The public perception and acceptance of wood-based bioenergy developments in the United States and beyond: Opportunities and Constraints

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A Thesis Submitted to the Honors College in Fulfillment of the Honors Minor

University of Wyoming

Summer 2020

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Abstract

Wood-based bioenergy (WBB) development is gaining interest domestically and globally, and its public acceptance is a significant component when determining implementation and achievement. This study investigated a deeper understanding of how and why economic, socio-cultural, historical, and ecological contexts have influenced the perceptions and acceptance of wood-based bioenergy, particularly in the United States, but also in some parts of the world. The aim of this research is to utilize literature that apply a range of methodologies which are used to enhance understanding of the local acceptance of WBB development. Methodologies used are described in further detail below, some include using a community capital framework (cultural capital) and social-ecological models (SES) with ethnographic methods (i.e semi-structured interviews, surveys, data analysis, and participant observation). Furthermore, this paper highlights the importance of social science research and methods in sustainable development, particularly its significance when addressing the opportunities and constraints made by communities when developing WBB. Results from reviewed literature suggest while there is support for bioenergy development, there are economic, political, and historical constraints that halt the development and use of wood-based bioenergy. This paper will be organized by opportunities and constraints found in reviewed literature as well as arranged into separate regions throughout the United States or placed in a separate category for case studies found outside the United States. The purpose of this is to 1) understand and unveil any connections between the community perceptions found in reviewed literature, and 2) make recommendations for future development of wood-based bioenergy.

Introduction and Background

Forests throughout the western United States and Canada have been undergoing unprecedented natural disturbances and ecological changes produced by the Mountain Pine Beetle (MPB), *Dendroctonus ponderosae*. In this region, the MPB have been infesting trees for at least 35 million years and are considered a native species, yet their populations have been increasing at faster rates due to rising temperatures and more frequent droughts (Jensen-Ryan et al. 2018). The results of the MPB epidemic have resulted in a significant tree mortality to more than 60 million acres across the Rocky Mountains in the western US and Canada (National Geographic 2015). Recent studies have found that climatic conditions, especially drought, more so affect the severity of forest health, which can result in forest fires. Climate change impacts comprising of increased temperatures, altered precipitation regimes, and increased trends of

drought has intensified the frequency, extent, and severity of pest and pathogen disturbances and catastrophic wildfires (Beeton et al. 2017, Allen et al. 2010, Bentz et al. 2009), Dennison et al. 2014). These ecological changes have been reinforced by social and historic management trends, such as fire suppression and former logging operations at the start of the twentieth century (Beeton et al. 2017, Haugo et al. 2010, Lyderson et al. 2013, BANR 2019). Although, the result of beetle-killed wood represents a vast bioenergy resource that requires no cultivation, circumvents food-versus-fuel concerns, and may have a highly favorable carbon balance compared to other forestry feedstocks (BANR 2019).

Wood-based bioenergy (WBB) development is gaining interest domestically and globally, and its public acceptance is a significant component for determining implementation and achievement. The utilization of WBB has been argued as a mechanism to mitigate the impacts of climate change, minimize greenhouse gas (GHG) emissions, reduce fire vulnerability, and to enhance rural economic development (Beeton et al. 2017, Neary et al. 2007, Schelhas et al. 2018, Mansuy et al. 2018, She et al. 2019, Takala et al. 2020, White 2016). Various concepts for carbon dioxide removal or sequestration have been proposed, such as the technologies that involve bioenergy, which is the production of fuels, electricity, or heat from biomass. These bioenergy developments have been successfully employed in select parts of the globe. Small mills spreading across the Rocky Mountains, like in Kremmling, Colorado, where Confluence Energy's wood-processing plant uses the material sawmills and loggers throw away, then turns it into a variety of products, including wood pellets that can be used to heat homes (Russell 2014). The plant can produce up to 80,000 tons of refined material per year, about 30,000 tons of which is used for wood pellets. Other places in the world like in eastern Finland, where forest regeneration has increased up to 50% in the last decade, has resulted in the growing, cultivation,

and careful management of trees for bioenergy (IRENA 2018). In the western United States and Canada, some species of trees take up to 15 years to reach full maturity; therefore, using fallen trees due to the MPB epidemic and natural disasters would be the best option for WBB development in this region. Where the MPB epidemic resulted in millions of down, or soon to be fallen beetle-kill trees, bioenergy development has been proposed to restore forest health, promote economic growth, and reduce climate change impacts.

The historical and contemporary socio-cultural, economic, and ecological contexts can enable or constrain the success of WBB development. Social acceptance has been found to be significant when implementing sustainable plans or actions, where within the three pillars of sustainability (economic, ecological, and social), one cannot thrive without the others (White 2016, Myllyviita et al. 2012). Myllyviita et al. suggests that cultural sustainability should be added to the pillars of sustainability due to the importance of cultural values when developing sustainable biomass production and forest management (Myllyviita et al. 2012). Cultural sustainability can be defined as 'the ability to retain cultural identity and to allow change to be guided in ways that are consistent with the cultural values of a people' (Sustainable Development Research Institute 1998, from Myllyviita et al. 2012). There are studies that suggest that there is a lack of public knowledge and awareness of bioenergy, where it can indirectly influence how people perceive costs, risks, and benefits associated with a new or emerging technology (Dowd et al. 2015). Schelhas et al. provides the theory of "sociotechnical imaginaries", which connects social imaginaries (i.e social, cultural, moral shared understandings) and technological development (Schelhas et al. 2018). Sociotechnical imaginaries are "collectively imagined forms of social life and social order reflected in the design and fulfillment of nation-specific scientific and/or technological projects" (Schelhas et al. 2018). With this theory, authors connect the

literature on sociotechnical imaginaries to anthropological literature on cultural models to then increase the understanding of the role imaginaries play in local communities that have bioenergy development. When people are subjected to powerful discourses, they tend to interpret them by reflecting on their own personal experiences, identities, knowledge, and a broad range of discourses to form their opinion (Schelhas et al. 2018, Dowd et al. 2015).

This paper will be addressing the influence of economic, socio-cultural, historical, and ecological contexts on the perceptions and acceptance of wood-based bioenergy particularly in the United States, but also in some parts of the world. The aim of this research is to utilize literature that apply a range of methodologies which are used to enhance understanding of the local acceptance of WBB development. Methodologies used are described in further detail below, some include using a community capital framework (cultural capital) and social-ecological models (SES) with ethnographic methods (i.e semi-structured interviews, surveys, data analysis, and participant observation). Furthermore, this paper highlights the importance of social science research and methods in sustainable development, particularly its significance when addressing the opportunities and constraints made by communities when developing WBB.

Methodological Approaches

Due to the increased prevalence of global interest in WBB, researchers have begun to understand how WBB developments are enabled or constrained due to public perceptions and knowledge. The literature reviewed for this study incorporates a range of methods to determine the advantages and disadvantages of WBB. Additionally, the range of methodologies presented in this study include employing a case study or scenario approach, whilst others provide contextual information such as policy or behavioral change theories. There is no best approach to

measuring economic, socio-cultural, and environmental impacts on WBB, the methods presented are purely a review of current approaches.

The focus of this paper is to present research from peer-reviewed articles found in online scientific journals. Similar to the works of White and Dowd et al., which use research surrounding public perception, economic, social, and environmental impacts of WBB development, this study also presents several methodologies used to measure and further understand the global public perception and acceptance of WBB development.

Community Capital Framework; Social Capital Theory

Vargas (FAO) gives an approach to understanding bioenergy and rural development in the context of small landholding agricultural production by applying a community capital framework. A community capital framework is defined as "analyzing community assets, as well as the way it organizes its efforts to achieve rural development (Vargas 2010), and "through a systemic approach by combining types of capital investment, interaction among capitals and outcomes (Emery et al. 2006). Vargas's analysis includes the seven types of capital: natural, cultural, human, social, political, financial and built. Cultural capital involves people's worldview and cultural expressions such as language, food, art, clothing, etc. In addition, Vargas argues that cultural capital can facilitate the understanding of how creativity and innovation encourage and promote each other. This holistic approach configures and stresses the importance of the use of the seven types of capital to better understand social change in the context of bioenergy. Additionally, as mentioned before, when attempting to create or solve a sustainable project or development, research must be focused on all contexts (economical, ecological, socio-cultural, and even historical). With cultural capital, studies have shown that there are some weaknesses in only utilizing cultural capital approaches, or "cultural vitality indexes" (CVI)

when determining whether a community would be open to change (Boglioli et al. 2019). Some research believes that the level of creativity in a community indicates its openness to change (the more creative a community, the more it will be open to bioenergy development) (WSU 2011). Community statistics such as art and museums, restaurants, parks, civic events, employment, businesses, etc. are used as a proxy for qualifying the willingness to change behavior or perceptions. Washington State University used a Community Capitals Framework originally coined by Flora and Flora in "Rural Communities: Legacy + Change" (Flora et al. 1992), where it is a tool to conceptualize a community system in a way that leads to effective community and economic decision-making and sustainable development (WSU 2011). In the "Ripple Effects Mapping for Evaluation", the curriculum is used to demonstrate how the Community Capitals Framework can trace the impacts of investments in one or more of the seven capitals. Moreover, WSU claims that successful communities pay attention to each of the seven capitals. This approach with the process of coding short (S), medium (M) and long (L) term impacts toward the Community Capitals Framework, gives quantitative measurements towards each of the seven capitals. The purpose of this is to not only understand if a community is open to change, but rather why and how they are or are not open to change. To better understand a community, research must dig deeper into the historical, economic, and environmental contexts that those communities experience, which results in how their perceptions and values are formed. Some claim that social capital "is context-dependent—and context is highly variable by how, when and whom, then any conclusion are themselves illegitimate as the basis for generalization to other circumstances" (Fine 2001). While quantifying a factor or context might be useful for economic developments within sustainability, using qualitative data in terms of ethnographic methods might be more suitable and accurate for WBB development.

There has been an increased use of the concept "social capital" in social science over the past few decades. Bjørnskov et al. gives an empirical look at the term "social capital", a term originally coined by Henry James in 1904. The researchers take a closer look at how 'social capital' has been "contemporarily" defined, conceptualized, and used by Pierre Bourdieu (1986), James Coleman (1988), and Robert Putnam (1993). The authors use John Gerring's (1999) concept evaluation framework to better understand if social capital is a 'good' concept in social sciences under the definitions given by Bourdieau, Coleman, and Putnam. Gerring creates eight criteria for conceptual goodness: 1) Familiarity; 2) Resonance; 3) Parsimony; 4) Coherence; 5) Differentiation; 6) Depth; 7) Theoretical Utility; and 8) Field Utility. The authors present the pros and cons to functionalist and non-functionalist social capital definitions. Putnam's 1993 definition "features of social organization, such as trust, norms and networks that can improve the efficiency of society", whereas Bourdieu and Coleman's definition, as explained by Bjørnskov et al., is a personal resource, which only indirectly has societal effects. Bjørnskov et al. critiques Putnam's definition as being functionalist, while Putnam's later definition in his work *Bowling Alone* (2000) which is "connections among individuals—social networks and norms of reciprocity and trustworthiness that arise from them" is described as a non-functionalist social capital definition. With the given definitions of social capital, Bjørnskov et al. argues that the range of definitions can be problematic for social science, where certain concepts such as "trust" and "cooperation" are not defined coherently; therefore, stresses the importance of coherence and resonance, according to Gerring. Bjørnskov et al. concludes that within Gerring's framework, social capital is not a good concept, and to abandon any functionalist definitions of social capital "as quickly as possible". Authors argue that social capital would not be useful if the separation of its characteristics (i.e trust, norms, and networks), if it were to be defined in that

sense; therefore, characteristics must be placed together to form a social capital concept to work. Furthermore, Bjørnskov et al. concludes that social capital should most likely be treated as a concept for individual-level analysis only. This conclusion is reached based on Putnam's use of a single social capital concept across 48 US states (90,000 respondents spanning over 23 years), where there is high diversity, plus different methods can create different outcomes. According to Gerring's framework, Bjørnskov et al. concludes that the wide conceptualization is not internally coherent, therefore, is not a good concept in social science. With the analysis presented by Bjørnskov et al., when using social capital in social science research, it is only useful when applied to individual-level analysis, not a whole population.

In Germany, some communities are known as "bioenergy villages" which is a community that can satisfy all of its electricity demand, at least half of its heating demand with local produced biomass, and the household consumers connected to the heating grid (Ruppert et al. 2008). Bock und Polach et al. use a social capital concept to examine if it drives techno-economic development of bioenergy villages found in Brandenburg, Germany (Bock und Polach et al. 2015). Using Putnam's definition and concept of social capital (trustworthiness, networks, formal and informal rules), they explore how the likelihood of cooperation (rules) coordinates the decision-making process or interactions of actors. Researchers define cooperation as "the degree of social and economic involvement of actors, which is coordinated by a certain governance structure", where the governing system places the rules to be effective among the rest of society, which is significant for guaranteeing rights and duties of society (actors). Actors are defined as channels, or social networks, that enhance the transfer of material and non-material resources (language, values, ideas and information, status and reputation, trust, and reciprocity. Researchers argue that the more immaterial resources that are transacted or used, the

more social capital increases. Furthermore, the researchers conclude that 1) WBB developments in a bioenergy village relied heavily on social relationships and equal distribution of information; 2) social capital and types of rules have an impact on cooperation; and 3) social capital and informal rules are not always helpful in implementing community grids, where it relies on a balance of leadership and collective action.

The social capital, cultural capital, and community capital frameworks are presented for the purpose of giving insight into how these methods have been used, and whether these methods can be useful for furthering WBB developments. It is up to researchers to decide what methods to use, and to explore the diverse approaches that are offered internally and externally of what is presented in this paper.

Cultural Sustainability Indicators; Criteria and Indicators (C&I) Framework

Myllyviita et al. presents the idea of cultural sustainability indicators, where researchers identified 49 indicators to measure cultural sustainability for WBB development in North Karelia, Finland. Researchers claim that cultural sustainability is neglected in sustainability research and assessments; therefore, the identified indicators can result in further discoveries of case-specific cultural sustainability and offer their framework to those working towards understanding the benefits and constraints of WBB development. The multi-dimensional sustainability assessment framework includes four WBB systems (i.e a local heating plant, a pellet factory, a combined heat and power (CHP) plant, and a biodiesel plant). The researchers then chose twelve experts with a professional background in bioenergy to identify cultural sustainability indicators. The sustainability assessment data related to the locality of the interviews and research; therefore, future assessments with this framework will differ due to

diverse economic, socio-cultural, environmental, and historical contexts, and the process will be case-specific sustainability indicators.

Kurka et al. explores the sustainability criteria and indicators (C&I) for WBB developments in Scotland, specifically Tayside and Fife. This approach was used with participatory methodology with two processes, 1) a pre-selection of suitable C&I by the researchers, and 2) a final selection by regional bioenergy experts in a multi-stakeholder forum (Kurka et al. 2013). The authors note that this type of method can provide an overview of the whole energy system, which includes observing the relationships of economic, social, environmental, and even technical contexts. Researchers suggest that this method can be significant when communicating and promoting dialogue regarding energy issues and sustainable development to stakeholders, policymakers, and the public (Vera et al. 2007). Additionally, for their selection process they identified those four categories based on reviewed literature on C&I frameworks. The authors concluded that this type of methodology for selecting C&I can be combined with participatory C&I to determine the significance and importance of each criteria and indicator by the participants. Furthermore, the researchers note that C&I frameworks can help and support performance assessments and participatory decision-making (Kurka et al. 2013).

Social-Ecological Systems (SES) Framework; Cultural Models

Beeton et al. (2017) used a social-ecological systems (SES) framework and resilience thinking to understand how and why WBB might contribute to forest and community resilience under change, plus how historical, socio-cultural, and political factors at multiple scales play out in local contexts. The SES approach emphasizes the interconnectedness of social and ecological systems, where humans depend on ecosystem services, which in turn are affected by

management decisions (Westley et al. 2002, Berkes et al. 2003, from Beeton et al. 2017). Walker et al. defines resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks" (Walker et al. 2004). Therefore, with resilience thinking, it links the concepts of adaptation and transformation to resilience (Folk et al. 2010) and acknowledges that SESs can exhibit multiple system states as a function of diverse stakeholder objectives and values (Nelson et al. 2007). Beeton et al. claims that using a SES resilience perspective to understand the connections and feedbacks in system factors allow conceptualizing how past actions limit contemporary and future options for WBB development. Schelhas et al. examined the ways that elements of the national bioenergy imaginary occurred in everyday talk about recent bioenergy development in communities in Georgia and Mississippi. Schelhas et al.s' research also reflects SES frameworks by using cultural models and conventional discourses of bioenergy through ethnographic research (i.e participant observation and semi-structured interviews). Schelhas et al. sheds light on the term "conventional discourses", coined by Strauss when researching the American discourses of immigration and social programs. Conventional discourses can be described as "repeating common expressions that are linked to shared ideas in particular groups, but are often fluid with people often mixing and matching expressions from the variety of different opinion groups with whom they interact" (Strauss 2012). Therefore, Schelhas et al. argues that with conventional discourses and the use of cultural models, it makes it useful to understand bioenergy imaginaries, or experiences and perceptions.

Under the support of the Bioenergy Alliance Network of the Rockies (BANR), Jensen-Ryan et al. also uses the SES frameworks to examine the multiple stakeholder perspectives when assessing the feasibility of using forests for energy production in the Medicine Bow Region of

Wyoming and Colorado (Jensen-Ryan et al. 2019). While mirroring Schelhas et al. research, Jensen-Ryan et al. stress the importance of SES frameworks, claiming "is necessary for broad-based and collaborative bioenergy development to provide local benefits" (Jensen-Ryan et al. 2019). Using SES models with cultural models, Jensen-Ryan et al. investigate multi-scalar stakeholder perceptions and attitudes concerning the ecological, economic, political, and social factors influencing WBB development. Cultural models are used to explain shared understandings of social phenomena within a given culture, plus providing individuals with an understanding of how to function within their society according to proper social behavior (D'Andrade 1995). With the formulation of SES frameworks and cultural models, it enhances the research of the diversity of social behaviors and cultural understandings among stakeholders' environmental contexts (Crane 2010).

Public Outreach

Monroe et al. investigates WBB outreach in the southern United States, specifically in Florida. Researchers aim was to provide educational materials for the interested public and community leaders to support the better understanding of environmental, economic, and technical components of bioenergy (Monroe et al. 2011). The researchers first study the research site, Alachua County, Florida, to then test the assumptions and outreach tools. Secondly, they researched and analyzed the population (audience) of the research site. This was for the purpose of understanding what they know and value, plus how they perceive messages and information. They stressed the importance of understanding what the public knows about WBB and their understanding of the potential for this type of energy development. Monroe et al. explains that "if communication tools provide the information experts wish to distribute but not the information that answers the audience's questions in a manner that the audience understands and

believes, they have failed". In the context of climate change, the increased awareness of its impacts and the knowledge of the renewable energy resource technologies can boost the public willingness to support climate-friendly technologies (Fytili et al. 2017). The next step the researchers take is a public perceptions survey to understand the concerns and ideas about WBB. Although 1517 surveys were distributed, only 298 were returned (19.8% response rate); therefore, researchers recognized that the low response rate does not reflect the knowledge and perceptions of the public. The next measure was to present the public with factual, interesting, and memorable information. Researchers then organized three focus groups in Gainesville, Florida to understand how citizens perceive and understand the information. This was also for the significant purpose of creating building public trust and acceptance through outreach opportunities that enable the public to learn, ask questions, and share concerns that can therefore facilitate public involvement in WBB discussions (Monroe et al. 2011).

Behavioral Change Theories

Theory of Planned Behavior (TPB)

Dael et al. explores attitude-behavior models, specifically the theory of planned behavior (TPB). This model, originally developed by Ajzen and Fishbien to address the nature of attitudes and their relations to overt behavior (Ajzen et al. 1980), was used to investigate how knowledge, perception, attitude strength, and intentions concerning bioenergy development are interconnected. Dael et al. measured behavioral intentions, intention to use (ITU) and intention to learn (ITL), to quantify whether providing more information via a standardized classroom lecture resulted in fully explaining the benefits of bioenergy development to then influence changed behavior and actions towards sustainable developments.

Readiness for Change (RFC)

Takala et al. applies the theory of Readiness for Change (RFC), which has been used to analyze the change processes of organizations in a variety of societal fields. For the purpose of individuality in a community, RFC can be defined as "the extent to which an individual or individuals are cognitively and emotionally inclined to accept, embrace, and adopt a particular plan to purposefully alter the status quo" (Holt et al. 2007, from Takala et al. 2020). Takala et al. uses the RFC behavioral change theory to focus on a transformational change in experiences and perceptions found in Finland forest owners.

Policy

Energy from biomass currently contributes to 10 percent of the global energy supply (International Energy Agency, 2017). Many countries, as individuals or grouped with other countries, have created long-term goals to meet renewable energy demands. The European Commission has set a goal to develop a competitive, resource efficient and low carbon economy by 2050 (Fytili et al. 2017). Public policies relating to biomass and bioenergy development plays a key role in supporting systems of energy innovation. At the state and national level in the United States, it is unsure how these policies impact innovation or development. According to White (2016), targeted government policies in some countries have been successful in encouraging bioenergy consumption. He acknowledges that there are many barriers to the implementation and development of WBB, but the increased importance of 'green' energy shows that those barriers can be overcome. In Mississippi and Georgia, some informants argue that a forest sustainability certification (Program for Endorsement of Forest Certification (PEFC); (Thiffault et al. 2015)) is based on an environmental and social agenda, or as a marketing tool for "sustainability" (Schelhas et al. 2018). Also, in this region, informants were characterized as

more conservative, therefore influenced more skepticism and hesitation towards government subsidies and investments in WBB. In the Medicine Bow Region, informants expressed the lack of funding provided by Congress for the United States Forest Service (USFS) to manage forests as a barrier to addressing MPB and WBB development (Jensen-Ryan et al. 2019). Informants also expressed that the regulatory oversight of the USFS is a barrier to effective forest management in this region.

In the late 1960s and early 1970s, the National Environmental Policy Act (NEPA), Endangered Species Act (ESA), and the Clean Air Act (CAA) provided public groups a tool to challenge forest management practices in court. As a result of these Acts, it influenced a large-scale reduction in timber harvesting on U.S public forest lands; thus, it has closed mills, smallholder and regional markets have been negatively affected, and the scope to manage forests has decreased in multiple places (Beeton et al. 2017).

The Intergovernmental Panel on Climate Change (IPCC) has recognized biomass from post-disturbance stands a potential feedstock opportunity for bioenergy (Edenhofer et al. 2011). Biomass production has been argued to be a tool to mitigate climate change, yet others have argued that it is not carbon neutral (Mansuy et al. 2018). Although, this might influence some countries to increase their biomass and bioenergy production. In Canada, production in the forest sector contributed $21 billion (1.25 percent) to the country's gross domestic product (Natural resources Canada, 2017), which makes Canada the largest global forest product trader. With the most biomass production per capita in the world, it represents 6.5 percent of the world's theoretical bioenergy potential (Stephen et al. 2016; Rogner et al. 2012). Although, about 94 percent of Canada's forests are public and fall under provincial jurisdiction; thus, each enforces a sustainable forest management (SFM) framework. There are eight forest biomass harvesting

policies and sustainable practices that are employed in Canada, such as: 1) forest operations; 2) retention and removal; 3) eligible stand; 4) soil nutrients; 5) physical soil; 6) biodiversity and wildlife; 7) riparian areas and watercourses; and 8) social, cultural, and aesthetics (Roach et al. 2014). In Flanders, Belgium, the share of renewable energy amounted to 5.6 percent in 2012, yet the target was 13 percent by 2020. In Finland, there were about 100 forest bioenergy cooperatives at the beginning of the 2010s (Vuorio 2013).

The Role of Policy Systems

Abrams et al. explore to what degree policies in the United States affect wood biomass development and production. Research has expressed that there is a lack of research in the United States to address the complex system of forest biomass policies, which in most cases involve economic, socio-cultural, environmental, and historical contexts. A "systems" approach is used to bring attention to questions of policy design and implementation while taking a closer look at how policies interact and impact one another at multiple scales. The focus of this research is to assess the multiple scales of policy influences individual policies, plus the interaction of policies "vertically" (by assessing the coherence of state and national policies) and "horizontally " (along many steps of the supply chain) (Abrams et al. 2017). In innovation and sustainable development, the use of a "systems of innovation" perspective have been placed in significant importance by numerous researchers (Buttoud et al. 2011, Stewart et al. 2001, Weiss 2011). In public policies, it has been found to be important in the outcomes of innovation (Abrams et al. 2017). With WBB innovation, this perspective can play an important role to understand the past and contemporary innovations and their relationship to other supportive or hindering factors and institutions (Abrams et al. 2017). Forest, energy, and environmental policies that are not related to WBB innovation can also have an impact on production. Abrams et al. explores the role of

bioenergy systems by conducting a survey to three West Coast states (Washington, California, Oregon) and three Upper Midwest states (Michigan, Minnesota, and Wisconsin). The selection for case study sites were chosen by the researchers for the purpose of the region's similarities in land ownership, presence of forest management, and present state biomass policy instruments. Surveys were administered to private firms representing four WBB supply-chain steps: 1) harvesting and transportation; 2) production of biomass into electricity or industrial heat; 3) production of biomass into energy products (wood pellets); and 4) consumption by institutional users like school and hospitals (Abrams et al. 2017).

This research revealed that supply chain players usually saw policy as significant when making decisions. In the federal public lands in the western United States, biomass energy policy is linked to wildfire risk reduction, resulting in policies supporting fuel reduction treatments (Becker et al. 2009). In some parts of the northwest United States where it is predominantly federal forest land, the raw material supply was a huge constraint for business firms (Allen et al. 2008). In the research conducted by Abrams et al., power/utility informants had a higher frequency of policy influences in their innovations and decision-making, while harvesters/haulers did not. Tax policies, such as the Business Energy Tax Credit (BETC), Biomass Producer and Consumer Tax Credit, and the Tax Credit for Renewable Energy Equipment Manufacturers were identified as influential. Disbursement policies were also seen as influential, such as the Biomass Crop Assistance Program (BCAP) and the Focus on Energy (Abrams et al. 2017). Federal regulations such as the Endangered Species Act and the Clean Air Act, counteracted and created unfairness between subsidies for other forms of renewable energy (wind and solar power).

The results present that informants favor a "hands off" approach to government involvement. Moreover, the researchers found that there is a lack of information regarding the biomass policy system, where informants had vague policy references (e.g. "grants" and "regulations") rather than clearly identifying the grant, regulation, or policy. Results further suggest that researchers exploring this similar topic should take caution, due to their insufficient response rate and acknowledging that the interviewed supply chain players might not represent the region's population. Therefore, they concluded that the results are case study and business specific, thus stressing the importance of carefully modeling the methods used. It is not fully known how WBB supply chain actors are able to recognize and analyze the policy system they operate within, as well as the other multi-scalar factors that influence supply chain operations (Abrams et al. 2017).

Starting in the 1970s, the Energy Crisis sparked concern with the domestic energy supply, which influenced many to value decreasing dependence on foreign energy resources. The Energy Tax Act (1978), Energy Security Act (1980), The Service Transportation Assistance Act (1982), Tax Reform Act (1982), and the Clean Air Act (1990) all supported and boosted ethanol productions with incentives and subsidies, making it competitive with gasoline (McCarl et al. 2007). These policies and acts, no question, influenced ethanol production in the United States during this area; furthermore, it was the beginning of bioenergy legislation. In 1996, the Farm Bill was created to increase agriculture bioenergy feedstock research and development programs. Then in 2002, the Farm Bill created more incentives, such as grants, programs, and public education, to support benefits of and investment into bioenergy products to boost bio-refinery production. In 2008, the Food, Conservation, and Energy Act (Farm Bill 2008) increased renewable energy programs in the United States, through funding biorefinery operations and

grants to small businesses. Although in 2007, the Energy Independence and Security Act (EISA), in conjunction with EPA05, mandated that at least 2.78 percent (default under legislation) of supplied gasoline by all parties in the United States must be biofuel. Yes, the mandate is not enforced, but if the percentage was not met during one fiscal year, then the remaining is added to the next fiscal year's percentage mandate. This has been argued to be ineffective towards increasing biofuel or bioenergy production in the United States.

E.U Local, National, and International Wood-based Bioenergy Perspectives (United States, Canada, and Russia)

Thiffault et al. explores the relationship between WBB feedstock supply chains to the biodiversity protection and sustainable forest management (SFM) under the European Union (EU) *Renewable Energy Directive (RED)*. In 2009, the implementation of *RED* mandated that 20 percent of the EU's final energy consumption must be renewable sourced by 2020, and 10 percent comprises road transportation fuels (European Commission, 2009). Although within *RED*, there are many areas that cannot be utilized for this purpose (primary forests, protected areas and highly biodiversity grassland, or untouched by humans). The researchers claim that because this policy creates a demand for WBB, regulators also could require standards for the market. Also noted, investment in WBB production depends on the global demand and trade, where the United States, Canada, and Russia are major exporters to the EU. The sustainability criteria within this policy mandate creates some potential challenges to the important producer countries, where each have diverse stewardship, governance structures, and forestry contexts (Thiffault et al. 2015). One of the criteria under *RED* that is problematic and constraining for WBB development is it cannot come from land untouched by humans (primary forests, protected areas, and highly biodiversity grasslands) for the purpose of supporting actions involved in protecting biodiversity and sustainable forest management. All countries involved under *RED*

have forests and lands that have been impacted or touched by humans. Climate change is impacting every mountain, body of water, vegetation, and animal on this planet, which is a result of human activities. For example, the increase of greenhouse gas emissions is a result of humans, which influences warmer temperatures and altered precipitation rates, which then leads to more frequent droughts. Additionally, the forests in the western United States are undergoing unprecedented climatic and environmental changes in forest health, resulting in increased rates of dead native trees and forest fires. So according to the definition of the Food and Agriculture Organization (FAO) "forests and other wooded lands of native species, where there is no clearly visible indication of human activity and the ecological processes are not significantly disturbed", the forests in the western United States are all very well protected for biodiversity and forest health; thus, technically cannot be utilized for WBB development and markets. The constraint with this criterion is the fact that the diversity of the United States, Canada, and Russia was not acknowledged in this policy by giving a global 'umbrella' policy. Perhaps, if the guidelines under *REDs* were country oriented and promoted sustainable development and trade, there could be a push for WBB within the countries. Thiffault et al. therefore stresses the importance of communication, collaboration, and outreach among stakeholders when addressing and implementing WBB developments.

Case Study Sites

This paper examines how certain regions of the United States and other countries around the world experience or perceive WBB development. The case study sites listed below were chosen because they have heavy forest and forest industry communities, and the reviewed literature overlapped with this paper's research purpose. The regions listed below are among those that have been researched for bioenergy innovation in the past decade. Each region or

country below includes the researcher(s), methods used, and for the purpose of future WBB development research, the available sample size (i.e respondents, informants/participants). The purpose of including sample size is to stress the importance of the amount of perceptions and experiences studied, thus creating more accurate results and less generalizations about the researched population. Although, some methods highlighted in this paper are more effective in reaching clearer results when the sample size is larger; therefore, methods used to research are arbitrary and research specific, where there is no best methodological approach to studying and measuring the public perceptions of WBB developments.

United States

Montana

(Beeton et al. 2014)

- Methods: Semi-Structured interviews
- Sample size: 17 interview participants

Wyoming and Colorado

(Jensen-Ryan et al. 2018)

- Methods: Socio-Ecological Systems (SES) framework; cultural models; Multi-sited ethnographic approach: semi-structured interviews, participant observation, data analysis
- Sample size: 31 interview participants, forest stakeholder affiliation

Arizona

(Neary et al. 2007)

- Methods: Examines the scope, costs, and environmental trade-offs
- Sample size: Not applicable.

Mississippi and Georgia

(Schelhas et al. 2018)

- Methods: Multi-sited ethnographic approach (interviewing stakeholder groups), cultural models
- Sample size: 175 interview participants

Florida

(Monroe et al. 2011)

- Methods: Public perceptions survey, focus groups
- Sample size: 298 survey respondents; three focus groups, 16 participants

West coast states: California, Oregon, Washington; Upper Midwest states: Minnesota, Wisconsin, Michigan

(Abrams et al. 2017)

- Methods: Review of policies, Telephone and web-based survey

- Sample size: 175 usable phone and web-based survey respondents (represented 39% of wood energy firms); 155 respondents received open-ended questions.

Outside United States

Northern Karelia, Eastern Finland
(Myllyviita et al. 2014)
- Methods: Two stages: First stage, interviews, defining cultural indicators, judgements for cultural sustainability indicators (SMART); Second stage, interviews, judgements for all cultural sustainability indicators
- Sample size: 12 interview participants, experts with bioenergy background

Finland
(Takala et al. 2020)
- Methods: Readiness for Change (RFC) theory, qualitative cognitive mapping approach, interview
- Sample size: 20 interview participants (forest owners), random

Canada
(Mansuy et al. 2018)
- Methods: Reviews the utilization of feedstock salvaged after natural disturbance
- Sample size: Not applicable.

Belgium
(Dael et al. 2017)
- Methods: Theory of planned behavior, classroom lecture (PowerPoint), structural equation modeling (SEM), survey
- Sample size: 715 participants—281 participants received a lecture

Germany
(Bock und Polach et al. 2015)
- Methods: Case study approach, Social capital and nexus of institutional arrangements, semi-structured interviews
- Sample size: 7 interview participants in Kerkow, 8 secondary interview participants in Kerkow

Scotland
(Kurka et al. 2013)
- Methods: Criteria and indicators (C&I), or system framework; Multi-stakeholder forum
- Sample size: 13 forum participants, all regional bioenergy experts

Results

The results of case study sites are organized into the opportunities and constraints of wood-based bioenergy (WBB) development. In addition, the following sections will reveal opportunities and constraints linked to economic, socio-cultural, environmental, and historical contexts within each region or country. The information presented in the section originates from

peer-reviewed literature that focuses on the public perceptions and multiple contexts that influence WBB development. The data presented is based on the information and results found by researchers, where some opportunities and constraints may be categorized differently (some researchers might find something to be an economic opportunity, where others might find it as an environmental opportunity, and vise versa). In some cases, researchers did not address some of the presented contexts; therefore, it is recommended to be explored in future research.

Wood-based bioenergy opportunities

Economic

United States

In western Montana, the MPB epidemic has created a market for the dead wood, where according to informants (Beeton et al. 2017), it may provide an important tool to offset treatment costs for restoration projects on public lands. The researchers also note that it might be a potential income source for private landowners as well as a tool to support local job opportunities for loggers and others who work in the forest industry. There is also an increase in market and job opportunities in the Medicine Bow Region of Wyoming and Colorado, where the result of the MPB epidemic has created millions of acres of dead trees (Jensen-Ryan et al. 2018).

Some informants within communities in Florida (Monroe et al. 2011) expressed that using wood for electricity would reduce dependence on foreign energy and keep dollars in the community. Informants also expressed that it would create more jobs if there was an entry level addition It was also found that the increased use of WBB in Florida is claimed to increase GDP, job opportunities, and enhance government revenues (Hodges et al. 2010). In Mississippi and Georgia (Schelhas et al. 2018), informants also expressed the importance of energy security and independence. The argument for energy security is expressed by many political leaders, as well

as key informants. The use of wood for electricity would also provide better markets for wood products, according to the informants.

Outside United States

Researchers have examined the effects of substituting fuelwood with food pellets in British Columbia, Canada, where there were significant fuel cost savings and improvements in human health, which resulted from decreased GHG emissions (Pa et al. 2013). Transportation logistics were also expressed by researchers, where it must be carefully planned to ensure profitability of the supply chain (Mansuy et al. 2017).

Socio-cultural

United States

In Mississippi and Georgia, the people from communities with bioenergy plants were engaged with all aspects of forestry and the forest industry (Schelhas et al. 2018). The forest products industry is very important to the way of life for those accustomed to forestry and the industry tied to it. Informants also expressed that they are desperate for any development which does not threaten public safety, and they would take anything except hazardous waste. Schelhas et al. also notes the industry participants usually referred to the wood obtained from the forest as "feedstock" of "product," which removes any relationship to land or forests. Furthermore, the researchers note that the interpretation of 'renewability' and 'sustainability' by forestry and forest owners create a narrow focus. The concepts refer to only the continued production of wood products and to be expanded to to include wildlife. The researchers found that the informants assumed forestry as a sustainable method to grow a renewable resource.

In western Montana, the researchers coded the social opportunities expressed by the informants as WBB would create more rural community development, decrease fossil fuel dependence, and more locally sourced and decentralized energy. Also, in Wyoming and

Colorado, informants expressed WBB would create more opportunities for heat sources, where wood can be used to heat schools, public buildings, and homes with wood burning stoves. The informants in this region also expressed WBB would create more jobs to keep families and children in their communities.

In the White Mountains of Arizona, the White Mountain Apache Tribe is very involved in forest management. After multiple devastating fires, one called the Rodeo-Chediski Fire, which was ignited on the White Mountain Apache Reservation, the aftermath created a stewardship contract. This White Mountain stewardship contract (2003) focuses on forest landscape restoration, thinning, piling, chipping, transporting and marketing wood fiber, seeding, water bar construction, and contour falling (Neary et al. 2007). Within this contract, a Multi-Party Community Monitoring Board was created as an adaptive management plan to welcome and evaluate the ecological, economic, and social aspects of the plan. Under NEPA, these goals address social goals, one being if they are meeting the expectations and needs of the tribal government and tribal members, as well as the public. This is important because under the stewardship contract, it requires collaboration with all parties involved, where the tribe was already thinning and burning on their lands.

Environmental

United States

In western Montana, informants expressed that WBB would restore and manage forests, mitigate climate change, reduce fire risks and pollution, enhance productivity and biomass, and increase carbon sequestration. Informants in Mississippi and Georgia also expressed that forests were valued more than timber, including wildlife, hunting, and aesthetics. The perception of climate change by these informants will be discussed further in the ecological constraints section.

In Wyoming and Colorado, informants expressed WBB would be beneficial for restoration and management of forests, the reduction of fire, and the utilization of a renewable resource.

Outside United States

In eastern Finland, some informants perceived climate change as less threatening and effectual, and more manageable; although, the mitigation of climate change motivates them to produce energy from wood (Takala et al. 2020). In Belgium, some informants expressed an increased use of bioenergy could help reduce the GHG effect and replace fossil fuels, but it depended on whether or not the informants were given a lecture (researchers theorized that this might be due to some participants not being aware WBB is renewable) (Dael et al. 2017).

Historical

United States

In the White Mountains of Arizona, prior to European settlement in the 1860s, the forest consisted of open-stand of large-diameter ponderosa pine with a large grass-forb understory (Neary et al. 2007). For most of the twentieth century, heavy sheep and cattle grazing followed by modern forest management, which haunted forest and grass fires; thus, resulted in dense, overstocked stands that created the current wildlife crisis in these mountains. Although in 1997, a partnership of federal, state, local, and private organizations began fire risk reduction programs to restore overstocked comfier forests around wild-land-urban interface zones (Neary et al. 2007). Like the Medicine-Bow region in Wyoming and Colorado, forest management since the early twentieth century has incorporated methods to mitigate the MPB epidemic. The focus of these measures was to protect timber resources for industrial purposes, but the measures diminished by the 1970s with more indirect control measures taking hold (Jensen-Ryan et al. 2019). Researchers described the land ownership in the Medicine Bow Region as the classic western “checkerboard,” with alternating sections of federal, state, and private lands, including

the Colorado State Forest State Park, parts of the Medicine Bow and Roosevelt National Forests, and the northwest corner of Rocky Mountain National Park (Jensen-Ryan et al. 2019). With many communities and land ownership dynamics in place, there are also a diverse range of forest management strategies.

Wood-based bioenergy constraints

Economic

United States

Throughout each case study site, there is an overlap of economic constraints themes expressed by informants. Wholesale electricity restricting has been argued to not develop sufficient wholesale competition and the 'power to choose', plus energy suppliers have not reduced prices for residential and small commercial electricity (Kelly et al. 2005). Almost all informants expressed concern with how WBB would compete with current energy markets, as well as the costs associated with developing WBB technologies and industries (Beeton et al. 2017; Schelhas et al. 2018; Jensen-Ryan et al. 2019; Abrams et al. 2017). More specifically, informants in the Medicine Bow Region expressed concern for market out-pricing, cost of infrastructure, removing and transporting waste, which was also expressed as a concern by informants in the West coast and upper-Midwest states (Abrams et al. 2017), guaranteed supply of wood, and the economic viability of stands (Jensen-Ryan et al. 2019).

The theme of 'government investment and promotion' was also expressed by many informants across the United States. In Mississippi and Georgia, informants reacted in diverse ways when government promotional efforts that included subsidies came into their town (Schelhas et al. 2018). The plant development setbacks and plant failures influenced some to believe that their community had been taken by a scam. Although, some countered this argument that other forms of energy, industries, and even forms of everyday technologies, have directly

been supported by governmental investments. Schelhas et al. found that individuals more involved in promoting economic development or expecting to be employed expressed more positivity than individuals who are not directly involved, such as minorities and poorer community members.

Outside United States

It is expressed by some researchers that an increase in global demand for WBB could create a major stress on the transportation system in forested regions (Richard 2010). Trucking transportation is one of the only transportation methods for WBB supply chain since railroad infrastructure is poorly developed and nonexistent in Canadian forested areas (Mansuy et al. 2017). Market liberalization in Canada has been claimed to have led to dissatisfaction, where the market structure has been blamed for higher electricity and heating prices (Dewees 2015). In Scotland, informants expressed concern with the economic viability of reprocessing waste materials into biofuel (Kurka et al. 2013). Furthermore, informants also argued that turning waste into biofuel would be the individual business decision of the bioenergy producer and the success of the waste re-processor companies in Scotland (Kurka et al. 2013). Informants in Scotland were also concerned with the availability of feedstock supplies, plus the increased dependency on imports. They also were concerned with not creating alternative, sustainable supply sources.

Socio-cultural

United States

Informants in western Montana expressed concern with rural and community development, where they want to keep families and children in their communities. This was also expressed by informants in Colorado and Wyoming. Opposition by the public and ENGO groups was found to be a social constraint in western Montana, where the historical factors will be further addressed in the historical constraints of this paper. In Georgia and Mississippi, African

American informants expressed that there is a lack of diversity in the hiring processes at bioenergy facilities. Schelhas et al. noted that in many rural areas in the Southern United States, there are still racial inequalities and minority hiring issues where bioenergy facilities are located. There were also informants that expressed there are unequal benefits to community members based on land holdings, which resulted in class tensions within these communities.

Outside United States

Examined by White (2016), results show that costs of investments in WBB infrastructure and production, plus supply sustainability, are the primary concern from informants. In Belgium, a higher price for bioenergy compared to other energy resources decreased the informant's intention to use WBB (Dael et al. 2017). Informants in Scotland were concerned with business and employment being taken away from large traditional industries which would also compete for the same biofuel supplies as the bioenergy industry (Kurka et al. 2013).

Environmental

United States

In western Montana, Colorado, Wyoming, Mississippi, and Georgia, informants expressed concern if WBB development would harvest wood in a sustainable or unsustainable manner. Some of these concerns stem from past logging operations, which will be discussed further in the historical constraints section. In the Medicine Bow Region, informants expressed concern with fire risk relating to the WPB epidemic, where some expressed it as "inevitable fires" which eliminate the need for short- and long-term MPB management (Jensen-Ryan et al. 2019). In this region, as well as every other U.S region, expressed concern with the environmental risks associated with the WBB development cycle, like short and long-term risks. Some expressed that they are unsure if WBB development is environmentally sustainable, where

GHG emissions and fuel costs with hauling and transportation are mentioned as environmental concerns.

In Georgia and Mississippi, climate change was referred to as global warming by most informants, and some denied its existence. Some found it difficult to believe that bioenergy is a reasonable way to mitigate climate change, mostly due to the environmental impacts associated with transporting products. In the Medicine Bow Region, informants viewed individual and/or collective action as pointless to addressing climate change mitigation in relation to WBB development and the MPB epidemic.

Outside United States

In Belgium, informants expressed that they did not perceive wood as being environmentally friendly, plus did not perceive it as being one of Belgium's main sources of bioenergy in the future (Dael et al. 2017). Takala et al.'s research revealed that informants' low acknowledgment of environmental problems may increase environmentally harmful decisions and activities. In Canada, moisture content is one of the main concerns when wood is being converted into bioenergy (Mansuy et al. 2017). With the large variability and uncertainties surrounding WBB development, it is argued to not be carbon neutral (Mansuy et al. 2017). Also argued by Mansuy et al., biomass removal may have a greater impact on the ecosystem than conventional logging. Informants in Scotland expressed concern with land use or change of landscape as a result of energy crop plantations (Kurka et al. 2013).

Historical

United States

In Mississippi and Georgia, informants expressed that there is a lack of trust in government promotion and investment, where a former mayor noted that the town has provided a lot of investment for a beef processing plant that resulted in bankruptcy. These concerns were

also themes throughout other case study cites, such as in western Montana, where in the mid-to-late 1990s, the United States Forest Service (USFS) acquired a majoring of land holdings (Plum Creek) when the corporate timber compact began to sell (Belsky 2015). The land ownership dynamics have resulted in transitioning from commodity-based economies focused on timber extraction to recreation-based and aesthetic economies. Additionally, many environmental groups have opposed timber harvest on public lands, which have successfully litigated timber sale contacts, which in turn impacted the USFS ability to perform harvest treatments (Beeton et al. 2017). These actions have directly impacted mill operators, loggers, and private landowners who are involved in forestry and the forestry industry.

Data Analysis, Discussion, and Recommendations

The results indicate that there are many similarities between the perceptions and experiences found across the United States, as well as other countries around the world. Although, there are many differences across the world due to the historical and socio-cultural contexts that each community highlighted in this paper experience. This paper addresses not only the public perceptions of wood-based bioenergy based on the economic, socio-cultural, environmental, historical, and political contexts, but gives multiple methodological and theoretical approaches when exploring WBB developments. Additionally, the results revealed themes, or similar perceptions and values, across each region and country, which were expressed by informants in the reviewed literature.

Economic Opportunities and Constraints

Many U.S case study sites expressed that WBB would increase job opportunities, decrease dependency on foreign energy resources, and create more markets for wood products. Outside the United States, there were little to no results indicating economic opportunities from

WBB development except that it created significant fuel cost savings and increased health in the communities. Therefore, this is a topic of future research that should be addressed for bioenergy development. It is acknowledged that there is potentially existing research on economic opportunities from WBB, but in the reviewed literature there was not.

Informants in the United States generally expressed concern with market out-pricing, cost of infrastructure, fuels savings, removing and transporting waste, guaranteed supply of wood, and the economic viability of stands. These values were also expressed as concerns by outside of the U.S informants,

Socio-Cultural Opportunities and Constraints

Informants in the U.S indicated that WBB would create more jobs, create more opportunities for heat sources, more community development, and a more decentralized heating source. Reviewed literature revealed decreasing dependence on foreign energy was a social opportunity, whereas other literature viewed it as an economic opportunity. Outside the United States, there were no clear socio-cultural indicators revealed by the researchers; therefore, it is recommended that future research addresses this.

For constraints, there was a diverse range of values expressed by informants, which might be due to the geographical location and historical contexts. Some informants inside and outside the U.S were concerned with rural and community development, costs of investments in WBB infrastructure and production, supply sustainability. The opposition by the public and ENGO groups also affect WBB production, which in turn influenced tension between environmental groups and those who work in forestry or forestry production. There were also concerns with the lack of diversity, racial inequality, and class tensions when developing WBB.

Environmental Opportunities and Constraints

Regions in the U.S valued restoring and managing forests, mitigating climate change, reducing fire risk and pollution, enhancing productivity and biomass, increasing carbon sequestration, recreation, and aesthetics. These values are expressed by the researched public regarding WBB development and its environmental opportunities. It is important to note that in almost most of the regions explored in the United States, the opinions and beliefs towards the relationship of climate change and bioenergy, or climate change alone, were diverse. Interviewees in regions such as Mississippi and Georgia, Wyoming, Colorado, and Florida, the range of opinions regarding climate change included 1) acknowledged its existence; 2) believed WBB would not help mitigate climate change; 3) Did not believe it existed and thought it was a part of a "political agenda"; and/or 4) believed group or individual efforts would not help environmental change and climate change. It is also important to note that in the Northwest and Upper Midwest regions of the U.S, informants did not address any policy, legislation, or environmental groups opinions, beliefs, or actions that related to climate change, with the exception of the Clean Air Act. The results stemmed from the methodology the researchers used, where the informants would mention or vaguely mention policy or legislation that have directly impacted their perception, actions, and business plan regarding WBB development (Abrams et al. 2017). This connection could lead to the conclusions that, 1) there are no state or federal regulation, policy, or act that relates to climate change mitigation, 2) there are no state or federal regulations, policies, or acts that relate to WBB being a tool to mitigate climate change; or 3) there are state or federal regulations, policies, or acts that relate to mitigation climate change, with or without WBB, but the informants are not influenced by them. Although, there are few policies and acts in the United States which relate to mitigating climate change and bioenergy

use (See Policy, pp.17-23). There is a history of bioenergy policies in the United States where a crisis like the Energy Crisis sparked legislation to support ethanol, which resulted in the increased use and production of ethanol. Therefore, policy indeed transforms and influences the energy system in the United States, which influences not only the perceptions and experiences of communities but affects the level of education and public outreach. With regards to outside of the United States, there are clear policies (See Policy, pp.17–23) which relate to mitigating climate change and bioenergy production or increasing environmental health and bioenergy production. It is important to note that informants found in countries outside the United States were more aware of climate change and acknowledged that bioenergy would be a potential tool for mitigating climate change.

Historical Opportunities and Constraints

The historical background of bioenergy development, government assistance, and land management trends have impacted WBB development in the United States. Some informants expressed that there is a lack of trust in government promotion and investment that have influenced some to be skeptical of government support in WBB. Informants also expressed concern with land ownership dynamics in their communities, where switching to recreation and aesthetic economies have influenced fewer timber sales and forest management. This can also be a result of environmental groups opposing timber harvest on public lands, which directly impacted those involved in forestry and the forestry industry.

Studies have shown the consistent supply, transportation costs, market value, and the competition with alternative fuels have hindered WBB development and use in the United States (Becker et al. 2011). The results from reviewed literature in this paper reflects and aligns with those findings. This empirical study highlights the opportunities and constraints of WBB found

across the United States and other countries around the world. Furthermore, results reveal there are similar opportunities and constraints made by the informants found in the reviewed literature. It is recommended that policymakers, landowners, researchers, and communities take these results into account when developing WBB. It is important to note that when policymakers are advancing towards WBB development, employing any of the social science methodologies that are highlighted in this paper have been found to be useful when incorporating the public perceptions and values in sustainability or a renewable energy resources and innovations.

Discussion and Recommendations

Based on the results of this study, governmental assistance such as investments, incentives, and programs might potentially support successful WBB developments in the United States. This conclusion is supported by acknowledging the historical background of domestic energy acts and legislation, which some in turn supported ethanol production. Therefore, it is a possibility if the United States or specific U.S states employed more incentives and programs regarding WBB, there would be increased development and use of WBB. It is also important to note that legislation or acts relating to climate change mitigation might potentially hinder WBB development in the United States, but specific states employing legislation relating to climate change mitigation and WBB might be successful. In addition, it is recommended that this is explored further in future research.

The Bioenergy Alliance Network of Rockies (BANR) has conducted research with forest stakeholders to understand the opportunities and constraints with WBB in the Rocky Mountains (Wyoming, Colorado, Montana, Idaho). Researchers work with industry partners to develop a program that addresses using MPB-impacted trees for biofuel and biochar production in this region. Social scientists under BANR (Jensen-Ryan et al. 2019) have conducted qualitative

research with theoretical frameworks to understand the public perceptions of the economic, socio-cultural, environmental, and political contexts that support or hinder biomass availability and WBB development. From 2017 to 2018, I got the opportunity to be an undergraduate research assistant for BANR under Dr. Sarah Strauss, where I assisted research by transcribing and coding interviews done by the BANR researchers. With this, I got a first-hand look at what the participants valued, believed, perceived, and experienced regarding the MPB epidemic, WBB, forestry, and the interior and exterior contexts. As a young college student only studying Anthropology (began to study sustainability and the environment further into college), I was unaware of what bioenergy was, nonetheless only had little knowledge of the energy system and the MPB epidemic. Moreover, researchers, plus this paper, stress high importance on WBB public outreach and education (Monroe et al. 2011) for sustainable developments, emerging energy innovations, and more specifically, wood-based bioenergy.

Other organizations that focus on bioenergy include the Clean Air Task Force (CATF), where their goal is to "redirect the production and use of bioenergy so that it contributes to—rather than undermines—decarbonization and climate stability," (CATF 2018). CATF specializes in biofuels, biomass, and forest-climate interactions in the United States. Furthermore, this organization works to guarantee the policies that promote and regulate bioenergy include provisions that accurately evaluate and address the climate impact of bioenergy. In Europe, the European Technology and Innovation Platforms (ETIPs) was created in 2016 to contribute to the development of cost-competitive, innovative bioenergy and biofuels chains, the implementation and strengthening of the bioenergy industry, and to increase the sustainability of bioenergy in Europe. With this mission and goal, through the ETIP Bioenergy, this organization

employs a process of guidance, prioritization, and support of research, technology development, and demonstration of bioenergy in Europe (ETIP Bioenergy 2020).

With the support and guidance from organizations, researchers, scientists, educators, and policymakers, implementing public outreach and awareness of the benefits of bioenergy is significant when developing WBB technologies and systems. Furthermore, research has shown that employing these actions can create more willingness to learn, act, and use bioenergy by the public (Monroe et al. 2011; Abrams et al. 2017; Takala et al. 2020; Dael et al. 2017; Fytili et al. 2017).

Summary and Conclusions

The focus of this paper was to explore the global economic, social-cultural, environmental, and historical opportunities and constraints of wood-based bioenergy. This exploratory study focused on a handful of global forestry communities and how values, perceptions, and experiences aligned with one another. The findings suggest that although WBB is gaining global interest, there are still economic, historical, and political factors that hinder WBB development.

This paper also highlights the methods used by researchers to explore the public perception of WBB and bioenergy. There is no correct methodology when exploring sustainability and energy developments, but social science methods are significant when researching these topics. In conclusion, it is recommended that policymakers, communities, and landowners explore WBB development opportunities for domestic energy use, increase in employment, mitigating climate change, and enhancing forest health.

References

Abrams, J., Becker, D., Kudrna, J., Moseley, C., 2017. Does policy matter? The role of policy systems in forest bioenergy development in the United States. *Forest Policy and Economics*, 75. 41–48.

Ajzen, I., 1991. The theory of planned behavior. *Organ. Behav. Hum. Decis. Process*, 50. 179–211.

Allen, T.T., Han, H.-S., Shook, S.R., 2008. A structural assessment of the contract logging sector in the Inland Northwest. *For. Prod. J*, 58. 27–33.

Ajzen, I., Fishbein, M., 1980. Understanding Attitudes and Predicting Social Behavior. Prentice-Hall, Englewood Cliffs NJ. p.278.

Bioenergy Alliance Network of the Rockies (BANR) http://banr.nrel.colostate.edu/#gsc.tab=0

Beeton, T.A., Galvin, K.A., 2017. Wood-based bioenergy in western Montana: the importance of understanding path dependence and local context for resilience. *Ecology and Society*, 22.

Becker, D.R., Nechodom, M., Shelly, J., 2009. Assessing the role of federal community assistance programs to develop biomass utilization capacity in the western United States. *Forest Policy Econ*, 11. 141-148.

Belsky, J.M., 2015. Community forestry engagement with market forces. A comparative perspective from Bhutan and Montana. *Forest Policy and Economics*, 58. 29–36.

Bentz, B.J., Regniere, D., Fettig, Hansen, E.M., Hayes, J.L., Hicke, A., Kelsey, R.G., Negron, J.F., Seybold., S.J., 2010. Climate change and bark beetles of the western United States and Canada: direct and indirect effects. *Bioscience*, 60. 602—613.

Bjørnskov, C., Sønderskov, K.M., 2013. Is Social Capital a Good Concept? *Social Indicators Research*.

Bock und Polach, C.v., Kunze, C., MaaB, O., Grundmann, P., 2015. Bioenergy as a socio-technical system: The nexus of rules, social capital and cooperation in the development of bioenergy villages in Germany. *Energy Research and Social Science*, 6. 128–135.

Boglioli, M., Strauss, S., Mueller, D., Budowle, R., Beeton, T., Jensen-Ryan, D., 2019. PowerPoint Presentation: Searching for Culture in "Cultural Capital": The Case for a Mixed-Methods Approach to Production Facility Siting. Bioenergy Alliance Network of the Rockies (BANR). Support by the Agriculture and Food Research Initiative Competitive Grant no. 2013-68005-21298 from the USDA National Institute of Food and Agriculture.

Buttoud, G., Kouplevatskaya-Buttoud, I., Slee, B., Weiss, G., 2011. Barriers to institutional learning and innovations in the forest sector in Europe: markets, policies and stakeholders. *Forest Policy Econ*, 13. 124—131.

Clean Air Task Force (CATF) 2018. https://www.catf.us/work/bioenergy/

Dael, M.V., Lizin, S., Swinnen, G., Van Passel, S., 2017. Young people's acceptance of bioenergy and the influence of attitude strength on information provision. *Renewable Energy*, 107. 417–430.

Dennison, P.E., Brewer., S.C., Arnold, J.D., Moritz, M.A., 2014. Large wildfire trends in the western United States, 1984-2011. *Geophysical Research Letters*, 41. 2928—2933.

Deutmeyer, M., Hektor B and Schouwenburg P-P, 2014. Financing Bioenergy Trade - History, status & outlook on securing sustainable bioenergy supply, demand and markets. Lecture notes in *Energy*. 191–212.

Dewees, D.N, 2005. Electricity restricting and regulation in the provinces: Ontario and beyond. Presented to Energy, Sustainability, and Integration—The CCGES Transatlantic Energy Conference, York University, Toronto, Canada, 9–10 September 2005.

Dowd, A., Rodriguez, M., Jeanneret, T., 2015. Social Science Insight for the BioCCS Industry. *Energies*, 8. 4024–4042.

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Seyboth, K., Matschoss, P., Kadner, S., von Stechow, C., 2011, Special report on renewable energy sources and climate change mitigation: summary for policymakers and technical summary (special report of the Intergovernmental Panel on Climate Change). Cambridge, England and New York, NY. Cambridge University Press.

Emery, M., Flora, C., 2006. Spiraling-up. Mapping Community Transformation with Community Capitals Framework. COMMUNITY DEVELOPMENT: *Jour. Comm. Development Soc.*, 37. No. 1.

ETIP Bioenergy, 2020. European Technology and Innovation Platform Bioenergy https://www.etipbioenergy.eu/about-ebtp

Fine, B., 2001. Social capital versus social theory. London: Routledge.

Flora, C.B., Flora, J.L., Houdeck, E., 1992. Flora Rural Communities: Legacy + Change. *Westview Press*.

Folke, C., Carpenter, S.R., Walker, B., Schaeffer, M., Chapin, T., Rockström, J., 2010. Resilience thinking integrating resilience, adaptability and transformability. *Ecology and Society*, 15.

Fytili, D., Zabaniotou, A., 2017. Social acceptance of bioenergy in the context of climate change and sustainability—A review. *Current Opinion in Green and Sustainable Chemistry*, 8. 5–9.
Gerring, J., 1999. What makes a concept good? A criterial framework for understanding concept formation in the social sciences. *Polity*, 31. 357—393.
Haugo, R.D., Hall, S.A., Gray, E.M., Gonzalez, P., Bakker, J.D., 2010. Influences of climate, fire, grazing, and logging on woody species composition among an elevation gradient in the eastern Cascades, Washington. *Forest Ecology and Management*, 260. 2204—2213.
Hodges, A.W., Stevens, T.J., Ragmani, M., 2010. Economic Impacts of Expanded Woody Biomass Utilization on the Bioenergy and Forest Products Industries in Florida. University of Florida. *Institute of Food and Agricultural Sciences, Food and Resource Economics Department*, Gainesville, FL.
IRENA, 2018. Bioenergy from Finnish forests: Sustainable, efficient, modern use of wood. *International Renewable Energy Agency, Abu Dhabi.*
International Energy Agency (IEA), 2017. Energy balance flows. Retrieved from http://www.iea.org/statistics/
Jensen-Ryan, D., Budowle, R., Strauss, S., Durbin, T.J., Beeton, T.A., Galvin, K.A., 2019. A cultural consensus of fire and futility: Harvesting beetle-kill for wood-based bioenergy in Wyoming and Colorado. *Energy Research & Social Science*, 58. Bioenergy Alliance Network of the Rockies.
Kelly, S., Moody, D., 2005. Wholesale electric restructuring: was 2004 the "Tipping Point"? *Electric*. J. 18 (2), 11–18.
Kurka, T., Blackwood, D., 2013. Participatory selection of sustainability criteria and indicators for bioenergy developments. *Renewable and Sustainable Energy Reviews*, 24. 92–102.
Lyderson, J.M., North, M.P., Knapp, E.E., Collins, B.M, 2013. Quantifying spatial patterns of tree groups and gaps in mixed-conifer forests: reference conditions and long-term changes following fire suppression and logging. *Forest Ecology and Management*, 304. 370—382.
Mansuy, N., Barrette, J., Laganière, J., Mabee, W., Paré, D., Gautam, S., Thiffault, E., Ghafghazi, S., 2017. Savage harvesting for bioenergy in Canada: From sustainable and integrated supply chain to climate change mitigation. *WIREs Energy Environment*, 7. p. 298.
Monroe, M.C., Oxarart, Annie., 2010. Woody biomass outreach in the southern United States: A case study. Biomass and Bioenergy, 35. 1465–1473.
Myllyviita, T., Hujala, T., Lähtinen, K., Sikanen, L., 2014. Identifying and rating cultural sustainability indicators: A case study of wood-based bioenergy systems in Eastern Finland. *Environment Development and Sustainability*.
National Geographic, 2015. The Bug That's Eating the Woods. *National Geographic Magazine*. https://www.nationalgeographic.com/magazine/2015/04/pine-beetles-forest-destruction-canada-rockies/
Natural resources Canada, 2017. Indicator: Exports. Retrieved from: http://www.nrcan.gc.ca/en/environment-climate-change/services/lightning/forest-fires.html
Neary, D.G., Zieroth, E.J., 2006. Forest bioenergy system to reduce the hazard of wildfires: White Mountains, Arizona. *Biomass and Bioenergy*, 31. 638–645.
Nelson, D.C., 1990. Institutions, institutional change and economic performance. *Cambridge University Press*, Cambridge, UK.
Pa, A., Bi, X., Sokhansanj, S., 2013. Evaluation of wood pellet application for residential heating in British Columbia based on streamlined life cycle analysis. *Biomass Bioenergy* 49, 109–122.
Richard, T.L., 2010. Challenges in scaling up biofuels infrastructure. *Science*, 329. 793-796.
Ruppert, H., Eigner-Thiel, S., Karpenstein-Machan, M., Girschner, W., Roland, F., Ruwisch, V., Sauer, B., Schmuck, P., 2008. Wege zum Bioenergiedorf. Leitfaden. Gülzow: FNR.
Roach, J., Berch, S.M., 2014. A compilation of forest biomass harvesting and related policy in Canada. *Technical Report 081*. Retrieved from www.for.gov.bc.ca/had/pubs/Docs/Tr/Tr081.htm
Rogner, H., Aguilera R.F., Archer, C., Bertani, R., Bhattacharya, S.C., Dusseault, M.B., Yakushev, V., 2012. Chapter 7–Energy resources and potentials. Global energy assessment—Toward a sustainable future. NY: *Cambridge University Press and the International Institute for Applied Systems Analysis*.
Russel, J.F., 2014. Breaking down old practices: Forest Service, Confluence Energy open new chapter in timber management. *Steamboat Pilot & Today*. https://www.steamboatpilot.com/news/breaking-down-old-practices-forest-service-confluence-energy-open-new-chapter-in-timber-management/
Schelhas, J., Hitchner, S., Brosius, J. P., 2018. Envisioning and implementing wood-based bioenergy systems in the southern United States: Imaginaries in everyday talk. *Energy Research & Social Science*, 35. 182–192.

Stephen, J., Wood-Bohm, S., 2016. Biomass innovation: Canada's leading cleantech opportunity for greenhouse gas reduction and economic prosperity. Retrieved from http://biocleantech.ca/Biomass_GHGEconomy_Canada_2016.pdf

Stewart, J., Ayres, R., 2001. Systems theory and policy practice: an exploration. *Policy, Sci.*, 34. 79—94.

Strauss, C., 2012. Making Sense of Public Opinion: American Discourses About Immigration and Social Programs. *Cambridge University Press*.

Takala, T., Kähkönen, T., Laakkonen, A., Tikkanen, J., 2020. Towards more sustainable bioenergy production—forest owners' readiness for change. *Scandinavian Journal of Forest Research*, 35. 1-2, 108–116. DOI: 10.1080/02827592.2020.1733072

Thiffault, E., Endres, J., McCubbins, J. SN., Junginger, M., Lorente, M., Fritsche, U., Iriarte, L., 2015. Sustainability of forest bioenergy feedstock supply chains: Local, national and international policy perspectives. *Society of Chemical Industry. Perspective: Sustainability of forest bioenergy. Biofuels, Bioproducts, Biorefineries*, 9. 283–292. DOI: 10.1002/bbb

Vargas, S., FAO, 2010. Chapter 4—Rural Development and Bioenergy: An Alternative Approach. *Food and Agriculture Organization of the United Nations*. 67—79.

Vera, I., Langlois, L., 2007. Energy indicators for sustainable development. *Energy*, 32.

Vuorio, K., 2013. Lämpöyrittäjätoiminta vuonna 2012. TTS:n tiedote: metsätyö, -energia ja yrittäjyys 4/2013 (765). 4 p. [In Finnish].

Walker, B., Holling, S., Carpenter, S.R., Kinzig, A., 2004. Resilience, adaptability, and transformability in social-ecological systems. *Ecology and Society*, 9.

Weiss, G., 2011. Theoretical approaches for the analysis of innovation process and policies in the forest sector. *Innovation in Forestry: Territorial and Value Chain Approaches*. 97—105.

White, W.A., 2016. Chapter 6: Economic and Social Barriers Affecting Forest Bioenergy Mobilisation: A Review of the Literature. *Forest Bioenergy Mobilisation. Mobilisation of Forest Bioenergy in the Boreal and Temperate Biomes*. Kingsmere Economics Consulting, Edmonton, AB, Canada. 84–101.

WSU, 2011. Ripple Effects Mapping (REM). https://ppe.cw.wsu.edu/ripple-effects-mapping/