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Woody Biomass Use Trends, Barriers, and Strategies: Perspectives of US Forest Service Managers

Shiloh Sundstrom, Max Nielsen-Pincus, Cassandra Moseley, and Sarah McCaffery

ABSTRACT

The use of woody biomass is being promoted across the United States as a means of increasing energy independence, mitigating climate change, and reducing the cost of hazardous fuels reduction treatments and forest restoration projects. The opportunities and challenges for woody biomass use on the national forest system are unique. In addition to making woody biomass usage pencil out, national forest managers must also navigate substantial public engagement and forest planning processes that add to the complexity of fostering woody biomass use opportunities on the national forest system. We report on the results of a survey of US Forest Service managers and staff members ($n = 339$) about the trends in, barriers to, and strategies for fostering woody biomass use on national forests and their surrounding communities. The results highlight the economic and market challenges as well as the need for a basket of policies focused on a broad array of strategies for biomass use.

Keywords: biomass utilization, US Forest Service, value-added utilization, biomass energy

In recent years, the US Forest Service, other private and public forest managers, renewable energy advocates, and rural community leaders have become increasingly interested in woody biomass for heat and electrical energy as well as for value-added wood products. Many believe that biomass from logging, fuels treatments, forest products, and urban wood waste can help to increase energy independence, mitigate climate change, and reduce the cost of hazardous fuels reduction treatments and forest restoration projects (Haynes 2002, Perlack et al. 2005, Neary and Zieroth 2007, Aguilar and Garrett 2009). Biomass use may also create opportunities for community economic development (Becker and Viers 2007). Although much of the recent policy discussion in the United States has focused on using woody biomass for energy (e.g., Aguilar and Garrett 2009), woody biomass has had a wide variety of uses that should also be considered in efforts to increase use (Levan and Livingston 2001, US Forest Service 2007; see Table 1).

Despite significant attention to increasing biomass use, development has been slow in many places. Areas with considerable federal landownership, in particular, have found it difficult to create new use opportunities. In addition to the economic challenges facing biomass use, US Forest Service managers have to negotiate challenges related to public engagement and the planning processes fundamental to national forest management (Becker et al. 2009a). Although improving national forest management and ensuring local communities benefit from their neighboring national forests are important public policy goals (Moseley 2002), these goals also increase the complexity of biomass use efforts.

Efforts to increase biomass use face a number of challenges and opportunities that vary across the United States. The barriers to use of woody biomass have been commonly characterized as unfavorable economic conditions, lack of markets and infrastructure, and public concerns about the environmental and human health implications of biomass harvesting and use (Becker et al. 2009a). For example, state and private professional foresters across the nation rated the costs of harvesting and transporting woody biomass as significant challenges to woody biomass use (Aguilar and Garrett 2009).

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Becker et al. (2009a) identified additional challenges including unreliable supply, low value, and a lack of existing industry. Environmental opposition has also arisen in a number of areas in response to proposals for biomass use facilities or large-scale biomass harvesting plans (Pelle 2000, Almquist 2006).

In addition to broad-scale economic and perception challenges, local and regional conditions can influence biomass use efforts (Neary and Zieroth 2007, Becker et al. 2009a, 2009b, Benjamin et al. 2009, Hjerpe et al. 2009). In the US South, where private industrial forest ownership dominates forested landscape and there is extensive forest products infrastructure, much of the focus on biomass use has been on large-scale electricity production that leverages existing forest management, transportation, and production infrastructure (e.g., Gan and Smith 2007, Langholtz et al. 2007). In contrast, the dependability of biomass supply in the northeastern United States may be limited due to the diversity of landowner and management objectives and uncertainty regarding the willingness of landowners to engage in timber harvest and biomass removal (Benjamin et al. 2009). Instead, in the northeastern United States, small-scale applications may be more feasible given the dominance of fragmented, nonindustrial private forestland. In the western United States, much of the landscape is dominated by public forestlands and forest practices have been subject to intense debate for decades. In addition, across much of the western United States, forest management and industrial capacity has declined over the past 20 years (Haynes 2002) and the harvesting and transporting of biomass from remote areas presents additional challenges (Nicholls et al. 2008). Successful biomass use in the western United States may require extensive partnerships and collaborative efforts to overcome challenges related to adverse public perception about the environmental impacts of biomass use and not-in-my-backyard (NIMBY) attitudes about use infrastructure and project scale (Almquist 2006, Stidham 2007). Biomass use proponents and public land managers and their collaborators will likely need to take into account the local social context of forest management to be successful in designing projects for developing use capacity and fostering trust.

There has been a rapidly growing body of research about barriers to woody biomass use, but much of it focuses on individual regions making comparisons unsystematic. In addition, although there is significant literature discussing the opportunities and challenges for wood biomass use in general (e.g., Aguilar and Garrett 2009), issues associated with national forest management and biomass use are unique and have been less studied. Finally, although there has been considerable attention to barriers, fewer studies have sought to understand the solutions that are emerging to address these challenges. In this study, we sought to understand the trends in, barriers to, and strategies for developing woody biomass use on and around the US Forest Service land across the United States. We used a nationwide online survey of national forest managers to ask the following research questions:

1. How do trends in national forest biomass removal and local use vary across the United States?
2. What barriers have national forest managers found most challenging and what strategies have they considered most important to overcome these barriers? How do these barriers and strategies vary across the United States?
3. How does the local context on and near national forests influence the importance US Forest Service managers place on active strategies to increase biomass use?

To address these questions, we surveyed US Forest Service district rangers and biomass coordinators. Although US Forest Service personnel are an important group associated with biomass use, it is important to note that their perspectives are influenced by the cultural and legal–administrative context in which they operate and may well be different from other groups involved in biomass use. It is also likely that stakeholders such as community leaders, environmental activists, and industry representatives could all see the challenges and opportunities of biomass use somewhat differently then US Forest Service personnel. Nevertheless, as important players in forest management the perspectives of national forest managers and staff are a unique and important pulse for biomass use.

Table 1. Biomass use categories.

Amount of added value	Examples
High-value products	Saw logs, veneer logs, and house logs
Low-value products	Paper pulp and chips for oriented strand board and other composite wood products
Value-added products	Posts and poles, tree stakes, trellises, rustic furniture, spindles, landscaping products, animal bedding, engineered wood products, and wood pellets
Minimal-value products	Hog fuel chips and residues for electricity, heat, cogeneration, or liquid fuels

Source: Adapted from US Forest Service 2007.

Methods

Online Survey Instrument

We developed an online questionnaire based on a review of gray and scholarly literature about biomass use (see especially Becker et al. 2009a, 2011, Nielsen-Pincus and Moseley 2009) and implemented the survey using a modified Tailored Design Method (Dillman 2000). Survey respondents were asked to (1) evaluate trends in biomass removal and use on their national forests and surrounding communities, (2) rate the significance of barriers to biomass use that they and their community partners have been facing, and (3) rate the importance of strategies and policy tools that they and surrounding communities have been using to promote biomass use.

Participants were first asked to rate the recent trend in biomass use in their area and recent trends for several different categories of biomass removal from their national forest or ranger district. Trends were measured on a 5-point scale that ranged from decreasing (−2) to increasing (2), with a midpoint (0) labeled as neither increasing nor decreasing. Second, participants rated the barriers to biomass use on their national forest or ranger district. We used individual items focused on specific issues including 14 economic and market development items, 8 national forest management items, and 15 items related to public concerns. We measured all barrier items on a 4-point scale ranging from not a barrier (1) to major barrier (4). Third, participants evaluated the importance of actively pursuing strategies for promoting biomass use. These included 6 individual biomass supply strategies items, 9 industry and market development items, 10 forest management and planning items,

10 public involvement and collaboration items, and 9 policy tool items. Each strategy was measured on 5-point scale ranging from not at all important (1) to extremely important (5). Fourth, participants were asked a number of questions about their role with the US Forest Service. These included the administrative level at which they work (i.e., region, forest, or district), the administrative region in which they work, and their job title. Participants were also offered the opportunity to express their opinions or provide explanations of their ratings throughout the survey using open-ended comments. The questionnaire was reviewed and pretested by members of the Biomass Working Group of the Rural Voices for Conservation Coalition, which includes local practitioners, US Forest Service managers, and decisionmakers from across the United States.

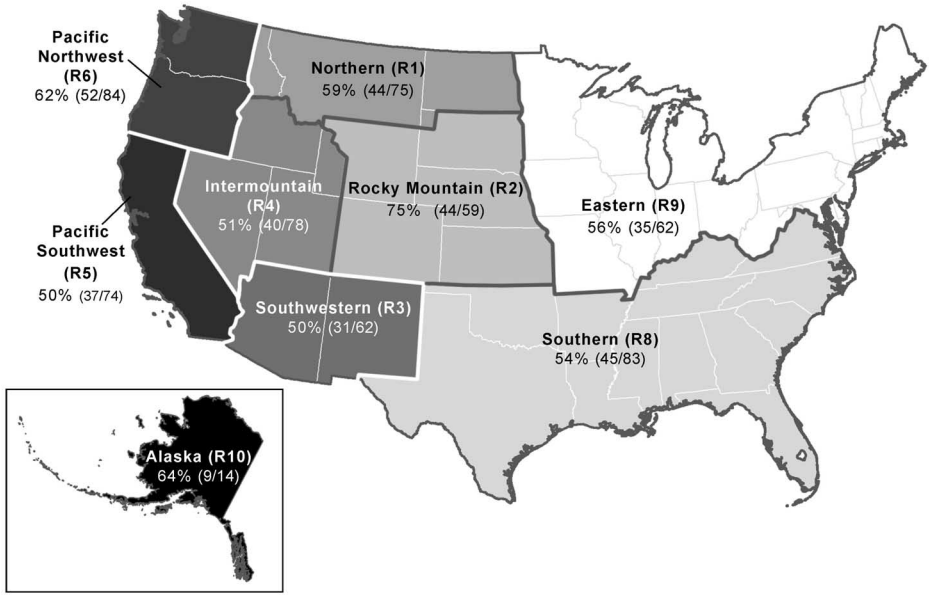


Figure 1. US Forest Service administrative regions and regional response to the online questionnaire (parenthetical notations indicate the US Forest Service region numbers).

Sample Frame and Data Collection

To answer questions about the unique issues of biomass development in the national forest context, our sampling frame included US Forest Service district rangers and technical staff such as biomass coordinators, vegetation, timber, and other natural resource staff. To identify the most current sample of line officers and staff, we called each national forest's reception line and asked for a listing of the current or acting district rangers and the technical staff on the forest most qualified to discuss issues of biomass use. Regional biomass coordinators were also contacted to help identify and corroborate forest-level technical staff whose job duties include working on woody biomass development. We pursued technical staff leads until at least one technical staff person per forest was clearly identified. We identified 445 district rangers and 141 technical staff at the forest and regional level for inclusion in the sample.

The survey was implemented in July and August 2010. We sent a link to the online survey by e-mail to the entire sample. Individuals were asked to enter an access code to target follow-up phone calls and e-mails to nonrespondents. Nonrespondents were subsequently contacted twice by e-mail and once by phone in the 4-week period after the initial invitation to participate.

Data Analysis

We report the proportions and means for each trend, barrier, and strategy item. For the proportional summary trend variables, responses were recoded as increasing for those who reported an increasing or slightly increasing trend in biomass removal and use and decreasing for those who reported a decreasing or slightly decreasing trend.

To develop a useful set of measures of the many barrier and strategy items, we conducted exploratory factor analyses using a principle components method with a varimax rotation, selecting only those factors with eigenvalues greater than 1.0. We used the resulting factor loadings to identify 8 underlying barrier and 10 underlying strategy constructs, each measured by a unique set of items. We created an index for each construct based on the average of the items loading greater than 0.50 on each factor. All but one of these barrier and strategy indices had Cronbach's α values greater than 0.70. The exception was an index of barriers related to transportation and access through private ownerships that consists of only two items with $\alpha = 0.51$. We chose to retain the index as part of the analysis because the two items are positively correlated ($\rho = 0.34$; $P < 0.0001$) and conceptually related; α-values also tend to be related to the number of items in the index.

We examined regional variations in trends, barriers, and strategies using one-way analysis of variance tests where US Forest Service administrative regions were effect coded so that parameter estimates for each region represent the deviation of each US Forest Service administrative region from the national mean (for the entire sample). Only significant deviations ($\alpha = 0.10$) from the national mean are reported.

Finally, we tested how local and regional context affect the importance US Forest Service managers place on actively pursuing strategies to promote biomass use by using an overall index that averaged the responses of all 10 of the strategies indices. This index had a Cronbach's α value of 0.87 and is interpreted as the overall importance of pursuing active strategies to promote woody biomass use. We then tested to see if there was a relationship between the overall strategy index and (1) US Forest Service administrative regions, (2) each barrier index, (3) trends for different biomass value categories, and (4) the overall trend of biomass removal in the respondents' area. Like the previous analyses, US Forest Service administrative regions were coded so that the regional parameter estimates represent the regional deviation from the national mean, this time while accounting for the influences of local barriers and trends.

Results and Discussion

A total of 203 district rangers (46% response rate) and 119 technical staff (84%) participated in the survey. In addition, 17 respondents took the survey without entering an access code. In total, 339 active US Forest Service employees completed at least some of the survey for an overall response rate of 57%. Responses to the question that asked respondents to report the administrative level at which they work roughly match

Table 2. National forest manager evaluations of trend in biomass use in their area for different biomass use opportunities (panel A) and one-way effects coded analysis of variance parameter estimates for the national trend and significant regional deviations from the national trend (panel B).

	Local trends in biomass use				Trend in biomass removal on national forests
	High value	Low value	Value added	Minimal value	
Panel A					
Increasing (%)	19	25	29	39	50
Not changing (%)	54	54	57	45	39
Decreasing (%)	28	21	14	16	11
Panel B					
Nation[a]	−0.25***	−0.12*	0.10*	0.17**	0.52***
Northern	–	−0.59***	–	−0.55***	−0.48**
Rocky Mountain	–	–	–	–	–
Southwestern	–	–	–	–	+0.31*
Intermountain	–	−0.40*	–	−0.39*	–
Pacific Southwest	–	–	–	+0.38*	–
Pacific Northwest	–	+0.48***	–	+0.40**	+0.40*
Southern	+0.52***	+0.40**	–	–	–
Eastern	+0.50**	+0.60***	–	+0.47**	–
Alaska	−0.64*	−0.66***	–	−0.72**	–
F-Value	3.21*	7.77***	0.97	5.19***	2.85**
n	308	299	292	282	317

[a] Responses were measured on a 5-point scale that ranged from downward (−2) to upward (2), with a midpoint (0) neither upward nor downward.
* $P < 0.1$; ** $P < 0.01$; *** $P < 0.001$.

the sample stratification, with approximately two-thirds coming from the district level and the remainder working at the forest or higher administrative levels. Response rates were also well distributed across all administrative regions (Figure 1). The minimum regional response was 50% in the Southwestern and Pacific Southwest regions and a maximum of 64% response in the Alaska region.

Current Trends in Biomass Use

Respondents reported different trends in biomass use in their area for different types of materials (Table 2, Panel A). Participants consistently reported a decline of use of high-value products such as saw logs, while more (nearly 2.5 times) participants reported an increase in use of minimal-value products, such as residues for electricity and heat, than reported a decrease. Roughly one-half of respondents reported no change in use of low-value material such as paper pulp and chips for composites. Although most respondents also reported no change in use of value-added materials such as posts and poles, approximately twice as many respondents reported increasing use as reported decreasing use. When queried generally about the trends in biomass removal from their national forest or ranger district, one-half of respondents reported increasing removal, and only 11% reported decreasing removal.

Regionally, there were significant variations from the national mean for all categories of biomass except for value-added products (Table 2, Panel B). Respondents in the Southern and Eastern regions were more likely to report an increase in use of high-value products, whereas respondents in the Alaska region reported a strong decreasing trend in high-value use. Although the national trend rating for use of low-value biomass products was only slightly negative, respondents in the Northern, Intermountain, and Alaska regions reported more significant declines and respondents in the Pacific Northwest, Southern, and Eastern regions reported increasing low-value use. The national trend for minimal-value products is slightly increasing; however, respondents in the Northern, Intermountain, and Alaska regions also reported declining use of minimal-value products. In contrast, participants from the Pacific Southwest, Pacific Northwest, and Eastern regions reported significantly increasing use of minimal-value materials. On average, respondents across the nation tended to report that the removal of biomass from their national forest or ranger district was significantly increasing; respondents from the Northern region tended to report no change.

Although respondents indicated that biomass removal from national forestlands was increasing, trends for biomass use were more variable with increases mostly reported for Pacific Northwest, Pacific Southwest, Southern, and Eastern regions and decreases were reported for much of the Interior Western regions and the Alaska region. Nationally, respondents reported an increasing trend in use of biomass for minimal-value and value-added products and respondents in much of the Interior West and Alaska reported downward trends for minimal-value products. These distinctions likely reflect the importance of existing industry for promoting biomass removal and use (Becker et al. 2009a) and the lack of sufficient markets and infrastructure to deal with pressing forest health and fuels reduction in the Interior West (Haynes 2002). Nationally, although respondents reported decreases in use of biomass for traditional high-value wood products, respondents in the Northeast and South reported increases in use. These increases may reflect substantial increases in standing timber over the last 50 years and recent increases in harvest volumes in those regions when compared with more stagnant and declining harvest volumes throughout much of the western United States (Haynes 2002). The general pattern of an increasing trend across the nation toward minimal-value products likely reflects the growth in new markets that may assist the public investments needed for fuel reduction and forest health restoration across much of the country. However, we find the reported decline in use of minimal-value products in the Interior West of concern in the context of increasing fire risk in much of the western Unite States (Westerling et al. 2006, Gude et al. 2008).

Barriers to Biomass Use

Exploratory factor analyses of the barriers to biomass use suggested eight categories of barriers related to biomass use (Table 3). Nationally, economic issues were rated the most significant barrier to biomass use (mean rating = 3.25) followed by market development (2.91), and US Forest Service capacity (2.54). Participants rated challenges to public trust (2.07), access and transportation (1.92), NIMBY attitudes (1.80), workforce training (1.72), and concerns about local benefit (1.59) all as minor barriers or less.

Table 3. Barriers to woody biomass use (item responses and factor loadings).[a]

Barriers	Major barrier (%)	Mean[b]	Factor loadings
Economic ($\alpha = 0.78$)			
1. High cost of transporting biomass	73	3.61	0.71
2. Low market value of biomass	63	3.47	0.78
3. Low financial returns to investors	49	3.32	0.78
4. High cost of harvesting biomass	44	3.19	0.70
5. Low energy prices	25	2.60	0.56
Market development ($\alpha = 0.75$)			
6. Lack of local markets for biomass products	60	3.36	0.68
7. Lack of existing biomass use capacity	48	2.54	0.79
8. Lack of existing wood products industry	30	3.13	0.81
9. Lack of existing transportation infrastructure	18	2.24	0.60
US Forest Service capacity ($\alpha = 0.78$)			
10. Declining US Forest Service budgets	36	2.91	0.60
11. Declining US Forest Service staffing levels	34	2.91	0.59
12. Lack of a guaranteed supply from federal lands	34	2.90	0.67
13. Lack of US Forest Service staff expertise in managing biomass projects	18	2.45	0.64
14. Lack of continuity of agency staff members	10	2.09	0.63
15. Lack of stewardship contracts and agreements	9	2.02	0.63
Public trust ($\alpha = 0.88$)			
16. Lack of agreement about harvesting biomass on public lands	16	2.24	0.73
17. Public perception that industry needs will drive forest management	14	2.24	0.73
18. Disagreement about forest health treatments	14	2.23	0.83
19. Negative perceptions about the impacts of biomass removal to the landscape	12	2.16	0.67
20. Lack of trust biomass facility developers	10	2.10	0.55
21. Disagreement about the need to remove hazardous fuels	9	1.96	0.72
22. Lack of trust of US Forest Service managers	5	2.01	0.72
23. The need to acquire adequate public input	4	1.72	0.50
Access and transportation ($\alpha = 0.51$)			
24. Lack of maintenance of US Forest Service roads	13	2.16	0.65
25. Need to cross private lands to access biomass on federal lands	5	1.66	0.80
NIMBY ($\alpha = 0.82$)			
26. Proposed location of use facilities	10	2.03	0.64
27. Air quality concerns	10	2.02	0.69
28. Water quality concerns	6	2.01	0.51
29. Noise concerns	3	1.52	0.82
30. Traffic concerns	3	1.57	0.86
Workforce ($\alpha = 0.75$)			
31. Competition with existing markets	10	1.91	0.60
32. Lack of a trained workforce for biomass utilization	10	2.04	0.70
33. Lack of a trained workforce for biomass removal	6	1.82	0.77
34. Competition for labor	1	1.34	0.68
35. Occupational hazards	0	1.27	0.68
Local benefit ($\alpha = 0.72$)			
36. Lack of local job creation	5	1.59	0.85
37. Projects not see to benefit local communities	4	1.61	0.75

[a] Factor loadings less than 0.50 are suppressed with one exception.
Declining forest staff levels is included in Forest Service capacity where it loads at 0.59 but dropped from access and transportation where it cross loads at 0.58).
[b] Responses range from not a barrier (1) to major barrier (4).

Regional variation from the national mean existed in five of the eight sets of barriers (Table 4), with most regional variation for barriers related to market development followed by barriers related to workforce capacity and public trust. Market development was rated as a significantly higher barrier in Interior Western United States and Alaska and a significantly lower barrier in the more developed regions of the Pacific Northwest, the South, and Northeast. Although the overall magnitude of workforce capacity as a barrier remained relatively low, areas that historically had a large forest products sectors such as the Northern and Pacific Northwestern region reported that the local workforce tended to be less of a barrier than in the Intermountain and Southwestern regions. Public trust in national forest managers was seen as a greater barrier to biomass use in the Northern and Pacific Northwest regions, where conflicts over national forest management have persisted for several decades. Other regional variations existed for barriers related to the economics of biomass use and US Forest Service capacity. Respondents from the Pacific Southwest region rated the economics of biomass use and US Forest Service capacity as significantly greater barriers.

Respondent ratings indicate that economic challenges and lack of market development are the most important barriers to promoting biomass use, although somewhat less challenging in regions with existing wood products industry and market infrastructure. Our results provide systematic evidence of the challenges on national forests and confirm previous research that suggests low-market value of biomass and lack of existing industry are the most important challenges to promoting biomass use (Aguilar and Garrett 2009, Becker et al. 2009a). In addition, our findings highlight the challenges related to US Forest Service capacity,

Table 4. National means and significant regional deviations for barrier to biomass use using one-way effects coded analysis variance.

	Barriers							
	Economic	Market development	US Forest Service capacity	Public trust	Access and transportation	NIMBY	Workforce	Local benefit
Nation[a]	3.25	2.91	2.54	2.07	1.92	1.8	1.72	1.59
Northern	–	–	–	+0.28**	–	–	−0.28**	–
Rocky Mountain	–	+0.23*	−0.21*	−0.35**	–	–	–	–
Southwest	–	+0.33*	–	–	–	–	+0.20*	–
Intermountain	–	+0.36**	–	–	–	–	+0.35***	–
Pacific Southwest	+0.18*	–	+0.20*	–	–	–	–	–
Pacific Northwest	–	−0.48***	–	+0.19*	–	–	−0.25**	–
Southern	−0.16*	−0.33**	–	–	–	–	–	–
Eastern	–	−0.68***	−0.21*	–	–	–	–	–
Alaska	–	+0.62**	–	–	–	–	–	–
F-Value	1.82*	9.75***	1.74*	3.21**	1.03	1.33	4.11***	1.22
n	315	320	322	322	324	317	307	308

Regional parameters indicate higher (+) and lower (−) deviations from the national mean.
[a] Responses ranged from not a barrier (1) to major barrier (4).
*$P < 0.1$; **$P < 0.01$; ***$P < 0.001$.

which was the third highest barrier nationally, with particular issues being seen in the Pacific Southwest. US Forest Service capacity is also reported as somewhat of a barrier nationally, and this is highlighted in the Pacific Southwest region where several recent projects have shown the achievements that are possible with adequate capacity (Neary and Zerioth 2007, Fleeger 2008).

Strategies for Biomass Use

Exploratory factor analyses identified 10 categories of strategies for biomass use (Table 5). Nationally, all 10 categories were rated at least somewhat important. Financial and policy incentives were rated the most important strategy to fostering woody biomass use (mean rating = 4.04), followed by developing use infrastructure (3.78), building partnerships and agreements (3.66), other policies tools (3.53), formal agreements to develop federal biomass supply (3.55), forest planning and management (3.38), US Forest Service staffing (3.22), supply diversification (3.22), public education (3.19), and private sector workforce training (3.13).

Respondents tended to rate strategies higher than barriers. In addition, we also found more similarity across regions in the importance of various strategies to increase biomass use (Table 6). Only 4 of 10 strategies exhibited regional variation. The greatest regional variation was reported for developing formal agreements (such as stewardship contracts, stewardship agreements, or memoranda of understanding) to ensure a federal supply of biomass. In Alaska, pursuing formal agreements was the most important of all strategies measured, whereas formal agreements were the least important of all strategies measured in the Eastern region. Respondents from the Eastern region rated strategies focused on improving forest planning mechanisms lower than the national average and building partnerships and agreement were also less important in the East as well as the South. In contrast, in the Southwest region improving forest planning mechanisms was as important as building partnerships and agreement. Supply diversification was seen as the least important strategy in the Southwest and Intermountain regions.

The relatively high importance respondents placed on most strategies to promote biomass use suggests that forest managers are working on multiple fronts to increase biomass removal and use given their current constraints. The higher ratings for financial and policy incentives and infrastructure development reinforce the importance of the "business" of biomass removal and use and concur with previous research that has identified the importance of government assistance for developing biomass use capacity (Aguilar and Garrett 2009, Becker et al. 2009b).

Respondents also affirmed previous case study research (Becker et al. 2009a) highlighting the importance of partnerships and building agreement. Respondents noted in open-ended comments on the survey that partnerships and agreement building can help to overcome the controversies and challenges associated with biomass removal. Partnerships and agreement building were considered less important strategies in the Northeast and South where industry infrastructure remains and there has been relatively less controversy over forest management.

Participants rated other US Forest Service–specific strategies such as planning and contracting mechanisms of less importance than incentives, market development, and public engagement strategies. However, forest planning mechanisms in the Southwest and contracting mechanisms in Alaska rivaled or outrated the importance of most other strategies, and both were of less importance in the Northeast. These regional variations likely reflect experience conducting large-scale restoration planning on public lands in the Southwest (Fleeger 2008, Hjerpe et al. 2009) and the importance of private landownership and existing industry and markets in the Northeast (Benjamin et al. 2009). The predominance of public land in the Intermountain and Southwest regions may also help to explain why diversification of supply is less important in those regions.

The Importance of Actively Pursuing Strategies for Biomass Use

We found that nearly one-third of the variation ($R^2 = 0.31$) in the importance respondents place on actively pursuing strategies to foster biomass use on their forest and surrounding communities was explained by their regional context and influenced by local barriers to biomass use and the current trend in use of minimal value materials (Table 7). Specifically, even after controlling for the barriers to and trends in biomass use, respondents in the Northern and Alaska re-

Table 5. Strategies to promote woody biomass use (item responses and factor loadings).[a]

Strategies	Percent extremely important	Mean[b]	Factor loadings
Financial incentive tools ($\alpha = 0.87$)			
1. Tax incentives for facility development	49	4.24	0.90
2. Tax incentives for harvesting and transporting biomass	47	4.19	0.86
3. Cost-share and grant programs for facility development and equipment purchases	45	4.23	0.84
4. Renewable energy standards/renewable profile standards	31	3.82	0.54
5. Net metering	16	3.33	0.52
Us infrastructure development ($\alpha = 0.84$)			
6. Developing facilities that source from multiple suppliers	35	4.06	0.84
7. Colocating new facilities with existing industrial infrastructure	25	3.81	0.80
8. Developing small-scale facilities	31	3.98	0.67
9. Developing large-scale facilities	16	3.41	0.67
10. Encouraging use of biomass in existing wood products industry	27	3.78	0.56
11. Developing alternatives to electricity production (e.g., heating and animal bedding, to name a few)	23	3.69	0.49
12. Using mobile and onsite processing	24	3.77	0.53
Partnerships and agreements building ($\alpha = 0.88$)			
13. Building agreement on acceptable fuels reduction and forest health treatments	28	3.75	0.61
14. Building agreement on facility siting	15	3.31	0.57
15. Building agreement on project scale	19	3.56	0.70
16. Developing public–private partnerships for facility development	23	3.57	0.79
17. Developing partnerships to promote local harvesting and use capacity	25	3.75	0.83
18. Developing partnerships to ensure adequate supplies of biomass	28	3.83	0.79
Forest planning mechanisms ($\alpha = 0.81$)			
19. Undertaking larger-scale environmental analysis	28	3.68	0.68
20. Using hazardous fuels and forest health funding	37	4.01	0.76
21. Improving forest road conditions	15	3.33	0.72
22. Developing projects that restore threatened and endangered species habitat	19	3.37	0.73
23. Increasing the intensity of biomass harvesting in specific areas	13	3.39	0.54
24. Focusing on projects that best meet performance targets	13	3.36	0.48
25. Developing agreements with private landowners for access to public lands	9	2.73	0.44
Stewardship contracts, agreements, and MOUs ($\alpha = 0.84$)			
26. Developing long-term stewardship contracts and agreements	28	3.67	0.89
27. Developing short-term stewardship contracts and agreements	17	3.50	0.85
28. Developing MOUs with stakeholders to secure federal biomass	15	3.26	0.79
Other policy tools ($\alpha = 0.77$)			
29. Government bonds and loans	27	3.65	0.63
30. Technical assistance programs for business	26	3.72	0.76
31. Mandates or incentives for use of green products in construction, energy, vehicles, or equipment	22	3.45	0.74
32. Harvest guidelines	12	3.26	0.82
Supply diversification ($\alpha = 0.84$)			
33. Sourcing a portion of biomass from nonfederal forestland	18	3.40	0.83
34. Sourcing a portion of biomass from mill residues	11	3.14	0.86
35. Sourcing a portion of biomass from other sources (e.g., urban wood waste)	10	3.05	0.86
Public education ($\alpha = 0.93$)			
36. Developing programs to explain how public concerns about biomass removal and use are being addressed	15	3.43	0.79
37. Developing programs to explain how concern about public health are being addressed	15	3.24	0.88
38. Developing programs to explain how concern about public nuisances related to biomass utilization are being addressed	11	2.95	0.89
39. Developing programs to explain concern about facility development and siting related to biomass use are being addressed	11	3.12	0.81
US Forest Service training and capacity building ($\alpha = 0.88$)			
40. Training US Forest Service staff in biomass use technologies and logistics	13	3.33	0.79
41. Hiring US Forest Service staff to help develop use capacity	13	3.05	0.89
42. Hiring US Forest Service staff to focus on biomass projects	11	3.03	0.90
Private sector workforce training ($\alpha = 0.96$)			
43. Developing workforce training programs for biomass harvesters	11	3.07	0.94
44. Developing workforce training programs for biomass use facility workers	11	3.08	0.94

[a] Only factor loadings greater than 0.50 are reported. Exceptions include several items that loaded below 0.5 and two cross-loadings where items loaded on two factors at greater than 0.50, where the most logical factor was chosen.
[b] Responses range from not at all important (1) to extremely important (5).
MOUs, memoranda of understanding.

gions placed greater overall importance on pursuing strategies to actively foster biomass use, perhaps reflecting the greater need for assistance in capitalizing on biomass opportunities in these regions. In contrast, respondents in the Southern and Eastern regions placed less overall importance on actively pursuing strategies, reflecting the function of existing markets for wood products and biomass. In addition, barriers related to US Forest Service capacity, workforce capacity, NIMBY attitudes, and concerns about whether local communities will benefit from biomass use all positively influenced the overall importance respondents placed on actively pursuing strategies to promote biomass use. The significance of these challenges suggest that forest managers and staff place more weight on those issues that can be managed through the public engagement and existing forest planning and manage-

Table 6. National means and significant regional deviations for strategy indices using one-way effects coded analysis of variance.

	Strategies									
	Financial incentive tools	Use infrastructure development	Partnerships and agreement building	Other policy tools	Stewardship contracts, agreements, and memoranda of understanding	Forest planning mechanisms	US Forest Service training and capacity building	Supply diversification	Public education	Private sector workforce training
Nation[a]	4.04	3.78	3.66	3.53	3.55	3.38	3.22	3.22	3.19	3.13
Northern	–	–	–	–	–	–	–	–	–	–
Rocky Mountain	–	–	–	–	–	–	–	–	–	–
Southwest	–	–	–	–	–	+0.28*	–	−0.38*	–	–
Intermountain	–	–	–	–	–	–	–	−0.33*	–	–
Pacific Southwest	–	–	–	–	–	–	–	–	–	–
Pacific Northwest	–	–	–	–	–	–	–	–	–	–
Southern	–	–	−0.33**	–	–	–	–	–	–	–
Eastern	–	–	−0.37**	–	−0.72***	−0.29*	–	–	–	–
Alaska	–	–	–	–	+0.79**	–	–	–	–	–
F-Value	0.76	0.91	2.39*	1.18	3.44**	1.69*	1.37	2.40*	1.13	0.89
n	284	308	311	283	306	318	312	288	306	282

Regional parameters indicate higher (+) and lower (−) deviations from the national mean.
[a] Responses ranged from not at all important (1) to extremely important (5).
* $P < 0.1$; ** $P < 0.01$; *** $P < 0.001$.

ment processes than on broader economic or market development barriers. Although economic and market development barriers were rated by respondents as the most significant challenges to biomass use across the nation, neither influenced the importance of strategies for biomass use, suggesting that US Forest Service managers may view these issues as outside of their scope of responsibilities or beyond their ability to control. The positive relationship between barriers and strategies suggests that forest managers respond to adversity by elevating the importance of strategies rather than responding fatalistically and avoiding the challenges to biomass use.

Respondents who reported an upward trend in the use of minimal-value products such as residues for electricity, heat, or cogeneration also placed greater importance on pursuing strategies to actively promote biomass use. This relationship likely reflects respondents' efforts to achieve multiple goals such as reducing costs for fuels reduction and forest restoration treatments, engaging local communities, and supporting ongoing forest management infrastructure.

Table 7. Influences on US Forest Service managers' evaluations of the overall importance of pursuing strategies to actively promote woody biomass use.

Coefficients	Estimate	Standard error
Region effects		
Northern	0.30**	0.11
Rocky Mountain	0.00	0.11
Southwestern	0.04	0.12
Intermountain	−0.05	0.12
Pacific Southwest	−0.10	0.11
Pacific Northwest	−0.05	0.10
Southern	−0.40**	0.13
Eastern	−0.26*	0.12
Alaska	0.52**	0.18
Barrier covariates		
US Forest Service capacity barriers	0.16**	0.06
Economic barriers	0.07	0.07
Market development barriers	−0.08	0.06
Workforce barriers	0.15*	0.07
Access and transportation barriers	0.02	0.06
Public trust barriers	−0.05	0.07
NIMBY barriers	0.18*	0.07
Local benefit barriers	0.17**	0.06
Trend covariates		
High-value use	−0.07	0.07
Low-value use	0.11	0.08
Value-added use	0.07	0.07
Minimal-value use	0.14*	0.08
Removal of biomass from national forests	−0.05	0.07
Constant	2.43***	0.27
R^2	0.31	
F-Value	4.46***	
Number of observations	227	

Parameter estimates are analysis of covariance results for the effect of regional context while controlling for respondent evaluation of barriers to and trends in woody biomass use.
* $P < 0.1$; ** $P < 0.01$; *** $P < 0.001$.

Conclusions

In this article, we evaluated the wide range of barriers to and strategies for fostering biomass use in and around national forests. For our respondents, economic viability, market barriers, and US Forest Service capacity were the most common barriers to biomass use. Although these findings are striking and emphasize the importance of economics, it is important to keep in mind that our respondents were US Forest Service employees and, as such, the results reflect their individual experiences and perspectives. Given the controversy and debate surrounding the ecological impacts, carbon neutrality, and local benefit of woody biomass use, it is possible that different types of respondents such as local community residents, environmental activists, and industry

representatives might perceive barriers differently. However, our findings support some earlier studies (e.g., Becker et al. 2009a, Aguilar and Garret 2009) that found similar challenges associated with markets, economics, and federal agency capacity when working on biomass development near public lands in the United States, rather than the opposition to biomass facilities that some studies have found with the development of large-scale facilities in Europe and elsewhere (e.g., Upreti 2004, Upham et al. 2007).

Although economic and market barriers may be central challenges, our US Forest Service respondents see a diverse set of strategies as necessary for overcoming these challenges. Many of these are not directly related to economics and markets but rather are strategies for collective action that could influence the success of local and regional efforts to overcome the economic challenges facing use. Respondents clearly pointed to the value of partnerships and forest management and contracting mechanisms as important tools to address local biomass use challenges.

We also found that the trends, barriers, and strategies vary considerably from region to region. This variation is likely a reflection of local contextual differences in forest products and energy sectors, land tenure, historic context, and social concerns. These regional differences in both barriers and solutions suggest that successful biomass use efforts will need to be aware of and able to adapt to local and regional circumstances. The variation also suggests that relevant national policies, such as the definition of biomass allowed under a renewable energy standard, would need to be flexible enough to be adapted to local conditions. Ultimately, fostering appropriate use of biomass from the national forest system will require a basket of strategies rather than a single approach to meet the diverse challenges and the diverse needs across the country.

US Forest Service employees are only one group of people engaged in biomass use. Continuing this line of inquiry with biomass and forest products industry representatives, environmentalists, local community leaders, and other stakeholders would provide valuable information for developing a more nuanced understanding of the dynamics of biomass use near public lands.

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