Enhancing Western Managers' Knowledge and Use of Available Economic and Financial Biomass Information and Tools: Annotated Bibliography

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INTRODUCTION

The overall goal of this Joint Fire Science Program project (07-3-3-03) is to provide a synthesis of information products available to federal land managers to enhance their ability to understand and deal with the economic and financial aspects of woody biomass removal as a component of fire hazard reduction treatments. Here, woody biomass is the sub- or non-merchantable portion of a merchantable tree (i.e. tops and limbs) or non-merchantable small whole trees that must be removed as part of prescription objectives. In locations with utilization infrastructure, woody biomass is typically burned in boilers for energy production, although there are a number of alternative uses.

This document synthesizes and evaluates the body of economic and financial biomass information, literature, tools and databases currently available to federal land managers in the western United States. It is hoped that this information acts to fill the gaps between existing information and tools and managers' awareness of and ability to use these tools and information to promote the use of biomass in place of open burning.

The following information includes information from web-based biomass related resources, literature from peer-reviewed journals, Forest Service publications, technical reports and releases, and white papers. More specifically, the location and characteristics of biomass-utilizing facilities in several western states, the types, tree sizes, and volumes of wood fiber these facilities purchase, the value of wood fiber delivered to these facilities, and GIS data depicting mill locations and biomass-utilizing facilities are among the information identified. The first section in this document lists biomass cost and volume estimator tools, models and related information; the second section contains an annotated bibliography of forest biomass related literature from a wide variety of publication outlets. The third section identifies sources of biomass, lumber, and log prices regionally and nationwide and the fourth section identifies biomass utilization facility locations and other related information.

BIOMASS ECONOMIC AND FINANCIAL MODELS AND TOOLS

BIOPAK

Means, Joseph E., Heather A. Hansen, Greg J. Koerper, Paul B. Alaback, Mark W. Klopsch. 1994. Software for computing plant biomass--BIOPAK users guide. Gen. Tech. Rep. PNW-GTR-340. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 180 p.

Means, Joseph E., Olga N. Krankina, Hao Jiang, and Hongyan Li. 1996. Estimating live fuels for shrubs and herbs with BIOPAK. Gen. Tech. Rep. PNW-GTR-372. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 21 p.

BIOPAK is a software package that contains a plant measurement library of over 1,100 documented equations that estimate plant components, e.g. leaf mass, leaf area, stem wood mass, bark mass, fuel size classes. BIOPAK can choose equations from those contained in an equation library using built-in assumptions based primarily on comparisons of plant dimensions, geographic area sampled and seral stage sampled for input data and prediction equations. Alternatively, a user can direct the program to search a specific subset of the equation library or use a particular equation for particular input data. In this manner, equations from other species may be used for species in the data for which equations are unavailable.

Available at: http://www.fsl.orst.edu/lter/data/tools/software/biopak.cfm?topnav=149
Online database of model equations:
http://andrewsforest.oregonstate.edu/data/abstract.cfm?dbcode=TP072&topnav=97
BIOPAK manual:
http://andrewsforest.oregonstate.edu/pubs/webdocs/reports/pub1659.pdf
Data requirements: Runs with DOS-type commands. Biomass estimations are made for many species based on prescribed measurements such as diameter, stem length, cover, etc. The independent variables are equation and species specific.
Contact: Don Henshaw dhenshaw@fs.fed.us henshaw@fsl.orst.edu don.henshaw@oregonstate.edu
Last updated: 2002

BIOMASS SITE ASSESSMENT TOOL (BIOSAT)

The Biomass Site Assessment Tool (BioSAT) model is used to identify the top 20 locations for 13 southern U.S. states. The trucking cost model of BioSAT is used with Timber Mart South 2009 (http://www.tmart-south.com/tmart/index.html) price data to estimate the total cost, average cost, and marginal costs for biomass facilities that use mill residues for up to 1.5 million dry tons of annual consumption. Costs in south Mississippi, southeast Georgia, southeast Oklahoma, southwest Alabama,and east Texas range from $25 to $38 per dry ton for up to 1.5 million annual dry tons. Additional research on BioSAT is forthcoming for 33 eastern U.S. states. These studies will include more types of woody and agricultural biomass (e.g., logging residues, pulpwood, corn stover, etc.). Additional cost models for transportation such as truck combinations with rail and barge will be components of BioSAT.

Available at: http://www.biosat.net
Data requirements: Unknown; contact BioSat for more information

Contact: James H. Purdue jperdue@fs.fed.us
Timothy M. Young tmyoung1@utk.edu
Last updated: October 2009

COORDINATED RESOURCE OFFERING PROTOCOL (CROP)

The U.S. Forest Service and Bureau of Land Management undertook a series of CROP pilot projects as a means of addressing the growing fuel load problem within major forest systems and the realized potential for fostering catastrophic wildfires within these systems across the United States. Focused on biomass removal (versus biomass inventory), the CROP model was initially developed in 2003 targeting unlevelized, uncoordinated, and erratic resource offerings from public forest lands at landscape scale. The key tenets of CROP projects are: to facilitate coordination of biomass removal between public agencies; facilitate the use of long-term multi-agency stewardship contracts to achieve biomass removal; increase the certainty of "levelized" biomass supply offerings from public agencies; invite investment back into a sustainable forest management landscape; and, heighten public trust and support for biomass removal from public lands operating within a transparent process.

Available at: http://www.forestsandrangelands.gov/Woody_Biomass/supply/CROP/index.shtml
Data requirements: None. Summaries of CROP projects already conducted are available at the web address.
Contact: Ed Gee eagee@fs.fed.us
Last updated: March 2009

FIA BIOSUM

Fried, Jeremy S.; Christensen, Glenn; Weyermann, Dale; Barbour, R. Jamie; Fight, Roger; Hiserote, Bruce; Pinjuv, Guy 2005. Modeling opportunities and feasibility of siting wood-fired electrical generating facilities to facilitate landscape-scale fuel treatment with FIA BioSum In: Systems Analysis in Forest Resources: Proceedings of the 2003 Symposium, p. 207-216.

FIA BioSum is a concept-based methodology that generates cost estimates, identifies opportunities and evaluates the effectiveness of fuel treatments in region-wide forested landscapes. The BioSum modeling framework incorporates a transportation cost model, a treatment cost accounting module, a log valuation model, and a crown fire hazard evaluator with Forest Inventory and Analysis (FIA) plot data.

Available at: www.fs.fed.us/pnw/**fia/biosum**
Data requirements: inventory plot data with expansion factors; road network with travel time per unit distance assigned to the road segments; silvicultural treatments coded in FVS; product prices. Also, a raft of assumptions, such as filters on what characteristics lead to an acre being a candidate for treatment, definitions of hazard, definitions of hazard improvement, choice of logging systems, objectives (make money, improve fuel hazard, maximize material removed, minimize material removed, etc.)
Contact: Jeremy Fried jsfried@fs.fed.us
Last updated: February 2009

FIRE RESEARCH AND MANAGEMENT EXCHANGE SYSTEM (FRAMES)

FRAMES is an internet based database that contains a library of data, documents, projects, tools, and webpages to support fire management and research. The goal of FRAMES is to provide a systematic method of exchanging information and transferring technology between wildland fire researchers, managers, and other stakeholders in order to make wildland fire documents, data, tools, and other information resources easy to find, access, distribute, compare, and use.

Available at: http://frames.nbii.gov/portal/server.pt
Data Requirements: Vary by selection
Contact: Greg Gollberg gollberg@uidaho.edu
Last updated: Continually

FOREST RESIDUE TRUCKING SIMULATOR (FORTS)

USFS Southern Research Station Forest Operations Research to Achieve Sustainable Management Research Work Unit 4703. Auburn, AL.

FoRTS is a spreadsheet based calculator designed to help compare alternative methods of moving biomass from the forest to a wood-using facility. It will estimate loading and hauling costs for different combinations of equipment, evaluate the best mix (numbers and types) of equipment, compare different hauling routes, examine reloading, or two-stage hauling opportunities. FoRTS does not provide actual costs because it does not include factors such as profit and overhead. It is intended to represent a relative comparison among options.

Available at: http://www.srs.fs.usda.gov/forestops/biomass.htm
Data requirements: Road travel route description; biomass materials (species, moisture content, etc); equipment selection (in-woods, transportation, processing)
Contact: Jason Thompson jasonthompson@fs.fed.us
Last updated: 2006

LANDSCAPE FIRE AND RESOURCE MANAGEMENT PLANNING TOOLS PROJECT (LANDFIRE)

LANDFIRE is an ongoing research project and database that contains geospatial data products that describe existing vegetation composition and structure, potential vegetation, surface and canopy fuel characteristics, historical fire regimes, and fire regime condition class. LANDFIRE provides fire and land managers with the information required to identify lands with wildland fuel build-up and facilitate the prioritization, implementation, reporting, and monitoring of landscape fuel treatments. These data may be used during specific wildland fire incidents to increase firefighter safety, pre-position resources, and evaluate fire behavior under a variety of weather conditions.

Available at: http://www.landfire.gov/index.php
Data requirements: Extensive. LANDFIRE is creating spatial data layers that include: all layers required to run fire modeling applications such as FARSITE and FlamMap, Existing Vegetation Type, Canopy Height, Biophysical Setting, Environmental Site Potential, Fire Regime Condition Class, and fire effects layers.
Contact: helpdesk@landfire.gov
Last updated: Continuous

NATIONAL ASSOCIATION OF CONSERVATION DISTRICTS WOODY BIOMASS UTILIZATION DESK GUIDE

This Guide is designed for use by Resource Conservation & Development and Extension professionals throughout the U.S. It also contains handouts and other resources to assist in educating respective audience. The Woody Biomass Desk Guide and Toolkit provides an overview of woody biomass production and utilization in the U.S., tips of how to provide effective outreach for clientele, and educational handouts to share with audiences. The purpose of this guide is to equip natural resource professionals and outreach specialists with the information and tools needed to increase awareness of the use of woody biomass for energy in the U.S.

Available at: http://nacdnet.org/resources/guides/biomass
Contact: Sarah Ashton sashton@warnell.uga.edu
Last updated: Online publication

USDA FOREST SERVICE REGION 6 FOREST PRODUCTS WEB PAGE LOGGING SYSTEMS & ECONOMIC PROGRAMS

This website contains information, programs and forms used in implementing forest health maintenance, restoration, and improvement projects on the 19 national forests in Oregon and Washington. The website houses many executable programs developed by the USDA Forest Service, and the software is public domain. Programs can only be installed on IBM-compatible machines.

Available at: http://www.fs.fed.us/r6/nr/fp/FPWebPage/FP70104A/Programs.htm
Data requirements: Variable; program specific
Contact: Rick Toupin rtoupin@fs.fed.us
Michael Daugherty rtoupin@fs.fed.us
Last updated: 2008

USDA FOREST SERVICE SOUTHERN RESEARCH STATION MOISTURE CONTENT CONVERTER

This is an Excel spreadsheet that converts wood moisture contents from either dry basis to wet basis or wet basis to dry basis. The moisture content of biomass affects the gross weight of the material that is being handled. Green material will have a higher density than drier material because of the extra water weight in the cells of the wood. In biomass markets, it is important for all parties to have a common understanding of the dry mass of material that is being sold or processed. Generally biomass loads are sampled for moisture content and then converted to a dry-basis measure such as "bone dry tons" or "bone dry units."

Available at: http://www.srs.fs.usda.gov/forestops/downloads/MC_Converter.xls
Data requirements: Percent moisture content to convert
Contact: Jason Thompson jasonthompson@fs.fed.us
Last updated: 2008

USDA FOREST SERVICE SOUTHERN RESEARCH STATION BIOMASS HEAT VALUES BY TREE SPECIES

Located here are tables of heat of combustion (Btu/ovendry pound) of stems and branches of 6-inch trees from 22 hardwood species growing on southern pine sites. Heat value, or heat of combustion, which is defined as the total amount of heat obtainable from ovendry material when burned in an enclosure of constant volume, allowing no deductions for heat losses, is a very useful parameter to know when dealing with biomass.

Available at: http://www.srs.fs.usda.gov/forestops/biomass.htm
Data requirements: Species
Contact: Jason Thompson jasonthompson@fs.fed.us
Last updated: 2007

USDA FOREST SERVICE SOUTHERN RESEARCH STATION BIOMASS PUBLICATIONS FROM THE FOREST OPERATIONS RESEARCH UNIT: A SYNTHESIS

The Forest Operations Research Unit at the Southern Research Station has been studying biomass-related topics since 1977. This CD aids the reader by organizing these publications in one easy-to-use CD. Included on the CD are an executive summary, two bibliographies, individual publications (in PDF format), and a keyword listing. The types of publications on the CD consist of presentation reports, published reports, portions of books, and master's theses.

Available at: http://www.srs.fs.usda.gv/pubs/biomass_cd
Data requirements: Vary by selection
Contact: Dana Mitchell danamitchell@fs.fed.us
Last updated: 2008

USDA FOREST SERVICE WOODY BIOMASS UTILIZATION WEBSITE

The Woody Biomass Utilization Team is an interdisciplinary team that promotes and facilitates the planning and delivery of an integrated, interdisciplinary approach to the recovery and utilization of woody biomass from ecological restoration and hazardous fuels reduction work. Field coordinators have been designated at each of the National Forest Regions and Research Stations to coordinate woody biomass utilization efforts throughout the Forest Service.

Available at: http://www.fs.fed.us/woodybiomass/index.shtml
State biomass supply links: http://www.fs.fed.us/woodybiomass/strategy/supply.shtml
Contact: woody_biomass@fs.fed.us
Forest Service Woody Biomass and Bioenergy Contacts:
http://www.fs.fed.us/woodybiomass/contact/fscontacts.shtml
Last updated: June 2009

BIOMASS PRODUCTION, COST AND RELATED LITERATURE

Abt, Karen L., Jeffrey P. Prestemon. 2006. Timber markets and fuel treatments in the western US. Natural Resource Modeling. 19(1): 15-43.

This paper presents a model of interrelated timber markets in the U.S. West to assess the impacts of large-scale fuel reduction programs on these markets, and concomitant effects of the market on the fuel reduction programs. The model maximizes area treated, given fire regime-condition class priorities, maximum increases in softwood processing capacity, maximum rates of annual treatments, prohibitions on exports of U.S. and Canadian softwood logs from public lands and a fixed annual treatment budget. Results show that the loss to U.S. private timber producers is less than the gains for timber consumers (mills).

Geographic area: Western United States
Keywords: wildfire, mechanical treatments, spatial equilibrium, welfare

Alabama Forestry Commission. 2009. Woody Biomass Energy Opportunities in Alabama. Montgomery, Alabama. Available at: http://216.226.177.78/Biomass/Woody%20Biomass%20Energy%20Opportunities%20in%20Alabama.pdf

This publication provides information on the woody biomass materials available in Alabama, timber harvest and price trends and per unit cost comparisons with traditional energy sources. It also contains references to further information that investors should find useful when deciding whether or not to install wood-using energy systems. References are provided to manufacturers of wood-using energy systems, grant sources, tax credit incentives, and case studies of others who have installed successful systems.

Geographic area: Alabama

Angus-Hankin, C., B. Stokes, A. Twaddle. 1995. The transportation of fuelwood from forest to facility. Biomass and Bioenergy, 9 (1-5): 191-203.

In spite of this simplicity secondary transport is typically responsible for between 20 and 40% of the delivered fuel cost. To achieve a full payload within maximum allowable load dimension restrictions the material transported must have a minimum bulk density of about 250 to 280 kg/m3. While conventional forest products generally exceed this limit, fuelwood in an unprocessed form may have a bulk density of only 120 to 150 kg/m3. To offset this problem fuelwood material can be compacted before loading, or compacted in the trailer, but, more frequently, it is comminuted before transport. Processing of fuelwood to a chip allows the use of standard transport systems designed for the transport of wood chips for the pulp sector. Major technological gains to improve the transport efficiencies of fuelwood are unlikely in the immediate future.

Geographic area: Non-descript
Keywords: Wood fuel, residues, transportation, bulk density

Arola, Rodger A.; Miyata, Edwin W. 1981. Harvesting wood for energy. Research Paper NC-200. St. Paul, MN: U.S. Dept. of Agriculture, Forest Service, North Central Forest Experiment Station.

This paper illustrates the potential of harvesting wood for industrial energy, based on the results of five harvesting studies and presents information on harvesting operations, equipment costs, and productivity. It further discusses mechanized thinning of hardwoods, clearcutting of low-value stands and recovery of hardwood tops and limbs and also includes basic information on the physical and fuel properties of wood.

Geographic area: Michigan
Keywords: logging, whole-tree chipping, fuelwood, mechanized thinning, clearcutting, residues

Arriagada, Rodrigo A., Frederick W. Cubbage, Karen Lee Abt, Robert J. Huggett Jr. 2008. Estimating harvest costs for fuel treatments in the west. Forest Products Journal, 58 (7/8): 24-30.

The costs for harvesting timber fur forest fire fuel reduction purposes were estimated for 12 states in the West. These simulation inputs were used to estimate average costs for 12,039 Forest inventory and Analysis plots in the West, and then that FRCS output was used develop regression equations that estimated costs as a function of small, medium, and large size trees per acre, as well as slope. Ground-based mechanical whole tree harvesting systems were cheapest in the areas where they could be used, with a mean cost of $620 per acre. The other three ground-based systems had mean costs ranging from $958 to $1,627 per acre. Cable yarder systems mean costs were much more expensive, at $2,794 and $3,535 per acre. The results do indicate that fuel reduction harvests in the West are expensive, and provide magnitudes of these costs that can be used for planning and budgeting purposes for landowners and forestry professionals.

Geographic area: Western United States

Ashmore, Colin, Donald L. Sirois, Bryce J. Stokes. 1987. Evaluation of roll designs on a roll-crusher/ crusher/splitter biomass harvester: test bench results. Proceedings of the Southern Forest Biomass Workshop; 1986 June 16-19; Knoxville, TN. Muscle Shoals, AL: Tennessee Valley Authority. p. 113-116.

An alternative to conventional methods of processing small diameter trees for energy use is roll crushing/splitting. The concept involves the crushing and splitting of stems to expedite field drying and to facilitate handling. This method has been considered a feasible alternative for handling stems found in short-rotation harvesting. This paper reports cn one of these objectives, the evaluation of roll designs by the Southern Forest Experiment Station for effectively feeding woody Southern biomass into a set of crush rolls. For each of four roll designs, the specific objectives were to determine feeding efficiencies, crushing/ splitting efficiencies, and operating restraints that would allow the greatest range of material site to feed through the primary and secondary rolls.

Geographic area: Canada

Atkins, Dave, Robert Rummer, Beth Dodson, Craig E. Thomas, Andy Horcher, Ed Messerlie, Craig Rawlings, David Haston. 2007. A report on conceptual advances in roll on/off technology in forestry. Smallwood News. October 08, 2007: 1-14, Missoula, Montana.

This study looks into increasingly severe fire seasons over the last two decades that have led policymakers to recognize the need for thinning overgrown stands of trees. Thinning presents a financial challenge and the problem is that hazardous fuel reduction projects —especially projects in the Wildland/Urban Interface— contain mostly smaller trees, which have traditionally lacked market value. Since these projects can't pay for themselves, managers have been looking for ways to reduce the net costs of fuel reduction projects.

Geographic area: Montana

Badger, Phillip C. 2002. Processing cost Analysis for biomass feedstocks. Oak Ridge National Laboratory, Oak Ridge, Tennessee. ORNL/TM-2002/199.

The purpose of this study was to identify and characterize all the receiving, handling, storing, and processing steps required to make woody biomass feedstocks suitable for use in direct combustion and gasification applications, including small modular biopower (SMB) systems; and to estimate the capital and operating costs at each step. Since biopower applications can be varied, a number of conversion systems and feedstocks required evaluation. The boundaries of this study were from the power plant gate to the feedstock entry point into the conversion device.

Geographic area: United States

Bain, Richard L., and Ralph P. Overend. 2002. Biomass for heat and power. Forest Products Journal, 52(2), 12-19.

Bain and Overend provide a national history of biomass used for energy, a brief market and supply analysis, and a current status of technology. They additionally identify research needs.

Geographic area: United States

Barger, Roland L. 1979. The forest residues utilization R&D program. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 5-16 p.

The purpose of this publication is to report the results of research conducted by the Residues R&D Program in harvesting and utilization opportunities for forest residue. Additionally, to provide a record of proceedings of the 3-day symposium exploring both research and industrial experience in residues utilization; to provide a compendium of information useful to those involved or interested in improving the recovery and utilization of forest residues.

Geographic area: Intermountain and Northern Rocky Mountains
Keywords: forest residues, wood utilization, timber harvesting, forest practices.

Barger, Roland L.; Benson, Robert E. 1979. Intensive utilization with conventional harvesting systems. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 77-95 p.

Forest residues utilization research has included case studies of the efficiency of existing harvesting systems in achieving close fiber utilization. Field evaluations included the use of in-woods chipping systems in gentle terrain; crawler skidder systems in gentle terrain; and skyline systems in steep terrain. In each situation, utilization standards ranged from conventional saw log utilization to near-total utilization of available fiber. Intensive utilization has been achieved concurrent with saw log harvesting, rather than through postharvest salvage. The total costs of harvesting merchantable material and residue together are partitioned to derive costs of residue recovery. Costs of recovery vary significantly among the case situations studied, and also vary with the method by which costs are allocated. Residue recovery costs commonly run $30-$60 per dry ton.

Geographic area: Rocky Mountain Region (Montana, Wyoming)
Keywords: forest residues, timber harvesting, wood residues, utilization, logging systems, timber harvesting productivity

Barnett, Paul E., Donald L Sirois, Colin Ashmore. 1986. Reduction of biomass moisture by crushing/splitting - a concept. In: Proceedings of the Southern Forest Biomass Workshop, 1985 June 11-14, Gainesville, FL. Gainesville, FL. University of Florida. p. 13-16.

A biomass crusher/splitter concept is presented as a possible means of maintaining rights-of-way or harvesting energy wood plantations. The conceptual system would cut, crush, and split small woody biomass leaving it in windrows for drying. A subsequent operation would bale and transport the dried material for use as an energy source. A survey of twenty southern power companies shows the potential applicability of a biomass harvesting system. Drying characteristics and power requirements are presented for three southern tree species.

Geographic area: Canada and southeastern United States

Baughman, Ronald K., Bryce J Stokes, William F. Watson. 1990. Utilizing residues from in-woods flail processing. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Workshop, "Harvesting Small Trees and Forest ResiduesÂ; 1990 May 28; Copenhagen, Denmark. Auburn, AL: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1990: 21-30.

A tub grinder was employed to process debris discharged by a flail. The machine successfully passed the material through a 7.62 cm screen and discharged the reduced debris into a chip van for transport. It was found that fuel production is directly dependent upon the production of clean chips by the flail/chipper portion of the system and the available biomass of the stand. Clean chips were produced at 57 green tonnes/PMH with fuel yields of from 14 to 21 green tonnes/PMH. The usual disposal of flail residues is an additional cost charged to the clean chips; processing turns the residues into a positive cash flow.

Geographic area: Oklahoma

Becker, Dennis R., Dalia Abbas, Kathleen E. Halverson, Pamela J. Jakes, Sarah M. McCaffrey, Cassandra Moseley. 2009. Characterizing lessons learned from federal biomass removal projects. Final report submitted to Joint Fire Science Program, 07-3-2-08. Boise, Idaho.

The purpose of this study is to identify and assess utilization challenges in different parts of the United States. The information collected through case studies is used to address persistent conventional wisdoms to biomass utilization that may help land managers better accomplish project objectives through informed planning and implementation. It may also be used to illuminate particular barriers to biomass utilization that can be addressed through policy development at the local, state, or national level.

Geographic area: United States

Benson, Robert E.; Schlieter, Joyce A. 1979. Residue characteristics in the northern Rocky Mountains. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-

INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 33-43 p.

In the northern Rocky Mountains, 350-450 million cubic feet (9.9 to 12.7 million cubic meters) of logging residue is generated each year. Up to 60 percent of the residue material is technologically suitable for wood products, but condition, size and product potential vary among forest types. Other factors which influence residue utilization are level of harvest, trends in wood processing, industrial uses and economic conditions.

Geographic area: Northern Rocky Mountains
Keywords: forest residue, logging residue, utilization

Benson, Robert E., Cameron M. Johnston. 1976. Logging Residues Under Different Stand and Harvesting Conditions, Rocky Mountains. USDA Forest Service Research Paper INT-181. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Volume and characteristics of logging resieues from 34 clearcut and partial cut harvest areas are presented. Residue volumes ranged from almost 3,600 cubic feet per acre down to 550 cubic feet per acre, depending on treatment. More than 60% of the residues were sound.

Geographic area: Montana, Wyoming, Idaho

Bergman R, Zerbe J. 2008. Primer on wood biomass for energy. USDA Forest Service, State and Private Forest Technology Marketing Unit, Forest Products Laboratory, Madison, WI (rev. Jan. 2008). Available at http://www.fpl.fs.fed.us/documnts/tmu/biomass_energy/primer_on_wood_biomass_for_energy.pdf

This paper explains and describes the concepts of wood energy on a residential, commercial, and industrial scale in the United States so that the Forest Service can help meet the demands of communities involved in the forest-products industry. In addition, terminology associated with this field is explained so individuals can develop a basic understanding of and familiarity with technical terms common to bioenergy. Definitions specific to wood energy are given at the end of this report.

Geographic area: United States

Bolding, M. Chad, and Bobby L. Lanford. 2005. Wildfire fuel harvesting and resultant biomass utilization using a cut-to-length/small chipper system. Forest Products Journal, 55 (12), 181-189.

This study examined and measured the feasibility of ground-based mechanical harvesting to reduce forest fuel buildup and produce energywood. It shows a cut-to-length harvesting system coupled with a small in-woods chipper provided a low impact way to harvest pre-commercial trees and tops along with merchantable logs. A smaller, less expensive chipper allowed operations to stay small and more efficient when compared to a larger operation and grinder. Productivity and cost results showed the system to be capable of harvesting non-merchantable trees and utilizing non-merchantable portions of merchantable-sized trees as energywood chips.

Geographic area: Alabama

Brinker, Richard W., and Robert A. Tufts. 1989. Whole-tree chipping in the Southern United States. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3

Symposium, “Harvesting Small Trees and Forest Residues”; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 140-149.

This paper provides a general overview of chipping wood for pulp and energy wood including fuel chip production costs, problems, innovations, and system designs.

Geographic area: South

Brown, James K. 1978. Weight and Density of Crowns of Rocky Mountain Conifers. USDA Forest Service Research Paper INT-197. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Relationships between live and dead crown weight and DBH, crown length, tree height, and crown ratio are presented for 11 Rocky Mountain conifers. Also included are partitioned estimates of crown foliage and branchwood. This study shows a high correlation between DBH and crown weight.

Geographic area: Northern Idaho and western Montana

Brown, James K. 1976. Predicting Crown Weights for 11 Rocky Mountain Conifers. Working part on Forest Biomass, Int. Union For. Res. Organ. Cong. June 22, 1976. Oslo, Norway, 13 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

For 11 conifer species in the Rocky Mountains the best fitting regression relationships between live and dead crown weight and DBH, crown length, tree height, and crown ratio were determined. Also determined were fractions of crown weight in foliage and branchwood diameter classes.

Geographic area: Northern Rocky Mountains (Idaho, Montana)
Keywords: tree biomass, crown sampling, crown weights, forest fuels

Brown, James K, J.A. Kendall Snell, and David L. Bunnell. 1977. Handbook for Predicting Slash Weight of Western Conifers. USDA Forest Service Gen. Tech. Rept. INT-37. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Procedures are provided for predicting weights of slash using tables of either slash weight per tree by DBH or slash weight per square foot of tree basal area by DBH. Slash weights include crowns and non-merchantable bole tips to 3 – 6 inch diameters. Slash can be predicted for material less than and greater than 3 inch diameters.

Geographic area: Idaho and Montana

Calkin, David, Krista Gebert. 2006. Modeling fuel treatment costs on Forest Service Lands in the Western United States. Western Journal of Applied Forestry. 21(4): 217-221.

This report intends to increase the accuracy of cost data available for planning and prioritizing fuel management in national forests. A survey of fire management officers was used to develop regression models that may be used to estimate the cost of hazardous fuel reduction treatments. The model was based on the USDA Forest Service Region, biophysical setting, treatment type, and design. The study found that treatment size described the largest amount of variation in cost per acre, with increased size reducing cost per acre, on average.

Geographic area: Continental United States
Keywords: Fuel treatments, prescribed burning, economics

Cleaves, David, Jorge Martinez, and Terry Haines. 2000. Influences on prescribed burning activity and costs in the national forest system. USDA Forest Service Gen. Tech. Rept. SRS-37. Southern Research Station, Asheville, N.C.

This study covers the results of survey concerning National Forest System prescribed burning activity and costs from 1985 to 1995. Four types of prescribed fire were looked at, including slash reduction, management-ignited fires, prescribed natural fires, and brush, grass, and rangeland burns. Ninety-five of 114 national forests responded to the survey providing rankings of importance for nine resource enhancement targets, 14 possible barriers to burning, and 12 factors that influence burning costs. Furthermore, the survey also asked the respondents the anticipated burning levels over the next ten years and what burning levels would be needed to achieve the desired management goals on National Forest System lands.

Geographic area: United States
Keywords: Ecosystem management, environmental laws, hazard reduction, management ignited fire, national forests, prescribed natural fne.

Clark A., J.R. Saucier 1990. Table for estimating total-tree weights, stem weights, and volumes of planted and natural southern pine in the southeast. Georgia For. Res. Paper 79. 23 p.

This article has tables and equations for estimating total-tree weights, stem weights, and volumes of plantation-grown loblolly, and slash when DBH and height to a four inch top or total height are known.

Geographic area: Mid-Atlantic & Southeast United States

Clark A., J.R. Saucier, W.H. McNab.1986. Total-tree weight, stem weight, and volume tables for hardwood species in the southeast. Georgia For. Res. Paper 60. 44 p.

This paper is the cooperative research with the USDA Forest Service, Southeastern Experiment Station and the Georgia Forestry Commission. Together they conducted a study to develop reliable weight and volume equations and tables for the hardwoods in the Southeast that are commercially important. The tables and equations developed estimate the green weight of wood and bark and volume of wood excluding bark in the total tree, stem to a four inch top, and stem to sawlog top for numerous commercially viable hardwood species in the Southeast are presented.

Geographic area: Southeast United States

Daugherty, Peter J., Jeremy S. Fried. 2007. Jointly optimizing selection of fuel treatments and siting of forest biomass-based energy production facilities for landscape-scale fire hazard reduction. INFOR. 45(1): 17-30.

This study looks into landscape-scale fuel treatments for forest fire hazard reduction that can potentially produce large quantities of material suitable for biomass energy production. The analytic framework FIA BioSum addresses this situation by developing detailed data on forest conditions and production under alternative fuel treatment prescriptions, and computes haul costs to alternative sites at which forest biomass-based energy production facilities could be constructed. This research presents a joint-optimization approach that simultaneously selects acres to be

treated by fuel treatment prescription and assigns bioenergy production facility locations and capacities. Effects of alternative fuel treatment policies on fuel treatment effectiveness, economic feasibility, material produced, generating capacity supported, and the location and capacity of assigned facilities are evaluated.

Geographic area: central Oregon & northern California
Keywords: joint optimization, spatially explicit facility siting, forest biomass energy.

Demchik, Michael C., Dalia Abbas, Dean Current, Don Arnosti, Myra Theimer, and Patty Johnson. 2009. Combining biomass harvest and forest fuel reduction in the Superior National Forest, Minnesota. Journal of Forestry, 107 (5): 235-241.

In this paper the impact of combined biomass/fuel reduction harvests on the pools of forest fuels was analyzed to determine whether biomass harvest reduced the cost of mechanical fuel treatments. Two potential biomass harvest systems were tested in wildland-urban interface areas on the Superior National Forest in Minnesota. Both systems performed similarly in terms of cost and efficiency at harvesting biomass. It was found that the cost of biomass harvest was impacted by site conditions, forwarding distance, the number of units harvested with one machine haul, the number of machines that were hauled, acres harvested, and inclusion of roundwood. Income from the sale of biomass did not cover the costs of harvest and delivery.

Geographic area: Minnesota
Keywords: energy, harvesting, cost assessment

Dwivedi, Puneet and Janaki R.R. Alavalapati. 2009. Stakeholders' perceptions on forest biomass-based bioenergy development in the southern US. Energy Policy, 37 (5): 1999-2007.

This study analyzes perceptions of four stakeholder groups regarding forest biomass-based bioenergy development in the southern US. Results suggest that NGO representatives perceived rural development as an important opportunity. Government stakeholder group noted that less or no competition with food production and promoting energy security were major strength factors. Conversion technologies that are still under trial were identified as a major weakness by industry representatives. Representatives of academia felt that the competition from other renewable energy sources could be a major threat. Overall, all stakeholder groups were in favor of forest biomass-based bioenergy development in the southern US.

Geographic area: Southern United States
Keywords: Southern US, forest biomass-based bioenergy development, stakeholders' perceptions

Edman, F. Talmage. 1989. Small stem thinning in the Pacific Northwest with barking and chipping in the woods. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 126-130.

This paper provides a brief history of the development of a system with to economically thin overstocked, naturally seeded stands in the Pacific Northwest. It also provides a comparison of flail debarking efficiency in the woods with small alder systems with a pulp log debarker in a satellite yard.

Geographic area: Puget Sound, Washington

Emergent Solutions, Christopher Allen and Associates. 2003. Pre-feasibility assessment: small diameter under (SDU) wood feedstock for a 10 MW co-generation facility at the Milltown dam site. Submitted to U.S. Forest Service – State and Private Forestry, Montana Community Development Corporation, Bonner Development Group. Available at: http://www.mtcdc.org/news-events/reportspublications.html

A pre-feasibility assessment is an early stage and limited analysis of the probable risks and returns of an investment. Focused on gathering preliminary information, it helps decision makers determine if there is a basis for investing additional capital and time in the proposed project. This pre-feasibility assessment to explore the potential of using SDU wood from local forests as the feedstock for a 10 MW co-gen plant concept at the Milltown Dam site.

Geographic area: Montana

Evans, Alexander M. 2008. Synthesis of knowledge from woody biomass removal case studies. The Forest Guild, Santa Fe, NM. 39 p.

Woody biomass – usually logging slash, tops and limbs, or trees that cannot be sold as timber – is the lowest valued material removed from the forest and presents economic and logistical challenges. This report brings together 45 case studies of how biomass is removed from forests and used across the country to demonstrate the wide variety of successful strategies, funding sources, harvesting operations, utilization outlets, and silvicultural prescriptions.

Geographic area: United States

Evans, Alexander M. and Robert T. Perschel. 2009. An assessment of biomass harvesting guidelines. Forest Guild, Santa Fe, NM.

This report compares the guidelines for harvesting woody biomass from various states including, Maine, Minnesota, Missouri, Pennsylvania, and Wisconsin. These biomass harvesting guidelines as well as this paper cover topics such as dead wood, wildlife, water quality, soil productivity, silviculture, and disturbance as it pertains to biomass removal.

Geographic area: Northeast United States and Canada

Eza, Douglas A.; McMinn, James W.; Dress, Peter E. 1984. Wood Residue Distribution Simulator (WORDS) . Gen. Tech. Rep. SE-28. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 6 p.

The Wood Residue Distribution Simulator (WORDS) attempts to find a least-cost allocation of residues from local sources of supply to local sources of demand, given the cost of the materials, their distribution, and the distribution of demand. The results are useful in evaluating the feasibility of developing wood energy either for a sub-region in general or for specific locales. This paper gives an example of its application to mill residues in the State of Georgia.

Geographic area: United States
Keywords: energy, supply, demand, Georgia

Fahey, Thomas D. 1979. Value ranking for utilizing lodgepole pine residues. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 239-250p.

Relative values per ton of log input are developed for poles, corral poles, house logs, lumber, studs, veneer, chips, and fuel on a current market basis. The techniques to reevaluate on different markets are demonstrated. Product specifications, demand, and potential to salvage significant volumes are also addressed.

Geographic area: Rocky Mountain Region
Keywords: Residues, forest products, lodgepole pine, poles, house logs, lumber, veneer, chips

Faurot, James L.1977. Estimating merchantable volume and stem residue in four timber species: ponderosa pine, lodgepole pine, western larch, Douglas fir. USDA Forest Service Research Paper INT-196, 55 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

This report presents tables and equation for estimating total cubic volumes of wood, wood residue, and bark for ponderosa pine, western larch, and Douglas fir. The equations and tables provide a means fore estimating wood and bark residue volumes from tops, bole sections, and smaller sub-merchantable stems. Tables and equations can also be used to estimate total cubic volume for the size classes, species, and locale sampled.

Geographic area: Montana

Fiedler, Carl E., Charles E. Keegan III, Daniel P. Wichman, and Stephen F. Arno. 1999. Product and economic implications of ecological restoration. Forest Products Journal, 49 (2), 19-23.

This study evaluated restoration prescriptions for three widely occurring ponderosa pine stand conditions and determine to what level the value of product removals could finance the treatment costs. The article compares the cost in both terrain suitable for ground-based harvesting systems as well as cable systems and with or without a roundwood pulpwood market.

Geographic area: Inland Northwest United States

Fiedler, Carl E., Charles E. Keegan, Todd A. Morgan, and Christopher W. Woodall. 2003. Fire hazard and potential treatment effectiveness: A statewide assessment in Montana. Journal of Forestry, 101 (2), 7.

This assessment of Montana used data collected from Forest Inventory and Analysis (FIA) plots across Montana and summarized by forest type, density, and structure. The focus of the analysis was on ponderosa pine/Douglas fir/ dry mixed conifer forests that had historically seen low-intensity fires. Applying the Fire and Fuels Extension to the Forest Vegetation Simulator crown fire hazard was modeled and two fire hazard reduction approaches, a thin from below approach and a comprehensive ecologically based treatment were evaluated.

Geographic area: Montana

Fight; Roger D., R. James.Barbour. 2005. Financial analysis of fuel treatments. Gen. Tech. Rep. PNW-GTR-662. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 20 p.

This paper discusses the My Fuel Treatment Planner (MyFTP) software to show the effect treatment variables have on the cost and net revenue from fire hazard reduction treatments in dry forest types of the Western United States. The study is meant to help design a hazard reduction treatment with the cost estimation of four ground-based systems, four cable systems, and two helicopter systems.

Geographic area: western United States
Keywords: Financial analysis, silviculture, fire, prescriptions, economics, fuel treatments

Fire Science Digest. 2009. Making biomass pay: obstacles and opportunities. Joint Fire Science Program, Issue 6. Available at: http://www.firescience.gov/Digest/FSdigest6.pdf

Here it is recognized that utilizing biomass taken from forests to cover the cost of fuel reduction is an attractive ideal. However, getting woody biomass from the forest to the consumer is economically and logistically difficult, and efforts to make biomass utilization profitable have been disappointing so far. JFSP-funded researchers have found that, while there is no recipe for building a successful economy around forest biomass, certain elements are essential: commitment and budget support from land-management agency leaders, processing and transportation infrastructure, developed or potential markets, and the ability of community members to work together. The researchers' findings give land managers and community leaders a basis for assessing whether biomass utilization can be successful in their communities.

Geographic area: United States

Forest Guild. 2008. Woody Biomass Removal Case Studies. Forest Guild, Santa Fe, NM Available at: http://biomass.forestguild.org

These case studies show that all aspects of woody biomass removals, from markets to mechanization, are evolving. This report identifies the building blocks for successful biomass projects – including public involvement, partnerships with contractors, and judicious mechanization of harvesting operations – that are present in the management of many forests across the country.

Geographic area: United States and Alaska

Forest Resources Association. 2007a. Adding a chipper to a treelength system for biomass collection. Technical Release 07-R-3. Rockville, Maryland. Available at: http://www.forestresources.org

Forest Resources Association. 2007b. Chipping biomass: A challenge in first thinnings. Technical Release 07-R-32. Rockville, Maryland. Available at: http://www.forestresources.org

Forest Resources Association. 2008a. Gathering and Transporting Hogfuel from Logging Slash. Technical Release 08-R-28. Rockville, Maryland. Available at: http://www.forestresources.org

This paper provides a brief description of how and Idaho logging contractor has developed an innovative collection and transportation method for gathering scattered logging slash and then processing and concentrating it into volumes more easily accessed by chip vans.

Geographic area: Idaho

Forest Resources Association. 2008b. New Sizing Head for Processing Slash Piles. Technical Release 08-R-29. Rockville, Maryland. Available at: http://www.forestresources.org

This short paper describes how working with neighboring industrial forest landowners, Grays Harbor Paper in Washington has developed a new processor head to assist securing additional hogfuel from existing logging slash piles.

Geographic area: Washington

Fresco, Nancy, Stuart F. Chapin, III 2009. Assessing the potential for conversion to biomass fuels in interior Alaska. Res Pap. PNW-RP-579. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 56 p.

In this study, the feasibility of switching from fossil fuels to wood energy in rural Alaskan villages in forested regions of interior Alaska are assessed. This analysis demonstrated that conversion to biomass fuels is economically viable and socially beneficial for many villages across interior Alaska. Modeling results based on recent data on rural energy use, demographics, economics, and forest dynamics indicated that the installation costs of biomass systems would be recouped within 10 years for at least 21 communities in the region. In addition, results showed that all but the largest remote communities in the interior could meet all their electrical demand and some heating needs with a sustainable harvest of biomass within a radius of 10 km of the village. Biomass conversion also offers potential social benefits of providing local employment, retaining money locally, and reducing the risk of catastrophic wildfire near human habitation.

Geographic area: Alaska
Keywords: Biomass fuel, carbon offset, interior Alaska, wood energy

Fried, J.S., G. Christensen, D. Weyermann, R.J. Barbour, R. Fight, B. Hiserote, and G. Pinjuv. 2005. Modeling opportunities and feasibility of siting wood-fired electrical generating facilities to facilitate landscape-scale fuel treatment with FIA BioSum In: Bevers, Michael; Barrett, Tara M., comps. Systems Analysis in Forest Resources: Proceedings of the 2003 Symposium; October 7-9, Stevenson, WA. PNW-GTR-656. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, pp. 195-204.

The FIA BioSum modeling framework that incorporates Forest Inventory and Analysis (FIA) plot data, a transportation cost model, a treatment cost accounting module, a log valuation model, and a crown fire hazard evaluator and was applied to a 28 million acre study area of western Oregon and northern California. It was shown that with four 50 MW biomass-fueled power plants strategically distributed over the study area, up to 5.3 million acres could be effectively treated with net revenue of 2.6 billion dollars, a merchantable yield of 9.5 billion cubic feet, and a biomass yield of 79 million green tons, if net-revenue maximizing fuel treatments are selected.

Geographic area: western Oregon and northern California

Gan, Jianbang, C.T. Smith. 2007. Co-benefits of utilizing logging residues for bioenergy production: The case for East Texas, USA. Biomass and Bioenergy, 31 (9): 623-630.

This study evaluated the co-benefits associated with the utilization of logging residues for electricity production in East Texas, USA. The benefits evaluated included the value of CO2 emissions displaced due to substituting logging residues for coal in power generation, reductions in site preparation costs during forest regeneration, and creation of jobs and income in local communities. Based on the 2004 Forest Inventory Analysis data and a 70% biomass recovery rate, annual recoverable logging residues in East Texas were estimated at 1.3 Mt (dry). These residues, if used for electricity production, would displace about 2.44Mt of CO2, Removing logging residues would also save $200–250 ha in site preparation costs. Input–output modeling revealed that logging residue procurement results in about 1340 new jobs created and 215M$ in value-added generated annually. These results offer new insights into the cost competitiveness of forest biomass and bioenergy production.

Geographic area: Texas
Keywords: Forest residues; Carbon value; Site preparation costs; Community impact; Electricity

Gibson, L. 2007. WMSP economic assessment. Conducted for WMSP multi-party monitoring FAO 2001. Global forest resources assessment. Forestry Paper 140, Rome, pp. 75-80.

This paper looks into the Healthy Forests Initiative to find the economic impacts on the timber harvesting and processing industry in the White Mountain Region of Arizona. The study's goal was to have a factual and critical baseline which quantitatively describes changes in firms in the forest industries in the region while also points out new ways that the area might capitalize on current and potential industry for more economic benefit from the forest cluster.

Geographic area: Arizona

Gingras, J-F. 1995. Harvesting small trees and forest residues. Biomass and Bioenergy. 9 (1-5): 153-160.

This report summarizes the progress achieved under the auspices of the Activity "Harvesting small trees and forest residues" during 1992 – 1994. The work performed included literature reviews to assess potentially recoverable material as a function of harvesting system, analysis of factors affecting chipping quality and productivity, a comparison of firewood processing technologies, small tree and residue harvesting method reviews, a description of some prototype combination machines for recovering roundwood and forest biomass and an update on multiple-tree handling harvester head development in the Nordic countries.

Geographic area: Canada, Finland, Norway, United Kingdom, Sweden
Keywords: Harvesting; residues; forest biomass; firewood; multiple-tree handling

Gonsior, Michael J. 1979. Outlook for new harvesting technology. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 113-146 p.

This paper analyzes harvesting per se as well as its role in the total forest management picture. Models are presented for testing the sensitivity of total management cost and the harvesting components of cost to alternative

silvicultural, utilization, and other forest management objectives. These models are used to discern opportunities for new harvesting technology.

Geographic area: Northern Rocky Mountains
Keywords: logging systems, timber harvesting, forest management, cost modeling, new technology

Grushecky, Shawn T., Jingxin Wang, David W. McGill. 2007. Influence of site characteristics and costs of extraction and trucking on logging residue utilization in southern West Virginia. Forest Products Journal 57 (7/8): 63-67.

The increased utilization of logging residues has received considerable attention as a potential source of renewable biomass and as a raw material for engineered and conventional wood products. We investigated the relationship between logging residue accumulations and site characteristics on 70 timber harvests in southern West Virginia. The average overall weight of wood residue remaining after timber harvest in the 14-county region was 10.4 tons/acre. Scenarios of residue extraction and trucking indicated a cost range of $58.20/cunit or $94.30 per thousand board feet (MBF) to $193.10/cunit ($312.80/MBF Doyle). These results suggest that extracting residues to the landing during harvesting would be most cost-effective. Likewise, the use of grapple skidders and appropriate loading and trucking equipment would be more economical than other systems modeled.

Geographic area: West Virginia

Hall, Richard B. 2008. Woody bioenergy systems in the United States. In: Zalesny, Ronald S., Jr.; Mitchell, Rob; Richardson, Jim, eds. Biofuels, bioenergy, and bioproducts from sustainable agricultural and forest crops: proceedings of the short rotation crops international conference; 2008 August 19-20; Bloomington, MN. Gen. Tech. Rep. NRS-P-31. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 18.

This paper describes how most wood bioenergy crop systems in the United States are still in the early stages of development, with a wide variety of approaches under test in different regions of the country. In the United States, dedicated wood biomass cropland is expected to increase to more than 2 million ha with an average production rate of 18 t/ha. Another 334 million dry t/yr can come from forest residues and wood wastes. This short paper provides a few examples.

Geographic area: United States (New York, Pacific Northwest, Minnesota)
Keywords: adoption impediments, cultural systems, Populus, Salix, yields

Hampton, H.M., S.E. Sesnie, B.G. Dickson, J.M. Rundall, T.D Sisk, G.B. Snider and J.D. Bailey. 2008. Analysis of small-diameter wood supply in northern Arizona. Forest Ecosystem Restoration Analysis Project, Center for Environmental Sciences and Education, Northern Arizona University.

This report looks specifically at how forest products businesses are likely to play a key role in the achievement of forest management activities to restore fire-adapted ponderosa pine ecosystems in Northern Arizona by reducing treatment costs and providing economic opportunities by harvesting, processing and selling wood products. A 20-member working group was put together to identify a level of forest thinning treatments as well as potential wood supply from restoration byproducts in Northern Arizona.

Geographic area: Northern Arizona

Han, H., J. Halbrook, and F. Pan. 2008. Economic evaluation of a roll-off trucking system removing forest biomass resulting from shaded fuelbreak treatments.USDA Forest Service, Six Rivers National Forest.

This study shows that mechanical removal of slash has not been successfully implemented in many areas due to limited accessibility to sites and the high costs associated with collection and transportation of slash. To address these issues, a roll-off truck paired with a small skid-steer loader was used to collect and transport slash to a centralized processing site where slash was ground as hog fuel for energy production. Financial analysis indicated that contractors can receive high rates of return on their invested capital after accounting for inflation and income taxes, but limited work opportunities are a concern for them.

Geographic area: Northern California
Keywords: biomass energy, fuel treatment, forest fires, roll-off containers

Han, Han-Sup, Harry W. Lee, Leonard R. Johnson, Richard L. Folk, and Thomas M. Gorman. 2002. Economic feasibility of Small Wood Harvesting and Utilization on the Boise National Forest – Cascade, Idaho City, Emmett Ranger Districts. University of Idaho, College of Natural Resources, Department of Forest Products, Moscow, Idaho, 61 pp.

This report discusses opportunities for biomass energy in southwest Idaho, looking at the amount of biomass available and potential costs and economic feasibility of harvesting small-diameter trees. Biomass in this report is classified into three different potential sources that include tops, limbs and small stems (slash) generated from harvesting larger commercial timber, the volume generated from thinning younger stands and finally traditional primary manufacturing processes that generate chips, shavings, and sawdust.

Geographic area: Idaho

Han, Han-Sup, Harry W. Lee, Leonard Johnson. 2004. Economic Feasibility of an Integrated Harvesting System for Small-Diameter Trees in Southwest Idaho. Forest Products Journal, 54 (2), 21-27.

In order to reduce the risk of wildfire in the Interior Northwest of the United States the economic feasibility of small wood thinning and utilization is considered in this article. The major factors influencing economic feasibility were forest harvesting methods used, road accessibility and conditions, hauling distances to processing facilities and the market price of thinning materials. This article also includes a detailed discussion of tree volume and potential product recovery in (roundwood/sawlog, clean chip, biomass fuel) with respect to a variety of harvesting methods (stump-to-truck, skyline, helicopter, mechanized whole tree) and their associated economic considerations.

Geographic area: Idaho

Hardy, Colin C. 1998. Guidelines for estimating volume, biomass, and smoke production for piled slash. Gen. Tech. Rep. PNW-GTR-364. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 p.

Guidelines in the form of a six-step approach are provided for estimating volumes, oven-dry mass, consumption, and particulate matter emissions for piled logging debris. Seven stylized pile shapes and their associated geometric volume formulae are used to estimate gross pile volumes. The gross volumes are then reduced to net wood volume

by applying an appropriate wood-to-pile volume packing ratio. Next, the oven-dry mass of the pile is determined by using the wood density, or a weighted-average of two wood densities, for any of 14 tree species commonly piled and burned in the western United States. Finally, the percentage of biomass consumed is multiplied by an appropriate emission factor to determine the mass of PM, PM10, and PM2.5 produced from the burned pile. These estimates can be extended to represent multiple piles, or multiple groups of similar piles, to estimate the particulate emissions from an entire burn project.

Geographic area: western United States
Keywords: Fuel, emissions, piled slash, smoke management

Hartsough, Bruce R. 1989. Harvesting small stems and forest residues in the Pacific Southwestern United States. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 100-107.

At the time of this paper, most forest residues were too expensive to recover, but some materials were being chipped at the roadside. This paper describes biomass-powered generating facilities and the sources of materials for the plants in California at the time it was produced.

Geographic area: California

Hartsough, Bruce R., Bryce J. Stokes. 1990. Comparison and feasibility of North American methods for harvesting small trees and residues for energy. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Workshop, "Harvesting Small Trees and Forest Residues"; 1990 May 28; Copenhagen, Denmark. Auburn, AL: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1990: 31-40.

In this study a database of North American harvesting systems was developed. Parameters for each system included site, material and product characteristics, equipment mix and production rate. Onto-truck and delivered costs per green tonne, and breakeven oil prices were developed using standard costing methods. Systems costs were compared over the ranges of piece size, volume per unit area removed, capital/labor ratio and other variables. Feasibilities of various systems were also compared.

Geographic location: North America

Hartsough, Bruce R., Erik S. Drews, Joseph F. McNell, Thomas A. Durston, Bryce J. Stokes. 1997. Comparison of mechanized systems for thinning ponderosa pine stands and mixed conifer stands. Forest Products Journal, 47(11/12), 59-68.

Presents a comparative study of three systems used for thinning pine plantations and mixed conifer stands. Whole-tree methods; Cut-to-length systems; Hybrid systems. All three produced small sawlogs and fuel chips. Time-motion data were collected to predict cost per unit volume.

Geographic area: California

Hartsough, Bruce R., Xiaoshan Zhang, and Roger D. Fight. 2001. Harvesting cost model for small trees in natural stands in the interior northwest. Forest Products Journal, 51(4), 54-70.

Data from numerous published studies were combined to estimate the costs of harvesting small trees in natural stands in the Interior Northwest of North America. This article discusses cost estimates for harvesting small trees in natural stands in the Interior Northwest of North America. The cost relationships for six harvesting systems were modeled. Specifically there were four harvesting methods for gentle terrain discussed (manual log-length, manual whole tree, mechanized whole-tree, mechanized cut-to-length systems) and two harvesting methods for steeper terrain (manual log-length, mechanized cut-to-length systems).

Geographic area: Inland Northwest United States

Hazel, Dennis W., Robert E. Bardon. 2008. Evaluating wood energy users in North Carolina and the potential for using logging chips to expand wood fuel use. Forest Products Journal, 58(5), 34-39.

A survey to characterize the extent and nature of commercial-scale wood energy in North Carolina was sent to 200 primary wood-processing, secondary wood-manufacturing and nonwood-processing facilities known to have used wood fuels in 2004. Ninety-four percent of responding facilities estimated their energy savings were 40 percent or greater by using wood energy instead of fossil fuels. Twelve percent of facilities were generating electricity, and 22 percent expressed interest in exploring the feasibility of generating electricity. Results suggest most wood residues produced by wood-processing facilities in North Carolina are currently being used as fuel. Thus, expansion of wood energy must be based on use of logging chips or municipal woodwastes. The main constraints found for using logging chips as a fuel were price, moisture, dirt, and chip size. Facilities that currently purchase wood residues for fuel indicated a willingness to purchase logging chips at similar prices in the future.

Geographic area: North Carolina

Henley, John W. 1979. Technical and economic aspects of harvesting dead lodgepole pine for energy. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 213-215p.

This study highlights the results of a study of the economic feasibility of harvesting dead lodgepole pine for fuel and products. Costs, production rates, and recoverable wood volumes were obtained from a 3-month study of a whole-tree logging operation in which dead lodgepole was harvested for fuel and products.

Geographic area: Oregon
Keywords: Lodgepole pine, harvesting, energy, residues

Host, John R. 1979. Low capital investment logging systems. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 97-111 p.

This report, part of a larger study of factors affecting the utilization of small trees, deals with the impact of capital investment on logging productivity. Equipment selling price is not an indicator of machine productivity. Translated into machine production costs, which do not include any wages, supervision, or overhead, it cost 12 to 48 cents to

skid each piece, with higher costs associated with higher priced skidders. Ten skidders and fifteen yarders were studied. The selling price of these machines ranged from $72,000 to $240,000. Yarding costs varied directly with selling price and ranged from $1.10 to $4.30 per piece and $5.77 to $23.90 per Cunit.

Geographic area: Northern Rocky Mountains
Keywords: capital productivity, logging production, logging costs, yarding, skidding

Howard, James 0. 1978. A technique for predicting logging residue volumes in the Douglas-fir region. USDA Forest Service Research Paper PNW-235. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon. 14 p.

This report presents the findings of a study for determining the feasibility of predicting the volume of logging residue on clearcuts prior to harvesting. Data were collected from 160 clearcuts on Bureau of Land Management (U.S. Department of Interior) and National Forest (U.S. Department of Agriculture) lands in western Oregon and western Washington. Multiple regression techniques were used to develop equations relating preharvest stand and economic characteristics to measured residue volumes. The regression procedure resulted in the development of individual equations for each of four Bureau of Land Management Districts in western Oregon. Separate equations were also derived for the National Forests in Oregon and those in Washington.

Geographic area: Pacific Northwest (Oregon, Washington)
Keywords: Residue measurements, clearcutting systems, computation, Oregon, Washington

Howard, James O. 1979. Wood for energy in the Pacific Northwest: an overview. Gen. Tech. Rep. PNW-GTR-094. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 28 p.

The first section describes fuel values and significant processes used to generate various energy products from wood. Physical, technical, and economic availability of the wood resource is discussed in the second section. The paper concludes with an outline of some critical problems in handling wood and some socioeconomic factors that impact the production of energy from wood.

Keywords: energy, biomass, wood utilization, Pacific Northwest

Hunter, M.E., W.D. Shepperd, J.E. Lentile, J.E. Lundquist, M.G. Andreu, J.L. Butler, F.W. Smith. 2007. A comprehensive guide to fuels treatment practices for ponderosa pine in the Black Hills, Colorado Front Range, and Southwest. Gen. Tech. Rep. RMRS-GTR-198. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 93 p.

This paper presents recommendations for fuels treatments in ponderosa pine forests in the Southwest, Colorado Front Range, and Black Hills of South Dakota stemming from a synthesis of existing knowledge in the peer-reviewed literature and discussions with fuels treatment practitioners. Specific treatments, the circumstances under which they can be applied, treatment effects, and recommendations related to where, how, and how often fuels treatments may be prescribed to achieve desired outcomes are described.

Geographic area: Southwest United States, Colorado Front Range, South Dakota Black Hills
Keywords: southwest, Black Hills, ponderosa pine, wildfire, forest thinning, prescribed fire

Hurteau M.D., G.W. Koch, B.A. Hungate. 2008. Carbon protection and fire risk reduction: toward a full accounting of forest carbon offsets. Frontiers in Ecology and the Environment, 6(9): 493-498.

This paper looks into the carbon sequestering abilities of forests and finds that policies currently in place promote avoidable carbon releases and discourage actions that would actually increase long-term carbon storage. When stand-replacing catastrophic fires move through an area, the study found that by thinning the area and prescribed burns would have reduced the carbon dioxide release from live tree biomass by as much as 98%.

Geographic area: Western United States

Hurteau, Matthew and Malcolm North. 2009. Fuel treatment effects on tree-based forest carbon storage and emissions under modeled wildfire scenarios Frontiers in Ecology and the Environment, 7.

This paper provides results of modeling the effects of eight different fuel treatments on tree-based C storage and release over a century, with and without wildfire. Model runs show that, after a century of growth without wildfire, the control stored the most C. However, when wildfire was included in the model, the control had the largest total C emission and largest reduction in live-tree-based C stocks. In model runs including wildfire, the final amount of tree-based C sequestered was most affected by the stand structure initially produced by the different fuel treatments. In wildfire-prone forests, tree-based C stocks were best protected by fuel treatments that produced a low-density stand structure dominated by large, fire resistant pines.

Geographic area: Sierra Nevada (California)

Ince, Peter J., John W Henley, John B Grantham, Douglas L. Hunt. 1984. Costs of harvesting beetle-milled lodgepole pine in Eastern Oregon. Gen. Tech. Rep. PNW-GTR-165. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32p.

The cost of harvesting and recovering round wood logs and whole-tree chips from small diameter lodgepole pine infested by mountain pine beetle was studied in the Blue Mountains of eastern Oregon in 1979. The average cost of producing chips was $31.30 per ton, wet, delivered 50 miles from harvest sites. A gross energy balance indicates that energy required by harvesting was about 3.4 percent of the gross energy content of the delivered products.

Geographic area: Oregon
Keywords: Logging enterprise costs, lodgepole pine, wood utilization, energy, insect damage, forest products, mountain pine beetle

Jenkins, Jennifer C., David C. Chojnacky, Linda S. Heath, Richard A. Birdsey. 2003. National scale biomass estimators for United States tree species. Forest Science. 49: 12-35.

This report compiled all available diameter-based allometric regression equations for estimating total aboveground and component biomass, defined in dry weight terms, for trees in the United States. A modified meta-analysis based on the published equations to develop a set of consistent, national-scale aboveground biomass regression equations for U.S. species was implemented. Equations for predicting biomass of tree components were developed as proportions of total aboveground biomass for hardwood and softwood groups. This analysis represents the first major effort to compile and analyze all available biomass literature in a consistent national-scale framework.

Geographic area: United States

Keywords: Allometric equations, forest biomass, forest inventory, global carbon cycle

Johansson, J., J. Liss, T. Gullberg, and R. Bjorheden. 2006. Transport and handling of forest energy bundles- advantages and problems. Biomass and Bioenergy. 30 (4): 334-341.

This study shows that bundles (especially if dry) are cheaper to transport than fuel chips in road transport bins. The useful cargo space is the limiting factor for trucks when transporting dry material. Transport cost decreased until the moisture content reached the critical levels, below 40.9% for chips in road transport bins and below 44.7% for bundles on timber truck. However, there are also other advantages with a dryer material.

Geographic location: Sweden
Keywords: Bundle; Forest fuel; Main hauling; Terminal; Timber truck; Road transport; Road transport bins; Transport cost; Wood chips

Johnson, Leonard R. Recovery of woods residues in the Intermountain Region. 1989. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, Harvesting Small Trees and Forest Residues; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 11-31.

At the time of this paper, it was found residue recovery operations in the intermountain region were mostly experimental, as mill residue supplies were adequate for hogfuel demand. However it was recognized that future wood fiber supplies and environmental concerns would provide incentives and markets for more residue recovery from the woods. This paper summarizes residue recovery research projects using a variety of equipment. Cost results are provided.

Geographic area: Montana, Idaho, Oregon, Washington

Johnson, L. 2002. Adapting conventional harvesting equipment to small diameter stands – The Fritz Experiments. In: Small Diameter Timber: Resource Management, Manufacturing, and Markets, proceedings from conference held February 25-27, 2002 in Spokane, Washington. Compiled and edited by D.M. Baumgartner, L.R. Johnson, and E.J. DePuit. Washington State University Cooperative Extension. (Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912. MISC0509. 268 pp.

In this study, two units, one on steep slopes and one on gentle slopes, were harvested using variations to conventional harvesting systems in northeastern Washington. On the steep slope unit, cut-to-length processing and forwarding were observed on the steep slopes in small diameter timber. Adjacent stands were harvested using the cut-to-length processor and a feller-buncher, but were transported to the landing with a cable yarder. On the gentle slope units, cut-to-length harvesting at 40-foot trail spacing was compared to whole tree harvesting, a unit felled mechanically but processed at the forwarder trail, and a unit felled by hand but processed at the trail when trail spacing was set at 130 feet. Comparisons are made between production and cost for these system variations. Harvesting costs on the gentle slope units were significantly less than on the steep slopes. Whole tree harvesting was the least costly system. On steep slopes, the lowest costs were observed with the cut-to-length processor and forwarder, followed by the costs of cable yarding and bunched logs uphill. The processing and bunching provided by the cut-to length processor appeared to improve production of the cable yarder when handling small timber.

Geographic area: Washington
Keywords: cable yarding, cut-to-length, whole tree harvesting, small timber harvesting

Johnson, Maxine C. 1979. Residue utilization and the regional economy. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 289-292p.

The wood products industry is vitally important to the economy of western Montana. Forty to forty- five percent of the earnings in western Montana's basic or export industries come from the wood products and paper industries. Whether or not forest industries in the Rocky Mountain region hold their own, decline, or expand in future years depends mostly upon the area's ability to compete in the national market, and upon the availability of raw materials. Increased residue use may prove to be Montana's only chance of maintaining the forest industry at or near its present level of activity.

Geographic area: Rocky Mountain Region and Montana
Keywords: residues utilization, timber availability, Montana

Johnson, Morris C., David L. Peterson. 2005. Forest fuel treatments in western North America: merging silvicultural and fire management. The Forestry Chronicle. 81(3): 365-368.

In order to accomplish complex and multiple management objectives related to forest structure, fuels, and fire disturbance, these two disciplines must be effectively integrated in science and practice. The authors have linked scientific and management tools to develop an analytical approach that allows resource managers to quantify and evaluate the effectiveness of alternative fuel treatments in dry interior forests of western North America.

Geographic area: Western United States
Keywords: fire behaviour, fire hazard, fuel treatments, silviculture

Keegan, Charles E. III. 1979. The economic availability of forest residue in the northern Rocky Mountains: A preliminary analysis. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 55-63 p.

The goal of this project is to estimate the cost of harvesting and transporting forest residues to processing centers in the northern Rocky Mountains. Regionwide estimates are to be made based on the detailed analyses of the volumes and types of forest residues available to selected individual manufacturing centers. The results of the analysis of the first manufacturing center are presented in this paper. The initial study area selected was Lincoln County, Montana, with Libby, Montana as the processing center. It appears from the analysis that substantial volumes of logging residue material would be available at a cost which would allow for its use in fuel and reconstituted wood fiber products as well as solid wood products.

Geographic area: Montana
Keywords: residue availability, residue utilization, residue cost

Keegan, C.E., M.J. Niccolucci, C.E. Fiedler, J.G. Jones, R.W. Regel. 2002. Harvest cost collection approaches and associated equations for restoration treatments on national forests. Forest Products Journal: 52 (7/8): 96-99.

This article provides several harvest cost estimation methods for forest managers. Methods discussed include elements of stump-to-truck timber harvest cost estimation methods in ecosystem restoration prescriptions. Particular attention is focused on cost estimation models for tractor and skyline systems in Montana with additional focus on cost variances incurred at different tree diameters and skidding/yarding distances.

Geographic area: Montana

Keegan, Charles III, Carl E. Fiedler, Fred J. Stewart. 1995. Cost of timber harvest under traditional and "New Forestry" silvicultural prescriptions. Western Journal of Applied Forestry, 10 (1): 36-42.

Harvest costs were estimated for New Forestry silvicultural prescriptions designed for application on national forest lands in western Montana. Estimates were derived using an expert opinion format and were compared using constant dollars with actual 1991 costs based on more traditional prescriptions. Costs were developed for three major logging systems (tractor with hand-felling, tractor with mechanical-felling, and uphill skyline with hand-felling) and four major stand types (lodgepole pine, mature ponderosa pine/Douglas-fir, second-growth pine/fir, and mixed conifer). Average harvest costs for New Forestry prescriptions ranged from no increase to 48% ($72/mbf) higher. In light of stumpage price increases of >$200/mbf since 1991, these increased costs should be a minor factor in determining the feasibility of future timber harvest.

Geographic area: Montana

Kellogg, L.D., and P. Bettinger. 1994. Thinning productivity and cost for a mechanized cut-to-length system in the Northwest Pacific coast region of the USA. Journal of Forest Engineering, 5(2): 43-54.

This production study of the single-grip harvester and forwarder combination looks at productive machine hour, delay-free PMH rates in a second growth thinning operation in western Oregon. Rates of production of marked by forester trees and trees selected by machine operator are discussed as well as specific techniques of forwarder operation in relation to site conditions are discussed.

Geographic area: Pacific Northwest (Oregon)
Keywords: mechanized logging, single-grip harvester, forwarder, logging cost, thinning productivity

Kelsey, Rick G.; Shafizadeh, Fred. 1979. Chemical characteristics of wood residues and implications for utilization. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 203-211p.

In the Northern Rocky Mountains, where dry or cold conditions predominate, woody residues remain sound without visual signs of decomposition for many years. The chemical composition of this weathered material does not change significantly and it can be utilized like greenwood. Since wood and woody residues are heterogeneous there are two basic approaches to its chemical utilization: (1) whole wood processing and (2) separation of the heterogeneous components followed by processing. The chemical utilization of woody residues is almost limitless, the major barrier being economics rather than technology.

Geographic area: Northern Rocky Mountains

Keywords: residue utilization, wood composition

Kerstetter, James D. 1979. Review of biomass gasification. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 223-236p.

This paper reviews the topic of biomass air gasifiers. The gasification process chemistry is outlined and the operating characteristics of two types of gasifiers are presented. A few typical applications are discussed and the economics for a particular system are presented in comparison with the costs of natural gas. Finally, the appendix gives a list of biomass research, demonstration projects and manufacturers.

Geographic area: United States
Keywords: gasification, biomass fuel

Kirkland, Larry A., H. Peter Steinhagen, Alton G. Campbell. 1991. The University of Idaho wood-fired boiler: A case study. Forest Products Journal: 41 (6): 54-56.

The University of Idaho converted its campus steam generating plant from natural gas to wood residue fuel. The combustion system typically burns chipped or hogged wood fuel 2 inches or less, at 35 to 50 percent moisture content (wet basis).Pre-dried fuel was used initially but the fines fraction caused operating and emissions problems. High quality, low moisture content fuel purchased in the summer was blended with wet hog fuel during the winter when steam loads were high. The wood-fired unit nets fuel cost savings of several hundred thousand dollars a year.

Geographic area: Idaho

Klepac, John, Bob Rummer, Jason Thompson. 2006. Evaluation of a cut-to-length system implementing fuel reduction treatments on the Coconino National Forest in Arizona In: The 29th Council on Forest Engineering Conference, W. Chung and H.S. Han editors. pp. 405-414.

Time and motion derived production and costs are estimated for a CTL system while implementing fuel reduction treatments in two stands on the Coconino National Forest in Arizona. Product recovery and fire behavior within each stand were also examined. Time and motion data collected revealed the harvester produced 33 cubic feet per productive machine hour while harvesting biomass. Biomass unit costs were $9.62 per cubic foot while harvesting biomass.

Geographic area: Arizona

Laitila, J. 2008. Harvesting technology and the cost of fuel chips from early thinning. Silva Fennica. 42 (2): 267-283.

This study compared and analyzed the procurement cost of whole tree chips when using supply chains based on comminution at the roadside landing or at the terminal. It also identified the bottlenecks of the most common logging systems used in Finland. The study was done by using existing and published productivity parameters and models. The two-machine system was found to be the most cost competitive logging system in precommercial thinnings thanks to both efficient cutting and, especially, forwarding work. In the manual worker based logging, the costs of felling bunching were the same as the mechanized system, whereas in forwarding the costs were almost double.

Geographic area: Finland
Keywords costs, early thinnings, energy wood, harvesting, logging, productivity

Lambert, Michael B. 1989. Harvesting small stems and forest residues in the Pacific Northwestern United States. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 90-99.

This paper addresses the imbalance of unused resources, costs of on-site fuel treatment, electrical power demands, technology and economic deficiencies in harvesting and transportation, and the shrinking average size of trees being harvested. In this paper two examples of integrated harvesting systems that produce energy wood and emphasize decisive allocation of the entire above-ground tree biomass are discussed. The processing systems and reasons for their approach are also discussed

Geographic area: Pacific Northwest

Leenhouts, Bill. 1998. Assessment of Biomass Burning in the Conterminous United States. Conservation Ecology [online] 2 (1). Available at: http://www.consecol.org/vol2/iss1/art1

Wildland fire has been an integral part of the landscape of the conterminous United States for millennia. Analysis of contemporary and pre-industrial (~ 200 - 500 yr BP) conditions, using potential natural vegetation, satellite imagery, and ecological fire regime information, shows that wildland fires burned 35 - 86 x 10^6 ha (megahectares) annually in the pre-industrial era, consuming 530 - 1230 teragram (Tg) of biomass. At present, in comparison, 5 - 7 Mha/yr burn, consuming 77 - 189 Tg of biomass annually. If historic fire regimes were restored to non-urban and non-agricultural lands today, 18 - 43 Mha would burn annually, consuming 285 - 602 Tg of biomass. For each era, 11 biomass (wildland and agricultural) burning emissions were estimated, and differences of similar magnitude were found. Estimates of contemporary fossil fuel emissions are also provided for comparison. Atmospheric, climatic, social, and ecological system effects from the decrease in area burned, biomass consumed, and emissions produced are discussed.

Geographic area: Continental United States
Keywords: air quality; biomass burning; climate change; conterminous United States; emission estimates; fire regimes; pre-industrial conditions; prescribed burning; wildland fire.

Leicht, Richard E. 1979. Intermountain region wood utilization and wood energy application program. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 217-221p.

In 1978 the U.S. Forest Service initiated a National Wood Utilization and Wood Energy Application Program to focus attention on application of existing and developing technology. In this paper, the mission and goals of this program are discussed. Additionally, problems such as access, economic feasibility, and long-term guarantees are discussed. The benefits and hazards of utilizing forest residues are summarized and the paper closes with mention of the U.S. Forest Service and Regional commitment and the future opportunities for wood energy.

Geographic area: Northern Rocky Mountains
Keywords: wood energy, wood residues, firewood, wood utilization

Loeffler, Dan, David E. Calkin, Robin P. Silverstein. 2006. Estimating volumes and costs of forest biomass in western Montana using forest inventory and geospatial data. Forest Products Journal. 56(6): 31-37.

This report studied the feasibility of using biomass for renewable energy production as an alternative to onsite burning. Due to the relatively low value of biomass, accurate estimates of volumes and costs of collection and transport are necessary if investment in this type of renewable energy production is possible. Through the use of forest inventory data, remotely sensed data, and spatial data of Ravalli County in Western Montana, it was determined that 12 to 14 green tons per acre of biomass are potentially available for biomass energy production at a reasonable delivered cost. A spatial framework for estimating biomass volumes and costs are established in this article utilizing publicly available forest inventory and remotely sensed data for Ravalli County, Montana. This study identified 67,000 acres of forestland where a potential fuel reduction treatment could deliver renewable biomass to the county at reasonable delivered costs.

Geographic area: Montana

Lowell, Eini, Debra Larson, Robert Rummer, Dennis Becker. 2005. In-Woods Decision Making of Utilization Opportunities to Lower Costs of Fire Hazard Reduction Treatments. Joint Fire Science Program: Project# 01-1-2-03. Boise, Idaho. Available at: http://www.firescience.gov

The result of this research is an accumulation of information on harvest costs and product values necessary for identifying economic thresholds of fuels reduction projects. This information was used to develop a Windows-based, public domain financial/engineering software program called the Harvest Cost-Revenue (HCR) Estimator that can be used to evaluate stand-level economic thresholds for harvesting small diameter ponderosa pine in the southwestern U.S. The HCR Estimator was developed for a variety of users including logging contractors and forest planners. Its purpose is to identify costs of fuel reduction treatments and evaluate in-woods decision-making regarding tree-selection, residuals left on site, and product suitability for regionally based wood markets.

Geographic area: Arizona (primary data collection)

Lowell, E. C., D. R. Becker, R. Rummer, D. Larson, L. Wadleigh. 2008. An integrated approach to evaluating the economic costs of wildfire hazard reduction through wood utilization opportunities in the southwestern United States. Forest Science: 54(3): 273-283.

This paper looks at the development of an integrated wildfire fuels reduction system from silvicultural prescription, through tree selection, harvesting, in-woods processing, transport, and market selection. Data on harvest equipment productivity, lumber recovery, and net profit (loss) for different levels of fuels reduction treatments in small-diameter ponderosa pine was collected from four 20 acre sites in Northern Arizona. This data was used in the development of the harvest cost-revenue (HCR) estimator, a financial and engineering software program.

Geographic area: Northern Arizona
Keywords: ponderosa pine, wildfire fuel reduction, financial analysis, harvest cost-revenue estimator

Lowery, David P. 1979. Extended use of residue for conventional solid wood products. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden,

UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 181-189 p.

There is no inherent difference between the wood from dead trees and green trees. Solid wood product studies have indicated that dead trees can be used for lumber, houselogs, and posts and poles although the amount of usable lumber is usually lower for dead trees than for green trees. Dead trees may be preferred for houselogs, posts, and poles; however, extra care is required in selecting and processing these products.

Geographic area: Northern Rocky Mountains
Keywords: dead tree utilization, dead tree lumber, posts and poles, lodgepole pine, western white pine

MacDonald, AJ. 2009. Assessment of economically accessible biomass. FP Innovations Technical Report, Quebec.

FPInnovations calculated the amount of forest biomass generated by timber harvesting operations on Vancouver Island and south coast mainland. Field measurements related the volume of roadside residues to the volume of harvested merchantable logs in a factor called the biomass ratio. Roadside residue volumes for the entire study area were calculated by applying the biomass ratio. Comminution and transportation costs were calculated, and volume reductions were made to account for accessibility and transportation costs.

Geographic area: Vancouver island, southwestern Canada
Keywords: biomass, inventory, residue, cost, roadside, dispersed

Maloney, T. M. 1979. Particle and fiber building products from residue raw material. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 171-179 p.

This paper will cover the definitions of the composition and composite materials, provide a brief history of this segment of the forest products industry, describe types of building materials now being produced or possible to produce, discuss recent developments, and present the role of forest residue raw materials.
Considerable research has been conducted on the use of dead standing trees of western white pine and lodgepole pine for use in various composition board materials. Economic analyses have shown that there are no particular cost penalties associated with the use of the dead material in comparison with standard green material after the raw material has been delivered to the plant site.

Geographic area: Northern Rocky Mountains
Keywords: residue utilization, building materials

Manfredo, Michael J., Martin Fishbein, Glenn E. Hass, and Alan E. Watson. 1990. Attitudes Toward Prescribed Fire Policies. Journal of Forestry 88(7): 19-23.

This article discusses social considerations with respect to public wildland forest fire policy. Social attitudes, beliefs and behavioral intentions of wildland fire are described as well as the public's knowledge of the effects of fire. This study details these social issues with regards to the 'let burn' policy and the 1988 fires in Yellowstone National Park.

Geographic area: United States

Markley, J.H. 1979. Practical considerations in using low quality wood in lumber, specialties, and plywoods. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 191-193 p.

This discussion examines some of the uses of low quality wood. The solid wood product families examined include composites, plywood, lumber, laminated lumber, and cedar products.

Geographic area: Rocky Mountains
Keywords: residue utilization, wood residues, wood products

Mason, C.L., B.R. Lippke, K.W. Zobrist, T.D. Bloxton, Jr., K.R. Ceder, J.M. Comnick, J.B. McCarter, H.K. Rogers. 2006. Investments in fuel removals to avoid forest fires result in substantial benefits. Journal of Forestry 104(1): 27.

Although large trees can be removed for valuable products, the market value for the smaller logs may be less than the harvest and hauling charges, resulting in a net cost for thinning operations. However, failure to remove these small logs results in the retention of ladder fuels that support crown fires with destructive impacts to the forest landscape. A cost/benefit analysis broadened to include market and non-market considerations indicates that the negative impacts of crown fires are underestimated and that the benefits of government investments in fuel reductions are substantial.

Geographic area: United States
Keywords: forest fuels, non-market values, small-diameter logs, cost/benefit analysis, forest fires

McIver, J.D., P.W. Adams, J.A. Doyal, E.S. Drews, B.R. Hartsough, L.D. Kellogg, C.G. Niwa, R. Ottmar, R. Peck, M. Taratoot, T. Torgersen, A. Youngblood. 2003. Environmental effects and economics of mechanized logging for fuel reduction in northeastern Oregon mixed-conifer stands. Western Journal of Applied Forestry, 18(4): 238-249.

Fuel reduction by mechanical thinning and removal was studied in mixed-conifer stands in northeastern Oregon. A single-grip harvester was coupled with either a forwarder or a skyline yarding system, and operational economics, fuel reduction, stand damage, soil disturbance, effects on soil biota and down-woody material were measured.

Geographic area: Oregon
Key Words: Fire risk reduction, soil compaction, skyline yarding, forwarder, single-grip harvester.

McMichael, Marvin. 1979. Utilizing residue material in pulping. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 194-196 p.

The pulp raw material shortage in 1973 and 1974 provided incentives for using whole tree chips at a number of pulp mills in the United States. Since 1974 pulp raw materials supplies have returned to more acceptable levels. As a result, whole tree chips are being used only on a limited basis. However, energy shortages during recent years have provided incentives for the utilization of whole tree chips. Currently, projects are underway in Montana, Idaho and Washington which will increase the demand for waste fuel.

Geographic area: Montana, Idaho and Washington
Keywords: residue utilization, pulping

McMinn, James C. and Alexander Clark III. 1988. Predicting residuals by stand condition and type of harvest. South. J. Appl. For. 12(3): 190-193.

This paper describes how in a mixed pine-hardwood stands in central Georgia, the tonnage of all trees not designated for harvest accounted for 89% of the variation in tonnage of standing residuals after conventional harvesting. Standing residuals weighed 5.4 to 29.3 tons/ac after conventional harvests, but an additional 2 to 13 tons of broken and uprooted material and 1 to 8 tons of hardwood tops would hinder recovery. A whole-tree system, for which small stems were harvested first, recovered 16 to 43 tons/ac, which was 56 to 94% more material than would have been left standing after conventional harvest of the same areas.

Geographic area: central Georgia

McMinn, James C. and Alexander Clark III. 1989. Influence of whole-tree versus conventional harvesting on recoverable biomass in pine-hardwood mixtures. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 32-43.

Seven areas in Georgia were harvested with a conventional system and three with a whole tree system. Pre- and post-harvest sampling of all standing woody biomass provided base data for estimating standing and downed residuals by initial stand conditions and harvest system. Relationships were developed to permit estimation of recoverable stand components.

Geographic area: central Georgia

Meyer, Vernon W. 1979. Harvesting efficiency: A historical perspective. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 67-76 p.

This paper briefly describes the history of the logging industry in the United States. Specifically, harvesting technology and methods are discussed. Many significant and far-reaching changes have taken place in the logging industry since its inception in the mid-17th century. But technological advances aimed at improved timber utilization have not come about quickly. It has been an incremental and continuous process.

Geographic area: United States
Keywords: logging, harvesting, history

Miller, D., T. Straka, B. Stokes, and W. Watson. 1987. Productivity and cost of conventional understory biomass harvesting systems. Forest Products Journal. 37 (5): 39-43.

In this study, conventional harvesting equipment was tested for removing forest understory biomass for use as fuel. Two types of systems were tested--a one-pass system and a two-pass system. In the one-pass system, the energywood and pulpwood were harvested simultaneously. In the two-pass system, the energywood was harvested in a first pass through the stand, and the pulpwood was harvested iris second pass. Equations were developed to estimate the cost per green ton of energywood. The two-pass system exhibited high harvesting costs when biomass amounts were low, but costs moderated as biomass amounts increased. The one-pass system harvesting costs were not sensitive to the amount of energywood present.

Geographic area: Southern United States (Alabama)

Mitchell, Dana L. 2005. Assessment of current technologies for communition of forest residues. ASAE Paper 05-8024. St. Joseph, MI: American Society of Agricultural Engineers. 9p.

This paper provides an overview of existing literature related to the harvest, communition and transport of forest residues. Past studies have investigated the systems associated with biomass harvesting. Researchers have explored whether to incorporate the biomass component with other forest product removals, or to harvest it in a separate entry. Land managers do not have the tools to adequately assess the cost of biomass processing prior to treatments. Handling residue can be awkward due to the size and arrangement of the material. Dirt and rocks can contaminate residues and cause equipment repair problems or reduced utilization of the resource. These issues coupled with the problems of comparing existing production studies lead to some of the reasons why land managers have difficulty in assessing communition processing costs.

Geographic area: Non-descript
Keywords: biomass, chippers, grinders, production, communition, forest residues, fuel, chunks

Mitchell, Dana. 2008. Felling small trees with a drive-to-tree feller-buncher. Technical release 08-R-16. Rockville, MD: Forest Resources Association, Inc. 2 p.

Conventional forestry equipment is often used to harvest small-diameter trees. The typical ground-based logging operation is highly mechanized, with the most common using feller-bunchers, grapple skidders, and a chipper or grinder. But these machines may not be economical when used in pre-commercial or unmerchantable thinning operations in which the number of trees to be removed per acre is high but volume per tree is low. Published studies commonly find that feller-buncher productivity (tons/productive machine hour) is directly proportional to tree diameter. As tree diameters increase, the tons produced per hour increase, resulting in a lower cost per unit of wood produced.

Geographic area: Alabama

Mitchell, Dana, Renee Ayala. [Compilers]. 2005. Biomass publications of the forest operations research unit: A synthesis. [CD-ROM]. USDA Forest Service, Southern Research Station, Auburn, AL. Available at: http://www.treesearch.fs.fed.us/pubs/20138

The authors of this synthesis have implemented several studies over the years, and this CD is an attempt to compile this data in a usable format. The Executive Summary has ten primary research topic areas related to biomass: Baling/bundling; biomass harvesting systems; biomass inventory' chipping systems; drying, storing, transporting and roll splitting; economic analysis; environmental effects; individual machines; proto-type machines; short rotation woody crop production.

Geographic area: United States

Mitchell, Dana, Tom Gallagher. 2007. Chipping whole trees for fuel chips: a production study Southern Journal of Applied Forestry, Vol. 31(4): 176-180.

This time and motion study determines the productivity and costs of an in-woods chipping operation to create biomass fuel from processing whole small-diameter trees. It was found that the cost of biomass chipping was comparable to other existing treatments such as cut-and-pile or mulching. Two different overstocked stands were studied with the same harvesting and chipping method.

Geographic area: Alabama
Keywords: biomass, hog fuel, harvesting, production

Mitchell, Dana, John Klepac. 2008. Processing woody biomass with a modified horizontal grinder. In: Proceedings of the 31st Annual Meeting of The Council on Forest Engineering: Addressing Forest Engineering Challenges for the Future. 7 p.

This study documents the production rate and cost of producing woody biomass chips for use in a power plant having specific raw material handling requirements. None of the samples from machines met the specifications needed. A horizontal grinder was modified to replace the teeth on the drum with chipping blades in order to process whole trees into biomass chips that met the power plant's size specification. The time and motion study gathered data on whole-tree processing for short fiber chips and long fiber chips. The average production rate ranged from 24.9 – 38.2 green tons/productive machine hour (gt/pmh). A machine rate of $161.20/pmh was calculated, resulting in a cost of $4.22/gt for producing the long fiber biomass chips.

Geographic area: Alabama

Mitchell, Dana, Bob Rummer. 2007. Processing woody debris biomass for co-milling with pulverized coal. In: ASABE 2007 Annual International MEeting, Minneapolis, Minnesota. 17-20 June 2007. 6 p.

This project proposed removing small diameter stems and unmerchantable woody material from National Forest lands and delivering it to a coal-fired power plant in Alabama for energy conversion. The biomass fuel to be created in this project must meet unique criteria that differentiate fuel chips created for the power plant from those of typical fuel chips. The wood fuel was to be created from whole-tree chips and co-milled with coal. After further review, it was determined that a cutting action, as opposed to a shearing action, was needed to meet the raw material handling requirements within the plant. Output from a specially equipped horizontal grinder was the final equipment choice.

Geographic area: Alabama
Keywords: biomass, forest engineering, harvesting, logging, chipper, grinder

Mitchell, Dana, Fernando Seixas, John Klepac. 2008. Modified precision-husky progrind H-3045 for chipping biomass. Forest Operations Review, Vol. 10(4): 1-5.

A specific size of whole tree chip was needed to co-mill wood chips with coal. The specifications are stringent because chips must be mixed with coal, as opposed to a co-firing process. In a partnership involving several entities, a trial was conducted to determine if wood chips could be created in a one-step in-woods process that would meet

the stringent requirements of the power plant. Precision-Husky, of Leeds, Alabama, volunteered to work with the partnership to manufacture a machine that would create the chips to the stringent specifications needed.

Geographic area: Alabama

Morris, G. 1999. The value of the benefits of U.S. biomass power. NREL/SR-570 27541. National Renewable Energy Laboratory, Golden, Colorado, 24 p.

This report estimates the value of ancillary services provided by the U.S. biomass industry in order to inform policy makers on the viability of the biomass industry. Specifically, criteria air pollutants, greenhouse gas emissions, landfill capacity use, forest and watershed improvement, rural employment and economic development and energy diversity and security of the biomass industry are discussed in detail.

Geographic area: United States

Nicholls, David. 2009. Wood energy in Alaska--case study evaluations of selected facilities. Gen. Tech. Rep. PNW-GTR-793. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 33 p.

This case study review considers successes and lessons learned from current wood energy systems in Alaska, and also considers opportunities for future bioenergy development. Biomass resources in Alaska are extensive and diverse, comprising millions of acres of standing small-diameter trees, diseased or dead trees, and trees having lowgrade timber. Biomass products in Alaska having potential for development are as diverse as wood pellets, cordwood (firewood), compost, wood-plastic composite products, and liquid fuels.

Geographic area: Alaska
Keywords: Alaska, biomass, bioenergy, wood energy, renewable, cordwood, sawmill residues.

Nicholls, David L., Robert A.Monserud, Dennis P Dykstra. 2008. A synthesis of biomass utilization for bioenergy production in the Western United States. Gen. Tech. Rep. PNW-GTR-753. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 48 p.

This study examines the use of woody residues, primarily from forest harvesting or wood products manufacturing operations as a feedstock for direct-combustion bioenergy systems for electrical or thermal power applications. Opportunities for utilizing biomass for energy at several scales, with an emphasis on larger scale electrical power generation at stand-alone facilities, and on smaller scale facilities such as governmental, educational, or other institutional facilities are examined. Barriers that tend to inhibit bioenergy applications, including accessibility, terrain, harvesting costs, and capital costs are identified and an evaluation the role of government as a catalyst in stimulating new technologies and new uses of biomass material is conducted.

Geographic area: western United States
Keywords: Biomass, bioenergy, fuel hazard reduction, renewable energy, harvesting, forest products

Nicholls, D., R. Monserud, and D. Dykstra. 2008. Biomass utilization for bioenergy in the Western United States. Forest Products Journal. 58 (1/2): 6-16.

This study examines the use of woody residues, primarily from forest harvesting or wood products manufacturing operations (and to a limited degree from urban wood wastes), as a feedstock for direct-combustion bioenergy systems for electrical or thermal power applications. Opportunities for utilizing biomass for energy at several different scales, with an emphasis on larger scale electrical power generation at stand-alone facilities, and on smaller scale facilities (thermal heating only) such as governmental, educational, or other institutional facilities, are examined.

Geographic area: Western United States

NREL. 1998. International and domestic market opportunities for biomass power Volumes I and II. National Renewable Energy Laboratory, Golden, Colorado, NREL/SR-570-25492.

This report examines the domestic and international markets for biopower. Domestic and foreign markets present fundamentally different challenges to private power developers. The domestic challenge lies in finding economically viable opportunities for biopower. Volume I outlines the current state of the U.S. biomass industry, discusses policies affecting biomass development, describes some demonstration projects currently underway, and discusses the future direction of the industry. It then explores the relationship between biopower and the impending restructuring of the electric power industry. The U.S. market assessment concludes with a discussion of various technological applications of biomass power.

Geographic area: United States

Pan, F., H.-S. Han, L.R. Johnson, and W.J. Elliot. 2008. Net energy output from harvesting small-diameter trees using a mechanized system. Forest Products Journal 58(1/2): 25-30.

This paper examines the efficiency of forest biomass used for energy. The study used net energy ratios to compare how much energy is consumed by mechanized harvesting systems of small diameter trees that are transported and used for forest biomass energy to the amount of energy (in BTUs) the forest biomass produces. The overall conclusion showed that forest biomass energy has an encouraging net energy ratio compared to other biomass sources, however increases in miles traveled and diesel fuel costs can inhibit the use of forest biomass for energy.

Geographic area: Arizona

Parhizkar, Omid, Robert L Smith. 2008. Application of GIS to estimate the availability of Virginia's biomass residues for bioenergy production. Forest Products Journal 58(3): 71-76.

Forest residues are widely dispersed across large geographical areas in Virginia, and there is little information on the location and the quantity of these materials. Geographic Information System (GIS) was used in this study to identify the availability of residues from wood manufacturers, landfills, and loggers. A graphical-mapping GIS program allows for the location of biomass residue from these facilities and estimates the available biomass residue in each county in Virginia. The residue information was collected through the survey of primary and secondary wood manufacturers, landfills, and loggers in Virginia. It was then incorporated into a GIS so that locations and quantities of various residues could be plotted.

Geographic area: Virginia

Patterson, David W., Matthew H. Pelkki, Phillip H. Steele. 2008. Productivity of the John Deere slash bundler in removing in-forest residues from pine harvest sites in the mid-South: four case studies. Forest Products Journal, 58 (7/8): 31-36.

In the summer of 2006, the John Deere 1490D slash bundler was brought to Arkansas so that four independent case studies could be conducted where no previous studies on the machine had been conducted in The South. The study sites were a clear cut, a second thinning and a first thinning harvested with conventional equipment. The fourth site was a thinning by cut-to-length equipment. The productivity rate of the machine ranged from 60 to 78 percent. Delays (i.e., saw binding, materials handling, and twine spools collapse) were the main problem of the first three sites and movement was the major nonproductive element at the fourth site. The bundles can be economically produced (based on current markets) and they can be stored for seven to 8 months.

Geographic area: Arkansas

Patton-Mallory, Marcia; Richard Nelson, Ken Skog, Bryan Jenkins, Nathan Parker, Peter Tittmann, Quinn Hart, Ed Gray, Anneliese Schmidt, Gayle Gordon. 2008. Strategic assessment of biofuels potential for the western U.S.. In: Zalesny, Ronald S., Jr.; Mitchell, Rob; Richardson, Jim, eds. Biofuels, bioenergy, and bioproducts from sustainable agricultural and forest crops: proceedings of the short rotation crops international conference; 2008 August 19-20; Bloomington, MN. Gen. Tech. Rep. NRS-P-31. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 42.

This is a short summary of an effort addressing the technical feasibility of producing biofuels in the western United States is described using spatially explicit biomass resource supply curves, a detailed transportation network model for the region, and costs for converting biomass to refined biofuels. This paper presents biofuel supply curves estimating potential future supplies of liquid fuels from biomass in the western United States as a function of market price.

Geographic area: Western United States
Keywords: biofuels, agriculture residues, wood residues, thinnings, grease, herbaceous energy crops, biomass supply estimates, network analysis

Perez-Verdin, Gustavo, Donald L. Grebner, Changyou Sun, Ian A. Munn, Emily B. Schultz, Thomas G. Matney. 2009. Woody biomass availability for bioethanol conversion in Mississippi. Biomass and Bioenergy, 33 (3): 492-503.

This study evaluated woody biomass from logging residues, small-diameter trees, mill residues, and urban waste as a feedstock for cellulosic ethanol conversion in Mississippi. Supply and cost of four woody biomass sources were derived from Forest Inventory Analysis (FIA) information, a recent forest inventory conducted by the Mississippi Institute for Forest Inventory, and primary production costs. According to our analysis, about 4.0 million dry tons of woody biomass are available for production of up to 1.2 billion liters of ethanol each year in Mississippi. The feedstock consists of 69% logging residues, 21% small-diameter trees, 7% urban waste, and 3% mill residues. Of the total, 3.1 million dry tons (930 million liters of ethanol) can be produced for $34 dry ton_1 or less. Woody biomass from small-diameter trees is more expensive than other sources of biomass. Transportation costs accounted for the majority of total production costs.

Geographic area: Mississippi
Keywords: Logging residues, Mill residues, Mississippi, Production costs, Small-diameter trees, Urban waste

Perez-Verdin, Gustavo, Donald L. Grebner, Ian A. Munn, Changyou Sun, Stephen C. Grado. 2008. Economic impacts of woody biomass utilization for bioenergy in Mississippi. Forest Products Journal, 58 (11): 75-83.

This study examined the economic impacts of woody biomass utilization for bioenergy conversion in Mississippi. Analysis of economic impacts was organized around three groups of events: (1) recovery of logging and thinning residues, (2) electricity generation from cofiring systems, and (3) construction and operation of biofuel facilities. Results showed that the single activity of recovery of all available logging and thinning residues would create a considerable number of jobs and stimulate the rural economy with more resources coming to local industries and households. Due to construction and operation costs, economic impacts of biofuels were higher than biopower. However, biofuels reported the lowest employment and value-added multipliers of all three groups.

Geographic area: Mississippi

Peterson, David L., Morris C. Johnson, James K. Agee, Theresa B. Jain, Donald McKenzie, Elizabeth D. Reinhardt. 2005. Forest structure and fire hazard in dry forests of the western United States. Gen. Tech. Rep. PNW-GTR-628. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 30 p.

This document synthesizes the relevant scientific knowledge that can assist fuel-treatment projects on national forests and other public lands and contribute to National Environmental Policy Act (NEPA) analyses and other assessments. It is intended to support science-based decisionmaking for fuel management in dry forests of the Western United States at the scale of forest stands (about 1 to 200 acres). It highlights ecological principles that need to be considered when managing forest fuel and vegetation for specific conditions related to forest structure and fire hazard. It also provides quantitative and qualitative guidelines for planning and implementing fuel treatments through various silvicultural prescriptions and surfacefuel treatments.

Geographic area: Western United States
Keywords: Crown fire, fire hazard, forest structure, fuel treatments, prescribed burning, silviculture, thinning

Prestemon, Jeffrey P., and Karen Lee Abt, and Thomas P. Holmes. 2002. The economic impacts of fire-related biomass reduction on government lands. In: Small Diameter Timber: Resource Management, Manufacturing, and Markets, proceedings from conference held February 25-27, 2002 in Spokane, Washington. Compiled and edited by D.M. Baumgartner, L.R. Johnson, and E.J. DePuit. Washington State University Cooperative Extension. (Bulletin Office, WSU, PO Box 645912, Pullman, WA 99164-5912. MISC0509. 268 pp.

This paper outlines a Joint Fire Science Program funded study, “A national study of the economic impacts of biomass removals to mitigate wildfire damages on federal, state, and private lands.” The study involves using the treatment-product and cost information provided by the Fire and Fire Surrogates study, another Joint Fire Science Program-funded research effort. This information is combined with timber inventory information across fire prone regions of the U.S. to develop treatment supply schedules for fire prone regions. Using GIS and other modeling techniques, this approach will quantify the small region and broad region supply responses to alternative scales of fire risk-related biomass reduction programs. Concurrently, information on timber product output will be assembled to identify product demand relationships.

Geographic area: United States

Puttock, G. 1995. Estimating costs for integrated harvesting and related forest management activities. Biomass and Bioenergy. 8(2): 73-79.

Often the deciding factor in the economical recovery of wood fuel is its relationship with some other objective such as stand establishment, stand improvement, or forest access. The costs and benefits arising from these related management activities are discussed. Two different approaches to estimating the cost of producing conventional products and fuel wood with integrated harvesting systems are also examined.

Geographic area: Canada, United Kingdom, northern Europe, United States
Keywords: Forest energy; biomass; integrated harvesting; marginal cost; joint product cost.

Puttock, G. 1987. The economics of collecting and processing whole-tree chips and logging residues for energy. Forest Products Journal. 37(8): 15-20.

In this study, the economics of collecting and processing whole-tree chips and logging residues (slash and residual timber) for energy use have been compared using data collected from four timber harvesting operations. Fuel produced from whole-tree chips is competitive with natural gas when hauling distances are 80 km or less. Whole-tree chips are a feasible substitute for oil when distances are less than 200 km. Logging residues are an attractive alternative to oil at hauling distances of less than 100 km, but cannot be competitive with the lower priced fossil fuels such as natural gas and coal.

Raymond, Crystal L., David L. Peterson. 2005. Fuel treatments alter the effects of wildfire in a mixed-evergreen forest, Oregon, USA. Canadian Journal of Forest Research. 35: 2981-2995.

The authors quantify the relationship between fuels and fire severity using pre-fire surface and canopy fuel data and fire severity data after a wildfire. Modeled fire behavior showed that thinning reduced canopy fuels, thereby decreasing the potential for crown fire spread. The potential for crown fire initiation remained fairly constant despite reductions in ladder fuels, because thinning increased surface fuels, which contributed to greater surface fire intensity. Thinning followed by underburning reduced canopy, ladder, and surface fuels, thereby decreasing surface fire intensity and crown fire potential. However, crown fire is not a prerequisite for high fire severity; damage to and mortality of overstory trees in the wildfire were extensive despite the absence of crown fire. Mortality was most severe in thinned treatments (80%-l00%), moderate in untreated stands (53%-54%), and least severe in the thinned and underburned treatment (5%). Thinned treatments had higher fine-fuel loading and more extensive crown scorch, suggesting that greater consumption of fine fuels contributed to higher tree mortality.

Geographic area: Oregon

Rawlings, C., R. Rummer, C. Seeley, C. Thomas, D. Morrison, H. Han, L. Cheff, D. Atkins, D. Graham, and K. Windell. 2004. A study of how to decrease the costs of collecting, processing, and transporting slash. Montana Community Development Corporation. Missoula, Montana

This study compares the costs of various slash transportation systems and found a roll on/off container system is not competitive with a regular highway chip van, unless part of that distance is inaccessible to the chip van. The roll on/off container system allows for recovery of residue from difficult-to-access locations. There are many variables to consider when determining the cost of hog fuel production and a simple spreadsheet model has been developed to help evaluate those variables as users choose the best combination of options.

Geographic area: Western Montana

Robatcek, John G. 1979. The implications of improved residue utilization on timber sale activities. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 269-272p.

The purpose of the paper is to discuss some of the implications of improved residue utilization on timber sales activities. Improved residue utilization on timber sales requires new and innovative economic and practical approaches on timber sales. Varying uses, resource needs, and economic limitations complicate the land manager's task of salvaging this material.

Geographic area: United States
Keywords: residues, utilization, economics, complicate

Roos, Anders, Robin L. Graham, Bo Hektor, and Christian Rakos. 1999. Critical factors to bioenergy implementation. Biomass and Bioenergy, 17: 113-126.

This paper contributes to the identification and analysis of barriers and drivers behind bioenergy market growth. It presents a framework for the analysis of both existing and projected bioenergy market potential, using economic concepts and models from transaction cost theory and industrial organization. The framework can be used for assessments of the potential for market growth of different bioenergy systems by decision makers in administration and industry. The framework is demonstrated with five cases of real bioenergy markets: Pellet residential heating in USA, bioenergy power in USA, pellet residential heating in Sweden, biomass district heating in Sweden, and biomass district heating in Austria.

Geographic area: United States, Sweden, Austria
Keywords: Bioenergy market; Nontechnical barriers; Energy policy

Rummer, Robert. 2004. Forest residues bundling project: New technology for residue removal. USDA Forest Service, Missoula Technology Development Center. [CD-ROM]. 0451-2M25-MTDC.

This CD-ROM provides an overview of biomass issues, determining where bundling works and does not, developing productivity and cost estimates, and assessing properties and quality of bundled biomass for energy production. The objective of this project was to examine the operational performance of the Timberjack 1490D Slash Bundler across a wide range of conditions found on typical western US forests. The bundler operated for approximately two weeks at each location to develop a productive operating environment. Stand conditions were assessed pre and post-biomass collection. In addition, detailed data about productivity, soil disturbance, residual stand impacts, and bundle quality were recorded.

Geographic area: Western United States

Rummer, Bob, John Klepac. 2003. Evaluation of roll-off trailers in small-diameter applications. In: Proceedings of the 2003 council of forest engineering 26th annual conference. Bar Harbor, Maine: University of Maine, New England Regional Council on Forest Engineering: 5 p.

This project studied the performance and costs of an innovative wood transport system using roll-off pallet racks to facilitate handling of small-diameter thinning material. Elemental studies defined the transport cycles and cost analysis compared the economics of the new system with conventional transport technology – a conventional 5-axle

logging truck with a shortwood trailer operating at 85% utilization and a conventional shortwood trailer system operating at 30% utilization.

Geographic area: New Mexico

Sampson, George R. 1979. Evaluating in-woods chipping feasibility. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 159-167 p.

This paper presents an evaluation of the test results and uses the results to predict the future of in-woods chipping Economic analysis of data from a demonstration test showed that in-woods debarking-chipping was only marginally competitive with conventional methods of harvesting roundwood for pulp chips. The future for in-woods chipping appears to be whole tree chipping. Cost of delivered chips may not be much different from conventional roundwood systems unless credits are taken for increased utilization and slash disposal.
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Geographic area: Arizona, Colorado
Keywords: chipping machines, logging economics

Samson, R. Neil, Megan S. Smith, Sara B. Gann. 2001. Western forest health and biomass energy potential. Submitted to the Oregon Office of Energy. The Samson Group, Inc., Alexandria, Virginia.

This article discusses the need for a reduction of fuels in forest ecosystems in order to mitigate the risk of catastrophic wildfire and the ability of the biomass industry to play a role in managing this risk. Generally, this article concludes that significant opportunities exist to link forest health treatments and biomass energy production. Several obstacles to this are discussed including the feasibility of biomass fuel delivery, the availability of viable biomass markets to forest managers at a reasonable distance and security assurances for the initial investment in biomass production facilities. The coordination of land management and energy policy is discussed.

Geographic area: Western United States (Oregon)

Schnepf, Chris, Russell T. Graham, Sandy Kegley, Theresa B. Jain. 2009. Managing organic debris for forest health: Reconciling fire hazard, bark beetles, wildfire, and forest nutrition needs. Pacific Northwest Extension Publication 609, University of Idaho, Moscow.

This publication outlines the role of forest organic debris (i.e. biomass) in inland northwest forests and provides general management strategies. It will help forest owners and those who work with them ask better questions to plan the best treatments strategy for each site in order to keep forests and wildlife more healthy and sustainable, while keeping risks from fire and insects within acceptable limits.

Geographic area: western United States

Schweitzer, Dennis L. 1979. An economist's perspective of residues. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 273-279p.

As the values of wood products increase, there are more economic opportunities to utilize residues. This is true both for dead-and-down materials and for previously unharvested stands which, together, make up the potential economic residues resource. A variety of research efforts are developing the information and technology necessary to take advantage of these opportunities. The key to minimizing future residues problems is to fully integrate residues considerations with overall forest resource planning.

Geographic area: United States

Scott, D. Andrew, Allan Tiarks. 2008. Dual-cropping loblolly pine for biomass energy and conventional wood products. South. J. Appl. For., 32(1): 33-37.

This study explores a dual-cropping system for southern pine bioenergy and solidwood products that began in 1982 in Louisiana. Direct-seeding pine in the interrows of a traditional pine plantation produced about 10.2 Mg per ha of biomass for energy at the age of 5 years but had no lasting effect on the planted pine height, diameter, or standing volume. The system is a viable method to produce both bioenergy and solidwood products. Herbaceous competition control and nitrogen (N) fertilization likely would make the system even more productive and profitable.

Geographic area: Louisiana
Keywords: fertilization, phosphorus, competition, stand development

Sedjo, Roger A. 1997. The economics of forest-based biomass supply. Energy Policy, 25 (6): 559-566.

This paper undertakes a preliminary exploration into the economics of generating energy from forest-based biomass. The study assesses the feasibility of greatly expanding the share of total energy consumption in developed countries that could be economically satisfied by biomass without fiscal subsidy support, given current technologies, and with plausible potential technologies ten years into the future. The study briefly considers the environmental effects of biomass usage compared with fossil fuels. Since wood has uses both as fuelwood for energy and as industrial wood for wood products, the comparative economics of these alternative uses are examined.

Geographic area: Worldwide
Keywords: forest economics, forest-based energy competitiveness of forest-based biomass

Robin P. Silverstein, Dan Loeffler, J. Greg Jones, Dave E. Calkin, Hans R. Zuuring, and Martin Twer. 2006. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels Management—How to Measure Success: Conference Proceedings. 2006 28-30 March; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

The potential for biomass utilization to enhance the economics of treating hazardous forest fuels was examined on the Bitterroot National Forest and surrounding areas. Initial forest stand conditions were identified from Forest Inventory and Analysis (FIA) data and the Forest Vegetation Simulator (FVS) was used to simulate stand growth and development and estimate removed volumes. Harvest and haul cost models were used to estimate stump to mill

costs. Temporal and spatial implications of utilization were examined to identify sustainable quantities and associated costs based on accessibility, haul distance, flow, and quantity of small-diameter material.

Geographic area: Western Montana

Sirois, Donald L., Colin Ashmore. 1986. Design considerations for a roll crusher/splitter for woody biomass. In: Program and abstracts: Fourth Southern Biomass Energy Research Conference; 1986 October 7-9; Athens, GA. Research University of Georgia and TVA/Southeastern Regional Biomass Energy Program: 33. Abstract.

The principal focus of biomass harvesting in the past has been the use of chipping systems to reduce a wide variety of woody materials down to small pieces for easier handling and transporting. However, chipping systems have several short comings that limit their operational environments. For example, a conventional chipping system might not be applicable for harvesting small diameter trees growing in powerline rights-of-ways and energy wood plantations. An alternative to conventional methods of harvesting small diameter trees for energy use is roll crushing/splitting. The concept involves the crushing and splitting of small diameter stems to expedite field drying and to facilitate handling by producing a uniform material for baling or modulating.

Geographic area: Non-descript

Sirois, Donald L., Bryce J. Stokes. 1985. Preparation of wood for energy use. In: Proceedings of the 5th Annual Solar & Biomass Energy Workshop; 1985 April 23-25; Atlanta, GA. Tifton, GA: U.S. Department of Agriculture Research Service. p. 173-174.

This paper presents an overview of sources and forms of raw materials for wood energy use and the types of machines available to convert them to the desired form for boiler fuel. Both the fuel source or raw material, and the combustion furnace will dictate the requirements for the processing system. Because of the wide range of processing equipment available, systems can be designed to meet most wood burning boiler requirements.

Geographic area: United States

Skog, Kenneth E., James Barbour. 2006. Estimating woody biomass supply from thinning treatments to reduce fire hazard in the U.S. West. In: Andrews, Patricia L.; Butler, Bret W., comps. 2006. Fuels Management-How to Measure Success: Conference Proceedings. 28-30 March, 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 657-672.

This paper identifies timberland areas in 12 western states where thinning treatments (1) are judged to be needed to reduce fire hazard and (2) may “pay for themselves” at a scale to make investment in forest product processing a realistic option. A web-based tool - Fuel Treatment Evaluator 3.0 - is used to select high-fire-hazard timberland plots from the Forest Service Forest Inventory and Analysis Program (FIA) database and provide results of simulated thinning treatments.

Geographic area: Western United States
Keywords: fire, fire ecology, fuels management, woody biomass supply, thinning treatments, fire hazard, Fuel Treatment Evaluator 3.0, Forest Service Forest Inventory and Analysis Program (FIA), fuel treatment market model, FTM-West

Skog, Kenneth E., R. James Barbour, Karen L. Abt, E.M. (Ted) Bilek, Frank Burch, Roger D. Fight, Robert J. Hugget, Patrick D. Miles, Elizabeth D. Reinhardt, Wayne D. Shepperd. 2006. Evaluation of silvicultural treatments and biomass use for reducing fire hazard in western states Research Paper FPL-RP-634. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 29 pages.

The purpose of this report is to begin to identify locations in the west where fire hazard reduction treatments have a potential to "pay for themselves" at a scale and over a long enough time to make investment in additional forest product processing infrastructure a realistic option. Treatments analyzed would treat 7.2 to 18.0 million acres, including 0.8 to 1.2 million acres of wildland urban interface area, and would provide 169 to 640 million oven-dry tons of woody biomass (bout 55% of biomass would be from sawlogs). Sixty to 70% of acres to be treated are in California, Idaho, and Montana.

Geographic area: Western United States
Keywords: Hazardous fuel reduction, simulation, FIA data, biomass utilization, harvesting costs, western states

Skog, Kenneth E. Robert Rummer, Bryan Jenkins, Nathan Parker, Peter Tittman, Quinn Hart, Richard Nelson, Ed Gray, Anneliese Schmidt, Marcia Patton-Mallory, Gordon Gayle. 2009. A strategic assessment of biofuels development in the Western States. In: McWilliams, Will; Moisen, Gretchen; Czaplewski, Ray, comps. Forest Inventory and Analysis (FIA) Symposium 2008; October 21-23, 2008; Park City, UT. Proc. RMRS-P-56CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 13 p..

This paper focuses on describing the methods used to estimate forest biomass supply curves and describing selected overall results of the analysis, including information on all forest and agricultural supply sources and maps indicating the estimated location of biofuels plants using cellulosic feedstocks that would include forest biomass feedstocks. The model developed here included information on forest biomass supply curves by county (developed using Forest Service FIA data), agricultural biomass supply curves, transportation networks, and capital and operating costs of selected conversion technologies. Results indicate biofuels could potentially provide between 5 and 10 percent of projected transportation fuel demand in the region with fuel price between $2.40 and $3.00 per gasoline gallon equivalence (gge) excluding local distribution costs and taxes. At a target price of $2.40/gge, forest biomass could supply an estimated 11 million oven dry tons per year, or about 9 percent of total feedstock supplied.

Geographic area: Western United States
Keywords: biofuels, agriculture residues, wood residues, thinnings, grease, herbaceous energy crops, biomass supply estimates, network analysis

Smith, Douglas S. 1979. Legislation and policy influencing wood resource utilization. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 281-284p.

The framework for harvesting and utilization opportunities for forest residues includes a number of long standing as well as recently enacted statutes. Air and water quality standards as set forth in legislation also have an effect on utilization opportunities. A further emerging factor pertaining to the harvesting and utilization of the forest biomass is our land base, and its availability. Recently the Senate has enacted a number of bills dealing with the question of timber economics.

Geographic area: United States
Keywords: residues utilization, forest policy, legislation

Snell, J.A. Kendall, James K. Brown. 1980. Handbook for predicting residue weights of Pacific Northwest conifers. Gen. Tech. Rept. PNW-103. USDA Forest Service Pacific Northwest Forest and Range Experiment Station.

Procedures are given for estimating weights of potential residue from Douglas fir and western hemlock. Preliminary estimates are given for six other species. Estimates are provided in pounds per tree and pounds per square foot of basal area for a 6 or 8 inch top. Estimates are also separated into less than 3 inch DBH and greater than or equal to 3 inch DBH. Tabular weigths include foliage, live and dead branchwood, and non-merchantable top.

Geographic area: western Oregon and western Washington
Keywords: Biomass, residue weights, conifers, weight tables

Snider, G., P.J. Daugherty, and D. Wood. 2006. The irrationality of continued fire suppression: an avoided cost analysis of fire hazard reduction treatments verses no treatment. Journal of Forestry. 104 (8): 431-437.

This study shows that without large-scale implementation of fire hazard reduction treatments, the costs of uncharacteristic crown fires in southwest forests will continue to increase. They examined the economic rationality of continuing this policy of emphasizing fire suppression activities over restoration-based fire hazard reduction treatments. They compared treatment plus fire suppression costs to the cost of fire suppression without treatments over 40 years for southwestern forests. This avoided-cost analysis estimates the amount one could invest in treatments to avoid the future cost of fire suppression.

Geographic area: southwest United States
Keywords: economics, restoration, avoided cost, fire, fire hazard redution

Stephenson, Everett H. 1989. Flail debarking: A historical perspective and review of current technology. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, “Harvesting Small Trees and Forest Residues”; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 162-169.

This paper provides an overview of the concept, development, and technology of flail debarkers.

Geographic area: United States

Stokes, Bryce J. 1992. Harvesting small trees and forest residues. Biomass and Bioenergy, 2(1-6): 131-147.

Eight countries collaborated and shared technical information on the harvesting of small trees and forest residues in a three year program. Proceedings and reports from workshops and reviews are summarized in a review of activities

and harvesting systems of the participating countries. Four databases were developed for harvesting and transportation of these materials.

Geographic area: Canada, Italy, New Zealand, Norway, Sweden, Switzerland, United Kingdom, United States
Keywords: Harvesting; residues; forest biomass; transportation: databases

Stokes, Bryce J., Douglas J. Frederick, Dennis T. Curtin. 1986. Field trials of a short-rotation biomass feller buncher and selected harvesting systems. Biomass 11(3): 185-204. Great Britain: Elsevier Applied Science Publishers, Ltd.

Sycamore has high promise as a short-rotation fiber and energy species on better quality sites in the Southeastern United States. There have been few studies on operational harvesting systems for hardwood plantations. A continuous-speed felling and bunching prototype machine was evaluated in harvesting a three-year-old, short-rotation sycamore plantation. A small tractor, grapple skidder, and large chipper were evaluate along with the prototype machine as complete harvesting systems. Prediction equations, production rates, and costs were developed for each component of the systems.

Geographic area: Southeast United States
Key words: Biomass, yield, production, harvesting

Stokes, Bryce J., Timothy P. McDonald, Tyrone Kelley. 1993. Transpirational drying and costs for transporting woody biomass - a preliminary review. In: Proceedings of IEA/BA Task IX, Activity 6: Transport and Handling; 1994 May 16-25; New Brunswick, Canada. Aberdeen, UK: Aberdeen University: 76-91.ld, Timothy P.; Kelley, Tyrone. 1993. Transpirational drying and costs for transporting woody biomass - a preliminary review. In: Proceedings of IEA/BA Task IX, Activity 6: Transport and Handling; 1994 May 16-25; New Brunswick, Canada. Aberdeen, UK: Aberdeen University: 76-91.

High transport costs are a factor to consider in the use of forest residues for fuel. Costs can be reduced by increasing haul capacities, reducing high moisture contents, and improving trucking efficiency. The literature for transpirational drying and the economics of hauling woody biomass is summarized here. Some additional, unpublished roundwood and chip drying test results are also included.

Geographic area: Worldwide

Stokes, Bryce J., Donald L Sirois. 1989. Recovery of forest residues in the Southern United States. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, “Harvesting Small Trees and Forest Residues”; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 32-43.

In the mid 1970's, the accelerated price increases for petroleum products forced rapid exploration into and adoption of alternative energy sources. A viable option for the forest industry was the recovery of woody biomass from unmerchantable trees and logging residues. Several studies estimated that an abundance of such forest materials existed in the southeastern United States. Other research concentrated on economical methods of converting forest residues into energy for industrial uses.

Geographic area: Southern United States

Stokes, Bryce J., D.L. Sirois. 1986. Evaluation of chipper-forwarder biomass harvesting concept. In: Proceedings of the Southern Forest Biomass Workshop; 1985 June 11-14. Gainesville, FL. Gainesville, FL: University of Florida. P. 62-67.

A chipper-forwarder system offers an alternative for biomass harvesting. Components are a small feller buncher for felling and bunching, and a chipper-forwarder that chips at the pile and transports the chips to roadside. In a case study on a mixed pine and hardwood site in Georgia after conventional harvesting, production rates and cost estimates for a prototype chipper-forwarder were developed. At forwarding distance of 153 m the cost of chipping and forwarding was estimated to be between $15 and $25 per dry tonne depending on initial investment assumptions.

Geographic area: Georgia

Stokes, B.J., D.L. Sirois, S.L. Woodfin. 1987. Preliminary evaluation of steel-roller round baler for woody biomass baling. In: Proceedings of the 9th Annual Meeting of the Southern Forest Biomass Workshop; 1987 June 8-11; Biloxi, MS. Mississippi State, MS: Department of Forestry; 167-174.

A round hay baler with little modification was used to bale small-diameter, crushed trees. The trees had been crushed using a series of compression rollers. Bale cores had to be developed by hand before the baler became self-feeding. Windrowed material was packed off the ground by the baler system after a core had been developed.

Geographic area: Southeast United States

Stokes, Bryce J., William F. Watson, I. Winston Savelle. 1985. Alternate biomass harvesting systems using conventional equipment. In: Saucier, Joseph R., ed. Proceedings of the 1984 Southern Forest Biomass Workshop; 1984 June 5-7; Athens, GA. Asheville, NC: U.S. Department of Agriculture, Forest Service. p. 111-114.

Three harvesting methods were field tested in two stand types. Costs and stand utilization rates were developed for a conventional harvesting system, without energy wood recovery; a two-pass roundwood and energy wood system; and a one-pass system that harvests roundwood and energy wood. The systems harvested 20-acre test blocks in two pine pulpwood plantations and in a natural pine sawtimber stand. The one-pass method resulted in the least cost and better utilization of biomass residue.

Geographic area: Alabama

Stokes, Bryce J., William F. Watson, Donald L. Sirois. 1987. Factors affecting power requirements for chipping whole trees. ASAE Paper 87-6012. St. Joseph, MI: American Society of Agricultural Engineers. 10 p.

This study was performed to evaluate some of the factors affecting the power requirements for chipping whole trees in the South for energywood. Results are presented for the effects of tree size, moisture content, and species on power requirements. Large and small in-woods disk chippers were used in field tests to determine the power requirements for chipping whole trees. Hardwood and softwood species were evaluated over a range of diameter classes and moisture contents.

Geographic area: Southern United States
Keywords: power, chipper, whole-tree

Sturos, John A. 1979. Outlook and opportunity for whole-tree chip quality improvement. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 147-158 p.

Three processes have been developed in the United States, one in Canada, and one in Finland for improving the quality of whole-tree and forest residue chips. They have potential application individually or in combination. Two of them have been applied commercially by the pulp and paper industry. Application of these processes coupled with integrated utilization of the various output wood, bark, and foliage fractions for fiber and energy products should promote the recovery of more forest residues.

Geographic area: United States, Canada, Finland
Keywords: bark removal, residues, biomass, utilization, foliage removal

Sturos, John A., Michael A. Thompson. 1989. Harvesting small stems and residues in the Lake States. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 108-117.

This paper presents an overview of several harvesting machines and systems considered new at the time this paper was produced. The systems were being applied in the hopes of improving profitability from harvesting small stems and residues. Productivities and costs typical to the Lake States region are also discussed.

Geographic area: Michigan, Wisconsin, Minnesota

Ter-Mikaelian, Michael T., Michael D. Korzukhin. 1997. Biomass equations for sixty-five North American tree species. Forest Ecology and Management, 97: 1-24.

The paper presents a comprehensive review of the biomass equations for 65 North American tree species. All equations are of the form $M = aD^b$, where M is the oven-dry weight of the biomass component of a tree (kg), D is diameter at breast height (DBH) (cm), and a and b are parameters. Equations for the following tree components were included in the review: total aboveground biomass, stem wood, stem bark, total stem (wood and bark), foliage, and branches (wood and bark). A total of 803 equations are presented with the range of DBH values of the sample, sample size, coefficient of determination R^2, standard error of the estimate, fitting method used to estimate the parameters a and b, correction factor for a bias introduced by logarithmic transformation of the data, site index and geographic location of the sampled stand(s), and a reference to the paper in which the equation (or the data) was published. The review is a unique source of equations that can be used to estimate tree biomass and/or to study the variation of biomass components for a tree species.

Geographic area: North America
Keywords: Author Keywords: Aboveground biomass; Stem wood biomass; Stem bark biomass; Foliage biomass; Branch biomass; Dry weight

Thompson, Jason. 2003. Productivity of a tree length harvesting system thinning ponderosa pine in Northern Arizona. In: Proceedings of the 2003 council of forest engineering 26th annual conference. Bar Harbor, Maine: University of Maine, New England Regional Council on Forest Engineering: 5 p.

A productivity study was performed on a tree length harvesting system thinning a Ponderosa pine stand in Flagstaff, Arizona investigating opportunities to lower the costs of fire hazard reduction treatments in over stocked stands. The harvesting system consisted of a Hydro-Ax 421 E rubber tired feller-buncher with a shear head, a Caterpillar 528 grapple skidder and a Denharco 4400 stroke delimber mounted on a Caterpillar 320C base. Detailed time study was used to gather productivity data for all machines in the harvesting system. This paper presents the results of the study including a description of the stand, study methods and productivity equations for each machine.

Geographic area: Arizona

USDA Forest Service 2005. A strategic assessment of forest biomass and fuel reduction treatments in western states Gen. Tech. Rep. RMRS-GTR-149. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 17 p.

This article assesses how forest biomass can be utilized with and the implementation of fuel reduction and ecosystem restoration objectives of the National Fire Plan for the Western United States. Both public and private forests are assessed in the region including standing tree volume with additional data on stem, limb and top volumes. Operational systems to conduct the treatments and their affects on the ecosystem as well as utilization opportunities and market implications are also discussed.

Geographic area: Western United States
Keywords: assessment, biomass, fuel reduction, inventory

Van Hooser, Dwane D. 1979. Resources evaluation and residue: where we've been and where we're going. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 27-32 p.

In this paper, it is outlined how Resources Evaluation has treated forest residue in the past, what changes have been made recently to more adequately address the forest residue, and finally to consider what changes will have to be made in the future to provide basic input into a forest residue decision model.

Geographic area: Rocky Mountain Region
Keywords: forest inventory, utilization, residues

Van Rees, Ken C.J. 2008. Wood bioenergy systems in Canada. In: Zalesny, Ronald S., Jr.; Mitchell, Rob; Richardson, Jim, eds. Biofuels, bioenergy, and bioproducts from sustainable agricultural and forest crops: proceedings of the short rotation crops international conference; 2008 August 19-20; Bloomington, MN. Gen. Tech. Rep. NRS-P-31. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 62.

This short paper discusses obstacles to woody biomass production in Canadian prairies. Among the obstacles for producer involvement in bioenergy systems is, first of all, changing the farmer mindset that growing a crop for longer than 1 year is not an impediment to earning money. At one time or another, most farmers in the prairies have

removed woody biomass on their farms to increase their capacity for growing crops and are reluctant to go back into "woody" systems. However, the newer generation of farmers may be less reluctant to do so because of an ability to take more risks, a greater environmental consciousness and better education.

Geographic area: Canada
Keywords: woody biomass, farmer perceptions, sustainability

Wade, Dale D. 1969. Estimating slash quantity from standing loblolly pine. Res. Note SE-125. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 4 p.

No significant difference were found between variances of two prediction equations for estimating loblolly pine crown weight from diameter breast height (d.b.h). One equation was developed from trees on the Georgia Piedmont and the other from tress on the South Carolina Coastal Plain. An equation and table are presented for estimating loblolly pine slash weights from either cruise data or harvested cords per acre.

Geographic area: Southeast United States (Georgia, South Carolina)

Watson, W.F., D.E. Miller, B.J. Stokes, M.L. Broussard. 1987. Energy budget for an energywood harvesting system. Proceedings of the Southern Forest Biomass Workshop; 1986 June 16-19; Knoxville, TN. Muscle Shoals, AL: Tennessee Valley Authority. p. 113-116.

The fuel and energy requirements for alternative energywood harvesting operations were determined from field operations. Comparisons were made among the total energy requirements including transportation for conventional operation and one- and two-pass energywood operations. The two-pass energywood operation requlred more energy per green ton than the other operations. Transportation required twice the energy as did the woods operations.

Geographic area: Alabama

Watson, W.F.; J.R. Ragan, T.J. Straka, B.J. Stokes. 1987. Economic analysis of potential fuelwood sources. In: Proceedings of the 1986 Society of American Foresters National Convention; 1986 October 5-8; Birmingham, AL. Bethesda, MD: Society of American Foresters. p. 339-342.

This paper compares fuelwood produced from logging residues and energy plantations on the basis of potential for production and expected costs at the various levels of production. Prospects for improving the production of fuelwood for each source will also be examined.

Geographic area: Southern United States

Watson, W.F., Robert F. Sabo, B.J. Stokes. 1986. Productivity of in-woods chippers processing understory biomass. Proceedings of the Council on Forest Engineering; 1986 September 29 Â– October 2; Mobile, AL. Auburn, AL: Auburn University. P. 69-72.

Productivity and cost per ton are predicted for two in-woods chippers (Norbark 20 and 27) where DBH. species groups, and moisture content are varied.

Geographic area: Alabama
Keywords: Transpirational drying

Watson, Billy, Bryce Stokes. 1994. Cost and utilization of above ground biomass in thinning systems. In: Proceedings of the meeting on Advanced Technology in Forest Operations: Applied Technology in Action; 1994 July 24-29; Portland/Corvallis, OR. Corvallis, Or: Oregon State University: 192-201.

The cost and utilization were compared for a thinning operation removing the stems as roundwood with a flail chipper operation. The flail chipper operation recovered an additional 4.2 tons of acceptable chips per acre which resulted in a higher return to the site. There was little difference in the cost of acceptable chips delivered to the digester between the two methods of thinning.

Geographic area: Louisiana
Keywords: Flail delimbing, debarking, woodlands chipping, logging costs, thinning

Watson, William F., Bryce J. Stokes. 1989. Harvesting small stems -- A Southern USA perspective. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 131-139.

Operations that harvest small stems using conventional equipment are discussed. A typical operation consists of rubber-tired feller-bunchers with shear heads, rubber-tired grapple skidders, and in-woods chippers. These systems harvest the small stems either in a pre-harvest, post-harvest, or integrated-harvest method. This unused forest biomass offered forest products firms an easy substitute for the fossil fuels being utilized at that time.

Geographic area: Southern United States (Alabama)

Watson, W.F., B.J. Stokes, and I.W. Savelle. 1986. Comparisons of two methods of harvesting biomass for energy. Forest Products Journal. 36 (4): 63-68.

This study focuses on two harvesting methods for utilization of understory biomass that were tested against a conventional harvesting method to determine relative costs. The conventional harvesting method tested removed all pine 6 inches diameter at breast height (DBH) and larger and hardwood sawlogs as tree length logs. The two intensive harvesting methods were a one-pass and a two-pass method. In the one-pass method, all material 1 inch DBH and larger was simultaneously harvested. With the two-pass method, the energy wood (same description as in the one-pass) was harvested in a first pass through the stand, and the commercial size wood being removed as tree length logs was harvested in a second pass.

Geographic area: Alabama

Windell, Keith, Sunni Bradshaw. 2000. Understory biomass reduction methods and equipment catalog. 0051 2826. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 156 p.

This report contains the results of numerous interviews, a field survey, and a literature search and discusses fuel reduction equipment and methods that have been tried in the past, those that are currently being used, and those that may warrant consideration in the future. There is also a catalog of equipment suitable to treat landscape areas before prescribed burns.

Geographic area: United States
Keywords: biomass, collection, disposal, Douglas-fir, fuel treatment, handling, management, ponderosa pine, prescribed fire, residues, thinning

Withycombe, Richard. 1979. Applications of a cost model to northern Rocky Mountain residues. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 45-54 p.

Whatever decisions are to be made concerning the possible use of forest residues, questions always arise about the costs of collecting and transporting them to a place where they might be used. The residue cost model consists of a series of seven tables, which allow the estimation of the collection costs of the types of residues common to the northern Rocky Mountains. The cost tables were developed from published studies of both conventional logging and residue collection.

Geographic area: Northern Rocky Mountains
Keywords: residue collection, residue utilization

Withycombe, Richard. 1979. Wood product and market trends influencing residue utilization. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains Symposium Proceedings 1979; November 28-30, 1979, Missoula, MT. GTR-INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, 285-288p.

The potential markets for forest residues can be classified into four primary categories. This paper deals with each of these categories separately, and attempts to indicate some of the major influences which are expected to change the trend of forest residue utilization for each of the potential uses. Of the four major potential uses for forest residues, none offer any immediate prospects for large scale use. We can expect cyclical demand for residues to supplement the material supply to the pulp and paper industry. The rising cost of energy could generate the greatest potential demand for residues.

Geographic area: Northern Rocky Mountains
Keywords: residues utilization, residue markets

Woodfin, Sammy, Doug Frederick, Bryce Stokes. 1987. Selected Harvesting Machines For Short Rotation Intensive Culture Biomass Plantations. ASAE Paper 87-1567. St. Joseph, MI: American Society of Agricultural Engineers. 18 p.

Numerous harvesting machines were evaluated in a series of annual tests on stands of different ages. Several different machines were used to harvest sycamore research plots in south Alabama. The machines varied from manually operated devices and conventional forestry equipment to sophisticated prototypes. This paper documents

the results of these evaluations as well as a rationale for the evolving development of short rotation intensive culture harvesting equipment.

Geographic area: Alabama
Keywords: Forest Engineering, Harvesting Machinery, Woodlots

Wright, Clinton S. and Robert E. Vihnanek. 2009. Estimating the biomass of hand-piled fuels for smoke management planning. Joint Fire Science Program: Project# 07-2-1-57. Boise, Idaho. Available at: http://www.firescience.gov

Dimensions, volume, and biomass were measured for 121 hand-constructed piles composed primarily of coniferous and shrub/hardwood material at sites in Washington and California. Equations using pile dimensions, shape, and type allow users to accurately estimate the biomass of hand piles. Equations for estimating true pile volume from simple geometric shapes and measurements of pile dimensions were also developed to allow users who require estimates of pile volume for regulatory reporting. Biomass and volume estimation equations are being programmed into a web-based calculator to allow users to estimate either value from pile dimensions.

Geographic area: Washington & California

Wynsma, B., R. Aubuchon, D. Len, M. Daugherty, E. Gee. 2007. Woody biomass utilization desk guide. 2400 – Forest Management. Washington, D.C.: U.S. Department of Agriculture, Forest Service, National Technology and Development Program. 84 p.

This paper is intended to be a reference guide to local land managers regarding locating and collaborating with biomass stakeholders. Give suggestions on how to use current National Environmental Policy Act (NEPA) planning tools to start up and maintain a biomass-utilization program and how to use cost-effective sale preparation techniques, including the preparation of timber sale, stewardship, and service contracts to provide increased supplies of biomass. Also looks at the viability of offsetting the costs of hazardous fuels and restoration treatments by utilizing small-diameter trees and other biomass.

Geographic area: United States

Yepsen, Rhodes. 2008. Forest thinning strategies for biomass utilization. BioCycle, 49 (12): 32-36.

This study looks at several projects that are testing new equipment and management practices that treat slash as a marketable commodity. Projects are often combined with research on profitability and best practices to educate loggers to utilize slash from their operations, and to promote use of woody biomass.

Geographic area: Montana

Young, T.M., D.M. Ostermeier, R.W. Mulach, J.D. Thomas, and R.T. Brooks, Jr. 1989. A simulation of harvesting systems for economic supply models. In: Stokes, B.J., ed. Proceedings of the International Energy Agency, Task VI, Activity 3 Symposium, "Harvesting Small Trees and Forest Residues"; 1989 Jun. 5-7; Auburn, AL.: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 170-183.

A harvesting simulation model was developed to estimate average total costs of whole-tree chip harvesting as a function of equipment configurations and stand characteristics. The harvesting simulation model was part of a larger

economic model used to estimate the economic availability of whole-tree chips for 62 potential energy plants in the southeastern United States. The harvesting model described in this paper was used to select a balanced harvesting system for 45 possible stand types.

Geographic area: Southeast United States

Young, Timothy M., David M. Ostermeier, J. Daniel Thomas and Robert T. Brooks. 1991. The economic availability of woody biomass for the southeastern United States. Bioresource Technology, 37: 7-15.

In this paper a deterministic model was developed to estimate the average total cost of producing whole tree chips for energy production. The model estimated harvest, transportation and stumpage costs and total costs were estimated for 62 potential plant sites in the southeast US. The model used a spatial analytical component and GIS to locate potential sites.

Geographic area: Southeast United States
Keywords: woody biomass, energy production, deterministic model, economic availability, average total cost.

Young, Timothy M., James H. Perdue, Andy Hartsell. Robert C. Abt, Donald Hodges, Timothy G. Rials. 2009. A real-time web-based optimal Biomass Site Assessment Tool (BioSAT): Module 1. An economic assessment of mill residues for the southern U.S. In: McWilliams, Will; Moisen, Gretchen; Czaplewski, Ray, comps. Forest Inventory and Analysis (FIA) Symposium 2008; October 21-23, 2008; Park City, UT. Proc. RMRS-P-56CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 22 p.

Optimal locations for biomass facilities that use mill residues are identified for 13 southern U.S. states. The Biomass Site Assessment Tool (BioSAT) model is used to identify the top 20 locations for 13 southern U.S. states. estimates when compared to demand point location based on a county centroid. The top 20 areas identified in the study region are located in south Mississippi, southeast Georgia, southeast Oklahoma, southwest Alabama, and east Texas. Costs in these areas range from $25 to $38 per dry ton for up to 1.5 million annual dry tons. Additional research on BioSAT is forthcoming for 33 eastern U.S. states. These studies will include more types of woody and agricultural biomass (e.g., logging residues, pulpwood, corn stover, etc.). Additional cost models for transportation such as truck combinations with rail and barge will be components of BioSAT.

Geographic area: Southern and eastern United States
Keywords: biomass, economic availability, siting model, BioSAT, mill residues

Zalesny, Ronald S., Jr., Rob Mitchell, Jim Richardson, eds. 2008. Biofuels, bioenergy, and bioproducts from sustainable agricultural and forest crops: proceedings of the short rotation crops international conference. Gen. Tech. Rep. NRS-P-31. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 76 p.

There is a substantial global need for development of biofuels, bioenergy, and bioproducts systems and technologies that can economically and sustainably produce short rotation crops across multiple temporal and spatial scales. Topic areas in these proceedings were biological and environmental; and economic and policy implications of sustainable biofuels, bioenergy, and bioproducts. Presentations addressed anatomy, breeding, genetics, physiology, ecosystem services, phytotechnologies, and production systems, as well as conversion technologies, costs and operational feasibility, environmental impacts and review, social factors, policy issues, and regional logistics.

Geographic area: United States
Keywords: biodiesel, biodiversity, biomass, conservation, crop improvement, ethanol, lignocellulosics, productivity, sustainability, yield

LOG AND MILL RESIDUE PRICE INFORMATION

FOREST PRODUCTS INDUSTRY RESEARCH PROGRAM
BUREAU OF BUSINESS AND ECONOMIC RESEARCH
THE UNIVERSITY OF MONTANA – MISSOULA

The Forest Products Industry Research Program monitors industry operations in Montana and Idaho, Arizona, Colorado, New Mexico, Utah, and Wyoming, and well as Pacific Coast states of Alaska, California, Oregon, and Washington. Research focuses on the forest products industry's size, diversity, and economic impacts providing quantitative evaluations of timber sources and use as raw material, mill production and sales, utilization of mill residues, as well as associated employment and payrolls, and the industry's role in regional, state, and local economies.

Available at: http://www.bber.umt.edu
Contact: todd.morgan@business.umt.edu
Last updated: Continuous

NATIONAL FORESTRY ASSOCIATION AND NATIONAL WOODLAND OWNERS ASSOCIATION (LOGPRICE.COM)

Internet links to log prices for all 50 states.

Available at: http://www.logprice.com
Contact: info@logprice.com
Last updated: February 2009

OREGON DEPARTMENT OF FORESTRY

Species specific sawlog prices by quarter for Oregon.

Available at: http://oregon.gov/ODF/STATE_FORESTS/TIMBER_SALES/logpage.shtml
Contact: Dan Corgan dcorgan@odf.state.or.us
Last updated: January 2009

TIMBER MART SOUTH

Timber Mart-South publishes quarterly and annual reports used by private companies, consultants, landowners, and others to assess market prices in the US South. Timber Mart South has been surveying and reporting timber prices since 1976, and market news since 1996. Quarterly news and prices are available by subscription or by individual issue to provide information on timber market changes in the US South as well as average prices in 22 areas of the southeastern timber markets.

Available at: http://www.tmart-south.com/tmart/index.html
Contact: Tom Harris harris@warnell.uga.edu
tmart@uga.edu
Last updated: Quarterly

USDA FOREST SERVICE NORTHERN REGION
FOREST AND RANGELAND APPRAISAL INFORMATION

The Northern Region timber sale summary reports and regional accomplishments are available on this site. Many of the reports are available on a quarterly basis and are usually posted 20 working days after quarter end.

Available at: http://www.fs.fed.us/r1/forest_range/timber_reports/timbersales.shtml
Contact: USFS Northern Region 406-329-3511
Last updated: Continuous

USDA FOREST SERVICE SOUTHERN RESEARCH STATION
TIMBER PRICES ON THE WEB

Internet links to timber prices, timber selling guidelines, stumpage prices and/or delivered log prices for many states.

Available at: http://www.srs.fs.usda.gov/econ/data/prices
Contact: Jeff Prestemon jprestemon@fs.fed.us
Last updated: July 2008

WOODPLANET

WoodPlanet helps buyers find suppliers and get price quotes, while at the same time allow sellers to move inventory and develop new relationships with buyers. Sourcing Service is a free service that allows buyers to locate suppliers and get price quotes quickly and efficiently. Suppliers may take advantage of a range of free and paid services. WoodPlanet gives sellers of wood products new opportunities to move inventory and develop relationships with buyers.

Available at: http://www.woodplanet.com/woodplanet_home.cfm
Contact: info@woodplanet.com, marketing@woodplanet.com, support@woodplanet.com
Last updated: Continuous

WOOD INDUSTRY SOURCEBOOK WEBSITE

This website is to provides information and tools to forestry entrepreneurs in developing new businesses, sustaining existing enterprises, and developing those business skills that will be necessary to become sustainable enterprises in Southwest forests. The site should also serve as a reference to community collaborative organizations that are striving to develop new economic development strategies revolving around forestry resources in their area. Similarly, economic development agencies may use this as a tool to make decisions. Also to provide technical transfer opportunities that promote the science of healthy forest ecosystems and the acceptable practices for reducing hazardous forest fuels.

Available at: http://www.littlecolorado.net/EntSourcebook/WoodIndustry.htm

BIOMASS UTILIZATION FACILITY LOCATIONS AND RELATED INFORMATION

BIOMASS ENERGY FOUNDATION

Website that discusses new developments in liquid fuels from biomass (especially Biodiesel and methanol), WoodGas stoves, and now increasingly BioChar and Charcoal. Site sponsors are interested and knowledgeable about all aspects of biomass energy, but particularly in high temperature conversion and pyrolysis and gasification that can produce heat, power and fuels. The site is used for research, consulting, publishing and travel activities in the field of biomass and gasification and the Foundation is able and willing to sponsor projects related to these purposes.

Available at: http://www.woodgas.com/index.htm
Contact: Tom Reed TomBReed@comcast.net
Last updated: September 2005

BIOMASS ENERGY RESOURCE CENTER (BERC)

The Biomass Energy Resource Center mission is to assist communities, colleges and universities, state and local governments, businesses, utilities, schools, and others in making the most of their local energy resources. BERC further strives to achieve a healthier environment, strengthen local economies, and increase energy security across the United States through the development of sustainable biomass energy systems at the community scale. BERC's particular focus is on the use of woody biomass and other pelletizable biomass fuels.

Available at: http://www.biomasscenter.org
Contact: http://www.biomasscenter.org/contact.html
Last updated: Unknown

NATIONAL RENEWABLE ENERGY LABORATORY BIOMASS MAPS

These maps illustrate the biomass resources available in the United States by county. Biomass feedstock data are analyzed both statistically and graphically using geographic information systems (GIS). The following feedstock categories are evaluated: crop residues, forest residues, primary and secondary mill residues, urban wood waste, and methane emissions from manure management, landfills, and domestic wastewater treatment.

Available at: http://www.nrel.gov/gis/biomass.html
Contact: http://www.nrel.gov/gis/webmaster.html
Last updated: October 2009

CALIFORNIA BIOMASS ENERGY ALLIANCE

Internet links of location and contact information to 29 biomass-fueled power plant facilities in California, as well as information related to the approximately 80 biomass power plants located in 19 states.

Available at: http://www.calbiomass.org/index.html
Contact: calbiomass@reesechambers.com

Last updated: Unknown

DATABASE OF STATE INCENTIVES FOR RENEWABLE ENERGY (DSIRE)

The DSIRE website provides a fast and convenient method for accessing a wide variety of information about renewable energy and energy efficiency incentives and regulatory policies administered by federal and state agencies, utilities, and local organizations. DSIRE tracks financial incentives for energy efficiency upgrades, purchases of energy efficient products and systems, and construction of new energy efficient buildings.

Available at: http://www.dsireusa.org
Contact: http://www.dsireusa.org/library/includes/GenericContacts.cfm?CurrentPageID=13
Last updated: February 2009

FOREST GUILD

The Forest Guild contains a substantial library of biomass related publications. Research Publications include syntheses of existing literature to answer policy questions. The Guild also conducts novel studies that advance the practice of excellent forestry. See our Research Program page for more information. The Forest Guild practices and promotes ecologically, economically, and socially responsible forestry—"excellent forestry"—as a means of sustaining the integrity of forest ecosystems and the human communities dependent upon them. The Guild engages in education, training, policy analysis, research, and advocacy to foster excellence in stewardship, support practicing foresters and allied professionals, and engage a broader community in the challenges of forest conservation and management.

Available at: http://www.forestguild.org
Contact: info@forestguild.org; Howard Gross howard@forestguild.org
Last updated: Continuous

FUELS FOR SCHOOLS

Fuels for Schools is a collaboration of USDA Forest Service, Idaho, Montana, Nevada, North Dakota, Wyoming, and Utah State Foresters. It is a federal and state partnership to promote and encourage the use of wood biomass as renewable energy in public and private buildings to facilitate the removal of hazardous fuels from forest lands. There are links to financing, funding opportunities and contacts.

Available at: http://www.fuelsforschools.info
Contact:

Idaho: ffsidaho@adelphia.net
Nevada: jperock@forestry.nv.gov
Utah: geoffmcnaughton@utah.gov
Bitterroot RC&D: bitterrootrcd@cybernet1.com
Montana: afarr@mt.gov
North Dakota: thomas.claeys@ndsu.edu
Wyoming: dperko@state.wy.us
Other States:
http://www.fuelsforschools.info/pdf/National_State_Forest_Biomass_Contacts.pdf

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MONTANA MANUFACTURERS INFORMATION SYSTEM

The Montana Manufacturers Information System (MMIS) addresses the geographic disadvantages Montana manufacturers face. The MMIS brings Montana Manufacturers closer to each other electronically, if not physically, by providing detailed and up to date information about each manufacturer's products, processes, and capabilities in one free easily accessible website. In addition the MMIS will help Montana manufacturers locate potential new customers by linking them with worldwide markets. Manufacturers and decision-makers can use the MMIS to identify new markets, new sources of materials, supplies, and services; pursue opportunities to supply products and services now being purchased out of state; locate potential partners for cooperative production, marketing, buying, and shipping; analyze the condition and outlook of Montana's manufacturing industries.

Available at: http://www.mmis.umt.edu
GIS shapefile of Montana mill locations available at:
http://www.mmis.umt.edu/IndList.asp?indcode=1000&Name=Wood,%20paper,%20furniture
Contact: **MMIS@business.umt.edu**
Last updated: Continuous

STATE BIOENERGY PRIMER
(INFORMATION AND RESOURCES FOR STATES ON ISSUES, OPPORTUNITIES, AND OPTIONS FOR ADVANCING BIOENERGY)

This State Bioenergy Primer is designed to bring many resources together that discuss biomass/bioenergy and provide useful, targeted information that will enable a state decision maker to determine if he/she wants or needs more details. The primer offers succinct descriptions of biomass feedstocks (Chapter 2), conversion technologies (Chapter 2), and the benefits/challenges of promoting bioenergy (Chapter 3). It includes a step-wise framework, resources, and tools for determining the availability of feedstocks (Chapter 4), assessing potential markets for biomass (Chapter 4), and identifying opportunities for action at the state level (Chapter 4). The primer also describes financial, policy, regulatory, technology, and informational strategies for encouraging investment in bioenergy projects and advancing bioenergy goals (Chapter 5). Each chapter contains a list of selected resources and tools that states can use to explore topics in further detail.

Available at: http://www.epa.gov/cleanenergy/documents/bioenergy.pdf
Contact: US Environmental Protection Agency, EPA 430-R-09-024
National Renewable Energy Laboratory, NREL/TP-6A2-44688

USDA FOREST SERVICE SOUTHERN RESEARCH STATION
U.S. WOOD USING MILL LOCATIONS

This dataset is based on information collected by mill data managers in Forest Inventory and Analysis (FIA) Units as well as collaborators in the Texas Forest Service, the Forest Products Laboratory (FPL), and the Focused Science Delivery Program of the Pacific Northwest Research Station (details below). The data describe wood-demanding mills of the continental United States. Data is restricted to primary wood processors – those that purchase logs or chips. Secondary processors of wood, such as paper mills that buy market pulp or rely entirely on recycled fiber are excluded.

Available at: http://www.srs.fs.usda.gov/econ/data/mills
Contact: Jeffrey Prestemon jprestemon@fs.fed.us
Last updated: October 2008

US DEPARTMENT OF ENERGY
ENERGY EFFICIENCY AND RENEWABLE ENERGY BIOMASS PROGRAM

The Biomass Program primarily carries out state and regional partnerships through cooperation with the National Biomass State and Regional Partnerships which consists of five Regional Organizations: Coalition of Northeastern Governors Policy Research Center, Council of Great Lakes Governors, Southern States Energy Board, Western Governors Association, and DOE's Western Regional Office. Information resources include listings and links to US state and regional biomass energy programs, information for industry, consumers, researchers, policy-makers and students.

Available at: http://www1.eere.energy.gov/biomass/state_regional.html
Contact:

Great Lakes Regional Biomass Energy Program: http://www.cglg.org/biomass
Northeast Regional Biomass Energy Program: http://www.nrbp.org
Pacific Regional Biomass Energy Program: http://www.pacificbiomass.org
Southeast Regional Biomass Energy Program: http://www.serbep.org
Western Regional Biomass Energy Program:
http://www.westgov.org/wga/initiatives/biomass

Last updated: February 2009

WOOD SUPPLY RESEARCH INSTITUTE

The Wood Supply Research Institute (WSRI) is a joint project of professional loggers, forest landowners, wood consuming mills, educators, and manufacturers that facilitates and funds research to promote and improve efficiency in the wood supply system. WSRI identifies and documents the structure and performance of the current wood supply system and identifies opportunities for improvement; investigates ways to operate more efficiently and cost-effectively; communicates research findings directly to WSRI members; publishes key findings to benefit the entire forest products industry.

Available at: http://www.forestresources.org/WSRI
Contact: tom.reed@plumcreek.com
Last updated: Continuous