Western Forest Health and Biomass Energy Potential

A Report to the Oregon Office of Energy

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5209 York Road
Alexandria, Virginia 22310

April 2001

PRINTED ON RECYCLED PAPER

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Foreword

The Western Biomass Consortium is pleased to endorse this thoughtful and important discussion of forest health and its link to biomass energy development.

The wildfires that swept the West during the summer of 2000 bore witness to the results of a failed decades-long fire suppression policy. Western state governments and the federal government are developing initiatives such as the federal fuel management program to try to reduce the dangers of catastrophic fire as quickly as possible.

This manuscript is especially timely because community awareness of fire dangers and the increasing cost of energy is high. After careful reading, one comes away with an understanding of the policies that created our present difficulties and the options available to us to address them. The issue of forest health is many faceted: it affects air and water quality and streamflow, greenhouse gas emissions, wildlife habitat and conservation. There is no easy resolution to the contentiousness inherent in efforts to establish new ways to deal with western forests.

Biomass energy development offers a synergistic opportunity to improve forest health while reducing the enormous costs of forest treatment. At the same time, increased biomass energy usage will reduce American dependence on foreign fossil fuels.

The authors of this manuscript provide a significant analysis of past problems as well as present opportunities to address those problems, with case studies of actual and proposed programs to develop biomass energy production facilities in the West.

We are grateful to the Oregon Office of Energy for enabling us to complete this publication. We believe that it is a useful addition to the dialogue around forest health. Its information makes for a better understanding of issues and positions.

Barbara Charnes, Executive Director
Western Biomass Consortium
Denver, Colorado

Acknowledgments

The authors thank Barbara Charnes and the members of the Western Biomass Consortium, who have not only encouraged this work but provided invaluable technical reviews as it went along. We are also indebted to the USDA Forest Service's Forest Products Laboratory in Madison, Wisconsin, and the DOE National Renewable Energy Laboratory in Golden, Colorado, which provided financial and technical support to an earlier white paper that has been incorporated into this study for the Oregon Office of Energy.

For providing review comments and data, we indebted to Bob Allen, Barbara Charnes, Nils Christoffersen, Lance Clark, Steve Jolley, Bob Judd, Tad Mason, Susan LeVan, Pat Perez, Howard Rosen, John Sheehan, Mark Yancey, and John White

For providing guide service, local expertise, and insight into Oregon conditions, we thank Dan Bishop, Jim Brown, Lance Clark, Noel Colby-Rotelle, Bruce Dunn, Gordon Foster, Mike Hayward, Walt Jennis, Russ Layne, Gary Lettman, Larry McCulgin, Brian Nelson, Doug Robin, Paul Service, Diane Snyder, John Szymoniak, and Rick Wagner.

If, in spite of all this good help, errors and deficiencies remain, they are ours, not theirs.

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Executive Summary

Large areas of Western forests need treatment to reduce flammable fuels. Without such reduction, these forests are likely to experience wildfires that threaten people, communities and the environmental integrity of the forests themselves (NCWD 1994, US GAO 1999, USDA Forest Service 2000). Time is short. Every year these forests remain untreated, fuel continues to build up and heightens the risk that the next ignition will become a catastrophic wildfire. The fires of the summer of 2000 sent a clear message: Something must be done, and the sooner the better. However, two significant obstacles remain: How do we effectively mobilize the necessary action? What should we do with all of the biomass that needs to be removed from at-risk forests?

Significant related federal action has taken place over the past year, and, in the case of Oregon, a major federal-state cooperative effort has been launched that addresses forest health issues. This report documents some of the forest conditions in the West and cites some of the studies that are available to people who wish to further pursue forest health issues. Also discussed are general energy issues tied to forest health and the role they play in any attempt to enlarge the biomass energy industry. Finally, this study looks at two areas of Eastern Oregon to provide a general sense of the amount of forest fuels that may exist there and the possibility that those fuels could be directed into biomass energy facilities.

The report's general conclusion is that significant opportunities exist to link forest health treatment and biomass energy production, but several obstacles must be successfully addressed before biomass energy developers are likely to move into the region. The obstacles to forging a link between forest health treatments and the biomass energy industry stem from two interlocking problems that require simultaneous solution. First, to make biomass fuel delivery feasible, forest managers must have a viable market within reasonable distance that pays an adequate price. Second, to assure payback of large initial investments, investors in energy production facilities must have a reliable fuel source at prices that allow competitive production over a long enough period. Today, neither of these situations exists.

The challenge for decision makers, then, is to bring energy policy and land management together to focus on a regional situation. Billions of dollars are at stake, as are the futures of hundreds of forest-related communities. In the past, these communities depended heavily on federal timber management policies, and they are now undergoing massive adjustments as federal timber harvests are reduced without associated forest activities or jobs to replace them. Also at stake is the health of millions of people and millions of acres of Western forests. Forests overloaded with stressed, dying trees will burn at some point, most likely in the near future.

Other values are at stake as well. Water from forested mountain watersheds is an extraordinarily valuable commodity in much of the West. Altered watersheds that no longer provide the normal quantity or quality of water impose hardship and cost on the region. On the other hand, restored and well-managed watersheds could confer equally significant benefits. Air quality is already well below thresholds desired for public health (primarily because of the amount of fossil fuels burned in the transportation sector) and cannot tolerate the additional pollutants that would result from a return to fire-based management of the region's forests and woodlands.

The situation cries out for a thoughtful, coordinated approach to new policy that addresses forest management, environmental regulation and energy supply. Such an approach is difficult at best—and is made even more difficult by the fact that the Western situation is larger than any state or local jurisdiction but is only one small part of the federal policy arena. With no clear "fit" between the scope of the problem and the reach of the political institutions available to address it, the current situation in the West challenges the United States in ways that are, perhaps, unprecedented. With exceptional challenge, however, often comes exceptional opportunity.

The exceptional opportunity in this case is to create a brighter environmental future, showing the way toward a future less dependent on imported and limited petroleum and more reliant on domestic, sustainable, renewable energy supplies. That future requires additional research and development, as well as policy support to break free of past economic limits. It offers a partial solution to forest problems that seem otherwise intractable.

From this limited study, we are convinced that the potential for breaking through the forest health-biomass energy gridlock is as promising in Eastern Oregon as anywhere in the West. Clearly, it will require more detailed studies than were possible in the brief period available for this general overview. Improved forest inventories on private lands, major changes in federal forest policies and better economic analyses of energy facility locations are all indicated. Many such efforts are under way, spurred by the sense of urgency created by the fires of 2000. The primary question, perhaps, is whether the current interest and momentum can be maintained should the next few years experience fewer wildfire problems or if other policy items capture the agenda. The problems and potentials, as outlined in the following report, will not go away. The authors hope that neither will the political will to develop solutions.

Part I—Forests and Biomass

Introduction

Millions of acres of forest and woodland in the Western United States have been historically shaped by fire. (Agee 1993 and 1990; Arno and Wakimoto 1988; Covington et al. 1994). Whether induced by lighting or by humans, fire once was the primary means of recycling carbon and nutrients for many forests of all kinds. European settlement and the introduction of grazing, farming, mining, forestry, and fire suppression greatly changed forest systems accustomed to fire regimes, and they underwent a long, slow buildup of woody biomass (Clark and Sampson 1995; Covington and Moore 1994; Everett et al. 1993). In the absence of fire, undergrowth and small trees thrived. Such additional growth in the forest was welcomed for many years as a sign of management success (Langston 1995).

In recent years, however, the toll of fire suppression on the ecosystems has become evident. Plant communities too dense for the moisture and nutrient conditions of a particular site compete with each other for limited resources. When the competition becomes excessive during dry spells, major diebacks occur (USDA Forest Service 1996). Native insects and diseases are usually the agents of death, but the stress of competition is an underlying cause (Sampson et al. 1994). As mortality rates increase, so do the flammable fuels. In many Western climates—characterized by dry summers and cold winters—biological decomposition is too slow to offset the fuel buildup (Harvey 1994). As more living and dead fuels are present, both in larger landscape patches and in the vertical structure of the forest, any ignition in dry weather is likely to result in a major wildfire (Anderson and Brown 1988; Covington et al. 1997). Absent any treatment to remove the fuel buildup, fires are inevitable (Sampson 1999). The fuels have no other route for recycling, and they accumulate until they are removed or burned.

Where fuel loads are high and fuel structures continuous, the result is intense fire that often behaves so violently that suppression may be impossible. Such intense fires kill plant communities that were historically tolerant of milder fires, and their heat causes serious and often permanent soil damage (Borchers and Perry 1990; Cromack et al. 2000; Neuenschwander and Dether 1995; Sampson and DeCoster 1997).[1] Recent research suggests that areas of extreme heat and damage are becoming a larger percentage of the total affected area within a forest fire perimeter (USDA Forest Service 1996; Covington et al. 1997).[2]

In addition to their on-site impacts, these wildfires impose enormous public and private costs. In 1994, the Forest Service spent close to $1 billion on fire suppression activities; in 1996, the figure was in excess of $835 million (USDA Forest Service 1997). Because there are homes and communities scattered throughout much of this territory, it was estimated that about one-third of these expenditures went toward trying to save private property from destruction (USDI/USDA 1995). The smoke from these wildfires affected air quality for weeks, producing more $PM_{2.5}$ (fine particulate) pollution in a few weeks in 1994 than all the nation's diesel engines and smokestacks emitted for the entire year (Core 1995).

Treatment to return forests to a more fire-tolerant condition—consistent with their historical development—usually involves removing excess fuels and introducing prescribed fire when conditions allow low-intensity burns (Arno 1995; Arno and Brown 1991; Biswell 1989; Oliver et al. 1994; Thomas and Agee 1986; USDI/USDA 1995; Mutch 1994). Although treatment approaches are fairly well known for most conditions, treatment is often absent because the material to be removed has low economic value, at-risk landscapes often cover prohibitively large areas, and many areas lack road access (Sampson 1997).

Federal land managers face an additional barrier to forest treatment in the form of groups opposed to harvesting or road building on federal forests. The federal government owns and manages 70 percent of the forest and woodlands in the West (Powell et al. 1993). Many federal lands have been designated as parks, wilderness or reserves, making them off-limits to vegetative manipulation. Such legal distinctions limit preventive treatment, but they do not change the wildfire hazards or the risks a system faces if it burns too severely. The problem of fuel buildup in Western federal forests poses an enormous policy dilemma to the federal government.

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[1] While soil damage has seldom been featured as a long-term fire effect, the increasing amount of fuels involved has brought attention to the fact that some areas may be damaged in ways that will affect long-term ecological functioning. See also Giovannini 1994, McNabb and Cromack 1990 and Sampson 1997.

[2] In their findings, the Assessment Team for the Interior Columbia Basin Study said, "The threat of severe fire has increased; 18% more of the fires that burn are in the lethal fire severity class now than historically." (Quigley et al., p. 181)

The fact that Western forests face a health[3] problem from fuel buildup is extensively documented. No universal agreement exists about a cure, but it is reasonably clear that a broad consensus supports identifying and treating high-priority areas. Some experts propose using hazard-risk models to identify high-priority areas and guide public debate. Several such models are in development across the West.[4]

In general, hazard-risk models help identify areas where there is high probability of ignition and where vegetative conditions will support high-intensity wildfires that put people, property and environmental values at risk. In many cases, the highest priority areas identified for treatment using hazard-risk models are those associated with the wildland-urban interface (Davis 1989), key watersheds that serve municipal water supplies or critical stretches of habitat for endangered fish such as Pacific salmon. Often, these are areas where existing roads and access combine to produce less public controversy about treatment than would occur for less-accessible areas.

What remains to be addressed, however, is the enormous problem of what to do with all of the material that results from reducing an area's fuel load (Nijhuis 1999). Although some of the material to be removed in a forest-health project may be saleable on local markets, much of it is not.[5]

On private forestlands, the value of biomass for energy is too low to cover the cost of gathering and hauling it to market. Owners may be willing to produce biomass fuel as part of a timber harvest where sawlogs, pulp and biomass can be combined. This allows some of the costs of biomass disposal to be written off and offers a least-cost way to achieve forest health goals. Private forest owners' decisions will be shaped by the technical information they receive from professional foresters and by the cost involved. If these owners can receive anything close to break-even prices, the result seems likely to be a significant biomass supply from the private lands of the region.

Forest treatments on federal lands raise political problems as well as economic, but the political climate of inertia regarding such treatment may be changing. In October 2000, the Forest Service released a major study that notes the agency will follow an executive order by collaborating with others to analyze the economic feasibility of increasing the use of biomass (USDA 2000). In addition, the Biomass Research and Development Act of 2000 (PL 106-224) provides a legislative mandate for the USDA and the U.S. Department of Energy to cooperate on policies and procedures that promote research and development leading to the production of biobased industrial products, such as fuels and chemicals. Under the act, applicants can earn grants, contracts and financial assistance for conducting research to improve the conversion of biomass into biobased products, for developing technologies that would result in cost-effective and sustainable industrial products, and for promoting the development and use of agricultural and energy crops for conversion into biobased fuels and chemicals. Also important is the inclusion within the FY 2001 appropriations bill of a major new $250 million fund for the Forest Service and the Department of the Interior to carry out fuel management activities.

This new federal emphasis on forest health and biomass development could have a significant impact in the West. For example, forest health problems in Eastern Oregon led Oregon Governor John Kitzhaber and Mike Dombeck, Chief of the Forest Service, to create the Blue Mountains Demonstration Area (BMDA) on June 30, 1999. The goal is to coordinate efforts so that ecosystem restoration will be accelerated in the Blue Mountains in a manner that benefits local communities and unites land managers and scientists in a cooperative effort across the landscape.

In both of the Oregon cases outlined in Part III, but particularly in Grant County, it appears that the single most important factor is not the amount of fuel physically available but the ability of the USDA Forest Service to carry out the kinds of forest treatments that would make that fuel available to a biomass energy facility. The fuels are there; the ability to deliver them in necessary quantities, over a long enough period of time, is not. Whether the new emphasis created by the 106th Congress and the creation of the BMDA

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[3] In this report, "forest health" means a sustainable, more fire-tolerant forest condition and the elimination of unnatural woody biomass accumulations that have resulted from fire suppression in the past.

[4] One of the early efforts to develop wildfire hazard-risk models was completed on the Boise National Forest, as described in Boise National Forest 1996. The approach was expanded in Sampson et al. 2000.

[5] In Arizona, Wallace Covington and his co-workers removed 58 tons of non-merchantable biomass per acre before they felt the ponderosa pine site had been properly prepared for a prescribed fire that would mimic historic fires; that is, the prescribed fire would not kill the large trees they were trying to save (Covington et al. 1997). They hand-raked around big trees and disposed of the excess material by open burning in a nearby pit. That is possible for a research project, but not feasible for large-area treatment. Moving to field scale treatments will demand methods that can be done with available labor and machines at reasonably low costs, and that can dispose of the material in some way other than open burning so that air pollution does not become the limiting factor.

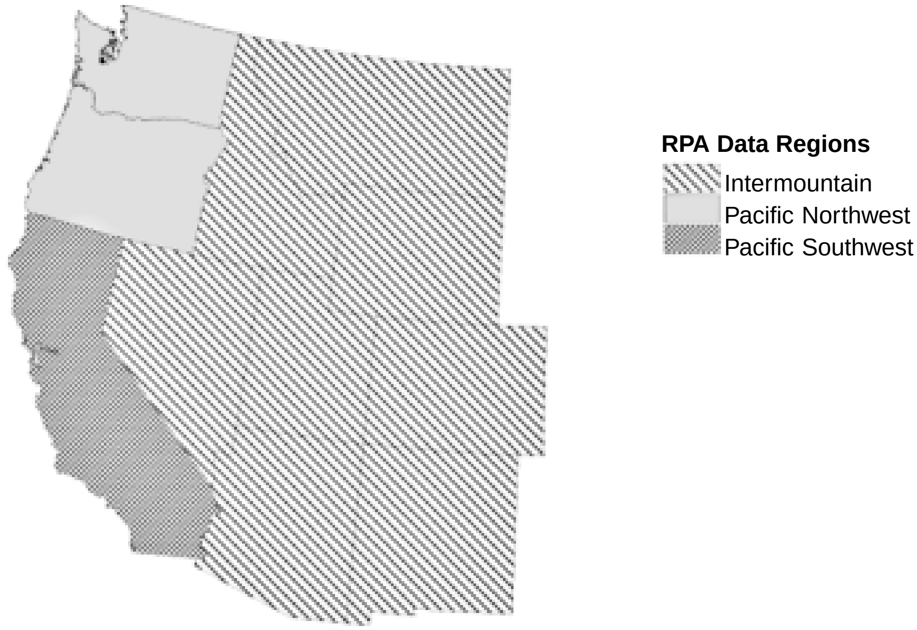

Figure 1.1 Forest resource data provided by the USDA Forest Service is often summarized by regions, as shown above for the Western United States. Note: These are not the same as Forest Service Administrative Regions.

will change that picture significantly is not yet clear, but the signs are at least hopeful.

This report is not a comprehensive attempt to establish the case for increased attention to the health of forests in the West. It is, at best, an overview that touches on a few situations and areas. A comprehensive dataset that ties current forest condition to locations does not exist. As a result, the report demonstrates that some forest types often exhibit a certain set of conditions, but no local conclusions can be drawn until local situations are assessed.

Nor does the report try to develop a prescription for treating specific forests as a means of returning them to a more fire-tolerant and sustainable condition. Those prescriptions must be adapted to the particular circumstances in each forest situation and can only be developed locally by people who understand those places and who must live with the consequences of their actions on the land.

This report will, instead, focus on what can be done to help provide a policy basis for environmentally, socially and economically positive approaches to forest-health problems and biomass development. The major focus is on the various methods through which biomass unsuited for current industrial uses can become a feedstock in energy production. Because much of the available feedstock in the West is on federal lands, the report places some emphasis on USDA Forest Service policy opportunities. However, regardless of land ownership, having excess biomass burned directly as a feedstock for electric power generation or used in the chemical production of biofuels would represent a more positive use than leaving it on the land to fuel a wildfire of destructive intensity.

With the limited data available, it is not possible to say with assurance how much land is in any particular condition, how much of that land should be considered high priority in a hazard-risk analysis, or whether public opinion would support treatment. What we can say with assurance is that hundreds of thousands—if not millions—of forested acres in the West need attention soon. As land managers and local communities struggle with how to respond, it is our hope that reasonable options will be found and that new approaches to biomass energy production have an opportunity to provide some of those options

General Forest Conditions and Wildfire Hazards

In the following discussion, references to “the West” refer to the 11 conterminous Western United States (Figure 1.1). Although generally well understood by the public, this area does not lend itself to easy analysis in terms of forest conditions. Data from the USDA Forest Service, which provides virtually all of the large-area information on forest conditions, are normally broken down by regions (Figure 1.1) (Powell et al. 1993). Those data presentation regions, it should be noted, are not the same as Forest Service Administrative Regions.

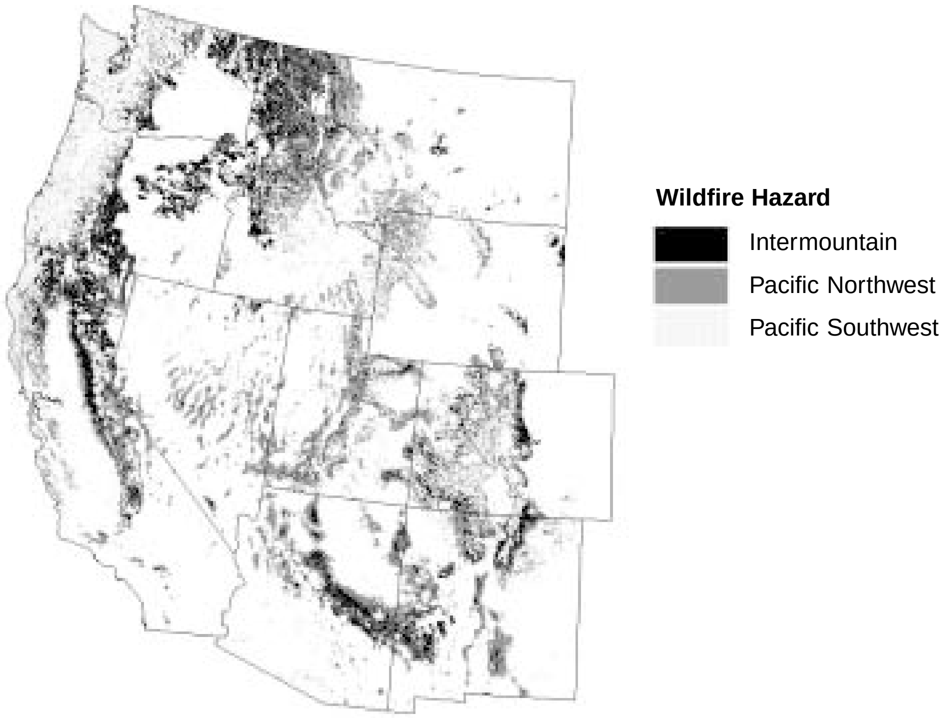

Figure 1.2 General wildfire hazard map of the Western U.S., indicating forest types that are at risk of suffering wildfires outside the historical range of severity (Sampson and DeCoster 1998).

There are anomalies that make these data interpretations a bit difficult at times. One is that Hawaii is included with California in the Pacific Southwest Region (PSW). The inclusion can, at times, influence regional dataset comparisons. We try to minimize that confusion by subtracting the Hawaii data out of the PSW regional data wherever possible.

The second difficulty arises in the Pacific Northwest dataset, which classifies the Douglas-fir forest type as one single type on both sides of the Cascade and Coastal mountain ranges. However, the west-side Douglas-fir is different from that of the east-side Douglas-fir. On the east-side, drier conditions and more frequent fires led to forests of mature ponderosa pine that were maintained as a seral-stage forest on Douglas-fir sites.[6] When those east-side forests are protected from fire, stands of small pines and Douglas-firs create a fuel ladder that supports lethal crown fires. A similar condition does not develop on the warmer, wetter Douglas-fir sites of the west-side forests. There, fire return intervals are much longer, and pure or nearly pure stands of mature Douglas-fir make up many of the highly valued old-growth forests. The fact that both types of forest are shown as "Douglas-fir" on the general forest type maps and in the datasets for Oregon and Washington creates some difficulty in sorting out exactly how much of each type of condition exists.

The final complexity is the enormous range of different conditions under which ponderosa pine occurs in the West. Because it tends to occupy many of the landscapes where settlement impacts have been most prevalent, and because it is one of the forest types that were most dramatically affected by fire suppression, ponderosa pine is one of the forest types of greatest importance in today's forest health concern.

The most pervasive influence on Western forest conditions has been fire exclusion. Its effect has been most pronounced on the forest types that historically experienced a regime of frequent, low-intensity wildfires (Agee 1998). Low-intensity fires once ranged over large areas of Western forests, leaving a patchy forest pattern that altered the effect of subsequent fires. A century of fire exclusion has often resulted in a convergence, or filling-in, of patch structure, so that now large areas are very similar. When wildfire strikes those areas, much larger areas may suffer more uniformly severe effects (Neuenschwander et al. 2000).

[6] A seral-stage forest is one that is held in a temporary or intermediate stage of succession (Helms 1998).

Table 1.1 Unreserved forest land (in thousands of acres), all productivity classes and all owners, Western United States (1997 RPA, Table 9).

	Pacific Northwest		*Pacific Southwest*[a]		*Intermountain*		*Western States*	
Forest Type	*Area*	*Percent*	*Area*	*Percent*	*Area*	*Percent*	*Area*	*Percent*
Pinyon-juniper	2,552	5.59	1,461	4.28	42,927	35.67	46,940	23.46
Douglas-fir	17,237	37.77	1,979	5.80	17,860	14.84	37,076	18.53
Ponderosa pine[b]	7,095	15.55	7,327	21.47	15,245	12.67	29,667	14.83
Western hardwoods	5,210	11.42	9,186	26.91	13,303	11.05	27,699	13.84
Fir-spruce	4,294	9.41	2,946	8.63	14,617	12.15	21,857	10.92
Lodgepole pine	2,426	5.32	166	0.49	10,499	8.72	13,091	6.54
Chaparral	235	0.51	4,386	12.85	126	0.10	4,747	2.37
Other softwoods	232	0.51	5,136	15.05	2,619	2.18	7,987	3.99
Non-stocked	900	1.97	697	2.04	617	0.51	2,214	1.11
Hemlock-Sitka spruce	5,108	11.19	11	0.03	1,510	1.25	6,629	3.31
Larch	287	0.63	0	0.00	889	0.74	1,176	0.59
Redwood	6	0.01	732	2.14	0	0.00	738	0.37
Western white pine	54	0.12	105	0.31	131	0.11	290	0.14
All Forest Types	45,636	100.00	34,132	100.00	120,343	100.00	200,111	100.00

[a] Hawaii is included in this regional summary. Its 1.6 million acres of unreserved forests are classified mainly as western hardwoods.
[b] Jeffrey pine is included with ponderosa pine, mainly in the Pacific Southwest.

Forest Types of the West

About 55 recognized forest types exist in the West, but more than 80 percent of the total unreserved forest area is described by the top five forest types in Table 1.1.

One of the challenges in looking at forest data and trends is to understand what they might indicate about forest condition. Most estimates of forest condition have historically been made on the ground, stand-by-stand, as foresters made decisions about forest management and treatment. There, the signs of an oncoming health problem may be fairly clear. Overstocked, stressed stands or symptoms of insect or disease outbreaks may signal the need to take management action.

Making broad-area estimates has been much more difficult, however. Until recently, the forest inventory data available from the Forest Service did not provide information about the stand condition of the forests. If the inventory showed the amount of acres and timber in the region that was in the 5-to-7-inch size category, there was little indication whether these were young forests that were growing freely and would soon become larger trees, or whether they were older, stagnated stands that would not grow another inch before insects or fire killed them. As the area of stagnated stands grows larger, this distinction becomes more important. Current studies are trying to provide better data, particularly on federal lands.

There are other methods, however, that may offer useful insights. An estimate developed by the Forest Service, and cited by the General Accounting Office, shows 39 million acres—almost one-third—of the National Forest system in the Interior West to be at high risk of catastrophic wildfire (GAO 1999). A more recent study conducted by Forest Service researchers developed improved data on historical vegetative conditions and coupled those with current conditions to arrive at estimates of the forest types that are significantly outside their historical range of variability (Hardy et al. 1999). These studies were then used to identify forested areas that were so far outside their historical ranges that a wildfire posed significant risks of altering their ecosystems through the destruction of one or more critical ecosystem components or processes. In plain terms, these were forests where the current fuel conditions pose a hazard so great that the ecosystems could be diminished in a long-term or permanent way if a wildfire is allowed to burn.

The study classified forest condition in three categories:

Condition 1—The ecosystem is largely intact and functioning in historical patterns. It may be subject to wildfire, but the disturbance patterns and severity should be fairly normal.

Condition 2—The ecosystem has undergone moderate changes, and conditions have shifted toward a less resilient system. A wildfire disturbance may or may not cause the loss of ecosystem components or processes.

Condition 3—The natural, historical disturbance regime of the ecosystem has been significantly altered, and the

Table 1.2. Estimated amount of forestland in the National Forest System, Western States, by historical fire regime and current condition, 2000.

Historical Fire Regime	*Condition 1*	*Condition 2*	*Condition 3*	*Fire Regime Totals*
0–35 years; low severity	4,846,406	23,719,091	24,158,447	52,723,944
0–35 years; stand replacement	762,311	621,459	284,168	1,667,938
35–100+ years; mixed severity	14,242,726	23,535,004	6,177,545	43,955,275
35–100+ years; stand replacement	3,689,236	830,755	7,561,081	12,081,072
200+ years; stand replacement	14,829,079	1,030,166	1,132,111	16,991,356
Class Totals	38,369,758	49,736,475	39,313,352	127,419,585

Source: Hardy and Bunnell 1999.

current condition predisposes the system to major changes, including the possible loss of key components or processes.

Obviously, Condition 3 describes places that should be of concern from an economic, environmental or national policy point of view. The best estimate is 39 million acres of Condition 3 forest exist in the National Forests of the Western United States. Table 1.2 highlights the fact that by far the largest category of Condition 3 forests includes land with historical fire regimes of 0 to 35 years and low-severity fires. That category is dominated by the ponderosa pine and dry Douglas-fir forests, reinforcing the conclusion that it is these forest types that are at greatest ecological risk.

The current condition of these high-risk forest areas is a result of past and current management—of that there is little controversy. The problem, of course, is how best to achieve the goal of returning them to a more ecologically stable state (Sampson 1992a). In the eyes of some people, it is best to allow nature to take its course. Because past management was part of the problem, they reason, it is important to prevent future management from continuing to meddle in the situation. Others see it differently. Past management has provided lessons upon which future management can be based, they say. Because of the enormous amount of fuel involved, the inevitable result of "letting nature take its course" is to see a fire that is likely to damage soils and watersheds, set forest ecosystems back into much degraded conditions and perhaps preclude forest recovery for generations. From this perspective, the future is best served by taking management actions that will improve the chances for the forest to become more tolerant of future wildfire conditions, preferably to the point where the forest ecosystem is sustainable long into the future (USDA Forest Service 2000).

Condition and Treatment Approaches to Forest Types of the West

Pinyon-Juniper—This most extensive forest type in the West is also one of the least well documented in terms of condition and change. Because it produces less than 20 cubic feet of wood per acre per year, this type of land has not been classified as timberland. As a result, the Forest Service has little information about its growth rates or area change. However, studies in Oregon demonstrate that juniper woodlands began increasing both in density and in area during the latter part of the nineteenth century (Miller and Rose 1995; Miller and Wigand 1994). Traditional Native American burning practices stopped when tribes were forced from their lands, cattle and sheep grazing reduced the grasses and shrubs that formerly carried fires through the landscape, and cowhands and settlers suppressed every grass fire they could handle.[7] Without periodic fire to hold its advance in check, juniper began to expand, aided, it appears, by the warmer and wetter conditions that followed the end of the "Little Ice Age" around 1850. As fire suppression and grazing have continued, juniper's expansion has proceeded virtually unchecked (Laroe et al. 1995).

Managing juniper forests is a major challenge, particularly for the Bureau of Land Management, which has extensive areas of remote pinyon-juniper woodlands. Few of

[7] When viewed from the standpoint of today's conflagrations, it is hard to imagine people with only shovels and wet blankets putting out a range or forest fire. When those fires were burning regularly, however, the fuel accumulations were much smaller, making the fires more manageable. Pyne (1982) tells the story of "beef drags," where a bull or cow would be slaughtered, split open, then dragged behind two horsemen; one riding on the fire side and on one the unburned side of an advancing grass fire. One chronicler says that such tactics could put out more range fire than 50 men working only with wet blankets and sacks.

the trees are cut for commercial purposes because no market exists except for occasional firewood or fence posts, and those trees that are cut generally are not part of a planned area-management scheme. Efforts such as chaining and grass planting have been largely unsuccessful in restoring desired grassland conditions. Prescribed fire is difficult to use successfully because tree densities are often too low to carry a fire from tree to tree, and the juniper's aggressive root systems keep grass and shrubs from growing profusely enough to help maintain the fire.

Another complicating factor for managers of juniper forests is that adjoining grasslands and sagebrush steppes often have been taken over by cheat grass (*Bromus tectorum),* an exotic annual that builds up large thatches of highly flammable dead material and that reseeds aggressively following a fire. Dry cheat grass ranges burn with dangerous speed, and the fire effect may be to favor the exotic weed rather than reduce it. It is estimated today that cheat grass has become a dominant species on 17 million acres of the Western sagebrush steppe, with the potential to infest another 62 million acres (Ferry et al. 1995). It is possible that some of the intensive-grazing schemes being tested in the West can help bring back perennial grass cover, but the invading junipers would need to be killed or removed first (Daggett 1995).[8]

Ponderosa pine—In addition to being the dominant forest type on some 28 million acres of Western forests (Table 1.1), ponderosa pine is an important component of the Douglas-fir forest types in the Intermountain Region (16 million acres) and the mixed conifer forests. In California, a similar species called Jeffrey pine is included with ponderosa in both the datasets and the management schemes. Historically, these species were often found in park-like stands with grassy understories maintained by frequent, low-intensity surface fires that burned through the dry summer grass, killing young trees and consuming fallen bark flakes, needles and branches. Because of the location of ponderosa pine forests on the lower and gentler portions of the Western landscape, it is likely that Native Americans ignited many of the historical fires in these forests as part of their land management strategy. Fire exclusion efforts that began with

[8] The use of intensive short-term grazing is increasingly promoted as a way in which native grass re-establishment may be possible.

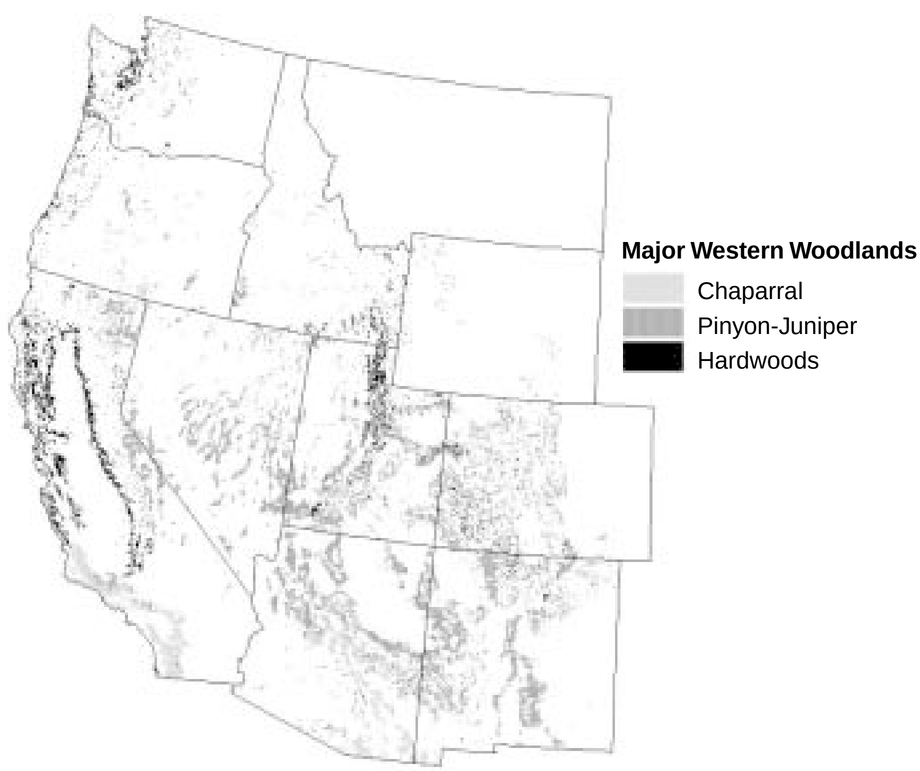

Figure 1.3 Woodlands with little or no commercial forest product output cover extensive areas of the West.

Figure 1.4 Ponderosa pine occurs under a wide range of conditions in the Western United States.

the earliest European settlers began to change these stands, and brush and small trees were able to grow around the larger pines (Mutch 1994). Because these forests were often found on the more-accessible foothills and steppes of the region, the valuable large trees were heavily harvested, often in the process of converting the land to crop or pasture.

Extending from Mexico to Canada, from elevations of less than 1,000 feet in the valleys of the North to more than 12,000 feet in the Southwest, and from annual precipitation zones of less than 16 inches per year up to more than 40 inches per year, ponderosa pine is a species of great diversity. This diversity contributes to significant differences in the conditions that affect the pines and their treatment.

In the drier, colder portions of the pine's range, for example, fire suppression coupled with slow decomposition rates can result in a large pile of bark flakes, needles and other debris on the forest floor and around the base of large trees. Where this has occurred, even careful use of prescribed fire may achieve such high heats around the base of trees that they are killed. A similar period of fire exclusion in the warmer, moister northern Idaho forests will not result in any significant buildup of ground fuels, and a prescribed fire that is properly handled poses no threat to trees.[9] With such a wide range of conditions possible, it is important that generalizations about this species be used with caution.

The impact of fire exclusion on ponderosa stands was noted as early as the 1940s by observers such as Harold Weaver, but conventional thinking for many years rejected the idea that fire might be necessary to protect the integrity of the ecosystem.[10] Today, prescribed fire is much more widely accepted, but the underlying situation has changed so dramatically that, as one study of the Blue Mountains of

[9] From discussions with Leon Neuenschwander, University of Idaho Forest Ecologist, about widely varying situations. For example, in Heyburn State Park in northern Idaho ground fuel buildup around large trees is virtually non-existent. In contrast, on the Boise National Forest, large piles of bark flakes make prescribed fire much more difficult to achieve without killing the large trees (See also Covington et al. 1997).

[10] This history is well reviewed in the works of Agee, Biswell, Covington and Pyne. Harold Weaver published his classic "Fire as an ecological factor in the ponderosa pine region of the Pacific slope" in 1943. The outcry raised by the article resulted in several subsequent articles being published with the following caveat imposed by his employer: "This article represents the author's views only, and is not to be regarded as an official expression of the Indian Service on the subject discussed." Being ahead of one's time is no easy task, as many of the fire researchers in the West discovered.

Oregon noted, removal of unnatural fuel accumulations and manipulation through mechanical harvest will be needed to modify current stand conditions before fire can play its historical role (Mutch et al. 1993).

A variety of estimates have been made concerning the amount of Western ponderosa pine forest that will need some form of fuel reduction or modification before it can be safely returned to an historical fire regime. However, until remote imaging technology can be improved to the point where fuel amounts and structures below the forest canopy can be estimated, there are no broad-area estimates that can accurately pinpoint either the amount or location of those areas.

What we can safely say is that millions of acres of ponderosa and inland Douglas-fir forests are at serious risk of lethal wildfires if they are not treated within the next decade or two (Covington et al. 1994). The best available estimates suggest that the area involved covers approximately 39 million acres (USGAO 1999; Hardy et al. 1998). These forests have reached conditions that are increasingly unstable and vulnerable (Scott 1998). Reaching such a precarious position has taken, in many cases, 100 years or longer. In contrast, devastation by wildfire would take only minutes or hours if trees are ignited during a dry, windy summer period, given their current condition.

If such wildfire occurs—as it has since 1989 on nearly one-third of the ponderosa pine forests of the Boise National Forest in Idaho—the recovery of many areas would be questionable. For the most part, these wildfires are uniformly lethal. In the 1992 Foothills fire, for example, even scattered lone trees and isolated north-slope pockets of pine were killed. Trees that had survived dozens of prior fires could not tolerate the heats generated by the amount of fuel being consumed (Sampson et al. 1994). The risk is that, for the foreseeable future, these lands will become brush fields rather than forests.

Ponderosa pine is also the Western forest type that is most often used and altered for residential and recreational development because it generally occupies the lower and more accessible areas. Treating ponderosa pine forests becomes even more urgent in the places where they form part of the "wildland-urban interface" made up of mixed forestland and development.

Treatment approaches to ponderosa pine generally focus on returning the stands to a condition that is likely to survive a future wildfire. This is generally done by removing or reducing understory fuels, thinning the stand to reduce the likelihood of a crown fire and pruning dead or low branches so that a ground fire is less likely to burn into the crowns (Scott 1998). Treatment guidelines are generally agreed upon by land managers, but they are still likely to be controversial with people who view timber harvest or tree cutting as the problem, not the solution.

Mixed conifer—Mixed conifer is the most complex of the forest types in the West, and one that is not broken out as a forest type in Forest Service data (see Table 1.1). These forests have a wide variety of coniferous and, in some places, hardwood species. They differ in their position on the landscape, their fire regimes, and the manner in which they respond to disturbances such as fire (Agee 1993). They are generally found at somewhat higher elevations or on cooler, moister landscape than ponderosa pine forests, and they may adjoin true fir, spruce-fir, sub-alpine or alpine areas at their upper limits. Ponderosa pine can be found as a seral species in most of these forest types, although it will not be present in every site. Douglas-fir also can be found in most of these forests, either as a seral or climax species. Much of the area listed as Douglas-fir (Table 1.1) in the Pacific Southwest and Intermountain data regions is included within this general category.

Although highly variable, most of these mixed conifer forests developed in connection with fairly short fire-return intervals, subject both to lightning-caused fires and Native American ignitions (Agee 1993). This resulted in many areas being dominated by the more fire-resistant seral species such as ponderosa and Jeffrey pine, western larch and Douglas-fir. Fire suppression has resulted in a significant increase of the less fire-resistant species such as white fir, grand fir, lodgepole pine, incense cedar and hardwoods. The result is a fuel build-up similar to that of the ponderosa pine forests and the likelihood that an ignition during dry conditions will turn into a lethal crown fire. Another ecological result is the decrease in biological diversity in the understory and on the forest floor because dense shade and competition from the trees has diminished herb and shrub components (Agee 1993).

Restoring these forests to a more fire-tolerant condition will be both complex and costly. The amount of biomass on many sites will make restoration with prescribed fire extremely difficult, often requiring two or three treatments. Fuel reduction treatments prior to prescribed fire may be needed in many places, and, in areas intermixed with housing and other development, some form of non-fire treatment regime may be necessary. These treatments often look like the "thinning from below" described for ponderosa pine, but the presence of additional species makes the design of a treatment project somewhat more complex. In general, thinning tries to not only reduce fuels and break up fuel ladders but also to shift species composition toward the more fire-tolerant species such as ponderosa and Jeffrey pine, western larch and Douglas-fir. In the process, most of the small and medium-sized white and grand firs, incense cedars, and Douglas-firs would be removed.

Lodgepole pine—Like all Western forests, lodgepole pine forests have been affected significantly by the fire-exclusion efforts of the last century. Although normally found at higher elevations and colder climates than ponderosa pine, this species is found in areas where remnant trees suggest that it has replaced ponderosa pine or mixed conifer forests (Figure 1.5). Because they are found in higher, colder areas, almost 82 percent of Western lodgepole pine forests are found in the Intermountain Region, and almost 90 percent of the lodgepole pine in that region occurs on the National Forests, National Parks and other public lands. Treatment for lodgepole pine would take place on some of the most wild and remote lands in the nation.

Lodgepole pine forests have developed under a combination of low-, moderate- and high-severity fires that have occurred in complex and not-very-well documented frequency and locational patterns. Estimated fire-free intervals have historically ranged from 50 to as long as 350 years (Agee 1993). The species is often found in fairly pure stands that have resulted from regeneration following a stand-replacing fire. The forests are susceptible to insect attack by mountain pine beetles, which can combine with small, patchy fires to create a mosaic of age and size patterns. Where fire suppression has been successful in preventing the small events, the result can be larger areas of more uniform stands that, when attacked by the mountain pine beetle, can produce epidemic conditions and wide-area mortality. This, in turn, can create conditions for larger-than-historical fires such as those at Yellowstone Park in 1988.

Because the dense stands that often characterize lodgepole forests allow room for few or no understory plants, and because surface fuels are limited, it is difficult or impossible to use a cool ground fire as the prescribed fire in many situations (Agee 1993). In the backcountry, what is called a "prescribed natural fire" may be a lethal crown fire, mimicking the natural regime. Often these would be lightning-ignited rather than management-ignited, but they would be allowed to run their course because they would burn in

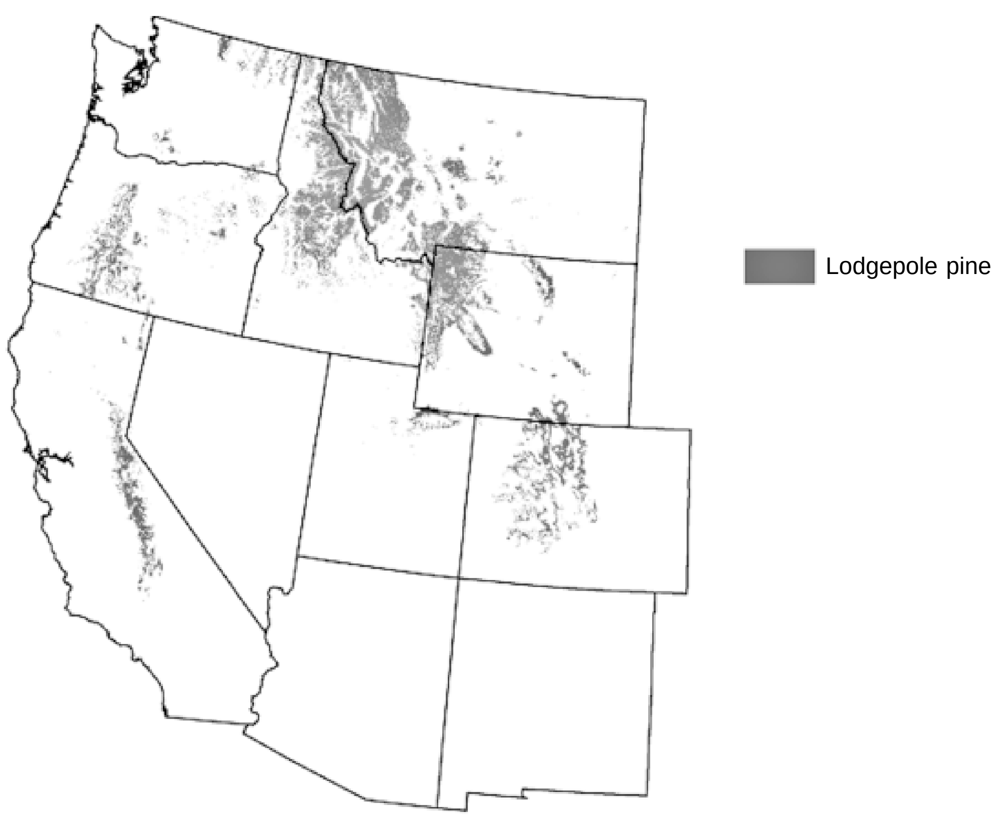

Figure 1.5 Lodgepole pine inhabits higher and colder areas, and its normal wildfire is usually stand replacing.

an ecologically acceptable manner. Where that is not feasible, however, fires would be suppressed, and any treatment would probably involve some form of fuel removal, either through biomass harvesting or thinning accompanied by pile burning of slash.

Environmental Issues and Forest Health Treatment

Soil Damage and Ecosystem Recovery

The most important impact of the large, intense wildfires of the recent decades is likely the damage to the soils. This soil damage is a much more serious and enduring setback than killed trees. Fire can reduce thin mountain soils to little more than bedrock. The most extreme fire and post-fire effects are long-term ecological setbacks that may permanently convert forest sites to shrub or desert sites. Where that happens, the price of allowing such high fuel loads to burn will be paid far into the future.

One problem with evaluating soil damage is that, in many cases, the extent of the damage will not be clear for years or even decades. In some places, on the other hand, the degree of damage is fairly apparent. In the 1992 and 1994 fires on the Boise National Forest, for example, some soils were so badly heat-damaged that the topsoil literally slid off the slope, in a process called *dry raveling*. Similar impacts were seen on the Buffalo Creek fire in Colorado (see Water Quality and Stream Flow below). In both cases, summer rainstorms caused additional soil erosion before protective ground cover could be re-established in some areas. Those sites were damaged to the extent that forest vegetation may not be able to regenerate on what is left behind. In other areas, the damage was less evident, although reduced organic matter and nutrient losses were clearly involved, particularly in the soil layer above the hydrophobic layer that was formed a few inches down (Agee 1993; Cromack et al. 2000; Giovannini 1994; McNabb and Cromack 1990; Sampson 1997).

What can be safely assumed is that the most marginal soils will suffer the greatest damage (Cromack et al. 2000). Soils with low organic matter and nutrient content in their pre-fire condition will experience far slower recovery following an intense wildfire. The extent of soil damage is determined largely by the degree and duration of heating that takes place. Degree and duration, of course, can be highly variable within the boundaries of any wildfire, so it defies easy generalizations.

In addition to changing soil quality, fire may significantly affect a burned site's micro-climate. The loss of shade, coupled with the loss of local seed sources, may prevent reforestation for decades or longer. Follow-up monitoring is being performed on many of the recent wildfire areas, but it is too soon to draw many conclusions about the degree to which the burned sites have been degraded. It is not yet clear whether these sites will simply be delayed a few years before they begin to recover, or whether they instead have begun a downward spiral of deterioration that could eventually turn into the desertification process. The marginal forest sites in the West are often very close to nearby deserts, and any significant soil change, particularly if it is followed by a period of adverse weather or permanent climate change, could significantly move the forest edge.

Air Quality

With prescribed fire being an important part of many forest treatment strategies, the issue of air quality must be addressed for many parts of the West. Wildfire emissions are often violent, difficult to monitor and impossible to regulate. Prescribed fire emissions, on the other hand, are relatively easy to monitor, and, because they occur as the result of human-caused events, are susceptible to regulation.

Under the Clean Air Act, the U.S. Environmental Protection Agency is responsible for this regulation. It established national standards in the 1980s for particulate matter (PM) smaller than 10 microns in size (commonly referred to as PM_{10}). After a lengthy review, the agency determined that there were important health effects associated with even very small particles and, as a result, established new standards for particulate matter smaller than 2.5 microns ($PM_{2.5}$). This change focused additional attention on the PM emissions from combustion smoke. More than 90 percent of wood smoke particulates are small enough to enter the human lung, and their average size is near enough to the wave length of visible light that they can scatter sunlight and dramatically reduce visibility (Pyne et al. 1996).

The amount of PM emitted by a fire event depends on the amount of fuel burned and the type of fire—flaming or smoldering. Total PM emission estimates range from around 25 to 40 pounds per ton of fuel burned, with the higher estimates associated with smoldering fires (Hardy et al. 1992). Precise modeling should be used to consider the type of fire in each event, but a rough estimate of about 30 pounds of PM for each ton of fuel burned in either prescribed or wild fires can be used (Hardy et al. 1992; Ward et al. 1989).[11]

[11] Colin Hardy, in a personal communication, cites estimates of 25 pounds of PM_{10} per ton of fuel consumed in a ponderosa pine broadcast-burn slash fire and 30 pounds of PM_{10} per ton of fuel burned in forest wildfires.

Table 1.3. Fuel consumption estimates for fire events in ponderosa pine on Douglas-fir site, Boise National Forest.

Type of fire event	*Tons of fuel consumed per acre*
Prescribed fire in low-density stand	11.0
Low intensity wildfire in low-density stand	20.0
Moderate intensity wildfire in high-density stand	74.0
High-intensity wildfire in high-density stand	79.5

Fuel consumption likewise can vary considerably among forest types and fire events, making a general estimate difficult to derive (Fahrenstock and Agee 1983). In the ponderosa pine research described below (see Designing Forest Health Treatments), fuel consumed per acre ranged from 11 tons for a prescribed fire in a low-density stand to 79.5 tons for a high-intensity fire in a high-density stand. (Table 1.3).[12]

We used the Forest Service's post-fire estimates of the amount of low-, moderate- and high-intensity fire contained within the boundaries of two large 1994 wildfire events on the Boise National Forest to derive an estimate of 47.2 tons of fuel per acre as an average over the 119,400 acres burned in the events (Neuenschwander and Sampson 2000). Those estimates indicate that the Boise National Forest could conduct a significant prescribed fire program, which, if successful in breaking up large areas of heavy fuels and reducing wildfire intensity, could result in a lower average annual emission of air pollutants.

Other factors to be considered in the impact of forest fires on air quality are meteorological conditions, which affect the direction, dispersion and impact of smoke plumes, and land use and population characteristics of the areas likely to be affected as a result. A smoke transport model for the West has been developed to test the likely outcome of large wildfire events (Rigg et al. 2000). A map produced by the model for two simulated 25,000-acre wildfires in Colorado is shown in Figure 1.6.

In planning for prescribed fires today, forest managers must consider fuel moisture conditions on the site along with current and forecast weather conditions. Managers must

[12] The plot data and FIRESUM results were input into the CONSUME (Ver 1.0) model to estimate the fuel consumption of the modeled fire events. This required that crown fuel consumption be added to the CONSUME outputs because that version of the model was limited to surface fuel consumption (Neuenschwander and Sampson 2000).

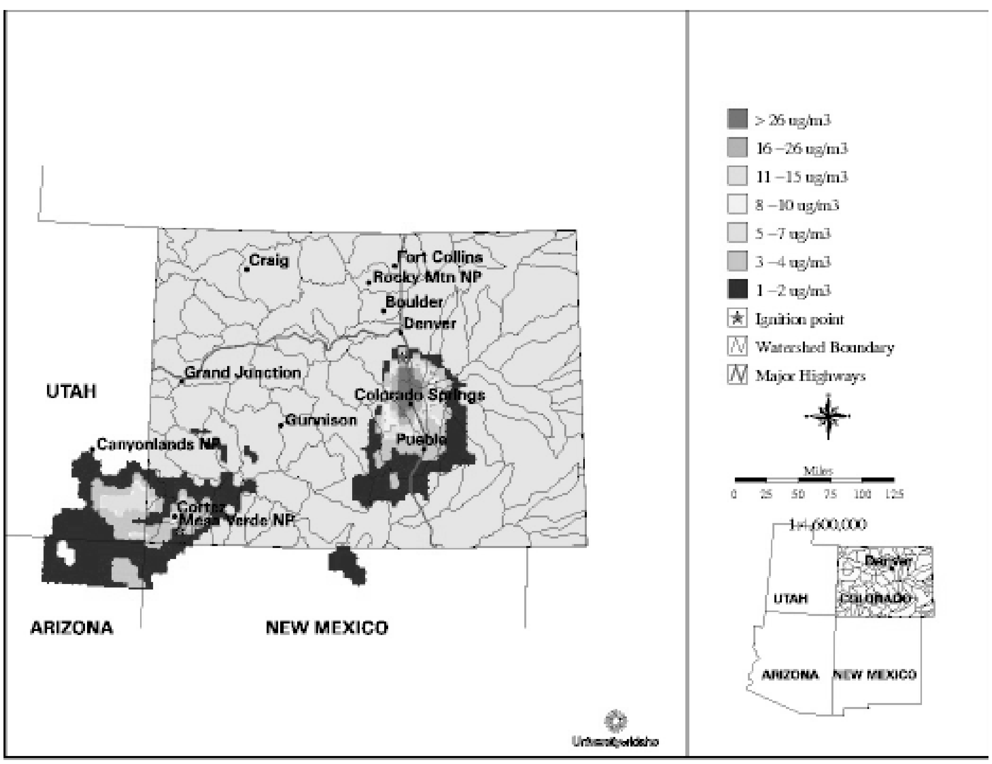

Figure 1.6 Maximum 24-hour PM_{10} concentration from two simulated wildfires.

make certain that the fire will burn with the intended effect on the forest vegetation and that the fire can be managed safely (Biswell 1989). They must assess wind conditions, which limit how burns may be undertaken and can affect air-quality considerations. Wind conditions will also determine the total amount of burning (and therefore smoke production) that will be allowed on a given day. In many areas, this combination of fuel moisture, wind and other weather conditions can amount to a fairly narrow window of opportunity between the time when the fuels are too dry and dangerous to burn and when they are too wet to burn at all.

The Western states have developed State Implementation Plans (SIPs) that establish procedures for regulating prescribed fire based on weather conditions, location, and the amount of fire proposed at any one time. Those SIPs are being reviewed in light of the new EPA guidance in regard to $PM_{2.5}$. Whether the new regulations will result in a further narrowing of the opportunity to use prescribed fire is not yet known.

What is apparent, however, is the enormous dilemma posed by the amount of fuels present, the increasing danger of large wildfires and the need to protect public health from the smoke of both prescribed and wild fire. With around 60 million people living in the West, concentrated mostly in large urban areas and inter-mountain valleys, the amount of smoke associated with a land management regime that depends entirely on fire is not acceptable. In a study that graphically illustrates the dilemma, Leenhouts estimated the presettlement levels of biomass burning in the conterminous 48 states. These estimates were then compared to current levels of burning as well as those levels of burning needed if wildland (non-urban or non-agricultural) ecosystems were returned to their historical fire regimes (Leenhouts 1998). Air pollution from biomass burning today, he estimated, is about one-seventh of what it was in the pre-industrial era, and a return to ecologically based fire regimes would result in a four-fold increase in $PM_{2.5}$ emissions. Such an increase, in light of the already worrisome levels of pollution from fossil fuel burning and other modern industrial activities, would clearly be unacceptable.

On the other hand, leaving Western forests untreated is not a workable solution for maintaining air quality either. The untreated forests will burn at some point. If they burn in their current fuel condition during the hot, dry season when most wildfires of any consequence occur, the pollution emissions will not only be enormous, they also will be concentrated into a few days or weeks during and after the event. The high smoke concentrations likely in some areas will pose serious health hazards, particularly to children, the elderly and people with respiratory disease.

The need to return Western forests to a more fire-tolerant condition seems, therefore, to hinge on avoiding such enormous impacts on air quality by mechanically removing excess fuel from much of the affected areas. Because the areas involved are huge and often remote, such an effort poses an enormous challenge. Because much of the material involved is economically marginal or sub-marginal, the costs will be enormous as well. The health of 60 million Westerners, however, may dictate that mechanical removal be considered as solutions for forest health are debated.

Water Quality and Streamflow

The National Forest System was established in 1905 in part to protect the nation's watersheds, and watershed protection was a major justification given for the purchase of the Eastern National Forests authorized by the Weeks Act of 1911 (Steen 1976). Today, it can be argued that the most valuable product of many forested areas is the clean water and reasonably stable flow regimes that result from forested watersheds. It also can be demonstrated that hydrophobic (water-repellant) soil conditions can result when lethal wildfires leave soil without vegetative protection. A subsequent rainstorm can do extraordinary damage to the watershed.

In one example, the 1996 Buffalo Creek fire southwest of Denver, Colorado, burned almost 12,000 acres of ponderosa pine forest. Because of the fuel and fire conditions, about two-thirds of those acres burned in a high-severity, lethal crown fire. The rest burned largely as a low-severity ground fire. Shortly after the fire, a thunderstorm dumped 2.5 inches of rain over the burned area, causing erosion losses that averaged 1.4 inches of soil removed across the 8,000-acre area of severe wildfire (Agnew et al. 1997; Cromack et al. 2000). The results downstream were catastrophic and continue today. At the Strontia Springs Reservoir operated by Denver Water, it was estimated that more sediment (200,000 cubic yards) was deposited in the first flush of Buffalo Creek flooding than had been deposited in the prior 13 years of the reservoir's life (Weir 1998). The cost of lost power generation revenues during the time when debris prevented turbine operation, of cleaning the wood debris out of the reservoir and of restoring drinking water quality and electrical generation service was estimated at nearly $1 million in the first clean-up, and the work continues today with each subsequent runoff event. Another continuing cost is created by the ongoing turbidity in the water, which raises treatment costs as well as the cost of sludge disposal created by the clean-up process.

In July 1998, a summer rainstorm in the Buffalo Creek watershed washed an estimated 50,000 cubic yards of new sediment into the reservoir. The utility estimates that sedimentation from continued runoff and movement of stream channel deposits above Strontia Springs could be in the range of 150,000 tons per year and could continue for many years, if not decades. Removing that sediment costs between $6 and $7 a yard. One storm alone created a liability of almost $350,000 for the water customers in Denver, and the annual figure could average $1 million or more.

The increased severity of today's wildfires can alter the amount of nutrients, sediment and organic debris delivered to streams and can increase runoff because of less water absorption by the soil and lower vegetative uptake of soil water (Wissmar et al. 1993; MacDonald et al. 2000). However, past forest management practices—particularly those practices tied to forest road construction, skid trials, landings, and clearcut harvests—have been linked to increased rates of soil erosion, water pollution and watershed damage as well. Evidence for the cause of watershed quality problems is not clearly tilted in one direction. Forest management may be essential for protecting water quality and watershed conditions, but, if done improperly, it also can be linked to undesirable effects. The stage is set for controversy over whether, and how, to treat forests for positive watershed benefits. That controversy finds its most fertile ground in dealing with the national forests that make up virtually all of the upper-elevation headwaters of the West.

Roads

Forest treatment projects to reduce wildfire hazards in Western forests are unlikely to raise serious water quality questions except where new forest roads are involved. The "thinning from below" techniques that would characterize most of the treatments in the ponderosa pine and mixed conifer forests will seldom expose the soil to additional erosion damage. Coupled with the application of "best management practices" (BMPs) designed to protect riparian areas and assure the proper installation and maintenance of landings, skid trails and stream crossings, these projects should have little, if any, effect on water quality or flow dynamics.

Roads are another issue. Opposition to installing new forest roads in roadless areas is extremely strong among environmental organizations, and any forest treatment project that involves new roads is certain to run into stiff controversy. The impact of roads on forest ecosystem integrity is serious enough that road density (miles of road per square mile of forest) was used as a specific proxy for forestland integrity in the Interior Columbia Basin Ecosystem Management Project (Quigley et al. 1996).

Many early logging roads throughout the West were poorly constructed. Many were built directly up stream bottoms, doing maximum damage to stream integrity. Others were built by cut-and-fill methods along steep hillsides to access lands with road grades that could accommodate the equipment involved. Many of those roads subsequently collapsed, and road failures have been identified as one of the biggest causes of erosion and stream damage associated with timber harvesting activities (Oliver et al. 1994). Cutting into steep hillsides meant intercepting sub-surface water transport zones, which, in some wet periods, could result in converting sub-surface flow to surface flow that concentrated in borrow pits, culverts and, ultimately, the stream itself. Intercepting sub-surface flow changes the hydrology of the watershed, increasing peak flows and reducing groundwater recharge. Under extreme conditions, these roads contributed to major hillslope failure, leading to mass soil movement into stream channels.

Another issue with roads on the National Forest System has been the fact that many of them were built to serve timber harvest needs because timber receipts often were the source of financing road building. Once built, however, these roads have served a variety of purposes, including recreation, forest management and protection access. But whether they are located and maintained to best serve these long-term purposes has been controversial.

So the question from a watershed integrity point of view seems to be: Can modern engineering techniques and equipment build access roads for forest treatments in a way that creates less watershed and water quality damage than will be experienced when untreated areas burn? This will be a vexing and controversial question in many areas because the trade-offs are not always clear, and the result in either case may be deterioration in water quality. What people often want, however—a nice stable watershed with pristine, untouched forests in the headwaters—may not be a realistic future for most of these lands, given their current condition and the hazards that they face.

Water Partitioning

A less controversial and less well-documented issue than roadbuilding is altering water partitioning on these watersheds. As rain and snow fall on a forested watershed, the forest vegetation affects how water is partitioned: the amount that soaks into the soil and ultimately feeds subsurface groundwater supplies, the amount that runs off the surface to affect streamflow, and the amount that evaporates back into the atmosphere to affect cloud formation and subsequent precipitation in adjoining regions.

Many Western watersheds, particularly those with high-elevation headwaters, depend heavily upon snowmelt for their summer streamflow. That fact has been the basis for a Snow Survey and Watershed Forecasting program that has been active since the 1940s in the Soil Conservation Service (now Natural Resources Conservation Service), in cooperation with the U.S. Weather Bureau and the state water resource agencies in the West.[13] Because many of the mountain snowpack monitoring sites were on National Forest lands, the Forest Service has been a long-time cooperator in the program, and Forest Service research has been extensive on the effects of different forest management regimes on snow accumulation, melting and runoff. Scientists have documented the effect of changing forest canopies through different forest harvest regimes. One British Columbia experiment showed that clearcut harvests can result in as much as 42 percent more snow water on the ground (Toews and Gluns 1986; Troendle and Kaufmann 1987).

Less research is available about how past fire suppression efforts have altered the forest canopy and the subsequent effect on snow accumulation, snowmelt and water partitioning. What is known is that canopy densities have increased significantly as young trees crowd around the large, widely spaced trees common in the West's stands of ponderosa pine, larch and Douglas-fir. Where canopy density increases, more snow is intercepted before it reaches the ground. Much of that snow (estimates are as high as 50 percent in arid, windy, alpine conditions) evaporates directly back to the atmosphere in a process called sublimation, where water changes from ice to vapor without going through a liquid phase (Schmidt 1991). Thus, to the extent that more snow is intercepted, less reaches the ground to ultimately contribute to surface or sub-surface flow.

In addition, as trees and other vegetation on the site increase, they demand a larger share of soil water, leaving less available to soak below the root zone and recharge groundwater supplies. To the extent this occurs, late-summer streamflow, which is largely provided by sub-surface flows, may be reduced. Year-around streams may then turn into intermittent streams, affecting both watershed flows and stream ecology.

The implications of this situation, if substantiated for particular watersheds or forest conditions, would be that restoring a more-historical forest structure through thinning from below and removing excess biomass would likely increase subsurface water supplies, recharge groundwater and improve dry-season streamflows. For many watersheds, changes such as these are essential to achieve sustainability for streams and their aquatic systems.

Greenhouse Gas Emissions

Forests have been identified as a major contributor to stabilizing the levels of atmospheric carbon dioxide, a major greenhouse gas (GHG) (Watson et al. 2000). By using carbon dioxide in the process of photosynthesis and converting much of it into stable wood, trees have the effect of storing carbon in a fixed state for many years (Sampson 1992b). Even beyond the life of the tree itself, the wood may remain intact as part of a piece of furniture, a book, a house, or other structure (Sampson and Hair 1992, 1996; Brown et al. 1996; Sedjo et al. 1998). National and international programs directed at mitigating climate change have included strategies to expand forest area, improve forest growth, extend long-term use of forest products and generally take advantage of the positive effects good forest management can have on the global climate (Clinton and Gore 1993).

But forests can also become a source of GHG buildups (Harmon et al. 1990). It has been estimated that up to 20 percent of recent global increases in atmospheric carbon dioxide is a result of the clearing and burning of tropical rainforests (Dixon et al. 1994). Similarly, it can be demonstrated that the forests of the Inland West are, in many places, carrying levels of biomass that are significantly higher than the historical range and are increasingly unstable as a result (Sampson 1997). When those forests burn in wildfires, the carbon releases will be significant. In the 1994 wildfires on the Boise National Forest, for example, it was estimated that more than 2.5 million tons of carbon were emitted as a result of the fuel consumed as 119,400 acres burned (Neuenschwander and Sampson 2000).

[13] There is a full literature documenting the snow survey program. Current products, in the form of monthly snow and watershed conditions in the winter and runoff conditions in the major watersheds of the West, can be found on the World Wide Web at *http://www.nwrfc.noaa.gov*

It was estimated that for the year 2000 (as of Sept. 27, 2000), the 11 Western states had experienced some 4.95 million acres of wildland fire (NIFC 2000). We estimated that 15 percent of the area burned had grass cover, 23 percent was shrub land, 21 percent was open forest and 41 percent was dense forest.[14] Based on those assumptions, the estimated emissions of carbon monoxide, carbon dioxide and methane from the fires that year would be in the range of 73 million metric tons of carbon equivalent.

That is not the end of the carbon cycle story, however. In those places where the forest burned at low severity, soils remained undamaged, and forest regrowth may begin again fairly rapidly. There, the new forest will begin to recapture carbon dioxide, and the result in a few years may be a forest where the amount of new carbon captured in the wood is similar to that which was emitted in the wildfire. In terms of global emissions, the site will be back in reasonable balance (Keane et al. 1997).

At the other end of the spectrum, however, are those areas that experienced a high-severity fire that killed trees and altered soils. These soils suffered severe loss of nutrients and organic matter and altered structure, and they may have become coarser in texture and may have lower future water-holding capacity (Cromack et al. 2000; Giovannini 1994). Under these conditions, the forest is likely to take decades, if not centuries, to become re-established and begin to recapture the lost carbon. Where this is the case, the land becomes a negative contributor in terms of the global dynamic: Having lost the carbon stock it was storing before the fire, it also suffers a diminution of its previous capacity to replace that carbon. In the 1994 Boise National Forest fires cited above, it was estimated that 25 percent of the burned area suffered high-intensity wildfire conditions (Neuenschwander and Sampson 2000). While high-intensity fire is not always correlated with high-severity soil impacts, the two are closely linked.

The effect of these wildfires in terms of greenhouse gas emissions is, therefore, doubled. Stored carbon is lost, and future carbon sequestration potential may be reduced. This is a political problem for a nation with an official goal of reducing carbon emissions and increasing carbon sinks in its forests.

Forest treatments before the fires occurred could have reduced excess fuels but would not have eliminated the lighting-caused ignitions, nor would they have altered the topography. However, they would have altered the intensity of the fire event. If an effective thinning-from-below had been conducted in the area prior to the ignitions, the resulting wildfire would have almost certainly been largely a ground fire, burning through the ponderosa pine forest with minimal damage to mature trees. This speculation is supportable on the basis that treated areas within these fires were documented to act in exactly that manner (see the Cottonwood Creek example in Wildfire Costs below).

A pre-wildfire forest health treatment alters wildfire intensity and reduces forest mortality and carbon emissions. However, the forest treatment itself affects the carbon dynamics of a site. The effect on greenhouse gas emissions of harvesting biomass depends on both harvest methods and post-harvest use of the wood.

Harvest methods that cause minimal soil disturbance result in less soil carbon loss during the post-harvest recovery period. Treatment that does not burn slash or ground debris following thinning may have fewer GHG emissions directly connected with the treatment. However, that advantage could be more than offset if a stand were subject to a wildfire that then burned more of the available fuels or killed the overstory trees because it struck in drier or windier weather than would have been tolerated under prescribed fire conditions.

Biomass harvested in forest treatment tends to be used for short-term purposes. Wood used for structural purposes keeps carbon in storage longer than does wood used for pulp and paper, but how forest treatment wood is used is largely a function of the size and quality of the material removed. Thinnings tend to be smaller material, so a higher percentage is likely to go into end uses that are more short-term in nature.[15]

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[14] These estimates were generated state-by-state, but there were no on-the-ground estimates from individual fire reports available. We used average biomass consumption estimates of 5 tons per acre for grass, 10 tons per acre for shrubs, 20 tons per acre for open forest and 50 tons per acre for dense forest. The numbers could change after the final fire reports are released, if individual fire reports are comprehensive.

[15] Row and Phelps suggest that for the total 1986 U.S. timber harvest, about 33 percent of the harvested material will be either still in use, residing in landfills or dumps, or burned to replace fossil energy by 100 years after harvest (Row and Phelps 1996). Most of the wood-to-energy captured by the Row and Phelps model represents the burning of mill and factory wastes in co-generation plants at the site. Cogeneration has become a common practice in the industry, spurred by air and water pollution regulations that stopped the former practices of open burning and dumping of waste materials. It is also possible to direct all of the excess biomass (not just mill wastes) into energy production, as will be discussed later, and in that case, the biomass can be assumed to replace fossil fuel sources. The substitution leaves fossil fuels in the ground, replacing a net transfer from fossil sources to the atmosphere with a recycling source that represents a closed loop between the atmosphere and the forest. The carbon involved thus becomes credited as an “offset” of fossil emissions.

The amount of biomass involved in forest treatment can be considerable, as will be discussed below. For example, Jolley estimated that 31 dry tons of material per acre were removed in mechanical thinning on a mixed conifer stand in northern California (Jolley 1995). Of that, 30 percent went into saw timber, 50 percent into pulp chips and 20 percent into boiler fuel to produce electricity. That amounts to about 15 tons of carbon per acre, of which about one-third to one-half could be estimated to go into long-term storage (in the form of wood products or building materials) or be used to offset fossil fuel consumption. These numbers suggest that a forest health program based on thinning alone could be credited with five-to-seven tons of carbon per acre of long-term storage and offset and about eight-to-10 tons of carbon per acre of near-term emissions.

Untreated, a stand of that type might emit up to 10-to-20 tons of carbon per acre in a high-intensity wildfire and continue to emit carbon for several years of post-fire recovery. Because of the high probability that untreated stands will face a fire event in the coming decades, the GHG emission tradeoff favors treatment.

Wildlife Habitat and Biodiversity Conservation

The role of forests as wildlife habitat and conservers of biodiversity is one of the most important public benefits associated with sustainable forest management. Thus, any management action that removes biomass to reduce wildfire damages in Western forests will also need to demonstrate a positive effect on biodiversity if it is to receive public support.

There is ample evidence that changes in the forest structure that accompanied the fire exclusion efforts of the past have suppressed understory plants, converted meadows to pine and fir thickets and eliminated both old-growth and savannah forest structures (Despain et al. 2000; Oliver et al. 1997). The question that arises is whether forest management activities can reverse this trend and begin to restore the patterns of landscape and species diversity that characterized the historical range on these forests. That is a question that must be answered specifically in the context of actual forest situations by people expert in those situations.

In general, however, restoring high-priority portions of these forests would improve both landscape structural diversity and biodiversity. This is achieved through the effect of thinning on releasing forest understory, forest floor species and wildlife habitat. Some management activities that remove biomass might also restore habitat for the species that need savannah and open structures to thrive. What is not clear is whether the potential adverse effects of management activities would offset these benefits.

One such adverse effect would be the impact of roads for treatment access on previously roadless areas. Roads are often cited as one of the major hazards facing wildlife and endangered species. The problem usually is not the roads themselves but the increased human access they allow into remote forest areas. Once constructed, the roads provide access that land management agencies find difficult to control. Increased road density in forest ecosystems can lead to disturbances that affect wildlife reproduction success, increased hunting of game species and increased human contact with species such as grizzly bear that often results in death of the animal.

Road building raises difficult management choices for agencies facing the possible loss of remote forest ecosystems to high-severity wildfire. Treatment may require roads for access, but roads themselves create difficult trade-offs, primarily in the area of people management. Unless roads can first be engineered for minimal environmental impact and then be closed or controlled to minimize human access, the disadvantages of road building are significant. Nevertheless, the disadvantages of leaving stands untreated may be equally or even more troublesome. For example, in their current dense stands, problem forests lack the savannah and open structures some species need. And if they burn, these forests are likely to convert to large-area uniformity that is not beneficial for biological diversity.

Designing Forest Health Treatments

In developing silvicultural standards to create more fire-tolerant stands, O'Hara and Keyes used fire behavior models to determine critical factors and tolerance levels (O'Hara and Keyes 1995). The critical factors they propose are minimum crown base heights (CBH) and minimum crown bulk densities (CBD). In using these critical factors to evaluate the five major forest types that dominate the forest landscape in the Northern Rocky Mountain region, they found little difference in the critical minimum crown base height among forest types. They found that critical heights ranged from 7 to 8.7 feet, meaning that less than 10 percent of the trees had crown bases below that height. Using the work of O'Hara and Keyes, it seems reasonable to propose that, in a forest where the bottom crown height is somewhere in the 8-to-10-foot range, a ground fire is unlikely to crown out and become stand-replacing unless localized stocks of fuel or fuel ladders provide the fire with the energy or access to reach crowns.

Once a fire crowns out, O'Hara and Keyes found the bulk density of the crown to be the most important factor in determining whether the fire stayed there or dropped back to the ground. Critical bulk densities were found to range from 0.02 lbs/ft^3 to 0.036 lbs/ft^3 among the different forest types. While most forest stands outgrow the critical density minimums by age 70, all cover types were found to go through higher-risk densities at younger ages.

Improving fire-tolerance through silvicultural methods generally requires thinning the stands from below and pruning the lower (often dead) limbs. O'Hara and Keyes' results indicate that effective treatment would leave fewer than 10 percent of the remaining trees with crown base heights below 9 feet. Effective treatment often can be accomplished with mechanical biomass harvesting operations, which are becoming more common. Mechanical harvesting removes small- and medium-sized trees, and it offers the added benefit that the movements of the mechanical harvester through the treatment area breaks off many dead lower branches of the "leave-alone" trees as it works. This can effectively achieve the pruning effect without added work or expense. Treatment would become significantly more expensive if hand pruning would be required.

University of Idaho forest ecologist Leon Neuenschwander took another approach to testing the effects of forest treatment on fire tolerance (Neuenschwander and Sampson 2000). He used plot data from several ponderosa pine stands on Douglas-fir sites in the Boise National Forest in the FIRESUM model, which produces estimates of fire behavior and tree mortality under different weather conditions (Keane et al. 1989). The plot data selected represent the three common untreated conditions: low density with a basal area of 250 ft^2/acre, medium density with a basal area of 150 ft^2/acre and high density with a basal area of 80 ft^2/acre. Also he used plot data taken from two of the commonly used silivicultural thinning treatments: thinned to 100 trees/acre—basal area 175 ft^2/acre and thinned to 50 trees/acre—basal area 144 ft^2/acre.

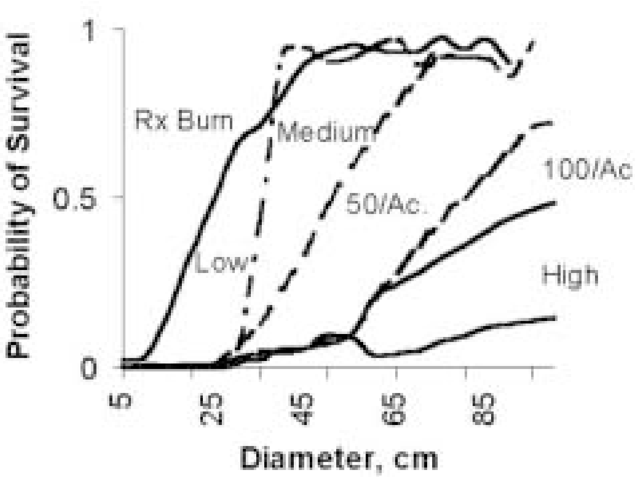

Figure 1.7 Average probability of survival by tree size (DBH), for five selected ponderosa pine stands under a range of wildfire regimes, compared to a prescribed fire (Rx Burn).

Fire weather variables were taken from the long-term records of a nearby weather station, and values between the 25th and 75th percentile of these data were used to calculate probable fire weather conditions.[16]

Neuenschwander's modeling showed that, under virtually all of the study's weather conditions, most wildfires could be predicted to kill the largest trees in the plots, even after the stands had been thinned. The results, shown in Figure 1.7, indicate that trees up to 50 centimeters (about 20 inches) in diameter breast height (dbh) have a very low probability of survival in most fire events. Untreated stands of low and medium density showed better survival probabilities than treated stands, probably because of the slash left behind in the thinning process. The best survival was achieved with the prescribed fire treatment, where trees larger than 25 centimeters (10 inches) in diameter had better than a 50 percent chance of surviving the range of fire conditions.

The conclusions to be drawn from both of these approaches are fairly similar. Most wildfires will turn into lethal crown fires in places where ponderosa pines (even very large ones) are surrounded by smaller trees and where surface fuels can provide a ladder from the ground into the canopy. Removing the ladder fuels in a thin-from-below strategy can reduce this risk, but leaving large amounts of dry untreated fuels on the ground may increase both fire risk and intensity. To assure that a thinning operation reduces fire risk for the remaining forest, the operation must either remove ladder fuels completely through biomass harvesting or carefully burn the fuels under moist conditions following mechanical treatment. Once restoration treatment is complete, future maintenance may depend more com-

[16] A random number generator chose 2,000 sets of wildfire weather data and 500 sets of prescribed fire data from these weather ranges. Five wildfire scenarios (ranging from one-to-seven fire events over 100 years) and one prescribed fire scenario (prescribed fire every 16 years) were then tested in 2,500 FIRESUM runs. An additional fire scenario with a mixture of prescribed and wildfire was tested on plot 3.

pletely on prescribed fire. Restoration may require several treatments, rather than trying to achieve a sustainable condition in the first effort (Agee 1993; Mutch et al. 1993).

The idea of using prescribed fire to return ponderosa pine forests to a more "natural" condition appeals to some ecologists, but the land-use complexity that surrounds many forests today often seems to preclude such an approach.[17] In areas where homes, farms and communities are intermixed throughout the forest, it is difficult to imagine any kind of forest management regime that relies exclusively on prescribed fire. The combination of smoke pollution and hazard to people and property likely means that a different treatment approach—one depending much more heavily on mechanical fuel treatments—will be required.

Two questions arise, however. First is the technical question: Can a "no-fire" treatment adequately mimic the essential ecological functions of fire? These functions include the periodic effect of a fire's heat on the germination or sprouting of some species, the selective impacts on species survival, and nutrient cycling. The answer is far from clear and the question deserves a great deal more research attention. The second question is: What will be done with the surplus biomass once it is removed from the forest in a "no-fire" treatment regime? Much of this material is non-merchantable in the usual wood markets and would not be removed from the forest in a traditional timber harvest. This is a problem facing managers searching for treatment options on all forest types, made even more difficult by the political opposition to removing trees from these forests.

In the last few years, a vigorous public campaign has been launched that seeks to convince Americans that all timber harvests on National Forests should be eliminated. The effort has been successful in that legislation to accomplish the goal has been introduced in Congress. For many of the overcrowded ponderosa pine forests in the West, a prohibition of future tree cutting may effectively eliminate the chance for ecosystem-based, restorative management projects and almost guarantees a lethal wildfire. Whether the eventual fires will permanently damage sites is unknown, but the risks of destructive heat levels rise as fuel levels continue to build. In a frightening paradox, a modern political movement that purports to "save" the public forests may contribute directly to their demise.

[17] The 1995 Federal Wildland Fire Management Policy and Program Review (USDI/USDA 1995) said, "Wildland fire, as a critical natural process, must be reintroduced into the ecosystem," then recognized "where wildland fire cannot be safely reintroduced because of hazardous fuel buildups, some form of pretreatment must be considered, particularly in wildland/urban interface areas." (page iii)

Economic Issues and Forest Health Treatment

The Economics of Harvesting and Hauling Forest Biomass

The basic problem with producing and delivering biomass fuels from forest treatments is tied to the fact that it is more expensive to handle a lot of little pieces in the woods than it is to handle fewer and larger ones. Thus, inevitably, a forest treatment that removes small stems will increase costs. Another problem is that the ability to cut, skid and handle small trees is nearly always tied to a field operation that is most economical when it can handle all of the trees in an area at one time. This is not only the least-cost method but also the least likely to cause environmental damage from machinery operations. Thus, a biomass harvest will, in most cases, be part of a larger forest treatment that removes the particular combination of sawlogs, pulpwood and biomass that needs to come out of the stand to restore healthy forest conditions (Lynch et al. 2000). If only the sawlogs and pulpwood are removed from the land at the time of the main operation, the collection and processing of the biomass left behind becomes so inefficient and expensive that the material will generally be burned on-site or ignored.

This can lead to significant technical and political controversy in designing forest health treatments, particularly on the federal forests. Foresters design the treatments to shape the stand for future growth. This means taking out excess trees, favoring certain species in many cases, thinning the stand to a density that allows for healthy tree growth and leaving trees that will maintain the type and quality of stand that is best suited to the site. If the process is done without other constraints, the result is often a harvest of a mixture of sizes and species that can contain enough high-quality logs to pay for the entire operation.

To some people, however, a treatment that includes the removal of large high-value logs looks like an old-fashioned logging operation, not a treatment to improve forest health. The result is criticism that the forest health treatment is simply a "cover" for removing valuable trees. One outcome of the controversy may be politically imposed rules that limit the harvest to trees below a certain size or diameter or that prohibit cutting certain types of trees. While those rules may sound logical in the abstract, they can be-ill suited to the situation on the land in many places. Where rules are in place, foresters are constrained from shaping the stand for best future health results based on their first-hand knowledge of the local ecosystem. Moreover, the resulting timber sale may be so uneconomic that no private contractor will undertake it. It is a very difficult political argument in today's high-controversy atmosphere, but allowing skilled field people to shape each stand for the best combination of environmental and economic results (both now and for the future) often can produce far superior results than will uniform rules. The magic phrase, of course, is "skilled field people," and the general level of trust these days between the environmental community and professional foresters is often very low.

Treatment Costs

Most of the mechanical treatment options for Western forests involve thinning from below, with the objective being a stand that more closely represents the historical stand in terms of species composition, spacing and structural arrangement. Historical replication is not always immediately possible because a treated stand is constrained by the same site possibilities inherent before treatment. It is almost always possible, however, to move a stand toward a better situation, even where fully desirable results may not be achievable.

Some treatments will be designed to get a site ready for a safe prescribed fire that can provide ecological processes such as soil heating, nutrient cycling and species selection. In areas where land use conflicts with prescribed fire or air quality limits its use, the treatment will be designed to reduce fuels, including slash and other fuels created during thinnings, to the point where they will not support an undesirably hot fire in the event of an ignition. In most cases, one goal is to return the forest to a condition where a subsequent wildfire will remain primarily on the ground, burning in a non-lethal manner so that it can be managed or suppressed if other factors dictate such action.

In contrast to traditional timber harvests, which were designed to remove the merchantable material that was profitable under existing market conditions, these treatments are designed to remove all the material needed to achieve the desired forest condition. That goal creates significant economic issues because much of the material that needs to be removed is either low-value or has no local market except where a wood-fired energy industry exists. Development of a disposal strategy is necessary, and while available options may not be profitable, they should be least-cost for the forest manager.

Costs are, however, not comparable across different land ownerships. In one study of timber sale and administration costs (which included surveying, prescription writing, environmental analysis and documentation, appeals and litigation, sale preparation and administration), the costs were estimated to be $52 per thousand board feet (MBF) for the Forest Service, but only $13/MBF for private industry lands (Keegan et al. 1996). Forest health treatment projects may widen that gap somewhat, depending on future policies. If, for example, Forest Service policy required that all trees to be removed must be marked before cutting, the fact that these treatments often remove hundreds of small stems per acre might impose such exorbitant costs that no project would survive. Even where the trees are not marked, the fact that more small stems must be handled will make the costs significantly higher than would have been experienced in a traditional timber harvest. In spite of these factors, Scott (1998) found that any one of the commonly used local forest health treatment approaches could produce net revenues given the timber prices available in 1996.

Creating a least-cost forest health treatment project begins with deciding what material needs to be removed from a forest stand in the restoration process. Often, managers can create a combination of sale units that can achieve both ecosystem restoration goals and maintain financial viability, even in difficult situations (Lynch et al. 2000). Some of the material may be suitable for commercial sawlogs for which local markets generally exist although prices may vary. Much of the material may be suited for pulp and paper production, but markets for wood chips tend to be more uncertain and, in many areas, unavailable. Where markets are available, suitable material can either be sorted and chipped in the woods or at a central mill or wood yard. If wood chips can be sold at a profit, the economics of a specific treatment project will be much more favorable than if the only outlets available for material of this quality is energy production or disposal.

The material that has neither sawlog or pulp chip values, but that needs to be removed to restore fire-tolerant conditions, provides either a huge cost obstacle to the land manager or a significant resource opportunity for the production of biomass energy, depending on the local situation. The amounts available from specific forest projects vary. The case studies in Part III illustrate the opportunities.

Biomass harvesting operations have been documented in connection with the wood-fired power plants operated by Wheelabrator Technologies Inc. near Redding, California. The forests involved are typically located on slopes of less than 30 percent, allowing the removal of trees with rubber-tired feller-bunchers that can remove the thickets crowded around the "leave" trees without damaging them. Past management, including decades of fire exclusion and selective harvest, have converted stands that were once composed primarily of ponderosa pine, sugar pine and Douglas-fir into stands dominated by white fir and incense cedar.

Stands to be treated are selectively marked to remove much of the white fir and incense cedar while leaving the most dominant, healthy, well-formed trees and favoring the pines and Douglas-fir. Small trees that crowd around selected leave trees are removed because they provide ladder fuels that can carry fire into the forest canopy.

No prescribed fire is used following treatment because there is an almost-total absence of activity fuels or ladder fuels remaining in the stand, though in most situations ground fires could be safely used. In cases where these treatments were conducted in a heavily urban-intermix area, it appeared that fire would pose unacceptable risks under virtually any prescription scenario.

In the harvest process, the trees removed are separated for highest economic return. In a "typical" stand, 2,000-to-5,000 board-feet of sawlog production per acre are anticipated, and biomass fuel yield averages 17 bone-dry tons (BDT) per acre. Where a market for pulp chips is available, the economics are significantly improved, and clean pulp chips are produced by portable field chipper-blowers and loaded directly into vans for transport. In an economic analysis of one such operation, Jolley estimated that 31 BDT of material were removed per acre, consisting of 10 BDT sawlogs (3 MBF), 15 BDT of pulp chips, and 6 BDT of hog fuel. Profits created largely by the sawlogs and pulp chips were estimated at $700 per acre (Jolley 1995).

We inspected these stands visually in 1995. After treatment, they were open, well-spaced stands dominated by pines and Douglas-fir. Of the pre-treatment merchantable material (more than 10 inches dbh in this example), from one-half to two-thirds remained as healthy, well-formed leave trees. Most of the suppressed and deformed trees in the understory were removed. Soil disturbance was minimal and restricted primarily to roads, landings and primary skid trails. The majority of the forest floor was intact, and it appeared that a fire, if ignited, would most likely be a cool ground fire that could do little or no damage to the residual stand.

It is also clear that the off-site environmental impacts of the biomass operation are significant. The 50 megawatt (MW) generating plant operated by Wheelabrator at Anderson, California, uses forest-produced biomass, mill waste, agricultural residues and woody wastes from local land development as well as other materials. In addition to the effects on forest health at the treated forest stands, the mill takes in wood wastes that would either be open-burned—creating regional air quality impacts—or land-filled. Rather than adding to the area's air pollution load, the power plant's virtually pollution-free exhausts represent a significant pollution reduction in a region that is currently struggling to achieve air quality goals.[18]

Wildfire Costs

Normally, the potential costs of a wildfire on the land in question are not factored into the economics of forest treatment options. Basically, the treatment program is funded directly out of the land manager's profits or budgets, while the costs of a wildfire are borne elsewhere, either by the public as a whole or by another aspect of the agency's budget. In the event the forest burns in a high-severity wildfire, the resource losses (usually timber values) are borne by the landowner or manager, sometimes being partially offset by a salvage harvest. In addition, any site degradation due to soil or watershed damage accrues to the landowner over time, even though it may not be recognized because it is lost opportunity rather than cash outlay.

Forest fires, particularly large, intense fires, can quickly run up enormous suppression costs. Fire fighting costs for the USDA Forest Service have averaged $216 per acre of fire in the West for the past 15 years (USDA Forest Service 1995). Estimates for the Boise National Forest in 1994 ran to $408 per acre (Table 1.4). Nationally, the total costs of bad fire years like 1994 or 1996 amount to close to $1 billion for the Forest Service alone. Expenditures by other state, local and federal firefighting agencies add to that total. Forest fires are major drains on the public treasury, particularly those fires that are large, intense and dangerous—a description that becomes more common every year as fuel conditions worsen and land use conflicts created by urban-type development in forested areas continue to grow.

Wildfire costs should be factored into the "no-treatment" option on many Western forests because, without treatment, a large, intense wildfire is virtually certain. The date and time of the event is unpredictable, making any attempt at a discounted cost estimate difficult. However, if the event seems reasonably certain within a decade or two, as many scientists argue, those costs are imminent enough

[18] One should note, however, that the near-complete combustion returns virtually all of the carbon in the biomass to the atmosphere because there is no charcoal and only very small amounts of ash produced in the process.

to warrant inclusion in the land management budget (Covington et al. 1994).

The amount of resource value lost depends on the timber stands killed, the market opportunity at the moment and the amount of salvage that can be recovered to offset the loss. It is also necessary to develop an estimate of the growing potential lost in the immediate future, particularly in the case of a mid-aged forest stand that would have produced some of its most rapid growth in the years ahead. Methods developed and used in the Forest Service since the early 1980s calculate least cost plus net value change (LC + NVC) as a means of evaluating the indirect benefits of fire protection.[19]

The spring 1994 prescribed burn of the Cottonwood Creek area on the Boise National Forest can be used as an example for these calculations. In August of 1994, the area was hit by the Star Gulch wildfire, one of the fires in the Idaho City Complex. Trees at the edge were killed as the high-intensity wildfire came in from adjoining untreated areas. Upon hitting the prescribed fire area, however, the fire dropped to the ground, where it burned through the thinned stand with little or no further damage. Table 1.4 gives the economic estimates of the resulting damage to the Cottonwood area from both the treatment and the subsequent wildfire and compares them to the damages suffered across the Idaho City Complex. In the Cottonwood area, every dollar spent on forest health treatment returned an estimated $6.58 in reduced wildfire losses and suppression costs.

Table 1.4 illustrates the implications of experiencing a high-intensity wildfire versus a mixed-intensity event. The 1992 Foothills fire was almost entirely high-intensity, while the 1994 Idaho City Complex was mixed. The estimated resource losses were more than double on the Foothills fire. Suppression costs remained the same because these were the averaged costs for the Boise National Forest over this period of high fire activity (Dether 1996).

There weren't enough trees killed in the Cottonwood area to ignite a political battle over whether to conduct a timber salvage sale. In all the untreated areas surrounding it, though, a sea of dead trees became the battleground over where, how much, and with what methods, salvage should be attempted. Today, the Cottonwood area is a living forest, 100-to-200 years ahead of its surrounding landscape in terms of forest successional growth. By those measures, the treatment of the Cottonwood area represented a political, economic and ecological success for the Forest Service, and it provides an example of how strategic treatment might affect a larger area.

Disposal of Excess Biomass

Estimating the Resource

As described so far in this report, there are forest situations in the West where a century or more of fire suppression has created biomass buildups that are contributing to forest health problems, that pose high risks of supporting a wildfire of such severity that site damage is likely, and that will not go away until they burn unless they are intentionally removed from the site by forest managers. We also have shown that a major obstacle to removal of this biomass, even in roaded, non-controversial forest situations, is the lack of a least-cost, environmentally safe disposal method or, in the best case, a profitable market.

A primary concern for potential investors considering a processing plant for forest biomass is knowing how much resource is available. Estimating the amount of biomass resource available requires taking two phases into consideration: forest restoration and sustainable forest production.

Forest restoration efforts will result in a large amount of biomass as fuel built up over decades through fire suppression is removed. Sustainable forest management on restored sites will most likely produce far less biomass. Even in those areas where prescribed fire is limited or not feasible, re-entry for biomass harvest is likely to be on a 15- or 20-year cycle, and the amounts of biomass available on a sustainable basis are likely to be smaller than the amounts removed in the initial restoration.

The re-entry cycle is a challenge for regional planners, who need to attract a biomass industry for the initial restoration period. They need to understand that biomass plants require a continuing, reliable biomass feedstock supply. These plants will need other sources of biomass once restoration is complete. In Table 1.5, we used currently available forest inventory data for the West to provide some indication of the amount of biomass that might be considered available during the restoration phase. It is based on the latest Forest Service data, which estimated forest volumes in 1996 (Smith 2000).

Several caveats must be observed in this analysis. The data have been published as regional summaries, which are useful in considering total resource supplies but mean little or

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[19] In a personal communication, Charles McKetta, University of Idaho forest economist, calls LC+NVC a "very old and straight forward way of evaluating the indirect benefits of protection." He cites Gorte and Gorte (1979), *Application of Economic Techniques to Fire Management* (Gen Tech Ref INT-53), and Hirsh et al. (1981), *The Activity Fuel Appraisal Process: Instructions and Examples* (Gen Tech Ref RM-83), as original sources.

Table 1.4. Comparative net value change and management costs of wildfire versus forest treatment, Boise National Forest, 1994.

Event for Comparison	*Acres*	*NVC or cost*	*Cost/Ac*	*Notes*
Wildfire — High Intensity	1,000			Scenario similar to Foothills wildfire, July-Aug 1992
Resource Loss		$1,400,450	$1,400	
Suppression Cost		$408,000	$408	
Total Losses/Costs	1,000	$1,808,450	$1,808	
Wildfire — Mixed Intensity				Similar to Idaho City Complex, July-Sept 1994
Low Intensity	550	$83,166	$151	
Moderate Intensity	200	$243,424	$1,217	
High Intensity	250	$350,113	$1,400	
Total	1,000	$676,703	$677	*Note: totals are average per acre costs (total acreage / total costs)*
Suppression Cost		$408,000	$408	
Total Losses/Costs		$1,084,703	$1,085	
Cottonwood Prescribed Burn Area				Treated in April 1994
Mosaic Unburned	200	$0		
Low Intensity	800	$11,200		
Total	1,000	$11,200	$11	
Implementation Cost		$12,000	$12	
Total Losses/Costs		$23,200	$23	
Wildfire Impact on Cottonwood Prescribed Burn Area				Treated area was re-burned in Star Gulch wildfire, Aug 1994
Low Intensity	900	$12,609	$14	
Moderate Intensity	60	$73,033	$1,217	
High Intensity	40	$56,018	$1,400	
Total Losses	1,000	$141,660	$142	
Total 1994 Losses/Costs		$164,860	$165	
Benefit: Cost Ratio — Cottonwood Treatment			$6.58	Benefits per dollar of treatment

nothing in terms of any localized situation. Biomass is a low bulk-density, low-value product, so feasible handling may be limited to a range of 25-to-50 miles. Whether an available resource supply of sufficient size exists for any localized development will require study conducted at that level.

The other caveat is that there are no indications of land ownership or land use designation on the Forest Service timber data except that the data come from timberland inventory plots. This means that the information does not include parks, wilderness or other areas where timber harvest is not allowed and does not come from the vast woodlands such as pinyon-juniper where growth rates are less than 20 ft^3 per acre per year. There may be areas included, however, where roadless considerations or other values may preclude consideration of biomass harvests or forest health treatments.

To minimize the likelihood of encountering those obstacles, we have considered only three forest types—ponderosa pine, Douglas-fir, and true firs—from the forest dataset. Then, to account for the fact that much of the volume of Douglas-fir in the Pacific Northwest is on the moist west-side forests of the Cascade and Coastal Range, we eliminated PNW Douglas-fir from our calculations and from the graphic display in Figure 1.8.[20]

[20] Our elimination of PNW Douglas-fir means we fail to count some Douglas-fir forests in Eastern Washington and Oregon where the historical forest included far more seral species like ponderosa pine and larch and where forest health treatments are badly needed today. However, such a consequence is unavoidable at this level of data consideration. The inventory data is shown in Table 1.5. See Part III of the report for consideration of Eastern Oregon conditions.

Table 1.5. Forest inventory data for three species in three Western regions, by size class in inches dbh (USDA Forest Service 2000)

Species/Region	*5-7”*	*7-9”*	*9-11”*	*11-13”*	*13-15”*	*15-17”*	*17-19”*	*19-21”*	*21-29”*	*29”+*	*Total*
						(million cubic feet)					
Ponderosa Pine											
INT	658	1,254	1,736	1,947	2,005	1,718	1,479	1,176	3,042	1,410	16,426
PNW	334	599	868	994	1,026	950	865	826	2,728	2,374	11,564
PSW	120	270	394	529	605	696	711	746	2,546	3,105	9,722
Western	**1,113**	**2,123**	**2,998**	**3,470**	**3,636**	**3,364**	**3,055**	**2,748**	**8,316**	**6,889**	**37,713**
True Firs											
INT	1,993	2,554	2,702	2,619	2,182	1,785	1,378	1,014	1,849	836	18,912
PNW	547	959	1,182	1,378	1,323	1,294	1,276	1,213	3,580	3,580	16,332
PSW	234	399	587	780	809	920	964	923	3,112	4,619	13,346
Western	**2,774**	**3,911**	**4,471**	**4,777**	**4,313**	**3,999**	**3,619**	**3,149**	**8,541**	**9,035**	**48,590**
Douglas-fir											
INT	1,419	2,502	3,243	3,672	3,615	3,336	2,792	2,171	4,612	1,689	29,052
PNW	1,225	2,558	3,621	4,427	4,825	5,011	4,744	4,517	13,741	24,889	69,559
PSW	314	499	670	656	680	748	723	703	2,644	6,261	13,898
Western	**2,957**	**5,559**	**7,534**	**8,755**	**9,120**	**9,096**	**8,260**	**7,391**	**20,996**	**32,840**	**112,509**

It is often stated that decades of timber harvest activities have left Western forests with few or no large trees left. These data, particularly as illustrated in Figure 1.8, tend to disagree. To the extent these forests are lacking in size and age cohorts, it would appear that concern should instead focus on the lack of trees in the 13-inch-to-21-inch range. Two possible explanations seem reasonable for the lack of trees this size in the age-size distribution. One explanation could rest on shortened harvest rotations and the harvest of smaller trees. Another could rest on the fact that overcrowded forest stands tend to stagnate. When the trees reach a certain size, growth slows dramatically as the competition for nutrients and water affect them.[21]

Based on this size distribution, one could argue that forest health treatments on these forests should remove trees under 12 inches in diameter where they are overcrowded or are creating ladder fuel problems around larger trees and that saving trees 12 inches or larger in well-spaced patterns could begin to help rebalance the resource distribution. Such a strategy would limit the amount of sawlogs that would result from the project, making the economics of the operation very difficult. Using these thinning assumptions, we can quickly estimate roughly how much biomass volume regional inventory data indicate are available. To do so, we developed Table 1.6 that includes the species and regions listed in Table 1.5 and adds incense cedar where it exists. Managers seek to remove incense cedar as they try to convert mixed conifer forests back toward a higher proportion of seral species like pine and Douglas fir.

We assumed in Table 1.6 that a higher percentage of the small material would be removed in the treatment process and that treatment would result in an average of around 15 tons per acre of biomass removed. The Intermountain Region would end up with the most acres treated—39 percent of the area covered by the three forest types—and the Pacific Northwest would end up with the least. In total, biomass harvest in the West could run in the range of 40 million tons per year for the 10 years of restoration treatment work. The total would almost certainly drop to somewhere in the range of 15-to-20 million tons per year as more prescribed fire became feasible.

The point here is not to provide an accurate biomass inventory. That should be accomplished on a location-by-location basis where biomass energy production or other

[21] We have inspected stands on the Boise National Forest containing trees ranging in size from 5 inches to 25 inches. After a forest treatment project, we counted rings on the stumps and discovered that all the trees removed were roughly the same age, even though they varied greatly in size. The stand had been established soon after one of the pioneer timber harvests, and the 5 inch trees were 120 years old. They were never going to grow into the next size cohort, and if they had been part of an inventory plot, they might have been measured in the same size range for the past 50 years.

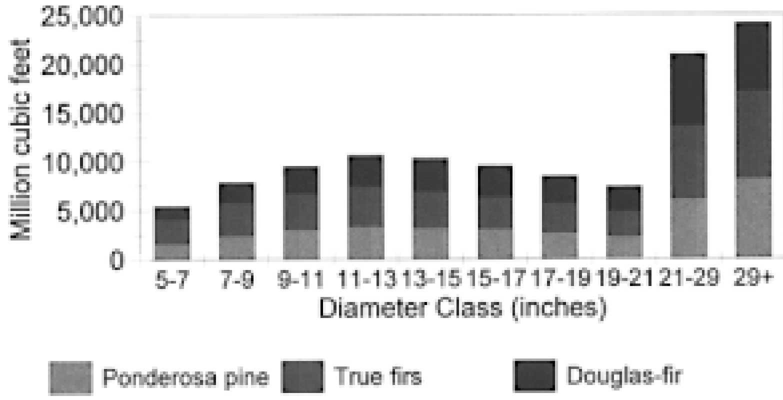

Figure 1.8 Merchantable wood in selected species, as shown in Table 1.5. (Douglas-fir in the PNW is omitted from this figure.)

processing is being contemplated. Rather, the point is to illustrate that a lot of biomass exists in these regions in just a limited number of forest types. This is true even assuming that almost all of the harvesting for 10 years would be limited to small-diameter trees removed in thinning and forest health treatment operations.

The heating value of Western softwoods is about 17 million Btu per bone-dry ton of biomass. Assuming one ton of bone-dry biomass converts to one megawatt-hour (MWH) of electricity under current technologies, that's 40 million MWH of power per year from a biomass resource that otherwise is a liability and hazard to the ecosystems where it exists today.

Table 1.6. Estimated biomass harvests possible in a 10-year accelerated forest-health treatment program for the Western United States, based on forest inventory of small-diameter timber in four target species.

Species	*Intermountain*				*Pacific Northwest*				*Pacific Southwest*			
	1000 ac	*Diameter Class*			*1000 ac*	*Diameter Class*			*1000 ac*	*Diameter Class*		
		5-7"	*7-9"*	*9-11"*		*5-7"*	*7-9"*	*9-11"*		*5-7"*	*7-9"*	*9-11"*
Douglas-fir	17,645	1,419	2,502	3,243	16,912				1,977	314	499	670
Ponderosa pine	14,482	658	1,254	1,736	6,286	334	599	868	7,267	120	270	394
True fir	14,213	1,993	2,554	2,702	4,278	547	959	1,182	2,936	234	399	587
Incense cedar						19	30	33		76	116	134
Saw timber (mcf)*		4,070	6,310	7,681		900	1,588	2,083		744	1,284	1,785
Non-merchantable		2,035	3,155	3,841		450	794	1,042		372	642	893
Total biomass (mcf)		6,105	9,465	11,522		1,350	2,382	3,125		1,116	1,926	2,678
Removal percentage		80%	70%	60%		80%	70%	60%		80%	70%	60%
Total biomass (MBDT)*		78	106	111		17	27	30		14	22	26
Annual removal (10 yrs)		7.81	10.60	11.06		1.73	2.67	3.00		1.43	2.16	2.57
Total acres	46,340				27,476				12,180			
Total annual harvest/region		29.48				7.40				6.16		
Annual harvest (1000 ac)		1,965				493				410		
Percent of area harvested in 10 years		42.41%				17.94%				33.69%		

* mcf = million cubic feet; MBDT = million bone dry tons

Part II—Biomass Energy Considerations

Introduction

Although there are many options for disposing of biomass thinned from overcrowded forests, the vast amount of biomass that needs treatment limits consideration of many of these possibilities. The USDA's Forest Products Laboratory has worked to develop a broad array of options for traditional and non-traditional forest products throughout the U.S. Most of the non-traditional products require small amounts of material and therefore do not match the large amounts of biomass to be treated in the West. However, there appears to be an excellent match between the vast amounts of biomass resource in the form of forest residues and the large biomass market demands of the biomass power and emerging biomass ethanol industries.

This is not to say that other non-traditional products are unimportant. There can be, in some cases, a combination of traditional products (saw logs, pulp, fuel wood etc.) plus non-traditional products (small stakes, chips for organic mulch, compost, animal bedding etc.) that may make a forest thinning project economically feasible. The primary problem, however, remains that these combinations of products have not, in most cases, added up to the total amount of biomass that needs to be removed. Where that is the case, a biomass energy market may be the key to initiating many forest restoration projects.

The use of biomass for energy will always be the lowest-value use. Where alternative or non-traditional wood products can be produced, those biomass users will out-bid the energy industry for the biomass supply. The biomass energy market can, however, be a useful adjunct to those market opportunities, providing a way of disposing of otherwise problematic residual material in a least-cost, if not profitable, manner.

From a biomass energy standpoint, unhealthy forests are only one of many sources that could eventually support a robust biomass energy industry. The U.S. sends more than 200 million tons of organic waste to landfills each year and currently idles about 50 million acres of farmland, some of which is suited for growing dedicated energy crops. To put this in perspective, if fully used, these resources could produce enough ethanol to power most U.S. vehicles. While this level of market penetration is not realistic in the foreseeable future, aggressive policies to encourage the development and use of biomass could help biomass ethanol producers eventually reach something on the order of 50 billion gallons of ethanol per year, according to NREL estimates (Sheehan 2000).

Sources of biomass other than forests may be important in providing a full feedstock supply over the economic lifetime of a biomass energy plant. Short-term cleanup of surplus forest biomass may not, by itself, provide for an economical installation. In other words, it may be important for proponents of biomass industry development to focus attention on the total biomass opportunities in forest, agriculture and municipal sources in some areas. What seems logical is that the industry will not develop around one source of fuel alone. A larger industry that uses a mix of biomass fuel sources will provide opportunities that do not exist today.

The two leading technological options for converting large amounts of biomass in the U.S. to energy are conversion of biomass to ethanol and conversion of biomass to electricity. A number of technological conversion methods exist to produce ethanol from biomass, several of which are in various commercial planning stages today. There are essentially two technologies in operation today for conversion of biomass in power generation: the current combustion technology and long-term gasification technology.

Former President Clinton in August 1999 showed strong support for biomass products with his Executive Order seeking to accelerate the development and use of biomass fuels, products and chemicals in the U.S. Its goal is to triple the use of bioenergy and bio-products by 2010 and generate as much as $20 billion per year in new farm and rural community income. (Clinton 1999).

Biomass Conversion to Ethanol

Overview

The United States needs alternatives to foreign oil for transportation to wean the country from its dependency on imported oil. Using biomass as a feedstock for ethanol production could expand the domestic ethanol market, improve national security, create jobs, dispose of burdensome biomass waste and produce a clean transportation fuel.

Biomass is composed of three components: cellulose (6-carbon sugars), hemicellulose (mostly 5-carbon sugars in hardwoods and herbaceous crops and 6-carbon sugars in softwoods) and lignin (the “glue” holding polymers, or long chains, of these two sugars together). The production of ethanol involves the use of chemicals, or a combination of chemicals and enzymes, to break down the cellulose and hemicellulose into sugars, which are then fermented into ethanol. The lignin may be burned to provide the heat and energy needed to drive the process. Research is under way to develop new methods and technologies that can improve the efficiency of these processes (Hinman 1997).

The current corn ethanol industry converts the starch in the corn kernel to ethanol. Starch is another 6-carbon sugar polymer, but it is a much different molecule than cellulose and requires a different technology. The remainder of the grain is converted to high-value products such as animal feed and corn syrup. The U.S. Department of Agriculture (USDA) recently determined that today's corn ethanol plants have increased production efficiencies to reflect a net energy gain of 25 percent; the U.S. Department of Energy's (DOE) new technology for biomass conversion to ethanol could increase production efficiencies up to about 4:1. Cellulose-based conversion to ethanol differs from the current starch-based conversion in that it is a more cost-effective process that uses the entire resource (Argonne National Laboratory 1999).

Using biofuels such as ethanol provides measurable air quality benefits by reducing vehicle emissions and abating field burning of some agriculture residues. Increasing the use of biofuels will reduce air pollution and the greenhouse gases that are implicated in the problems of global climate change. An estimated 40 percent of today's smog, 33 percent of annual carbon dioxide emissions and 67 percent of carbon monoxide production comes from automobiles and other forms of transportation (Hinman 1997).

Production of biofuels can also contribute to cleaner air by providing a clean biomass disposal method that reduces the pollutants associated with open-field burning of agricultural crop residues such as rice straw or sugar cane bagasse. Located near forests that need surplus biomass removed as a means of lowering wildfire intensity, biomass energy facilities could also provide a disposal outlet that would result in lower emissions from wildfires.

Another benefit of bioethanol[22] is that the lignin component allows the biomass conversion process to be power independent in a stand-alone bioethanol plant. Also, by colocating a bioethanol plant with an existing biomass power plant, it is possible to cogenerate electricity in the associated power plant that would burn the lignin component. Lignin has the same energy content as a mid- to high-grade coal, but it lacks coal's sulfur and nitrogen. Preliminary reports indicate that co-locating a bioethanol plant with a biomass power plant is quite cost-effective because of lignin use. Therefore, some of the first biomass ethanol plants in the U.S. (particularly in California) may be colocated with power plants to help cut down capital costs such as boilers and water treatment facilities (Yancey 2000).

Ethanol as a Transportation Fuel

The Clean Air Act of 1970 signaled the beginning of a new era in which the United States federal government began relying on national standards to enforce environmental quality. First revised in 1977 and again in 1990, the Clean Air Act affects the health and economic welfare of millions of U.S. citizens. Air pollution levels have dropped significantly, including an 89 percent decline in emissions of lead between 1988 and 1993. In the same time period, a 20 percent decline of particulates is reported, along with a 26 percent decline in sulfur oxides and a 37 percent reduction in carbon monoxide, some of which is due to ethanol use (DOE 1995).

The 1990 Clean Air Act Amendments encouraged the development of alternative fuels as well as cleaner blended fuels. Alternative fuels are specifically defined as methanol, ethanol and other alcohols, reformulated gasoline and diesel, natural gas, liquefied petroleum or propane, hydrogen and electricity.

The final version of the Clean Air Act Amendments in 1990 stopped short of mandating the sale or use of alternative fuels, but the act does incorporate several programs requiring cleaner fuels, opening up the fuels market to nonpetroleum gasoline additives. The two most important programs with respect to gasoline composition are the Oxygenated Fuels and Reformulated Gasoline programs.

Oxygenated Fuels Program

The Oxygenated Fuels program was designed to combat carbon monoxide, which is a product of the incomplete burning of carbon found in transportation fuel. In 1990, 42 urban areas with 22 million people exceeded the EPA's National Ambient Air Quality Standard for carbon monoxide. Since November 1992, gasoline sold in the winter in high-pollution areas is required to contain a minimum of 2.7 percent oxygen by weight, equating to about 10 percent ethanol in gasoline. This added oxygen causes more com-

[22] In this discussion, the term "bioethanol" refers to ethanol produced from lignocellulosic biomass (or cellulose), in contrast to ethanol produced from grains, such as corn.

plete combustion of the fuels, resulting in lower carbon monoxide emissions.

Fuel additives such as ethanol and ethyl or methyl tertiary butyl ether (known as ETBE and MTBE, respectively) supply the extra oxygen for these oxygenated gasolines. The majority of MTBE used in the U.S. is imported; MTBE imports reached 1.5 billion gallons in 1997 alone (RFA 1998). Under the Oxygenated Fuels program, these additives, mostly in the form of MTBE, are used in about one-third of the nation's gasoline, displacing 100,000 to 200,000 barrels of oil per day. However, health concerns about MTBE, along with discoveries of underground gasoline tanks leaking MTBE into ground water, have caused state and federal legislation to be enacted that phases out MTBE use.

The Oxygenated Fuels program has been a success. A 95 percent reduction in the number of days exceeding the carbon monoxide health standard was reported within the first year of the program. The program is estimated to reduce vehicle carbon monoxide emissions by 15 percent to 25 percent.

Reformulated Gasoline Program

A second type of pollution problem, one addressed by the Clean Air Act's Reformulated Gasoline (RFG) program, is ozone formation. Ozone is the major component of smog and presents the U.S. with its most difficult urban air quality problem. Nearly 100 cities exceed the EPA's National Ambient Air Quality Standard for ozone, which is based on the highest ozone level a sensitive person can tolerate. There are nine urban areas inhabited by 57 million people affected by severe ozone pollution. These areas experience levels of 150 percent or more of the acceptable level of ozone.

Reformulated gasoline containing oxygenates substantially lowers tailpipe emissions that produce urban smog and toxic air pollutants, including carbon monoxide, carbon dioxide and sulfur oxides. To reduce evaporative emissions, reformulated gasoline standards mandate refiners to lower the vapor pressure of gasoline before blending in oxygenates (Clean Fuels Development Coalition 1997). Overall emission performance standards require RFG to achieve at least a 20 percent to 25 percent reduction in hydrocarbon and toxic compound emissions beginning in the year 2000 (DOE 1995). Requirements call for 22 percent of U.S. gasoline to be reformulated, displacing between 100,000 and 350,000 barrels of oil a day.

Reformulated gasoline eliminates more than 300,000 tons of air pollution annually, equivalent to taking 7.5 million vehicles off the road. A General Accounting Office report concluded that oxygenates in RFG will displace nearly 4 percent of U.S. gasoline consumption annually and, if fully implemented, could displace 10 percent (Durante 1996). Although it costs about 2 to 4 cents more per gallon than conventional gasoline, RFG reduces toxic emissions by nearly 20 percent more than the Clean Air Act actually requires (DOE 1995).

Adding oxygenates to RFG has two main benefits. Oxygen dilutes and replaces aromatics, such as the carcinogen benzene, and increases engine efficiency, causing gasoline to burn more completely. These two benefits make oxygenate addition one of the most feasible alternatives for refiners to achieve the required abatement in air toxics, while also reducing tailpipe sulfur, olefins and total volatile organic compound (VOC) emissions.

Environmental Issues and MTBE

MTBE, the fossil-based oxygenate that has been California's oxygenate of choice, has recently been found to have major environmental problems. In California, MTBE—a suspected carcinogen in animals and a highly persistent contaminant in water—has been leaking into groundwater from underground gasoline storage tanks and has been detected in drinking water. The governor of California has issued an executive order to phase out MTBE use in gasoline by 2002 (Davis 1999; Graf and Koehler 2000). The California governor's Environmental Policy Council concluded that ethanol is a safe and preferred oxygenate alternative; if it were to fully replace MTBE at its current level of use, the ethanol demand could potentially reach as much as 550 million gallons per year (Graf and Koehler 2000; Hickox 1999). This increased ethanol demand would create a greater market pull not only for ethanol but also for its required feedstocks such as wood residues.

Benefits of Bioethanol

Bioethanol can be manufactured from feedstocks that are troublesome to the environment and to communities nationwide. For example, many areas of the United States have become burdened with solid waste disposal, causing landfills to turn away waste and leaving few options. In California, even simple refuse such as yard trimmings is piling up and creating problems. California has legislation in place requiring a 50 percent reduction of municipalities' solid waste going to landfill sites. These wastes could be converted into ethanol. Ethanol-plant side-products—various acids and terpenics such as gallic acid—may be highly marketable products in the future (Greef 1999). It has been estimated that California alone has enough biomass to support an ethanol industry of 1 to 1.5 billion gallons per year. Most of that biomass is a burdensome waste disposal problem today (Forrest 1999). In contrast, the total ethanol production of the U.S. currently stands at 1.5 billion gallons a year (ABA 2000b).

As we have discussed above, the benefits of the use of bioethanol include the reduction of air pollutants from tailpipe emissions. In addition, the growth of new tree and plant sources of biomass recaptures carbon during photosynthesis. This process absorbs atmospheric carbon dioxide, which has been associated with global climate change.

Bioethanol Production and the Western Market

The estimated cost of bioethanol has dropped from \$3.60 a gallon in 1980 to between \$1.15 and \$1.43 a gallon in 2000. Advances in feedstock processing and biotechnology could reduce bioethanol costs to between \$.69 and \$.98 per gallon over the next two decades (DiPardo, in Graf and Koehler 2000).

Most of the cost reduction estimates are based on the introduction of superior enzymes and process designs, a result of research conducted for almost two decades at the U.S. Department of Energy's National Renewable Energy Laboratory (Mielenz et al. 1996). It should be noted that these cost projections do not include government tax incentives.

A rough estimate based on pilot plant results shows that 200 bone-dry tons (BDT) a day or 70,000 BDT a year of western softwood biomass are required for production of 3-to-6 million gallons of ethanol a year in a biomass ethanol plant, depending on the technology chosen. Estimates indicate that the 70,000 BDT a year would produce 3.6 million gallons with dilute nitric acid technology, 5.6 million gallons with an advanced enzymatic process and 6 million gallons with a concentrated sulfuric acid process. The conversion efficiency rate depends on the type of biomass feedstock used and its sugar content, (amount and types of 5- versus 6-carbon sugars in the biomass) as well as the technology used (acid versus enzymatic hydrolysis, etc.)(Yancey 2000; NREL 1997).

Ethanol demand in the Western states of California, Arizona, Nevada, Oregon and Washington rose from 154 million gallons in 1992 to 214 million gallons in 1996 but dropped to 124 million gallons in 1997 as California and Washington changed their policies (NREL 1997). However, this demand is still significantly more than the current ethanol production capacity on the West Coast, which is estimated at only 14 million gallons per year. If additional Western supplies could be developed from biomass, the advantage in reduced transportation costs for Western producers is estimated to be between 5 and 15 cents per gallon when compared to importing Midwest sources.(Yancey 2000)

Figure 2.1 Ethanol costs per gallon are projected to fall significantly by 2010 (Sheehan 2000).

Status of the Bioethanol Industry

The U.S. Department of Energy and the National Renewable Energy Laboratory (NREL) have been working closely with state agencies and a wide range of industrial partners to accelerate the advancement of new bioethanol technology.

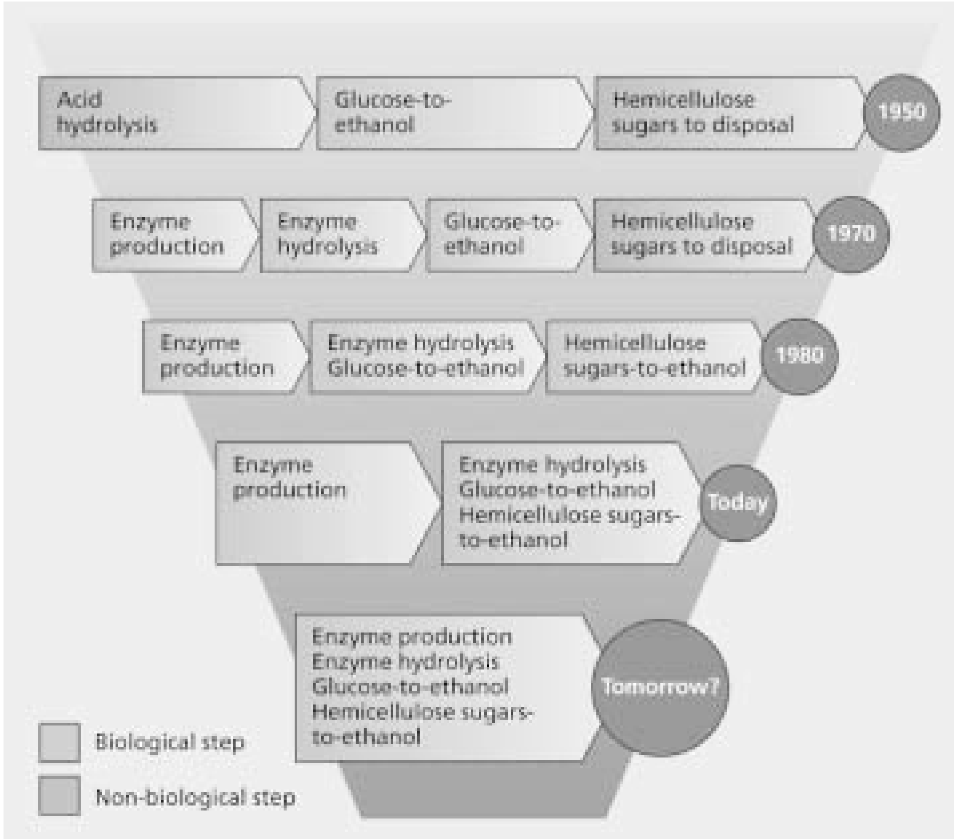

Figure 2.2 Progress of biomass-to-ethanol conversion technology (Sheehan 2000).

DOE and NREL, along with California's Energy Commission, Air Resources Board, and Food and Agriculture Agency, are exploring the possibility of California producing its own domestic bioethanol to curb toxic transportation emissions and simultaneously stimulate its economy. One of DOE's objectives is to have the first new-technology bioethanol plant operational in 2002. Several biomass ethanol plants are being considered for construction in California, with operations projected to begin by 2003. The projects, using an array of technologies, include:

■ *City of Gridley*: In California, BC International Corporation (BCI) will use its technology on waste rice straw, alleviating open-field burning. This plant may also use forest residues and will most likely be co-located with an existing biomass power facility.

■ *Collins Pine*: BCI, in cooperation with Collins Companies, a large private timber firm, is planning a plant fed by forest residues. The plant will be sited in Chester, California, near an existing sawmill operation and will also use sawmill residues as feedstock.

■ *Arkenol, Inc.*: In a plant project near Sacramento, California, Arkenol will use a patented new technology to convert rice straw to ethanol and other feedstocks such as lactic and citric acids. This project will use a proprietary hydrolysis process, a technology different from the one to be employed at the BCI/Gridley project. The same process can work with forest biomass if a steady, long-term supply can be guaranteed (Greef 1999). While this plant is on hold, Arkenol is also considering a plant in Southern California using the paper component of municipal solid waste (ABA 2000a).

Several other plants that could be coupled to existing biomass power plants may be feasible in California. Many biomass power plants went out of business in recent years because of the ending of California's Standard Offer contracts stemming from Public Utility Reform Policy Act (PURPA) legislation. California has lost about 300 megawatts of its 880-megawatt capacity supplied by these plants (California EPA 1997). A bioethanol plant would be able to derive enough kilowatt-hours of electricity from the lignin component of biomass to operate the bioethanol plant and still have excess electricity left over for sale to the power market. In some cases, it would be beneficial to co-locate a biomass ethanol plant with existing power plants, which might improve the economics enough to keep some of these power plants operational (NREL 1997a; Yancey 2000).

Front Range Forest Health Partnership Feasibility Study

The Front Range Forest Health Partnership consists of public, private and citizen groups organized to investigate possible options for using wood residues generated through forest thinning and through commercial activities in urban communities along Colorado's Front Range. The partnership's 1998 feasibility study, prepared with the help of the Forest Service and the National Renewable Energy Laboratory, contains an inventory of woody biomass resources and a siting analysis for potential forest biomass-to-ethanol facilities.

The study concludes that:

- More than 520,000 bone-dry tons per year of material are available within a 50-to-100 mile radius of the Denver Metropolitan area.
- Coors Brewing Company of Golden, Colorado, is the most viable site for an ethanol plant. Coors already produces some ethanol from waste beer at its Golden facility.
- A biomass ethanol plant is feasible but questions of secure supply and transportation cost must be resolved.

Quincy Library Group Feasibility Study

The Quincy Library Group, a forest health advocacy group located in Quincy, California, used assistance from the California Resources Agency to perform a feasibility study of building and operating a biomass ethanol plant in Northern California. NREL provided technical support and publication. The proposed plant was based on the group's plan for strategic thinning of the region's federal forests as a way of reducing fire danger, improving forest health and restoring forest ecosystems.

The forest thinning plan was enacted into law in October 1998 as the Herger/Feinstein Quincy Library Group Forest Recovery Act of 1998.[23] Under this law, the Quincy Library Group has received full funding of about $30 million in 2001 for a five-year program of thinning 40,000 to 60,000 acres per year. However, the plan continues to face significant opposition from environmental organizations.

The Quincy Library Group is trying to address the forest health situation that is common in many areas of the West as we have discussed in Part I of this report. The challenge is to find an economically feasible and environmentally suitable way to dispose of large quantities of non-marketable small trees and other biomass. The feasibility study concluded (NREL 1997)[24]:

■ There is adequate biomass in the region for one or more plants. In studies of forests within a 25-mile radius of four proposed plant sites, sustainable supplies ranged from 187,000 to 336,000 bone-dry tons per year.

■ Feasible sites for production facilities exist; sites near existing or former sawmill sites, with access to existing biomass power plants, showed the most promise.

■ Several operating technologies were evaluated for feasibility, with plant sizes limited to the estimated sustainable biomass supply within a 25-mile radius. The resulting plants would range from 11.8 million gallons per year to 28.2 million gallons per year, well within the market demand of the Western states.

■ Not all of the plants were equally attractive economically. One plant located far from an existing biomass power plant showed a negative internal rate of return for technology based on the dilute sulfuric acid process. The others all showed a positive internal rate of return.

■ Sensitivity analysis indicated that the economics of these plants was most sensitive to feedstock cost and the ability of prospective owners to find financing.

■ Environmental impacts, while needing adequate attention, are manageable within the current policy authorities.

■ A 15 million-gallon per year bioethanol plant, co-located with an existing biomass electricity generating plant, would produce about 28 plant jobs and 60-to-128 jobs in the woods for gathering feedstock. These would be aug-

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[23] The Herger/Feinstein QLG Forest Recovery Act of 1998 was part of the Omnibus Appropriations Bill for FY 1999, P.L. 105-277.

[24] All of the conclusions in this section come from the Northeastern California Ethanol Manufacturing Feasibility Study (NREL 1997). This study, composed of several intensive studies of various aspects of the project, is available through the Quincy Library Group on the Internet http://www.qlg.org.

mented by an additional 93-to-122 indirect or multiplier jobs. In total, the plant could generate between 184 and 250 jobs in its local area, for an annual estimated payroll of nearly $5 million.

■ Because the most sensitive factors in the analysis are feedstock supply and cost, a method of assuring long-term supplies and prices seems critical to the success of such a venture, particularly in the case of the initial efforts.

Legislation Affecting Ethanol

The recent detection of the oxygenate MTBE in California groundwater has put oxygenates in general, including ethanol, under close public scrutiny. Many federal and state bills under consideration would affect the California and national ethanol market. Several pieces of proposed federal legislation, if passed, would free oil companies from a mandate for the use of oxygenates in California by allowing them a waiver from the Clean Air Act's oxygenate standard. While the aim of legislation such as H.R. 11 is to decrease or eliminate the use of MTBE due to groundwater concerns, its passage could also take away future opportunities for ethanol in the state (H.R. 11, 106th Cong., 1st sess. [1999]).

The California EPA and California Energy Commission estimate that about 300-to-580 million gallons of ethanol will be used annually without an oxygenate waiver, but only 150-to-300 million gallons per year will be used if the waiver passes (California Energy Commission 1999; Hickox 1999). The latter estimate, particularly on the lower end, is not a very significant market for biofuels considering the potential for producing 1-to-1.5 billion gallons per year of ethanol in California from indigenous biomass. However, the biofuels market is still worth pursuing by local bioethanol producers who could exploit their transportation advantage to compete for the market.

Biomass Conversion to Power

Overview

Forest and other biomass is currently being used for conversion to electric power through conventional combustion technology. The biomass power industry is composed of about 350 plants with combined capacity of about 7,800 megawatts, according to a DOE database. Of those plants, 45 are idle, equating to 655 megawatts of unrealized capacity. The plants are spread out over most of the U.S., with plants in every state except West Virginia, Colorado, Delaware, Indiana, Kansas, Nebraska, New Mexico, New Jersey, North Dakota, Rhode Island and South Dakota. In addition, another 650 industrial plants generate electricity with biomass for their own use. The biomass power industry employs more than 66,000 people in the U.S. and has an investment base of about $15 billion (NREL 1999). It is estimated that 50,000 megawatts of biopower could be generated by 2010 using advanced technologies and improved feedstock supplies. Biopower plants require a guaranteed, long-term biomass fuel supply to ensure operation (DOE 1995a).

Of the industrial combustion facilities, 148 plants use existing boilers at pulp and paper mills. The technology used in the pulp and paper industry was designed for waste disposal initially, but new technology focusing on energy production will improve efficiencies (SERBEP 1995). In California, the plants were originally built under Standard Offer contracts stemming from the qualifying facility mandate under the Public Utility Reform Policy Act (PURPA); several are cogeneration facilities. PURPA fueled the rapid development of the biopower industry until the mid-1980s, when the industry began to level off. The early contracts were based on the belief that fossil fuel prices would continue to increase. When that did not happen, utility companies purchased many of the remaining above-market contracts and retired the non-competitive facilities. Expiration of contracts and competition for biomass resources have put pressure on the biopower industry to close or revitalize the less efficient plants. Plants in California and the Northeast are feeling pressure on their revenues as avoided cost rates (cost of building new capacity) paid for electricity have declined (DOE 1996). By December 1996, California had lost about 30 percent of its existing biopower capacity, with 30 biomass power plants operating and 15 more that could be returned to service if conditions warrant (California EPA 1997).

Stand-alone biopower producers often play an integral role in the management of residue and waste flows in a region, accepting waste materials that would otherwise be landfilled or open-burned. To the benefit of the biopower plant, the fuel cost is often only that of transporting these materials. The feedstock issue is at the core of sustainability for biopower. While the use of dedicated biomass crops for energy production is recognized as neutral in terms of the net emission of carbon dioxide, the current use of biomass waste and residues for power production also decreases greenhouse gas emissions by capturing and using material for conversion to energy that might otherwise be composted, creating greenhouse gases such as methane (California EPA 1997).

Although biopower is generated currently through the combustion, or burning, of biomass, recent advancements in biomass power generation include gas turbines (such as BIOTEN GP's modular suspension combustion system or Power Generating's direct-fired turbine) and gasification. U.S. DOE is working with the existing biopower industry to improve the efficiency of its equipment (DOE 1993). Advanced biomass steam-turbine systems have efficiencies as high as 40 percent; in comparison, combined-cycle gas turbines using natural gas have efficiencies as high as 55 percent (DOE 1995a).

Policy Considerations of Biopower

The 1992 National Energy Policy Act (EPACT) established two highly attractive incentives for biopower:

- A 1.5 cent/kWh tax credit for closed-loop biopower systems
- A 1.5 cent/kWh payment that will be available to nonprofit utilities—that is, municipal and rural co-op utilities—for biopower produced. The payment will be administered by U.S. DOE (EPS 1992).

The closed-loop tax credit is not being used because of the definition of the term "closed-loop," which limits the qualifying feedstock to biomass that has been grown for the sole purpose of energy production. Efforts are now underway to expand this definition to include agricultural and forest residues. This change in the law would benefit existing biomass power plants and perhaps save some of these plants from shutting down.

In the past, electrical utility restructuring was putting significant pressure on existing biopower plants in the form of lower power prices, which challenge both utilities and independent power producers. Recent increased demand for power and a shortage of new generation produced price spikes in Western electricity markets in late 2000 and the early months of 2001. The changed market conditions, if these prices remain high, favor new biopower development. At the time of this publication, it is unknown whether the change in market conditions will be temporary or long-lasting.

In the U.S., utilities are converting into multiple companies competing for smaller pieces of the power business—that is, generation, power brokering, transmission, distribution and on-site energy services. The fossil fuel supply infrastructure provides a competitive challenge to biopower development, with the Energy Information Administration projecting a favorable fuel supply environment for coal and natural gas until 2010. Natural gas represents the majority of expected new capacity, with 30 such plants in the planning stages for California alone (ABA 2000c).

Co-firing Biomass with Coal

Co-firing biomass with coal is an opportunity for some parts of the biomass supply industry located near coal-fired power plants that rely on high-sulfur coal.[25] Co-firing can assist with market development, aiding in uncertain fuel supply and delivery issues in some states. Co-firing offers a relatively inexpensive way to significantly reduce SOx, NOx, and CO emissions.

A 1993 study of the status and potential for co-firing of biomass with coal in the Great Lakes Region concludes that no significant technical barrier exists to the increased use of co-firing (Irland and Fisher 1993). Co-firing waste-wood biomass with high-sulfur coal is potentially attractive to some utilities in the U.S. because it avoids the addition of costly flue gas scrubbers, or simply permits the use of cheaper, higher sulfur coal even under tight constraints by EPA (DOE 1997).

Studies by the Electric Power Research Institute have indicated that co-firing with biomass at levels up to 15 percent can be economical when the difference in cost between coal and wood is in the range of $0.25 to $0.40 per million BTU. However, when coal costs $1.00 to $1.50 per million BTU, it is difficult for biomass to compete (SERBEP 1995).

Several fuel characteristics need to be considered that will influence the efficiency of co-firing opportunities (Junge 1989). Physical and chemical analysis of the materials can determine moisture content, heating value, fuel density, energy density and fuel combustion rates. Table 2.1 indicates some of these values for a few types of biomass and fossil fuels (Irland and Fisher 1993).

Gasification

To achieve higher efficiencies, biomass can be converted into a gaseous form called producer gas through a procedure called gasification. The U.S. DOE has helped develop

[25] The Boardman Coal Plant in Oregon burns mostly low-sulfur coal and therefore may not be a good candidate for biomass co-firing. California has no coal plants, which rules out the co-firing option for that state.

Table 2.1. Fuel Parameters for Selected Biomass and Fossil Fuels

Fuel Parameters	*Dry Wood Pellets*	*Typical Hogged Fuel*	*Municipal Solid Waste*	*Pennsylvania Coal*	*Wyoming Coal*	*No. 2 Fuel Oil*
Moisture content (% wet basis)	10.0	40.0	30.0	1.3	2.5	0.0
As-fired heating value (Btu/wet pound)	8,127.0	5,418.0	4,500.0	13,800.0	9,345.0	19,430.0
Fuel bulk density (pounds per cubic foot)	35.0	22.0	12.0	50.0	45.0	53.9
As-fired energy density (Btu per cubic foot)	284,400.0	119,200.0	54,000.0	690,000.0	420,500.0	1,047,000.0
Fuel feed rates (cubic foot per million Btu)	3.5	8.4	18.5	1.4	2.4	1.0

gasification pilot projects using producer gas around the nation, hoping to achieve efficiencies upwards of 50 percent in the future.

Biomass gasification and hot-gas clean-up systems technologies, such as contained in the SilvaGas™ process (FERCO 2000), are being developed that will meet the fuel requirement of combustion turbines. This allows the use of biomass in high-efficiency systems such as steam-injected gas turbines and combined-cycle systems and may help some biopower plants be more cost-effective through co-firing with natural gas (DOE 1993). Gasification of biomass has the potential to add much new capacity to the existing biomass power industry. While research on gasification is not complete, these facilities should offer improvement in efficiency, emissions and the range of feedstock types they can use.

Fuel cells are being developed to convert gaseous fuel directly to power using a process analogous to that of a battery. Using gasified biomass as a fuel source, power cycle efficiencies approaching 60 percent may be possible. Much work still needs to be done using hot-gas clean up in addressing gas quality for fuel cells (DOE 1993).

Status of Today's Biomass Gasification Pilot Projects

A small number of biomass gasification plants now at different phases of construction will serve as test facilities and pilot plants for the future industry. The major pilot plants include:

■ *Burlington, VT, Gasifier Project*: Burlington Electric Department's McNeil Generating Plant has been producing wood-fired biomass power at its 50 megawatt per year plant, but it recently integrated a new gasification technology to add more capacity. DOE, along with the technology licensee Future Energy Resource Corporation (FERCO), has added a 15 megawatt per year gasifier as a pilot plant. The plant successfully attained full operation in August 2000 producing electric power from biomass in a conventional gas turbine (ENS 2000). The initial full-capacity burn converted more than 285 tons of wood chips derived mainly from low-quality trees and harvest residues into more than 140 megawatt-hours of electric power (FERCO 2000). This project does not require a hot-gas cleanup system and produces a higher Btu gas stream than other gasification systems. Industry partners include: FERCO of Georgia (which is cost-sharing 50 percent of the total project with DOE), McNeil, Battelle and Zurn Nepco of Maine (ABA 1998; DOE 1997a, 1997b).

■ *Chariton Valley Resource Conservation and Development (RC&D) Project*: This Iowa project is a public/private partnership between U.S. DOE, U.S. Department of Agriculture and the Chariton Valley RC&D Area, under DOE/USDA's Biomass Power for Rural Development Initiative. About 500 local farmers and landowners are aligned with the combined research and investment power of 14 organizations. The project will be growing switchgrass on 30,000-to-40,000 acres of underutilized, marginal cropland. The partnership received authorization from USDA Farm Services Agency for a 4,000-acre demonstration project supporting the development of energy crops on existing Conservation Reserve Program (CRP) land, as the CRP is phased-out (DOE 1996a). As of 1998, 75 percent of the acres in the Chariton test plots had been planted in switchgrass (West Bioenergy 1998). A test firing of 1,500 to 2,000 tons of switchgrass at Alliant Power's Ottumwa Generating Station is planned prior to Spring 2001. The test firing will determine the feasibility of using a dedicated supply of southern Iowa biomass as a fuel source.

Table 2.2. Typical soil erosion rates and chemical use of selected food and energy crops (National Biofuels Roundtable 1994).

Crop	*Soil Erosion ($Mgha^{-1}yr^{-1}$)*	*Nitrogen ($Kgha^{-1}yr^{-1}$)*	*Phosphorous ($Kgha^{-1}yr^{-1}$)*	*Potassium ($Kgha^{-1}yr^{-1}$)*	*Herbicide ($Kgha^{-1}yr^{-1}$)*
Corn	21.8	135	60	80	3.06
Soybeans	7.1	10	35	70	1.83
Herbaceous energy crops	0.2	30	50	90	0.25
Short-rotation woody crops	2.0	60	30	80	0.39
Pasture	2.0	20	30	30	0.15

■ *Niagara Mohawk Power Corporation Project*: This co-firing project in upstate New York and the surrounding region is also part of the DOE/USDA Biomass Power for Rural Development Initiative, with the cost estimated at about $14 million over six years, including a 45 percent federal cost-share. The feedstock for the plant is a hybridized fast-growing willow tree, developed by the State University of New York at Syracuse Biomass Program and dedicated for energy crop purposes. Niagara Mohawk represents The Salix Consortium, a partnership of more than 25 research institutions, farmer groups, governments, environmental groups and five power-generating companies. The willow energy crop will be grown on 2,600 acres of land. At least 26 local farmers have committed to invest their resources in the facility, which is expected to produce between 37 and 47 megawatts of electric capacity through co-firing with coal (DOE 1996b). More than 370 acres of commercial biomass crops had been established as of 1999; 18 smaller 1-to-2 acre trial sites had also been established in seven eastern states and Canada (Abrahamson 1999). This project would be the first true closed-loop biopower plant in the U.S.

Environmental Impacts of Biopower

Biopower plants produce virtually no sulfur emissions, helping mitigate acid rain and air pollution. Combustion of biomass results in less ash than coal combustion, reducing ash disposal costs and landfill requirements. Global warming impacts are reduced because of the recapture of carbon through photosynthesis. The CO_2 emissions from the nation's current fuel mix is more than 600 metric tons of CO_2 per gigawatt-hour, and additional biopower could help bring the net emission level down.

Several of the biomass power projects cited above produce benefits such as soil and water conservation, reduced fertilizer and herbicide use, water quality protection, and a broadened rural economic base during growth of alfalfa, switchgrass or dedicated energy plantation crops (see Table 2.2). Of course, dedicated energy crops also can be used as feedstock for ethanol and chemical production

Biomass power benefits include the following (CBEA 1988):

- Reductions of particulate matter (PM_{10}), NOx, SOx, CO, and volatile organic compounds (VOCs), with the greatest reduction in CO. The monetary value of these reductions to the environment is about $14 million per year.
- Avoidance of open burning of 1.1 million tons per year of wood residues, saving taxpayers an estimated $25 million per year.
- Diverting waste from landfills (1.7 million tons per year from 1994 figures), saving taxpayers $55 million per year.
- For 50,000 acres treated by thinning, more than 10 percent of acreage will have a reduction in burning with a value of $17-to-$54 million per year (water/watershed loss varies from $169-to-639/acre).
- Employment benefit of $165 million per year, with an estimated employment of 6,600 people at biomass power plants and in collection, processing and transport operations.
- Tax revenues of $67 million per year, including estimates for power plants, fuel processing facilities and license fees on fuel trucks.
- Displacement of fossil fuel-derived electricity, providing diversity and reliability through distributed generation (from 1991 to 1995, calculated values varied from $90-to-$156 million per year).
- Increased water yield from areas of biomass fuel collection estimated at 1.1-to-2.1 million acre-feet per year with a value of $55-to-$148 million per year.

Supplemental Opportunities for Biomass Utilization

The primary barrier to increased biomass use appears to be economic. Given the competitive position of fossil-based energy options compared to biomass, additional opportunities to improve biomass economics through production of co-products are being sought by both the bioethanol and biopower industries.

A larger and more profitable opportunity than biomass power and fuels may lie in the ability to extract valuable chemical compounds from biomass prior to or during its conversion to biofuels or combustion for energy. Research on a variety of products from woody biomass has produced several options that may help significantly improve biomass energy economics. Most of the companies now working to build biomass ethanol plants are strongly considering conversion of at least some of the biomass to chemicals, such as different types of acids or lignin-based chemicals. Such a diversion of biomass will undoubtedly help in the economics of energy from biomass, as output options for products can vary depending on markets for the different products. The larger corn ethanol plants now rely on market pull to sway their production among different commodities such as ethanol, animal feed or corn syrup. In the future, once these specialty biomass chemicals are proven cost-effective, more biomass-based chemicals will be co-produced along with ethanol and power in a "bio-refinery" operation (ABA 2000b).

The Lake Tahoe Biopower Program

The Lake Tahoe Biopower Program, a proposed project in California and Nevada, has as its goal the improvement of forest health by thinning excess woody biomass and using it as a renewable energy source. The Lake Tahoe program study is exceptionally relevant for Oregon's biomass efforts because its issues and problems are similar. The results of resource assessments, green power market research and marketing strategy development provide a template that Oregon may find useful in developing its biomass programs.

The Lake Tahoe Biopower Program aims to develop cost-effective market outlets for woody biomass as a way to improve forest health in the Lake Tahoe Basin, a 519-square-mile area on the California/Nevada border. The program study was funded for the Nevada Tahoe Conservation District by the US DOE's Western Regional Biomass Energy Program (WRBEP) and prepared by McNeil Technologies (2000). Participants include government agencies, private industry, community organizations and environmental groups.

The Lake Tahoe Basin ecosystem has been dramatically altered since the mid-nineteenth century. It was logged extensively during the early years of settlement, and old-growth pines were replaced by regrowth of fire-susceptible firs. As a result of the exclusion of natural fires, lack of thinning and above-average rainfall earlier in this century, Tahoe Basin forests are now characterized by over-crowded, even-aged trees and dense undergrowth. A catastrophic fire could threaten the basin's soil, water and wildlife habitat, as well as its human residents and their property.

A previous WRBEP report (see McNeil 2000) concluded that the basin produces substantial amounts of excess woody biomass and that removing it could improve forest health, reduce fire risk and provide a renewable energy source. A presidential forum on forest health objectives estimated that a potential sbiomass yield of 45,500 bone-dry tons (BDT) per year was available, based on a per-acre yield of 13 BDT per year on 3,500 acres of USDA Forest Service and private timberlands. Using all the 26,000 bone-dry tons of biomass generated from mechanical thinning of just National Forest land could provide up to 27 gigawatt-hours of electricity per year.

The Lake Tahoe Basin program, if implemented, would capitalize on existing infrastructure. Biomass would be harvested, chipped and transported to the Sierra Pacific Industries (SPI) biomass cogeneration plant in Loyalton, California (or to some other biomass power generator). The cogeneration plant would burn the wood chips and produce biopower for sale to utility customers. The cost range for biomass prepared and delivered to the Loyalton plant is $52.41 per bone-dry ton (low estimate) and $112.50 per bone-dry ton (high estimate).[26] A preliminary study by the Sierra Pacific Power Company (SPPCo) concluded that SPPCo has sufficient transmission capacity to handle 3-to-4 MW of additional power from the Loyalton plant.

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[26] All costs and quantities reported were converted from green to bone-dry tons using a biomass moisture content of 52%, based on biomass testing performed by South Tahoe Refuse Company (STR). Biomass production costs for the Lake Tahoe study are based on data collected by the USFS and time and motion studies at forest restoration sites in Colorado and elsewhere in the Western US. These costs include stumpage, capital costs, labor costs, fuel costs and equipment maintenance costs. Chipping costs are taken from a prior chipping cost study by NEOS Corporation and a cost-shared study in support of the current project by STR. Transport costs are based on published biomass trucking costs and actual STR costs between a Tahoe area USFS site and the SPI Loyalton plant, a distance of 75 miles. See McNeil 2000.

Total estimated biopower costs—including collection, chipping, transport, generation and marketing—were estimated at $.075 per kilowatt-hour (kWh) as a low estimate and $0.129 per kWh as a high estimate. The difference between high- and low-end costs depends on the costs of delivered biomass fuel. Using a low-end scenario, a household with a monthly demand of 200 kWh would pay an additional $4 per month to meet all its electricity needs with biopower.

The costs mentioned above exclude California Energy Commission (CEC) credits, which are currently available at a rate of $0.015 per kWh for both California producers and consumers of renewable energy (including solar, wind, biomass and other green technologies). Factoring in the CEC credits, the biopower premium over conventionally produced electricity is $.02 per kWh as a low estimate and $.074 as a high estimate. However, as the date of this publication, the CEC supplier credit was targeted to be phased out by 2002, further increasing the price premium of biopower over conventional power in the future.

To be successful, the Lake Tahoe program will need a viable customer base for its power output, and that base will have to include customers from both residential and commercial sectors. An essential factor for success is recruitment of large commercial customers who are willing to commit to buying a significant quantity of biomass-based energy. Businesses that depend on the natural beauty of Lake Tahoe's forests can benefit from both improved forest health and public recognition of their role in supporting sound forest management. Federal agencies are also a good target due to a recent Executive Order (White House 1999) instructing agencies to increase their use of renewable energy. State, regional and local governments are potential customers and program supporters as are environmental groups and "green" product retail establishments.

Product differentiation is a challenge for renewable energy. The renewable power provider must be able to link biomass-derived power directly to the benefits it can have for local areas. Likewise, a tangible description of the benefits of forest management needs to be established and delivered to target consumer markets. People will be more likely to support biopower use, even at a price premium, if they associate it with sustainable forests, water quality improvement and reduced fire risk.

Results of a 1997 study[27] evaluating customer attitudes toward, and willingness to pay for, electricity generated from alternative sources indicated that both California and Nevada utility customers view the benefits of renewable energy options as outweighing perceived problems or barriers. Available information on willingness-to-pay suggests that utility customers in the Lake Tahoe Basin will pay more for biomass energy. The low end of the price premium, $.02 per kWh, is comparable to that for wind power from the Windsource Program in Colorado, and that program has more than 10,000 subscribers. A caveat: There is often a discrepancy between what people say they are willing to pay, as recorded through surveys, and what they actually do, in terms of actual sign-ups for green power programs. Using more conservative sign-up rates would better forecast actual subscriptions.

[27] In late 1997, a joint effort between SPPCo, the Nevada State Energy Office, and NREL resulted in an evaluation of customer attitudes towards and willingness to pay for electricity generated from alternative energy sources. See McNeil 2000.

Part III—Eastern Oregon Case Studies

Overview

We looked at two counties in Eastern Oregon—Grant and Wallowa (see Figure 3.1)—to evaluate factors important for encouraging the development of bioenergy as a market option for biomass removed by forest health treatments. Both counties are rural, with their forest economies dominated by National Forest lands. Recent cutbacks in federal timber harvests have significantly affected both counties.

The situation in Eastern Oregon is somewhat similar to that of the Lake Tahoe region discussed in Part II. In addition to similar forest types and conditions, the major factor in both regions is the importance of National Forest system management and the potential for harnessing biomass energy as an avenue through which to pursue more sustainable and healthy regional forests.

Plainly stated, the potential for an economically feasible biomass facility in either Grant or Wallowa counties will rest on whether a satisfactory, long-term forest health treatment plan can be implemented on the local National Forests. Forest biomass from other lands (mainly non-industrial private ownerships) would also be important to any future plan, but if an energy facility could be built and break-even prices established, that feedstock seems reasonably well assured. Without the biomass from the federal lands, however, feedstock supplies would be inadequate.

As noted below, the Forest Service faces many problems in establishing a viable forest treatment program, but the agency is actively working to address them. In addition, Congress has weighed in with new policy and program support. Formidable economic and political obstacles remain, however, and whether current efforts will succeed is yet to be seen.

The forests and forest-related communities of Eastern Oregon, like those in much of the rest of the West, are at great risk. As time passes, the problems get more severe and the risks increase; these situations are not, as some would hope, self-correcting. In Eastern Oregon, as throughout much of the West, time is of the essence and effective, well-designed action is the only hope for avoiding a continuing string of destructive wildfires.

Figure 3.1 Map of Oregon with counties highlighted.

Eastern Oregon Forest Conditions and Fuel Availability

From a forest health standpoint, the forests of Grant and Wallowa counties in Eastern Oregon are typical of forests elsewhere in the region. On the warm, dry sites dominated by ponderosa pine, years of fire suppression have resulted in dense undergrowths of pine and fir. On the cooler, wetter sites, the same has happened, with the seral species such as ponderosa pine and Western larch being surrounded by fir thickets that provide fuel ladders, assuring that any fire is at high risk of becoming a lethal crown fire. A significant proportion of both public and private forest land needs forest health treatment and stand shaping to become more resilient and sustainable.

It appears that there is an ample fuel supply to sustain an energy facility in each county, based on the small or uneconomic trees that need to be removed. It is also clear that an accurate quantification of the amount of fuel that is physically available, and the amount that is feasible to deliver to a facility, is impossible to do at this time. The forest inventory data available are simply not current or specific enough in terms of stand structure and condition to make informed estimates. In the following sections, general quantifications are made from acreage estimates, but a more accurate inventory would be preferable.

On the private lands, the physical supply numbers are largely unavailable because of the lack of current inventory data, and the information available from satellite imagery is too coarse in resolution to make an adequate evaluation of stand structure and condition. We did not assess private industry lands for this study. In general, they will have better inventory data but may be reluctant to publicize it. They may also have been thinning enough over the years that their lands are less characterized by the over-stocked, sickly stands that are the highest priority for forest health treatment.

To the extent that biomass fuels exist on non-industrial lands, their availability should be fairly good. Landowners have not undertaken stand treatments largely because the material can't be marketed. This has led here, as elsewhere, to logging operations that remove too many of the large trees (those that pay) and left too many of the small and deformed trees (those that cost more per unit of wood to harvest and haul than they are worth). Achieving a biomass market that could help close the economic gap would remove a significant barrier to increased forest treatment, and any program that could supplement the remaining below-cost gap would create still more activity. Because the landowners in Eastern Oregon have mostly mid- to large-size holdings, a few leading operators taking the initiative would both produce a significant amount of fuel and help spread the idea to others. State foresters are ready, willing and competent to help landowners plan and implement the needed practices, and they are prepared to move a program ahead. On the National Forest lands, a more complex situation emerges, as discussed below.

Using the general land ownership and land cover data available, we can make rough estimates of the amount of biomass that might be available for energy facilities in the region. Because of the limited nature of the data, these estimates are necessarily broad and make no attempt to address the desires of landowners or the capability of the federal lands to implement projects that produce biomass (a critical factor, as noted below). As with any other biomass facility proposal in the Western region, any local energy facility that depends heavily on using the excess biomass present in

Figure 3.2 Many of the ponderosa pine forests in Eastern Oregon have dry fuels from the ground up that will result in a lethal crown fire if an ignition occurs. (photo by Neil Sampson)

today's forests must face the fact that, once initial restoration treatment is complete, these forests will not continue to provide the same level of biomass on a sustainable basis. Our estimates are "clean-up" estimates, based on how fast people may be able to treat forests in serious need. Average annual yields after the initial clean-up will be lower. The enormous acreage involved in many of these areas, however, suggests that neither the "clean up" progress nor the evolution to increased use of prescribed fire will significantly reduce the availability of forest biomass from these forests for at least two-to-three decades.

The National Forests

Thousands of acres on the National Forests of Eastern Oregon urgently need forest health treatment. Forest Service technicians recognize the need and have developed treatment prescriptions they feel would be effective at achieving the desired results. Data on the type, amount and location of acres needing treatment are available and rapidly improving as Forest Service personnel continue to field-verify stand examinations and fuel model studies.

The problems on the National Forests are largely political and institutional. Even on areas that forest plans have identified as having no legal constraints or difficult assessment issues, such as stream buffers or National Recreation Area rules, any proposal for forest health treatment must go through intensive consultations on a variety of Endangered Species Act (ESA) issues and is subject to legal and procedural appeals. Nearly every project proposal will trigger such appeals, and, even where the appeal is not upheld, the time and cost involved drains the agency's resources and further limits the amount of land where treatment needs can be addressed.

Forest Service staff point out that the stand-shaping projects they now wish to do are much different from past timber sales. A different goal for stands and different constraints apply today. Some constraints (such as diameter limit cutting or wide no-cut buffers along streams) seem to many people to make little or no sense from an ecological standpoint. The staff is able to plan within these constraints, but even projects that fall within the constraints often run into a tangle of consultations and appeals that stops progress. Part of the present impasse may be because the language of Forest Service planners has not changed sufficiently, and outside observers reading proposals think they sound exactly like old-time timber sales. Some people who oppose stand treatments argue that they are not needed or justified. For whatever combination of reasons, the institutional process is so viscous that producing any progress is agonizingly difficult and slow. In the face of the urgency felt by many land managers to treat the most vulnerable areas before they burn, the situation is doubly frustrating.

One impact of the current political situation is the increased chance that forest treatment projects on the National Forests, when they can finally be implemented, may not be fully appropriate. The time taken in the planning and appeals process can run 18 months to three years in length. By the time the appeals have been settled and the project launched, it is not uncommon for conditions on the land to have changed so much that the planned treatment needs to change. Modifying treatment plans is often avoided, however, because any significant change would trigger an entire new round of planning and appeals (Snyder 2000). In an attempt to guarantee good treatment, the procedural steps now in place can often have the opposite effect of preventing land managers from doing the type of adaptive management of which they are capable.

Forest Service contracting procedures raise other institutional issues. The ability to sign multiyear land treatment contracts may be essential to supporting an investor's willingness to build an energy facility. However, changes in policy or legislative approval may be required before the Forest Service can make such contracts. Flexibility is needed to combine all of the wood products into one contract, so that both merchantable timber and biomass can be harvested simultaneously. Support for such flexibility, as part of "stewardship contracts," appears to be developing within the Forest Service, but new contracting regulations to specifically allow it were not in final form in fall 2000, according to Forest Service employees.

A more recent issue has risen with the Forest Service policy to charge the cost of road construction and maintenance to each timber sale or road user. On some recent federal sales, the amount required for roads and slash disposal has exceeded the amount charged for the stumpage. In addition, private landowners who need to use Forest Service roads to haul their timber are being charged road use fees. The combined effect is that, on some private as well as public land, economically marginal forest health treatments are pushed even further outside marginal feasibility. In the case of biomass, where marginal values and high costs are already a problem and much of the cost is in hauling the material, adding the road costs may be particularly difficult to overcome.

Thus, even though the National Forests in Eastern Oregon have a significant need for fuel treatment that could result in a large, sustainable supply of biomass to an energy facility, the obstacles and uncertainty involved in realizing that supply remain to be overcome. New legislation, discussed below, may help address some of these issues, but its effects are yet to be realized.

Grant County

Grant County encompasses some 2.9 million acres in central Oregon, 79 percent of which are in the John Day River Basin. The main fork of the John Day River lies in a valley that runs East and West through the center of the county. Elevation ranges from about 2,000 feet in the southwest corner of the area to about 5,500 feet in the north and southcentral parts, and more than 9,000 feet on the highest peak. The climate of the county is continental with very dry, hot summers and cold winters. Precipitation ranges from a low of less than 10 inches annually to as high as 50 inches annually in the mountains, with an average for the county of 15.43 inches. More than half of the county is in federal ownership (Table 3.1). Almost 70,000 acres are private forestland.

Forest and Forest Management Conditions

Local experts note that many large private landowners are not active forest managers. Ownership of many of the ranches has changed recently, and the marketable timber was sometimes harvested to help pay for the sale transaction. As a result, many of the forests are not in good condition and could use stewardship treatment.

No detailed landowner statistics were found for Grant County. One problem facing local landowners is that Grant County locations are a 200 mile one-way haul from the Columbia River markets for pulpwood, so the price of pulp has to be strong before it is feasible to harvest and haul anything but sawlogs. Often, pulpwood is below that price level, making forest treatment an economic loser that landowners are reluctant to undertake.

Some professionals disagree with the current expansion of prescribed fire on the federal lands in the area. Their basic contention is that the federal agencies are making spring underburns that will probably not mimic the ecological processes needed in the forest. Obviously, the historical fires were more concentrated in the summer and early fall, but the extreme risks posed during those dry periods will inhibit burning then. The idea that emerges from this disagreement, which would almost certainly raise local debate, is that many of these areas will need mechanical fuel removal prior to re-establishment of a fire regime that begins to approximate the historical regime.

Interviews with the staff of the Malheur National Forest at John Day revealed that ecosystem analyses exist that quantify the extent of the fuel management problem for both the Bear Valley and Long Creek areas. Among the findings: "approximately 51% of the area is highly susceptible to spotting, torching and crowning. Fires occurring on the lower slopes now present a significant risk of damage, large fire growth and extreme rates of spread" (USDA Forest Service 1999). Much of the land, particularly in the Bear Valley District, is less than 40 percent slope and can be mechanically harvested. This is also the lower, more rolling terrain largely composed of dry ponderosa pine forests that have been in-filling in recent decades and now need forest health treatment.

In an analysis of the Galena Watershed, which is in the Long Creek/Bear Valley District, it was noted that about 25 percent of the watershed area had burned in large wildfire events since 1994. The fires' effects were severe, killing most conifer trees (USDA Forest Service 1999). About 77 per-

Table 3.1–Grant County land ownership and private land use

Landowner class	*Acres*	*Private Land Use*	*Acres*
Private	1,208,466	Rangeland	1,066,699
USDA Forest Service	1,508,500	Pasture & hay land	38,478
USDI Bureau of Land Management	176,650	Forest	69,883
		Cropland	20,720
State and municipal	6,864	Other	12,686
TOTAL	2,900,480	TOTAL	1,208,466

Source: Grant Soil and Water Conservation District

Table 3.2 Estimated ranges of biomass fuels currently available from Grant County forests

Land Ownership	*Estimated Area*	*Biomass Now Available*		*Estimated Annual Production for 10 years*	
		Low	*High*	*Low*	*High*
		(thousand bone-dry tons)		*(thousand bone-dry tons)*	
Private non-industrial	69,883	700	1,000	70	105
National Forest*	485,000	4,850	7,275	485	728
Total	554,883	5,550	8,275	555	833

* Source: Malheur National Forest statistics: General forest area in Grant County.

cent of the watershed is identified as high wildfire hazard, in large part because of the existing condition of timber stands. This watershed contains about 127,500 acres, and, although it is almost entirely within the National Forest, it also contains 10,000 acres of private lands, raising concerns about future fires in the wildland-urban interface areas.

The estimates in Table 3.2 indicate that solving the gridlock on Forest Service lands seems to be the only way to expand biomass energy production in Grant County. If the estimates are even remotely close, and something on the order of 87 percent of the forest resource in the county is on National Forest lands, any facility in this area will need to not only solve the local marketing problems (see below) but also be the beneficiary of a new and different approach to contracting and managing forest health treatment projects on the National Forests.

Energy Conditions and Outlook

Grant County holds considerable experience with wood-fired energy plants. Prairie Wood Products has two 8-megawatt cogeneration plants associated with its mills. At the time these facilities were installed, the mill waste was adequate to supply needed feedstock. The mills were running at full capacity, at times with double shifts, and sawing large trees with thick bark, resulting in large volumes of waste biomass for the energy plants. Today, those same mills are down to one shift, sawing small logs with thin bark, and the amount of waste for fuel has dropped dramatically.

As a result, both mills must buy hog fuel at times. They buy some by back-hauling from Western Oregon mills on their chip trucks, but they appear to be positioned to purchase some additional field-produced biomass if it were offered at competitive prices. At times in recent years, they have burned their own pulp chips to keep up with winter demand in the cogeneration plants. The market opportunity from these two small mills is, however, small. An 8-megawatt mill needs about 240 bone-dry tons of biomass fuel a day, and they are probably 75 percent to 80 percent self-sufficient at this time. Even if they purchased the rest of the hog fuel they need from local woods operations, it would only amount to around 40-to-50 units a day. That would represent the production of about three-to-five acres (at an average biomass yield of around 10-to-15 bone-dry tons per acre), which is probably not enough to warrant the effort to grind and haul the material, even if the price were above break-even.

There is a concern in Grant County that the higher cost of electrical production in the local biomass plants has resulted in higher-cost power rates because of the nature of the long-term contracts involved, and local consumers thus pay higher power rates than those in surrounding areas. This is a 20-year-old artifact from the Public Utility Regulatory Policy Act of 1978 (PURPA), which required public utilities to purchase power from qualified local facilities at their avoided cost. Most of those contracts foresaw the price of energy rising sharply, but instead, generating costs fell significantly. That left utilities such as the Oregon Trail Electric Cooperative, which serves much of the region, with long-term contracts to purchase power at prices that did not change as other prices dropped. Those higher prices have been passed on to consumers through rates based on the utility's wholesale cost of power.[28]

Local perception is that rates are higher specifically because biomass plants are the source of power, but the perception is somewhat inaccurate. At the time the PURPA contracts were signed, the purchasing utilities would have been under the same regulations whether the power was generated with biomass, gas or coal. The rate situation appears, therefore, to be related to the long-term contracts and

[28] At the date of publication, the West is facing steep increases in the wholesale price of power. These price increases may overshadow the effect of the long-term contract prices paid by the local utility, although this may not change public perceptions.

the unforeseen market shifts. The experience in the region may, nevertheless, require a potential biomass energy developer to address the PURPA issue directly with local consumers and officials to overcome reluctance about biomass energy. It would appear that any new market for power will need to be based on the anticipated demand and market in the area, not on an existing or future PURPA contract. Exactly what that may mean, as deregulation continues to change the energy industry, remains to be seen.

Wallowa County

Wallowa County lies in the far northeastern corner of Oregon in a beautiful, remote area of mountains that surround a green, grassy prairie. Its 7,500 residents have depended on the combination of forestry, agriculture and tourism for many years. About 70 percent of the county is federal land, and about 30 percent of the forestland available for harvest is publicly owned. Recent cutbacks in federal timber sales that have affected many Western communities have had a major impact on Wallowa County. From an estimated harvest of around 73 million board feet in 1985, the National Forest timber sales fell to around 1 million board feet in 1995, and they are anticipated to be zero in 2000 (Wallowa Resources News 2000).

Of an estimated 1.36 million acres of National Forest lands in the county, 56 percent are in wilderness areas, and 7 percent are either unsuited for forest production or are in riparian areas or other reserves. The Hell's Canyon National Recreation Area accounts for 29 percent of the National Forest land, and although it is legally available for timber management, the practical facts are that carrying out forest health restoration projects in it may be politically unacceptable. This leaves an estimated 115,000 acres, or 8 percent, of National Forest lands available for timber harvest and, we assume, available for forest health treatments as well (Wallowa Resources 2000).

Wallowa County has about 150,000 acres of private industrial forestland and 130,000 acres of non-industrial private forestland. The largest industrial forestland owner is Boise Cascade Corporation. A partial list of private owners provided by Wallowa Resources (see Table 3.3) indicates that some 84 percent of the non-industrial forest acres are held in ownerships of 500 acres or larger and that this size category involves almost one-fourth of the owners in the county. This high proportion of large property owners is similar to what was reported by local observers in Grant County.

From a forest health standpoint, the forests of Wallowa County are fairly typical of elsewhere in the region. On the warm, dry sites dominated by ponderosa pine, years of fire suppression have resulted in dense undergrowth of pine and fir. On the cooler, wetter sites, the same has happened, with the seral species such as ponderosa pine and Western larch being surrounded by fir thickets. A significant proportion of both public and private forestland needs forest health treatment and stand shaping to become more resilient and sustainable. An analysis of current stand conditions in the Wallowa Valley and Eagle Cap Ranger Districts provided by the Forest Service indicates that on about half of the forested area, where one might historically expect to find multi-sized forests dominated by large trees, around one-third of the area is dominated by small trees with closed canopies typical of the in-filled stands described across the West (USDA Forest Service unpublished).

It seems clear that—based on the small or uneconomic trees that need to be removed for forest health treatment in Wallowa County—there is an ample fuel supply to sustain an energy facility. Compared to Grant County, the resource availability is more closely balanced between the private and public sectors. It is also clear that it is impossible to make an informed estimate of the amount of fuel that is physically available and the amount that is feasible to deliver to a facility. On private lands, as noted above, the physical supply numbers are largely unavailable. On National Forest lands, institutional issues raise significant barriers.

Table 3.3 Ownership size distribution of a partial list of Wallowa County forest landowners.

Ownership size category	*Owners*	*Acres*	*Owners*	*Acres*
	(number)		*(percent)*	
Less than 40 acres	25	433	17.4	0.5
40 to 99 acres	28	1614	19.4	1.7
100 to 499 acres	57	12,760	39.6	13.6
500 acres or more	34	79,181	23.6	84.2
Total	144	93,988		

Table 3.4 Estimated ranges of biomass fuels currently available from Wallowa County forests.

Land Ownership	*Estimated Area*	*Biomass Now Available*		*Estimated Annual Production for 10 years*	
		Low	*High*	*Low*	*High*
		(thousand bone-dry tons)		*(thousand bone-dry tons)*	
Private non-industrial	130,000	1,300	1,950	65	195
Private industrial*	150,000	1,500	2,250	75	225
National Forest	115,000	1,150	1,725	57	172
Total	395,000	3,950	5,925	395	593

*Private industrial forests may contain less surplus biomass per acre than either non-industrial or public ownerships because of a more intensive management strategy over past years. No data were available, however, so these estimates reflect the general ranges thought to exist in the forests of the region.

There is, however, a sense of urgency in Wallowa County about the need to resolve these issues, perform the needed assessments and launch a major forest health treatment program. The urgency is based on several concerns: The high wildfire risk facing untreated forests, the continued erosion of the institutional capacity to deal with forest health treatment, and the continued talent drain in the county that could make restoring institutional capacity even more difficult in the future.

The wildfire risk has been assessed above for the region (see General Forest Conditions and Wildfire Hazards in Part I), and Wallowa County's risks are typical. The summer of 2000 did nothing to ease the concern, as day after day saw the valley filled with smoke haze from wildfires across Hell's Canyon in Idaho and from nearby fire events. The wrong set of weather and moisture combinations could result in thousands of acres of public and private forest lost in a matter of hours or days.

The loss of institutional capacity is a continuing financial and human problem that increasingly concerns local leaders. As mills close and jobs are lost both in the industrial sector and in-woods operations, companies move out and so do skilled people. Young people leave the area and do not apprentice into the jobs that require skill and training. An example is the emergence of increasingly sophisticated machines like feller-bunchers and single-head processors that cut down selected trees and ready them for delivery to the landing. These machines are expensive and complicated and are costly to operate. Properly run by a skilled operator, they can shape a forest in desired ways rapidly and efficiently. As operators become more skillful, the need to mark trees for cutting or retention decreases, and many operators can go through an unmarked stand and produce a final result that meets all sustainability criteria. Damage to remaining trees is so rare that it is often difficult to convince people after a few months that any activity has taken place in the forest. Where that is possible, the costs are minimized and the benefits of forest health treatment maximized. But the key is skill and experience. Where contractors are forced out of business, those skilled people may be lost, either to the community or the industry or both. That seems to be happening as a result of the federal timber program slowdown, and there is great concern in the community that, unless something can be done soon to restore some forestry work, there will be a total loss of forestry sector jobs.

Wallowa County has, like many of its rural counterparts, been exporting young talent for decades. Although the population has remained largely stable, the balance seems to consist largely of exporting high school graduates who go off to college and find jobs elsewhere and importing retirees who come back to enjoy the quality of life in the area. The net result is a community that is getting less and less capable of expanding its work force to meet a future need, no matter what the nature of that need.

The existence of a local market for small-diameter wood, perhaps supplemented by energy facilities, is seen as one of the cornerstones for moving the county's economy forward. A study by Wallowa Resources reports: "Extensive consultations with private forest owners, industrial forest managers, the local mills and both USDA Forest Service and Oregon Department of Forestry staff isolated small diameter wood processing (using timber less than 7 inches in dbh) as the single best opportunity for natural resource based business development in Wallowa County" (Wallowa Resources unpublished).

The "small-log" opportunities have recently been enhanced by the installation of capacity at the Joseph Timber

Company to process 20-foot logs with a 3-inch diameter at the small end. Such equipment opens up a significant opportunity in light of the resource conditions and could be complementary with a biomass facility. Particularly where trees of this small size are skidded whole to a landing for processing, the fact that all the small and large trees can be processed and sorted in one place creates enormous piles of woody material that can be run through a tub grinder and used for biomass fuel.

One such pile (shown in Figure 3.3) was estimated by the author to contain somewhere in the range of 4,500 cubic yards of material. Assuming a specific gravity of 0.30 for piled material, that would translate to around 1,000 bone-dry tons. Because it was estimated that the pile represented a landing for about 20-to-40 acres of timber harvest, the biomass yield would have been around 25-to-50 bone-dry tons per acre in a harvest operation that was not designed to capture biomass. It was also apparent, however, that there had been no pulp chipping at the site, so the fuel amounts would be significantly reduced if much of the pile had been sorted for pulpwood. Without either a pulp or fuel market, the likely fate will be a winter pile burn.

Figure 3.3 A huge pile of waste material that could have been converted into energy marks the landing of a recent forest harvest in Wallowa County, dwarfing Rick Wagner and Lance Clark, ODF foresters (photo by Neil Sampson).

Summary and New Hope

As the above discussion indicates, a significant amount of woody biomass is available in Eastern Oregon, particularly biomass that is not merchantable in either traditional or new small-wood industries. The problems of capturing the resource, and, at the same time, improving the forests of the region, are political and economic. The political problems focus largely on the ability of the Forest Service to implement the kinds of forest health treatments its specialists want to implement, while the economic problems affect all landowners alike. Non-merchantable biomass is expensive to harvest and deliver, and it is of low-value at the point of delivery. Unless biomass harvesting can be combined into a forest health project that removes both merchantable and non-merchantable material at the same time, it is doubtful that it can ever be a financially profitable (or even break-even) activity. On the other hand, the ability of both public and private landowners to improve the health of their forests and make them less likely to succumb to epidemics or wildfires is a value that can encourage these harvests if the economic costs can at least be minimized or balanced.

As this report was being finalized, Congress reacted to growing pressure from Western interests and, spurred by the summer 2000 wildfires, enacted new wildland fire emergency appropriations as part of the 2001 appropriations bill (P.L. 106-291). Although it is still too early to tell exactly how the implementation of this bill will facilitate forest health treatment in the West, the legislative language itself is fairly straightforward.

The bill authorizes the secretaries of the Interior and Agriculture to conduct fuel reduction treatments on federal lands using all available contracting and hiring authorities. The focus is on urban-wildland communities that are at high risk of wildfire. The bill urges all federal agencies to implement expedited procedures for hazardous fuel reduction and post-burn treatments on federal lands.

The capacity of this new money and encouragement to galvanize action on the federal lands remains to be seen. What is clear, however, is that concern over forest health in the West is no longer limited to a handful of scientists, ecologists and land managers. Forest health is now a recognized national issue, and finding a way to weave public land management, private land incentives and energy production together is perhaps one step closer to reality.

The current political concern is also informed by significant new studies on forest health and a new Forest Service proposal on the needed response. In October 2000, the Forest Service released a major study entitled “Protecting People and Sustaining Resources in Fire-Adapted Ecosystems: A Cohesive Strategy” as one response to the GAO Report of 1999 (USDA 2000). It contains the following passage:

> Because understory biomass has little or no value, disposing of it becomes problematic. Small diameter material, however, may become more economically feasible if assessments for its utilization more comprehensively evaluate tradeoffs and risks to watershed and species values, public health and safety, and other factors that may benefit from reducing fuels in fire-adapted ecosystems. Projected wildland fire costs, resource losses, and environmental damage, all suggest that developing and supporting markets for using excess woody biomass are desirable (USDA 2000).

The Forest Service report also notes that, “Consistent with Executive Order 13134 ‘Developing and Promoting Biobased Products and Bioenergy,’” the Forest Service will “collaborate with other agencies and organizations to conduct economic feasibility analyses of increased biomass utilization (USDA 2000).”

These commitments have been supplemented by the passage of the Biomass Research and Development Act of 2000 (PL 106-224) and the inclusion within the FY 2001 appropriations bill of a major new $250 million fund for the Forest Service and the Department of the Interior to carry out fuel management activities. P.L. 106-224 provides a legislative mandate for the USDA and the U.S. DOE to cooperate on policies and procedures that promote research and development leading to the production of biobased industrial products, such as fuels and chemicals. Under the act, applicants can earn grants, contracts, and financial assistance for conducting research on improved biomass conversion technologies for the production of biobased products, for developing technologies that would result in cost-effective and sustainable industrial products, and for promoting the development and use of agricultural and energy crops for conversion into biobased fuels and chemicals.

The fruits of these measures may be improved methods for biomass-to-energy conversion and lower prices for biomass fuels, making them more competitive with fossil fuels. As additional markets for understory biomass develop, what was once both a valueless commodity and an expensive disposal problem may become an important part of building the transition from a fossil-based society to a renewable-based society during the twenty-first century. Aggressive use of these new policy authorities should provide the basis for a much more rigorous study of feasibility for new biomass energy facilities in Oregon, as well as in other affected areas in the West.

The development of a biomass energy industry in Eastern Oregon would almost certainly depend on the assurance of a predictable fuel supply from federal forests. That goal has been and may continue to be out of reach because of the variety of complex administrative and political obstacles. The new national recognition of the urgency involved in providing appropriate forest health treatment may, however, be the catalyst that helps push enough of these obstacles aside so that federal agencies can take the needed steps. These steps will almost certainly include policy and budget commitments for managing to improve forest health and administrative changes that allow for multi-year contracts based on stewardship contracting principles, which would allow a local energy facility investor to bank on having at least 10-to-15 years of fuel supply from the federal lands. This basic assurance, coupled with an aggressive partnership with the Oregon Department of Forestry for planning and implementing forest health projects on non-federal lands, would make the goal of a feasible biomass energy facility in Eastern Oregon much more achievable.

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