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Financial considerations of policy options to enhance biomass utilization for reducing wildfire hazards

Dennis R. Becker [a,*], Debra Larson [b], Eini C. Lowell [c]

[a] University of Minnesota, 1530 Cleveland Ave N, Saint Paul, MN 55108-6112, United States
[b] Northern Arizona University, Flagstaff, AZ, United States
[c] Pacific Northwest Research Station, USDA Forest Service, Portland, OR, United States

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ABSTRACT

The Harvest Cost–Revenue Estimator, a financial model, was used to examine the cost sensitivity of forest biomass harvesting scenarios to targeted policies designed to stimulate wildfire hazardous fuel reduction projects. The policies selected represent actual policies enacted by federal and state governments to provide incentive to biomass utilization and are aimed at addressing particular challenges in the production lifecycle of trees to final product. Policies were modeled to compare financial impacts on a per-acre project basis for three scenarios of harvest intensity in southwestern ponderosa pine stands classified as being at high risk of wildfire. This allowed for identification of key cost nodes and how particular policies might better allocate limited resources. Effects of limiting the size of trees harvested and access to biomass markets were also modeled. This analysis showed that the co-location of processing facilities that results in shorter distances traveled is the single most important strategy for reducing costs for all three scenarios modeled. Per acre subsidies and certified product premiums were the next highest ranked in providing economic incentive, followed by production tax credits and cost-share programs. Fuel surcharge waivers and transport tax credits provided the least gains.

1. Introduction

Utilization of the biomass from hazardous fuel reduction efforts is an increasingly important aspect of national wildfire planning. By increasing the utilization of woody byproducts, the scope and speed of treatments may be increased by offsetting some of the cost associated with wildfire risk reduction. Investments in biomass removal to avoid wildfires may in turn result in substantial economic and environmental benefits (Mason et al., 2006).

Several policies have been passed in recent years at both the federal and state level to stimulate the implementation of fuel reduction projects. Many of those policies target biomass utilization. For instance, multi-year contracting authority has been granted to the Bureau of Land Management and USDA Forest Service to allow for Stewardship End-Result Contracts to remove trees and brush from overly dense forests (P.L. 108-7 § 323). Millions of dollars in grants to communities and wood processors have been awarded to build capacity to utilize forest biomass from fuel treatments (Becker et al., 2009; GAO, 2006). Various state incentives for renewable energy production have been implemented (Becker and Lee, 2008), and research and demonstration for biofuels using forest residues is burgeoning (Solomon et al., 2007). The challenge is weighing the benefits and costs of different incentive or investment options relative to their margin of gain. It is also important to consider the intangible benefits to communities and landscapes that accrue at different temporal scales.

Whether focused on the wildland–urban interface or remote forested regions, the scale of needed forest restoration and fuel reduction approaches 182 million acres of forestlands across the United States (Schmidt et al., 2002). Of that, perhaps 9.5 million acres of public forests and 5.1 million acres of private forests could be eligible for thinning in just the western United States (Skog et al., 2006). Considering that the cost of mechanical removal of biomass can exceed $1000/acre, it is hard to imagine the fiscal resources necessary to pay outright for fuel reduction treatments across a significant portion of at-risk forests (Prestemon et al., 2008).

Enter the promise of biomass utilization. Increasingly, state and federal land managers and tribes are looking to the utilization of the byproducts of fuel reduction treatments, which are commonly trees small in diameter, as a way to offset costs and increase the number of acres treated (GAO, 2005; Patton-Mallory, 2008). Fundamental to this is the ability of wood product markets to absorb the volume and type of material generated. However, solving the wildfire problem is not as simple as building new processing facilities in proximity to at-risk

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* Corresponding author. Tel.: +1 612 624 7286.
E-mail address: drbecker@umn.edu (D.R. Becker).

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forests. Challenges related to the consistency of supply from public lands, quality of wood available for harvest, variability in harvest efficiency, competition with traditional forest product markets, and market sensitivity to transport costs contribute to the complexity of the problem and the failure of policy to entice entrepreneurial investment (Shelly et al. 2006; Nechodom et al., 2008). Targeted policy can be used to minimize challenges, but the threshold for effective intervention differs by region and even within regions where forest conditions and market outlets may widely vary.

To be certain, the lack of wood processing infrastructure and capacity to utilize biomass is a significant obstacle in many areas (Spelter and Alderman, 2005), but the reasons for a lack of industry capacity vary. The softwood lumber industry in the interior west consumed 830 million cubic feet of logs in 2000 to produce nearly 5.8 billion board feet of lumber and 485 million cubic feet of biomass residues. Assuming the need to thin 1 million acres annually (average of 1000 cubic feet removed per acre), we will need to find uses for an additional 1 billion cubic feet per year (Haynes, 2003). Not only is the existing capacity insufficient, but in parts of the United States where fire danger is greatest, mills are frequently designed to handle large logs and are unable to use the smaller trees commonly harvested from fuel reduction projects (Keegan et al., 2004; Spelter and Alderman, 2005). Likewise, the availability of biomass from federal lands has been inconsistent where ecological concerns and litigation linger or where there are inadequate resources to administer contracts (GAO, 2005). Lack of a consistent supply of biomass hinders investors' ability to recoup costs and ultimately results in a paucity of manufacturing infrastructure (Shelly et al. 2006).

Variability in harvest costs and market returns also pose a challenge. The density of fuels, which is a function of tree species and size, and past forest management activities affects harvest costs. Costs also vary by type of equipment used, the ability of local logging contractors to remove the size and volume of trees necessary, and site conditions such as slope, proximity to sensitive areas, and operability (Lowell et al., 2008). The market value derived from a given project can also vary substantially depending on the volume harvested by tree size class, quality of wood removed, and regional and national demand (Barbour et al., 2008).

Consistency in the availability of wood product markets is lacking. Viable market outlets will depend on travel distance, market availability, and consumer demand for products. If the volume sold is inconsistent or saturated markets having an abundance of biomass drives prices down, then it will be difficult for businesses to predict financial returns and amortize investments (Shelly et al. 2006). Furthermore, if the resource base is comprised of material having a low market value or is of limited use, then when combined with transportation costs that can range upwards to 60% of total project costs (Han et al., 2004), biomass utilization is a challenging financial endeavor (GAO, 2006).

One way of facing these challenges, from a policy perspective, is to focus on the impediments at each step in the production lifecycle from harvesting trees to transport, manufacturing, and consumer markets. Nechodom et al. (2008) provide a general framework of policy options that focuses on 1) reduction in harvest costs for fuels treatments including transportation, 2) expansion of value-added products manufactured from fuel reduction material, and 3) capturing the market value of ecosystem services enhanced by fuel reduction activities. We use this framework to identify and compare state and federal policies aimed at stimulating biomass utilization.

The purpose of this study is to conduct a comparative financial analysis of the effects of various policies to the on-the-ground costs of biomass removal. Cost-to-revenue thresholds are produced by a financial model called the Harvest Cost–Revenue (HCR) Estimator (Becker et al., 2008) applied to three discrete harvest treatments for southwestern ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.). Baseline results were generated for market conditions consisting of high-value logs for kiln-dried dimension lumber, low-value rough-cut green lumber, and dirty chips for energy production. Using the three reference stand treatments, eight incentive policies and four market options were applied to each scenario comparing project-level costs to identify policies that increase revenue. Regional economic impacts were not included in the analysis.

2. Stand and treatment considerations

Because forest conditions, species composition, and tree form vary widely from one area to another only one tree species type was modeled for this analysis. Three levels of harvest intensity were modeled for ponderosa pine stands classified as being at high risk of wildfire in the southwest (Fire Regime Condition Class III). Harvest levels were determined based upon removal intensities used in wildfire risk reduction treatments modeled from inventory data collected from the Coconino National Forest in northern Arizona (Larson and Mirth, 1999). Table 1 depicts three stands with three different mechanical treatments (scenarios); each project was 100 acres. Pre-treatment stand conditions were dominated by small diameter trees less than 5-in. dbh. The majority of harvested trees per acre (tpa) were less than 10-in. dbh with all trees less than 5-in. dbh removed. Each treatment assumes a reduction in hazardous fuels to a low severity level (Fire Regime Condition Class I).

The first scenario is a full restoration stand-treatment with a 16-in. dbh cap on an existing stand with an approximate tree count of 600 tpa. No trees were cut that were larger than16-in. dbh and the stand basal area was reduced from 138 ft^2 to 63 ft^2. Approximately 563 tpa were harvested. An intermediate cut with no diameter limit on the size of trees harvested was applied to a second stand with similar conditions as the first. The initial basal area was reduced to 81.4 ft^2 from 206.7 ft^2 with an average of 505 tpa harvested across all size classes. The final stand-treatment scenario, Scenario 3, had more trees less than 2-in dbh than the Scenarios 1 and 2. A fuel reduction treatment with a 16-in. dbh limit on the size of trees harvested resulted in greater retention of mid- and large-sized trees. An average of 1000 tpa were harvested, which reduced basal area from 147 ft^2 to 63 ft^2.

3. The policies evaluated

We examined a range of state and federal policies for their effect on the financial viability of fuel reduction projects. The policies reflect specific approaches to providing utilization incentives targeted at different steps in the production lifecycle from harvesting and transportation to manufacturing and consumer markets. The range of policies allows for comparison of the relative financial benefit of one approach over another on a project-level basis.

3.1. Harvesting cost offsets

We examined four policies that either directly or indirectly affect harvest costs based on the size of trees cut, stand density, and equipment used. Total project costs will also vary depending on species type and distribution, site operability, and considerations for environmental factors like wildlife habitat or sensitive soils.

The first harvest policy assessed subsidizes the cost of biomass removal through a reduction in the stumpage value or an increase in the payment to contractors for services provided; the assumed financial offset is the same. Where no stumpage value exists or where profits are insufficient to offset removal costs, the federal government may provide payment for the cost differential either as an integrated resource service contract or through a goods-for-services Stewardship End-Result Contract (2003 Appropriations Act, P.L. 108-7). For the purpose of this analysis, we assume an offset of $500/acre paid to the contractor either by the federal government or through state programs like the taxing authority created by the Colorado Forest

Table 1
Trees per acre (tpa) and basal area for three ponderosa pine stand-treatment scenarios in northern Arizona (Larson and Mirth, 1999).

	Scenario 1				Scenario 2				Scenario 3			
	Full restoration cut (16-in limit)[a]				Intermediate cut (no size limit)[b]				Minimal cut (16-in limit)[c]			
	Initial		Residual		Initial		Residual		Initial		Residual	
dbh	tpa	Basal area	tpa	Basal area	tpa	Basal area	tpa	Basal area	tpa	Basal area	tpa	Basal area
1	254.5	1.4	0.0	0.0	181.8	1.0	0.0	0.0	484.8	2.6	0.0	0.0
2	54.5	1.2	0.0	0.0	54.5	1.2	0.0	0.0	139.4	3.0	0.0	0.0
3	57.5	2.8	0.0	0.0	72.7	3.6	0.0	0.0	124.2	6.1	0.0	0.0
4	33.3	2.9	0.0	0.0	24.2	2.1	0.0	0.0	54.5	4.8	0.0	0.0
5	39.4	5.4	0.0	0.0	9.1	1.2	0.0	0.0	57.6	7.9	0.0	0.0
6	27.2	5.3	3.0	0.6	6.1	1.2	0.0	0.0	48.5	9.5	3.0	0.6
7	27.2	7.3	3.0	0.8	21.2	5.7	0.0	0.0	21.2	5.7	3.0	0.8
8	9.1	3.2	3.0	1.0	18.2	6.4	0.0	0.0	21.2	7.4	3.0	1.0
9	27.2	12.0	3.0	1.3	21.2	9.4	0.0	0.0	21.3	9.4	6.1	2.7
10	12.1	6.6	0.0	0.0	21.2	11.6	0.0	0.0	30.3	16.5	18.2	9.9
11	18.2	12.0	9.1	6.0	18.2	12.0	6.1	4.0	21.2	14.0	9.1	6.0
12	15.1	11.9	3.0	2.4	15.2	11.9	6.1	4.8	9.1	7.1	6.1	4.8
13	3.0	2.8	0.0	0.0	21.2	19.5	0.0	0.0	12.1	11.2	9.1	8.4
14	6.1	6.5	6.1	6.5	9.1	9.7	9.1	9.7	15.2	16.2	6.1	6.5
15	9.1	11.2	6.1	7.5	15.2	18.7	6.1	7.5	9.1	11.2	6.1	7.5
16	12.2	17.0	6.1	8.5	24.2	33.8	9.1	12.7	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	6.0	9.5	3.0	4.7	0.0	0.0	0.0	0.0
18	6.1	10.8	6.1	10.8	12.1	21.4	9.1	16.1	3.0	5.3	3.0	5.3
19	0.0	0.0	0.0	0.0	3.0	5.9	3.0	5.9	0.0	0.0	0.0	0.0
20	3.0	6.5	3.0	6.5	6.0	13.1	3.7	8.1	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	3.0	7.9	3.0	7.9	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	9.4	3.0	9.4
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	3.0	11.1	3.0	11.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	617.8	137.8	54.5	63.0	563.4	206.7	58.3	81.4	1,075.7	147.3	75.8	63.0

[a] 16-in dbh limit on the size of trees harvested; 60-basal area target.
[b] No limit on the size of trees harvested; 80-basal area target.
[c] 16-in dbh limit on the size of trees harvested; 60-basal area target.

Improvement Districts (HB07-1168). The analysis of this policy is referred to as option (1-a).

Another type of cost offset is to subsidize the purchase price or interest paid on investment in harvesting equipment. A challenge for contractors is securing sufficient resources to invest in the types of harvesting and handling equipment needed for efficient biomass removal (Becker et al., 2009). The high cost of entry and the risk of securing enough volume to amortize investments is a deterrent. Several states have passed legislation in response to this challenge. Washington State, for example, exempts all equipment purchased for biomass removal from state sales taxes (Washington RCW 82.08.960, 82.12.960). The Wisconsin Energy Independence Fund and Loan Program provides cost-share grants for up to 50% of investment costs or 4% interest on qualifying investments up to 15 years not to exceed 25% of total project costs (2007 Wisconsin Act 20 § 560.126). In Arizona, annual property taxes are reduced for qualifying equipment through the Healthy Forest Enterprise Incentives Program (A.R.S. § 41-1516). For this analysis, we examine the sensitivity of project costs to a reduction in investment costs through two incentives. Option (1-b) allows a 3% sales tax waiver on the purchase price of harvesting equipment and option (1-c) provides a 50% equipment cost share.

A fourth policy option influencing harvest costs is the establishment of a diameter limit on the size of trees harvested. In addition to economic and ecological considerations for how many trees and of what size to harvest, social considerations make this a contentious policy option. Formal agreements exists whereby trees larger than a certain diameter size are off-limits from harvesting on some public lands. Such diameter cap limits have been effective in speeding the implementation of projects where environmental concerns are heightened (Schindler et al., 2002). The tradeoff is that fuel reduction treatments may not be as effective as without a size limit, and from a financial standpoint there could be a reduction in revenue because of fewer, higher-valued large trees removed (Larson and Mirth, 2004). Option (1-d) varies the treatment design of the baseline stand-treatment Scenario 2 to analyze the financial effects of a diameter cap limit. Scenarios 1 and 3 incorporate a diameter cap in the stand treatment.

3.2. Transportation incentives

Transportation costs may be as much as 60% of overall project costs (Han et al., 2004). To reduce those costs, incentives focusing on the reduction of diesel fuel excise taxes for certified businesses transporting forest biomass to or from processing facilities was analyzed in option (2-a). We simulate the effect on transportation costs of waiving a federal excise tax of $0.20/gallon (International Fuel Tax Association, 2009).

Another transportation incentive analyzed was a subsidy similar to one authorized as part of the 2005 Energy Policy Act (P.L. 109-58) in which each ton of woody biomass collected from a qualifying source and transported to a bioenergy or biofuels facility is eligible for an offset payment to the contractor. Oregon passed similar legislation paying contractors $10/green ton for transport of woody biomass to bioenergy or biofuels facilities (HB 2210). The intent is to provide incentive to contractors to remove residual biomass rather than burning the biomass in the forest or leaving to decompose. The impact

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of a $10/green ton subsidy is analyzed for two market options: option (2-b) a combined chip and log market, and option (2-c) a chip only market where all harvested material, regardless of tree size, is chipped for biomass.

A fourth option influencing transportation costs are policies encouraging the location of log and biomass processing facilities in proximity to harvest sites. Log sort yards on county or state lands or local tax incentives can encourage businesses to locate in areas that minimize transport distances. Similarly, state or federally designated enterprise investment zones may be in proximity to harvest sites. Option (2-d) assumes the co-location of a new solid log and biomass processing facility within an average of 10 miles of forest harvest sites.

3.3. Expansion of value-added markets

The benefits derived from fuel reduction projects can include a variety of ecosystem and social benefits. We model the cost of providing those benefits by passing on them to consumers in the form of an environmental surcharge or a premium paid for fuel reduction products to stimulate favorable manufacturing and consumer markets. The first option (3-a) targets the creation or expansion of biomass markets through procurement policies. In particular, we assessed state mandates for the production of forest bioenergy. Many states have a renewable portfolio standard requiring a certain percentage of energy produced come from qualifying renewable energy sources. For instance, that amount is 25% by the year 2025 in Minnesota (Chapter 136, File 145). The result is the creation of a biomass market where perhaps none previously existed, or an increase in the price paid resulting from increased demand created through power purchase agreements.

Another market-based incentive is the use of production tax credits paid on units of power generated. The Biomass Energy Production Incentive in South Carolina (HB 3649) is one such example in which eligible providers are paid a production credit of $0.01/kilowatt-hour (kWh) or $0.30/therm (100,000 Btu) for energy produced from biomass resources. For this analysis, the added value of $0.01/kWh, assumed equal to $17.22/green ton (USDA Forest Service, 2004), is passed on to the logging contractor as a premium paid for the biomass removed. The impact of this incentive is analyzed for two market conditions: option (3-b) a combined chip and log market, and option (3-c) a chip only market where all harvested material, regardless of tree size, is chipped for biomass.

A fourth policy option is the added value for products certified as originating from sustainably grown forests. Forest certification from organizations like the Forest Stewardship Council® or Sustainable Forestry Initiative® provide a market-based mechanism whereby contractors may be paid a premium for raw logs sold to manufactures, who pass on the added costs to consumers. Although such premiums are not widely available, option (3-d) assumes that the log premium paid to loggers is $5/green ton for dimension-lumber grade logs.

4. Estimating costs and project revenue

4.1. The HCR Estimator

We used the HCR Estimator to compare project-level costs with expected financial return for different market scenarios. This public-domain engineering and financial analysis software program can be used to evaluate stand-level financial thresholds for any number of harvest sites and market conditions for ponderosa pine in the southwest United States. The scenarios we model depict a range of site conditions and market situations commonly experienced in the region. Application of the HCR Estimator to other regions is limited by the degree to which harvested trees have similar form as southwestern ponderosa pine. Site operability will also vary by location. The model inputs include per acre estimates of harvest removal, equipment type and utilization rate, residual biomass handling, distances traveled to processing facilities, labor rates, and contract specifications. Revenue projections consider log and biomass specifications and quantities as a function of market, stand characteristics, and treatment design.

The strength of the HCR Estimator is that it allows users to assess the influence of differing market options on profitability relative to financial inputs. This provides a critical step in the development of a fully integrated system capable of anticipating how changes in policies affect project costs and, in turn, the sensitivity of project costs to market factors (Lowell et al., 2008). At every functional step, a decision is made that influences profitability. The aggregate of these decisions influences the financial viability of fuel reduction projects and ultimately the viability of wood products businesses.

4.2. Project equipment and other parameters

The equipment set used to model biomass harvesting reflects commonly used set-up for industrial-scale forestry in the region. We modeled a whole-tree harvest system for each of the three stand-treatment scenarios using the following inputs (Table 2): 177-horsepower (hp) whole tree feller-buncher; 175-hp skidder with 500-ft average skid to a landing; 138-hp stroke delimber; 130-hp log loader; and 500-hp chipper. Wages, benefits, and employer costs for workers' compensation and unemployment insurance are constant. Sizes of trees utilized and distanced to processing facilities are dependent upon the specifications for each product market modeled for each scenario.

Table 2
Equipment and market parameters used to model net revenue.

Project and market parameters	Unit/rate
Whole-tree harvest system	
Hydro-Ax 621E rubber tired feller-buncher	177 hp
Purchase price (years owned)	$195,523 (3)
Utilization rate	65%
Caterpillar 528 grapple skidder	175 hp
Purchase price (years owned)	$203,619 (3)
Utilization rate	60%
Average skid distance	500 ft
Denharco 4400 stroke-delimber (Cat 320C)	138 hp
Purchase price (years owned)	$375,628 (3)
Utilization rate	80%
Prentice RT-100 loader	130 hp
Purchase price (years owned)	$151,764 (3)
Utilization rate	65%
Bandit Beast 3680 grinder	500 hp
Purchase price (years owned)	$214,071 (3)
Utilization rate	65%
Off-highway diesel fuel price	$3.25/gal
Equipment mobilization distance	12 miles
Average ground slope	16%
Loan amortization period	5 years
Operating season	9 months
Total area treated	100 acres
Employee compensation (40-h workweek)	
Hourly wage rate (equipment operators)	$18.75/h
Fringe benefits (leave, insurance, retirement)	5% of hourly wage
Workers' compensation rate	34% of hourly wage
State unemployment compensation rate	2.5% of hourly wage
Overhead (not including profit)	10% of total costs
Trucking rate	$0.15/ton mile
Log trailer capacity (chip van capacity)	25 tons (22 tons)
Moisture content (wet moisture)	55%
Market specifications	
Market #1: dimension lumber, price[a]	$23/green ton (60 miles)
Minimum diameter size	7-in top (inside bark)
Market #2: low-grade pallet lumber, price[a]	$19/green ton (35 miles)
Minimum diameter size	5-in top (inside bark)
Market #3: dirty chips for energy, price[a]	$22/bone-dry ton (45 miles)
Minimum diameter size	3-in dbh and larger

[a] One-way distance to manufacturing or processing facility shown in parentheses.

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4.3. Product markets

Assumptions were made about the availability of markets and specifications for the size of material utilized in order to compare project costs and revenue. Different market specifications are possible and may result in different outcomes. Three product markets are included in the baseline analysis. Market 1 is logs delivered for the manufacture of kiln-dried dimension lumber. Minimum raw log requirements are 8-ft in length, 7-in. small end diameter (inside bark). There is no maximum diameter or length limit. A conservative estimate of delivered log price is $23/green ton with an average one-way haul distance of 60 miles. Market 2 takes the logs that are not suitable for Market 1 and processes them into rough-cut green, low-grade lumber. Market 2 logs are at least 6-ft in length with a minimum 5-in. small-end diameter (inside bark). The delivered price is assumed at $19/green ton with 35 mile one-way haul distance. Market 3 is a dirty chip biomass market for energy production, utilizing those trees 3-in. dbh and larger not going to Markets 1 or 2, boles too small for other markets, and tops and branches. Dirty chips include needles and bark. Market 3 delivered dirty chip price is assumed to be $22/bone-dry ton with a one-way haul distance of 45 miles. Smaller trees and brush not directed to Market 3 are hand-felled and scattered in the forest.

For modeling purposes, the HCR Estimator optimizes volume to the highest value market, paid on a per ton or cubic feet basis. The useable log volume per market was determined as a function of geometric tree form and taper (Becker et al., 2008; Husch et al., 1982). The number of sawlogs allocated to each market for any given stand is therefore dependent upon the specifications for the highest value log market. If the log specifications are such that only the largest trees qualify or that longer logs are required, then logs not qualifying for that market will be allocated to the next highest value market. The amount of biomass generated from each harvested tree is therefore dependent upon the log specifications and allocation of the useable portion of the tree to the highest valued market.

5. Baseline results

First, a baseline set of HCR Estimator results were developed to serve as comparators against which the various policy options were analyzed. This baseline incorporated the previously described equipment and market parameters as applied to the three stand-treatment scenarios. The HCR Estimator baseline results are presented in Table 3.

In terms of total costs, stand-treatment Scenario 1 (full restoration with 16-inch dbh cap) and 3 (minimal treatment with 16-in. dbh cap) were similar, each costing about $3800/acre to treat. Scenario 2, the intermediate cut without a diameter cap, was the most expensive at about $6400/acre due to the increased costs of harvesting and transporting a greater volume of logs to market. The percentage of trees 8-in dbh and larger harvested in Scenario 2 was 27% compared to 13% in Scenario 1 and 8% in Scenario 3.

The major cost nodes per scenario represented on a total scenario basis, however, were similar. Log harvesting costs were 19 to 20% of the total costs, chip harvesting ranged from 2 to 5%, the lop and scatter residual treatment was 1 to 2% of total costs, and other costs including transportation ranged from 73 to 79%. Total project costs are most sensitive to transportation followed by log harvesting costs. Factors effecting transportation include the quantity of material shipped, distance to manufacturing facility, speed traveled, moisture content of logs and biomass, and highway legal load limits.

The revenue generated per scenario was unique to the volume of trees harvested per acre and the log specifications of Markets 1 and 2. The dimension lumber market (Market 1) from Scenario 2 generated a greater proportion of revenue (79%) than in Scenarios 1 (67%) and 3 (57%); there were more trees harvested in Scenario 2 that qualified for Market 1 than in the other scenarios. Whereas, the low-grade pallet market (Market 2) generated about 33% and 43% of the revenue for Scenarios 1 and 3, but only 21% for Scenario 2. In all scenarios, the chip market (Market 3) generated less than 1% of total revenue, which was less than one-half the cost of chipping the material.

Net profit (loss) per the baseline scenarios were determined by subtracting total project costs from the total revenue. All three stand-treatment scenarios yielded losses, ranging from $826/acre for Scenario 1 to $1095/acre for Scenario 2.

6. Policy results

We used the HCR Estimator to apply the eight selected policies and four market options to the three stand-treatment scenarios. The results of each scenario are presented on a net profit (loss) basis in Table 4. We then analyze the policy options that had the greatest positive effect on net revenue (Table 5).

Siting processing facilities for dimension lumber and biomass energy to within 10 miles of harvest sites, option (2-d), significantly increased net profit for each of the three stand-treatment scenarios, making each financially feasible. This is consistent with the baseline results in which transportation costs were the majority of total project costs (64–69%) and that reductions in distance traveled significantly reduces the break-even threshold. The $500/acre harvest subsidy, option (1-a), was the next most profitable policy for Scenarios 1 and 3. In contrast, an increase in dimension lumber market price as a function of product certification, option (3-d), was the next most profitable in Scenario 2. Certified product premiums followed for Scenarios 1 and 3, and a $500/acre harvest subsidy was next highest for Scenario 2. These results too are consistent with the baseline results in which log harvest costs and dimension lumber revenue are critical factors in determining total net profit (loss).

The equipment cost-share policy, option (1-c), was the next most profitable incentive resulting in a total direct savings of more than $570,000 amortized over the five-year economic lifespan of the equipment and resulted in a net decrease in total project cost of between 30% and 37%. The production tax credit of $.01/kWh, option (3-c), followed for Scenarios 1 and 3 in which all trees were chipped for biomass. This option increased net profitability by 23% and 28% respectively for Scenarios 1 and 3, and 11% for Scenario 2. All delimbing and

Table 3

Per acre cost and revenue for baseline stand-treatment and market scenarios.[a,b]

Cost or revenue node	Scenario 1	Scenario 2	Scenario 3
	Full restoration cut (16-in limit)	Intermediate cut (no size limit)	Minimal cut (16-in limit)
Log harvesting costs			
Felling	$101 (2.7)	$153 (2.4)	$106 (2.8)
Skidding	$183 (4.8)	$307 (4.8)	$176 (4.7)
Delimbing	$264 (6.9)	$435 (6.8)	$271 (7.2)
Loading	$188 (4.9)	$293 (4.6)	$198 (5.3)
Chip harvesting costs			
Felling	$40 (1.1)	$18 (0.3)	$62 (1.6)
Skidding	$46 (1.2)	$29 (0.5)	$63 (1.7)
Chipping	$45 (1.2)	$66 (1.0)	$51 (1.4)
Residual treatment costs			
Felling residuals	$32 (0.8)	$35 (0.5)	$60 (1.6)
Scattering residuals	$10 (0.3)	$11 (0.2)	$18 (0.5)
Other costs			
Equipment mobilization	$29 (0.8)	$29 (0.5)	$29 (0.8)
Transportation	$2524 (66.3)	$4429 (69.4)	$2395 (63.5)
Administrative overhead	$345 (9.1)	$579 (9.1)	$341 (9.0)
Total project costs	$3807	$6384	$3769
Market revenue			
Market 1: dimension lumber	$1991 (66.8)	$4166 (78.8)	$1583 (56.5)
Market 2: pallet lumber	$973 (32.6)	$1094 (20.7)	$1202 (42.9)
Market 3: dirty chips	$17 (0.6)	$29 (0.5)	$16 (0.6)
Total project revenue	$2981	$5289	$2801
Net profit (loss)	($826)	($1095)	($968)

[a] Assume that all markets are viable year around.

[b] Figures in parentheses are the percentage of total project costs or revenue.

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Table 4
Per acre net profit (loss) for stand-treatment scenarios by type of policy intervention.

Policy option	Scenario 1	Scenario 2	Scenario 3
	Full restoration (16-in limit)	Intermediate (no size limit)	Minimal (16-in limit)
Baseline model	($826)	($1095)	($968)
Reduce harvesting costs			
(1-a) $500/ac harvest subsidy	($326)	($595)	($468)
(1-b) 3% equipment sales tax waiver	($787)	($1070)	($948)
(1-c) 50% cost share for equipment	($530)	($687)	($674)
(1-d) 16-in dbh cap		($898)	
Transportation incentives			
(2-a) $0.20/gal fuel surcharge waiver	($803)	($1051)	($941)
(2-b) $10/g ton biomass tax credit	($810)	($1064)	($949)
(2-c) $10/g ton biomass tax credit, no logs[a]	($764)	($1359)	($810)
(2-d) Co-location of facilities[b]	$634	$956	$312
Value-added markets			
(3-a) No chip market	($670)	($979)	($780)
(3-b) $0.01/kWh tax credit[c]	($798)	($1043)	($937)
(3-c) $0.01/kWh tax credit[c], no logs[a]	($635)	($971)	($698)
(3-d) Premium for certified products[d]	($370)	($188)	($620)

[a] There are no log markets and all material used for dirty chips.

[b] Co-location of dimension lumber mill and biomass energy facility; one-way distance to facility is 10 miles.

[c] $0.01/kWh converts to $17.22/green ton (50% moisture content) (USDA Forest Service 2004).

[d] $5/green ton premiums paid for logs to be manufactured into dimensional lumber.

log-handling costs were eliminated by removing the log markets, and transportation distances to chip markets were shorter than for log Market 1, which was the primary outlet in the baseline model.

The least profitable incentive was the $10/green ton transportation tax credit, option (2-b). The 3% sales tax waiver on the purchase price of qualifying equipment, option (1-b), and the waiver of the $0.20/gal diesel fuel surcharge, option (2-a), also provided little benefit relative to the other policies modeled.

The effect of harvest diameter limits on profitability was demonstrated through manipulation of Scenario 2 (intermediate cut scenario) to exclude all trees larger than 16-in dbh, option (1-d), regardless of how such limits might affect stand treatment priorities or fuel reduction. The result was a net decrease in total project costs ($1708/acre) and revenue generated ($1511/acre). Given the volume and distribution of harvested trees larger than 8-in dbh (cutoff for allocating logs to Market 1) and the comparatively higher costs of transporting logs than in Scenarios 1 and 3, diameter limits actually decreased costs more than the amount of revenue lost. This is contrary to the conventional wisdom that diameter limits reduce profitability (Larson and Mirth, 2004).

However, transport costs were about 72% of the total cost savings when applying a diameter cap to Scenario 2, suggesting that the distance to processing facilities is more important than the size of the cap. This illustrates the complexity of maximizing revenue when the allocation of logs to the highest value markets is insufficient to cover the marginal costs of added transportation to those markets. In Scenario 2, the threshold of log transport costs-to-increased product revenue results in a net profit at about 35 miles in the baseline model, assuming no diameter limit. However, depending on the proximity of processing facilities and the market value of harvested trees larger than the set cap, diameter limits may also reduce net profit, which is in line with past research. The threshold of profitability will therefore vary depending on the distribution of harvested trees by size class, travel speed, moisture content, and other factors affecting the volume transported.

The value of the material removed also affects thresholds of profitability. In particular, removing residual biomass usually left on site to decay, within limits to soil productivity, may increase total revenue. The effect of biomass markets on project costs was demonstrated in option (3-a), where a with and without biomass market analysis was conducted. The baseline model (Table 3) assumes biomass markets are present for energy generation. The intermediate cut scenario (Scenario 2) resulted in the greatest revenue generated from added biomass utilization at about $29/acre but the corresponding costs of $113/acre for harvesting and chipping that material far exceeds revenue. From strictly a financial perspective, it is not profitable to pursue chip markets in this scenario, despite the emergence of biomass energy markets and the added revenue realized.

To stimulate biomass energy markets, we modeled the effect of a $0.01/kWh production tax credit passed on to contractors, option (3-b). The result was an increased payment for biomass of $17/green ton added to the baseline delivered price, which resulted in an increase in revenue of between 3% and 5%. Still, total project costs exceeded revenue. Subsequentially assuming that all trees are chipped for biomass and that log markets were either not available or not preferable, option (3-c), total project losses decreased by between 11% and 28%. Removing log Markets 1 and 2 resulted in a revenue transfer to the chip market, but for Scenarios 1 and 3 in which fewer trees qualified for the log markets, the loss in revenue was less than the reduction in delimbing and log-handling costs. There was less change in Scenario 2 because of the greater loss in value from log Market 1.

Table 5
Impact of policy options on the percent increase in net profit in comparison to the baseline results.

Scenario 1		Scenario 2		Scenario 3	
Full restoration cut (16-in limit)	% increase	Intermediate cut (no size limit)	% increase	Minimal cut (16-in limit)	% increase
(2-d) Co-location of facilities	177	(2-d) Co-location of facilities	187	(2-d) Co-location of facilities	132
(1-a) $500/ac subsidy	61	(3-d) Certified product premium	83	(1-a) $500/ac subsidy	52
(3-d) Certified product premium	55	(1-a) $500/ac subsidy	46	(3-d) Certified product premium	36
(1-c) 50% equipment cost-share	36	(1-c) 50% equipment cost-share	37	(1-c) 50% equipment cost-share	30
(3-c) $0.01/kWh credit, no log	23	(1-d) 16-inch dbh cap	18	(3-c) $0.01/kWh credit, no log	28
(3-a) No chip market	19	(3-c) $0.01/kWh credit, no log	11	(3-a) No chip market	19
(2-c) Transport tax credit, no log	8	(3-a) No chip market	11	(2-c) Transport tax credit, no log	16
(1-b) 3% sales tax waiver	5	(3-b) $0.01/kWh tax credit	5	(3-b) $0.01/kWh tax credit	3
(3-b) $0.01/kWh tax credit	3	(2-a) Fuel surcharge waiver	4	(2-a) Fuel surcharge waiver	3
(2-a) Fuel surcharge waiver	3	(2-b) Transport tax credit	3	(1-b) 3% sales tax waiver	2
(2-b) Transport tax credit	2	(1-b) 3% sales tax waiver	2	(2-b) Transport tax credit	2
		(2-c) Transport tax credit, no log	−24		

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Finally, we modeled the effect of a $10/green ton transportation subsidy added to the existing delivered price, option (2-b). Revenue increased between 2% and 3% over the baseline model. Even though the greatest basal area reduction was observed for Scenario 2 resulting in the greatest increase in total revenue, corresponding harvest costs more than exceeded the increase in revenue. Assuming all trees are harvested for biomass chip markets and that log markets are not available, option (2-c), losses decreased 8% and 16% for Scenarios 1 and 3, respectfully. The removal of log markets actually increased losses in Scenario 2 by $264/acre (24%) because of the large number of logs and subsequent value of those logs greater than 8-in. dbh for Market 1.

7. Discussion

We adopted the general framework of policy options presented by Nechodom et al. (2008) in which biomass utilization is encouraged either through a reduction in harvest and transport costs, or expansion of value-added markets to capture the value of fuels treatments. We used the HCR Estimator on stands of ponderosa pine in the southwest United States to examine the sensitivity of treatment scenarios to policies designed to stimulate biomass utilization by targeting steps in the production lifecycle. The results provide a rare comparison of policy approaches on a project-level basis, which is useful to examine the sensitivity of key cost nodes to overall project profitability. The ability to isolate cost nodes also allows for examination of how net profit is affected by stand-treatment objectives for fuel reduction, and how stand dynamics (e.g., stand density, volume by size class) affects decisions about where to locate processing facilities, log market allocations, and the types of equipment used. Our analysis most demonstrates the importance of having markets in proximity to harvest sites, the effect of value-added markets on net profit, and the disproportionate value of chip markets. It also illustrates the variability of project-level costs and how the interaction of policy approaches affects net profit.

For the given scenarios, the transport of raw material was the single greatest cost. Targeted policies such as waiving fuel surcharges or subsidizing the volume of biomass hauled, however, had minimal effect. Only the proximity of markets to harvest sites was sufficient to offset costs (option 2-d), which was not surprising given that transport costs were between 64% and 69% of total project costs and were highly dependent upon distance traveled. Transportation subsidies would have to be substantial to result in a significant change; the offsets achieved through the new federal Biomass Crop Assistance Program (BCAP) (P.L. 110-234, § 9011), which offers a dollar-for-dollar transportation cost share up to $45/dry ton, is notable. Alternatively, reducing transport distances is difficult to accomplish, particularly where local markets are irregular or quickly become saturated resulting in the need to travel longer distances to access available markets. This is the case in the southwest in which there is limited forest products manufacturing capacity, but also in other regions of the country like the Front Range of Colorado and the Great Basin.

Without mobile processing technology or small-scale distributed facilities, many harvest sites will be too great of a distance from processing facilities to be financially viable, the threshold of which will vary by forest stand and market. That said, polices affecting the siting of facilities in proximity to one another (co-location) and to the resource base, for instance through enterprise investment zones, may be appropriate and could capitalize on already existing programs at both the state and federal levels. In areas dominated by federal lands, policies affecting the flow and consistency of raw material may be most appropriate to encourage investment in proximity to the resource base.

Policies targeting expansion of value-added markets were also important. In particular, an increase in the price paid for delivered raw material, either through payment of product premiums (option 3-d) or a subsidy on the value of services provided (option 1-a), resulted in substantial added revenue (Table 5). However, the mere presence of markets in proximity to project sites is insufficient if those markets are so small that loggers have to travel longer distances in order to sell all their material. This illustrates the importance of projecting realistic market outlets based on the capacity of the local forest products industry and the price manufactures are willing to pay.

Several other policies individually increased project feasibility but also were insufficient to cover all cost. Equipment cost-share programs (option 1-c) and production tax credits (3-c) produced laudable results of up to 36% cost reduction. The surprising finding was the disproportionate value of chip markets to the cost of chipping. In scenarios where no chip market existed or where loggers were not required to remove harvest residues from the project site, profitability actually increased. Unless chip markets exist in proximity to project sites and the price paid offsets the added costs of harvesting, chipping and transporting this material, then the utilization of harvest residues will not only be financially insufficient but will not subsidize the cost of fuel reduction treatments.

In order to increase profitability, another option is to combine policy approaches. In the absence of any one best approach to address the range of forest conditions and treatment prescriptions that exist across a landscape, the strategic coupling of policies may provide added incentive at different steps in the processing chain. For instance, combining a transportation tax credit of $10/green ton with a biomass removal subsidy for services provided may result in a net profit. Similarly, combining state incentives targeting equipment purchases or production tax credits with matching federal programs can help stimulate investment in certain locales. Finding ways to combine federal, state and local policies could be the most effective way to accomplish hazardous fuel reduction in places where the benefits to multiple public agencies and communities can be identified.

The importance of coupling is that the selected policies should work together and target barriers to utilization, but that those barriers will be different from location to location. We modeled some of the variability in this analysis (e.g. stand density, distribution, market specifications). But determining which policies work best together or are most important to pursue will depend on situational factors like the amount of federal or state aid required relative to the cost of local fuel treatments and avoided cost of lost ecosystem services (Mason et al., 2006). There is also the need for analysis of the distribution of costs and benefits to determine who receives the monetary and social value of fuel reduction treatments relative to who pays. The timing of benefits will also influence political viability. If costs are incurred today to develop biomass harvesting and processing capacity then the benefits will need to materialize within a sufficient period to justify those investments. Finally, an evaluation of particular policies is necessary to determine progress towards state and national fuel reduction objectives, to measure regional economic impacts of these investments, and to monitor program implementation.

8. Conclusion

The project-level analysis conducted for this study is useful for comparing utilization policies and the sensitivity to particular cost nodes, but forest management decisions also require knowledge of how to manage for multiple, and sometime competing, objectives. A diameter limit on the size of trees harvested, for instance, may significantly affect profitability but decisions about whether to impose such restrictions or at what size also impacts the effectiveness of fuel reduction treatments as well as, say, wildlife management objectives. Consideration for these interacting objectives is necessary for effective policy design and implementation.

The harvest, transport and market-based policies modeled in this analysis are not mutually exclusive. The effectiveness of policies reducing harvest costs, for instance, is influenced by stand treatment scenarios as are policies targeting the manufacturing and production of biomass. The interaction of variables affecting policy outcomes will vary

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by location making it difficult to optimize policy approaches across the landscape. How policies target particular barriers to utilization or provide adequate incentive for manufacturers and consumers will also change over time. Yet, despite these abundant challenges, there exist many examples of the mutually reinforcing linkages among state and federal policies for hazardous fuel reduction, biomass utilization, and sustainable forest management. Learning from these examples will be critical.

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