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# Synthesis of Knowledge from Woody Biomass Removal Case Studies

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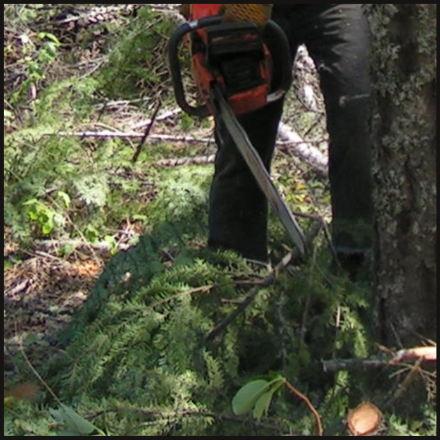
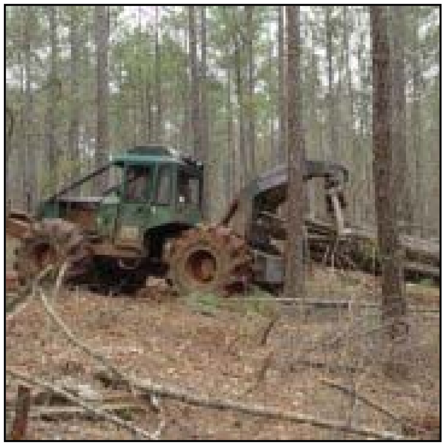
Alexander M. Evans

A SUMMARY OF
KNOWLEDGE FROM THE
Joint
Fire Science
Program







This report would have been impossible without the participation of the land managers and other professionals who submitted case studies and guided the analysis. The Joint Fires Science Program (07-3-2-02) funded the research and publication of this report via the US Forest Service, Region 3.

Detailed information on each of the case studies discussed in this report is available at: http://biomass.forestguild.org. The case studies are also available on compact disc by contacting the Forest Guild.

The cover photo credits: loader from Nate Wilson (1025), log truck from George McKinley (1028), peeled logs from Lomakatsi Restoration Project (1014), logger with chainsaw from Lomakatsi Restoration Project (1014), before and after treatment from Doug Manion (1021), and skidder above from Carl Schmidt (1022).

*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.*

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# 1. Executive Summary

Interest in woody biomass from forests has increased because of rising fossil fuel costs, concerns about greenhouse gas emissions from fossil fuels, and the threat of catastrophic wildfires. However, getting woody biomass from the forest to the consumer presents economic and logistical challenges. Woody biomass is the lowest-value material removed from the forest, usually logging slash, small-diameter trees, tops, limbs, or trees that can not be sold as timber. 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. The case studies are available at http://biomass.forestguild.org.

Seven main themes emerged from collecting and comparing the biomass removal case studies: **objectives**, **collaboration**, **ecology**, **fire**, **economics**, **implementation**, and **regional differences**.

Biomass removal projects tend to combine multiple **objectives** such as ecological restoration, wildfire hazard reduction, forest-stand improvement, rural community stability, employment, and habitat improvement.

**Collaboration**, with both the interested public and contractors, is a key element in successful projects. Stewardship contracting presents a flexible way to develop partnerships and invite constructive public involvement.

The **Ecological** impacts of biomass removals, both positive and negative, need more research. States and non-governmental organizations are creating guidelines for biomass harvesting that may help to protect forests and alleviate concerns about the impact of removals.

**Fire** is the main driver of many biomass projects. In many cases, the goal of biomass removals is to reduce forest fuels and wildfire hazard. Biomass removal provides substantial ecological benefits when it helps to re-establish natural fire regimes.

The **economics** of biomass removal are challenging. The case studies demonstrate that biomass removal projects are rarely a source of income. However, some managers generated a profit by combining multiple forest products in the removal, taking advantage of fluctuations in the biomass market, and selling to established outlets.

The **implementation** of biomass harvests benefit from mechanization as well as dividing the harvesting and handling of forest products among multiple contractors. New technologies were tested in some case studies, and others on the horizon offer the potential for further cost reductions.

The case studies reveal **regional differences** and the importance of designing projects to fit the biophysical conditions and social context of each site.

Taken together, 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 harvest operations—that are present in the management of many forests across the country.

# 2. Introduction

*Biomass being chipped after a fuel reduction project. Photo from Ken Reed ([1020](1020)).*

Removal of biomass material for hazardous fuel reduction or stand improvement is both a key forest management challenge and a significant opportunity for achieving management objectives. Woody biomass has long been a useful but underutilized byproduct of forest management activities. Now rising energy costs, concerns about carbon emissions from fossil fuels, and the threat of catastrophic wildfires have greatly increased interest in using woody biomass from forests. For example, the U.S. Department of Energy (DOE) has set a goal to increase domestic biofuels use from about 2.1 to 51 billion gallons by 2030, and to increase biopower use from about 2.1 to 3.8 quadrillion BTU (DOE 2006). A substantial portion of the biomass needed to fuel this increase in renewable energy may come from forests. In fact, one report estimates U.S. forests could yield 368 million dry tons of useable biomass per year, which is 260 percent of current estimates of woody biomass use (Perlack et al. 2005). Use of wood as a replacement for fossil fuels has the potential to reduce greenhouse gas emissions and contribute to climate change mitigation (Eriksson et al. 2007, Perschel et al. 2007).

Technically, the term woody biomass includes all the trees and woody plants in forests, woodlands, or rangelands. This biomass includes limbs, tops, needles, leaves, and other woody parts (Norton et al. 2003). In practice, woody biomass usually refers to material that has historically had a low value and cannot be sold as timber or pulp. Biomass harvesting might even remove dead trees, down logs, brush and stumps (MFRC 2007). Markets determine which trees are considered sawtimber material and which are relegated to the low-value biomass category. As markets change over time and from region to region, different kinds of material are considered biomass, but in general it is a very low-value product. In some cases, woody biomass is defined by how the material is used. For example, any material burned for energy is defined as biomass (PA DCNR 2008). In this report, the term woody biomass refers to vegetation removed from the forest, usually logging slash, small-diameter trees, tops, limbs, or trees that cannot be sold as higher-value products such as sawtimber.

Even with increasing interest in the utilization of woody biomass, getting it from the forest to the consumer presents economic challenges. In most cases, harvesting and transporting woody biomass is relatively costly because smaller stems have low value by volume and high handling costs, and most forest harvesting systems were originally designed for larger-diameter timber.

Across the country, forest managers have risen to the challenge and have developed a wide variety of strategies, funding sources, and prescriptions for removing biomass. The 45 case studies collected for this report provide a snapshot of the successful strategies managers have used to remove woody biomass from the forest as well as important lessons they have learned. These case studies focus on the forest side—the planning, harvesting, gathering, and transporting—of biomass removal. There are a number of other resources that provide insight into different aspects of woody biomass removal, including:

- Catalogues of small-diameter-utilization case studies, e.g., *Small Diameter Success Stories* Vol. I, Vol. II, Vol. III (Livingston 2004, 2006, 2008).
- The technological side of biomass use for energy, e.g., *Where Wood Works* (Bihn 2007) and *Wood Chip Fuel Specifications and Procurement Strategies for New Mexico* (BERC 2006).
- Assessments of woody biomass supply, e.g., Coordinated Resource Offering Protocol (CROP) and Loeffler et al. 2006.
- Wildfire hazard reduction treatment planning, e.g., Fuels Planning: Science Synthesis and Integration (USFS 2004a).

The case studies come from parks, conservation lands, private forests, state lands, and federal ownerships. Each case study focuses on the project level and details silvicultural prescriptions, harvesting techniques, products, markets, and prices. The synthesis of these case studies provides insight into successful strategies as well as potential pitfalls. The results paint a picture of the state of biomass removals in the U.S. and provide land managers with examples of how to implement wildfire hazard reduction and stand improvement strategies using biomass removal and utilization.

*Low-quality logs removed with a cable skidder. Photo from Jeff Smith (1034).*

# 3. Case Studies

Throughout this report, case studies are referenced with an index number and linked to the case study webpage within the biomass.forestguild.org website. The website allows users to search by project location, forest type, products generated, type of contract, primary treatment objectives, and land tenure. The following annotated list provides a brief introduction to the individual case studies by region.

### *Northeast Region*

- Forest Savers LLC, VT (1006) – The landowner cancelled this thinning project because of a worsening financial climate. The contractor planned to use a novel mulching machine.
- Harvesting for Community Wood Energy, VT (1007) – Vermont Family Forests helped create this collaborative Fuels for Schools project.
- Yale School Forest, CT (1011) – The landowner removed firewood and sawtimber for silvicultural objectives.
- Clover Hill Tree Farm, VT (1013) – Stand rehabilitation was facilitated by biomass utilization at an existing energy plant, though the landowner had some concerns about the effect of biomass removals on soil, nutrients, and site productivity.
- Whole Tree Chipping on Delectable Mountain, VT (1032) – Foresters took advantage of a low-grade market when it was available in order to remove low-grade material and improve overall quality of the residual forest.
- Townsend State Forest, MA (1035) – This forest-stand improvement thinning was used as a demonstration of biomass harvesting.
- Residual Stand Problems after a Whole Tree Harvest, NH (1044) – A post-harvest evaluation demonstrated the potential problems with whole tree harvesting, including cutting unmarked trees and damage to crop trees.

### *Central Hardwoods Region*

- Maple Regeneration Sale, PA (1012) – FORECON, Inc. combined sawtimber and biomass removal for silvicultural objectives.
- Forest Improvement Harvest, WV (1031) – The landowner took advantage of a market for biomass in order to accomplish his goal of improving the quality, vigor, and commercial desirability of the remaining trees.
- Thinning in an Ozark Forest, MO (1043) – This case study was based on research comparing the costs and impacts of mechanized versus hand felling in a crop tree management thinning.

### *Great Lakes Region*

- Biomass Thinning in Jack Pine, MN (1003) – The Nature Conservancy used biomass removal to achieve habitat restoration objectives.
- Study of Biomass Bundling, MN (1042) – A collaborative team including the Institute for Agriculture and Trade Policy, the University of Minnesota, the University of Wisconsin-Stevens Point, and the U.S. Forest Service conducted a field test of various biomass harvesting techniques using the state biomass harvesting guidelines.
- Shovel Logging in Tornado Salvage, WI (1045) – A severe storm forced loggers to take a creative approach to harvesting windthrown trees.

### *Southeast Region*

- Biomass Removal for Red-Cockaded Woodpecker Habitat, GA (1022) – A Wildlife Refuge removed biomass to improve habitat and used sawtimber to help carry the sale. Prescribed fire was integral to the project goals.
- Biomass in Land Conversion, NC (1023) – This case represents an activity most land managers want to avoid: conversion from forest to another land use. Biomass removal was a side product of the land conversion, not the driver.

*Before and after biomass removal in North Carolina. Photo from Nate Wilson (1025).*

- North Carolina State University (NCSU) Mulcher Test, NC (1024) – NCSU tested the efficiency of the Fecon FTX440 in chipping small-diameter trees.
- Whole Tree Chipping on Private Land, NC (1025) – This project shows how biomass removal can help generate a profit from thinning operations, or at least break even.
- Whole Tree Chipping on the Talladega NF, AL (1041) – Researchers from the U.S. Forest Service tested the efficiency of whole tree chipping for biomass removal in loblolly and longleaf pine.

### *Southwest Region*

- Rancho de Jicarita, NM (1004) – A private landowner navigated changing markets and government incentives in a continuing restoration effort that has spanned decades.

- Juniper Extraction, NM (1016) – The operator used a novel implementation of an excavator to extract juniper in order to test the potential wood supply for a proposed biomass-to-energy facility.
- Las Vegas Watershed, NM (1017) – This municipal project demonstrates the difficulties of implementing biomass projects, including administrative problems, steep slopes, and broken machinery.
- P&M Plastics Collaborative Forest Restoration Project, NM (1026) – The Collaborative Forest Restoration Project is an example of innovative funding mechanisms to support biomass removal.
- Fire Risk Reduction / Forest Restoration Treatment, AZ (1030) – Northern Arizona University researchers helped ensure that this treatment accomplished both restoration and wildfire hazard reduction objectives.
- White Mountain Stewardship Project, AZ (1036) – The purpose of this stewardship project was to thin 150,000 acres of primarily small-diameter ponderosa pine trees, emphasizing wildland urban interface (WUI) areas surrounding communities in the White Mountains of Arizona. Three case studies from the project include:
    - Eagar South WUI Fuel Reduction Project (1037) – This project focused on harvesting ponderosa pine and has produced sawtimber for a lumber mill and chips for a pellet mill.
    - Los Burros Ecosystem Management Area (1038) – Though the purpose of this project was to reduce hazardous fuels and restore forests, the number of acres ready for treatment far exceeds the available treatment funding.
    - Nagel Forest Health Project (1039) – A significant part of this project was in a replanted burn area which became a monoculture of ponderosa pine in need of restoration to improve habitat and wildfire hazard.
- New Mexico Forest and Watershed Restoration Institute Case Studies, NM (1040) – Biomass removal in Sugarite Canyon State Park had a very high treatment cost per acre, in part because there was no biomass market.

***Interior West Region***

- Clancy Fuel and Bug Pile Removal, MT (1018) – The Bureau of Land Management (BLM) used a stewardship contract to remove piles that threatened to create either bark beetle or smoke problems.
- Arkansas Mountain Stewardship Project, CO (1020) – The BLM and a local coal-fired power plant worked together to facilitate the use of woody biomass in the power plant.
- Transportation Corridors Fuels Reduction Stewardship Project, ID (1029) – The organization Framing Our Community helped incorporate community energy into this biomass project.

### *Pacific West Region*

*Landing piles utilized for biomass chips. Photo from Mike Bechdolt (1010).*

- Point Reyes National Park Eucalyptus Removal, CA (1001) – Invasive species management in this park required biomass removal.
- Manzanita Lake Campground Thinning, CA (1002) – Public outreach built acceptance of biomass removal as part of restoration, even in a national park.
- Collins Pine Elam Thin, CA (1005) – A sale from 1998 demonstrates the Collins Pine Company's long-term program to pay for small-diameter removals through utilization and subsidies from sawtimber sales.
- Building Markets for Western Juniper, OR (1008) – A project within the Gerber Stew Stewardship Contract where the contractor found a new market for clean western juniper chips.
- Thinning Mixed Conifer Stands, OR (1009) – The second case study from the Gerber Stew Stewardship Contract where biomass utilization was an alternative to a mulching treatment.
- Utilization of Landing Piles, OR (1010) – A third case study from the Gerber Stew Stewardship Contract where paying to have material trucked long distances (up to 250 miles) was beneficial from a smoke management perspective.
- Penny Stew Stewardship Contract, OR (1014) – The Lomakatsi Restoration Project used this project as an opportunity to move from conflict over forest management to collaboration and sold a wide variety of products to established and new markets.
- Boulder Creek Stewardship Demonstration Project, OR (1015) – Another Lomakatsi Restoration Project harvest which was unusual because it actively managed a late successional reserve and maintained community support.
- Fuel Reduction on Private Land, CA (1019) – A private landowner sold chips from a fuel reduction project to help cover the costs. The treatment appears to have changed the behavior of the Whitmore Fire.
- Sidwalter Wildland-Urban Interface Project, OR (1021) – Fuel reduction on the Warm Springs Reservation, as exemplified by this case study, has reduced harvest costs over time and maintained a strong link to the tribal energy production facility.
- Weaverville Community Forest, CA (1027) – Using a stewardship contract model, this project focused on community collaboration and produced a wide array of products, from sawlogs to chips to firewood to wreaths.

- Boaz Forest Health and Small Diameter Utilization Project, OR (1028) – Community involvement and support helped this project survive a year's delay due to threatened and endangered species concerns.

### ***Alaska***

- Biomass for Energy in Interior Alaska, AK (1033) – Although this project is still in the planning phase, it presents a way for communities to use abundant forest resources to replace costly fossil fuel.
- Woody Biomass for Village Heat, AK (1034) – An isolated Native community has proposed replacing fossil fuel with woody biomass for heating.

*Before and after treatment at Lassen Volcanic National Park. Photo from Jon Arnold (1002).*

# 4. Methods

To build the case studies collection, the Forest Guild reached out to its national network of foresters and natural resource professionals, along with its federal, tribal, and local partners. We gathered examples from a wide array of ecosystems, removal methods, and agencies. The case studies cover a broad range of project objectives, treatment techniques, and prescriptions.

We assembled an advisory council of land managers, academics, line officers, representatives from non-profit organizations, and administrators to advise the project. The advisory council helped select case studies from a larger list initially assembled by the Forest Guild, identify the key variables to measure in each case study, and extract the key aspects of planning and implementation that led to a project's success. Based on our consultation with the advisory council, we constructed a consistent set of descriptive variables to analyze the case studies (see Appendix I – Project Variables). Variables were designed to capture the key facets of a wide range of biomass removal project types. All the variables were not applicable to every case study. For instance, fuel-reduction objectives would not be a concern in northern hardwoods forests unlikely to experience fire.

Seven main themes emerged from a review of the case studies. Each of these themes is discussed in more detail in Sections 5 through 11, with reference to specific case studies by index number in parentheses, which in the digital version of this document link directly to the case study webpage.

### Themes

***Objectives* –** Woody biomass removal projects tend to have multiple objectives such as ecological restoration, fire hazard reduction, forest-stand improvement, rural community stability, employment, and habitat improvement.

***Collaboration*** – Collaboration, with both the interested public and contractors, is a key element in successful woody biomass removal projects.

***Ecology*** – Ecological concerns about biomass removal remain, but few projects incorporate monitoring to allay those concerns.

***Fire*** – Fire is a key element in biomass removal projects located in ecosystems where fire is an important natural disturbance.

***Economics* –** Although some biomass removal projects are able to generate a profit or at least break even, most projects must be subsidized. Contractors, utilization markets, haul distances, and the mix of removed products all affect profitability.

***Implementation*** – Many biomass removals rely on hand felling and traditional skidding operations, although machines designed for biomass removal are beginning to move from the experimental phase to everyday operations and may make future projects more efficient.

***Regional Differences*** – Regional differences in biomass utilization and objectives reflect both forest type and ownership variations across the country.

# 5. Objectives

Woody biomass removal projects almost always have multiple objectives. Biomass utilization is typically secondary to objectives such as ecological restoration, fire hazard reduction, forest-stand improvement, and habitat improvement.

- Biomass removal projects often involve multiple benefits in addition to their primary objective (1001, 1005, 1006, 1009, 1018, 1027, 1028, 1029, 1030, 1033).
- Many biomass removal projects are driven by silvicultural objectives, such as increasing the growth of the remaining crop trees (1005, 1011, 1012, 1013, 1025, 1031, 1032, 1035).
- Woody biomass removal from forests can be a crucial part of ecological or habitat restoration (1002, 1003, 1010, 1015, 1022).

The multifaceted nature of most biomass projects sets the stage for many of the other themes discussed below. For example, because biomass removal projects have multiple objectives, many require more than one contractor (see Section 10 Implementation: Multiple Contractors) or may be able to take advantage of multiple funding sources (see Section 6 Collaboration: Multiple Funding Sources).

Although much attention has been focused on biomass removals where the main purpose is fuel reduction, it is important to recognize that many projects are driven by silvicultural or restoration aims. Forest managers often want to remove small-diameter or otherwise low-value trees to increase the growth of the remaining trees or to permit new seedlings to grow. These silvicultural objectives are easier to achieve when markets and infrastructure reduce the cost of biomass removals. Restoration objectives are often required with biomass removal where fire is the dominant disturbance regime (see Section 8 Fire), but in some cases the objective may be to grow bigger trees faster to replicate late successional forest conditions as soon as possible (e.g., 1015).

*Before and after treatment in eucalyptus. Photo from Alison Forrestel (1001).*

## 6. Collaboration

Collaboration, with both the interested public and contractors, is a key element in successful woody biomass removal projects.

- Contractors or loggers can be partners in creating workable biomass removal projects (1002, 1008, 1009, 1014, 1015, 1026, 1045).
- Some projects are successful because of early and direct public participation, especially in areas with a history of conflict (1004, 1014, 1015, 1018, 1026, 1027, 1028, 1029).
- Sufficient funding may require combining multiple funding sources (1002, 1008, 1009, 1017, 1028, 1036, 1038).
- Stewardship contracting is a flexible tool for biomass removal (1008, 1009, 1010, 1014, 1015, 1017, 1018, 1020, 1027, 1029, 1036, 1037, 1038).

### *Contractors as Partners*

Biomass removal projects, because of their complexity, novelty, and potential for conflict, greatly benefit from collaboration. As mentioned above, the contractor can make or break a biomass removal project: "Forestry workers represent a skilled workforce that will likely be the foundation of any significant fuel-reduction program" (USFS 2005a). Projects can help to train and support loggers. For example, the Lomakatsi projects in Oregon (1014, 1015) and the Framing Our Community project in Idaho (1029) invested resources in training new workers and supporting existing workers with employment opportunities. The P&M Plastics Collaborative Forest Restoration Project in New Mexico (1026) is an example of a project that faced challenges because of a workforce in need of training. Biomass removal projects may face more workforce problems than standard timber harvests because fewer contractors are willing to tackle the difficulties of moving high-volume, low-value material (i.e., 1008). In areas with well-trained and efficient workers, projects can become partnerships between land managers and contractors. For example, when the BLM's Klamath Falls Resource Area proposed a slash mastication treatment for a mixed-conifer thinning project, it was a contractor who suggested and ultimately implemented a biomass removal and utilization project.

### *Public Participation*

The public plays an important role in biomass removal projects. While their involvement is more important for public than private lands, the wood energy project in Lincoln, Vermont, demonstrates the importance of public engagement across land tenures (1007). Another example of the benefits of public engagement comes from the Clancy, Montana, project (1018). Even though the project was not profitable in an economic sense, public support for biomass utilization helped keep the project going and may help create enough momentum to build a market for biomass utilization in the Helena Valley. Collaboration can also bring intangible benefits to managers and organizations, such as building trust, new attitudes, shared knowledge, new policies, and improved job satisfaction (USFS 2004a).

In regions with a history of conflict, public participation in projects can make the public feel more comfortable with forest management decisions. More than 300 people toured the Boaz project in Oregon (1028), which helped allay fears that the project would not adequately protect a threatened species of salamander. Both the Boaz project and the Penny Stew Stewardship Contract, also in Oregon, included partners, such as the Klamath-Siskiyou Wildlands Center, that had previously used litigation to stall or cancel other forest management projects. In an analysis of Healthy Forests Initiative projects in southeastern Oregon, substantial public participation was linked with project success (Evans and McKinley 2007). The White Mountain Stewardship Contract's success is due in part to collaborative relationships between the U.S. Forest Service and the community (Abrams and Burns 2007).

### *Multiple Funding Sources*

Many of the projects on public lands used a mix of funding sources to accomplish their objectives. BLM projects were able to combine money allotted for fuels reduction, forestry, and fire to remove and utilize biomass (1009, 1010, 1020). Other project funding included the National Fire Plan (1001, 1002, 1030), the U.S. Forest Service Resource Advisory Committees (1002, 1028), the Healthy Forest Restoration Act (1021), the Secure Rural Schools and Community Self-Determination Act (1028), a county resource conservation district (1027), and the Federal Emergency Management Agency (1017). Another localized funding source, the Collaborative Forest Restoration Program based in New Mexico (1026), may soon have a national counterpart through the Forest Landscape Restoration Act, S. 2593 (FLRA). FLRA would establish a program at the U.S. Forest Service and the U.S. Department of the Interior to carry out collaborative ecological restoration treatments for priority forest landscapes.

### *Stewardship Contracting*

On BLM and U.S. Forest Service land, stewardship contracting provides a new and flexible tool for biomass removal. While other sources provide a more detailed assessment of stewardship contracting (e.g., Abrams and Burns 2007 and Davies et al. 2008), it has become central to biomass removals on federal land. Stewardship contracting is well suited to biomass removals because it allows the integration of several objectives into a single plan. While timber sale contracts tend to focus on a single product, stewardship contracts can include both sawtimber as well as biomass (Abrams and Burns 2007). Because stewardship contracts can span multiple years and can focus on "best value," they can help support the development of local infrastructure for biomass removal.

Perhaps the most important aspect of stewardship contracting is collaboration. Stewardship contracting "directs the U.S. Forest Service and the Bureau of Land Management to collaborate with their neighboring landowners, interested community members and business leaders to develop forest and watershed restoration projects that meet the needs of the community, the agencies and the land" (Davies et al. 2008). A number of the case studies combine stewardship contracting with public participation (1014, 1015, 1027).

# 7. Ecology

Ecological concerns about biomass removal exist and few projects incorporate monitoring to allay those concerns.

- Ecological concerns about biomass removal exist (1013, 1028, 1036, 1044).
- Biomass removal from forested sites can serve as a tool to promote ecological restoration (1001, 1003, 1014, 1015, 1022, 1030).
- Few projects monitor ecological impacts beyond anecdotal information on soils (1008, 1026, 1030, 1042, 1044).
- New guidelines for biomass harvesting are being created to protect ecosystems and allay fears about removal of forest biomass (1042, 1043).

*A ponderosa pine stand after a restoration treatment. Photo from Alex Finkral (1030).*

### *Concerns about the Impact of Biomass Removals*

Biomass removal projects continue to raise concerns about ecological impacts, in part because of increased demand for biomass utilization. Forest managers and the public have expressed concern that removal of more biomass from forests could impact site quality or nutrient status (e.g., 1013). One older project (1005) and several more recent projects (1025, 1027, 1042) suggest that responsible biomass removals can be conducted without noticeable soil or site-quality impacts. Another concern is the spread of invasive species and noxious weeds. Invasive plants and animals can be carried in by harvest machinery or take advantage of the harvest disturbance (1031, 1008).

Almost every case study in this analysis contained some element of ecological restoration, watershed management, or habitat improvement. In some cases, the restoration element was limited to reducing the potential for uncharacteristic wildfires, and hence the consequential negative ecological impacts of severe wildfires. However, few projects reported rigorous ecological monitoring. This may be due to the fact that most projects had only recently been completed or that our focus was on collecting operational rather than ecological case studies. Projects on federal lands must conduct an analysis of environmental impact under the National Environmental Policy Act (U.S. Congress 1969). Some projects on federal lands go beyond requirements to investigate the impacts of their treatments. For example, the BLM's Klamath Falls Resource Area is working with academics to understand the impacts of biomass removals, particularly from woodlands (1008). More data of this sort on ecological impacts, or lack thereof, will be needed to help increase acceptance of woody biomass removal from forests.

### *Scientific Literature on Impacts of Biomass*

The following review of scientific literature on the impacts of biomass removals presents an overview of important areas of research. Most ecological concerns about biomass harvests focus on dead wood, soil compaction, nutrient loss, plants, or wildlife (Reijnders 2006). Dead wood (including coarse woody material (CWM), fine woody debris, and snags) plays an important role in the ecosystem, providing everything from wildlife habitat to carbon storage. A brief review of recent research suggests that responsible harvesting practices, such as those outlined in Minnesota's biomass guidelines (MFRC 2007), can remove woody biomass without significant impacts on dead wood. For example, a recent study on the Superior National Forest in Minnesota showed that the experimental biomass harvest had a small effect on the number of snags or on the amount of CWM (1042, Arnosti et al. 2008). In addition, across the seven test sites where snags were measured, only three sites had a lower number of snags after harvest (Arnosti et al. 2008). Reductions in CWM were small (≤ 2 tons per acre) and one site showed an increase in CWM (Arnosti et al. 2008). However, other treatments have shown a possible decrease in the average length of large logs that offer habitat for wildlife (McIver et al. 2003).

It appears that the impact of soil compaction can be limited by good harvest layout and use of appropriate vehicle types. A study of impacts from fuel reduction in northeastern Oregon showed minimal effects (1.4 percent of the site) on soil compaction (McIver et al. 2003). A U.S. Forest Service study estimated that 70 acres of thinning in western forests yield about the same amount of sediment as 1 acre consumed in wildfire (USFS 2005a). The amount of compaction and the time it takes soil to recover from compaction are driven by soil type (USFS 2005b).

*Coarse woody material in a hemlock/hardwood forest in Connecticut. Photo from Zander Evans.*

Nutrient loss is a concern in biomass harvests because dead wood slowly releases nutrients back to the soil and the forest (Johnson and Curtis 2001, Mahendrappa et al. 2006). However, there are few analyses of the effects of removals on nutrient levels. A report on impacts of biomass harvesting from Massachusetts suggests that with partial removals (i.e., a combination of crown thinning and low thinning that removes all small trees for biomass and generates from 9 to 25 dry tons per acre) stocks of calcium, the nutrient of greatest concern, could be replenished in 71 years, which is less than the stand rotation (Kelty et al. 2008). Minnesota's biomass guidelines present data that show soil nutrient capital is replenished in less than 50 years even under a whole-tree harvesting scenario (Grigal 2004, MFRC 2007). A study from Denmark indicates that harvesting of whole green trees can have a short term (four year) negative impact on site productivity of the remaining stand because of reduced availability of nitrogen, phosphorus, and potassium (Nord-Larsen 2002). When harvested trees were left in the stand for one growing season, there were no growth impacts (Nord-Larsen 2002). Nitrogen fixation in CWM is an important source of this limiting element in both terrestrial and aquatic ecosystems (Harmon et al. 1986). About 6 percent of carbon stored in forests is in dead wood while about 11 percent is stored in forest floor litter (USEPA 2007).

Biomass removal can affect tree seedlings and regeneration as well as other plants. Removal of slash after a harvest can also increase deer browse on tree seedlings (Grisez 1960) and diminish conifer seedling survival (McInnis and Roberts 1994). Slash removal can change species composition and reduces species richness of liverworts and mosses (Åström et al. 2005). Mastication of biomass material can reduce richness of native understory species, though this effect can be mitigated through prescribed burning (Kane et al. 2006). Fungi depend on dead wood for nutrients and moisture and, in turn, many trees rely on mutualistic relationships with ectomycorrhizal fungi (Hagan and Grove 1999).

Wildlife impacts depend on specific species requirements, making generalization difficult. Changes in forest structure will benefit some species while harming others, although where biomass removal is part of a restoration project, it will generally benefit wildlife (Bies 2006). Research in the Pacific Northwest suggests that encouraging "understory development, large trees, overstory diversity, and dead wood structure (snags, large logs) will generally benefit wildlife diversity" (Lehmkuhl et al. 2002). However, CWM reductions may negatively impact salamanders (Butts and McComb 2000), and deer mice abundance declined in one study (though ground squirrels, long-eared chipmunks, and brush mice were unaffected) (Amacher et al. 2008). Other species-specific studies show relatively small wildlife impacts. Research into the effects on shrews (Moseley et al. 2008) and mole salamanders (Moseley et al. 2004) in coastal-plain loblolly pine forests showed little impact of CWM removal (as a surrogate for biomass removals) on either organism. A study in a southern Appalachian upland hardwood forest showed no significant impact of mechanical understory reduction or burning on amphibian or reptile abundance or diversity (Greenberg and Waldrop 2008). Slash removal may also negatively impact ground-active beetles (Gunnarsson et al. 2004), though leaf litter arthropods were not significantly affected by fuel reduction treatments in the Sierra Nevada (Apigian et al. 2006).

The existing scientific studies cover a very small range of the potential impact of biomass removals, and more research is needed to adequately analyze the vast range of forest types and ecological conditions (Mallory 2008, Titus et al. 2008).

### *Biomass Harvesting Guidelines*

Because of the increase in woody biomass removals from forests, many states and certifying bodies are creating new guidelines or updating existing standards. Maine, Minnesota (1042), Missouri (1043), Pennsylvania (1012), and Wisconsin have all released recommendations for biomass harvests, while other states including Maine, Wisconsin, and Michigan are currently developing guidelines. These guidelines focus on the amount of CWM left on site, wildlife and biodiversity, water quality and riparian zones, soil productivity, and silviculture. For example, Minnesota guidelines recommend to “leave all pre-existing CWM and snags possible” and to “retain and scatter tops and limbs from 20 percent of trees harvested” (MFRC 2007). Pennsylvania's guidelines suggest leaving 15 to 30 percent of harvestable biomass as CWM (PA DCNR 2008), while Missouri's guidelines suggest 30 percent (MDC 2008). Pennsylvania and Minnesota suggest leaving all snags possible and Missouri recommends 6 snags per acre in upland forests and 12 per acre in riparian corridors.

Certification organizations are also recognizing the rising importance of woody biomass removals. The Forest Stewardship Council’s (FSC) standards for the U.S. are currently under revision and changes related to biomass harvesting are under consideration. The FSC national standard covers much of the same ground that other biomass guidelines do, although at a more general level since they are nationwide. The FSC’s standards contain sections on wildlife habitat, dead wood, and retention, all of which affect biomass harvests. The Sustainable Forestry Initiative has also begun a revision process during which the review committee will assess whether additional guidance is needed for woody biomass harvests. A summary table that compares the elements of biomass guidelines is in Appendix II – Summary Table of Biomass Guidelines.

## 8. Fire

*Prescribed fire in Sequoia National Park. Photo from Eric Knapp.*

Fire hazard reduction drives biomass removal projects in most fire-adapted forests. The unprecedented scale and cost of recent wildfires across the Western U.S. have drawn public attention to the problem of unnaturally dense forests that may soon ignite. There is a widespread push to reduce fuels—live and dead biomass—that have accumulated during many years of fire suppression policies. In addition to the basic desire to reduce fire hazard, the case studies demonstrate the impact of fuels treatments on fire behavior, the importance of prescribed fire in maintaining fuel reduction benefits, and potential fire related co-benefits of biomass utilization.

- The case studies provide some anecdotal evidence that biomass removals can alter fire behavior (1019, 1026).
- Prescribed fire can be important to maintain the fuel reduction benefits provided by biomass removals (1003, 1022, 1030).
- Reductions or offsets of smoke and carbon emissions may help justify biomass utilization projects (1010, 1018, 1030).

### *Treatment Effects on Fire Behavior*

In two case studies biomass removals were followed by wildfire. The Whitmore Fire in California was moving through the crowns until it reached an area on private land that had been thinned. When the fire reached the thinned stand, it dropped to the ground and fire fighters were able to get the blaze under control (1019). When the Ojo Peak Fire in New Mexico ran into a treated area, the running crown fire dropped to the forest floor and continued through the understory, consuming slash before it returned to the crown upon exiting the treated area (1026). Both of these examples provide anecdotal information based on reports from fire fighters and forest managers.

Scientific studies bear out the anecdotal evidence from the case studies. A review of fires on 11 national forests in Arizona and New Mexico found that fire severity in pine-grassland forests was lower in stands where fuel loads had been reduced (Cram et al. 2006). Treated forest stands on the Blacks Mountain Experimental Forest in California also experienced significantly lower fire severity than untreated stands, which experienced almost complete mortality (Skinner et al. 2005). Most of the fuel treatments (about 405 of 480 acres) reduced fire behavior from a crown fire to a surface fire during the Angora Fire in the Lake Tahoe Basin (Murphy et al. 2007). Other research generally supports the idea that biomass removal can lessen the severity of wildfire (Omi and Martinson 2002, Pollet and Omi 2002, Martinson et al. 2003, Lezberg et al. 2008). Modeling and simulation efforts also suggest that treatments are able to reduce fire severity (Fulé et al. 2000, Fiedler and Keegan 2003, Stephens and Moghaddas 2005, Mason et al. 2007, Huggett Jr. et al. 2008, Schmidt et al. 2008).

### *Reintroduction of Fire as a Natural Process*

Almost all of the research mentioned above highlights not just the positive impact of fuel treatments on fire behavior, but the importance of re-introducing fire. Prescribed fire has a strong influence on subsequent wildfire behavior but, perhaps more importantly, the reintroduction of fire is important from an ecological perspective and is a cornerstone of fire-adapted ecosystem restoration (Covington et al. 1997, Allen et al. 2002). The reintroduction of fire, whether prescribed or natural, is crucial to maintaining low-fuel loads and appropriate tree densities (1003, 1022, 1030). Fire is the most cost effective and ecologically appropriate way of maintaining the wildfire hazard reduction benefits of biomass removal. For example, the estimated treatment costs for prescribed fire can be as low as $12 per acre (USFS 2004c). "Wildland fire use" uses naturally ignited fires that occur within pre-designated areas and conditions to accomplish management goals (USFS 2004d).

### *Fire-Related Benefits of Biomass Utilization*

In addition to reducing wildfire hazard and severity, biomass utilization can have both smoke management and carbon benefits. By utilizing woody biomass from fire-adapted forests, managers have more control over the timing and quantity of smoke that is produced. Woody biomass may burn standing in the forest during wildfire or in piles after having been cut in a fuel reduction treatment. Either way, neighboring communities are faced with a potential smoke problem. By removing the material and using it in some way, the smoke can be reduced or eliminated. Two case studies demonstrate the smoke avoidance advantage of using piled biomass (1010, 1018).

*Aftermath of the Ojo Peak Fire in New Mexico. Photo from Kent Reid (1026).*

As concern over greenhouse gases increases and carbon markets become a reality, the carbon emissions from burning biomass will become a greater concern. Utilization of biomass temporarily stores the carbon from woody biomass in products or allows it to be used in place of fossil fuels to generate heat or power. Where biomass replaces fossil fuels in heat or power generation, its carbon is still released but less total carbon is released than if the biomass was burned in the forest and fossil fuels were used to generate the heat or power (Finkral and Evans 2008).

## 9. Economics

Although some biomass removal projects are able to generate a profit or at least break even, most projects included in this report were subsidized. Contractors, utilization markets, haul distances, and the mix of removed products all affect profitability. Common themes include the following:

- Even with existing markets for woody biomass, removal is a cost, not an income source (1001, 1003, 1004, 1006, 1008, 1009, 1010, 1016, 1017, 1018, 1023, 1030).
- Biomass can help generate income or at least break even (1005, 1012, 1013 1019, 1025, 1028, 1031, 1032).
- Combining removal of more valuable products with biomass removal can make projects feasible (1002, 1005, 1011, 1014, 1015, 1022, 1031).
- There are new markets for biomass that have emerged or are hoped for (1008, 1014, 1016, 1020, 1021, 1029).
- Biomass markets fluctuate, so timing sales can be important (1004, 1006, 1011, 1012, 1032).
- As demand for biomass increases, there may be competition for supply and therefore price increases (1007).
- Biomass is sometimes hauled long distances for utilization (1010, 1027, 1029, 1032).
- Insufficient annual funding can be a major impediment to fuel reduction treatments (1036, 1037, 1038, 1039).

*Loading a chip van on a BLM pile removal project in Montana. Photo from Mike Small (1018).*

### *Costs*

Our case studies range from projects that generate an income for the landowners to projects that cost $2,000 per acre. The median cost for projects that did not generate income was $625 per acre. These prices are similar to estimates from 2005 for the cost of bringing woody biomass to the roadside, which ranged from $400 to $1,630 per acre depending on forest type and terrain and had a median value of $680 for gentle slopes (USFS 2005a). Costs for biomass removal in Colorado ranged from as low as $100 per acre where fuels could be left on site to $1,100 per acre where markets for biomass were weak (Lynch and Mackes 2003). Projects that face unusual constraints incur costs on the higher end of the spectrum. For example, a thinning project near Los Alamos National Laboratory in New Mexico cost $6,000 per acre to chip and removed 80 to 120 green tons per acre, in part because of the potential for radioactivity in the chipped material (Bill Armstrong, personal communication). It is important to note that biomass removal costs are notoriously difficult to estimate because there are critical gaps in the data and methods for predicting treatment costs (Rummer 2008), and because treatment costs are driven by unique conditions in each stand (Lynch and Mackes 2003, USFS 2005c).

### *Income Generation*

The case studies represent a wide spectrum of low-grade wood prices: from $0.10 to $40 per ton for chips. Some prices and costs are obscured by separating treatment costs from product sales revenue. For example, on a BLM Klamath Falls Resource Area project in Oregon (1009), the nominal per-acre cost was $345, but the sale of chips generated approximately $64 per acre. Another element in the pricing of biomass removal is the cost of not removing biomass. For some fuels reduction projects, lower firefighting costs may be an appropriate comparison. One study calculated the avoided future cost of fire suppression to be between $238 and $601 per acre in the Southwest (Snider et al. 2006). In the BLM Klamath Falls example, the original treatment proposal had been slash mastication at $266 per acre, which is close to the cost of biomass removal once the value of the chips is subtracted ($280 per acre). The value of avoided fire suppression is just one of a number of potential nonmonetary co-benefits from biomass. Other co-benefits include reduction of smoke emissions (1010, 1018), reduction or offsets of carbon emissions (1030), creation of local jobs and industry expansion (1014, 1015, 1029), and habitat improvement (1002, 1003, 1010, 1015, 1022). A report from the National Renewable Energy Laboratory estimated that biomass power plants created 4.9 full-time jobs for each megawatt of generating capacity (Morris 1999). Where biomass removal is linked to forest-stand improvement, co-benefits include the future growth of crop trees (1005, 1011, 1025, 1031), regeneration harvests, natural regeneration, and avoided costs of planting (1012, 1013, 1032, 1035).

### *Combining Multiple Forest Products in Biomass Removal Projects*

The case studies show that biomass removal is closely tied to harvesting larger, more valuable trees (1002, 1005, 1011, 1014, 1015, 1022, 1031). A technical release from the Forest Resource Association supports this idea: “Income from this type of biomass volume alone is not enough to sustain a logging operation. Biomass is a low-value product or by-product that can add to the bottom line for loggers and increase utilization and return for landowners” (FRA 2007b). This can mean searching for the best price for each product class. In fire-adapted forests, "the ability to separate and market larger-diameter logs for higher-value products is critical to the net revenues or costs of fuel treatments" (USFS 2005a). The combination of low-grade material and high value material is important in fuel reduction treatments because across the Western U.S. over the next five years more than half of the volume removed is likely to be sawtimber (Barbour et al. 2008).

### *Markets*

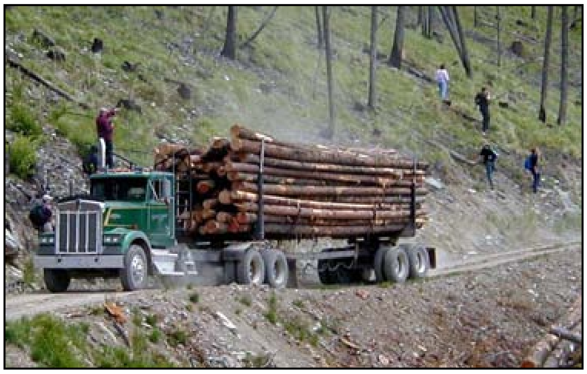
While this report is focused on the forest side of biomass removals and not the utilization side, markets play too strong a role to ignore. Markets for biomass can determine whether or not it is removed from the woods at all (Bowe and Bumgardner 2006). Managers must be aware of existing markets, how markets and prices change over time, emerging markets, and product requirements. Biomass markets fluctuate, so timing sales can be important (1004, 1006, 1011, 1012, 1032, Lynch et al. 2000). Discovering or cultivating new markets for biomass takes both creativity and long-term partnerships. The case studies presented in this report (e.g., 1014) as well as those from the *Small Diameter Success Stories* series (Livingston 2004 Vol. I, 2006 Vol. II, 2008 Vol. III), show that biomass can be utilized for many products, from tipi poles to a component in plastic signs.

One of the most important emerging markets for biomass is energy production. The U.S. as a nation and individual states have set goals to increase the use of renewable energy, which leads to an increased use of woody biomass (DOE 2006, PA DCNR 2008). Using wood for heat and power is attractive because it is renewable, can reduce carbon and other emissions, is less expensive than fossil fuels in some cases, and can be produced domestically as a substitute for imported fossil fuels. How woody biomass markets will evolve remains to be seen. Some wood energy projects have realized their potential to provide a market for low-grade wood, while others have not materialized. For example, the wood-to-energy facility that helped drive the case study Harvesting Juniper with an Extractor in New Mexico (1016) may never be built. Like many wood-to-energy facilities, the facility's construction was hampered by environmental permitting, supply concerns, and the economics of electricity generation. One of the key factors to encourage new markets as well as to ensure the survival of existing markets is consistent supply (GAO 2006).

As biomass markets grow and mature competition for biomass from forests may affect prices. In Vermont, for example, biomass prices have been relatively stable until recently, but high diesel prices have increased demand for low-grade wood. Part of the increase in demand comes from the 27 schools that have converted to woodchip heating over the last 20 years (1007). An analysis of expanded biomass removal in the Western U.S. shows large potential market impacts, but impacts vary by silvicultural practice (i.e., thinning from below or thinning based on stand density index) (Ince et al. 2008). In addition to demand effects on biomass pricing, oil prices have a dual effect on low-grade wood prices. On one hand, price increases in oil products such as heating oil and diesel is an incentive to switch to lower-cost wood heating or power generation. On the other hand, increases in diesel prices add to the cost of cutting, hauling, and processing woody biomass. The net effect of rising oil prices remains unclear.

All markets have product requirements, and managers should be aware of the specifications of each potential buyer. For example, heating and electrical facilities may require a high-grade, clean fuel from sawmill residue or be willing to accept a low-quality hog fuel from miscellaneous woody material (BERC 2006). The price of biomass is directly tied to product specifications. In Minnesota, for instance, bundled biomass has a lower price than an equivalent amount of loose material (1042, Arnosti et al. 2008).

### *Haul Distances*



*Log truck on private land in Montana. Photo from Zander Evans*

While a short-haul distance from forest to utilization lowers project costs, based on our case studies long-haul distances do not necessarily doom a project to failure. For example, projects such as Delectable Mountain, Vermont, sent chips 70 miles and pulp wood 100 miles and was still able to generate a profit (1032). In the West, successful projects such as the Weaverville Community Forest, California, had chips trucked 65 miles (1027), and the Elk City, Oregon, project sent pulpwood 125 miles (1029). Of course, as diesel costs rise, the shorter the haul distance the better for project profitability. A 2008 Minnesota analysis recommends a maximum haul distance of 100 miles (Arnosti et al. 2008). An analysis of Western forests used a price of $30 per dry ton delivered to the mill for chips and chip transport costs of $0.35 per dry-ton-mile to estimate a maximum of 86 miles to break even on hauling cost, exclusive of treatment costs (USFS 2005a). A study in West Virginia found the average haul distance for low-grade wood was 123 miles and the distance to market did not effect the amount of biomass left on site (Grushecky et al. 2007). However, in southwestern Wisconsin long distances to markets meant biomass was left in the woods (Bowe and Bumgardner 2006). Opportunities to minimize hauling costs such as roll-on containers (Livingston 2008 p. 14) and low-cost back-hauls may also be available.

## 10. Implementation

Many biomass removals rely on hand felling and traditional skidding operations, although machines designed for biomass removal are beginning to move from the experimental phase to everyday operations and may make future projects more efficient.

- Many biomass removals rely on hand felling and traditional skidding operations (1001, 1002, 1004, 1006, 1007, 1012, 1026, 1027, 1028, 1029).
- Some of the more profitable biomass removals also tend to be more mechanized operations (1005, 1013, 1025). However, increased mechanization does not guarantee profitability, and stand type influences harvest activities.
- Some projects require multiple contractors, each of whom focuses on a different portion of the project. For example, one contractor cuts sawlogs while another cuts biomass (1002, 1003, 1018).
- New technologies focused on brush removal or mastication (1006, 1016, 1024, 1042) may offer lower-cost biomass removal options in the future but have not yet been integrated into standard operations in these case studies.

### *Mechanization*

The effects of increased mechanization vary with forest type, site factors, and the specifics of the mechanization. In this set of case studies, some of the more profitable operations were also more mechanized (1005, 1013, 1025, 1043). However, increased mechanization is no guarantee of profitability. When harvesting machines are not well suited for small-diameter trees, the cost of mechanized felling is inversely proportional to tree size. For example, a study comparing harvesting costs in a lodgepole pine stand showed a harvester to be $4 per ton more expensive to operate than manual felling (Rummer and Klepac 2002). The same study points out that labor costs are likely to be the largest cost component, so assumptions about and changes in wages are central to overall cost estimates. Another consideration is health and safety of forest workers, which is usually improved by mechanization (NIOSH 2005).

Mechanization must be matched to the stand and well integrated into the rest of the harvesting operation. For example, a full-sized chipper may require significant harvesting capacity, such as multiple cut-to-length teams, to avoid idle time (Bolding and Lanford 2005). Decision support tools that help operators adjust the degree and type of mechanization to the distribution and type of material to be harvested can increase efficiency (e.g., the harvest cost-revenue estimator for the Southwest (Becker et al. 2008) or My Fuel Treatment Planner (USFS 2005d)).

### *Multiple Contractors*

While combining multiple products can help make biomass projects successful, dividing the harvesting and handling of those products may also increase efficiency. In several case studies the project manager hired more than one contractor to take advantage of each contractor's expertise (1002, 1003, 1018). The machines, planning, and implementation of biomass removals can be sufficiently different from traditional timber harvest that the biomass portion of a harvest should be left to contractors who specialize in such operations. In addition, it may be more efficient to schedule biomass and timber removal at different times (FRA 2007a).

### *New Technologies*

New technologies that are designed specifically for biomass removal may reduce the costs of cutting and processing small-diameter material. One case study highlights a brush mulcher specially designed to shred all the smaller underbrush, tops, and slash (1006). Another describes the testing of a mulching system (Fecon FTX 440) combined with a modified corn hopper to collect the chips (1024, see also Small Diameter Success Stories III p. 16). In the Western U.S., mastication is most efficient at fuel loadings of less than 25 tons per acre and where the residual stand has fewer than 100 trees per acre (USFS 2004b). An alterative to chipping or mulching systems is densification of biomass from forests through bundling systems (Arnosti et al. 2008). Other publications have focused entirely on harvesting technologies (Windell and Bradshaw 2000, RE Consulting and Innovative Natural Resource Solutions LLC 2007).

*Feller-buncher harvesting low-grade white pine. Photo from David Paganelli (1013).*

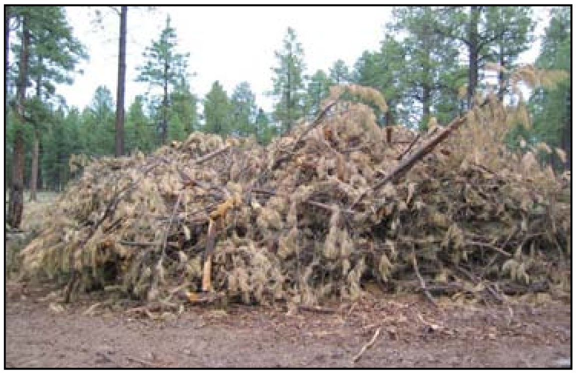
*Biomass removal in ponderosa pine. Photo from Mike Small (1018).*

## 11. Regional Differences

While there are commonalities between biomass removal projects across the country, there are also some important regional differences.

- Stand-development processes differ by forest type and dictate the silvicultural role of biomass removal.
    - In some Eastern hardwoods forests, biomass removals focus on removing poorly formed, diseased, or stressed trees to improve remaining crop trees (1011, 1012, 1013, 1031).
    - While forest-stand improvement occurs in Western coniferous forests (1005, 1009, 1028), the overriding driver for biomass removal is a reduction of fuels.
- The small percentage of public ownership in Eastern forests translates into less public participation in forest management such as biomass removal. However, community involvement can still help insure the success of a biomass project (1007).

Perhaps the most important lesson to draw from regional differences in biomass removal is that project specifics should be driven by the biophysical conditions and social context of each site. Strategies that fit fuel reduction projects in ponderosa pine may be inappropriate for the northern hardwood forests of Vermont.



*Slash pile after a thinning in ponderosa pine. Photo from Zander Evans (1030).*

*The Aquila Power Plant and biomass from BLM project. Photo from Ken Reed (1020).*

## 12. Commonalities of Success

If success is achieving what one sets out to accomplish, then each biomass removal project has a slightly different kind of success. The case studies highlight consistent elements of success across projects, including:

- Early and substantial public involvement.
- Partnerships with efficient contractors.
- Existing markets with favorable prices.
- Mechanization where appropriate to the stand type.

### *Public involvement*

Involving the public early and building support for any harvesting operations, including biomass removal projects, can mean the difference between success and failure. Public participation can help overcome hurdles through support for public funding, responses to specific stakeholder concerns, and strengthening of partnerships and collaborations that are increasingly necessary for effective forest management. In contrast, public opposition can result in costly litigation and delays. Community participation can range from direct involvement of community members in forest management and utilization to general support for biomass removal and utilization. Successful collaboration takes work and a long-term commitment. Other publications provide more detail on building successful collaboration (USFS 2004a).

### *Partnerships with Contractors*

Contractors (i.e., loggers, truckers, and others involved in operations) are key players in any biomass removal project. Projects in areas without efficient and reliable contractors may have to focus on building local capacity before they can become successful. In locations where good contractors are operating, partnerships that ensure their economic survival benefit all parties. The case studies show examples where contractors have identified opportunities to generate income from slash removal as well as examples where the lack of skilled workers caused the project to fail.

### *Markets*

Projects implemented in an area without existing biomass markets have an additional hurdle to overcome and should be undertaken with the acknowledgment that losses on the initial project may lead to more efficient and financially sustainable projects in the future. Long term relationships with biomass users can help build markets. Recent increases in energy costs, concerns about carbon emissions, and new renewable fuel goals may cause a significant shift in forest biomass markets. Increased use of woody biomass from fuel reduction projects and stand improvement thinnings for heat and power may better offset the cost of forest management.

### *Mechanization*

While increased mechanization is not a guarantee of success, equipment such as feller-bunchers and masticators can help efficiently remove woody biomass or reduce it to chips. In North Carolina, for example, the contractor in one case study received a lower price for woody biomass because his operation did not have the capacity to produce a large enough volume of chips, while in a different case study the contractor was able to generate income even with a 100-mile haul distance by using an array of harvesting machines.

*Chips from a BLM removal of western juniper. Photo from Mike Bechdolt (1008).*

*Hand thinning on a stewardship contract. Photo from the Lomakatsi Restoration Project (1014).*

## 13. Conclusions

The case studies described in this report show that all aspects of biomass removals from forests are evolving. Markets are expanding as new uses are perfected and new energy plants are built. Technology is adapting to the requirements of small-diameter material. More land managers and communities are trying to restore fire-adapted ecosystems. New administrative and regulatory options are available. Collaborative partnerships are more common. More contractors are becoming expert in handling low-grade material. Guidelines are beginning to establish best management practices for biomass removals.

Challenges remain, such as lack of funding, distant markets, and insufficient science to document the sustainability of removals. Building the scientific case for sustainable biomass removals will strengthen harvesting guidelines and help expand public support. While the case studies show the importance of collaboration, they do not provide a step-by-step guide for collaboration. Managers need more tools and opportunities to develop skills for working with the general public, non-governmental organizations, federal agencies, and contractors on both public and private lands. Creating successful landscape-scale, collaborative projects is particularly important since such projects can provide economies of scale, stimulate rural economies, re-establish natural fire regimes, and reduce the risk of uncharacteristic wildfire.

The solutions for successful biomass removal are as varied as the forest types where projects occur or the objectives land managers seek to achieve. This report has identified building blocks for successful biomass projects, elements that can be encouraged in many forests across the country including public involvement, partnerships with contractors, and judicious mechanization of harvest operations. Rising oil prices, carbon concerns, wildfire hazard reduction requirements, and interest in renewable fuels may help expand markets and thereby expand the number of forests where biomass removals are profitable.

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## 16. Appendix I – Project Variables

- **Project ID**

1 Project name
2 Land ownership
3 Location
4 Forest type

- **Context**

5 Is this project a part of a landscape plan?
6 In a wildland urban interface (WUI)?
7 Acreage treated
8 Type of contract
9 Funding source
10 Collaborators and partners
11 Project start date
12 Project completion date

- **Treatment Goals**

13 Restoration, watershed or habitat improvement
14 Reduce fuel load
15 Firebreak
16 Salvage
17 Forest stand improvement

- **Treatment specifics**

18 Primary treatment objective
19 How does biomass removal fit with other objectives?
20 Treatment description
21 Description of contractors
22 Travel distance for contractors
23 Type of equipment used
24 Treatment of residual slash if any
25 Treatment cost per acre
26 Trucking costs

- **Utilization**

27 Products from project
28 Price for products
29 Date of sale
30 Did biomass markets exist before the project?
31 Type of utilization
32 How well did the woody biomass match the utilization options?
33 Distance to utilization

- **Treatment guidelines**

34 Diameter limit
35 Basal area reduction
36 Crown coverage
37 Fuel loading
38 Retention guidelines
39 Treatment of snags and downed logs
40 Soil impacts
41 Other ecological impacts monitored

- **Pre treatment data**

42 Fuel load
43 Stem density (stems/ac)
44 Basal area (ft$^2$/ac)
45 Canopy closure (%)
46 Height to live crown base
47 Snags and downed woody material
48 Size class distribution
49 Tree species composition
50 Presence of invasive species
51 Soil and other ecological data

- **Post treatment data**

52 Fuel load
53 Stem density (stems/ac)
54 Basal area (ft$^2$/ac)
55 Canopy closure (%)
56 Height to live crown base
57 Snags and downed woody material
58 Size class distribution
59 Tree species composition
60 Presence of invasive species
61 Soil and other ecological data

## 17. Appendix II – Summary Table of Biomass Guidelines

| | ME | MN | MO | PA | WI | FSC |
|---|---|---|---|---|---|---|
| **Dead Wood** | | | | | | |
| Coarse woody material | √ | √ | √ | √ | √ | √ |
| Fine woody material | √ | √ | √ | √ | √ | √ |
| Snags | √ | √ | √ | √ | √ | √ |
| **Wildlife and Biodiversity** | | | | √ | | |
| Wildlife | √ | √ | √ | √ | √ | √ |
| Sensitive wildlife species | √ | √ | √ | √ | √ | √ |
| Biodiversity | √ | √ | √ | √ | √ | √ |
| Plants of special concern | √ | √ | √ | √ | √ | √ |
| Sensitive areas | √ | √ | √ | √ | √ | √ |
| **Water Quality and Riparian Zones** | | | | | | |
| Water quality | √ | √ | √ | √ | √ | √ |
| Riparian zones | √ | √ | √ | √ | √ | √ |
| Non-point source pollution | √ | √ | √ | | √ | √ |
| Erosion | √ | √ | √ | √ | √ | √ |
| Wetlands | √ | √ | √ | √ | √ | √ |
| **Soil Productivity** | | | | | | |
| Chemical (Nutrients) | √ | √ | √ | √ | √ | √ |
| Physical (Compaction) | √ | √ | √ | √ | √ | √ |
| Biological (Removal of litter) | √ | √ | | √ | √ | |
| **Silviculture** | | | | | | |
| Planning | √ | √ | √ | √ | | √ |
| Regeneration | | √ | | √ | √ | √ |
| Residual stands | √ | √ | √ | √ | √ | √ |
| Aesthetics | | | √ | √ | √ | √ |
| Post operations | √ | √ | √ | √ | √ | |
| Re-entry | | √ | √ | √ | | |
| Roads and skid trail layout | √ | √ | √ | √ | √ | √ |
| **Disturbance** | | | | | | |
| Insects | | √ | √ | √ | √ | √ |
| Disease | | | √ | √ | √ | √ |
| Fire | | √ | √ | √ | | √ |
| Fuel reduction | | √ | | √ | | √ |
| Pesticides | | √ | √ | | | |
| Invasives | | √ | √ | √ | | |
| Conversion from forest | | | √ | √ | | √ |

For more information see http://www.forestguild.org/biomass.html