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A supply chain analysis framework for assessing state-level forest biomass utilization policies in the United States

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ABSTRACT

The number of state policies aimed at fostering biomass utilization has proliferated in recent years in the United States. Several states aim to increase the use of forest and agriculture biomass through renewable energy production. Several more indirectly encourage utilization by targeting aspects of the supply chain from trees standing in the forest to goods sold. This research classifies 370 state policies from across the United States that provides incentives for forest biomass utilization. We compare those policies by types of incentives relative to the supply chain and geographic clustering. We then develop a framework for policy evaluation building on the supply chain steps, which can be used to assess intended and unintended consequences of policy interactions. These findings may inform policy development and identify synergies at different steps in the supply chain to enhance forest biomass utilization.

1. Introduction

Utilization of forest biomass has emerged as a key strategy for addressing a variety of environmental and energy related needs in the United States. On the one hand, forest biomass has the potential to provide significant amounts of feedstock for bioenergy production, which may help offset desired reductions in fossil fuel use [1]. On the other hand, it can help accomplish desired reductions in hazardous fuels that feed wildfires [2], and provide a means for restoring unhealthy forests plagued by insects and disease or creating suitable wildlife habitat [3]. As a result, there has been a proliferation of state policies seeking to stimulate forest biomass utilization.

Building on examples from other parts of the world, particularly in Europe [4,5], states have passed a range of legislation promoting the use of biomass, including production tax credits for renewable energy generation, cost-share programs for equipment purchases, and new contracting rules for raw material procurement. The strategies are varied but the goals — and often the challenges they are meant to address— are similar [6]. This proliferation has been so rapid that there lacks a basic understanding and classification of state policies, much less an evaluation of their efficacy individually and in conjunction with other local, state, and federal interventions. This information is critical to the development and refinement of policies aimed
at addressing the variety of environmental concerns and consumer demands of public and private forests.

The purpose of this analysis is to: (a) identify current state-level forest biomass utilization policies in the United States; and (b) to categorize them relative to their position on the biomass supply chain. A traditional way to characterize policies would be to focus on the types of incentives or

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instruments used [7,8]. They can be categorized, for example, by type of tax incentive, regulations enacted, or contracting mechanisms employed. We use this categorization but then build upon the structure presented by Roos [9] and present a framework for organizing policies by the stage in the supply chain that they seek to affect and by the types of instruments employed. We also compare policies by region of the country to identify geopolitical and physical resource patterns. The purpose of the framework is to organize disparate state policy practices so that analyses can focus on policy synergies and the unintended consequences of their interaction. Focusing on the particular stages of the supply chain may enable policy makers and policy advocates to identify particular interventions to target bottlenecks to utilization, interaction affects of policies, or to assess the degree to which current policy practices are conducive to stated goals. Such a framework may also contribute to increased understanding of the factors critical to bioenergy development in the United States and abroad [10].

2. Conceptual framework

Theories of environmental governance and analysis have been sparsely applied to the field of biomass and bioenergy. Existing studies largely focus on the technical feasibility of biomass utilization [11]. Those that have focused on policy have evaluated the effectiveness of individual policies [12], or narrowly on resulting economic [13,14] or market impacts [15]. A handful of studies have evaluated the effectiveness of policy instruments that are designed to foster bioenergy development [4,5,16,17], factors related to their implementation [10,18], and social considerations for policy design [19].

These studies provide an important foundation upon which to evaluate policy instruments. But, there is a need to expand analyses to understand the range of policies being used as well as interaction among policies, including at different levels of government [20], and the synergies created or unintended consequences [21,22]. Analysis is also needed to identify which mixture of policy instruments can best achieve desired outcomes [23].

Policy instruments may be defined as "the set of techniques by which governmental authorities wield their power in attempting to ensure support and effect or prevent social change" ([24], p 21). The social change in this context means change in how we generate electricity and heat, and fuel for transportation and manufacturing. Social change can be achieved more readily through a complementary mix of policy instruments than using individual policies because firms and individuals face different constraints and opportunities; a single policy will not change the behavior of all relevant actors [25].

Van Gossum and colleagues [23] advance a framework for analysis that identifies four key features of effective policies. First, a broad range of policy instruments, such as tax incentives, regulations, or technical assistance programs are needed to affect social change and that policy performance will depend on the optimal pairing of these instruments with appropriate institutions at local, state, and federal levels [20]. Second, policy instruments that invoke motivational and informative structures are preferred to policy interventions that are highly coercive, especially when actors perceive that there could be self-interest in adopting new approaches [26]. This is the case with bioenergy development, renewable energy generation, forest restoration, and economic development, which collectively offers opportunities for mutual benefit. Third, instruments may effectively influence behavior of some firms but not all of them and not all the time, and therefore must be responsive and flexible to change. This is important in the context of bioenergy development because of the rapid escalation in policies, both state and federal, and the evolving context of forest management and climate change [27,28]. Fourth, approaches that create win–win scenarios encourage actors to exceed policy requirements. This too is relevant to providing adequate incentive for private forest landowners to participate and where requirements on energy producers result in more efficient or diversified production.

Using this framework, we broadly assess state policies in the context of the diversity of instruments employed and the degree to which they cumulatively reflect a motivational versus coercive structure to stimulate biomass utilization. The interaction of individual state policies, responsiveness to change, and measures of mutual reinforcement were not included in this analysis, nor were federal policies. However, it is important to note the array of federal policies that exist, many of which provide financial assistance for bioenergy development in the states [29–31]. The American Recovery and Reinvestment Act of 2009 [32] is particularly significant in the magnitude of funding authorized for renewable energy, harvesting of biomass for wildfire risk reduction, and for the range of policy instruments used to shift to carbon-friendly energy sources.

Although biomass has long been utilized for a variety of purposes, next-generation bioenergy and biofuels production are emerging as a key dimension of a national energy strategy. Proponents believe that forest biomass has the potential to make a significant contribution to domestic energy sources and one that is renewable [33,34]. Coupled with the potential for rural community development and the restoration and enhancement of the nation's public forests, and especially those at risk of wildfire, insect and disease epidemics, biomass utilization is receiving increased attention in the development of state energy policy [35,36]. In the absence of and in addition to federal initiatives, states are in a position to make investments based upon the types and volume of forest resources present and their ability to leverage private investment.

3. Methods

Biomass is broadly interpreted in state statues as any plant-based material that may be utilized for electricity, biofuel production, or thermal heating. Forest biomass is generally defined as the by-product of forest management, restoration, and hazardous fuel treatments, including trees and woody plants (e.g., limbs, tops, needles, leaves) [37]. Also included are residues from primary and secondary wood-processing

facilities (e.g., sawdust, mill shavings, cut ends), biomass from dedicated energy crops (e.g., Poplar plantations), and wood construction material. For the purposes of this analysis, biomass utilization is defined as the use of woody material in the production of a full range of wood products including engineered lumber, pulp and paper, heat and power, and other bio-based products like plastics and biofuels [37].

State forest biomass polices were identified using three sources. First, the Database of State Incentives for Renewable Energy [38] provided detailed summaries of renewable energy policies at the state level including those that create incentives for the use of forest biomass. Information was collected on policy elements, dates enacted, target audiences, and authorities. Second, our database was expanded to include other biomass-relevant legislation using FindLaw.com legal search engine [39] and the State Energy Program website [40]. Thirdly, experts were contacted from state agencies and professional associations for information concerning current and forthcoming biomass policies. The primary point of contact was the director or manager of the state energy office or program. At least one person from each state was contacted to verify information.

To be included in the database, a policy had to be current state law that explicitly focused on forest biomass in a list of approved feedstocks, or broadly include biomass from which woody material was not explicitly disallowed. Policies targeting other types of biomass, such as anaerobic digestion of agriculture feedstocks, were not included, nor were policies aimed at general commerce unless biomass was explicitly stated (e.g., depreciation of equipment value). Ultimately, 370 distinct policies were identified across all 50 states as of November 2008 that directly or indirectly affected the utilization of forest biomass [6].

The database was organized by types of instruments employed, which included six categories derived from the policy literature [7,8,17]: tax incentives, cost-share programs and grants, rules and regulations, financing, procurement, and technical assistance (Table 1). Tax incentives, for instance, included state policies directed at property or production tax credits for the generation of renewable energy using biomass. Financing included policies such as loan programs and bonding for facility development whereas procurement policies included requirements for the types of materials used in building construction. State renewable energy mandates generally required suppliers of electricity to provide a certain percentage of energy from renewable resources, though in a few states purchasers of electricity were regulated through procurement policies. All policies were classified by the authors and crosschecked for consistency. Where there was more than one approach used, policies were classified by their dominant intent, which was determined by the enabling legislation.

4. Forest biomass supply chain

Biomass harvested from public and private forestlands passes through a gauntlet of stages from trees standing in the forest to various consumer markets. Policies may directly or indirectly influence how trees are harvested and sorted, the portion of the tree used for biomass versus solid wood production, the form (e.g., logs, wood chips, compressed fuel) by which biomass is transported, the type of manufacturing or conversion technology used, and the transport and marketing of finished products to consumers. We organized the our supply chain accordingly, starting with the harvesting of trees and progressing through stages of transportation, processing, and consumer purchase [41] (Fig. 1). For our purposes, forest management and planning activities were not included. However, silvicultural prescriptions and timber stand improvement strategies can significantly affect biomass production and subsequent decisions about where to locate facilities.

In the first step in the supply chain, trees and shrubs are harvested and the raw logs are sorted and transported to various locations for processing and manufacturing or chipped on site. Logs and harvest residuals might also be chipped on site and transported for biomass processing. Once at a processing facility, logs are resorted for market optimization and the processing residues may be collected for reuse (e.g., wood shaving, cut ends). Another option is that the logs themselves could be chipped and used for paper production, engineered products, or for energy. Ultimately, the final product is transported to consumer markets by road or rail or moved via electric transmission or gas pipelines. Organizing policies by these steps helps to identify policy interventions targeted at different stages in the utilization process.

5. Classification of policy approaches

Using the supply chain to classify policies, the instruments in Table 1 were overlaid to highlight the types of policies that could be used to enhance biomass utilization. A conceptual diagram is provided in Fig. 2, where hypothetical relationships between the policy type and step in the supply chain are illustrated. In reality, any policy instrument could be used at any step in a variety of supply chain configurations [41]. Our review of state policies suggests that some instruments were more common for certain steps.

5.1. *Overview of policies*

We identified 370 state policies across the 50 states [6]. Taken together, they illustrate the scope of state-level efforts to create incentives for forest biomass utilization. Looking across the states, some have been more active in the total number of policies directed at biomass while others have targeted efforts in particular aspects of utilization or are partial to certain types of instruments. Massachusetts, for instance, had more policies than any other state, which were equally distributed across types of instruments. Missouri meanwhile had a similarly high number of policies but almost exclusively focused on technical assistance programs. A number of policies have been enacted in Wisconsin but they have mostly focused on cost-share and grant programs to assist industry. Every state had at least one policy directed at biomass utilization, though nine states had three or fewer biomass-specific policies.

Table 1 – Type of policy instruments and examples related to forest biomass utilization.[a]

Policy type	Example policy
Tax Incentives	
Sales tax credit	Reduction or exemption from state sales tax the purchase of equipment for harvesting, transportation, or processing of biomass.
Corporate or production tax credit	Deductions or exemptions from taxes paid for installing certain types of biomass manufacturing systems; may include credits for the volume of biomass used in production or the amount of energy produced.
Personal tax credit	Income tax credits and deductions related to the installation of certain types of renewable energy systems.
Property tax credit	Exemptions, exclusions, and credits for property (including equipment) used for the siting of manufacturing facilities or the transport of biomass.
Cost-Share and Grants	
Cost-share	Funding through a waiver of fees or supplemental resources for the purchase or operations cost of equipment used.
Grants	Funding through competitive grants to purchase equipment, support research, product commercialization and marketing.
Rebates	Funding the purchase or installation of qualifying manufacturing systems.
Rules and Regulations	
Renewable energy standards	Requires utility companies to use renewable energy for a certain percentage of their retail electricity sales or generating capacity.
Interconnection standards	Governs how energy producers connect to the grid.
Green power programs	Consumer option to purchase electricity generated from renewable resources.
Public benefit funds	Sets aside funds from utility bills for renewable energy development.
Equipment certification	Standards for the efficiency or quality of equipment used to process biomass.
Harvest guidelines	Establishes best management practices for removal and procurement of biomass.
Financing	
Bonds	Allows governments to borrow to support construction of facilities including installation of wood boilers to heat industrial facilities.
Loans	Provides financing for the purchase of equipment and may include micro-loans, low-interest, and zero-interest loans.
Procurement	
Procurement	Mandates or provides incentives for use of bio-based products in the construction, processing, heating, or operation of vehicles or equipment.
Net metering	Requires utilities to buy-back excess power generated from renewable sources.
Technical Assistance	
Training programs	Courses or certificates offered to businesses or staff to develop technical expertise.
Technical assistance	Coordination of research, disseminates information, or assists with business planning and grant writing.

a Sources: [7,8,38].

Across all the states, tax initiatives were the most common policy instrument followed in use by technical assistance programs and procurement policies. Most of the 370 policies identified were broadly aimed at providing incentives for renewable energy through motivational structures and about half explicitly focused on forest biomass as the principle feedstock. Just a handful of those identified forest health, wildfire, or habitat improvement as motivating forces behind the policy.

5.2. *Policies by supply chain step*

5.2.1. *Harvesting*

By organizing state policies by their use within the supply chain, it becomes clear that an overwhelming number were directed at manufacturing or consumers (Table 2). By comparison, policies directed at biomass-harvesting were less frequent. Twenty harvesting-related polices were identified in 15 states and more than half of those were focused on technical assistance programs to train loggers and landowners on certain types of harvesting equipment or to conduct resource plans to estimate the volume of biomass available for use. States having enacted harvesting policies included Louisiana and Oregon, which are characteristic of biomass producing regions, but also states like Nevada and Missouri are seeking to affect forest management and stimulate their respective biomass industries. In a few other cases, such as Minnesota and Pennsylvania, states adopted guidelines designed to influence how biomass is harvested, where it can be sustainably removed, and safeguards for future production.

5.2.2. *Transportation*

Only two policies were identified as including provisions for offsetting the cost of transportation despite transportation being identified as a primary obstacle to increased utilization [42]. The Oregon Renewable Fuels Standard [43] provides a 9 \$ t^{-1} green tonne income tax credit for the removal and use for energy of biomass directly from the forest. The Arizona Healthy Forest Enterprise Incentives Program [44], which was classified in the analysis as a manufacturing policy, also included provisions for reducing state diesel fuel surcharges from 30 to 70 \$ m^{-3}. This policy was enacted in Arizona to offset the high cost of transportation due to distant processing facilities, whereas the Oregon law was spurred by high transport costs resulting primarily from difficult resource access. Both policies provide incentive to overcome particular transportation barriers that exist in other regions. Considering the differences in regional challenges, various types of policies could be envisioned, such as changes in regulations on legal highway load limits for hauling biomass or an exemption from property taxes paid on trucks used to haul biomass.

5.2.3. *Manufacturing*

The largest number of policies was directed at manufacturers and processors of bio-based products. These policies most commonly provided tax incentives and production tax credits to motivate energy production. Tax incentives frequently were property tax credits for qualifying biomass production. For instance, a Rhode Island law [45] allows cities and

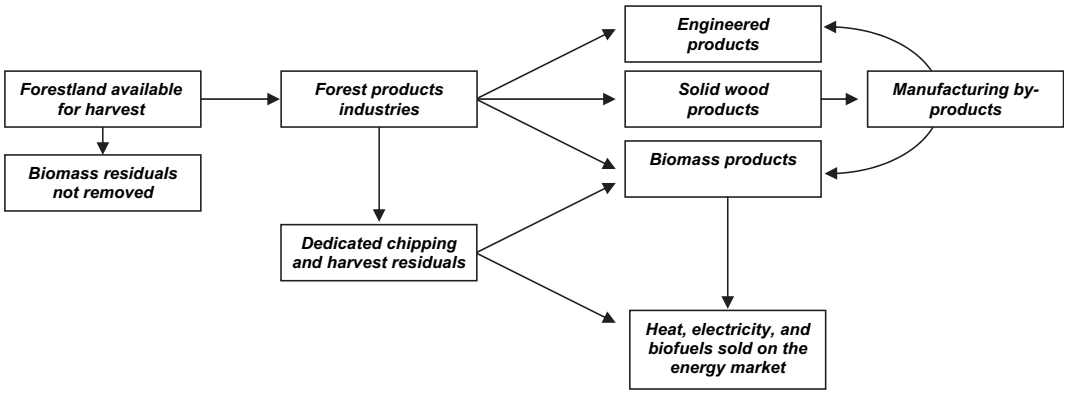

Fig. 1 – Wood biomass supply chain.

townships to exempt renewable energy systems from property taxation. Production tax credits often resembled a New Mexico law [46] in which businesses are entitled a corporate income tax credit of 10 $ MWh^{-1} for the first 400 GWh produced annually from wind or biomass for a period of 10 years. Other types of manufacturing tax incentives included, for example, exemptions for purchases of qualifying equipment or feedstocks, such as the Georgia Biomass Sales and Use Tax Exemption [47] in which forest residues, wood pellets, or biofuels must be utilized in the production of energy.

A number of manufacturing policies were also focused on cost-share programs. They included, for instance, the offset of costs for installing bioenergy facilities or equipment. Technical assistance programs were also used in all steps in the supply chain but most frequently targeted manufacturers. They included programs targeting research funding for studying the feasibility of specific products (e.g., cellulosic ethanol) or through partnerships and government initiatives to explore economic development opportunities. Many targeted the development of statewide action plans or the adoption of renewable energy technology through demonstration projects highlighting commercially available technologies, such as the North Dakota biomass demonstration and education program [48].

Policies targeting the financing of biomass enterprises were the least employed for any step in the supply chain, but included a number of important programs offering low-interest loans to manufactures (and consumers) such as in the North Carolina's Energy Improvement Loan Program [49]. Coercive instruments like rules and regulations were less frequently used, but of interest was the growing number related to biofuels production. A query of the database reveals 46 biofuels policies that have been enacted in 25 states. Of those, 19 are tax incentives and 14 related to technical assistance programs, but an increasing number are leaning towards requiring gasoline or diesel blending with biofuels.

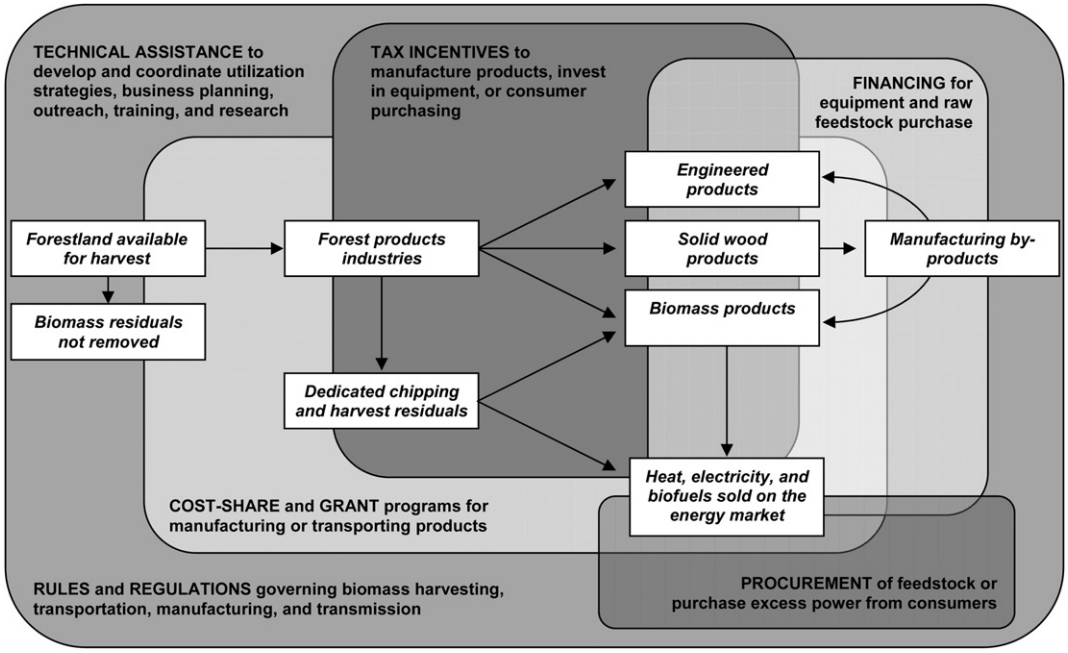

Fig. 2 – Types of biomass utilization policies organized by steps in the biomass supply chain.

Table 2 – Number of biomass utilization policies by state, policy instrument, and step in the supply chain.

State	Policy instrument							Supply chain				
	Cost-share & grants	Technical assistance	Financing	Procurement	Rules and regulations	Tax incentives	Total policies	Harvesting	Transportation	Manufacturing	Consumer markets	Total policies
Northwest												
Alaska	1	0	1	0	0	1	3	0	0	3	0	3
Idaho	2	1	2	1	0	3	9	0	0	6	3	9
Montana	0	0	0	0	1	10	11	0	0	7	4	11
Oregon	1	2	1	1	3	4	12	1	1	7	3	12
Washington	2	0	1	1	1	8	13	0	0	7	6	13
Wyoming	0	0	0	0	1	1	2	0	0	1	1	2
West Coast												
California	2	3	1	0	2	5	13	1	0	11	1	13
Hawaii	2	1	1	2	2	1	9	0	0	6	3	9
Southwest												
Arizona	1	0	0	2	1	2	6	0	0	3	3	6
Colorado	1	2	2	1	2	2	10	2	0	4	4	10
Nevada	1	0	0	2	2	2	7	1	0	3	3	7
New Mexico	0	2	0	1	0	5	8	1	0	5	2	8
Utah	0	1	0	2	0	3	6	0	0	3	3	6
Midwest												
Illinois	2	0	1	3	0	1	7	0	0	5	2	7
Indiana	0	0	1	1	0	0	2	0	0	1	1	2
Iowa	2	1	2	1	2	4	12	0	0	9	3	12
Kansas	0	1	0	0	0	4	5	1	0	2	2	5
Missouri	0	6	1	1	3	1	12	1	0	8	3	12
Nebraska	0	0	1	1	0	0	2	0	0	0	2	2
North Dakota	2	5	0	1	1	3	12	2	0	7	3	12
Oklahoma	0	1	2	2	0	0	5	0	0	1	4	5
South Dakota	1	1	0	2	0	1	5	0	0	2	3	5
Lake States												
Michigan	2	1	0	1	0	2	6	0	0	3	3	6
Minnesota	2	1	1	1	3	1	9	2	0	6	1	9
Ohio	2	4	0	2	3	1	12	0	0	10	2	12
Wisconsin	6	3	0	2	3	0	14	2	0	6	6	14
Northeast												
Connecticut	4	1	1	2	3	1	12	0	0	6	6	12
Delaware	2	0	0	2	0	0	4	0	0	3	1	4
Maine	3	0	0	1	1	1	6	0	0	4	2	6
Maryland	0	0	0	1	1	3	5	0	0	3	2	5
Massachusetts	3	2	3	3	2	2	15	0	0	11	4	15
New Hampshire	2	1	1	1	1	1	7	0	0	4	3	7
New Jersey	0	0	1	3	3	0	7	0	0	4	3	7
New York	1	2	1	3	2	1	10	0	0	5	5	10
Pennsylvania	2	1	0	2	2	0	7	2	0	3	2	7

Rhode Island	0		1	1		2		1		1		6		0		0		1		5		6
Vermont	2		2	1		1		0		2		8		0		0		3		5		8
Southern Appalachia																						
Kentucky	0		1	0		1		0		3		5		0		0		4		1		5
North Carolina	2		4	1		2		1		4		14		1		0		6		7		14
Tennessee	0		4	1		0		0		0		5		0		0		3		2		5
Virginia	0		0	0		4		0		0		4		0		0		1		3		4
West Virginia	0		1	0		1		0		0		2		0		0		1		1		2
South																						
Alabama	1		3	0		0		0		1		5		0		0		3		2		5
Arkansas	0		0	0		2		1		0		3		0		0		1		2		3
Florida	4		3	0		1		0		2		10		1		0		8		1		10
Georgia	0		0	0		0		0		3		3		0		0		3		0		3
Louisiana	0		1	0		1		1		0		3		1		0		1		1		3
Mississippi	0		1	1		0		0		0		2		0		0		1		1		2
South Carolina	1		2	1		0		0		2		6		0		0		5		1		6
Texas	0		1	0		2		3		3		9		1		0		5		3		9
Total policies	59		67	31		66		52		95		370		20		1		215		134		370

5.2.4. *Consumer markets*

In the last step of the supply chain, policies targeting consumer markets were of various forms. On the one hand, procurement policies were widely used to establish requirements on utilities to buy-back excess energy produced from consumers who have installed qualifying biomass energy systems (net metering). A number of states have also enacted requirements or a preference for using certain materials for new building construction for which energy savings can be achieved or that reduce carbon dioxide emissions through certain manufacturing processes (e.g., LEED Standards). Twelve states have enacted policies providing such incentives where forest biomass qualifies. Tax incentives were also frequently used to create consumer demand. For instance, tax credits and exemptions were common for residential installation of renewable energy systems. The Vermont sales tax exemption [50] is an example where small-scale distributive energy systems of up to 250 kW are tax exempt.

5.3. *Regional clustering and variation*

5.3.1. *Policy instruments*

We examined policies by region, compared policy instruments used, and step in the supply chain (Fig. 3). Within regions, the Midwest and West Coast used a wide variety of approaches while the West Coast had a slight preference for tax incentives (Table 3). In the Midwest, the greatest percentage of policies provided technical assistance followed closely by tax incentives and procurement. More than half the enacted policies in the Northwest, by comparison, were related to tax incentives geared towards manufacturing, and about one third of policies in the Southwest and South were similarly targeted. The greatest percentage of policies enacted within the Lake States targeted utilization through cost-share and granting programs followed by technical assistance and regulatory policies, almost all of which were geared towards manufacturing.

The Southern Appalachian region is notable in that there were comparatively few cost-share programs, tax incentives, or regulations. The Northeast region, by comparison, employed a diversity of policy approaches with a preference towards consumer procurement programs, manufacturing cost-share and granting programs, and rules and regulations directed towards manufactures. Of the 59 cost-share and grant programs across the country, 43 explicitly targeted manufacturers. Of those, 15 were in the 11 northeast states and eight in the four Lake States.

5.3.2. *Supply chain step*

Looking across the supply chain, most policies, as previously identified targeted manufacturing and consumer markets and only a few were related to transportation (Table 3). Within the harvesting step, however, most policies were related to providing technical assistance, with the Southwest and Midwest leading the way. The Southwest and Lake States proportionally had the greatest number of harvesting policies given the number of states in each region. In the Lake States, for example, biomass-harvesting guidelines were developed in Minnesota and Wisconsin to establish safeguards for sustainable production. The Northwest and Southern

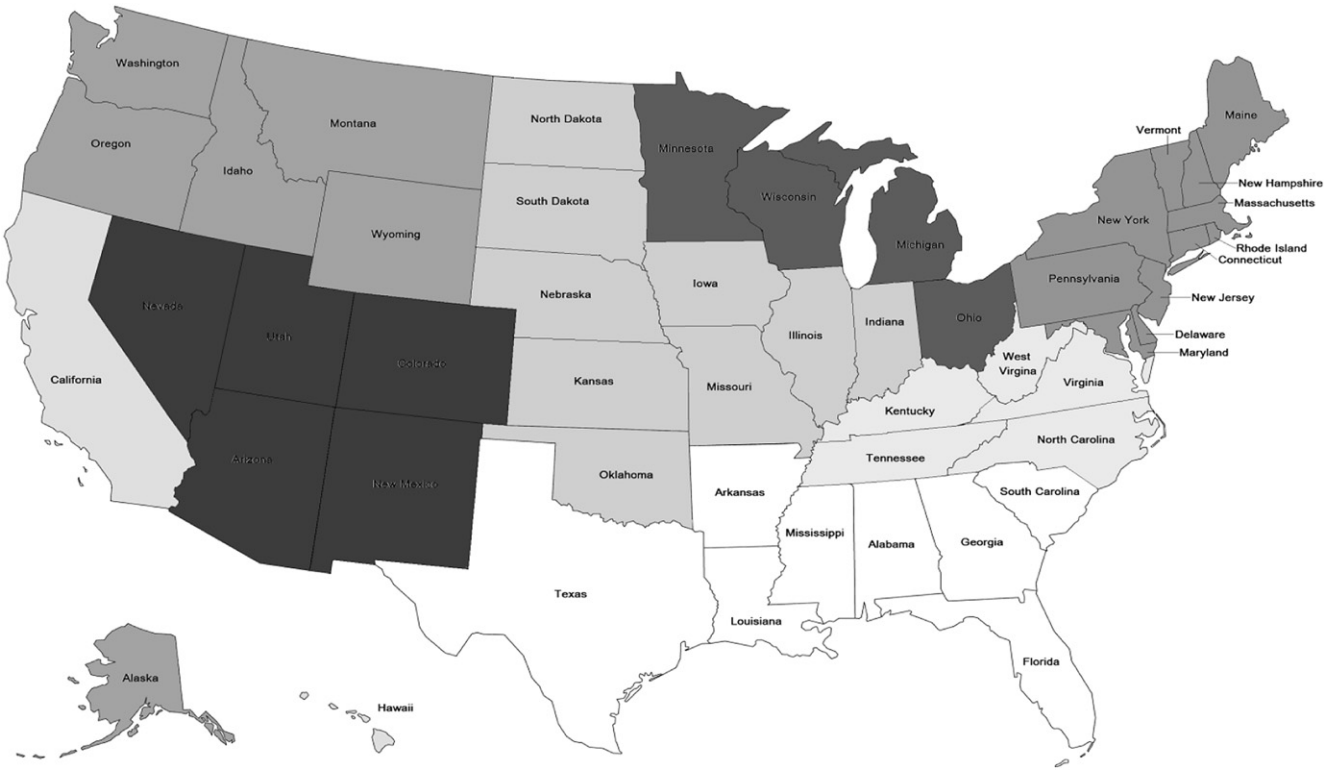

Fig. 3 – Regional classification of states.

Appalachia by comparison had the fewest policies given the number of states.

In each region, states enacted multiple policies targeting manufacturing. The West Coast, for instance, averaged more than eight policies per state, though most of those were in California (Table 2). The Lake States averaged more than six policies per state with most of those in Ohio, which employed a diversity of policy approaches. The Northwest followed with about five policies per state targeting the manufacturing sector. Tax incentives were the most common approach within those states, particularly among Idaho, Montana, Oregon, and Washington, but the configuration of their policies differed. The greatest number of policies targeting manufacturing was in the Northeast where cost-share and granting programs were common as were rules and regulations, typically related to renewable energy mandates, which were common throughout the county.

As a percentage of total consumer policies, the Northeast averaged more than three policies per state. More than half were related to procurement involving net metering or LEED certification. The Southwest and Lake States followed with an average of three policies per state, concentrated most in Wisconsin in the Lake States and evenly spread across the Southwest. States in the South, by comparison, enacted relatively few consumer policies.

6. Discussion

The distribution of policies across regions, instruments employed, and supply chain step allows policy makers to consider the range of approaches taken to encourage biomass utilization and their potential interaction. The utility of the diagram in Fig. 2 is that, for any given region, policy gaps may be identified that would facilitate utilization efforts or to help businesses make strategic investments in infrastructure. Likewise, the framework allows for an examination of how policies interact within a broader context and in particular, the effectiveness of individual policies working synergistically with (or against) existing policies within the supply chain. The framework can also serve to inform neighboring states and policy advocates of the types of approaches taken to create incentives to use biomass.

In the analysis, we found that motivational policies targeting manufacturing were clearly the most common strategy, and that within the range of those policies, tax breaks and cost-share or granting programs were the most common. We also found consumer procurement policies, and rules and regulations targeting manufacturers to be common. In fact, many states employed a diversity of policy instruments, which based upon Van Gossum's policy analysis framework [23], would be conducive to successfully expanding biomass utilization. In terms of the types of instruments employed, motivational structures were also preferred over more coercive policies related to rules and regulations. Though, certain regions were more apt to employ rules and regulations, which were often targeted at manufacturing.

The overlay of policies also revealed that transportation policies were rarely enacted, despite its widely documented barrier to increased utilization. Recognition of such gaps in the supply chain can help policy makers consider the effectiveness

Table 3 – Biomass utilization policies by region, instrument used and step in the supply chain.

Supply chain	Region (No. States)[a]								
	Northwest (6)	West Coast (2)	Southwest (5)	Midwest (9)	Lake States (4)	Northeast (11)	Southern Appalachia (5)	South (8)	Policy total
Harvesting									
Cost-share	0	0	1	1	0	1	0	0	3
Tech assistance	0	1	3	3	1	0	1	2	11
Financing	0	0	0	0	0	0	0	0	0
Procurement	0	0	0	0	0	0	0	0	0
Rules and regs	1	0	0	0	3	1	0	0	5
Tax incentives	0	0	0	0	0	0	0	1	1
Subtotal	1	1	4	4	4	2	1	3	20
Transportation									
Cost-share	0	0	0	0	0	0	0	0	0
Tech assistance	0	0	0	0	0	0	0	0	0
Financing	0	0	0	0	0	0	0	0	0
Procurement	0	0	0	0	0	0	0	0	0
Rules and regs	0	0	0	0	0	0	0	0	0
Tax incentives	1	0	0	0	0	0	0	0	1
Subtotal	1	0	0	0	0	0	0	0	1
Manufacturing									
Cost-share	5	3	1	5	8	15	1	5	43
Tech assistance	2	3	1	8	5	7	7	6	39
Financing	4	2	2	3	1	3	1	2	18
Procurement	0	0	1	3	1	1	1	0	7
Rules and regs	2	4	4	5	6	14	1	5	41
Tax incentives	18	5	9	11	4	7	4	9	67
Subtotal	31	17	18	35	25	47	15	27	215
Consumer markets									
Cost-share	1	1	1	1	4	3	1	1	13
Tech assistance	1	0	1	4	3	3	2	3	17
Financing	1	0	0	5	0	6	1	0	13
Procurement	3	2	7	9	5	20	7	6	59
Rules and regs	3	0	1	1	0	1	0	0	6
Tax incentives	8	1	5	3	0	5	3	1	26
Subtotal	17	4	15	23	12	38	14	11	134
Total	50	22	37	62	41	87	30	41	370

a See Fig. 3.

and interaction of individual policies in a broader context. For instance, the failure of a particular policy, such as a mandate to deliver a certain percentage of renewable energy by the year 2025, may be unduly influenced by high transportation costs. Misdirected resources at the state level towards enforcing regulatory mandates could retard opportunities for providing tax incentives directed at transportation. Alternatively, federal rules and regulations disqualifying biomass from national forests for use in the federal renewable fuels standard [51] could inadvertently shift investments in processing infrastructure away from states in which there is a sizable amount of federal forestlands and thereby undermine state efforts.

To use our framework to guide policy decisions, it is necessary to first identify local and regional priorities and in particular, the challenges of biomass removal and subsequent utilization along the supply chain. Previous research highlights factors such as site operability [52], composition and quality of trees harvested [53,13], market specifications [15,42], distance to processing facilities [54], and technology [55]. Each has a unique impact on utilization success and may vary by

region, which is why policies uniquely tailored to local challenges are appropriate. Yet, where overlap among states and regions exists, policy makers and advocates may learn from attempts to alleviate bottlenecks.

Our analysis shows that some regions, like in the South, have taken few steps towards incentivizing biomass utilization. In other regions like the Southwest where wildfire risks are high and there exists limited biomass infrastructure, more targeted policies and a greater diversity of policy instruments may be necessary to overcome barriers. Likewise, some states are actively seeking to provide incentives appropriate for their desired level of utilization, which may serve as examples to neighboring states. States such as Colorado, California, Minnesota, North Carolina, and Oregon are innovators in their respective regions, not because of the number of policies enacted but for the diversity and types of approaches taken. It will be interesting to see if in places like the Front Range of Colorado with virtually no existing processing capacity, whether or not biomass utilization will flourish. Learning from these examples will be essential in crafting legislation appropriate for the types of forest resources present and the scope of the utilization problem. It will also be necessary to examine opportunities to develop new sources of energy that avoid the unintended consequences of over development.

The implication of differences in policy design is that performance may vary based upon the challenges they were enacted to address and the interaction at the state and federal level. These factors highlight the importance of context in understanding instrument choice [20]. The proliferation of policies is encouraging in that examples of innovation will emerge that may efficiently address society's needs. But, without an understanding of the types and scope of policies in place, there are bound to be redundancies in failure and inefficiencies in practice. There will also be state and regional preferences for particular instruments or for supply chain steps in which to focus. The choice of instruments will also be "between often competing and most often conflicting values of effectiveness, efficiency, legality, democracy and legitimacy" ([23] p 397). Some instruments may work well together while others may not. This information is critical to policy refinement.

7. Conclusion

We presented a framework for classifying bioenergy policies that we believe provides a critical step towards being able to evaluate the efficacy of state and federal efforts, and one that enhances how we view the interaction and complementary mix of instruments. By overlaying instruments on the physical movement and production of biomass, our goal was to provide a framework that would help policy makers and advocates: (a) characterize the range of policy approaches relevant to their region; (b) identify gaps in policy design; and (c) to provide timely information as they attempt to be responsive to local needs. However, we have still a limited understanding of how policies interact with each other and with local resource conditions and governance processes to produce, foster, or inhibit biomass utilization.

Our framework raises several important questions for future research. First, is there a correlation between policy instruments and levels of existing biomass production capacity, the political climate (e.g., propensity to regulate), or the types of technical challenges present? Second, are policy instruments that target specific steps in the supply chain more or less effective at stimulating biomass utilization? Third, how do policies within and among states create synergy or work against one another, and how do they interact with other federal or local initiatives, or with policies not having utilization as the fundamental objective? Finally, how will bioenergy policies interact with emerging state, regional, and federal climate change policies? These questions provide insight into opportunities to exploit complementary policies and the myriad of relationships that may diminish their effectiveness.

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