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Oregon’s Biomass Producer Tax Credit—Impacts of Land Ownership on Woody Bioenergy Use

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Abstract

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From 2007 through 2017, Oregon implemented an incentive program for biomass collection and production. This research evaluates renewable biomass production and deliveries during a 3-year period (2012 to 2014) in which this tax credit was in place. We evaluated total delivered tons, average payments per load, delivered location, and average transportation distance of woody biomass. We found that total delivered tons of biomass decreased each year between 2012 and 2014, as did the number of users participating in the tax credit program. The average delivered tons, by participant, was more than double in 2014 its level in earlier years, suggesting that fewer, larger entities were participating. We also evaluated differences in biomass delivery, based on receipts, transportation distances, and tons delivered, for each land ownership class. There were statistically significant differences between private and public land ownership for 2012 and 2013 but not for 2014, which included fewer applicants.

Our study showed that effective biomass utilization policies need to provide sufficient economic incentives to encourage adoption by both participants and biomass energy producers, and, to be effective, to consider the complete supply chain and type of energy produced. Future economic conditions in Oregon will most likely include rapid changes in renewable energy technologies and fluctuations in fossil fuel prices, and any truly effective renewable energy policies must be sufficiently nimble to account for these and other uncertainties.

Keywords: Biomass, torrefaction, forest restoration, tax credit, renewable energy policy.

Contents

Introduction

Ecosystem Services and Bioenergy

Ecosystem services are the benefits that people obtain from ecosystems (MEA 2005); the importance and value of ecosystem services are being recognized from local to global scales (Costanza et al. 1997, Daily 1997, Farley and Costanza, 2010, Kroeger and Casey 2007, LaRocco and Deal 2011). The Millennium Ecosystem Assessment (MEA 2005) recognized four categories of ecosystem service: provisioning, regulating, supporting, and cultural services. Provisioning services include food, freshwater, timber, and fiber for human use. Regulating services help to maintain a world in which it is possible for people to live, providing benefits such as flood and disease control, water purification, climate stabilization, and crop pollination. Supporting services include nutrient cycling, soil formation, and primary production from our ecosystems. Cultural services include recreational, spiritual, aesthetic, and cultural values. Ecosystem services can also include secondary benefits such as reducing the risk of wildfires, increasing carbon sequestration from forests, and use of biomass as an alternative to burning fossil fuels for energy (Mitchell et al. 2009, Oliver and Deal 2007, Schroder et al. 2016, UNFCCC 2007). Thus, the four categories of ecosystem services together provide a diverse array of services and benefits to society.

Forests and forest management also play an important role in sequestering carbon and reducing greenhouse gas (GHG) emissions. Forests can sequester large amounts of carbon in several ways—as standing forest (carbon sinks), in wood products, and in avoided emissions when wood is used as a substitute for products such as steel, concrete, and brick that require fossil fuels to produce (Oliver and Deal 2007). Thinning forests to reduce fuel loads may reduce the severity of wildfires as well as maintain and enhance carbon sequestration (Kashian et al. 2006). Fuel treatments can also be useful for maintaining air quality, water quantity, and wildlife habitat, and should be considered based on their benefits to multiple ecosystem services, not just carbon sequestration. Fuel treatments can be particularly useful to enhance carbon storage in forests with low-severity, high-frequency fire regimes and fire return intervals on the order of years to decades (Hurteau and North 2009, Mitchell et al. 2009), especially forests that have experienced biomass accumulation resulting from fire suppression (Brown et al. 2004). In these ecosystems, fuel treatments can effectively reduce subsequent wildfire severity and carbon emissions, assuming that biomass would be burned in a power plant for energy production rather than burned onsite in the forest. Accounting for energy use and assessing alternative energy sources other than coal and other fossil fuels could play an important role in reducing the effects of climate change.

These ecosystem services could play an integral role in increased biomass use in Oregon, especially if they become more highly valued in the marketplace. Key services include climate change mitigation through reduced fossil fuel (coal) use; reduced wildfire risk owing to hazardous fuel reduction; air quality improvements if bioenergy is generated in place of fossil energy (including coal); and potential water quality improvements (especially after a wildfire occurrence) (Brown et al. 2004, Deal et al. 2012, Dupraw 2014, Mitchell et al. 2009). In Oregon, hazardous fuel removals near communities could provide an array of ecosystem services, including those mentioned above, as well as enhanced employment opportunities. However, to realize their full benefit, one requirement is a long-term biomass supply that is tailored to wood energy systems already in place. Successful ecosystem service management will need to address entire landscapes, encouraging landowners to work cooperatively toward landscape-level goals (Irland 1994). This is likely to be especially relevant in Oregon, given its diverse forest types, significant wildfire potential, and dynamic energy needs.

Oregon's East-Side Forests and Forest Products Capacity

Decades of reduced management activity and aggressive fire suppression have contributed to higher tree density as well as increased insect and disease mortality in the forests of eastern Oregon. These conditions have increased both the risk and extent of catastrophic wildfire (Ager et al. 2012). Concurrently, forest products manufacturing in the region has declined substantially. This decline has significantly diminished market outlets and options to utilize biomass from forest restoration activities on federal lands, creating an undesirable cycle.

To reduce wildfire risk, the state of Oregon and the U.S. Forest Service have increased their focus on collaboration for longer term stewardship contracts. The lack of viable markets for this low-value woody biomass is directly related to the high treatment costs associated with biomass removals, which exceed the market value of woody biomass from alternative sources. However, if economic hurdles can be overcome—through stewardship contracting and other vehicles—biomass removals in eastern Oregon could benefit not only facilities such as torrefied wood producers but also local sawmills, harvesting operations, and regional employment.

Residues from wood products manufacturing represent a potential major source of biomass and are generally much less expensive than woody residues from forest harvesting activities. More than 45 wood products facilities are located in eastern Oregon (an area defined as being east of the crest of the Cascade Mountains) (Swan et al. 2012). In the Blue Mountains of eastern Oregon, sawmills account for 11 of 19 active wood products manufacturing facilities (Gale et al. 2012). Wood products residues could become an important aspect of biomass utilization in eastern Oregon because they are sometimes considered a waste product, available at lower prices than forest harvesting residues or fire-hazard thinnings. However, wood products residues are often used onsite to heat lumber drying kilns, and in some cases, sawmills could use some or all of their residues for this purpose.

The Oregon Biomass Producer or Collector Tax Credit

The Oregon Biomass Producer or Collector (BPC) tax credit was enacted in 2007 to provide incentives for the production, collection, and transportation of biomass used for energy production in the state (Austin 2011). This program was introduced as a portion of a larger biofuels package by then Oregon Governor Ted Kulongoski, with the intent to grow the biofuel market in Oregon. The tax credit was authorized through tax year 2017 and had wide latitude regarding the types of biomass accepted, with each source of biomass having a different rate schedule (table 1). Under the program, eligible biomass could be used to produce electricity from anaerobic digestion, pellets, or torrefaction as well as various types of biofuels (solid, liquid, or gaseous states). However, some types of biomass were ineligible, including firewood or charcoal, demolition debris, urban wood waste, or yard debris.

Several studies have examined how the Oregon BPC program affected the supply and delivered price of Oregon-sourced biomass. White et al. (2013b) compared actual delivered prices of woody biomass sourced in Oregon in 2011 to forecasted prices without the Oregon BPC and found that actual prices were lower by $10.68 per bone-dry ton (BDT). The same study found that the Oregon

Table 1—Tax credits for various biomass fuels under the Oregon biomass tax credit program

Biomass type	Credit	Units
	Dollars	
Oil seed crops	0.05	Pound
Grain crops	0.90	Bushel
Virgin oil or alcohol	0.10	Gallon
Used cooking oil or waste grease	0.10	Gallon
Wastewater biosolids	10	Wet ton
Woody biomass:	10	Green ton
Vegetative biomass from agricultural crops	10	Green ton
Animal manure or rendering offal	5	Wet ton
Yard debris and municipal food waste	5	Wet ton

Source: Nielsen-Pincus et al. 2011.

BPC was responsible for between 58,240 and 136,500 BDT of additional woody biomass being delivered to bioenergy facilities. Similar results for the impact of the Oregon BPC during 2010 were reported in Nielsen-Pincus et. al. (2011).

White et al. (2013b) summarized data for 2010 and 2011 Oregon BPC for seven types of biomass. Here, woody biomass tax credits accounted for more than 85 percent of dollars received in 2010, with the remaining six biomass types accounting for about 15 percent of the total. In 2011, this amount was 70 percent for woody biomass with the remaining six biomass types accounting for about 30 percent of the total. In addition to in-state markets, eastern Oregon logs and wood fiber are shipped out of state to 23 destinations, mostly in California and Washington (Swan et al. 2012).

Our current study is intended to provide a context for biomass utilization, renewable energy use, and ecosystem services in Oregon. We do so by evaluating woody biomass supply and delivered fuel costs as influenced by the Oregon BPC during 2012, 2013, and 2014. We consider how land ownership in Oregon is related to the volume of woody biomass delivered, total payments received, and transportation distance. We also provide an analysis of the influence of land ownership on biomass deliveries in Oregon, extending previous work that considered broader based benefits (Nielsen-Pincus and Moseley 2009, Nielsen-Pincus et al. 2011, White et al. 2013b). We consider these factors in a broad policy context that addresses relevant renewable energy themes among Oregon, the United States, and international energy users. Our study is timely in that Oregon's original tax credit program came to a close in 2017, so this research can help inform any future policies. Numerous stakeholders may benefit from this research, including Oregon's wood products industry, environmental and conservation groups, federal and state land managers, and those interested in innovative new uses of biomass including torrefaction.

Methods

We used Oregon BPC data from 2012, 2013, and 2014 to analyze biomass volumes delivered, total receipts, transportation distance, and delivered price of biomass, identifying trends occurring over time. All data were tabulated by the Oregon Department of Energy and were based on individual participant records for a given year. We considered each of these factors for three classes of forest land ownership: private, national forest, and "various" owners. We conducted analysis of variance (ANOVA) tests between land ownership classes for each of these factors, for all 3 years. When significant differences were indicated, we then conducted Bonferroni post-hoc pairwise comparison tests to determine pairwise differences in means, by ownership class. Finally, we summarized aggregate data for all tax credit participants over the full 3-year period for tons delivered, total receipts, dollars per ton, and transportation distance.

In Oregon, forest landowners include the National Forest System (12.5 million ac), private landowners (including industrial and nonindustrial) (10.2 million ac), and the Department of the Interior's Bureau of Land Management (2.4 million ac) (ODF 2006). Some applicants using the Oregon BPC were biomass collectors, who purchase and receive woody biomass at their facility from harvesters before delivering the material to a biofuel producer. The Oregon tax credit program required applicants to have ownership of biomass material at some point in the supply chain, but not to own land. Therefore, it is possible that some applicants were third-party processors who then sold biomass to end users.

For the purposes of this research, most of the various applicants were those who received woody debris but were not directly involved in sourcing biomass. Various applicants could have received biomass from private, state, federal, or other lands, among other entities. For our data, most of the various entries were from a single enterprise. Because the Oregon reporting system collected data on large amounts of biomass from diverse locations but with different contracting officers and systems, there was a need to modify the state's system for the purposes of our research. We did this by creating a separate category of "various" when it became clear that biomass could not be neatly characterized as originating from private, state, or federal lands.

Results

Biomass Produced Over All Years (2012–2014)

During 2012, 2013, and 2014, 264 participants delivered biomass as part of the tax credit program (figs. 1 through 4). However, some of these participants were involved in more than a single year; therefore, the number of unique participants was less than 264. Most participants (138 out of 264) delivered less than 1,000 tons per year, while nearly 74 percent of participants (195 out of 264) delivered up to 3,000 tons per year (fig. 1). A few larger firms (13) each delivered more than 10,000 tons of biomass, resulting in greater total tonnage than from all other participants combined. Total receipts followed closely the patterns for delivered tons of biomass, with most participants (58 percent) receiving less than $15,000 per year (fig. 2). However, 14 larger firms (5 percent) had annual receipts of greater than $150,000 per year.

Transportation distances ranged from less than 40 to more than 400 mi, with 40 to 79 mi being the most represented category (32 percent) (fig. 3). It is assumed that all biomass was transported by truck, although this was not specified by respondents. Biomass prices were most often in the range of $35 to $45 per green ton, encompassing 53 percent of respondents (fig. 4). However, there is clearly a "sweet spot" of less than 200 mi of transportation that also was sold for $30 to $45 per green ton.

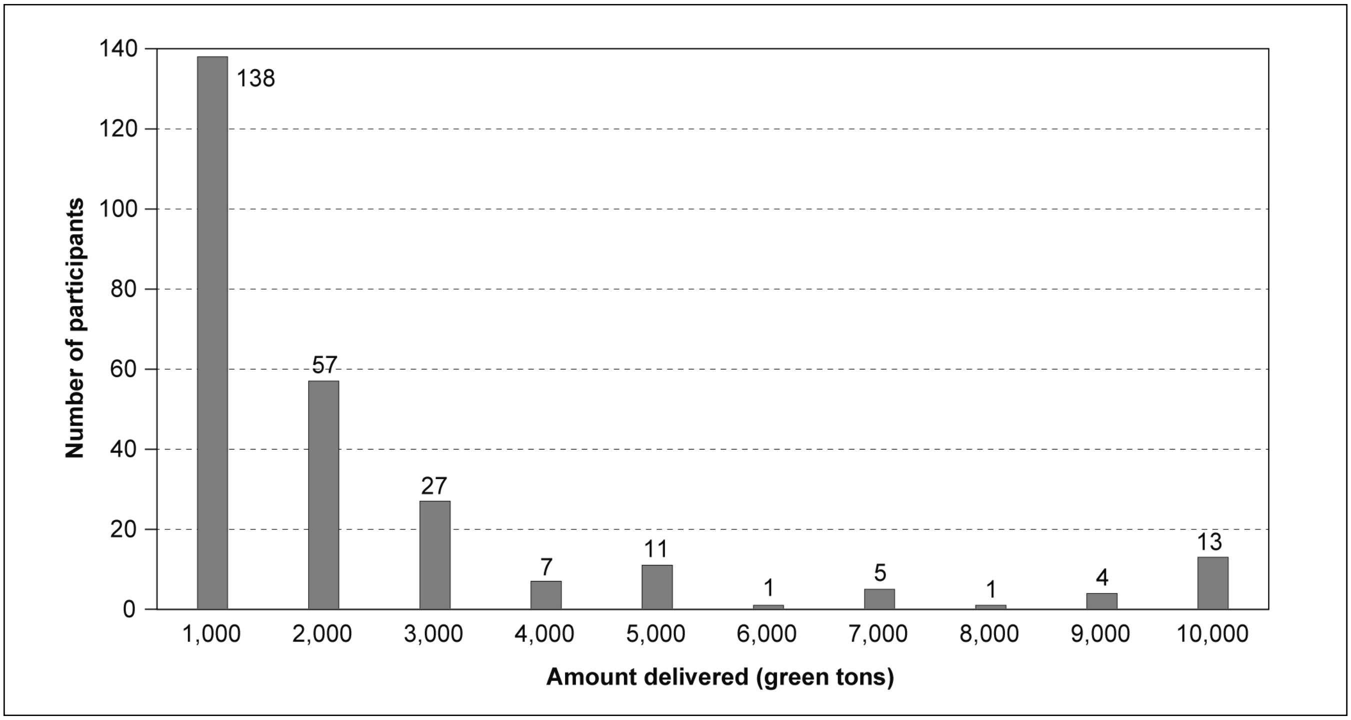

Figure 1—Total weight of biomass transported for participants in the Oregon biomass tax credit program for all deliveries from 2012 to 2014.

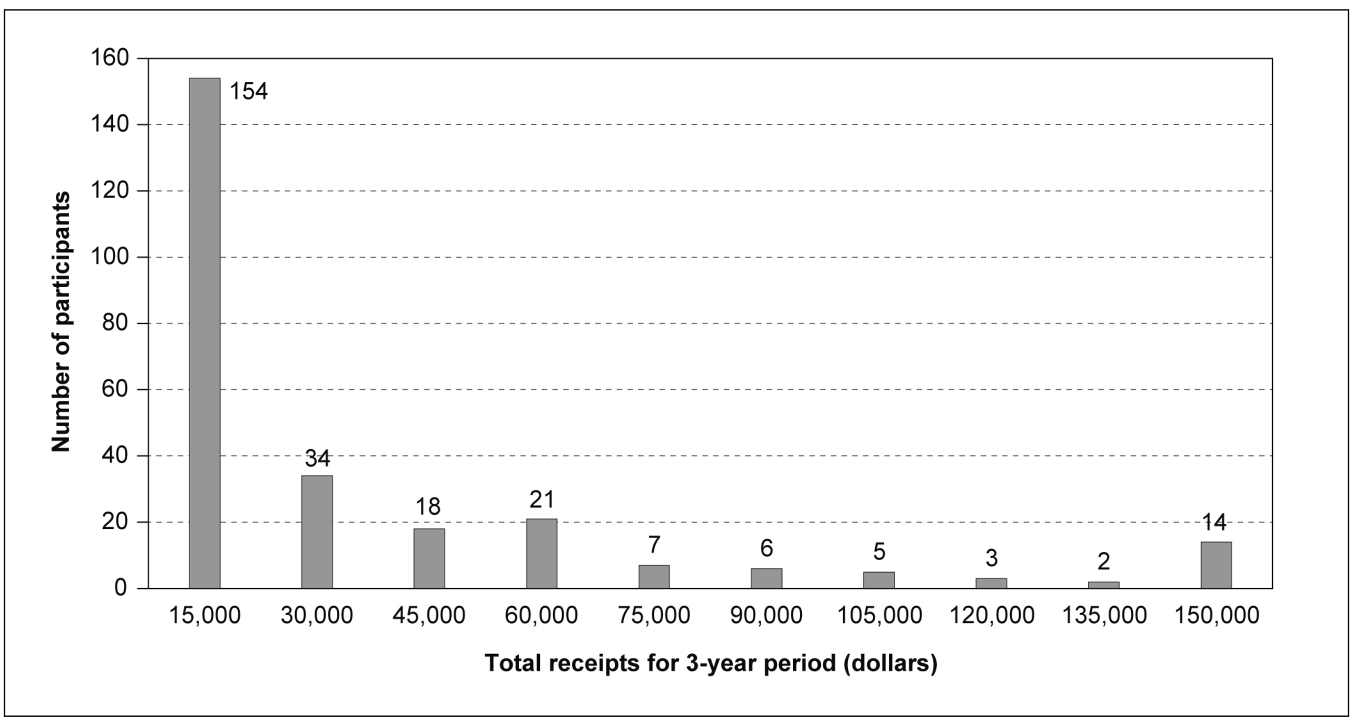

Figure 2—Total receipts for participants in the Oregon biomass tax credit program for all deliveries from 2012 to 2014.

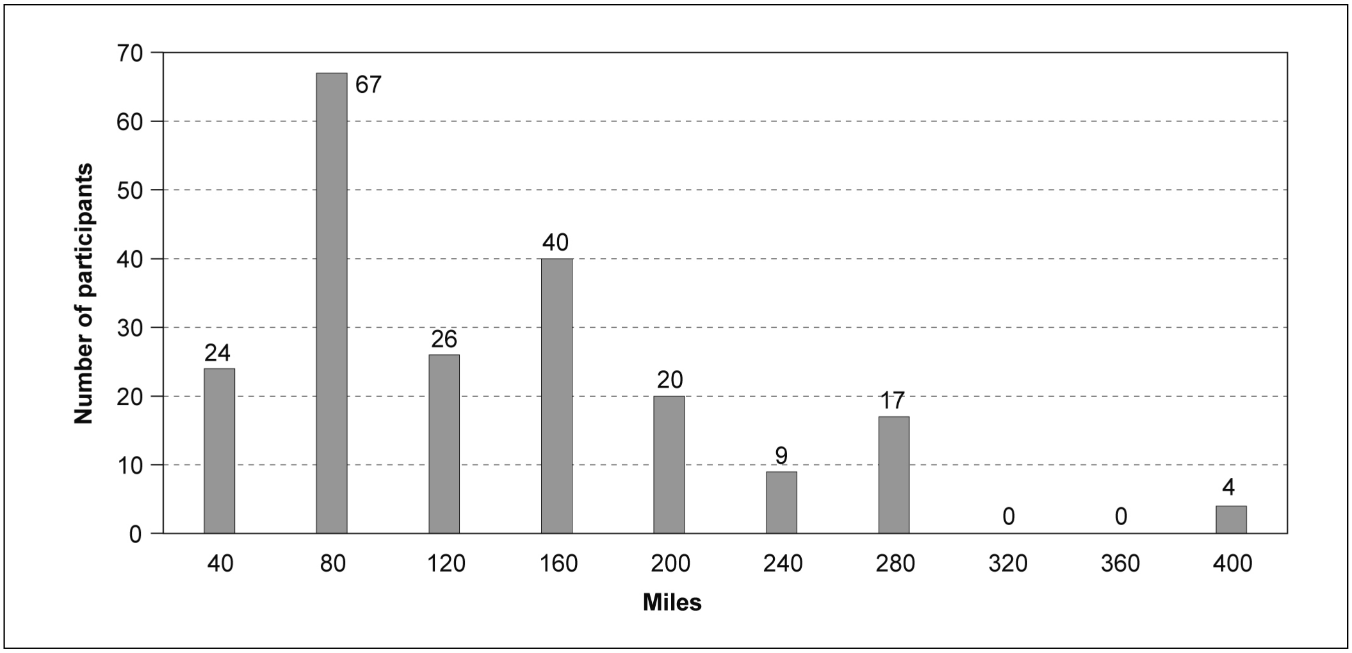

Figure 3—Transportation distances for participants in the Oregon biomass tax credit program for all deliveries from 2012 to 2014.

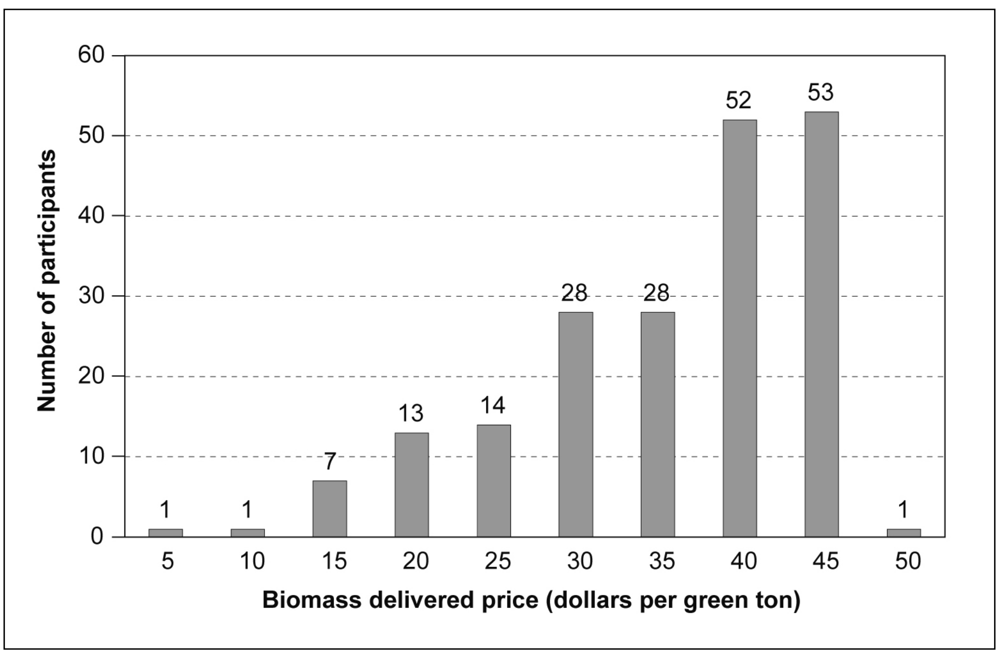

Figure 4—Biomass prices for participants in the Oregon tax credit program for all deliveries from 2012 to 2014.

Delivery of Biomass by Year

We found that average woody biomass deliveries during 2012, 2013, and 2014 were 24.6, 20.7, and 29.0 green tons per load, respectively. However, the average value per load for 2012, 2013, and 2014 was $384.50, $451.10, and $512.32, respectively. In 2012, a total of 151 users participated in the tax credit (in 2013, this dropped to 76 users, and in 2014 was only 20 users). In 2012, the average participant delivered 1,232 BDT of biomass (in 2013, this average was 1,342 BDT, and in 2014 was 2,919 BDT) (table 2). Therefore, over this 3-year period, there were fewer participants delivering larger amounts of biomass. This is especially true for Forest Service lands (fig. 5), where average biomass deliveries increased to more than 6,000 green tons in 2014.

Table 2—Summary statistics for 2012, 2013, and 2014 Oregon biomass tax credit data

	Delivered tons	Average tons per load	Average moisture content	Bone-dry tons	U.S. dollars per bone-dry ton	Average revenue	Average revenue
			Percent, dry basis			*Dollars per load*	*Dollars per ton per load*
2012:							
Average	2,010	25	60	1,232	37	385	16
Minimum	3	3	42	2	5	0	
Maximum	41,646	36	90	23,468	45	1,109	31
Standard deviation	4,820	9	11	2,855	8	340	38
Number	151	151	151	151	94	148	
2013:							
Average	2,047	21	63	1,342	33	451	22
Minimum	2	2	42	1	13		
Maximum	30,835	33	91	23,356	65	1,325	40
Standard deviation	4,410	11	11	3,178	10	311	27
Number	76	76	76	76	75	76	
2014:							
Average	4,690	29	61	2,919	31		
Minimum	30	20	47	25	8		
Maximum	17,924	54	82	11,551	45		
Standard deviation	4,906	7	11	3,212	10		
Number	20	20	20	20	19		

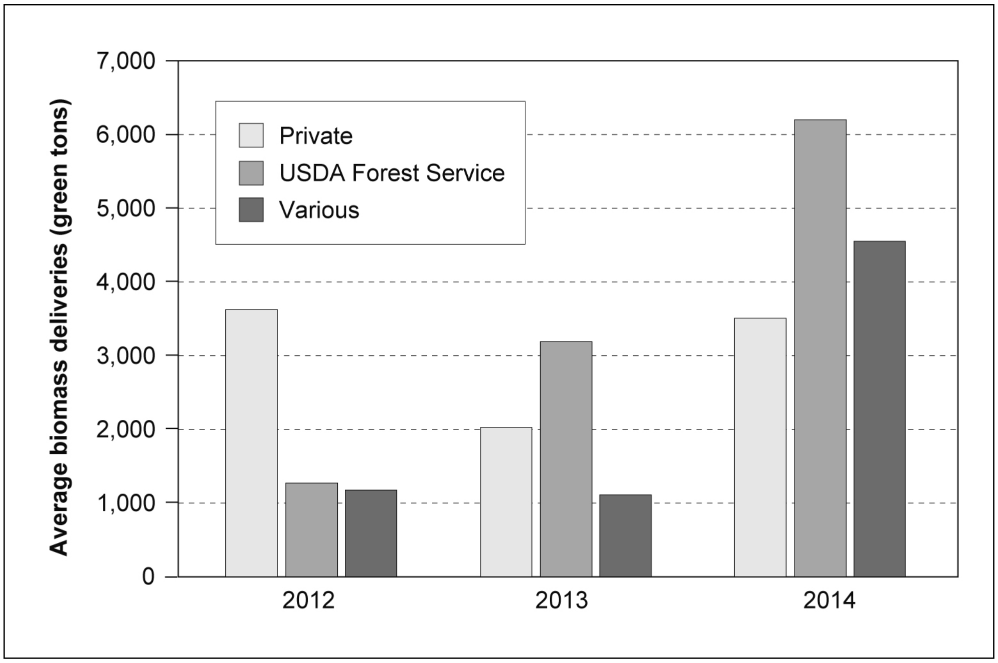

Figure 5—Average biomass deliveries, by land ownership, for participants in the Oregon biomass tax credit program from 2012 to 2014.

Effect of Land Ownership on Biomass Delivery

As noted above, the Oregon tax credit data we used reflected three ownership classes: private, Forest Service, and "various," with the latter consisting largely of a single user. We conducted ANOVA comparisons for land classes based on total biomass volume, total receipts, and transportation distance. We found statistically significant differences based on land ownership class, for 2012 and 2013 (tables 3 and 4).

For 2012, there were statistically different results between land ownership categories for each response variable. Private landowners were characterized by having the greatest number of tons delivered, highest dollar amounts per BDT, highest total receipts, and shortest transportation distance (table 3). Private landowners had significantly different means from both other land ownerships for both total receipts (private landowners greatest) and transportation distance (private landowners least). Note that very few "various" landowners reported transportation distances (with 6 reporting out of 33 landowners). For 2013, dollars per BDT was the only response variable showing significant differences between land ownership classes. Here, private landowners (average of $36.33 per BDT) were significantly different than "various" landowners (average of $27.83 per BDT). There were no statistically significant differences between land ownership classes for tons delivered, total receipts, or transportation distance (table 4). For 2014, there were no significant

Table 3—Land ownership effects for select biomass parameters in the Oregon tax credit program in 2012

Land ownership class	Number	Average[a]
Tons delivered (2012):		
Private	56	3,625*a*
U.S. Forest Service	72	1,273*b*
Various	33	1,176*ab*
p-value = 0.016		
Dollars per bone-dry ton (2012):		
Private	50	39*a*
U.S. Forest Service	33	36*ab*
Various	16	32*b*
p-value = 0.0121		
Total receipts in dollars (2012):		
Private	56	66,493*a*
U.S. Forest Service	72	9,717*b*
Various	33	6,020*b*
p-value = 0.00068		
Transportation distance in miles (2012):		
Private	56	75*a*
U.S. Forest Service	72	153*b*
Various	6	138*b*
p-value = 1.06×10^{-9}		

[a] Means sharing a common letter are not significantly different at the 0.05 confidence level using Bonferonni's pairwise comparison test.

differences between land ownership classes for any of the response variables (tons delivered, dollars per BDT, total receipts, or transportation distance). However, the total number of participants in the tax program was considerably lower than for previous years (typically about 20) (table 5).

Discussion

Key Trends in Oregon Biomass Utilization

The Oregon BPC displayed mixed results in terms of stimulating biomass delivery and utilization, and its long-term effects are not yet known. During 2012–2014, participation declined, as did the volume of woody biomass delivered. This was in part due to a new accounting procedure implemented during this period that based payments on oven-dry rather than green weight, effectively reducing the tax credit in some cases by close to 50 percent. By 2014, only four participants delivered more

Table 4—Land ownership effects for select biomass parameters in the Oregon tax credit program in 2013

Land ownership class	Number	Average[a]
Tons delivered (2013):		
Private	28	2,026
U.S. Forest Service	22	3,190
Various	27	1,112
p-value = 0.258552		
Dollars per bone-dry ton (2013):		
Private	27	36*a*
U.S. Forest Service	22	35*ab*
Various	27	28*b*
p-value = 0.004253		
Total receipts in dollars (2013):		
Private	28	43,915
U.S. Forest Service	22	85,319
Various	27	36,570
p-value = 0.423849		
Transportation distance in miles (2013):		
Private	28	59*a*
U.S. Forest Service	22	197*b*
Various	0	—
p-value = 6.11×10^{-6}		

[a] Means sharing a common letter are not significantly different at the 0.05 confidence level using Bonferonni's pairwise comparison test.

than 5,000 tons of biomass, and the total number of participants was 20 (fig. 6), as compared to 2012, in which eight participants delivered more than 5,000 tons of biomass from a total of 145 participants. Thus, there appeared to be fewer larger participants after the tax credit was effectively reduced. A second impact of the tax credit change was a greater variability in biomass prices received. Although the maximum prices received were consistent for all 3 years, it is clear that the dispersion of prices was considerably greater in 2014 than in previous years (fig. 7). Thus, any policies leading to greater stability in biomass prices or number of participants could be considered if the program is extended beyond 2017.

Land ownership also played an important role in these trends. Woody biomass delivered from private landowners showed significantly different results from biomass sourced from the Forest Service in many categories, including total volume delivered, payments received, and transportation distances. In 2012, this difference

Table 5—Land ownership effects for selected biomass parameters in the Oregon tax credit program in 2014

Land ownership class	Number	Average[a]
Tons delivered (2014):		
Private	10	3,508
U.S. Forest Service	8	6,201
Various	2	4,551
p-value = 0.536788		
Dollars per bone-dry ton (2014):		
Private	9	32
U.S. Forest Service	8	29
Various	2	35
p-value = 0.760902		
Total receipts in dollars (2014):		
Private	9	48,168
U.S. Forest Service	8	130,865
Various	2	106,081
p-value = 0.317548		
Transportation distance in miles (2014):		
Private	10	73
U.S. Forest Service	8	106
Various	1	30
p-value = 0.336335		

[a] Means sharing a common letter are not significantly different at the 0.05 confidence level using Bonferonni's pairwise comparison test.

was most pronounced with statistically significant differences in all categories (table 3). In particular, transportation distances tended to be shorter from private lands, where most shipments were less than about 130 mi (fig. 8). For federal lands, distances appeared evenly distributed for distances of up to about 280 mi, with some shipments of more than 400 mi (fig. 8). These results suggest that Oregon policies to stabilize key parameters such as biomass price, net realized tax benefit, and the number of participants will help create greater predictability of biomass utilization. Consistent biomass supplies are a critical element in developing supply chains and infrastructure needed to support fledgling biomass energy industries.

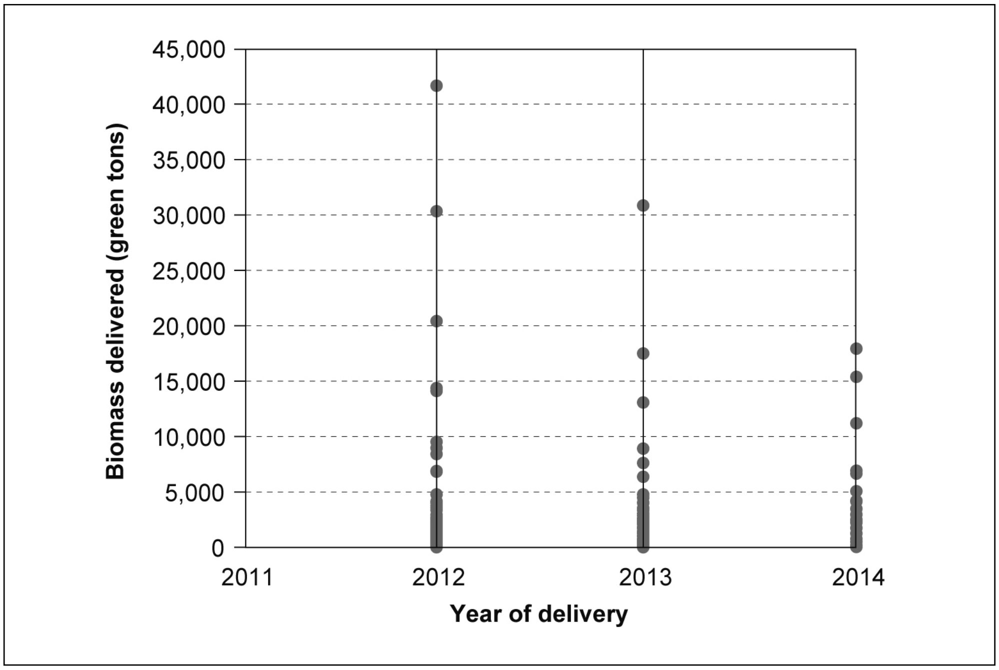

Figure 6—Total weight of biomass transported, by year, for participants in the Oregon biomass tax credit program from 2012 to 2014.

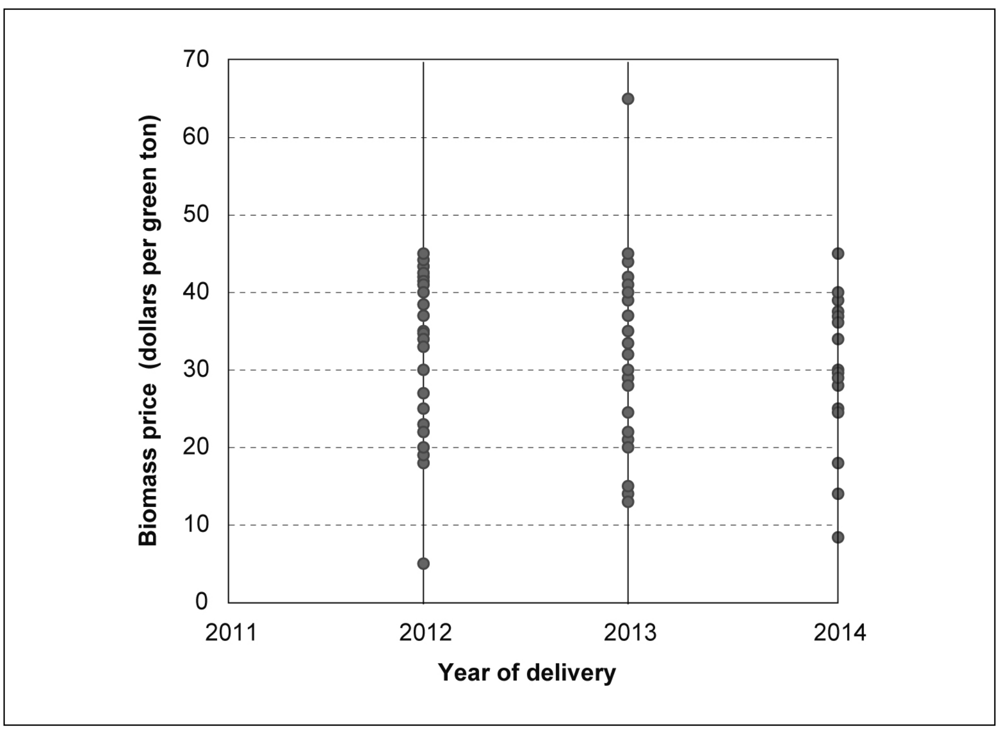

Figure 7—Biomass price, by year, for participants in the Oregon biomass tax credit program from 2012 to 2014.

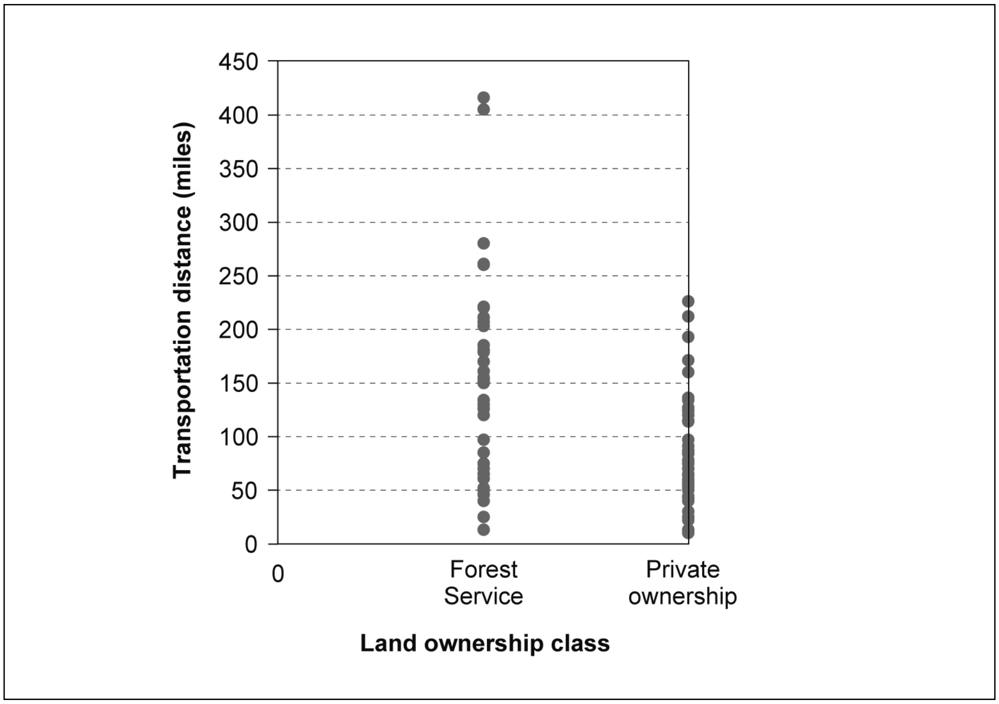

Figure 8—Transportation distance versus land ownership class for participants in the Oregon biomass tax credit program from 2012 to 2014.

Policy Implications for Bioenergy Development

Policies to enhance biomass development can be broadly classified into at least five broad categories: tax incentives (including sales tax credits, production tax credits, and property tax credits); cost sharing (including grants and rebates); rules and regulations; financing assistance, and technical assistance (Becker et al. 2011). Fire risk mitigation policies could include harvest cost subsidies (e.g., reduced stumpage values), and transportation cost subsidies (e.g., reductions in diesel fuel taxes). Other incentives could be structured to help log and processing sites become established near harvest sites, or to encourage renewable energy production (e.g., production tax credits when producing energy from biomass) (Becker et al. 2009). Fuel quality considerations, including moisture content and the presence of bark or foliage, will influence factors such as heat value for power generation as well as suitability for processes such as torrefaction. Therefore the continuation of a tax incentive for biomass utilization could be expanded in scope to consider these and other specific factors. This is important because Oregon's tax incentive discussed in this report—although broad-based—could be considered to have been too general to have lasting impacts on biomass use. As wood energy infrastructure develops for applications such as small-scale thermal, cofiring, aviation fuels, biochar, and torrefied wood, Oregon's tax policy could remain current with these applications and markets. Further, emerging wood-based industries (such as cross-laminated timber, which is used to build high-rise structures out of wood) could have a bearing on amounts of mill residues generated, and associated bioenergy opportunities.

Renewable Energy Policies—From Local to Global Scales

A number of nations in Europe have led the way in renewable portfolio standards and related policy incentives, some of which have been in effect since the 1990s. Marques et al. (2010) used a fixed-effects panel model to consider factors driving renewable energy adoption in European Union (EU) nations and also by non-EU members, finding that policies were beneficial overall for promoting renewable energy. Menegaki (2011) also used a panel data framework to evaluate the economic growth of EU nations accruing from renewable energy use. Using a random effects model with GHG emissions, employment, and energy consumption as explanatory variables, Menegaki (2011) found short-term relationships between renewable energy use, GHG emissions, and employment. Zhao et al. (2013) also employed a large-panel data approach (covering 122 countries over 30 years), finding a direct link between renewable electric policies and renewable electricity generation. However, they also found that an increasing number of polices over time can actually lead to diminishing returns in policy effectiveness. Kilinc-Ata (2016) considered both EU nations and U.S. states in an econometric approach to renewable energy policies. Using panel regression tests, he considered the effect of feed-in tariffs, quotas, tenders, and tax incentives in promoting renewable energy growth. Feed-in tariffs and tax incentives were found to stimulate electrical generation from renewables, while quotas were less effective. Polzin et al. (2015), in a study of about 30 countries, also found that feed-in tariffs were effective—especially for less mature renewable energy technologies (while emissions trading was generally more effective for mature technologies). Other studies (Sarzynski et al. (2012) found that, within a suite of renewable energy policies, the ones providing short-term cash incentives—e.g., rebates, grants, and tax incentives—tend to promote more rapid and extensive deployment of renewable energy.

Federal and State Renewable Energy Policy in the United States

Since the early 2000s, state governments have taken the lead in developing renewable energy policies in the United States. Several options have been explored, including a mandatory green power option, which requires electricity suppliers to allow customers to purchase green power from a specified provider (Delmas and Montes-Sancho 2011). In cap-and-trade policies (also referred to as GHG emission trading), limits are placed on total carbon emissions rather than specifying generation technologies. Although feed-in-tariffs (also known as standard offer contracts) have proven effective, they can be complex. For example, Couture and Gagnon (2010) evaluated seven different configurations and design options for feed-in tariffs. Finally, a leading green energy policy implemented by some U.S. states is the renewable portfolio standard (RPS), which will be the focus of the remainder of this discussion.

A renewable portfolio standard has the primary goal of increasing the proportion of renewable electricity generation. An RPS requires "electric utilities and other retail electric providers to supply a specified minimum percentage (or absolute amount) of customer demand with eligible sources of renewable electricity" (USEPA 2018). Such RPSs had been adopted in at least 30 states by mid-2013 (Galik et al. 2015), with an additional 8 states having adopted less binding "renewable portfolio goals." Many states have established target years of 2025 by which renewable energy goals will be met.

Although RPSs have proven successful in most states, they have produced mixed results. Carley (2009) found that states with an RPS typically increased renewable generation; however, RPSs were not significant predictors of the total renewable energy generation by a given state. Conversely, Yin and Powers (2010) found that RPSs did have a positive influence on renewable power development. Menz and Vachon (2006) concluded that RPSs had a positive effect on renewable power—particularly wind energy. Eastin (2014) also reviewed the effectiveness of RPSs in the United States primarily from an air quality perspective. Carly (2011) found that RPSs were most effective when neighboring states also had RPSs, resulting in a geographic diffusion of renewable energy.

Multiple Policy Instruments and Renewable Energy Types

According to the database of state incentives for renewables and efficiency (DSIRE, http://www.dsireusa.org/), it is not at all uncommon for states to adopt multiple renewable energy policy instruments (Cheng and Yi 2017), and policy effectiveness has been found to vary by energy source (e.g., biomass vs. wind vs. solar). Only two policy measures were found to be effective for all types of renewable energy—investment incentives and feed-in tariffs. In related work, Bird et al. (2011) studied the effectiveness of multiple renewable policies on reaching RPS targets. They found that RPSs combined with cap and trade programs could lead to short-term benefits greater than either measure alone. However, the electricity prices resulting from combinations of policies produced varying results. Shirmali and Kniefel (2011) evaluated all 50 U.S. states over a 16-year time series. They found that, when considering pairs of renewable energy technologies, a given policy incentive could affect wind or biomass energy resources differently than geothermal or solar energy.

In a related study, Basher et al. (2015) considered panel data models to evaluate renewable energy policy effectiveness for 19 countries over a period of 22 years. A typical assumption in time series studies is that the dependent variable (in this case the contribution of renewable energy) will be stationary about some mean. However, this work found strong evidence (17 of 19 countries) that the renewable energy share was not stationary. Polzin et al. (2015) considered the influence of renewable energy policy incentives when evaluating both actual market conditions and technological maturity. They found that market-based instruments (e.g., GHG emissions trading) are appropriate for mature technologies. Prasad and Munch (2012) pointed out the importance of policy instruments such as carbon taxes in reducing GHG emissions, because proximate measures such as clean electricity targets do not necessarily reduce carbon emissions.

Shrimali and Kniefel (2011) considered broad policy measures for numerous renewable technologies, including wind, biomass, geothermal, and solar. They found that penetration of all technologies can benefit from "clean energy funds" and "green power options." However, for a specific type of technology, voluntary portfolio standards were more effective. Shrimali et al. (2015) considered the relation between federal and state energy policies, finding that the national production tax credit for renewable energy production did enhance state-level policies. However, regulatory uncertainty surrounding federal tax credits can also create uncertainty in state renewable energy deployment. Carly (2011) also considered the effect of a carbon price on reducing carbon dioxide (CO_2) emissions, finding that a price of $50 per ton can generate significant carbon savings but that a carbon price combined with an RPS can be most effective. These findings demonstrate the importance of considering several factors when adopting state-level policies, among them the types of renewable energy incentivized, the maturity of technologies, and whether similar federal policies may already be in place. This is important, especially in states like Oregon that have abundant hydropower, wind, and biomass resources.

Woody Biomass Policies in the United States

Biomass utilization can be directly related to the use of other renewable energy technologies, and policies to enhance these technologies are intertwined. State woody biomass policies can be broadly grouped into financial incentives (including tax incentives, subsidies, and grants) and nonfinancial incentives (including rules and regulations, education, and consultation) (Guo et al. 2012).

In the Southeastern United States, Galik et al. (2015) considered multistate RPSs, finding that effective regional policies can result in greater levels of forest carbon sequestration. They also identified states such as North Carolina, New

Mexico, and New Hampshire that have separate "carve-outs" within their RPSs for biomass energy. These provisions often combined bioenergy with other renewables such as manure (methane gas), hydroelectric, and geothermal energy. Becker et al. (2011) evaluated biomass utilization state policies, identifying 370 policies (as of 2010). They considered policy effectiveness at different points of the supply chain, including harvesting, transportation, and manufacturing. The greatest number of policies was directed toward manufacturers and processors of biobased products (82 policies). White et al. (2013a) considered a national perspective of woody biomass in the United States and provided economic models for the use of short-rotation-woody biomass crops, harvest residues, and hazardous fuel removals.

Renewable energy policies must be evaluated over time to gain a true sense of their effectiveness. When considering a time-series approach, a common characteristic is often to assume that electricity generation will be stationary about a mean. However, Basher et al. (2015) found strong evidence to suggest that this is not always a valid assumption (in 17 out of 19 policies they studied). Delmas and Montes-Sancho (2011) found that the choice of independent variable (e.g., renewable energy generation vs. renewable energy capacity) can greatly influence findings. And, because most RPSs specify that a certain percentage of energy generation will be renewable, it is possible that carbon emissions could actually increase over time even if the renewable energy share is also increasing. Thus, state policymakers must carefully choose one or more policy instruments and evaluate conditions under which they would be most effective, considering unintended consequences and potential limitations.

These studies and others demonstrate the difficulty in making direct comparisons of RPS success. One challenge in making state-to-state comparisons is that specific policies can differ broadly in their construction, the way goals are specified, and their effectiveness over time. Although RPSs in most states specify only renewable electricity generation, some states also allow thermal generation, energy efficiency, and in some cases, nonrenewable generation to be credited. Further, RPSs may become inefficient under certain circumstances because they do not reward nonrenewable energy sources that have lower carbon emissions (e.g., natural gas when it is used to replace coal for power generation) (Eastin 2014).

Policy Implications—Ecosystem Services, Biodiversity, and Social Values

Woody biomass from hazardous fuel treatments could provide a number of important ecosystem services, including fire risk reductions (Shroder et al. 2016), improved forest resiliency, wildlife habitat, and recreational use (Foley et al 2014, Gaines et al. 2010, Smith et al. 2011). In the potential utilization of forest residues for energy, the benefits from displacing fossil fuels occur instantaneously; using forest residues for energy is preferable to burning them onsite or letting them decay onsite, as both would have greater CO_2 emissions (Miner et al. 2014). Forest harvest regimes on large landscapes are linked to the degree of biological diversity, disturbance patterns, and land use change—all of which can influence production and availability of woody biomass (Spies and Johnson 2007).

Conserving biological diversity can pose challenges for land managers, and effective adaptive strategies for dealing with climate change require a socioecological systems perspective. These include manipulation of stand and landscape structure to increase resilience, as well as engaging in multiownership land use planning (Spies et al. 2010). Policies promoting bioenergy can be used to enhance energy security, rural economic development, and climate change mitigation (Soderberg and Eckerberg 2013). However, large-scale use of bioenergy can spur conflicting views regarding socioeconomic benefits, especially in rural areas. At the forefront is the issue of conserving biodiversity in areas where intensive forest management is practiced.

In the Pacific Northwest, and primarily in Oregon, there are more than 30 formally organized forest collaborative groups (USDA FS 2017) that are working with the forest industry, conservation groups, and economic development councils to actively manage regional forests. One of their key efforts is to find markets for small-diameter trees harvested in the thinning of forests to reduce wildfire risk and improve forest health. The Forest Service has implemented a national Collaborative Forest Landscape Restoration Program (CFLRP) to increase the pace and scale of restoration in the region (Dupraw 2014), and there are four large CFLRP projects in Oregon and Washington that are funded for 10 years. These CFLRP projects create a large supply of small-diameter trees that are currently piled and burned onsite or underutilized. Coordination of restoration projects with a dependable supply of biomass would both encourage an increase in the scale of restoration projects in the region and help reduce the uncertainty of supply for large electrical power plants that will have huge demands for biomass.

Oregon Context

This research is relevant to renewable energy development in Oregon in several respects. Oregon has established an RPS goal to produce 50 percent of the state's electricity from renewable resources by 2040 (ODE 2017). Wind power accounted for 11.3 percent of the electricity generated in Oregon in 2015 (AWEA 2016). It is therefore likely to far outshine bioenergy in the near term.

State policies must consider all the renewable energy technologies in their portfolio to be effective, especially because combinations of renewable feedstocks can behave differently under different sets of policies. Oregon's current RPS (as in many other states) includes renewable electricity only. However, states are increasingly broadening the list of eligible energy products for their RPSs, including thermal generation (Heeter and Bird 2013). Because Oregon has far greater biomass use in thermal energy systems (than is used to generate electricity), inclusion of a thermal energy component could bode well for Oregon's renewable energy future. White et al. (2013a) indicated that, if the biomass tax credit addressed in this paper were replaced with incentives for capital expenditures, construction of up to 10 small-scale thermal energy facilities per year would be feasible. Continued policy measures such as the RPS will help Oregon enter a new phase of wood energy utilization. Past research has shown that the benefits of biomass use are tangible—an estimated $850,000 in economic activity for each 10,000 BDT of forest biomass delivered (Nielson-Pincus et al. 2011). Effective policy measures can be customized to benefit various points in the biomass supply chain, including harvest, transportation, production, and use (Becker et al. 2011).

Overall, Oregon woody biomass utilization policies rate highly, including an overall rank in the top five U.S. states (Guo et al. 2012). However, decreasing participation in the Oregon biomass tax credit program could necessitate new innovations to remain viable. As a practical consideration, policy changes in Oregon must be verifiable and be administered efficiently, minimizing transaction costs for participants and administrators. In this context, a small number of well-designed policies adopted simultaneously could be more effective than numerous policies phased in gradually (Zhao et al. 2013). As of 2009, Oregon had 13 regulations related to biomass utilization (Becker et al. 2011) and 12 biomass policy instruments, which included four tax incentives and three regulations (Guo et al. 2012). Oregon policymakers could streamline these initiatives to become more effective at increasing bioenergy use in an environment of uncertain policies. Other policy considerations in Oregon could include renewing the tax credit to include both biomass energy generators and consumers, including biomass thermal energy, and increasing biomass eligibility to include urban-derived residues.

A strong and vibrant biomass industry will support Oregon's wood products manufacturers as well as contribute many other ecosystem services and community benefits. Secondary benefits accruing from ecosystem services could include reducing the risk of wildfires, increasing carbon sequestration by forests, or the use of wood byproducts and biomass as an alternative to burning fossil fuels for energy. There is strong interest among bioenergy stakeholders in Oregon (Stidham and Simon-Brown 2011); however, future challenges include access to long-term consistent biomass supplies as well as access to forest products (including biomass) from federal lands. Oregon's experience with biomass utilization and renewable energy generation could have broad implications across the Western United States where coal-fired power plants are considering cofiring coal and biomass, transitioning away from coal altogether, or considering other bridge strategies to reduce fossil fuel consumption while increasing renewable energy use.

Conclusion and Policy Implications

Biomass will play an important role in the renewable energy future of Oregon as its RPS stipulates that 50 percent of the state's electricity generation come from renewable resources by 2040. Given Oregon's extensive forest resources and strong economic base from wood products, part of this energy mix could include biomass. Bioenergy policies can be designed to create meaningful incentives for sustained effectiveness. For example, tax credits can reflect the true economic value of green vs. dry biomass to encourage participation. Efficient use of biomass is especially important in light of reduced timber harvests, as well as the increased fire frequency and acres burned over the past few decades. Policies can also be focused on enhancing biomass use from both west-side (wet) and east-side (dry) forest ecosystems.

Oregon's electrical generation picture is rapidly changing, with a large coal power plant scheduled for retirement and an energy void that must be filled. Although wind energy has experienced rapid growth and is likely to meet some of this demand, other contributors such as solar power, biomass energy, and energy efficiency could also play key roles. Employment benefits from biomass processing, transportation, and utilization could be substantial, and should be weighed against those of other technologies (such as wind, solar, and geothermal) when designing policies that enhance Oregon's economic growth as well as its resource utilization. Perhaps the key finding from our current study is that effective biomass utilization policies must take a long-term view and provide sufficient economic incentives to encourage use. In the case of biomass, successful incentives would also consider the complete supply chain and type of energy product, serving as many participants as possible. Future economic conditions in Oregon will be difficult to predict, but key among them could be rapid changes in renewable energy technologies, rapid fluctuations in fossil fuel prices, and rapid changes in macroeconomic conditions that could lead to recessions (Marques et al. 2010). Truly effective renewable energy policies must be nimble enough to account for these and other uncertainties.

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Metric Equivalents

When you know:	Multiply by:	To find:
Miles (mi)	1.609	Kilometers
Acres (ac)	.405	Hectares
Tons (ton)	.907	Tonnes or megagrams

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