA) program. A component of FIA's work collects forest harvest data through the Timber Product Output (TPO) studies (USFS, n.d.). Questionnaires are sent out on a biennial basis to all primary wood processors. The responses provide an estimate of industrial uses of roundwood, which also includes residues generated during primary processing, including mill and logging residues. Data are available during the timeframe of interest (2001 to 2015) for all Southern States.

The two datasets, biomass power and forest harvest, provide an overview of the potential impact of the growth of biomass power on forest resources in the South. The biomass power data, as described above, are reported at the plant level, which have been aggregated by State and year to produce a sample population for all 13 States over 8 years ($n = 8$ for individual States as well as for summed totals for all Southern States), using only the biennial sample years (2001, 2003, etc.) to align with the TPO data. The forest harvest data are also aggregated from the facility to a county and then State level for each component of interest (e.g., roundwood harvest, mill residues, etc.) and year ($n = 8$, as above). Comparing longitudinal trends and Spearman's rank correlation coefficients between the datasets opens the discussion of wood fiber utilization in bioenergy. In order to better understand wood utilization and feedstock sourcing for an area with increasing biomass power, a case study on Virginia is explored. The case study includes semi-structured interviews with utilities and a biomass power facility and primary wood processor in the State, which represent the entities responsible for the growth of biomass power in the State.

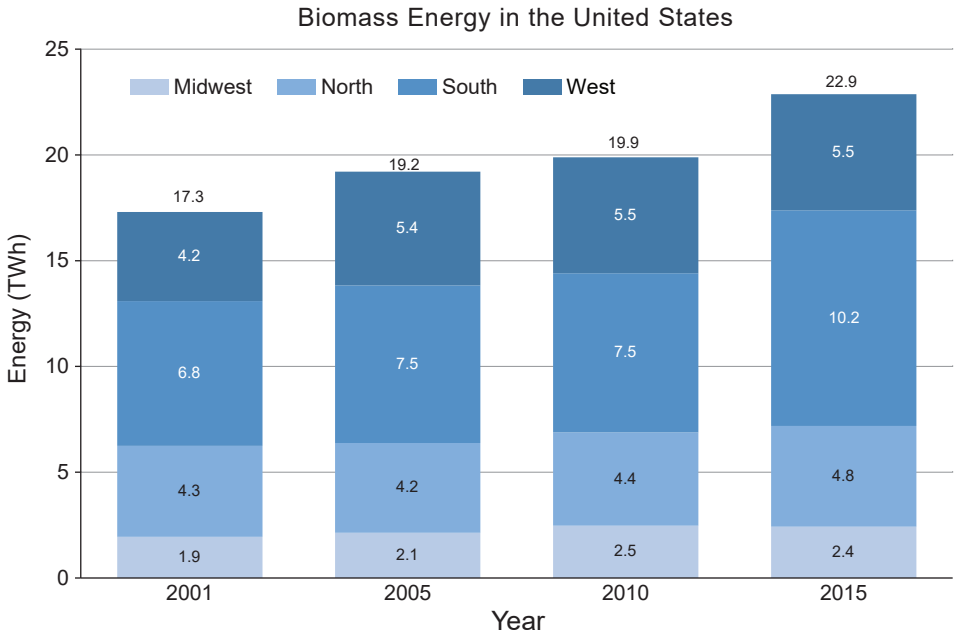

Figure 2—Biomass energy generation from wood solids in terawatt-hours in the United States, 2001–2015 (USEIA 2016b).

RESULTS AND DISCUSSION

Power Production from Solid Wood

The EIA data show that by comparing biomass power capacity and year, there was significant ($r_s = .921$, $p = .001$, $n = 15$) growth of biomass power during the study period for the South as a region from 2001 to 2015. There was considerable variability among States, with Virginia experiencing the greatest growth of installed biomass power capacity; Alabama, Louisiana, Oklahoma, and Tennessee experiencing losses in installed capacity; and Mississippi with no installed capacity during this period. Florida, Georgia, North Carolina, South Carolina, Texas, and Virginia all experienced significant ($p < .05$, $n = 15$) growth, with at least a 90-percent increase in installed capacity. Biomass power using wood solids represented an average of 5 percent of total renewable power capacity in the South from 2001 to 2015, which also includes wind, solar, hydroelectricity, and other biomass. Biomass power fueled by wood solids increased by 2 percent during the study period as a proportion of total renewable energy capacity in the South. Additionally, the States that experienced large increases in installed capacity did not always experience large percentage increases in the proportion of biomass power to the State's total renewable capacity due to the concurrent growth of other renewables (table 1).

From 2001 to 2015, biomass power capacity in the South grew 186 percent, from 609 MW in 2001 to 1,741 MW in 2015. Additionally, the majority of the growth that occurred for biomass power in the South occurred in the short timeframe between 2010 and 2015 (fig. 3). Interest in biomass in the South is likely driven by abundant forest resources coupled with existing harvesting and manufacturing networks that produce large quantities of waste wood through logging and milling. The growth in renewable biomass power in the South may also be attributed to the relatively poor wind and solar resources when compared to other regions in the United States.

Table 1—Installed, operating nameplate capacity of biomass power using wood solids as their primary fuel in megawatts (and percent of total renewable power capacity) for Southern States, 2001–2015

State	2001	2003	2005	2007	2009	2011	2013	2015
Alabama	128 (4%)	128 (3%)	128 (3%)	168 (4%)	128 (3%)	136 (3%)	197 (5%)	110 (3%)
Arkansas	15 (1%)	17 (1%)	17 (1%)	17 (1%)	17 (1%)	17 (1%)	17 (1%)	17 (1%)
Florida	81 (7%)	81 (8%)	80 (7%)	87 (7%)	87 (7%)	87 (7%)	238 (15%)	218 (13%)
Georgia	19 (1%)	11 (0%)	31 (1%)	27 (1%)	27 (1%)	47 (2%)	147 (5%)	228 (7%)
Kentucky	4 (0%)	5 (1%)	5 (1%)	5 (1%)	5 (1%)	5 (1%)	4 (0%)	5 (1%)
Louisiana	110 (24%)	110 (28%)	100 (18%)	100 (16%)	100 (16%)	100 (18%)	100 (14%)	100 (13%)
Mississippi	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
North Carolina	122 (6%)	130 (6%)	175 (8%)	182 (8%)	175 (8%)	377 (15%)	377 (13%)	233 (6%)
Oklahoma	5 (1%)	5 (0%)	5 (0%)	5 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
South Carolina	70 (5%)	70 (5%)	70 (4%)	70 (4%)	70 (4%)	70 (4%)	210 (11%)	220 (12%)
Tennessee	46 (2%)	22 (1%)	3 (0%)	2 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
Texas	5 (0%)	5 (0%)	5 (0%)	5 (0%)	5 (0%)	49 (0%)	163 (1%)	169 (1%)
Virginia	4 (0%)	99 (7%)	99 (7%)	98 (7%)	98 (6%)	98 (6%)	443 (24%)	443 (24%)

Source: USEIA (2016a).

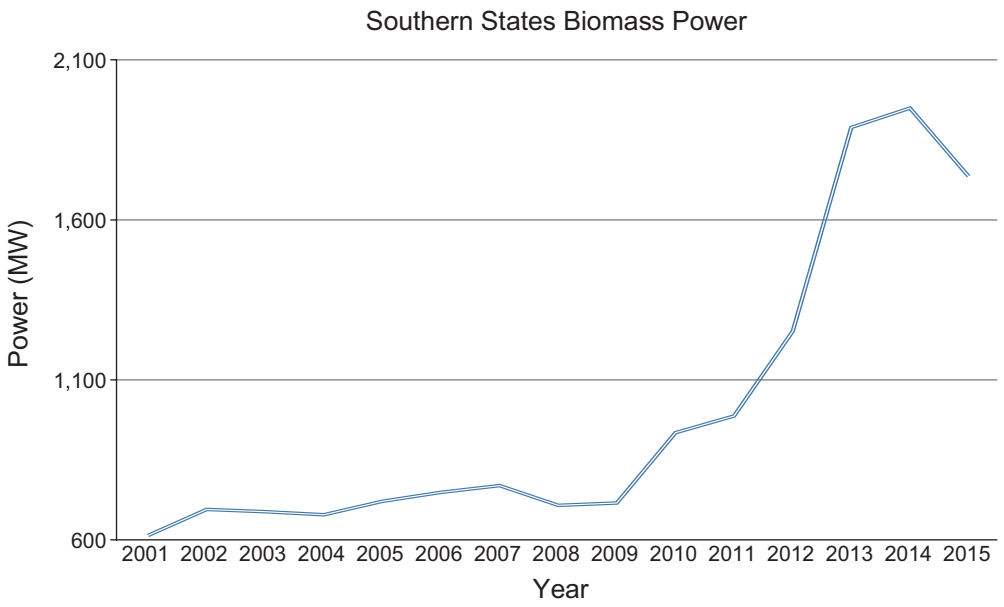

Figure 3—Installed, operating nameplate capacity in megawatts of biomass power plants using wood solids as their primary fuel in the South, 2001–2015 (USEIA 2016a).

Timber Products Output

In order to better understand impacts on southern forests from biomass power, it is valuable to analyze removals from forests by primary wood processors. The U.S. Forest Service's TPO data (USFS, n.d.) provide a longitudinal survey of forest resource usage during the timeframe of interest. Comparing the EIA and TPO data provides insight into the effects, or lack of effects, of increasing demand for wood as fuel for biomass power on timber harvest. Market influences on wood fiber consumption are highly varied and one single sector, even with substantial increases in demand, will not be able to account for overall changes in production volumes. It is nevertheless interesting to assess increased demand on supply and correlating relationships between a subset of wood utilization and total production.

For comparative purposes, it is useful to understand the volume of fuel needed for Southern biomass boilers as well as what proportion of total removals of forest material the biomass power sector represents. According to the USEIA (2016b), the 1,741 MW of installed, operating biomass power in the South generated 10.2 million megawatt-hours (MWh) of energy in 2015. Conventional commercial boilers burning comminuted wood solids consume approximately one bone-dry ton (BDT), or 2,000 pounds at 0-percent moisture content, per MWh. Given that 10 BDT of chips are equivalent to roughly 1,000 cubic feet (MCF) of roundwood (USFS 2007), this results in a demand of approximately 1.020 billion cubic feet (BCF) of roundwood from the biomass power sector in the South in 2015, which represents 12 percent of roundwood production in that year. The fuel used for biomass boilers does not exclusively come from roundwood production, as some proportion of the feedstock comes from mill residues, logging residues, and nonforest sources. Nevertheless, it is a substantial increase in demand, up from 0.685 BCF of roundwood equivalent (6.8 million MWh) in 2001, or 8 percent of roundwood production from southern forests in that year.

Overall, roundwood products harvested in Southern States for industrial and nonindustrial products such as sawlogs, pulpwood, fuelwood, veneer, etc. were lower in 2015 than 2001. In 2001, combined roundwood products output for all Southern States totaled 8.759 BCF and reached a low in 2009 of under 7 BCF. By 2011, a recovery had begun in roundwood products harvested in Southern States, ending with 8.328 BCF harvested in 2015 and nearly returning to the level prior to the Great Recession in 2008. This trend was generally true for all surveyed States, though individual States saw greater growth post-2009 than others (fig. 4).

The EIA data on biomass power do not show the same economic downturn during the Great Recession that forest harvest experienced, nor do they reflect the gradual recovery seen in roundwood harvest after that point. EIA data show a 17-percent growth rate across the South from

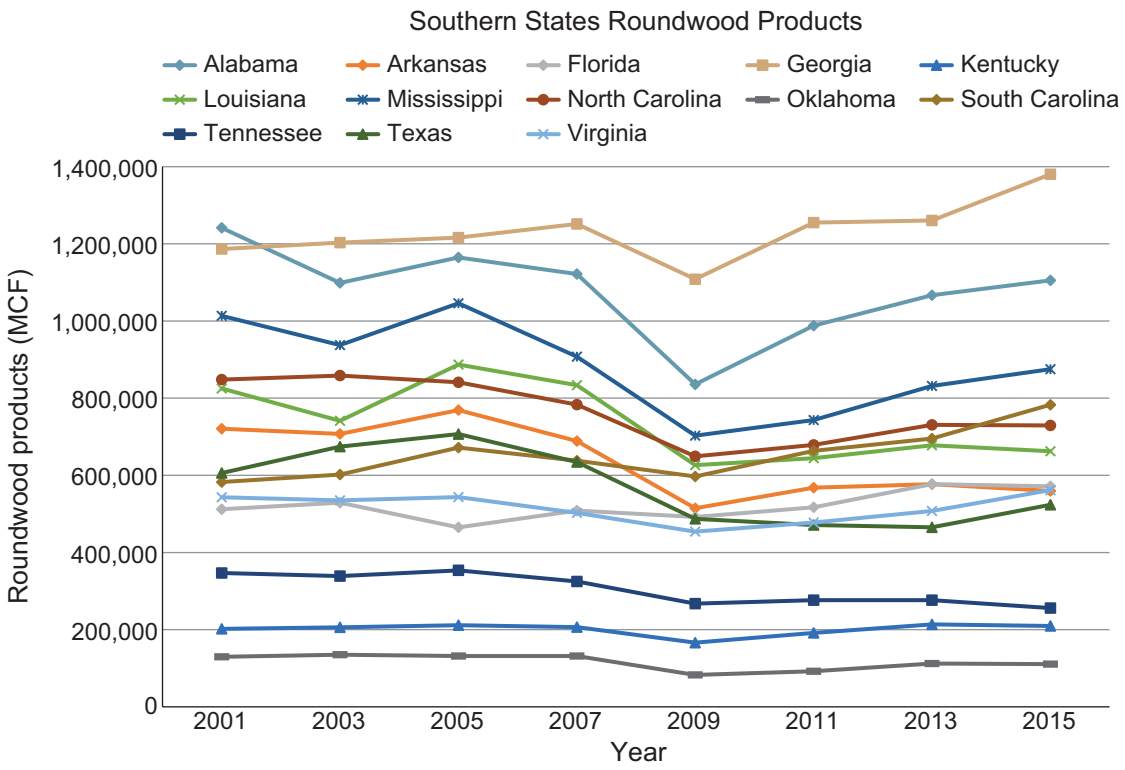

Figure 4—Roundwood products harvested by State in thousand cubic feet, 2001–2015 (USFS, n.d.).

2001 to 2009 and then a 145-percent growth rate from 2009 to 2015. In contrast, TPO data show roundwood harvest in the South experiencing a 20-percent decrease from 2001 to 2009 and only a 19-percent increase from 2009 to 2015, with the roundwood harvest level in 2015 ending 0.43 BCF below the harvest level in 2001. Temporal changes in biomass power and roundwood products show a weak negative correlation ($r_s = -.461$, $p = .206$) across the South, although there are some States that show a significant positive correlation (where $r_s > .5$ and $p < .05$): Georgia ($r_s = .757$, $p = .030$), Oklahoma ($r_s = .874$, $p = .005$), and Tennessee ($r_s = .758$, $p = .029$). However, only Georgia experienced growth in biomass power capacity; Oklahoma and Tennessee's biomass power capacity correlated well with roundwood production figures as both variables decreased over time.

TPO data indicate that mill residues in the South produced during this timeframe followed a similar trajectory as roundwood harvest, with a slight increase from 2001 to 2005 (a gain of 0.03 BCF to a high of 3.222 BCF in 2005), proceeding to a low in 2009 of just under 2 BCF, and a rebound to 2.53 BCF by 2015 (fig. 5). Mill residues include all byproducts generated during roundwood manufacturing across all industries and constitute three primary categories: (1) bark, (2) coarse residues such as chips, and (3) fine residues such as sawdust. The complementary trend found in mill residues and roundwood products harvest is intuitive given that with decreasing total roundwood harvest comes decreasing mill residue output. The data show that the independent variable that determines mill residues produced, lumber recovery in milling operations, did not change substantially over the time period studied; however, this can also be partially attributed to the modeling and estimators used to determine mill residue production.

In the TPO data, mill residues are not only represented by produced volumes but are also classified by end-use (e.g., fiber byproducts, fuel byproducts, etc.). From 2001 to 2015, an average of 49 percent of all mill residues in the Southern States was used as fuelwood or fuel byproducts. This category includes fiber utilized in industrial, residential, and institutional fuel applications. It is noteworthy that the mill residue fuel category also includes pellet fuel production, which experienced exponential production increases after 2004 in the South (Abt and others 2014). However, pellet fuels in the South are primarily exported in the form of utility-grade pellets for biomass energy production abroad and are generally not used in domestic electricity production (USEIA 2017). TPO data combine all fuel uses together for mill residues, meaning that it is not possible to ascertain figures

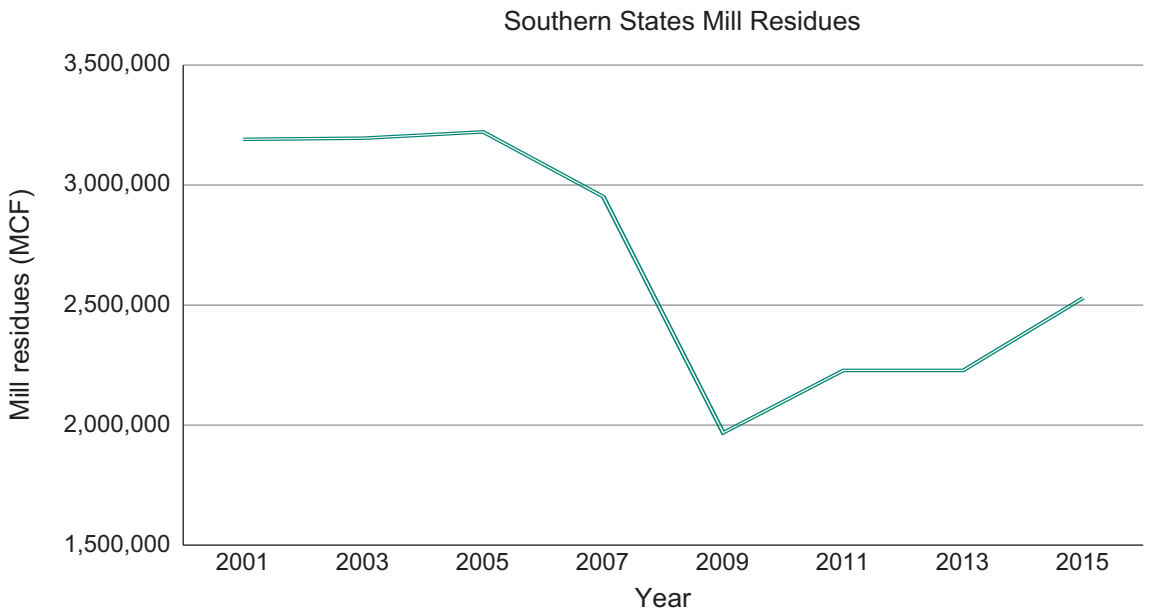

Figure 5—Mill residues produced in the South in thousand cubic feet, 2001–2015 (USFS, n.d.).

specifically for mill residues used in domestic biomass electricity production. Nevertheless, it is still useful to look at longitudinal change, which shows a very similar trajectory as total mill residues and overall roundwood harvest (fig. 6), but does not reflect substantial increases in mill residues for use as fuel despite increases in two market sectors.

When viewed as a percentage, Southern States' mill residue usage for fuel did not change much from 2001 to 2015; the proportion of mill residues used as fuel stayed consistently at approximately 50 percent, with the rest of the mill residues going into products such as fiberboard and <1 percent going unutilized. Mill residue volumes for fuel follow effectively the same trajectory as total mill residue production, with steady production at the beginning of the time period, a sharp decline during the Great Recession, and a recovery post-2008. The data in this class of mill residue usage vary from State to State. For example, North Carolina, which experienced significant growth in biomass power, used 38 percent of the State's mill residues as fuel on average during this

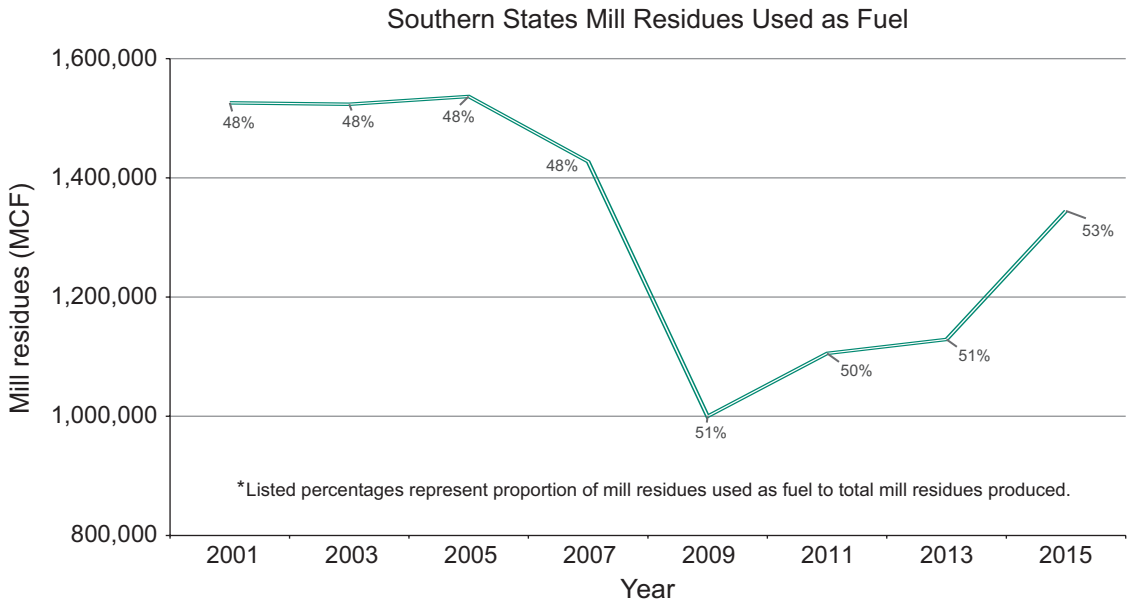

Figure 6—Mill residues used as fuel in the South in thousand cubic feet (and percentage of total mill residues), 2001–2015 (USFS, n.d.).

timeframe, while Louisiana, which experienced a slight decline in biomass power, used an average of 62 percent as fuel. Overall, mill residue production in the South does not correlate significantly ($r_s = -.452$, $p = .260$) with the increase in installed biomass power in the region.

Virginia, which saw the greatest biomass power capacity increase post-2000, yields a similar result for mill residues relative to that of the South as a whole. On average over the time period for this study, 44 percent of mill residues was used as fuel or fuel byproducts in the State. While that percentage reached a high of 53 percent in 2015, which corresponds with 443 MW of operating biomass power, that is a difference of only 3 MCF in the volume of mill residues used for fuel from 2001, in which there were 4 MW of operating biomass power. Along with the overall increase in Virginia, there was an increase in the percentage share of coarse residues used as fuel in 2013 and 2015, rising from an average of 6 percent from 2001 to 2011 to 11 percent and 13 percent, respectively. This is noteworthy because coarse residues are typically the highest value mill residue (due to a diverse array of utilization pathways, such as fiberboard), indicating that the increase in biomass power could have resulted in increased demand for mill residues. Yet even in the State with the largest increase in installed capacity for biomass power, there were only minor changes in the amount and type of mill residue utilization.

The TPO data on logging residues, unlike those for roundwood harvest and mill residue, are modeled based on two factors: local FIA inventory data and State-level log utilization studies (e.g., Bentley and Johnson 2010, Mathison and others 2009). Taking that into consideration, there were some differences in the trend in logging residue production during the studied timeframe compared to roundwood and mill residues. This distinction is likely a product of the way the data are modeled for each State, which is based on the year that a State log utilization study was performed and an average removal value, not the actual removals in a given year. Additionally, it is noteworthy that the logging residue data do not include any end-use information. While roundwood harvest and mill residue figures are further classified by end-use, logging residues may have been left in the forest or extracted, information which is not captured in the TPO data. It is likely that logging residues provided at least some of the additional fuel for new biomass power plant installations in the South; however, determining amounts and proportions would require further study.

The logging residue data follow the same general trend as roundwood harvest and mill residue production, increasing from 2001 to 2005 and decreasing thereafter. While roundwood harvest and mill residue production rebounded post-2009, logging residues effectively stayed level in the South during this time period at a little over 2 BCF annually from 2009 to 2015 (fig. 7). As has been shown in the roundwood harvest data and the mill residue data, the addition of biomass power in the South did not result in a monotonic association with additional generation of logging residues ($r_s = -.119$, $p = .271$), which is intuitive given the relationship between timber harvest and logging residues.

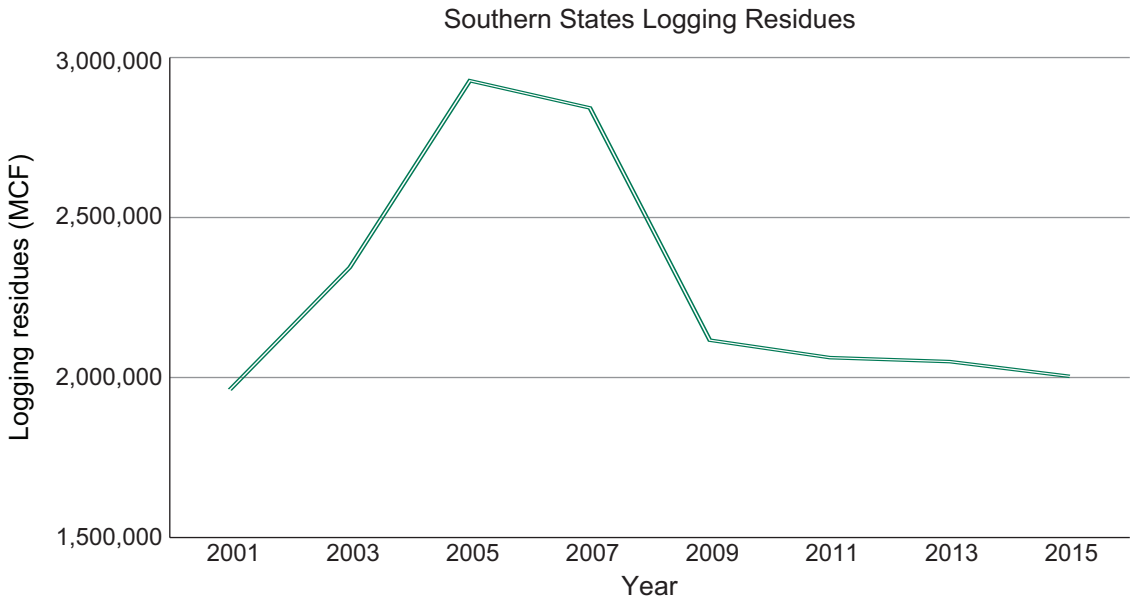

Figure 7—Logging residues produced in the South in thousand cubic feet, 2001–2015 (USFS, n.d.).

There is a fourth category in the TPO dataset, "other removals," which represents trees removed not directly related to roundwood harvest. This category includes pre-commercial thinning, land use change to nonforest where the removed roundwood was not utilized in primary processing, trees killed in timber stand improvements, and other volume not captured in the roundwood harvest or logging residue categories. "Other removals" figures are also estimated using modeling and incorporate temporally specific TPO estimates with moving average estimates of removals from the forest inventory (average annual removals over a 10-year period). This effectively dampens the likely annual fluctuations (e.g., Van Deusen 2002) in "other removals," similar to the logging residue data, and makes the data relatively incongruent with the roundwood harvest and mill residue figures used in this research.

With that caveat, on average for the South, "other removals" not captured in roundwood harvest or logging residues made up approximately 10 percent of total removals annually, with a range for individual States' averages from 5 to 17 percent of total removals. It is likely that some portion of the "other removals" category was utilized for biomass electricity production. However, similar to the issue with logging residues, it is not possible to characterize its change over time through a similar analysis, as was done for roundwood harvest and mill residues due to the aforementioned modeling constraint and the lack of end-use data for "other removals."

For the first 5 years of the study period, some Southern States' forest products industries saw modest growth and most of the industry was either stable or experienced small declines. Between 2007 and 2009, the Great Recession had a negative effect on southern forest industries (Brandeis and others 2012, Hodges and others 2011), which is evident in all aspects of the TPO data, both from an aggregated perspective of the South and for each individual State. Post-recession (2011 to 2015), roundwood products and mill residues experienced 10-percent and 22-percent growth, respectively (USFS, n.d.). The EIA data show rapid growth post-recession, with biomass power capacity increasing by 77 percent from 2011 to 2015 (USEIA 2016a).

Overall, when viewing the installed power capacity data from the EIA alongside the TPO data, the two datasets lack significant correlation. When comparing southern biomass power capacity with the volume of total removals, which includes roundwood products, logging residues, and other removals from 2001 to 2015, there is a slight negative correlation between the datasets ($r_s = -.452$, $p = .006$). Across the board, there was a lack of effect on timber removals and residue generation given rising levels of installed biomass power. While it is not possible to ascertain an understanding of biomass power feedstock sourcing from the TPO dataset given the breadth of additional market impacts influencing roundwood products, mill, and logging residues, a case study for a smaller geographic region will shed light on this question.

Case Study: Virginia

Virginia was chosen for this case study as it experienced the largest growth in biomass power capacity between 2001 and 2015. The State had 4 MW of installed operating nameplate capacity in 2001 and 443 MW of installed capacity by 2015. The growth seen from 2012 to 2013 in the State was a result of investments by two separate utility companies, Dominion Virginia Power (DVP) and Northern Virginia Electric Cooperative (NOVEC), as well as a pulp and paper manufacturer, WestRock. DVP converted three coal plants to biomass in the State (Ruppert 2013), adding 213 MW of biomass capacity to their portfolio, which already included a 90 MW biomass power plant installed in 1994. Additionally, DVP installed a hybrid coal and biomass power plant in Virginia that can use up to 20 percent wood as fuel (which does not count toward the utility's or State's total biomass capacity as wood is not the primary fuel). NOVEC commissioned a new biomass power plant that added to the utility's renewable portfolio. Finally, WestRock decommissioned a coal-fired boiler at their paper mill in Covington and replaced it with a biomass boiler. The additional biomass power capacity in Virginia had various motivating factors and resulted in an impact on forest operations.

Virginia enacted a voluntary target for renewable energy in 2007, known as a Renewable Portfolio Standard (RPS). The goal of the program is for investor-owned utilities in the State to generate 15 percent of their electricity from renewable sources by 2025. The program allows for the creation of Renewable Energy Certificates (RECs) from eligible renewable energy technologies, which includes biomass. RECs may be sold independently from the sale of electricity and represent an additional revenue stream. DVP's, NOVEC's, and WestRock's biomass facilities comply with the Virginia RPS law, which requires renewable energy goals met using biomass power to utilize a feedstock classified as a "biomass based waste to energy resource" such as mill residues, pre-commercial thinnings, tree trimmings, and logging slash (Virginia Electric Utility Regulation Act of 2007. Public Law §56-585.2 576-596). Each of the three entities involved in the growth of biomass power in Virginia was interviewed to understand the driving factors behind their interest in biomass and the feedstocks utilized for the power plants.

As of 2013, DVP uses 2–2.5 million green tons (GT) of biomass fuel annually. This equates to approximately 2,000 GT of fuel each day for each of their new facilities and 3,300 GT for their Pittsylvania plant. The facilities operate for most of the year, with some planned outages for maintenance and transmission load reliability needs. Dominion takes mainly fuel chips, with some bark, arboricultural and municipal tree grindings, and sawdust from sawmills, although sawmill residues constitute a minimal part of their purchasing and are only used as fuel in one of their four biomass facilities. Most of their fuel comes in the form of in-woods chips from logging residues; they purchase no fuel from primary harvest.

Originally, DVP intended to use a 50-mile purchasing radius from the plant for biomass fuel, but recently has been able to purchase from a 75-mile radius, and has on occasion sourced from up to 100 miles. DVP has seen no supply shortage of fuel. Their purchasing is done through WestRock, a large paper manufacturer, as well as through direct buys with loggers. In the areas that DVP purchases fuel, it is common for logging operations to bring chippers to remove and transport the logging residues as an added economic incentive to timber harvest.[1] Although Dominion did not comment in the interview on the impetus for converting three facilities to biomass, their website indicates they were selected as "reasonable and cost-effective" projects that will ultimately provide customer savings. The website also points out the environmental benefits of biomass over coal and the economic development and job creation related to logging, chipping, and hauling fuel to the facilities (Dominion Energy 2017).

NOVEC uses around 360,000 GT of fuel per year at their biomass power facility. The utility is able to source the majority of their fuel from 30 to 35 miles from the plant and notes that sometimes their fuel suppliers are willing to haul biomass further distances. The predominant type of material used as fuel is chipped logging residues, which makes up approximately 85 percent of the fuel purchased by the utility. The rest is mill residues and urban wood in the form of grindings. Similar to DVP, NOVEC only burns waste material and does not directly contribute to the primary harvest of roundwood. Local logging operations that provide fuel to the biomass plant have told the utility that there is more material available from their timber harvesting operations than purchased by the utility.

Regarding the motivation to install a new biomass power plant, their website states that biomass is a "dependable, economical, and environmentally friendly" baseload power option with an abundant feedstock of wood waste in Virginia (NOVEC 2013). In 2009, NOVEC was considering their production capacity needs and an increasing demand for power from their customers. At the time, there was also a push from the Federal Government for a nationally mandated RPS, which would have required NOVEC to produce a certain percentage of their power from renewable sources. This was an important consideration for the utility as they were planning an expansion of their energy portfolio and looking into renewables. Biomass power has greater reliability and less intermittency than other renewables and has a smaller land use footprint, all considerations that were important to NOVEC in their decision to construct a biomass facility.[2]

The biomass power plant at the WestRock paper mill uses approximately 700,000 GT of fuel annually, using an average of 2,200 GT per day. They have the largest sourcing radius of any of the Virginia biomass plants interviewed, with up to a 100-mile radius for fuel and up to a 150-mile radius for pulpwood for paper production, the processing of which generates over half of the material used in their biomass boiler. The approximate split of fuel used in their biomass boiler is 40 percent bark generated on-site, 15 percent sawdust generated on-site, 15 percent purchased bark, and 30 percent logging residues. WestRock initially purchased utility and landscape grindings but has since phased out their use due to the lower energy content of the material. This facility uses the smallest proportion of logging residues of the biomass power plants interviewed in Virginia, which is logical due to the large amount of waste wood generated on-site, one of their driving reasons for the installation of the new biomass plant.

Prior to the biomass generator installation, the mill had fossil fuel generators in addition to their two recovery boilers burning black liquor. WestRock saw an economic opportunity to replace one of their aging coal-fired boilers with a biomass boiler that would reduce their greenhouse gas emissions, result in a lower cost overall, and transition to a more secure fuel source.[3]

[1] Personal communication. 2017. Dominion Virginia Power representative, Senior Fuel Buyer, 120 Tredegar Street, Richmond, VA 23219.

[2] Personal communication. 2017. NOVEC representative, Director of Origination and Plant Operations, 10323 Lomond Drive, Manassas, VA 20109.

[3] Personal communication. 2017. WestRock representatives, Power Operations Supervisor and Mill Manager, 104 W. Riverside Street, Covington, VA 24426.

What was discovered from all of the new installations of biomass power is that there was an exclusive focus on fuel that would otherwise be considered a waste product. When analyzing the reasoning for this, there are two primary considerations. The first is economic: logging residues can be purchased and delivered for a low price relative to the cost of roundwood, assuming there is not strong local competition from other bioenergy or residue-using facilities (Galik and others 2009), and that transportation distances are short. The interviews with fuel buyers and others involved in biomass power in Virginia showed that the increased demand for forest residues led to the addition of grinders or chippers to logging operations in order to meet the demand for residues. Conversely, timber operators without grinders were unlikely to be able to take advantage of this additional revenue stream. This is especially true in the mountain region of western Virginia, where steep slopes and more difficult access often preclude the addition of these types of machinery to logging operations.

The second consideration is the generation and sale or use of RECs. For the utilities, these biomass conversions and installations have the ability to produce RECs, which help to accomplish environmental goals for the companies and to generate additional revenue. Compliance with Virginia's RPS is voluntary, but RECs add a value to power production beyond the price paid by electric customers. Because DVP's, NOVEC's, and WestRock's biomass facilities all comply with the biomass-specific language in the Virginia RPS law requiring feedstock classified as a waste to energy resource, all of the new biomass facilities are eligible to generate and sell RECs. Virginia's RPS is a unique situation in the South, where the majority (62 percent) of States do not have legislation that allows for the generation of RECs or sets renewable energy targets, whether mandatory or voluntary (NCSL 2018). As such, the findings in the Virginia case study are not necessarily applicable to other Southern States.

There are some key points learned by analyzing biomass power in the State that experienced the most growth in the South. Virginia, like most of the rest of the Southern States, did not demonstrate a correlation between either the quantity of timber harvested or the amount of mill residues used as fuel with the growth of biomass power. As there was no measurable effect on the amount of roundwood harvested relative to increased biomass power capacity, and by extension the amount of mill and logging residues produced, it is likely that the additional demand for woody biomass created by the new installed capacity of wood-burning boilers is sourced in a manner not captured by the harvested roundwood data.

By investigating key players involved in the new biomass power facilities in Virginia, it is evident that the newly installed biomass power plants focused on waste material as their fuel sources, which did not result in additional tree harvesting. This finding may not be applicable to other Southern States considering the language in the Virginia RPS requiring waste wood feedstocks to qualify as a renewable biomass energy facility, a stipulation unique to Virginia. Four other Southern States have RPS laws: North Carolina (Renewable Energy and Energy Efficiency Portfolio Standard. N.C. Gen. Stat. Public Law §62-133.8), Oklahoma (Renewable Energy Fuels and Oklahoma Energy Security Act. Oklahoma Statute title. Public Law 17 §801.1 et seq.), South Carolina (South Carolina General Assembly. S.C. House Bill 1189 120th Session. Public Law 2013-2014), and Texas (Restructuring of Electric Utility Industry. Texas Utility Code Ann. Public Law §39.904). In addition to Virginia's regulation, Oklahoma's is the only other regulation that mentions biomass feedstocks, though it simply encourages the use of cedar (*Juniperus virginiana* L.) and wood residues but does not have a waste to energy feedstock requirement as Virginia's RPS does.

When analyzing carbon for biomass power in Virginia, the exclusive focus on waste wood is an important consideration. In a peer review of the U.S. EPA's draft "Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources," it was noted that biomass energy is not always carbon neutral, with the feedstock's production and consumption cycles playing the primary role in determining carbon neutrality (Swackhamer and Khanna 2011). As those authors and others (e.g., Lamers and Junginger 2013) point out, harvesting trees specifically for fuel in biomass power curtails their continued absorption of carbon and can result in an overall carbon debt. However, using waste wood as a biomass power plant's feedstock, such as was found to be the case in Virginia, results in a carbon neutral form of power generation.

While the growth of biomass power in Virginia may have resulted in net carbon benefits for the energy sector, there are other potential environmental impacts from the usage of logging residues as fuel for biomass power. As discussed earlier, removing logging residues potentially impacts soil nutrient cycling, erosion control, tree growth, and other ecosystem services. Virginia and many of the other Southern States do not have regionally specific guidelines related to best practices of logging residue removal, though there are guidelines for the region from the Forest Guild Southeast Biomass Working Group (Forest Guild Southeast Biomass Working Group 2012). In these

guidelines, for example, the authors recommend leaving approximately one-third of the downed woody material during a biomass harvest to sustain desired ecosystem services on an average site, but stress the importance of site-specific knowledge to determine appropriate harvest practices. Given the growth seen in biomass power since 2000, implementation of logging residue harvest guidelines will be critical to achieving the climate benefits of biomass power while ensuring the sustainability and ecological sensitivity of using increasing amounts of wood to energy production.

FURTHER RESEARCH

This investigation focused on the overall effect on timber harvest from the growth of biomass power in the South as well as feedstock sourcing in Virginia. Findings indicated that there was no strong correlation between timber harvest levels or mill residue utilization and additional biomass power. Specific biomass power fuel sources are not found in the TPO data, but further investigation found that the primary fuel for new biomass installations in Virginia came from logging residues and other waste wood. Existing literature indicates that the implementation of site-appropriate management practices can mitigate the potential negative effects from the removal of logging residues; however, guidelines to inform Best Management Practices (BMPs) relative to soil type, slope, forest structure, tree species composition, etc. must continue to be developed and integrated into logging operations. Abbas and others (2011) did a comprehensive review of biomass harvest guidelines, and the authors ultimately recommended developing regionally specific rules.

In order to sustain ecosystem services when harvesting for biomass power, logging sites should be evaluated using spatial data and environmental sampling to determine site suitability and examine factors such as geology, acid deposition, chemical hydrology, and soil type. Developing a biomass harvesting atlas and regional guidelines that are informed by longitudinal studies relative to distinct ecosystems and educating foresters and timber operators will ensure the sustainability of harvesting for both timber and biomass power.

It is also key to understand the impacts that the removal of logging residues have on both wildfire risk and fire intensity, especially with respect to a changing climate and more frequent and intense occurrences of wildfire. Utilizing small-diameter wood produced from forest restoration projects for biomass energy is an area of emerging science that merits additional research, as well as building on underlying science that models fire behavior post-thinning. By conducting research on different forest types important to the South, the region will be able to achieve forest restoration by removing hazardous fuels that can pay their way out of the woods through the support of the biomass industry, alongside other industries that use small-diameter timber.

Another area of importance in bioenergy research is developing regional disturbance-based biomass strategies. Forest stands across the South experience mortality events from fire, insects, disease, and severe weather, often yielding large volumes of low-value wood. Identifying existing infrastructure that can utilize wood produced by disturbance events and developing spatial data to inform utilization efforts should be undertaken in a pro-active fashion, taking biomass power into account. Approaching disturbance events from a perspective of preparedness will likely lead to greater overall utilization post-disturbance.

While this analysis considered wood converted into electricity in the South, a complete analysis must also include wood grown domestically and converted into electricity in other countries. Southern States, concurrently with the growth of domestic biomass power, have seen increased production of utility-scale pellet fuels since 2000 (USEIA 2017), primarily due to demand for renewable wood fuels in Europe for both heat and power (Lamers and others 2012). When considering the impacts wood-to-energy technologies have on forest resources, pellet production is an important aspect to analyze in future research endeavors.

A significant limiting factor for the utilization of forest material in biomass energy is the relatively high transportation costs of a low-value material such as logging residues, which was captured in the limited fuel purchasing radii found for the interviewed biomass power plants in Virginia. Research characterizing the economics of transporting biomass and investigating new methods and technologies to improve transportability could lead to increased adoption of biomass power. Additionally, research into the financial feasibility and logistics of adopting smaller-scale, distributed power generation using biomass close to the forest is of value.

Finally, it is important to develop a better understanding of the cultural and social acceptance of bioenergy and to continue to perform research in this field over time. Scientific research focusing on understanding public perception of low carbon energy will aid in efforts to increase its adoption and to allow entities to address public concerns in a transparent fashion. In a study on factors affecting bioenergy implementation, positive impacts

on the local economy were found as one of the primary drivers of favorable views toward bioenergy in Maine. The researchers indicated that further research was needed to understand how biomass power demonstrates importance to local economies (Roos and others 1999). In a study of stakeholder groups in bioenergy and their perception of strengths, weaknesses, opportunities, and threats, strengths and opportunities were found to be of the highest import among the stakeholder groups surveyed, however the study did not assess the opinions of forest landowners and energy consumers (Dwivedi and Alavalapati 2009), both of whom have an important role to play in the development of bioenergy. Opposition to biomass power and other forms of bioenergy has the potential to slow or, in some cases, halt new projects (e.g., Upreti and van der Horst 2004). Characterizing and addressing specific issues from the public, as well as education and outreach, is a crucial step towards developing a low carbon economy that maintains the support of the people and ensuring that new developments meet the needs of the public and local environments.

CONCLUSION

This study analyzed changes in biomass power capacity and forest harvest and utilization in the Southern United States between 2001 and 2015. Increases in biomass power using wood solids as their primary fuel were not found to have significant correlation with timber harvest levels, nor was a correlation found between mill residues used as fuel and additional biomass power capacity. There are inherent limitations in the TPO data at the scale of this research, most notably the difficulty in drawing conclusions relative to a single sector due to the various market forces acting on timber harvest. As a result, a case study was also undertaken on Virginia, which experienced the largest capacity and percentage growth in biomass power in the South. The case study interviewed the businesses responsible for new or converted biomass power plants and revealed that their primary feedstocks were waste wood, such as logging residues generated during timber harvests. This finding is encouraging in terms of the implications of the climate forcing agents generated by biomass power plants, though it may be unique to Virginia due to specific language in the State's Renewable Portfolio Standard requiring waste to energy feedstocks for biomass power to qualify for the generation of Renewable Energy Credits.

With the growth that biomass power has seen in the South since 2000, it is important to understand its effect on forest resources. The Forest Service and other forest managers and landowners in the South may see an increase in demand for wood fiber as a result of additional installations of biomass power plants. This could be viewed as an opportunity to find economical methods to perform forest health cutting, timber stand improvements, and forest thinning for hazardous fuel reduction, all of which generate low-value wood suitable for use in biomass power. It could also be seen as an additional revenue stream for primary wood processing facilities and timber harvest operations. However, it is important to approach new biomass power installations, as well as any removal of biomass from forest ecosystems, with respect to the climate forcing effects of biomass power, the ecological sensitivity of forests in order to sustain the multiple services they provide, and the needs and desires of local communities.

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This research analyzed two datasets to determine the effects of increased installations of biomass power plants on forest resources with a specific focus on the South, the region in the United States that experienced the largest growth in biomass power capacity using wood solids between 2001 and 2015. Using data from the U.S. Energy Information Administration and the U.S. Department of Agriculture Forest Service, effects on timber harvest and residue production and utilization relative to the increased need for wood fiber from new biomass power plants were assessed. The study found a negative correlation between installed biomass power capacity and total forest removals ($r_s = -.452$, $p = .006$) and mill residues produced ($r_s = -.452$, $p = .260$) over the 15-year period. Timber harvest and residue figures across the South were flat prior to the Great Recession in 2008 with modest (19-percent) growth during the latter half of the study period. In contrast, biomass power experienced 186-percent growth from 2001 to 2015, the majority of which occurred after the Great Recession. Using a case study in Virginia, the State with the largest increase in installed biomass power capacity, it was found that newly installed biomass power plants were using exclusively waste wood, such as logging residues, which are not directly captured in Timber Product Output data. Political, ecological, and climatic considerations of biomass energy are also discussed, as well as further research needs on biomass utilization for power production.

Keywords: Biomass, biomass power, forest harvest, Timber Products Output, wood utilization.

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