Discussion Paper 12 (DP12): Eastside Forest Biofuel Alternatives

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Introduction

Under the Washington State Governor's Climate Change Challenge (Executive Order 07-02), direction was given to assess and develop renewal energy alternatives. Of the alternatives that are possible, biomass conversion comes second only to hydro power as a source of renewal energy within the State. Biomass can be obtained from many sources including agriculture, forestry and municipal solid waste (MSW). Forest management residues, typically burned in piles after timber harvests, represent a large source of woody biomass that is currently underutilized and could be available as a carbon neutral energy feedstock as a replacement for fossil fuel. Forest thinnings aimed at reducing fuel loads in Eastern Washington forests can also provide woody biomass for clean renewable energy with an added benefit of reducing the risks and costs associated with forest fires. Residuals from the manufacture of forest products have proven to be a readily available and cost-effective source of biomass for energy generation (Perlack et al 2005). Wood biomass is uniquely versatile in that it can be a source of firm electrical power with steam and heat as valuable byproducts or it can be used to produce liquid and gaseous fuels to reduce reliance on fossil fuels for transportation applications.

A recently completed Washington State University (WSU) assessment of organic material resources potentially available annually for bioenergy production in Washington (Frear et al. 2005) identified wood residues from timber harvesting and processing as the single largest source of State biomass feedstocks (Figure DP12.1.); nearly twice the volume of all other sources combined (municipal, agricultural, and animal wastes).

Of the 49% of total biomass identified as forestry related, there are portions of the inventory that are un-utilized at present as well as those where better utilization is possible. Potentially available forest biomass can come from logging slash currently left on site after harvest is complete or from thinning and removal of otherwise non-merchantable trees such as surplus fuel loads, pre-commercial thinnings, or land clearing debris. Woody biomass is also available in the form of waste residuals generated from lumber and paper manufacture. The Frear et al. (2005) study examines the biomass feedstocks available in Washington State from current harvest and process activities but should be considered as a conservative estimate since additional volumes that could develop from increases in fuel reduction activities to reduce fire hazard are not included. The recoverable energy potential to be derived from black liquor, a paper-making residual, is also not included. In a study to examine potential removals of biomass to reduce hazardous fuel loads in inland west forests, Rummer et al. (2005) found that in those areas of Washington forests considered at highest risk of destructive wildfire (Fire Condition Classes 2 and 3), 242 million bone dry tons should be removed to adequately reduce hazard.

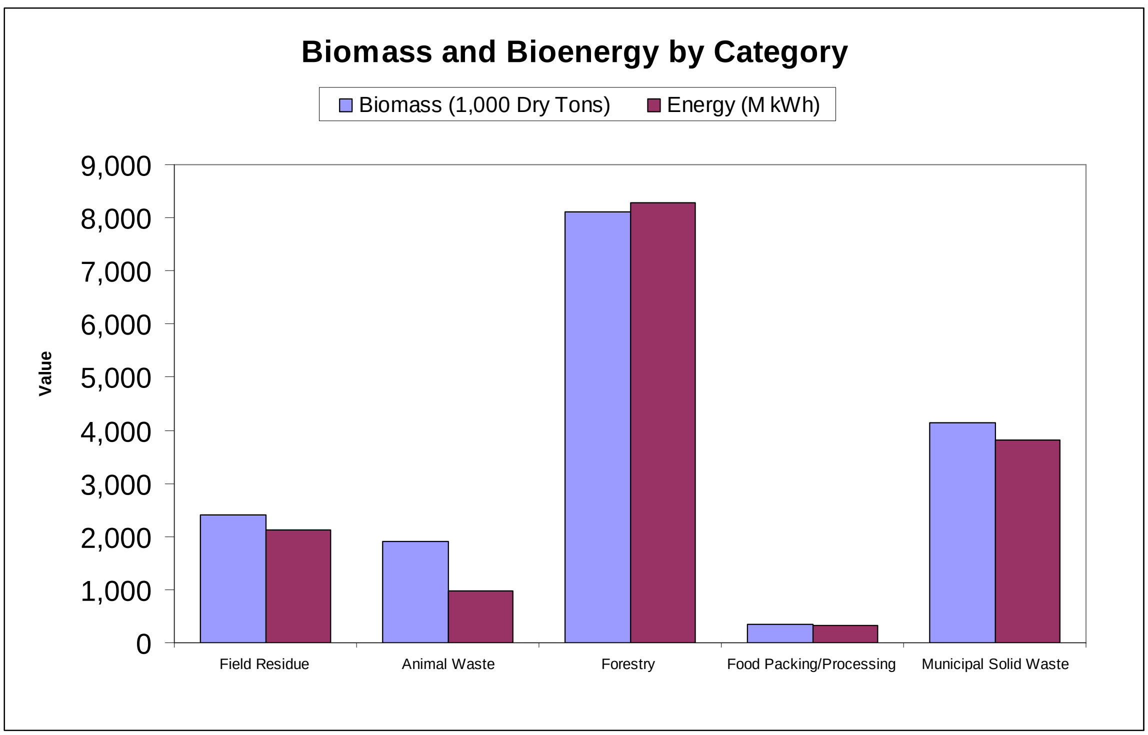

Figure DP12.1: Washington State Available Annual Biomass (Frear et al. 2005)

Eastern Washington Private Forests Biomass Potential - Case Study

Small Diameter logging residue

We illustrate one method for refining forest biomass availability estimates using simulated harvest data from Eastern Washington private and tribal forests. The approach we use to arrive at potentially available biomass brings together a species, site, and owner group specific assessment protocol based on existing standing biomass, historic harvest rates, allocation of biomass within current milling facilities and projection of future biomass availability. Estimates of total standing biomass can be calculated using standard Forest Inventory and Analysis (FIA) inventory data that include tree species, diameter, and crown ratio. Tree growth is derived using the Forest Vegetation Simulator (FVS) growth model which generates changes in tree characteristics at ten-year intervals. FVS is run within the Landscape Management System (LMS), integrated forest analysis software, which was developed at the University of Washington (McCarter, 1998). From growth data and harvest simulations, total and merchantable stem volume are calculated within the growth model. The relationships between stem volume and the biomass of leaves, roots, and stem for each tree are estimated using published allometric equations (Jenkins et al. 2003) and converted to carbon equivalents as part of a carbon accounting model. Per-tree biomass estimates are expanded to a per-acre basis using standard forest inventory techniques (Marshall and Waring 1986, Monserud and Marshall 1999).

LMS provides an estimate of total merchantable volume to a specified top diameter by using a log bucking algorithm and sort table specific to eastside species and forest conditions to differentiate between sawlog, small sawlog ("hewsaw") and pulp wood. Hewsaw, or small sawlogs, are defined in the Washington Administrative Code (WAC 458-40-610 (18)(e)) as those which measure less than 7" in top diameter and are less than 20 feet long. Pulp wood is comprised of logs that that are either too small or defective to be suitable for lumber manufacture. The LMS estimate of log volumes identified what percentage of the logs would enter the sawmill for processing into lumber and what percentage of processed material would become chips and hog fuel.

The LMS volume estimate is based on simulations of annual harvest that assume an historic annual rate of removal by owner group and location within eastern Washington. The simulated estimates of log volumes were compared to the Department of Revenue (DOR) scaled volumes for the 2002-2006 period. Further estimates of biomass type and volume were generated from surveys of Inland West sawmills that identify the percentage of the total scaled wood that was turned into long-lived products such as lumber, veneer, or oriented strand board (OSB), medium-lived products such as medium density fiber board (MDF), and short-lived products such as paper, hog-fuel, and beauty bark (Johnson et al. 2007).

The differences between LMS-estimated merchantable log volumes and the Jenkins estimates of total biomass are used to approximate the total volume of tops and limbs that remain in the woods after harvest of a merchantable stand of timber. Removal of such logging slash would be advantageous to reduce fire hazard while eliminating the need to burn residuals after harvest. The recovery of this material has historically not occurred because of the high cost of removal. Accounting for avoided costs with respect to pollution mitigation and fire hazard reduction when coupled with renewable energy generation, however, may be a desirable justification for recovery of this material (Mason et al. 2003).

Biomass available from manufacturing residuals can be estimated as the difference between the ratio of saw and pulp log scale volume and the LMS estimate of the ratio of pulp to sawlog grade material that is harvested from the current inventory. The Eastside log volume report from the Washington State Department of Revenue (DOR) for timbersheds 6 and 7 was used to determine approximate tonnage, ratios of small to large logs, and percentage of pulp delivered to sawmills (DOR 2007). The distributions of sawlog, hewsaw and pulpwood from Eastside privately-owned forestlands for 2002-2006 are given in Table DP12.1. Timber regions were established to reflect the log tributary areas of milling facilities. The Yakima region contains all the private plots for Yakima, Benton, and Klickitat counties. The Okanogan contains only Okanogan County whereas the Wenatchee region contains Douglas, Chelan, and Kittitas counties. The Tonasket region is Ferry County. The Southeast region includes Lincoln, Asotin, Columbia, Garfield and Walla Walla counties. The Northeast region includes Stevens, Spokane, and Pend Oreille counties.

Table DP12.1: Eastside volume splits arriving at the mill

Region	FVS NF code	sawlogs MBF	tonnage MBF	total MBF	chw/sml tons	ton: sawlog MBF	% pulp	% hewsaw
Yakima	603	497,241	17,174	514,415	148,137	3%	85%	15%
Okanogan	608	55,558	2,439	57,997	19,432	4%	59%	41%
Wenatche e	617	266,739	28,389	295,128	222,190	11%	53%	47%
Tonasket	699	79,008	7,216	86,224	51,497	9%	25%	75%
Southeast	614	99,816	2,613	102,429	20,526	3%	54%	46%
Northeast	621	1,128,419	93,000	1,221,419	665,540	8%	26%	74%
2002-2006 Total	all	2,126,781	150,831	2,277,612	1,127,322	7%	39%	61%

In Table DP12.1 'sawlog MBF' is the total sawlog volume, measured in thousand board feet (MBF), over the 5-year period. 'Tonnage MBF' is the conversion of log volumes sold by weight to MBF based on the DOR conversion rate of 9 MBF/ton for pulp and 6.5 MBF/ton for small logs (hewsaw). 'Chw/sml tons' is the total tonnage of chipwood and small logs over the five years. The ratio of DOR's conversion from tons to MBF was used to calculate the total harvest percentages of sawlogs, pulp and hewsaw by region. Table DP12.1 indicates that only 3-11% of the timber volume reaching eastside mills is classified as tonnage wood and of that volume a range of 25-85% is pulp wood. As both sawlog and hewsaw wood is milled into lumber products, these figures suggest that the potentially available raw biomass that is not used for long-lived products ranges from 1.4% in the Southeast region to 5.6% in the Wenatchee region. The chipwood that reaches the mills as whole logs has economic value as chips for OSB and in pulp and paper manufacturing. A portion of the residuals generated from the milling process are also used to produce chips. Clean and appropriately sized wood chips have a high value as raw material for paper production and therefore are not likely to be used as lower value biomass feedstock for energy production so long as there are operating paper mills in the transport region.

In contrast to the DOR estimate of 2.7% pulp volume arriving at the mill, the LMS estimate of pulp volume averages 19.5% for state and private harvests and 45.2% for fire risk reduction treatments on National Forests. The differential between the volume numbers for private forests suggests that approximately 16.8% of the pulp quality logs with a top diameter greater than 4 inches remain on the landing or in the woods and must be disposed of in order to control fire risk. This 16.8% of the volume based on LMS estimates would be available as a potential biomass source. The residual biomass can be estimated by determining total volume harvested. Per acre availability of biomass can be estimated by correlating the number of available acres with the total volume removed.

According to the DOR timber harvest figures, 2,277,612 MBF were removed from Jan 1, 2002 to Dec 31, 2006 on private eastside forests (Table DP12.2). For the same owner groups, the 1991-2001 (11 years) figures are 6,228,976 MBF. If an estimated 16.8% of the inventory was harvested but not removed as discussed above, then 1.4 billion board feet equivalent of biomass residuals were produced over the 16-year period. This volume would be equivalent to 89 MMBF/year (338,745 BDT/year) (Table DP12.3) that is currently un-utilized piled material from harvests on private forests.

Table DP12.2: MBF harvested from 2002 to 2006 from eastside private forests (excludes tribal)

Region	NF code	MBF sawlogs	MBF tonnage wood	Total Volume Harvested	% tonnage wood	MBF conversion ratio *	** cut/ available acre
Yakima	603	497,241	17,174	514,415	3.5%	8.35	1.8
Okanogan	608	55,558	2,439	57,997	4.4%	7.57	0.3
Tonasket	699	79,008	7,216	86,224	9.1%	7.00	0.4
Wenatchee	617	266,739	28,389	295,128	10.6%	7.83	2.1
Southeast	614	99,816	2,613	102,429	2.6%	8.42	1.5
Northeast	621	1,128,419	93,000	1,221,419	8.2%	7.17	2.2

* Lower numbers imply a larger percentage of small logs (hewsaw) in the estimated tonnage to MBF conversion. A value of 7.75 is a 50/50 split of hewsaw to pulpwood, so Okanogan, Tonasket and NE Washington are merchandizing a lower percentage of pulp wood relative to other regions

** Prorated for comparison to 11 year averages from 1991-2001

Table DP12.3: MBF harvested from 1991 to 2006 from eastside private forests (excludes tribal)

MBF harvested from 1991 to 2006 from eastside private forests (excludes tribal)					
Region	**private acres***	**total 1991-2006 harvest**	**16.8% landing residual**	**MBF residuals per year**	**BDT residuals per year**
Yakima	616,585	1,652,459	277,613	17,351	72,475
Okanogan	401,165	336,139	56,471	3,529	13,357
Tonasket	518,782	327,315	54,989	3,437	12,036
Wenatchee	305,931	1,456,915	244,762	15,298	59,898
Southeast	146,329	413,234	69,423	4,339	18,261
Northeast	1,201,555	4,320,526	725,848	45,366	162,718
Total Eastside Private	3,190,347	8,506,588	1,429,107	89,319	338,745

* doesn't reflect land transfers.

** Harvest volume removed on average over the 16 year period from 1991-2006

Per year harvest over 16 years 531,662 MBF

The total Private and Tribal harvest for the 1991-2000 decade and the long-term average harvest for private and tribal forests are given in Table DP12.4. If we assume that the ratio of landing residual to timber volume removed is approximately the same for these two owner groups and that these long-term harvest levels are sustained, then 1.2 billion board feet of residuals are available per decade from eastern Washington tribal and private harvests which equates to 474,439 BDT/year. This biomass volume is currently unutilized and represents an untapped resource that could be used to reduce emissions from disposal that is required under fire regulations, and while providing needed feedstock for renewable energy.

Table DP12.4: Private and Tribal Harvests with estimated landing biomass availability

Private and Tribal Harvest by Region and Timbershed				
MBF per decade per region				BDT per decade
Timbershed	Region	1991-2000	Long term average	Landing Residuals
7	Southeast	296,210	206,472	14,598
7	Tonasket	641,768	720,102	42,366
7	Northeast	2,972,774	2,427,302	146,266
6	Wenatchee	1,072,501	1,227,066	80,717
6	Yakima	2,394,967	2,229,543	156,456
6	Okanogan	563,607	535,321	34,035
All	All	7,941,827	7,345,805	474,439

Forest Residues – tops and limbs

A second untapped biomass source is the volume of tops, branches, and non-merchantable material left after harvest. As an estimated 90% of the dry forests and 70% of the moist and cold private forests are harvested using ground-based machinery (Johnson et al. 2007). Logging slash is potentially available as it accumulates at the forest landing. Fire regulations decree that a substantial component of the tops and limbs that are left on site must be burned to reduce fire risk. Carbon emissions from site preparation using fire assume that approximately 80% of the residual tops and limbs are disposed of in this manner. Using this material for energy generation would reduce the cost and pollution of slash burns while reducing reliance upon fossil fuels.

By applying national scale biomass estimators (Jenkins et al. 2003) to the FIA data used for harvest simulations, it is possible to predict the biomass that would be available from the branches and tops of trees for all harvested stems.

The biomass equations from Jenkins et al. (2003) equations take the following form:

$$y = ae^{b*dbh}$$

where y is the mass or volume being predicted, dbh is the diameter at breast height, and a and b are species-specific parameters. Stem volume is multiplied by specific gravity of each species to estimate stem mass. Within LMS, the carbon module estimates not just biomass, but carbon as well. In the carbon module, the mass of carbon is estimated by multiplying tissue mass by species-specific carbon concentrations. The need for species-specificity in these parameters arises from species differences in allometric equations (Gholz et al. 1979), specific gravity (Panshin and de Zeeuw 1970), and carbon concentrations (Vertregt and Penning de Vries 1987). The carbon amounts are then summed over the several parts of the tree. Per-tree estimates are expanded to a per-acre basis using standard forest inventory techniques (Marshall and Waring 1986, Monserud and Marshall 1999). Carbon accumulation in biomass is estimated by the changes in carbon standing stocks.

The average ratio of crown carbon to stem carbon is .33. Based on 100-year simulations that consider the detailed species specific criteria used in the Jenkins equations and harvest volume targets from private forests in Eastern Washington equivalent to historic rates, we can calculate the carbon content from the crown and branches of harvested trees (logging slash) to estimate biomass of these materials. The average per acre volume of biomass by region and decade is given in Figure DP12.5. As expected, areas where stem volume removal per acre is high, such as the Northeast region, also have a high average volume of dry biomass left on site.

Table DP12.5: Potential biomass from harvested crowns and limbs per acre harvested

Average harvested crown dry biomass (metric tons/acre)							
Decade	**Okanogan**	**Southeast**	**Tonasket**	**Wenatchee**	**Yakima**	**Northeast**	**All Regions average**
1991	12	20	20	45	29	32	28
2001	17	21	25	44	28	27	27
2011	22	20	31	34	30	26	28
2021	20	13	34	34	24	28	26
2031	14	7	35	18	22	28	22
2041	20	10	41	26	27	37	29
2051	17	4	41	27	22	34	26
2061	15	11	32	21	24	39	25
2071	24	10	39	22	26	33	28
2081	50	10	40	21	23	40	28
2091	23	13	32	20	29	50	30
2101	19	14	29	20	29	34	27

Table DP12.6 applies the per-acre volume to the number of acres that would need to be treated to meet current harvest targets for Eastside private forests to arrive at an estimate of available biomass per year by region. Projections of the average yearly biomass output for the first 3 decades beyond the inventory update period (1991-2001) (Table 8) suggest that approximately 1.3 million metric tons of dry biomass per year would be available. This estimate assumes that harvest levels remain consistent with the historic average harvest rate by region and that all tops are skidded to the landing and utilized. Under current logging practices approximately 80% of this volume is skidded to the landing and burned to reduce fire risk. Whether the biomass was removed for processing or burned would depend on the economic recovery rate of the material.

Table DP12.6: Per year estimate of available dry biomass from crowns

Average harvested crown dry biomass metric tons/year							
Decade	**Okanogan**	**Southeast**	**Tonasket**	**Wenatchee**	**Yakima**	**Northeast**	**Grand Total/per year**
1991	70,546	71,153	87,716	194,361	364,674	495,794	1,287,948
2001	85,017	46,906	109,607	203,485	407,164	470,988	1,323,391
2011	104,820	47,936	111,804	206,834	344,476	445,033	1,256,967
2021	97,222	31,645	105,926	208,336	413,529	402,070	1,257,165
2031	91,242	9,763	99,126	220,870	390,302	415,764	1,236,351
2041	115,657	10,600	116,302	151,835	418,988	405,962	1,219,421
2051	93,500	6,560	134,926	206,023	375,864	420,385	1,241,154
2061	91,270	43,603	134,397	225,012	398,710	402,044	1,289,122
2071	91,560	16,363	134,419	109,144	395,123	373,994	1,119,477
2081	80,119	17,183	136,572	157,150	402,782	382,356	1,174,903
2091	110,933	30,040	133,104	219,135	444,750	439,221	1,370,462
2101	87,057	18,017	127,748	226,334	355,551	370,491	1,188,862

Table DP12.7: Projected biomass availability per year for the first 3 decades

Region	Average harvested crown dry biomass metric tons/year
Okanogan	95,686
Southeast	42,163
Tonasket	109,113
Wenatchee	206,218
Yakima	388,390
Northeast	439,364
Grand Total/per year	**1,279,174**

The total available biomass from private and tribal forest harvests in Eastern Washington is estimated at 1.4545 million BDT/year. Increases in restoration thinnings and surplus fuels removals would logically increase this estimate as would volumes from public forests.

Biomass from Mill Residues

In addition to accounting for changes in annual production and decomposition of carbon from the forest pools across the landscape and through time, we identify how the end use of lumber affects the amount of biomass available to meet energy needs. Based on milling surveys the LMS carbon model distributes harvested stem carbon into long-lived and short-lived products. These product pools are decayed at rates that reflect their eventual return to the atmosphere as carbon dioxide, with a default of 80 years for long-lived products. Because solid wood products, and particularly those in long-lived products, have a higher value than bioenergy and produce a greater carbon benefit through the substitution effect (see Discussion Paper 5 on carbon accounting), their highest and best use is for lumber, veneer, and panel products. Potential bio-energy feedstock sources include bark, sawdust, and planer shavings.

Product yields, however, are sensitive to log size. Figure DP12.2. illustrates typical lumber recovery ratios for a range of log diameters. Lumber recovery from total log volume will range from 25% in a log with a 4 inch top diameter to 70% in a log with a 16 inch top diameter. Therefore the volume available for chip production (paper) and biomass ranges from 30-75% depending on the size of the input log.

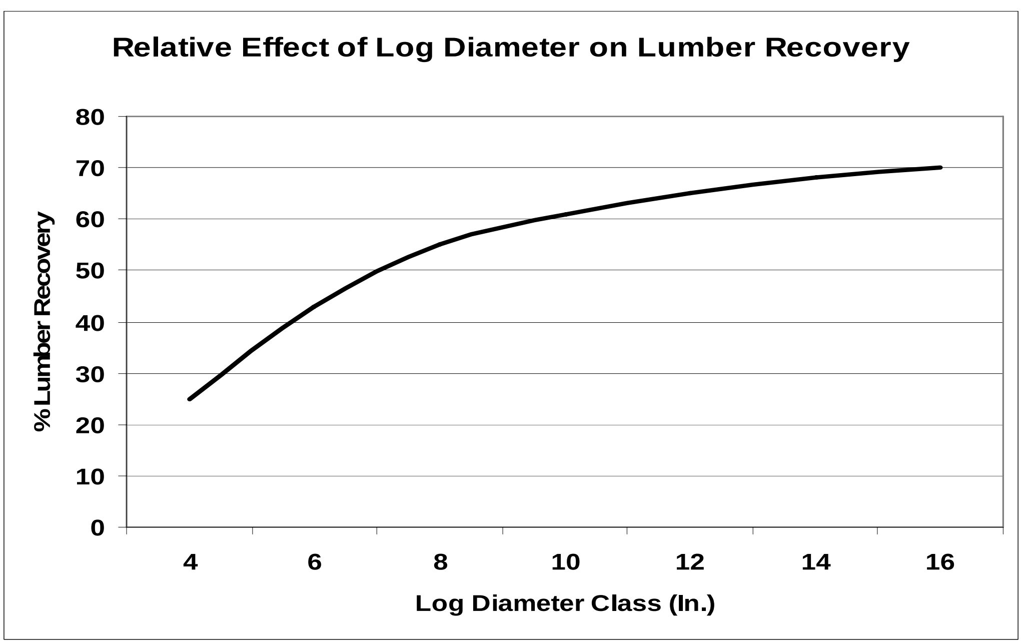

Figure DP12.2: Recovery Rates for different log sizes (Dramm)

Based on mill surveys we have estimated average outputs of biomass residuals to be 150,000 BDT/year. While much of this biomass may currently be utilized for combined heat and power applications, investments in improved conversion technologies could result in increased yields of energy per unit input of biomass.

The above estimates of biomass from timber harvest and process in Eastern Washington, though incomplete, serve to highlight the need for further investigation of biomass potential from forest operations. Challenges and opportunities for future research into forest biomass availability are presented in Tables DP12.8 - DP12.13.

Table DP12.8: Logging and Pre-Commercial Thinning Residuals (Slash)

From the Forest: **Currently pile-burned or left on site**	
Challenges	**Opportunities**
Frear et al. (2005) found that significant volumes of forest harvesting residuals may be available for energy feedstocks. Other investigations of the forest biomass resource have produced disparate volume estimates (Rummer et al. 2003, Western Governors Assoc. 2006, Tellus Institute 2002) but all agree that potential forest residual volumes are significant. Needed now is finer resolution research to develop more definitive information on quantity, variety, location, ownership, environmental impact, and economics in support of state energy planning.	Investigation of forest residuals volumes and locations by ownership can provide estimates for magnitude comparison of currently available biomass verses potentially available biomass. This information will be valuable to energy planners, policy makers, and investors in support of marginal costs and benefits analysis by owner type and project magnitude.
Sensitivity analysis of potential supply flow estimates through time must be developed from modeled growth and harvest activities linked to manufacturing for future decades based upon a variety of market and policy expectations.	Policy makers, planners, and investors that seek to expand use of bioenergy will need to know about biomass supply sustainability. This information will also be important to scientists investigating alternative conversions and outputs.
Economic benefits from potential biomass-to-energy projects, should be assessed to estimate direct and indirect jobs as well as local, state, and federal taxes.	Since most forest residuals originate in economically depressed rural areas, jobs, taxes, and avoided social service costs associated with distributed energy development, should leverage high as public benefit.
Energy accounting simulations are needed to compare energy expended verses energy gained from forest biomass utilization. Pollution benefits associated with cessation of open burning, reductions of process emissions, and bioenergy substitution for fossil fuel-derived energy should be estimated with implications for air quality improvement. Life Cycle Analysis (LCA).	Comparison of energy efficiency and pollution benefits of bioenergy options with non-renewable fuel alternatives will highlight the magnitude of non-market public benefits associated with bioenergy development. Future air quality restrictions on slash burning may alter current economic burdens for removal and make residue utilization more imperative.

Table DP12.9: Fuels Reductions and Forest Health Thinnings from Overstocked Inland Forests

From the Forest: **Currently Underutilized**	
Challenges	**Opportunities**
There is an emerging scientific consensus that overstocking, weather trends, insect infestations, and resultant high mortality have created a forest health crisis in Eastern Washington with implications for linking restoration to biomass-to-energy development (DNR 2004, UW 2006, Sampson et al. 2001). A coarse resolution assessment by Rummer et al. (2003) indicates that forest health biomass removals could be a significant source of biomass. Methodologies for volume and cost estimates for forest health thinning activities customized for Eastern Washington forests are needed that consider ownership, harvest type, and transportation distance to determine potential project tributary areas. Economic analysis should be linked to avoided costs of fire suppression.	In 2006, about 400,000 acres of forestland was consumed by wildfire in Eastern Washington. Direct costs for fire suppression, not including the value of lost resources, surpassed $100 million. Forest health thinnings that generate biomass for renewable energy while avoiding wildfire costs have dual economic and environmental benefits yet the magnitude and availability of this resource are poorly understood. Research that links avoided fire suppression costs with strategies for biomass utilization will improve public understanding of cost/benefit trade-offs associated with reduction of excess forest fuel loads to restore forest health.
Sensitivity analysis of potential supply flow estimates through time must be developed from modeled growth and harvest activities for future decades based upon a variety of market and policy expectations. Regrowth studies have shown that thinning cycles to reduce fuel loads will be needed every 20-40 years (Mason et al. 2003, Peterson et al. 2005).	Policy makers, planners, and investors that seek to expand use of bioenergy will need to know about the sustainability of biomass supplies that result from forest health treatments. This information will also be important to scientists investigating alternative energy conversions and outputs with possible feedstock additions from agricultural residues available in Eastern Washington.
Economic benefits from potential biomass-to-energy projects that utilize surplus forest fuel loads should be assessed to estimate potential direct and indirect jobs as well as local, state, and federal taxes.	Since most forest residuals originate in economically depressed rural areas, jobs, taxes, and avoided social service costs associated with distributed energy development should leverage high as public benefit.
Energy accounting simulations are needed to compare energy expended verses energy gained from utilization of biomass from forest fuels removals. Energy budget comparisons should be expanded to include avoided energy consumption associated with wildfire suppression. Pollution benefits associated with reductions of wildfire smoke and bioenergy substitution for fossil fuel-derived energy should be estimated should also be considered in the context of LCA methodologies.	Energy expended in fire suppression is enormous and generally underestimated. Comparison of energy efficiency and pollution benefits of bioenergy options with non-renewable alternatives will highlight the magnitude of public benefits associated with combining fuels treatments to reduce wildfire hazard with bioenergy development.
There are any non-market values and environmental benefits associated with reduced incidence and intensity of wildfire including clean air, clean water, habitat protection, etc. A cost/benefit analysis of public investment in reductions of hazardous forest fuel loads is needed that quantifies both market and non-market values.	Removal of the many small trees that create ladder fuels is known to be costly and may not be covered by the current market value of biomass. However, reduction of wildfire hazard and utilization of biomass for energy development can be shown to produce significant public benefits that are generally underestimated (Snider et al. 2006, Mason et al. 2003, Morris 1999).

Table DP12.10: Silvicultural Treatments for Development of Old Forest Habitats and Biodiversity

From the Forest: Currently Underutilized	
Challenges	**Opportunities**
Scientific evidence has shown that thinning of younger previously-harvested forests in Western Washington can accelerate the development of old growth characteristics Scientists, environmentalists, and forest managers are recommending more active management in young stands (Curtis et. al. 1998, Franklin et. al. 2002, Heiken 2003, Carey et al. 1996). Research is needed to examine the potential to link silvicultural practices for enhanced biodiversity with provision of biomass for renewable energy feedstocks.	Development of "biodiversity pathways" that utilize silvicultural applications to accelerate creation of old forest habitats in Western Washington has been well researched but never linked to ancillary benefits such as biomass for energy feedstocks. Investigation of these dual benefits will help inform policy decisions for Western Washington forests.
Sensitivity analysis of potential supply flow estimates through time derived from biodiversity treatments must be developed from modeled growth and harvest activities for future decades based upon a variety of market and policy expectations.	Policy makers, planners, and investors that seek to expand use of bioenergy will need to know about the sustainability of biomass supplies that result from biodiversity treatments.
Economic benefits from potential biomass-to-energy projects that utilize harvested materials from biodiversity treatments should be assessed to estimate potential direct and indirect jobs as well as local, state, and federal taxes.	Since most forest residuals originate in economically depressed rural areas, jobs, taxes, and avoided social service costs associated with distributed energy development should leverage high as public benefit.
LCA assessments should be conducted to estimate pollution implications of utilizing biomass from Western Washington biodiversity treatments.	Research on links between pollution reduction and habitat development will help to inform forest policy development in Western Washington.

Table DP12.11: Dedicated Energy Crop Trees

From the Forests: Currently Underutilized	
Challenges	**Opportunities**
After the energy crisis of the 1970's it seemed that the U.S. was poised to create a bio-based energy industry that utilized fast growing hybrid trees. However, once the high energy costs subsided and long term petroleum supplies seemed assured interest in bioenergy waned. Dedicated biomass plantations have the advantage that they can be located near to energy generation facilities thereby reducing transportation costs. An examination of the potential for dedicated tree plantations to augment current biomass supplies is needed.	Additional sources of woody biomass can be derived from dedicated energy crops of fast-growing tree species such as willow, eucalyptus, poplar, and others. Technologies for growing willow and poplar are well advanced. These sources of energy feedstocks can be combined with forest and mill residues to increase raw material availability with improvements in bioenergy efficiencies and economics. Dedicated energy crops can be established near coal generation facilities and used as co-fire feedstocks to reduce pollution.

Table DP12.12: Primary and Secondary Wood Manufacturing Residuals

From the Mills: **Largely Utilized but with Opportunities for Expansion**	
Challenges	**Opportunities**
Current and potential biomass residuals from primary and secondary forest products manufacturers must be identified and quantified subject to a variety of market and policy expectations. Shifts in annual harvests of merchantable logs will logically influence availability of biomass.	Established flows of production residuals are potentially a low cost biomass that may be utilized in combination with other biomass resources. Assessment of current and potential supplies will help inform development of State forest and energy policy.
The percent of underutilized or under valued biomass must be determined.	Underutilized waste streams represent costs to businesses and lost opportunities to generate clean energy.

Table DP12.13: Pulp and Paper Manufacturing Residuals

From the Mills: **Largely Utilized but with Opportunities for Expansion**	
Challenges	**Opportunities**
Waste streams from pulp and paper manufacturers must be identified and quantified.	Pulp and paper residuals represent significant renewable energy feedstocks.
Recent policy developments in Washington such as the Energy Initiative, I-937, appear to overlook the present and potential importance of pulp and paper mills to state renewable energy generation infrastructure in spite of significant contribution (Tellus Institute 2002). Renewable energy and pollution implications of losses to pulp and paper mill infrastructure should be examined. The public costs of replacing this grid-connected generation infrastructure should be considered. Comparisons of process alternatives for pulping residuals from Washington mills should be investigated to quantify comparative potential economic and environmental benefits from upgrade investments.	The pulp and paper industry is an essential part of wood utilization infrastructure in Washington yet this important industry is currently in decline and its environmental and economic contributions to the public may be underestimated. Policy makers will benefit from knowledge of the vital role of this industry in ensuring economic viability other forest product sectors while contributing low cost renewable energy. The primary pulping residual is black liquor which may have significant potential for increased renewable energy contribution and value-add product recovery (Larson et al. 2003).

Conclusions

Woody biomass is a uniquely versatile energy feedstock that can be a source of firm electrical power with steam and heat as valuable by-products or it can be used to produce liquid and gaseous fuels to reduce reliance on fossil fuels for transportation applications. Valuable industrial chemicals can be extracted in the process. Residuals from the manufacture of forest products have proven to be a readily available and can be a cost-effective source of biomass feedstocks. Biomass energy derived from process residuals is already widely used in Washington. New developments in black liquor energy recovery could increase renewable energy contribution. Forest management residues, typically burned in piles after timber harvests or left on the forest floor represent another large source of woody biomass that is currently underutilized. Forest thinnings such as fuel load reductions on Eastside dry land forests or biodiversity thinnings in Westside forests can provide woody biomass for significant additional renewable energy feedstocks with many added public benefits. Forest thinnings have been identified in several federal studies as the nation's largest untapped source of woody biomass. The potential magnitude of dedicated energy plantations is not known.

While several research projects have produced estimates of forest biomass availability and all confirm that the resource is significant and environmentally attractive, results have been disparate and subsequently should be recognized as preliminary, and of coarse resolution. More detailed work as identified in the eastside forest case study is needed. There are many avoided costs and environmental benefits associated with biomass-to-energy development that are not adequately understood and are not reflected in energy economics. As well, potential economic development benefits and tax revenues of wood utilization in depressed rural communities should be compelling but have not been quantified in energy cost/benefit analysis. A comprehensive analysis of the availability, quantity, variety, location, ownership, environmental impact, and economics of potential forest biomass utilization is needed to support State energy planning.

A broader assessment methodology of avoided costs, jeopardized opportunities, economic impacts, and environmental services associated with wood biomass utilization for renewable energy must reasonably be developed for inclusion in environmental impact assessments for forest management and other projects. Life Cycle Analysis linked to economic valuation should be conducted to compare the pollution performance of energy alternatives. A thorough and critical investigation of the complex environmental, institutional, political, and economic challenges associated with development of wood-to-energy resources would help with development of integrated forest and energy policy in Washington State.

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