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What do people think about the environmental, social, and economic impacts of the wood pellet industry? An exploratory study of residents living near pellet plants vs. urban residents in states with pellet manufacturers

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ABSTRACT

This research provides insight into the wood pellet manufacturing industry from residents' perspectives in the US South, focusing on environmental, social, and economic constructs. The region is the world's largest producer and exporter of wood pellets. We sought to investigate in-depth socio-economic dynamics and fill a gap in knowledge of the human dimension relationships between the wood pellet industry and public supply-side issues in the US South. Two rounds of a web-based survey were sent to 7,500 residents in the two pellet-producing sub-regions within the US South: the Gulf Coast (Louisiana and Mississippi) and the Atlantic Coast (South Carolina, North Carolina, and Virginia). Within these regions, surveys were sent to randomly selected residents, by zip code, 18 years or older, who live within a 50-mile radius of selected pellet mills (rural) or in the two largest Metropolitan Statistical Areas (MSA) (urban) within each state containing a pellet mill. Compared to urban respondents, rural/proximal respondents within the 50-mile radius of pellet manufacturers were more aware of the existence of the wood pellet industry and had an overall more positive of the sector. Overall, urban-area respondents have a greater affinity for the environment and were generally more concerned with humans producing negative impacts on the environment. However, specific to the pellet sector, rural/proximal respondents think that the wood pellet sector is more effective in protecting the environment. Regarding social behaviors and perceptions, relative to urban respondents, rural/proximal respondents felt that the pellet industry is a superior sector in supporting communities, is concerned about the needs of communities, creates quality jobs, and is a good industry to work for. Results for the last construct, economic perceptions, show that urban respondents strongly believe that their community has a strong economy relative to rural/proximal respondents. This suggests that new sectors, such as the pellet industry can provide much needed economic development in rural geographic areas.

INTRODUCTION

Renewable energy has proliferated in recent years, mainly due to mandated use or subsidization in many of the world's electricity-generation sectors. Solar, wind, and hydropower are the leading sources of renewable energy. In addition, biomass, either agricultural or wood-based, has become a viable alternative to fossil fuels for energy generation. Technological advancements and economies of scale, due to increased use in these renewable energy sources, have created increasingly cost-efficient, competitive, and dependable alternatives to fossil fuels. The focus of this research, biomass energy in the form of wood pellets, has been a relatively recent phenomenon in global energy generation markets for electricity generation.

Global consumption of wood pellets has been on an upward trajectory for the past decade, particularly in the two largest demand regions, the European Union (EU) and Asia; demand is expected to continue increasing under current policy conditions (Thrän et al. 2017). Concurrent with increasing demand, the United States' (US) industrial wood pellet manufacturing industry has developed into the most significant global producer and exporter of pellets; predominately from the Southern[1] region (Mendell 2019). Over 95% of production in the South is exported to the EU, where wood pellets have become an integral part of strategies to mitigate carbon dioxide (CO_2) and other GHG emissions (Henderson et al. 2017). The US has received considerable attention as exports have increased from negligible amounts in the early 2000s to around 6 million metric tons (MMt) in 2018 (Greene 2019).

The wood pellet industry is divided into two markets, the non-industrial or heating market, and industrial market. Non-industrial market demand is attributed to pellet applications in commercial and residential heating, such as boilers and stoves. Industrial market demand derives from power stations substituting coal with pellets to produce energy for national, regional, or local grids. Over the past 10 years, global markets have drastically increased as more countries incorporate climate change policy and incentivize both production and consumption of wood-based biomass pellets. Growth of the industry in supplier countries coincides with demand developments in the industrial market.

Of the overall global wood pellet sector, the industrial market share in 2010 was 38%, and by 2016 rose to 50%; it is forecasted to continue increasing to 63% by 2025 (Strauss 2017a). By 2025, the

global industrial market is expected to reach 43 million metric tons (MMt), of which 22 MMt will be consumed in Europe (Strauss 2017b). This article focuses on the industrial component of the pellet sector. A generalized schematic of the wood pellet supply chain from the forest to power-generation customer is shown in Figure 1.

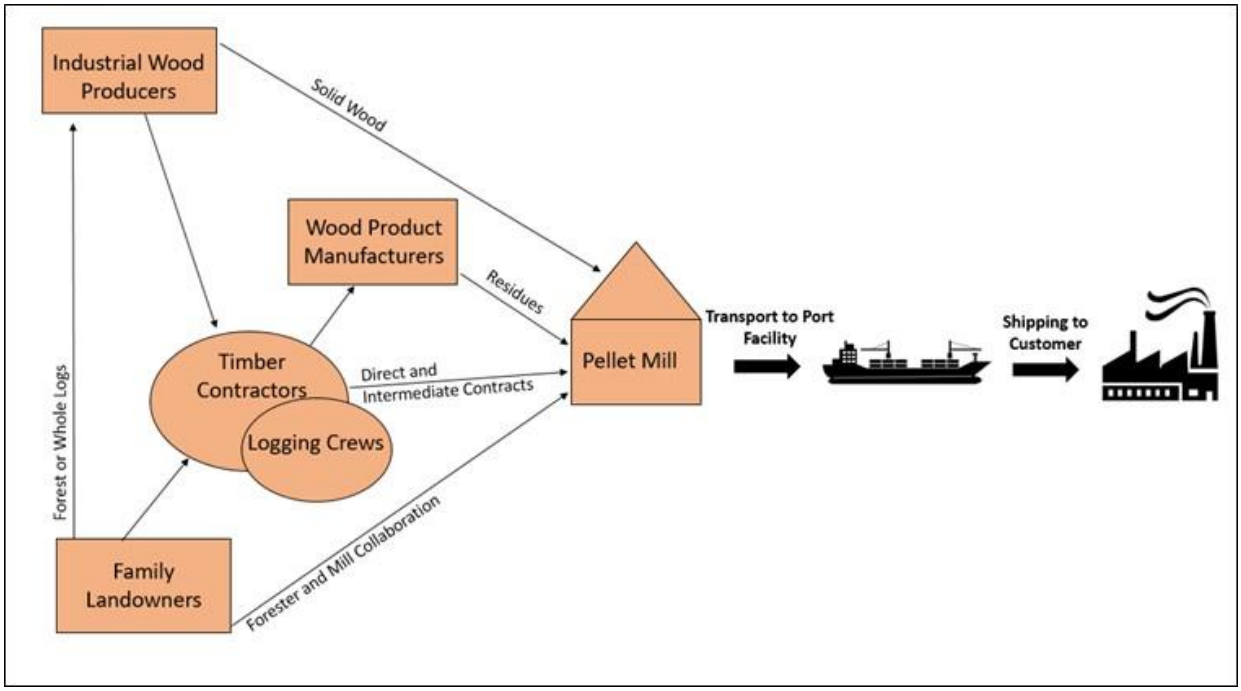

Figure 1. Wood pellet supply chain upstream and downstream of a pellet mill (adapted from Diaz-Chavez et al. 2019).

The literature on wood pellets has tended to focus on chemical and energy characteristics compared to fossil fuels, carbon sequestration, GHG emissions, and other pollutants. Other environmental and economic issues have also been studied. Examples of issues in the environmental area include timber harvesting, life-cycle analysis of pellet production, and energy expenditures in the supply chain from the forest to end-users. In the economic area, analyses tend to examine policy instruments, economic impacts, and investment opportunities that have evolved with increasing demand. However, while these aspects of wood pellets have been studied intensively, a limited amount of research has focused on social dimensions of the industry.

Specifically, there is a significant gap in the knowledge base regarding the relationship between the US wood pellet manufacturing industry and the public specific to environmental, social, and economic perceptions of residents as they relate to the industry.

History and drivers of the wood pellet industry

Wood comprised 10% of US residential energy consumption in 1982, a 6% increase since the first oil crisis of 1973, but as oil prices stabilized and new technologies for heating were established, consumption decreased to 6% in 1991, then 4% by 1997 (Song et al. 2012). By the mid-1990s, expansion of US natural gas extraction led to it eventually becoming a more widely used and lower cost fuel alternative compared to wood pellets in domestic markets. With less than a dozen commercial manufacturers, the US pellet industry did not experience much development until the mid-1990s, as the global energy landscape began to change.

As a means to bring consistency to pellet production, in 1995 the Pellet Fuels Institute (PFI), a non-profit organization incorporated in 1985, introduced the first nationally recognized pellet standards to the growing US pellet industry. These standards established criteria for premium (residential) and standard (industrial) grade wood pellets, which were quickly adopted by the pellet manufacturing industry (Spelter and Toth 2009). At the turn of the 21st century, EU foreign policy sparked a new paradigm in demand for industrial pellets which, in turn, prompted rapid investments in the US pellet industry. Since 2004, US pellet production to meet export demand increased dramatically, particularly in the South.

Although US timber inventory is only 10% of the Earth's total, 96% of US consumption of industrial wood comes from domestic supplies. The US has 766 million acres of forestland, of which timberlands, forests available for forest products, comprise 514 million acres (Oswalt et al. 2014; 2018). In order to remain consistent between the presentation of regional forests resource data provided by the US Forest Service (USFS) and regional pellet data, the regions recognized by the US Energy Information Administration (EIA) are used. The Eastern region is comprised of the USFS North region, the Western region is comprised of both the USFS Rocky Mountain and Pacific Coast regions, and the Southern region remains consistent with the USFS South region. The three regions are presented in Figure 2. The Southern region, which is commonly referred to as the nation's "Wood basket," contains almost half of the nation's timberlands at 40%, compared to 32% in the East and 27% in the West (Oswalt et al. 2018). In 2015, the South's Forest product manufacturing sector accounted for 6% of US manufacturing gross domestic product (Jefferies 2016). The Southern region also led the nation in industrial earnings in 2018, accounting for 33.9% of the four US census regions (Bureau of Economic Analysis 2018).

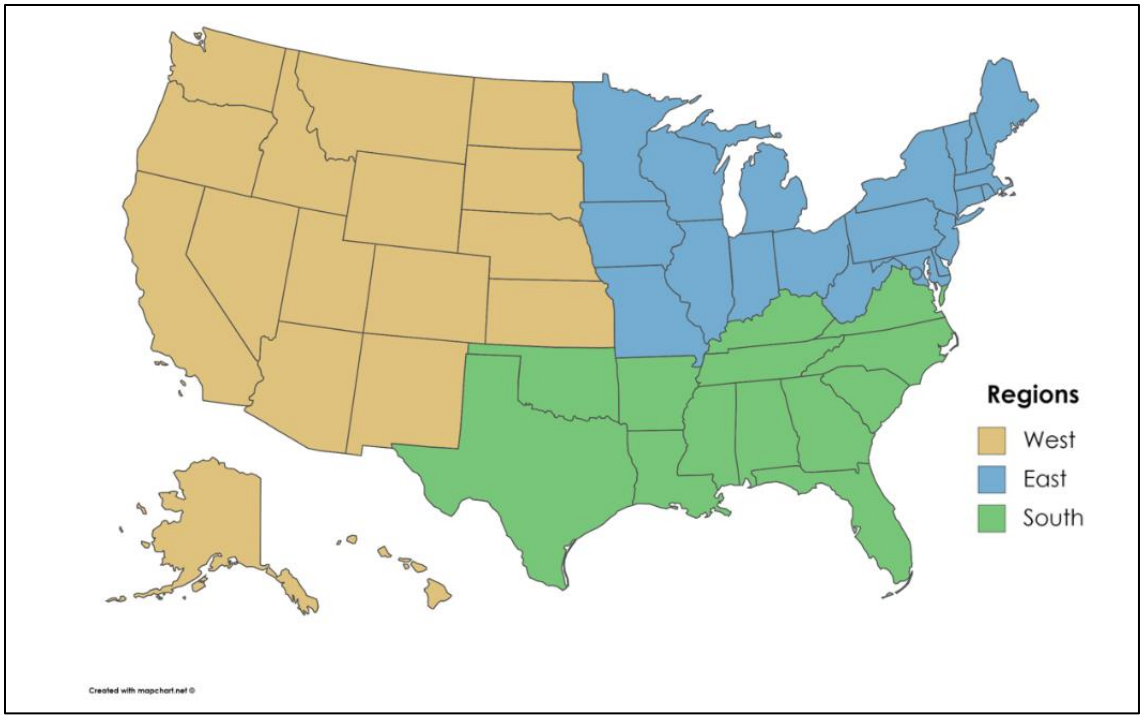

Figure 2. US regions and states within them (US Energy Information Administration regions).

Since 2011, the South (Table 1) has led the US in both wood pellet production and exports, accounting for 99.5% of total US wood pellet exports in 2017 (Abt et al. 2014). The Southern region contains approximately 73% of the 12.9 Mt US operating capacity with 42 of the nation's 125 operating pellet mills for 2019 (BBI International 2019).

Table 1. Wood pellet mill statistics for the three US regions.

Region	South	West	East	Total
Operating mills	42	27	56	**125**
Percentage of operating mills	33.6%	21.6%	44.8%	**100%**
Operating capacity	9.4	1.1	2.4	**12.9**
Percentage of operating capacity	73%	9%	18%	**100%**
Idled mills	2	4	1	**7**
Capacity of idled mills (MMt)	0.61	0.12	0.085	**0.82**
Mills Under Construction	1	1	1	**3**
Capacity of Mills Under Construction (MMt)	1	0.09	0.036	**1.1**

Source: BBI International (2019).

As a result of the concentration of pellet mills and production capacity, this research focuses on the Southern region. The region produced 5.5 MMt in 2017, a 5.2% increase from 2016, and exported 95% of production (Walker et al. 2018). Amongst the seven most significant companies in the US, six are based entirely out of the South and comprise 81% of the region's 2019 operating capacity (Table 2) (BBI International 2019). A multitude of available shipping ports along the eastern seaboard and Gulf of Mexico allows the South to export 98% of all US wood pellets, which have become the third-largest exported wood product from the US (Goetzl 2015).

Table 2. Seven largest US wood pellet manufacturing companies and capacities

Company	Operating Mills	Capacity (MMt)	Southern Capacity (MMt)
Enviva	7	3.4	3.4
Drax Biomass	3	1.6	1.6
FRAM Renewable Energy	4	0.96	0.96
Lignetics	12	0.87	0
RWE Innogy	1	0.75	0.75
Highland Pellets	1	0.6	0.6
Pinnacle	1	0.27	0.27
Total	**29**	**8.45**	**7.58**

Source: BBI International (2019).

Demand and supply for industrial wood-based pellets

Europe is not only the largest consumer of wood pellets, but it is also the most significant regional producer, accounting for around 50% of global production in 2018 (Flach et al. 2019). Germany, Sweden, and Latvia lead EU production with 2.4, 1.8, and 1.57 MMt produced in 2018, respectively. Although Russia contains a higher production capacity than Germany, Germany is the largest producer of European pellets and the world's third-largest producer due to the country's high non-industrial utilization rate (Flach et al. 2019). Sweden is the third-largest producer in Europe but does not heavily export nor rely on imports; the country fluctuates between 70% and 90% self-sufficiency in supplying domestic demand (Flach et al. 2018). However, in terms of exports, Canada, followed by Latvia and Vietnam, are second, third, and fourth to the US (Thrän et al. 2017).

Emerging supply countries such as Vietnam are developing pellet infrastructure coinciding with existing wood product industries. As mentioned earlier, Vietnam is a significant supplier of wood pellets to East Asian demand countries. Supply rates, similar to consumption rates, depend on the favorable establishment of policy, subsidies, and incentives that assist in the stages of production. As the world's largest producer and for purposes of this research, the US pellet manufacturing industry will be the focus of this supply analysis.

In 1996, the European Union (EU) prepared for the 1997 COP-3 in Kyoto by adopting a position of a 15% emissions reduction by 2010 from the 1990 baseline. Before the conference, the European Commission published a white paper in 1997 titled *Energy for the Future: Renewable Sources of Energy*, where it set a non-binding target to utilize 12% RES in overall energy generation by 2010 (European Commission 1997). As a compliance mechanism to the Kyoto Protocol, the 2001 EU Directive on Electricity Production from RES developed a framework to promote a renewable and low-carbon European economy. The directive set an overall 21% RES contribution target for electricity markets by 2010 (European Commission 2001). In 2005, a Biomass Action Plan was released to reduce foreign dependence and high prices of fossil fuel by increasing development, financing, and use of the EU's woody biomass for energy (European Commission 2005).

At the end of the Kyoto Protocol's first period, the EU-15 reached a 11.7% GHG emissions reduction, exceeding the 8% commitment; 12 new member states that had joined by 2007 attributed to the EU-27's overall 19% reduction in emissions from the baseline year of 1990 (European Commission 2017). However, in terms of the 2001 directive, 2008 EU electricity generation consisted of 16.6% RES, nearly a fifth of which was attributed to biomass (European Commission 2009; Roubanis et al. 2010).

The RED is part of a broader EU initiative known as the Energy and Climate Change Package, with objectives to reduce GHG emissions by 20% from the 1990 baseline, utilize 20% RES in energy production, and improve energy efficiency by 20%, by 2020. The package also includes the Directive on emissions trading, the Effort-Sharing Decision, and the Directive on carbon capture and storage. According to 2017 EU renewable energy progress reports, member states collectively achieved a 16% share of energy from RES in 2014 and estimated to reach 17% by 2016 (European Commission 2018a).

In December of 2018, EU Parliament released a recast version of the RED (RED II) with new binding targets of 32% overall renewable energy production and 15% renewable energy production in the electricity market for the period of 2021-2030 (European Commission 2018b). Sustainability criteria received significant attention, as to address criticisms over carbon-neutrality concerns of solid biomass energy production and emissions accountability under prior EU policy (European Commission 2019b). A new regulation was added to enhance criteria regarding origins of biomass used for RES targets. As with the RED, the RED II is part of a larger package of legislation known as Clean Energy for all Europeans, a compilation of eight policies in an attempt to form an energy union within the EU (European Commission 2019a).

The RED and RED II incentivize compliance of renewable targets with monetary penalties in the case that member states do not meet individual targets. The directives enforce compliance of sustainability criteria by withholding eligibility for support schemes and subsidies. Support schemes and subsidies are laid out in member states' national renewable energy action plans, which include support for investment, support to production, and support to research and development initiatives. Support for investment includes tax credits, property tax abatement, grants, and other business tax incentives. Support to production includes subsidies such as feed-in tariffs (FIT), feed-in premiums, and renewable energy quotas with tradeable certificates.

Growth in global pellet trade rose 19% in 2013, year over year, then declined to 7% in 2014 and 2015 (Walker 2018). As EU and East Asian markets grew, new power station construction was planned, and conversions and new stations came online, resulting in projected global trade to expand (Figure 3). In 2017, trade increased by 13% to 18.9 MMt, and then 26% to 23.8 MMt in 2018 (Walker 2018).

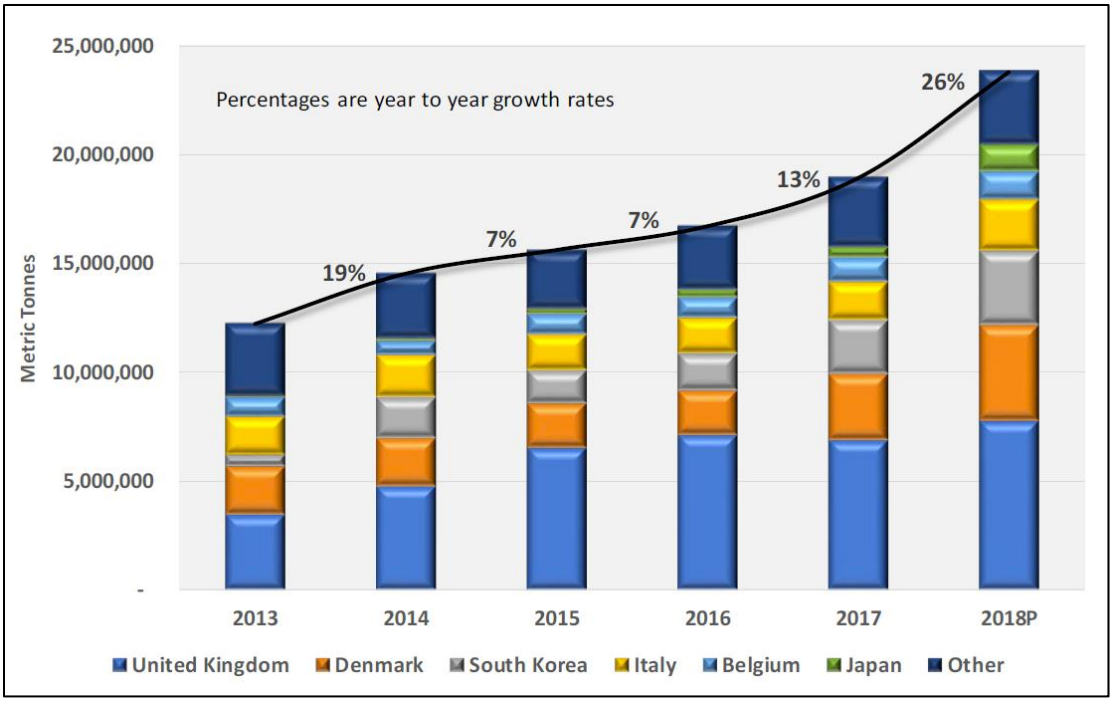

Figure 3. Global pellet imports 2013-2018 from the UK, Denmark, South Korea, Italy, Belgium, Japan, and other major demand countries in metric tons, provided by FutureMetrics (Walker 2018).

European industrial pellet demand increased at an average rate of 11.5% per year since the implementation of the RED in 2009. In 2017, the EU-28 consumed 24.1 MMt, around 75% of global consumption (Flach et al. 2019). In 2018 the EU-28 consumed 27.35 MMt (Flach et al. 2019). Consumption in 2018 represented 118% increase in demand since 2011. The EU imported 8.7 MMt of pellets in 2017, of which 5.2 MMt were imported from the US (Flach et al. 2019). In 2018, European imports rose to 10.35 MMt, of which 6.1 MMt were imported from the US (Flach et al. 2019). Estimates for 2019 indicate an increase in consumption to 30 MMt, and imports to 12.2 MMt (Flach et al. 2019).

Within the European Union, the United Kingdom is the world's leading consumer of wood pellets. The country is attributed with the most significant increase in demand from 2012 to 2018, at 471% (Flach et al. 2019). This increase is a direct result of power plant conversions, particularly by the Drax Group. The Drax Group owns the largest power station in the UK and Western Europe; located in Shelby, North Yorkshire, Drax produces 7% of UK electricity. Initially, the power station consisted of six coal-burning generators with a 3,960 MW energy capacity strategically constructed next to the Shelby coalfield. In 2013, Drax converted the first of four generators to run

on pellet fuel. In 2016, Drax announced that 70% of the company's energy was produced from wood pellets, which accounted for 20% of UK renewable energy (Drax Biomass 2019). Each of the four converted units can burn 2.3 MMt per year, consequently increasing UK pellet demand (Flach et al. 2018).

The Dutch countries of Belgium and the Netherlands contribute to wood pellet demand almost entirely through industrial markets. Belgium imports over 75% of demand from non-EU sources; mainly the US and Canada (Flach et al. 2019). Belgium has two pellet-firing power stations, Engie Electrabel's 80 MW Les Awirs and 205 MW Max Green (Walker 2018). Belgian pellet demand has remained relatively consistent with an average growth rate of 4.2% since 2011. However, the Netherlands has experienced significant fluctuations.

On the other side of the globe, East Asian markets are expected to contribute to the majority of industrial pellet demand growth after 2019 (Strauss 2017a). Since the implementation of Japan's FIT scheme, 84 biomass power plants have been approved for funding, and additional consideration has been given to over 100 more projects (Thrän et al. 2017). The 20-year term of FITs allows Japanese consumers to purchase long-term supply contracts with other countries. From 2012 to 2017, Japanese imports grew 600% from 71,981 Mt to 506,353 Mt; the country imports 80% of consumption from Canada and 11% from Vietnam (Iijima 2017). To remain compliant with minimum generation efficiency requirements, 22 Japanese coal-firing power stations, producing over 200 MW, have announced intentions to co-fire wood pellets. One report reveals utilization rates of 1%, 5%, and 15% wood pellet mix in co-firing by these 22 stations have demand potentials of 0.8, 3.9, and 11.7 MMt per year, respectively (Strauss 2017a). However, Japanese demand by 2025 is estimated to be 9.5 MMt; half from co-firing power stations and a half from dedicated wood pellet power stations (Walker et al. 2018).

South Korean companies under the RPS are contributing to a steadily increasing demand. Imports grew 31%, 1.8 MMt to 2.4 MMt, from 2014 to 2017; 90% of 2017 imports were from Southeast Asian countries, mainly Vietnam (Mendell 2018). The country has become the world's third largest wood pellet market and is expected to continue growing (Walker 2018). Unlike Japan, South Korean buyers purchase pellets on a short-term basis due to uncertainty towards the value of tradeable RECs and a public tendering procurement system for fuels; the tendering system is used as part of an anti-corruption measure (Walker et al. 2018). Recent announcements from

Canadian producers negotiating with Korean buyers may be an indication of more long-term supply contracts with western countries in the future.

Trends in wood pellet supply have followed the upward trend in consumption. Since 2011, the industry has grown at an average rate of 14% per year (Thrän et al. 2017). Global production was estimated between six and seven MMt in 2006, which doubled to 14.3 MMt in 2010. By 2015, global production was over 26 MMt, of which more than one third was internationally traded. At the end of 2018, global production was estimated to be 36 MMt. The US, Canada, and Germany are the world's largest pellet producing countries.

The UK, Italy, Denmark, Germany, and Sweden consumed eight, 3.75, 3.5, 2.2, and 1.8 MMt, respectively (Flach et al. 2019). Consumption in Germany and Italy is primarily non-industrial. However, consumption in Denmark, Sweden, Belgium, the Netherlands, and the UK is primarily for energy production and contribute toward policy targets. Denmark, the UK, the Netherlands, and Belgium are the major importing countries, and the EU wood pellet market is expected to continue growing. However, further expansion may be limited by the sustainability criteria imposed by individual member states and/or a reduction in subsidies and incentives provided to power generating enterprises.

Rural and urban communities

We now turn our attention to the rural-urban resident dichotomy of perceptions across three dimensions, environmental, social, and economic. Rural communities are often associated with marginalization due to insufficient public infrastructures, population decline, transitioning economics and demographics, and geographic remoteness (Bock 2016). Rural communities are also associated with homogenous and under-developed areas, agricultural jobs, disadvantaged populations, low population density, and low social innovation. On the other hand, urban areas are defined by high population and building densities. Urban communities are associated with heterogeneous and developed areas, non-agricultural jobs, and high social innovation with sufficient public infrastructure.

The definition of rural areas in examining rural development has been met with much ambiguity. For example, regarding the social context of rural communities, Castro (2012) generalizes that the family is the most stable organization in rural communities. This synopsis is accurate for many

rural examples, but other modern literature suggests that rural communities contain remarkable heterogeneity and evolving nature, moving away from a generalized homogeneity and disadvantaged reputation (Campbell et al. 2004; Meador 2019; Diaz-Chavez 2019).

Based on the definition of rural areas provided by the US Census Bureau, the 2010 Decennial Census reported that almost 60 million people, 19% of the population, lived in rural areas (US Census Bureau 2019). Table 3 depicts the Rural-Urban composition of the US for the period from 1900 to 2010 (US Census Bureau, various years).

Table 3. Composition of the US in terms of Rural and Urban areas (1900-2010).

Year	Urban Area Composition	Rural Area Composition
1900	39.6%	60.4%
1910	45.6%	54.4%
1940	56.5%	43.5%
1950	64.0%	36.0%
1960	69.9%	30.1%
1990	75.2%	24.8%
2000	79.0%	21.0%
2010	80.7%	19.3%

Historically, the reduction of rural populations has been contributed to increased economic opportunities in large cities, resulting in patterns of migration from rural to urban areas for employment opportunities and increased social innovation, otherwise known as urbanization. Xie, Weng, and Fu (2019) found that urbanization is occurring more rapidly in the South compared to Northern states. As a result, rural communities in the region are losing valuable and necessary tax bases, experiencing overall economic losses much faster than that of urban areas. As people move away and local governments lose tax bases, a snowball effect occurs. Less tax money results in lower expenditures for public infrastructure, which further encourages people to migrate to urban areas.

The study

In this research, “pellet manufacturing facility” or “pellet mill” refers to a facility where industrial pellets are produced and “power station” refers to an industrial facility that produces energy in the

form of heat, electricity, or both. As the industrial wood pellet industry grows, it is vital to understand public perceptions, as they may have implications on the formation of policy, corporate investment in manufacturing facilities, the future of wood pellet bioenergy in the US, and future environmental, social, and economic impacts of this emerging industry.

The study region was composed of two main US South sub-regions where pellet production is concentrated; the Gulf Coast, including Louisiana and Mississippi, which utilizes softwood pine as primary feedstock and the South Atlantic Coast, including North Carolina, South Carolina, and Virginia, which utilizes hardwood as primary feedstock. In a companion article, we focus on regional differences across the same constructs and dimensions.

The study objective was to investigate attitudes, awareness, behaviors, perceptions, and underlying issues of the wood pellet manufacturing industry from perceptions of people that live in rural areas, specifically those living near or in communities where pellet mills are located compared to urban residents in the US South. Further, we examine environmental, social, and economic constructs and compare responses and profiles between these two groups. For the balance of this paper, rural equates to residents living within a 50-mile radius of a wood pellet mill.

METHODS

This study was conducted by administering a web-based survey to residents within a 50-mile radius of selected pellet mills (rural) and residents living within the two largest metropolitan statistical areas (MSA) (urban) in each state where these mills are located. Although it would be valuable to understand the pellet industry's perceptual dynamics from the perspective of many stakeholders, due to time and funding constraints, as well as the pressing need to study resident opinions, residents were the focal group.

The US Census Bureau defines urban areas as areas with a population of 50,000 or more people, and rural areas are defined as areas not included within an urban area. However, since zip code boundaries, rather than cities, were used to identify residents within a 50-mile radius of pellet mills, residents within the 50-mile radius were the rural sample and residents within MSAs were the urban sample. The Census Bureau defines MSAs as core areas containing a substantial

population nucleus, together with adjacent communities having a high degree of economic and social integration.

We combined regional respondents to focus on the rural-urban facet of the overall research. The rural segmentation yielded six wood pellet mills and while 10 MSAs fell into the urban segment. (Table 4 and Table 5). The 50-mile radius around mills was chosen to gather data from residents who potentially experience direct impacts from the industry, supply forest feedstock to mills, or live in rural communities. MSAs were elected to act as an urban comparison, contrasting the potentially more intimate mill radii.

An email list comprised of 7,500 residents, including demographic data, was purchased from the direct marketing services company, Exact Data. The list was randomly but proportionately selected by ZIP code and limited to residents 18 years or older that owned or rented homes within the collected ZIP code lists.

List parameters, spanning 171 counties and 1,139 ZIP codes for inclusion in the sample frame were: 1) Counties with a land mass of 50% or more contained within the 50-mile radii from selected pellet mills; 2) Counties within MSAs defined by the US Office of Management and Budget and; 3) Residents older than 18 years of age. As shown in Figure 4, the radii around mills 1 and 2 overlapped, as well as the radii around mills 2 and 3, causing duplicates amongst individual ZIP code lists. To resolve this issue, duplicates were kept in the list for mill 1 and deleted from the mill 2 list. The same procedure was followed for mills 2 and 3. Mill 2 maintained the duplicate codes, which were removed from mill 3. Duplicate ZIP codes also occurred between mill 3 and Baton Rouge and Memphis MSAs, mill 4 and Virginia Beach- Norfolk- Newport News MSA, mill 5 and Raleigh- Cary MSA, and mill 6 and Greenville- Mauldin- Easley and Columbia MSAs. To resolve this, every other duplicate was deleted from one list and maintained by the other. In the case that a mill's ZIP code list coincided with two MSAs, the procedure was repeated for the second MSA once the first was completed. In addition, ZIP codes with a population of zero were removed.

The quasi-control sample base of this study allowed us to draw comparisons between residential perceptions by proximity to pellet manufacturers, and in urban settings. These comparisons used demographic, knowledge, and perception data.

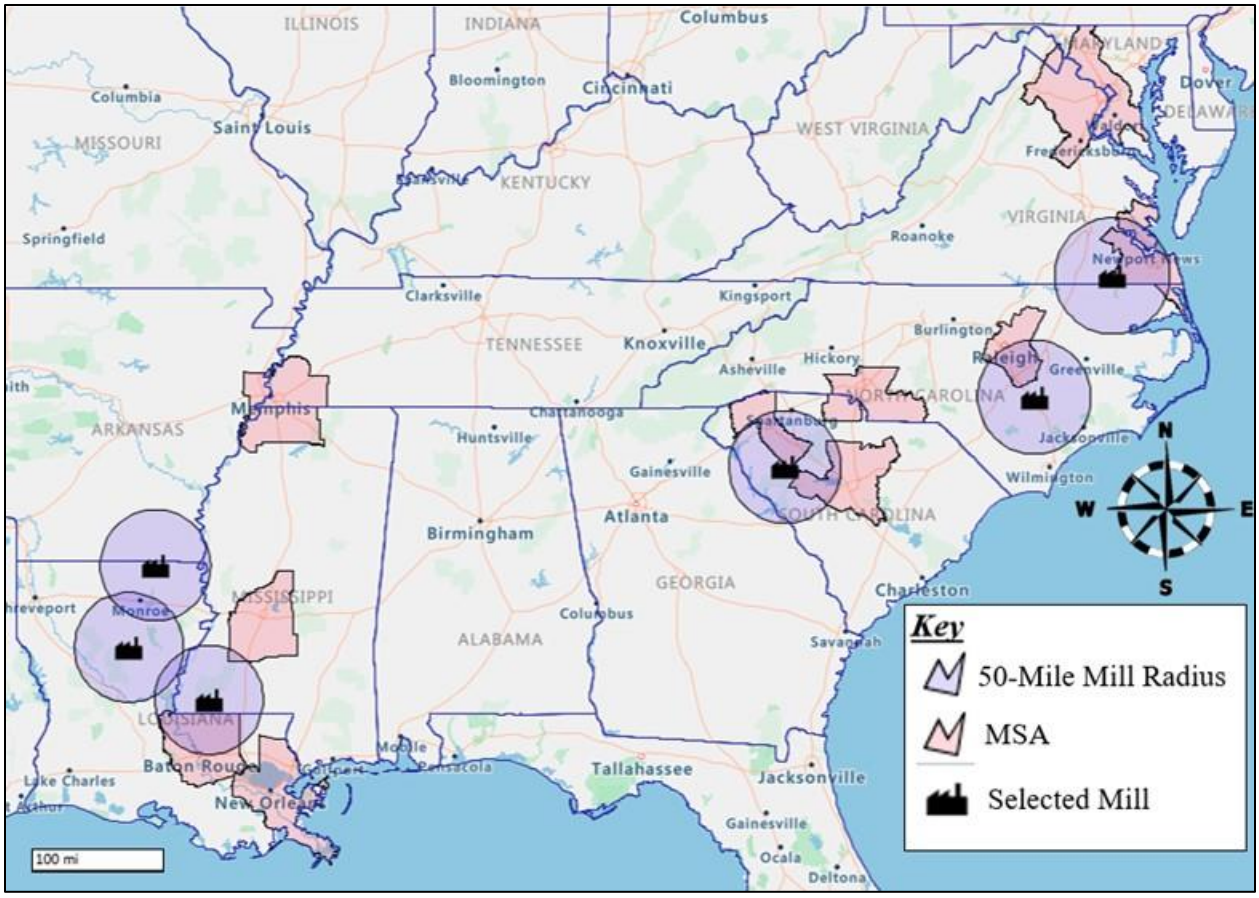

Figure 4. Study areas including six selected wood pellet mills and 10 metropolitan statistical areas (created using eSpatial)

Table 4. Wood pellet mills included in the study.

Mill	Morehouse	Lasalle	Amite	Southampton	Sampson	Greenwood
Company	Drax Biomass	Drax Biomass	Drax Biomass	Enviva LP	Enviva LP	Enviva LP
State	LA	LA	MS	VA	NC	SC
2019 Capacity (Metric Tons)	525,000	525,000	525,000	550,000	500,000	600,000

Table 5. Metropolitan statistical areas included in the study.

State	MSA 1	MSA 2
LA	New Orleans-Metairie	Baton Rouge
MS	Memphis	Jackson
NC	Charlotte-Gastonia-Rockhill	Raleigh-Cary
SC	Greenville-Mauldin-Easley	Columbia
VA	Washington-Arlington-Alexandria	Virginia Beach-Norfolk-Newport News

Survey instrument design and implementation

Environmental, social, and economic constructs were included in four sections within a web-based questionnaire. Each of the four sections contained questions regarding perceived impacts relevant to issues of the industry, such as pollution, effects to municipal infrastructure, and employment opportunities. An awareness section was included to measure the general awareness and knowledge of residents concerning the wood pellet manufacturing industry. The final section was comprised of socio-demographic inquiries to compare sample data to the population data gathered from data provided by the list company, ExactData.

The survey instrument contained fixed response, open-ended, and scale questions to measure the environmental, social, and economic constructs, which were independent variables influencing the dependent variable, company profiles. Scale questions were adapted from Likert-type scale found in Bruner, James, and Hensel's (2001) *Marketing Scales Handbook*, volume III, and Bearden, Netemeyer, and Haws (2011) *Handbook of Marketing Scal*es, 3rd edition. Open-ended questions were designed to give respondents the opportunity to present answers that were not included in the survey instrument.

Procedures, follow up efforts, and data analysis were implemented using a modified version of the Tailored Design Method (Dillman et al. 2014). The survey instrument was developed and administered using Survey-Monkey®. The initial mailing was sent to 7,500 recipient emails. A second mailing was sent 10 days after the initial mailing to non-respondents and partial respondents to remind them to complete the questionnaire. *At the time of the second mailing,*

Hurricane Dorian was threatening the Gulf and Atlantic Coasts, which may have impacted the ability of potential respondents in its path to complete the questionnaire, affecting the response rate of the survey.

Data management and analysis

The survey variables were exported from Survey-Monkey® into a database in Microsoft Excel® to ease the process of further analysis. The Excel database stored records of returned responses from each mailing, demographic variables from the list provider ExactData, and data obtained by the survey instrument. Statistical analysis of the data was performed using SPSS version 25; a statistical program widely used in social science research. Descriptive statistics, including frequencies and mean responses, independent sample two-tailed t-tests, χ^2 test, and Analysis of Variance (ANOVA) tests were utilized for the analysis.

RESULTS

Response rate and respondent demographics

Of the 7,500 surveys administered, 1,112 were either undeliverable or inappropriate due to respondents' previous unwillingness to participate in Survey-Monkey® based surveys, or their unwillingness to participate in this survey. The total number of useable surveys received was 122, for an overall adjusted response rate of 2%. *Due to such a low response rate, the study can only be positioned as exploratory.*

An adjusted response rate was calculated using the following formula:

Adjusted Response Rate = Useable Surveys / [Total Sample – (Undeliverables + Unusables)] %

Nonresponse bias was measured using an independent sample two-tailed t-test conducted on age, zip code, and income, comparing respondents and non-respondents that did not fall into the undeliverable or unusable categories. No statistically significant difference was detected at $\alpha = 0.05$ significance level. In addition, research has shown that late respondents typically respond similarly to non-respondents (Armstrong and Overton 1977). Accordingly, respondents to the second mailing were used as a proxy for non-respondents and compared to first mailing respondents using 84 continuous variables. Less than 5% of all continuous variables comparing

first and second mailing respondents were found to be statistically significantly different at α = 0.05 significance level; therefore, nonresponse bias was not a problem.

Approximately 53.8% (n=65) of respondents were female. Annual 2018 household income was more than $100,000 for 52.3% (n=63) of respondents, and 58.5% (n=65) were 55 or older. In terms of ethnicity, 84.4% (n=64) of respondents were white or Caucasian and 66.2% (n=65) have a college (B.S. or B.A.) or advanced degree (M.S., Ph.D., MBA, JD). As for political affiliation, 38.5% identified as Republican while 33.8% identified as Democrat and 16.9% identified as independent (n=65). The density of responses received is geographically represented by Figure 5, which was based on respondent ZIP codes. Of the 122 respondents, 72.1% were urban and 27.9% were rural with some overlap occurring (Figure 6).

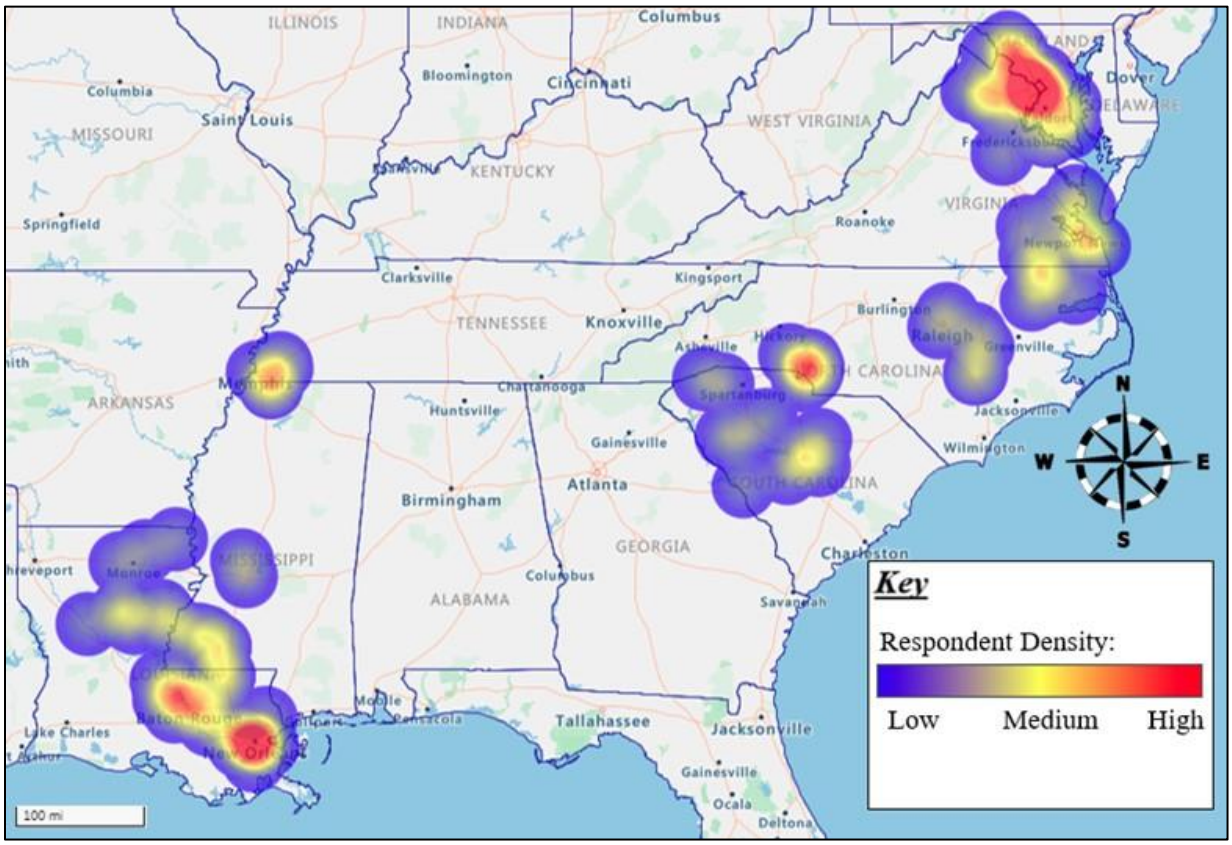

Figure 5. Geographic distribution and density of responses (n=122).

Urban and rural comparisons

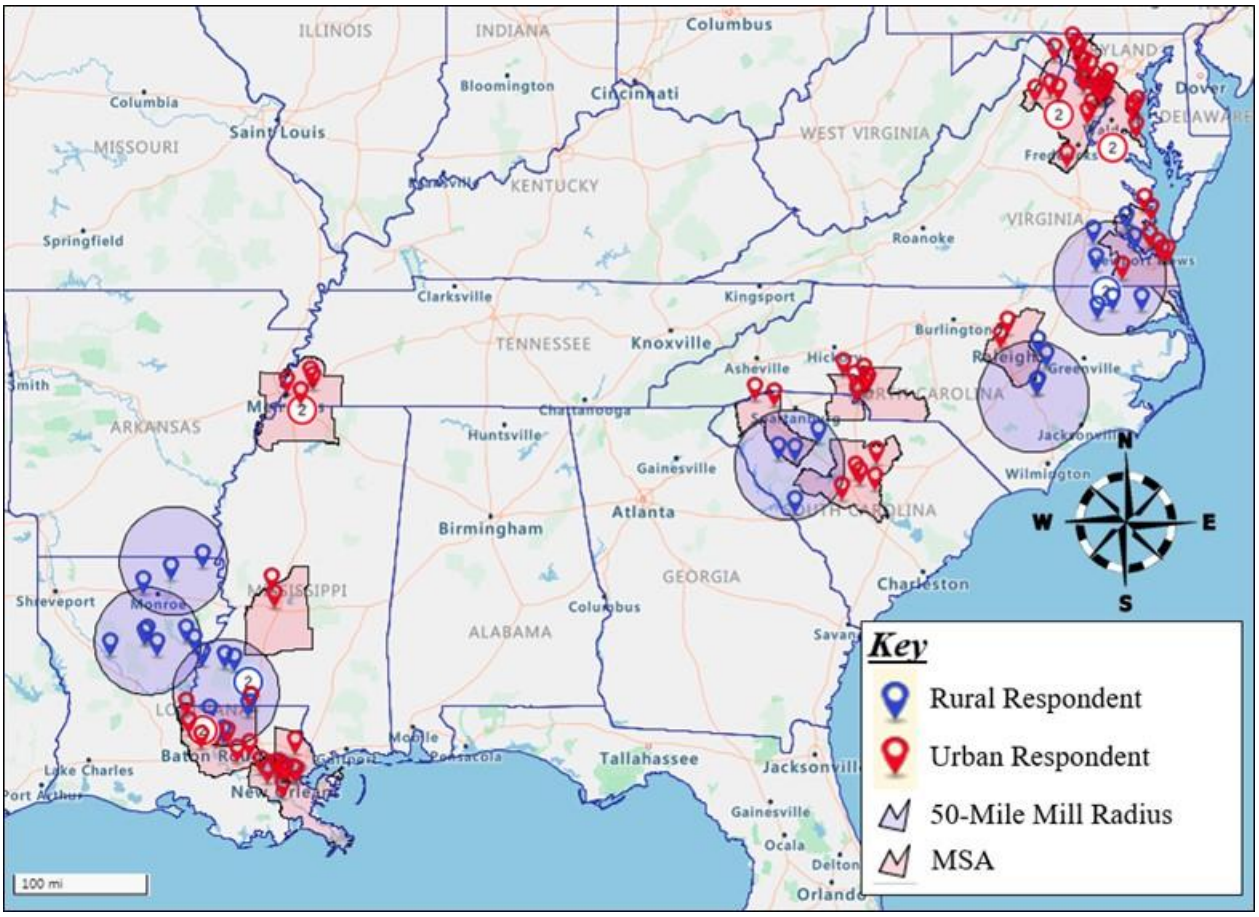

Figure 6. Map of urban and rural respondents with overlap indicated (n=122).

General awareness and knowledge of the wood pellet industry

Using an independent sample two-tailed t-test, rural respondents reported a statistically significant higher awareness of the wood pellet manufacturing industry compared to urban respondents (p=0.007 at $\alpha = 0.05$) (Figure 7). The mean response to this question was 2.2 for urban respondents and 3.0 for rural respondents on a five-point Likert-type scale (1=Not at all aware; 2= Not very aware; 3= Neither aware nor unaware; 4= Somewhat aware; 5= Very aware). Also, when asked if they were aware of any pellet manufacturers, 51.9% of rural respondents reported they were compared to 21.7% of urban respondents.

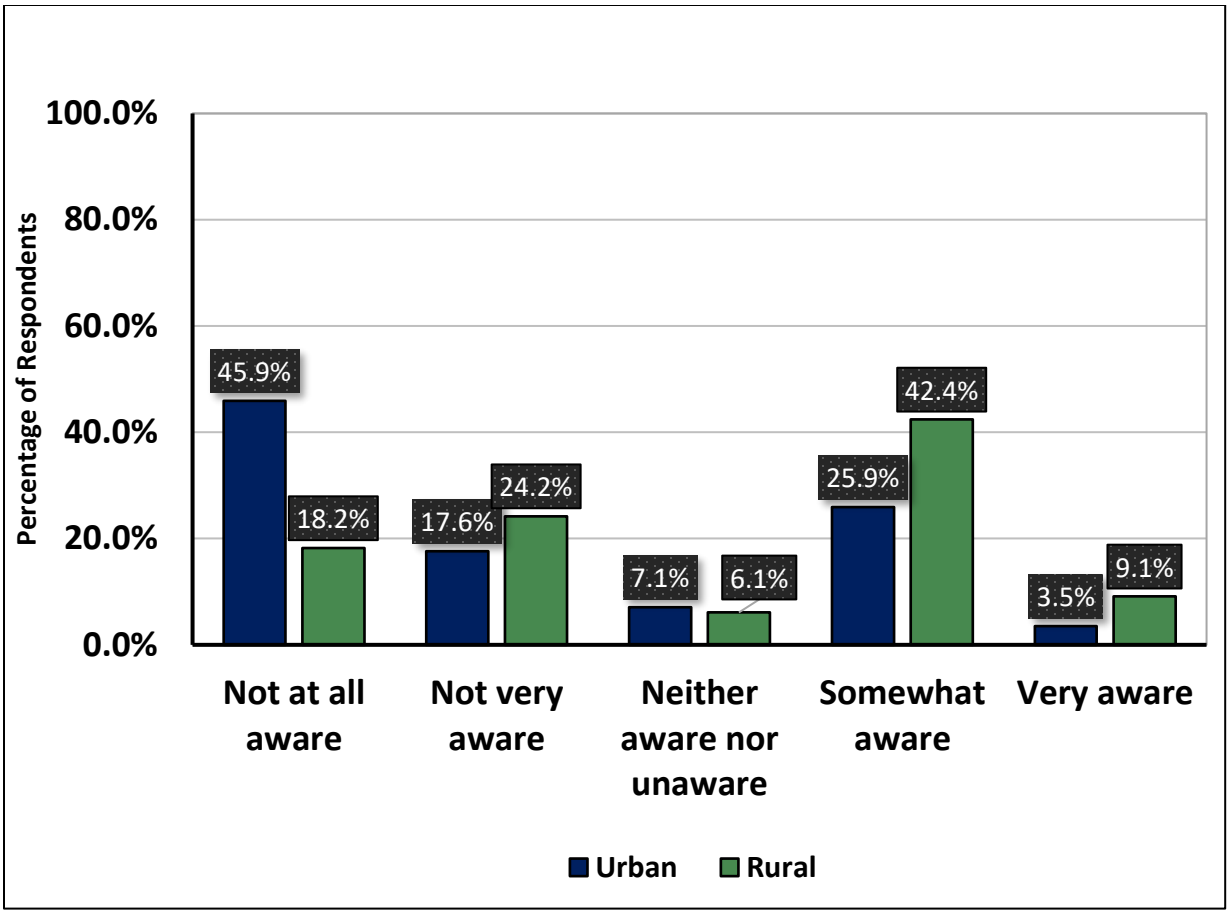

Figure 7. Awareness of the wood pellet manufacturing industry (n=118) (1=Not at all aware; 2= Not very aware; 3= Neither aware nor unaware; 4= Somewhat aware; 5= Very aware)

Independent sample two-tailed t-tests were employed to examine whether the awareness and knowledge of pellet manufacturers and industry differed between rural and urban respondents (Table 6). The difference in means of both items were statistically significant between urban and rural respondents at $\alpha = 0.01$ significance level, indicating rural respondents were more aware of manufacturers in their states and knowledgeable about the industry because of their higher mean answers. However, the means of the second item were both below the neutral point of three which indicated that neither group claimed to be very knowledgeable about the industry.

Table 6. Awareness and knowledge of the wood pellet manufacturing industry (n=68) (1=Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

Item	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
I am aware of wood pellet manufacturers in my state.	2.0	3.3	*p*=0.000**
I am very knowledgeable about the wood pellet manufacturing industry.	1.8	2.5	*p*=0.008**

Figures 8 and 9 present what urban and rural respondents think wood pellets are made from and what they are used for, respectively. Both figures are ranked in descending order based on urban responses.

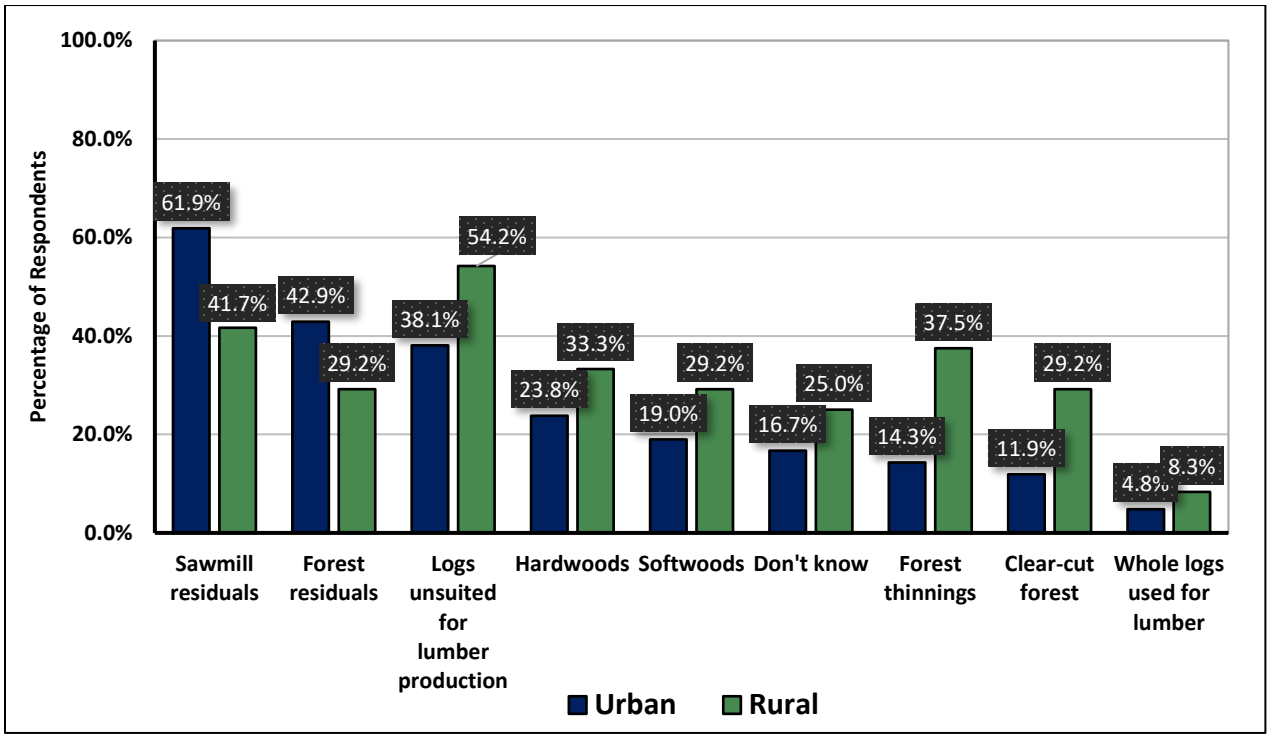

Figure 8. What urban and rural respondents think wood pellets are made from (n=66) (Multiple responses possible).

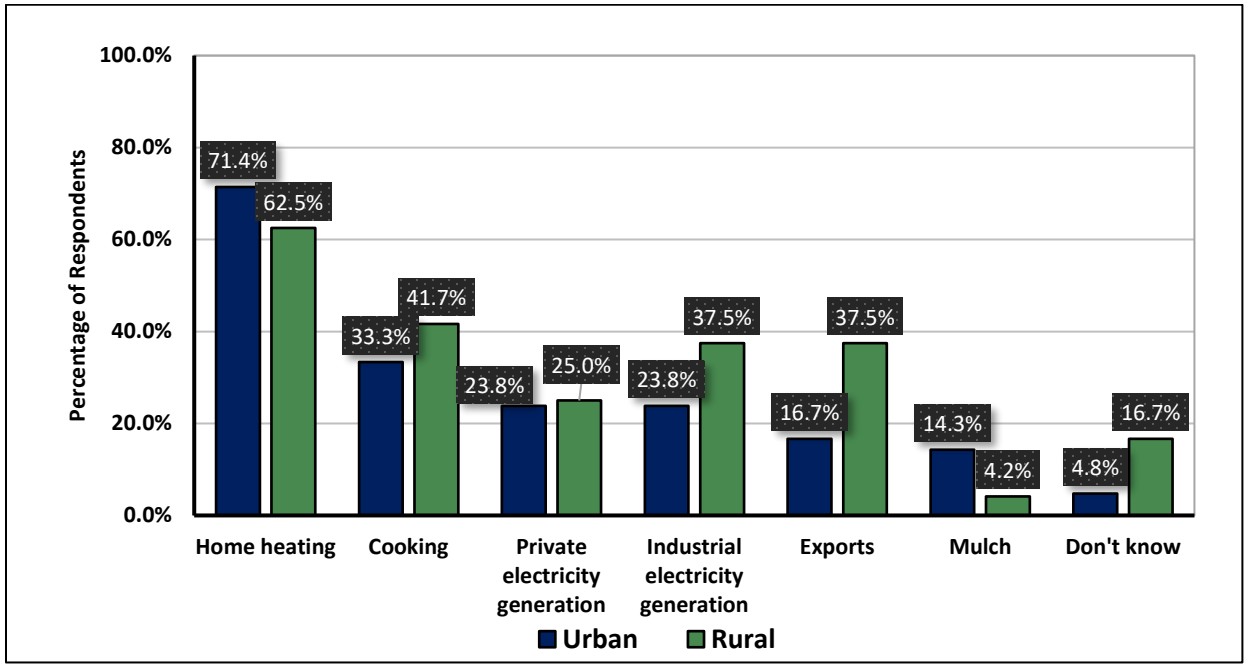

Figure 9. What urban and rural respondents think wood pellets are used for (n=66) (Multiple responses possible).

Environmental, social, and economic perceptions

Respondents were asked to rank their level of agreement for three banks of statements to examine environmental, social, and economic perceptions on five-point Likert-type scales (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree). Tables 7, 8, and 9 summarize the results by providing mean responses between urban and rural respondents as well as P-values from independent sample two-tailed t-tests between means.

An adapted version of the New Environmental Paradigm scale (Dunlap et al. 2000) was used to gauge the environmental affinity of respondents and is presented by Table 7. Five items were statistically significantly different between urban and rural respondents at $\alpha = 0.05$ significance level, including two that were significantly different at $\alpha = 0.01$. For these five items, urban respondents reported a statistically significantly higher environmental affinity. Urban respondents more strongly disagreed that "the balance of nature is strong enough to cope with the impacts of industrialization", "climate change caused by humans has been greatly exaggerated", "humans were meant to rule over the rest of nature", and "climate change is a naturally occurring phenomena, not caused by humans." Urban respondents more strongly agreed that "humans are

accelerating the rate of global warming." Even though the difference of five items were not statistically significant, the means showed that overall, people that live in urban areas have a greater affinity for the environment and were generally more concerned with humans producing negative impacts on the environment.

Table 7. Environmental affinity of respondents (n=98) (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
Humans have the right to modify the environment to suit their needs.	2.6	2.7	*p*=0.692
Human economic needs are more important than protecting the environment.	2.0	2.2	*p*=0.338
When humans interfere with the environment it often produces disastrous consequences.	3.9	3.7	*p*=0.446
The balance of nature is strong enough to cope with the impacts of industrialization.	2.0	2.6	*p*=0.015*
Humans are accelerating the rate of global warming.	3.8	2.9	*p*=0.003**
Climate change caused by humans has been greatly exaggerated.	2.7	3.5	*p*=0.016*
Humans were meant to rule over the rest of nature.	2.2	3.0	*p*=0.008**
Humans will eventually learn enough about global warming to be able to control it.	2.7	2.6	*p*=0.48
If things continue on their present course, we will soon experience a major climate change catastrophe.	3.4	2.9	*p*=0.074
Climate change is a naturally occurring phenomena, not caused by humans.	2.5	3.3	*p*=0.011*

Five statements related to social/ community issues were used to evaluate the social aspect of respondents as they relate to natural resources, recycling, and the environment within their community (Table 8). Both groups were generally concerned about the environmental impacts of companies and natural resources within their community and were generally willing to be

inconvenienced in order to positively affect their community. Two items were statistically significantly different between urban and rural respondents at α = 0.05 significance level, including one that was significantly different at α = 0.01. Urban respondents more strongly agreed that themselves or their family recycle and that their community offers a recycling program. However, as stated in the literature review, rural areas generally have insufficient public infrastructure compared to urban areas. Therefore, the difference in recycling practices and programs was to be expected.

Table 8. General social behavior and perceptions of respondents (n=93) (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
It is important to me that the companies in my community do not harm the environment.	4.3	4.1	*p*=0.316
I/my family recycles materials such as glass, plastic, and paper.	4.1	3.2	*p*=0.002**
My community has a recycling program in place for materials such as glass, plastic, and paper.	3.9	3.1	*p*=0.012*
I am generally concerned about the natural resources in my community such as forest, air, and water.	4.3	4.3	*p*=0.972
I am willing to be inconvenienced in order to participate in recycling that is environmentally friendly in my community.	4.0	3.8	*p*=0.450

General economic perceptions were evaluated using seven statements related to local economic conditions and government support (Table 9). Although the difference was not statistically significant, respondents from urban areas agreed more that governments should provide financial support to develop local businesses compared to rural respondents, who agreed more that industry should stand on its own. Only one item was statistically significantly different between the groups at α = 0.01 significance level. Urban respondents more strongly agreed that their community has a strong economy. Once again, this was to be expected since rural areas are generally associated *with marginalization.*

Table 9. General economic perceptions of respondents (n=91) (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
Job creation is important to my community.	4.3	4.5	*p*=0.304
My community has a strong economy.	3.8	2.9	*p*=0.001**
A strong economy is important to my community.	4.5	4.4	*p*=0.638
Local government should provide financial support to develop/ maintain businesses in my community.	3.3	3.0	*p*=0.364
State government should provide financial support to develop/ maintain businesses in my community.	3.3	3.1	*p*=0.618
The Federal Government should provide financial support to develop/ maintain businesses in my community.	3.2	2.9	*p*=0.410
Industry should stand on its own without government support/ intervention.	3.3	3.4	*p*=0.623

Respondents were asked to provide their level of agreement on a five-point Likert-type scale regarding the need for different sources of energy to be a priority in the US. According to independent sample two-tailed t-tests, no statistically significant difference was found between urban and rural respondents at α = 0.05 significance level. The means of both groups ranked solar followed by hydro energy to be the highest priorities, while woody biomass ranked third to last, and coal the least prioritized (Figure 10).

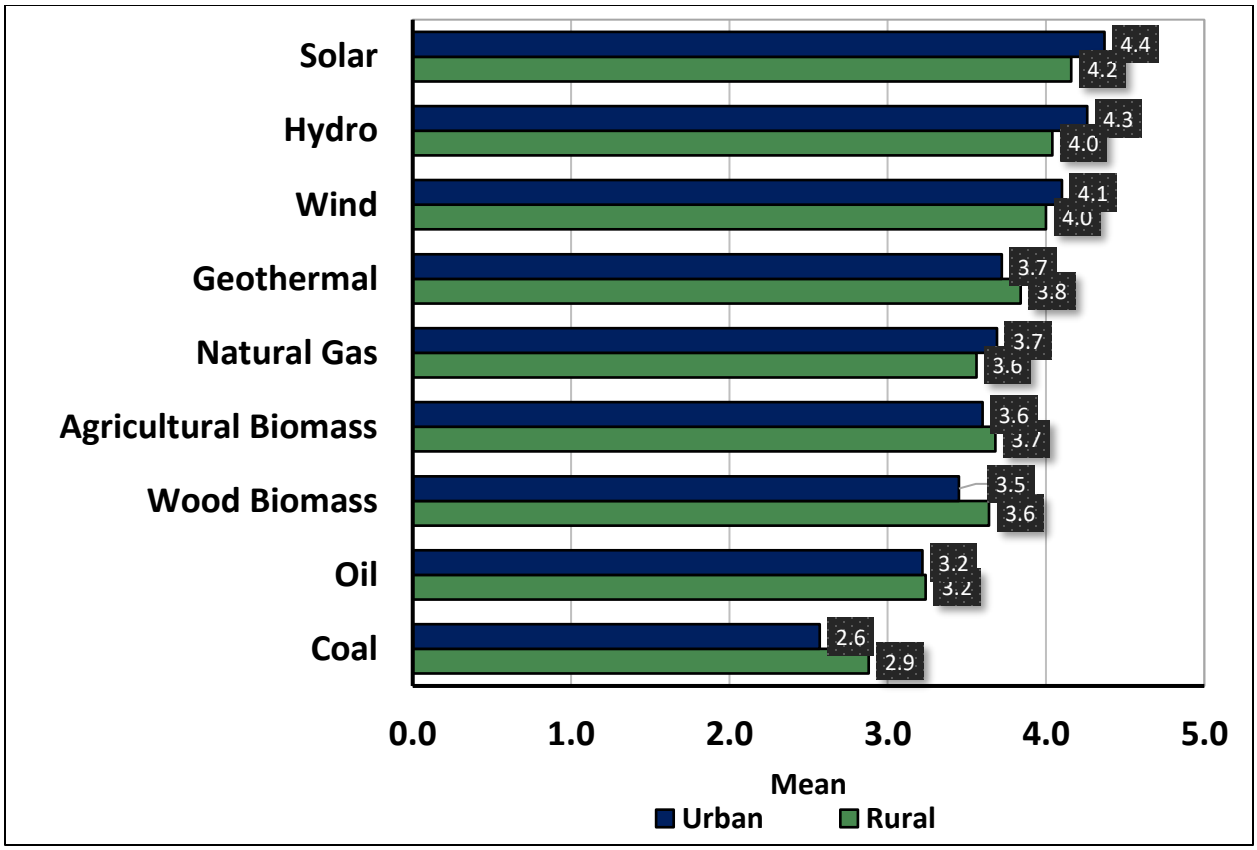

Figure 10. Different sources of United States energy ranked by respondent priority (n=84) (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

Respondents were also asked for their level of agreement regarding wood pellets as a viable energy alternative to fossil fuels (Figure 11). Although no statistically significant difference was found at $\alpha = 0.05$ significance level, the means were 3.1 for urban respondents and 3.5 for rural respondents on a five-point Likert-type scale (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree), indicating that people living in rural areas thought wood pellets to be more viable compared to urban areas. Similarly, the overall opinion of using wood pellets for energy was more positive from rural respondents than that of urban respondents, although the difference was not statistically significant at $\alpha = 0.05$ significance level). Utilizing a five-point Likert-type scale, means of 3.3 and 3.6 were determined for urban and rural respondents, respectively. Both groups had a generally positive opinion of using wood pellets for energy with 46.3% of urban and 52.2% of rural respondents reporting either somewhat positive or extremely positive.

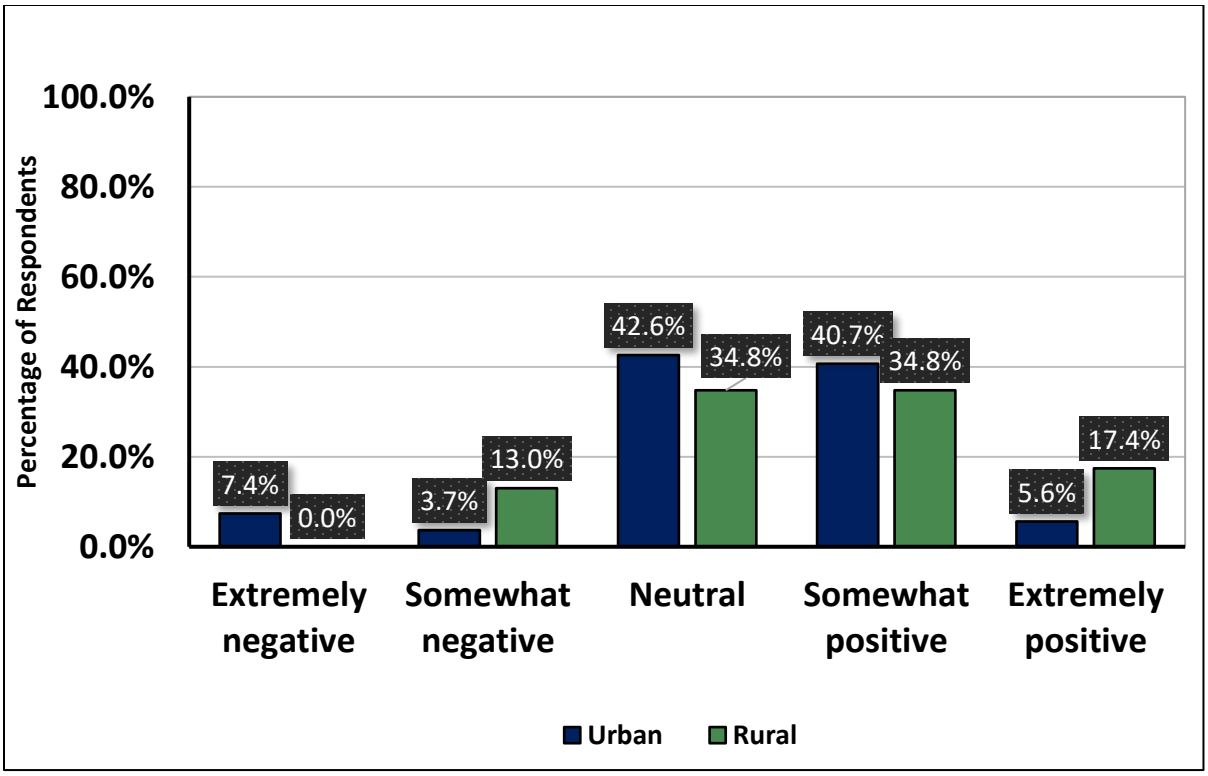

Figure 11. Overall opinion of using wood pellets for energy (n=77) (1= Extremely negative; 2= Somewhat negative; 3= Neutral; 4= Somewhat positive; 5= Extremely positive).

Environmental perceptions of the wood pellet manufacturing industry

The questionnaire evaluated residents' trust and perceptions of the wood pellet manufacturing industry's environmental responsibility and impacts. Respondents were asked to rank their level of agreement on five-point Likert-type scales (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree). Table 10 summarizes urban and rural responses regarding five environmental statements dealing with the industry. Overall, respondents were generally neutral toward these statements. An independent sample two-tailed t-test revealed that the mean difference of one of these statements was statistically significant between urban and rural respondents at $\alpha = 0.05$ significance level. Rural respondents more strongly agree that the industry is effective in its efforts to protect the environment.

Table 10. Environmental perceptions regarding the wood pellet manufacturing industry (n=79) (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
I trust the wood pellet manufacturing industry to act in the best interest of the environment.	3.2	3.2	*p*=.706
I think the wood pellet manufacturing industry utilizes appropriate forest management practices.	3.2	3.4	*p*=0.225
Currently, the wood pellet manufacturing industry is effective in its efforts to help protect the environment.	3.1	3.4	*p*=0.045*
Wood pellets are an environmentally superior alternative method of energy generation relative to fossil fuels.	3.1	3.5	*p*=0.051
Harvesting trees to manufacture wood pellets is not harmful to the environment.	2.8	3.3	*p*=0.061

Respondents were also asked to give their opinion of the impact that the wood pellet manufacturing industry has on six environmental items using a five-point Likert-type scale (1= Extremely negative; 2= Somewhat negative; 3= Neutral; 4= Somewhat positive; 5= Extremely positive). The average mean for all six items was used to develop an environmental impact index. Table 11 summarizes rural and urban responses on these six items and the index. Items are ranked by least negatively impacted to most negatively impacted by average of the means with the index at the bottom. Using an independent sample two-tailed t-tests, two items were found to be significantly different between urban and rural respondents at α = 0.05 significance level. The industry's impact on "wildlife habitat" and "sustainable forests" was perceived more negatively by people that live in urban areas. Although the differences were not all statistically significant, respondents from urban areas reported that the industry more negatively impacted all environmental items compared to rural respondents.

Table 11. Opinions of the wood pellet manufacturing industry's environmental impacts (n=73) (1= Extremely negative; 2= Somewhat negative; 3= Neutral; 4= Somewhat positive; 5= Extremely positive).

	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
Air Quality	2.7	2.9	*p*=0.475
Soil Quality	2.9	3.1	*p*=0.287
Water Quality	2.9	3.1	*p*=0.206
Forest-based Recreation	2.8	3.2	*p*=0.107
Wildlife Habitat	2.7	3.2	*p*=0.018*
Sustainable Forests	2.9	3.4	*p*=0.012*
Environmental Impact Index	2.8	3.1	*p*=0.073

Social perceptions of the wood pellet manufacturing industry

The questionnaire evaluated residents' perceptions of the wood pellet manufacturing industry's social concern and contribution toward local communities. Respondents were asked to rank their level of agreement on five-point Likert-type scales (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree). Table 12 summarizes urban and rural responses regarding six social statements dealing with the industry. Overall, respondents living in rural areas reported a higher level of agreement with all of the statements, indicating that rural respondents more approved of the industry's social interactions compared to urban respondents. These findings may be a result of the rural respondents' 50-mile proximity to and more intimate interactions with the industry. Independent sample two-tailed t-tests revealed that four of the six statements were statistically significantly different between urban and rural respondents at α = 0.05 significance level, including two mean differences that were statistically significant at α = 0.01. Rural respondents more strongly agree that the wood pellet manufacturing industry "is concerned about the needs of communities", "is a good industry to work for", "creates quality jobs", and "is a superior industry for communities."

Table 12. Social perceptions regarding the wood pellet manufacturing industry (n=68) (1= Strongly disagree; 2= Somewhat disagree; 3= Neutral; 4= Somewhat agree; 5= Strongly agree).

	Urban $\bar{x}$	Rural $\bar{x}$	Significance (at α=0.05)* (at α=0.01)**
Contributes to community activities and services.	2.9	3.1	*p*=0.132

Contributes to community economic health.	3.1	3.4	p=0.112
Is a superior industry for communities.	3.1	3.4	p=0.041*
Is concerned about the needs of communities.	2.8	3.3	p=0.030*
Creates quality jobs.	3.2	3.7	p=0.002**
Is a good industry to work for.	3.0	3.5	p=0.001**

Respondents were also asked to rank their level of concern regarding 11 social issues associated with converting wood to pellets for energy production; on five-point Likert-type scales (1= Not concerned at all; 2= Not very concerned; 3= Neutral; 4= Somewhat concerned; 5= Very concerned). The means of these 11 social issues were averaged for all respondents to create a production concern index. Although independent sample two-tailed t-tests did not reveal any statistically significant differences between urban and rural respondents at $\alpha = 0.05$ significance level, urban respondents had a higher production concern index of 3.5 compared to the rural 3.3, indicating that urban respondents were more concerned with production issues compared to rural. In fact, urban respondents were more concerned with seven of the 11 issues presented, including "Air pollution", "Forest degradation", "Soil degradation", "Damage to forest health", "Water pollution", "Safety due to increased road traffic", and "Noise pollution from pellet manufacturers."

Figures 12 and 13 present the social issues ranked in order of highest to lowest concern for urban and rural respondents, respectively.

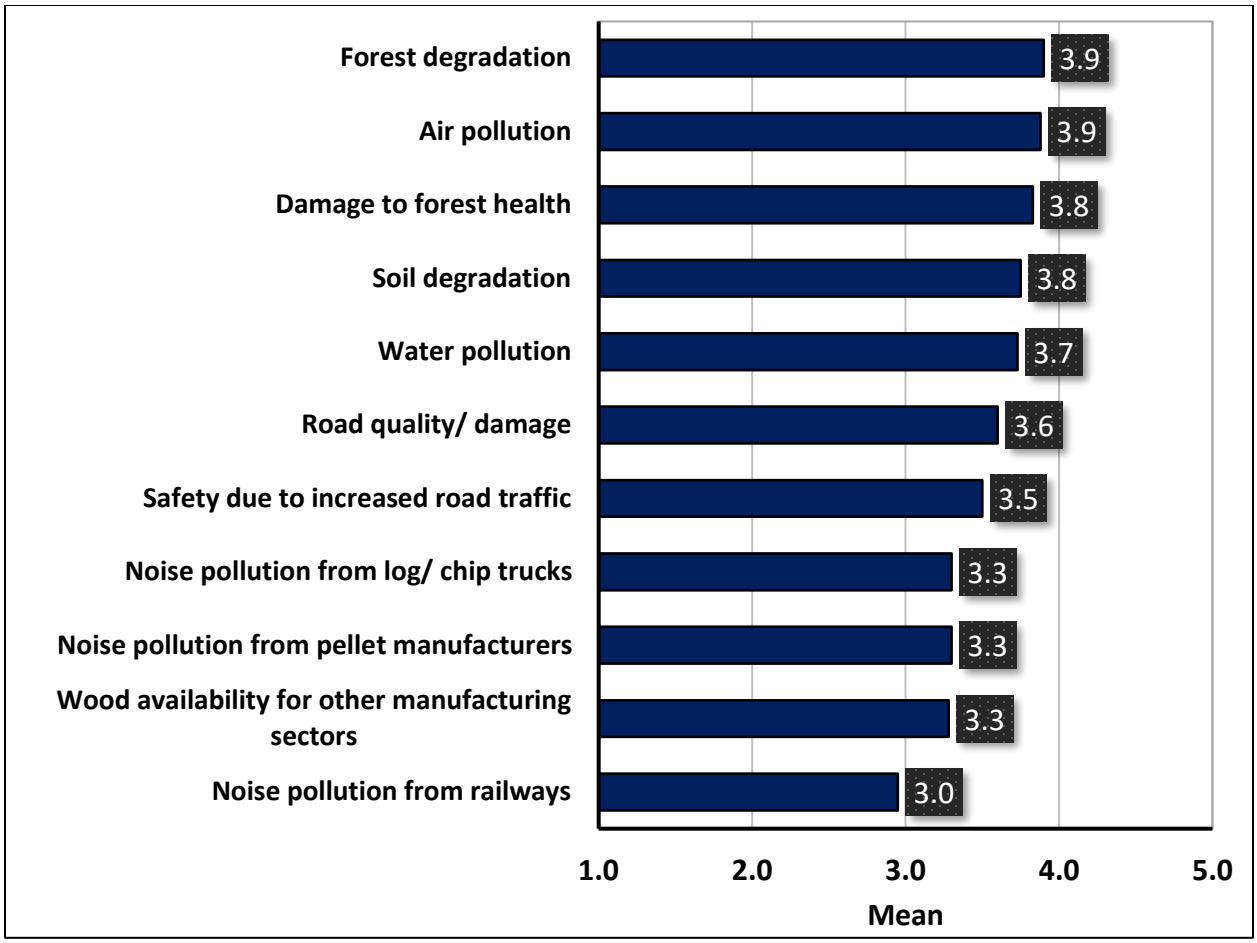

Figure 12. Social concerns of urban *respondents (n=40) (1= Not concerned at all; 2= Not very concerned; 3= Neutral; 4= Somewhat concerned; 5= Very concerned).*

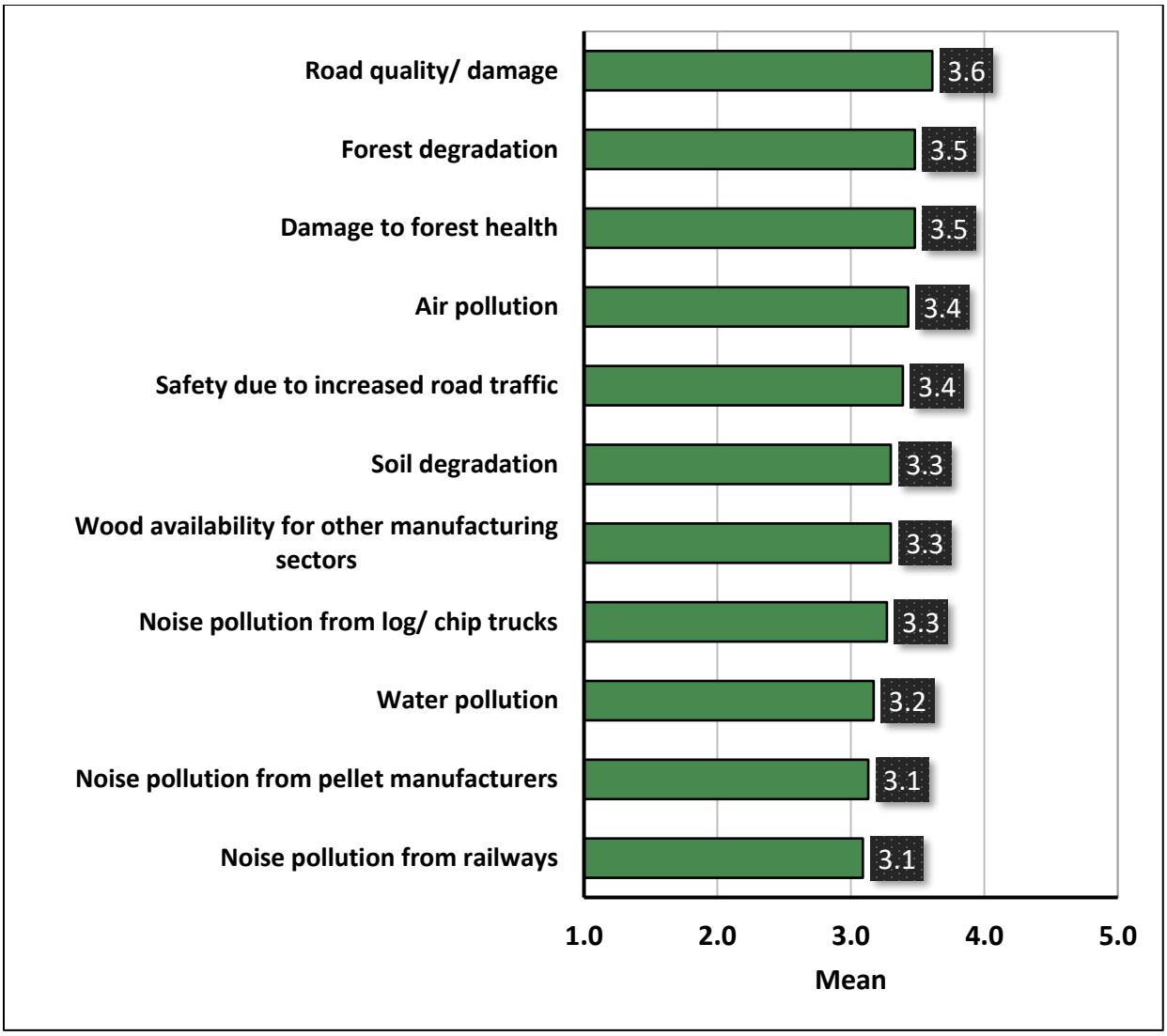

Figure 13. Social concerns of rural *respondents (n=23) (1= Not concerned at all; 2= Not very concerned; 3= Neutral; 4= Somewhat concerned; 5= Very concerned).*

Economic perceptions of the wood pellet manufacturing industry

Of the 30% of respondents that owned forestland in their state of residence, 35% were urban respondents and 65% were rural. On average, respondents from urban areas owned 19 more acres of forestland compared to respondents from rural areas. Using an independent sample two-tailed t-test it was determined that there was no statistically significant difference at $\alpha = 0.05$ significance level between urban and rural respondents regarding the amount of forestland owned.

Respondents were asked to indicate the types of financial support that they believe local, state, and federal governments should provide to the wood pellet manufacturing industry from a list that

included “Property Tax Incentives”, “Sales Tax Incentives”, “Investment Tax Credits”, Job Creation Incentives”, and “Development Grants.” Overall, state government received the largest proportion of responses from both urban (46.2%) and rural (43.1%) respondents across all items, indicating respondents from both areas thought government funding should primarily be provided by state governments.

DISCUSSION AND CONCLUSIONS

In this study we sought to determine the attitudes, awareness, behaviors, perceptions, and underlying issues of the industry from perceptions of the general public, specifically those of residents living near or in communities where pellet mills are located (rural) and residents within the two largest MSAs of each state where selected mills are located (urban). This research better frames these issues from the perspectives of Southern residents and helps to identify relationships between the wood pellet manufacturing industry and the general public.

Results suggest that rural respondents were more aware of the wood pellet manufacturing industry and more strongly approved of the industry’s environmental, social, and economic impacts and contributions toward local communities. Rural respondents were less concerned about negative environmental and social impacts of the pellet industry and generally had a more favorable view of the economic contributions the pellet industry offers. Specifically, rural respondents reported only air quality to be negatively impacted, while urban respondents reported all environmental items to be negatively impacted.

Similarly, rural respondents were less concerned with social issues the pellet industry could influence compared to urban respondents. The economic benefits of the wood pellet manufacturing industry for rural areas seemed to outweigh the environmental and social impacts. Rural respondents generally held the wood pellet manufacturing industry in higher regard compared to urban respondents.

Implications and future research

The general public is an important stakeholder in the context of any extractive industry such as coal, minerals, oil, natural gas, and forest products. The human, social, and financial capital influencing the general public are of significant interest to extractive-centric enterprises seeking

long-term success. Transparent and responsible use of natural resources are expected by local communities in return for these sources of capital. In the context of the wood pellet manufacturing industry, initiatives are being developed by companies to better communicate environmental efforts though community outreach programs. There is a significant gap in the knowledgebase and research regarding business-community relationships of the wood pellet manufacturing industry. Scant primary empirical research has been conducted that examines the environmental, social, and economic perceptions of residents as they relate to the industry.

We hope that the results of this exploratory research can open the door to further examination of how wood pellet manufacturing companies can develop or improve community engagement initiatives. The revelation of environmental, social, and economic perceptions of this emerging industry allows companies in the South to better align their goals to that of resident public perception and examine potential future impacts based on respondent perceptions. The research findings can also be useful to local and state governments for formulating new policies to promote and ensure sustainable forest management practices are adhered to in order for wood pellet to operate. In the future, public policy is likely to place increasing importance on environmentally responsible business practices that affect the overall health of the general public, sustainability of natural resource extraction, and mitigation of climate change.

This study suffered from a low response rate and, as such, can only be cast as exploratory. The lack of non-response bias is encouraging but a larger sample frame would offer more than a glimpse of rural and urban resident perceptions of the wood pellet industry in the US South.

Going forward, future research should investigate perceptions from a broader range of stakeholders involved with the wood pellet manufacturing industry. An examination of perceptions from forest landowners, supply chain intermediaries, government entities, and the pellet industry itself would further help to understand perceptions and overall attitudes toward the wood pellet manufacturing industry.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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