Pacific Northwest and Alaska Regional Bioenergy Program

Five Year Report: 1985-1990

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MASTER

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Preface

This five-year report describes activities of the Pacific Northwest & Alaska Regional Bioenergy Program between 1985 and 1990.

Begun in 1979, this Regional Bioenergy Program became the model for the nation's four other regional bioenergy programs in 1983. Within the time span of this report, the Pacific Northwest & Alaska Regional Bioenergy Program has undertaken a number of applied research and technology projects, and supported and guided the work of its five participating state energy programs. During this period, the Regional Bioenergy Program has brought together public- and private-sector organizations to promote the use of local biomass and municipal-waste energy resources and technologies.

This report contains information on the mission, goals and accomplishments of the Regional Bioenergy Program. It describes the biomass projects conducted by the individual states of the region, and summarizes the results of the program's technical studies. Publications from both the state and regional projects are listed.

The report goes on to consider future efforts of the Regional Bioenergy Program under its challenging assignment. This region has abundant biomass resources and growing bioenergy markets. Meeting its potential will contribute to the mitigation of global climate change and help reduce our national dependence on imported oil.

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Overview

The U.S. Department of Energy (DOE) administers programs in five regions to encourage regionally specific application of biomass and municipal waste-to-energy technologies to local needs, opportunities, and potentials.

Each regional program undertakes the following studies:

- identification and assessment of regional biomass types and availability;
- comparative cost analyses of biomass and other energy sources;
- assessment of local bioenergy application options — residential, commercial, institutional, industrial; and
- identification of transportation and infrastructure limitations of biomass energy suppliers, distributors, and users.

The Regional Biomass Energy Program was established at the national level by Congress in 1983. The enabling legislation instructed DOE to support regional biomass energy programs in other regions of the country similar to one managed in the Northwestern United States since 1979 by the Bonneville Power Administration.

In 1984, the Congress further refined the scope and direction of the regional program. It specified that activities should include technology transfer, industry support, resource assessment, and the matching of local resources to local energy needs. Identical language has appeared in each year's legislation since.

The Pacific Northwest & Alaska Regional Bioenergy Program (the Regional Bioenergy Program) was created in 1978 and became the model for the other programs, which now include 49¹ states. The program at first focused on wood-derived fuels.

The Pacific Northwest & Alaska program has four basic components:

- a State Grant component provides funds (with a 50 percent matching requirement) to each state in the region. The aim is to strengthen and integrate the work of state agencies involved in biomass energy;
- an Applied Research and Applications effort addressing a series of questions relating to technical and environmental facets of bioenergy use;

¹Hawaii is not included in any regional program.

-
- a Technology Transfer effort to provide accurate information and assistance on developing bioenergy options; and
 - a Long-Range Regional Planning effort, with substantial involvement from the private sector, to identify activities necessary to promote greater development and use of biomass energy.

The DOE and BPA are responsible for program planning and budgeting, financial and funding management, and guidance and evaluation of program activities.

Program support is provided by federal and state agencies of the region responsible for land management, resource development, energy development, and environmental protection. Representatives of these agencies comprise the Biomass Utilization Task Force, which advises

the program manager on resource development options and opportunities, and issues and considerations:

- Bonneville Power Administration;
- U.S. Forest Service, Region VI;
- Bureau of Land Management;
- EPA, Region X;
- U.S.F.S. Pacific Northwest Research Station;
- Alaska Energy Authority;
- Idaho Department of Water Resources;
- Montana Department of Natural Resources and Conservation;
- Oregon Department of Energy;
- Oregon Forestry Department;
- Washington State Energy Office; and
- Washington Department of Natural Resources.

Participating States

Alaska	Idaho
Oregon	Montana
Washington

Introduction: The Biomass Energy Challenge

Business is under increasing pressure to conserve its resources, address environmental concerns, and reserve capital for uses that best support profit objectives. Energy-related investment is not exempt from these constraints.

For a decade, fossil fuels have enjoyed a price advantage over most biomass fuels which carried over into capital-investment decisions. Change is foreseeable, however, as environmental regulations raise waste-disposal costs, in effect subsidizing energy conversion of waste biomass.

At the same time, this region's most convenient biomass fuel, woody residues, will grow dearer. Old-growth logging, a lavish residue generator, is fading out. The reduced supply will be bid up on the international fiber market, adding emphasis on MSW fuels.

Woody fuels are open to a wide range of applications with growth potential, despite worries about air quality and public health. Aside from residential wood heating, which is hampered by increased restriction of traditional stoves, growth is expectable for the new generation of clean-burning residential heaters, industrial and institutional space-heating, industrial process heat, cogeneration, thermoelectric power generation and transportation fuels. The clear role of the

Regional Bioenergy Program here is to provide technical information and assistance regarding fuels, technologies, and environmental impacts.

The Regional Bioenergy Program must focus on giving the public useful information on:

- public policy and institutional considerations affecting land and resource management, and environmental and technology impacts related to bioenergy;
- progress in resource recovery and development, energy conversion, applications and proof-of-concept activities including mechanical, thermal, thermochemical and biochemical processes; and
- biomass feedstocks including wood, MSW, crop residues and energy crops.

Target audiences for these information and technology-transfer activities include:

- public institutional, commercial, industrial, and utility sectors;
- biomass-related land-management and environmental interests; and
- relevant consulting engineers, financial institutions, plant managers, equipment manufacturers and educators.

Biomass Energy Resource/System Development Approach

LIMITING CONSIDERATIONS

Environmental protection mandates
 Economics and financing
 Markets and transportation
 Siting and regulatory requirements
 Ecological concerns and sustainable development

Information is needed on many factors to evaluate biomass
 fuel opportunities: availability, energy values, fuel characteristics,
 conversion applications, environmental impacts, costs and
 handling methods.

Developing Biomass Energy Opportunities

Even though woody biomass comprises a large resource base in the Pacific Northwest and Alaska, more and better information is needed about other resources, recovery opportunities and conversion targets-of-opportunity.

Mission, Goals and Objectives

Goal 1: To expand the program's technology transfer, information and education activities, for increased public acceptance of biomass fuels as realistic energy options.

Issues: Effective technology transfer offers constructive solutions to well-defined problems and encourages economic growth and capital investment. To accomplish this the program must respond to industry's energy needs, decision processes and investment criteria.

Objective: Improve the regional information program and seek opportunities for bioenergy demonstrations with real solutions for real problems. Encourage local commerce, use appropriate technology, and encourage capital investment.

State energy offices will seek cooperation of other state agencies, private activities and trade associations. The state energy offices will also be centers for technical help and information, and will cooperate in inter-regional efforts.

Program activities will be publicized in agency, technical and trade publications, a program yearbook, and other publications.

The program will sponsor seminars, conferences, forums and workshops. Audiovisual and print material will be prepared for industry, regulatory, consumer and environmental audiences.

Goal 2: Continue to improve biomass fuel, fuel-recovery, and energy-conversion technologies, and mitigation measures to reduce negative environmental impacts, especially for MSW conversion.

Issues: More information is needed about biomass fuel availability and recovery technology, and about bioenergy opportunities. The public environment for MSW energy recovery is changing. Other variables to be observed include competing uses for the fuel, changing economics in related industries, and changing federal and state regulations.

Objective: Continue to define and assess the regional resource base, and to publish the findings. Relate bioenergy opportunities to changes in public policies and attitudes.

Objective: Continue defining and monitoring environmental issues and regulations related to

biomass technology. Support projects to improve combustion, reduce emissions, and abate local pollution.

Goal 3: Continue to support bioenergy ventures with technical and commercial activities working toward use of local biomass for local energy needs.

Issues: Critical market factors include concern about long-term fuel supply and cost, predictions of power shortages, shifting oil and natural-gas prices, and dearth of operating experience.

Objective: Demonstrate technical and economic feasibility through resource inventories, technical assistance and current case histories.

Goal 4: Build private-sector confidence in state energy agencies by cost-sharing selected industrial biomass ventures.

Issues: Cost-sharing opens the door to broader industry inquiries, distributes financial and proprietary risk, develops relationships with potential users, accelerates technology development and transfer. Cost-sharing aids state insight into industry needs, and state/industry networking.

Objective: Ensure cosponsor interest and motivation by limiting DOE funding to 25 percent with a \$25,000 ceiling and requiring local government or private co-funding.

Objective: Encourage lively interchange between grass-roots operators and R&D personnel.

Mission

The mission of the Regional Bioenergy Program is to expand the use of biomass energy in cost-effective, environmentally sound ways. Since biomass resources occur widely in the region, their local use to supply energy can:

- strengthen local economies;
- expand the choice of fuels;
- reduce import dependency; and
- alleviate environmental problems.

Pioneering biomass-recovery project in Olympic National Forest (see page 26)

—photo by Craig L. Chase

Accomplishments

The Regional Bioenergy Program has sponsored numerous technical studies and participated in many technical assistance-projects. Some of the highlights:

A five-state cooperative energy program has developed the ability to focus regional development findings on local problems and opportunities, to share specialized expertise, and to consult on the mitigation of regulations that unintentionally restrict the recovery or transportation of biomass fuels, or applications of bioenergy technology.

Woodstove air pollution

Extensive studies have been conducted of residential woodstoves and their emissions. These have included baseline studies of woodstove particulate and gas-phase emissions, fuel consumption, combustion efficiency, emission-sampling methods, environmental impacts, mitigation measures, and regulation. That series of studies also investigated catalytic retrofit devices, fuel-loading variations and in-situ performance. A second round of studies focused on advanced-technology devices, operated both in laboratories and in homes. They were shown to have substantially less adverse

environmental impact and better efficiency than conventional stoves. Contemporaneously, consumer-education programs began effectively demonstrating the clean-up of woodstove-impacted, non-attainment airsheds by voluntary means. In one community, a strategic partnership of the state energy authority, the Regional Bioenergy Program, and an industrial investor has set out to achieve PM-10 attainment status in a smoky rural town, to allow the resumption of industrial growth. They propose to wean householders away from woodstoves and convert them to biomass-fueled electric heat, in part by accepting cordwood in payment of heating bills.

Municipal solid-waste utilization

An MSW-to-energy project for which the Regional Bioenergy Program provided initial support is about to go on line in Tacoma. The project will co-fire RDF with timber-industry wastes and coal, using a revamped steam generator that had been out of service for years.

Co-firing

In a related activity, the use of multiple fuels in steam plants is under study in Alaska. Co-firing reduces the consumption of scarce or

expensive fossil fuel by combining it with inexpensive or even unwanted biomass fuel. It can be a viable way of reducing a small community's solid-waste disposal problem. One test of coal/wood co-firing has been run at the Army's Fort Wainwright. Other tests by the Alaska Energy Authority have explored other fuel combinations, several including MSW. The state's studies have extended to emission toxicity; co-firing, which can ameliorate undesirable emissions of some fossil fuels, can also generate a different set of harmful compounds. The Alaska Energy Authority has established a database on characteristic co-firing emissions, and explored related risk assessment.

Fuel characteristics

Testing and characterization of regionally plentiful biomass fuels is underway: wood, MSW, MSW fractions and agricultural residues, separately and in combination. This multi-year project is intended to expand use of conventional biomass fuels and to qualify other fuels incorporating grass straw, mixed waste paper, and woody yard trimmings.

Technology transfer

State energy agencies have had striking success in using grants by the Regional Bioenergy Program to demonstrate bioenergy applications that solve local energy needs, particularly in public installations. Each state has published a guidebook on local energy-project permits and regulations. The regional publications program, now in its 11th year, has published a Biomass Energy Project Development Guidebook to aid managers, engineers and financial officers. The guidebook is being expanded now, to serve newly targeted user and regulatory audiences. An international bioenergy conference will be held in Idaho in the spring of 1991.

Forest-residue resource

A system for estimating the residues created by logging in the region's five states was prepared and published. This compilation consolidates logging-residue estimator ratios with the prospects for whole-tree harvesting of small-diameter stands. Data are distinguished by owner class and forest type, site and size, and other characteristics.

Whole-tree harvesting

A five-year demonstration of recovery technology for utilizing a dense stand of small trees was conducted in Washington's Olympic National Forest. Self-financed reforestation without wasting the biomass was the purpose. Harvesting systems and in-the-woods processing systems were developed by cooperating private firms, to convert the trees to whichever products might be saleable at the time, from fuel to lumber.

Site productivity

Long-term productivity studies were begun on 44 pairs of second-growth forest sites in western Washington and Oregon. Each pair had been preserved after being clear-cut about 40 years ago; one site of each pair was cleaned off by slashburning, the other site by other means. The unique studies will seek cause-and-effect comparisons of intensive-management practices, with special attention to site productivity.

In these projects, the Regional Bioenergy Program seeks active cooperation and cost-sharing from other participants. In this way, resources are highly leveraged and have broad support among all sectors.

Summaries of state projects and the applied research and technology-transfer activities are presented in subsequent chapters of this report.

State Technical Assistance

State energy agencies participate in the Regional Bioenergy Program through its State Technical Assistance activities. In this way, the regional program reaches state interests that are able to influence the development or expansion of bioenergy. These include such areas as regulatory and facility siting, resource management, environmental-impact mitigation, and local economic development.

The state energy agencies have a major role in technology transfer. To meet this responsibility, they monitor bioenergy projects, serve as information centers on technology options and applications, offer guidance on regulatory requirements and permitting, and provide technical assistance in evaluating energy opportunities.

For outreach, they supply trade and professional publications with articles and program and project information, they participate in professional societies and programs, and they network with other public institutions.

The state bioenergy programs receive \$75,000 annually from DOE to support these activities and their states provide an additional \$37,500 in matching funds. The Regional Bioenergy Program also provides up to \$25,000

annually in each state as a 25 percent matching grant for demonstration projects.

Population ² :	550,043
Geographical area ³ :	361,887 thousand acres
Timberland ³ :	15,763 thousand acres
Timber production ³ :	852 thousand cu ft
Fuelwood production ³ :	9,499 thousand cu ft
Mill residue, fuel ³ :	41 thousand dry tons

²1990 U.S. Census

³*Forest Statistics of the United States, 1987*; Waddell, Oswald and Powell, Pacific Northwest Research Station PNW-RB-168

It took a satellite-relayed telephone system linking every village to resolve Alaska's communications problems. The state's energy challenge, also the consequence of great distances and thin population, is less simple.

The Alaska State Bioenergy Program is managed by the Alaska Energy Authority, Department of Commerce and Economic Development. It addresses five biomass resources: Logging residues from coastal old-growth forests and marginal inland forests, debris from farmland clearing, and agricultural and municipal solid wastes.

Program Activities

The state has a keen interest in solid-fueled, co-fired applications. Co-firing offers a number of opportunities or advantages. It can:

- stretch imported fuels;
- improve emissions; and
- mitigate disposal problems.

A major report on co-firing, *Use of Mixed Fuels in Direct Combustion Systems*, was completed in 1989 by D.C. Junge, a member of the School of Engineering faculty of the University of Alaska Anchorage.

The publication is aimed at a wide audience of industrial, agricultural, military and commercial managers and planners, consultants, and regulators. It offers a format for evaluating co-firing opportunities.

Co-firing trials in Alaska have included:

- wood-chip/coal trials, by the City of Fairbanks;
- feasibility study of MSW, wood, and salt-

Collecting mixed wood/coal fuel samples during test firing at Fort Wainwright at Fairbanks, Alaska

—photo by Craig L. Chase

**FUEL PARAMETERS FOR FUELS WHICH ARE COMMONLY USED
IN CO-FIRING APPLICATIONS***

FUEL PARAMETERS	Dry Wood Pellets	Dry Wood	Typical Hogged Fuel	Municipal Refuse Solid Waste	Derived Fuels	Penn. Coal	Utah Coal	Wyo. Coal	No. 2 Fuel Oil	No. 6 Fuel Oil	Natural Gas
Higher heating value (Btu/dry lb)	9,030	9,030	9,030	6,400	7,700	13,982	13,291	12,460	19,430	18,300	19,800
Moisture content (% wet basis)	10	10	40	30	24	1.3	5.2	25.0	0	0	0
As-fired heating value (Btu/wet lb.)	8,127	8,127	5,418	4,500	5,800	13,800	12,600	9,345	19,430	18,200	19,800
Fuel bulk density (Lbs/cu. ft.)	35.00	16.00	22.00	12.00	4.00	50.00	47.00	45.00	53.90	58.70	0.0503
As-fired energy density (Btu/cu. ft.)	284,400	130,000	119,200	54,000	23,200	690,000	592,200	420,500	1,047,000	1,074,000	1,000
Fuel feed rates (Cu. ft./MMBtu)	3.5	7.7	8.4	18.5	43.1	1.4	1.7	2.4	1.0	0.9	1,000
Ash input rate (Lbs/MMBtu)	3.2	3.2	3.2	56.3	20.5	7.5	5.1	4.0	0	0.07	0

Sources:

Design and Operation of Industrial Boilers Fired with Wood and Bark Residue Fuels. Solar Energy Research Institute, SERI/TR 09380-1, August 1982

Steam, Its Generation and Use, 38th Edition. Babcock and Wilcox, 1975

Guidelines for Co-Firing Refuse Derived Fuel in Electricity Utility Boilers. EPRI Publication CS-5754, Vol. 2, June, 1988

*From *Use of Mixed Fuels in Direct Combustion Systems*, David C. Junge, Alaska Energy Authority

contaminated wood-waste fuels for steam generation at Wrangell; and

- coal/wood chips at Fort Wainwright.

Several surveys and assessments by the Alaska Energy Authority provide prospective users with information about the fuel resource and conversion opportunities, and guide them through state and local permit processes. These include:

- *Biomass Inventory and Disposal Cost on Agricultural Lands in Alaska*, 1988;
- *Biomass Resource Update*, 1987;
- *Biomass Conversion Opportunities*, 1987; and
- *Biomass Permit Handbook*, 1986.

Future Activities

The Alaska Energy Authority has a statutory mandate to review alternative-energy resources when evaluating new energy-production facilities. The Alaska Bioenergy Program is pursuing strategies under that charge that call for:

- promoting responsible development of the forest-products industry to improve and stabilize the availability of inexpensive wood waste;
- sponsorship of biomass inventories to provide data on the availability, location and accessibility of woody biomass for energy, for use in commercial timber and wood-waste harvest planning;
- in high-fuel-cost areas, demonstrating bioenergy conversions in public buildings; co-firing wood and MSW with coal in state and federal power plants, promoting bioenergy in new public construction; and
- promoting residential and small commercial wood heating and cooking in wooded rural regions.

Idaho

Population ^a :	1,006,749
Geographical area ^a :	52,692 thousand acres
Timberland ^a :	14,533 thousand acres
Timber production ^a :	330,129 thousand cu ft
Fuelwood production ^a :	5,555 thousand cu ft
Mill residue, fuel ^a :	576 thousand dry tons

Potatoes, grain, trees and cattle typify the resources on which Idaho's economy is based, and explain the state's broad interest in bio-energy. Idaho has seen dramatic population gains in the past 20 years.

It gained 32.4 percent in the 1970's, and another 900,000 arrivals are expected by 2000. A formal economic-growth program is in place, with a strategy of meeting energy needs by developing local bioenergy opportunities.

The state's Solid Waste Management Plan offers financial incentives, technical assistance and help with permits for resource recovery and conservation. MSW energy-recovery plans have been studied in 10 counties, but local resistance prevented meeting a goal of 10.5 MW from MSW by 1990.

^a1990 U.S. Census

^aForest Statistics, PNW-RB-168

Program Activities

The state bioenergy program is managed by the Energy Resources Bureau of the Idaho Department of Water Resources, with operating plans derived from the state economic-development objectives. Idaho has a ready supply of biomass resources, including forest and mill residues, agricultural and food-processor residues, and municipal solid waste.

Idaho is the regional program's specialist in the use of medium- to large-scale wood-fueled energy systems outside the forest-products industry, and in anaerobic fuel production from farm and food-processing residues.

A low-interest energy loan program offers up to \$100,000 for institutional, \$50,000 for agricultural and \$10,000 for residential conversion projects. To qualify, projects must conserve energy through efficiency, while displacing conventional energy supplies with energy generated from renewable resources.

Some projects under the loan program include:

St. Mary's Hospital, Cottonwood, Idaho

A 28-bed hospital built in 1964 was heated by two oil-fired boilers. These were put on standby in 1980, replaced by an electric boiler. In 1980 the two old boilers were converted to burn wood pellets, financed by a low-interest state energy loan. The conversion cost \$40,000 to remove burners and install doors, overfire blowers, hopper stokers, a conveyor, storage and electric controls. Annual heating costs dropped by about \$19,000 in 24-hour, year-around operation.

Country Haus Restaurant and Village Motel, Cottonwood, Idaho

Seeing the hospital's successful fuel conversion, the motel owner replaced an electric boiler system with a solid-fuel boiler. The \$8,500 project delivers about 245 MM Btu/year or 70,300 kWh/year at an annual cost of \$4,600, saving about \$2,800.

University Energy Grant

A state energy grant helped launch wood-fueled heating for the University of Idaho, Moscow. The project, originated by the university, has yielded valuable lessons. It replaced more than 2.5 million therms (2.5×10^{11} Btu) of gas heat a year, and cut fuel costs by more than half.

While hogged and chipped residues from local mills are the basic fuel, the project was designed to co-fire as much as 10 percent paper, to reduce the university's disposal cost and divert unyclable waste paper from the municipal landfill. Paper pellets and cubes have been test fired and, in time, the furnace is expected to take all the paper left after recycling.

The project was conceived in 1981 as an alternative to soaring petroleum prices. The price of natural gas has fluctuated since then, but the university has reduced its fuel costs by more than two-thirds of the 1982 price.

The steam plant is believed to be the largest reciprocating-grate gasifier of its kind, with heat-recovery efficiency greater than 75 percent. It generates up to 60,000 lbs/hour of steam at 150 psig for space heating. Daily fuel consumption is 30 to 120 bone-dry tons (BDT).

Secondary objectives of the project were to provide educational and research opportunities, and to benefit the local economy.

A number of educational benefits — graduate research projects, class projects and lecture opportunities — have been realized.

One doctoral study established the furnace ash as an amendment for commercial farmland, increasing grain or legume yields as much as 20 percent from chemically fertilized soil.

Among the economic benefits, a cash market was created for locally generated cedar residue that previously was landfilled, with three to 12 loads of fuel a day for local haulers.

The university's physical-plant management believes the plan is broadly applicable to any large-scale energy consumer with access to abundant, nearby, low-cost woody biomass.

The energy agency has published technical information reports and surveys aimed at providing prospective users with factual information about the fuel resource and its conversion opportunities, and guiding them through state and local permit processes. They include:

- *Assessment of Potential Targets To Use Biomass Resources;*
- *Forest Residue Assessment in Idaho;* and
- *Permitting Guidebook for Bioenergy Projects in the State of Idaho.*

Future Activities

A National Bioenergy Conference is set for March 18-21, 1991, at Coeur d'Alene, in conjunction with an annual meeting of state biomass energy coordinators.

This conference will focus on small-scale bioenergy applications for industry, farming and institutions. It will offer oral presentations and technical forums in research, development and applications of bioenergy technologies.

Some topics suggested in the call for papers included environmental aspects of bioenergy development, combustion systems, seed oils, resource management, co-firing, nontraditional biomass fuels, biogas, facilities management, and project development and financing.

Organizers are the Regional Bioenergy Program and the Idaho Department of Water Resources.

Population ⁷ :	799,065
Geographical area ⁸ :	92,765 thousand acres
Timberland ⁸ :	14,736 thousand acres
Timber production ⁸ :	256,528 thousand cu ft
Fuelwood production ⁸ :	13,400 thousand cu ft
Mill residue, fuel ⁸ :	687 thousand dry tons

Montana is aggressively developing alternative-energy options under its statewide Renewable Energy and Conservation Plan, which is partly financed by a severance tax on extraction of its large fossil-fuel deposits. At the same time, Montana participates in the Regional Bioenergy Program through its Biomass Utilization and Cogeneration Program. Both programs are managed by the Montana Department of Natural Resources and Conservation. Montana is the regional program's specialist in straw-fired energy systems, fermentation and enzymatic production of liquid fuel, and small wood-fired energy systems.

Program Activities

The energy agency has completed a number of projects to inform prospective users about the fuel resource and conversion opportunities, and guide them through state and local permit processes. These include:

- *Straw Combustion Energy Systems, Literature Search and Evaluation;*
- *Productivity and Cost of Processing Fuelbark in Montana;*

⁷1990 U.S. Census

⁸Forest Statistics, PNW-RB-168

- *Conversion of Safflower to Diesel via the Soap-Pyrolysis Process*; and
 - *Montana's Bioenergy Project Permitting Guidebook*.
- Other recent project reports include:
- *Directory of Montana Biomass Energy Facilities*;
 - *Energy from Crops and Agriculture Residues in Montana*
 - *Mill Residue Availability in Montana*; and
 - *Montana Mill Residue Assessment and Guide*.

Under the Renewable Energy and Conservation Program, 10-year loans are available to commercialize renewable-energy technologies. Some 21 loans have been awarded since 1983 for projects ranging from equipment for retrieving forest residues on steep slopes to storage facilities for fuel-pellet manufacturing.

Future Activities

Operation of a diesel locomotive fueled by a vegetable-based oil will be demonstrated in a two-year project at Montana State University, which developed the process with the University of Idaho. The oil, derived from familiar commercial crops such as safflower and canola, will be conditioned by a soap-pyrolysis process for use in a medium-speed diesel engine.

Oil-seed crops are familiar to Montana growers, and there is excess milling capacity. If adopted, the fuel could displace some imported oil, reduce air pollution, and open a new market for an existing local crop.

Another innovative project will trade cordwood for electric heat, aiming to reduce residential wood-combustion emissions and improve air quality in the town of Libby.

The incentive is economic development: an 80 percent reduction of particulate pollution is needed meet EPA air-quality requirements for a permit to operate a proposed bigger sawmill.

An existing 8 MW turbine generator and hog-fuel boiler will be dedicated to the heating project. To minimize the additional cash burden on residents, who traditionally cut and haul their

own fuel, cordwood will be accepted in payment of the increased electricity bills.

The project will extend the life of the local landfill by utilizing mill residue that is otherwise landfilled. At the same time, it will establish a new revenue source: transportation charges or tipping fees for the avoided cost of landfilling.

Population ⁹ :	2,842,321
Geographical area ¹⁰ :	61,546 thousand acres
Timberland ¹⁰ :	22,084 thousand acres
Timber production ¹⁰ :	1,711,390 thousand cu ft
Fuelwood production ¹⁰ :	124,171 thousand cu ft
Mill residue, fuel ¹⁰ :	5,371 thousand dry tons

Some 80 percent of Oregonians live in the long, narrow, single-ended Willamette Valley, sandwiched between the state's most productive forests. Picturesque Cascade Range volcanoes on the eastern skyline are obscured periodically by manmade pollutants from slashfires, grass-field burning, woodstoves, or freeways. The Regional Bioenergy Program is among the agencies working to reduce the emissions. Traditionally, the timber industry has disposed of its logging debris by burning this vast biomass resource, often within sight of potential bioenergy users.

Residential wood heating is traditional in much of the valley, and woodstove emissions are a major public health concern. In Oregon's southern counties, stove emissions are the main reason for "non-attainment" air-quality

⁹1990 U.S. Census

¹⁰Forest Statistics, PNW-RB-168

Wood Conversion vs. Installed Oil, Gas or Electricity (\$/Year To Heat a Home) *			
Appliance / Fuel Cost **	10 MMBtu/yr	50 MMBtu/yr	100 MMBtu/yr
Convert to conventional woodstove /\$100 cordwood			
Cash (15-yr amortiz.)	\$ 253	\$ 568	\$ 962
3-yr loan (yrs 1-3)	524	839	1233
3-yr loan (yrs 4-15)	129	444	838
Convert to catalytic /\$100 cordwood			
Cash (15-yr amortiz.)	382	622	922***
3-yr loan (yrs 1-3)	908	1148	1448
3-yr loan (yrs 4-15)	140	380	680
Convert to refractory /\$32 sawdust unit			
Cash (15-yr amortiz.)	359	433	526
3-yr loan (yrs 1-3)	1000	1074	1167
3-yr loan (yrs 4-15)	64	138	231
Convert to residential pellet furnace /\$65-ton pellets			
Cash (15-yr amortiz.)	351	558	818
3-yr loan (yrs 1-3)	848	1055	1315
3-yr loan (yrs 4-15)	122	329	589
Convert to residential pellet furnace /\$130-ton pellets			
Cash (15-yr amortiz.)	403	818	1336
3-yr loan (yrs 1-3)	900	1315	1833
3-yr loan (yrs 4-15)	174	589	1107
Installed System Oil /\$0.60 gallon	99	337	633
Oil /\$1.00 gallon	140	540	1040
Gas /\$0.60 therm	120	440	840
Gas /\$1.00 therm	173	707	1340
Electricity /\$0.04 kWh	137	605	1190
Electricity /\$0.05 kWh	167	755	1470
Electricity /\$0.06 kWh	196	900	1780
Electricity /\$0.07 kWh	225	1045	2070
<p>* Assumes new woodstove installation, maintenance, flue cleaning, catalyst replacement, electricity; compared to existing conventional systems</p> <p>** 10 MMBtu = energy-efficient home, mild climate; 100 MMBtu = big, non-efficient home, cold climate</p> <p>*** Cash purchase; assumes 10% investment alternative</p> <p>Source: OMNI Environmental Services, Inc., <i>Environmental Impacts of Advanced Residential and Institutional (Woody) Biomass Combustion Systems</i>, Beaverton, OR, January 1988.</p>			

conditions that have resulted in ceilings clamped on industrial growth in the Rogue River Valley and the Klamath Basin.

One of the most profitable crops in the valley is grass seed, grown in fields that are burned annually to control plant diseases and weeds. Public outcry and legislative pressure are driving a search for another control method. When one is adopted, straw disposal will become necessary, and cost-effective fuel applications are under study.

Solid-waste disposal problems are acute. Statewide, about 3,360¹¹ tons of MSW is generated daily, mostly in the Willamette Valley. Municipal solid waste from Portland, the largest city, is hauled 130 miles east. An energy-recovery project that was to replace a full landfill was rejected in the 1980's. However, one of Portland's neighboring counties provides fuel to a mass-burn MSW plant that converts 550 tons of waste a day into 11 MW of energy, which is bought by the local privately owned utility.

A virtually untapped energy resource for the state is vast tracts of insect-killed lodgepole pine in forests of Eastern Oregon. Jackstrawed, they await a technology capable of converting them profitably to fiber or fuel.¹²

Program Activities

The Oregon Department of Energy manages the state bioenergy program. Its regional specialty study areas are indoor air pollution from woodstoves, bioenergy-related PM-10 air pollution, and field-crop residue collection and conversion.

The state has been a leader in studies of woodstove pollution. Current emphasis is on improvement of community airsheds where residential wood heating is a major problem.

One such town, Klamath Falls, developed a neighborhood-level wood-heating information program that is credited with great improvement in the local airshed, which has registered the worst 24-hour PM-10 particulate pollution reading ever recorded in the nation.

That mark was set after a cold, clear January morning in 1988, when monitors found 792 micrograms of particulate pollutants per cubic meter of air. The maximum cumulative reading allowable to meet EPA's National Ambient Quality Standards is 150, and 600 is rated a public-health emergency.

The community information program is credited with a 53 percent reduction in pollution during its second season. The program's goal is to bring the airshed to EPA compliance, so that industrial expansion can be permitted without mandatory source offset restrictions.

Oregon offers two bioenergy financial incentives; an alternative-energy tax credit and a small-scale energy loan. Both are administered by the Oregon Department of Energy.

The agency has issued several basic surveys for prospective users with information about the fuel resource and conversion opportunities, and to guide them through state and local permit processes. They include:

- *Bioenergy Conversion Opportunities,*
- *Literature Review of Residential Wood Combustion Impacts on Indoor Air Quality,* and
- *Guide to Oregon's Environmental Permits of Biomass Energy Projects.*

¹¹ *Assessment of Biomass Resources for Electric Generation in the Pacific Northwest*, James D. Kerstetter, Ph.D.

¹² There is concern that such utilization might remove nutrients needed by the area's thin volcanic soil for sustained-yield management, and forestry scientists are studying the question.

Population ¹³ :	4,866,692
Geographical area ¹⁴ :	42,483 thousand acres
Timberland ¹⁴ :	16,848 thousand acres
Timber production ¹⁴ :	1,484,193 thousand cu ft
Fuelwood production ¹⁴ :	154,826 thousand cu ft
Mill residue, fuel ¹⁴ :	2,540 thousand dry tons

Biomass fuels are conventional for industry in Washington, where sawmill boilers have been fired with hog fuel for more than a century. Despite the availability of low-cost hydroelectric energy in most areas, some 25 percent of the state's industrial energy comes from wood.

Consequently, the Washington State Energy Office is the Regional Bioenergy Program's information center on clean, efficient operation of steam boilers burning hog fuel.

But Washington has more than sawmill and forest debris in its biomass fuel mix. The State Legislature is aggressively seeking energy solutions to biomass disposal and contamination problems, and the State Energy Office is working on a number of projects to divert waste-stream components into energy.

With a highly visible landfill crunch and tightening environmental regulations, MSW energy recovery is gaining a grudging respectability. Metropolitan Seattle, nursing its dwindling disposal space with a successful recycling program, plans to ship 420,000¹⁵ tons of garbage a year by train and barge 300 miles to an Oregon landfill.

¹³1990 U.S. Census

¹⁴Forest Statistics, PNW-RB-168

¹⁵Seattle Solid Waste Utility

Seattle's neighbor Tacoma, also facing landfill closure, has refitted an idle steam generator to co-fire MSW with wood and coal while generating 45 MW of net power. Skagit County and the cities of Bellingham and Spokane have taken similar steps. Other plants are under consideration. The state's annual energy potential from MSW is estimated at 60 megawatts.¹⁶

Another resource-related environmental problem, air pollution from slashfires, is proving more difficult. State air-quality goals require a 50 percent improvement by 2000. Authorities assumed that timber companies would cooperate by allocating more logging debris for chipping, hog fuel or cordwood, reducing the need for cleanup by slashburning.¹⁷

Following the lead of the Legislature in exploring new biomass markets, the State Energy Office has also become the Regional Bioenergy Program's center of information on thermochemical liquid fuels. The agency's role is principally technology transfer — assessment through research literature — but, in order to make projections, it has commissioned original research at times to fill data gaps. The Solar Energy Research Institute is a major information source.

Thermochemical strategies under study include:

- gasification of hog fuel into a synthesis gas which can be catalytically converted into methanol or diesel fuel;
- fermentation of mixed waste paper (including junk mail) into ethanol; and
- fast pyrolysis of powdered wood into liquid fuel and chemical stock.

¹⁶ *Assessment of Biomass Resources for Electric Generation in the Pacific Northwest*, by James D. Kerstetter, Ph.D.

¹⁷ A research project funded by the Regional Bioenergy Program discovered, instead, that the amount of logging debris left in the woods had sharply increased since adoption of the state goal. However, the research project did develop an improved model for estimating slashfire pollution, lowering the emission level for which the industry is held responsible.

STEAM PLANT NO. 2 PROCESS DIAGRAM

Tacoma City Light's converted steam plant co-fires RDF, coal and hog fuel

Program Activities

The Washington State Energy Office recently contributed two major studies to foster bioenergy development.

One is a "white paper" evaluating bioenergy as a component of the region's future energy supply. The other is an appraisal of mixed waste paper, including junk mail, as biomass fuel.

The study of the regional potential of biomass energy was requested by the Northwest Power Planning Council (NPPC) as a backgrounder for the council's forthcoming revision of the 20-year regional energy plan.¹⁸

The background paper¹⁹ was drafted by James D. Kerstetter, bioenergy manager of the Washington State Energy Office. It concludes that biomass resources can make a significant contribution, and that cost comparisons with fossil fuels may improve in time, when true environmental costs are factored in.

The paper says the region's biomass resources could technically and economically

provide up to 1,600 MWa of standalone power at less than 5 cents/kWh in nominal dollars, assuming 1988 startup, and considering competing demands for the resource.²⁰

The mixed-paper analysis was made for the State Legislature's Joint Select Committee on Preferred Solid Waste Management. It concluded that mixed waste paper is physically suitable for co-firing with other fuels, but its regulatory standing and financial feasibility are doubtful if the EPA were to classify it as MSW.

From that analysis, the inquiry developed into a thermochemical study of fermenting mixed waste paper into sugar and then refining it into ethanol.

Other major state energy publications have been:

- *Industrial Wood Fuel Market Assessment in Washington State*; and
- *Guide to Washington's Permits for Biomass Energy Projects*.

¹⁸ The NPPC is a four-state agency created by the federal Northwest Power Act of 1980. It is charged with planning for regional energy needs, with mitigating energy-related fish and wildlife habitat losses, and with increasing the public's voice in energy planning.

¹⁹ *Assessment of Biomass Resources for Electric Generation in the Pacific Northwest*, by James D. Kerstetter, Ph.D.

²⁰ Washington State Energy Office

Applied Research and Technology Transfer

High among the goals of the Regional Bioenergy Program are the application of biomass resource-recovery and energy-conversion technologies, and identification and mitigation of adverse environmental impacts. The program consistently has sought to refine fuel and conversion technologies and to enhance the credibility of bioenergy solutions for industrial energy needs.

Some of the basic questions it has addressed are:

FUEL (Resource development):

- What types and quantities of fuel are available at a given price?
- What factors determine price?
- What policy and institutional considerations influence the availability of biomass resources for energy?
- What are competing uses and considerations?
- How long will the material be available?
- Is proven machinery available for recovery, processing, and transport?

COMBUSTION:

- What are the combustion characteristics?
- Processing and handling peculiarities?
- Pollution-control requirements?
- Can it advantageously be co-fired?

CONVERSION:

- Is there a dependable energy-conversion technology?
- Is a backup energy source needed?
- Is the process acceptable to the local community?
- Does it create its own waste-disposal problem?

As the answers are found, tested and compiled, a technology-transfer task follows: informing potential users and policymakers.

It is important for them to understand that bioenergy is a viable energy option with a number of environmental benefits. In many cases, biomass-to-energy applications offer competitive, workaday processes using off-the-shelf modular units, fundable by prudent bankers.

Resource Development: Supply

Forest Residue Estimates

Since 1980, the program has supported studies to improve the estimating of forest residues.

Conversion ratios have been calculated and tested that translate harvested board feet and acreage into residue-volume estimates. One such ratio yields the volume of residue per 1,000 board feet of timber harvest. Another gives residue volume per harvested acre, with qualitative data on diameter and length, soundness, slope and distance from road, and number of pieces per acre by diameter and length. The results are adjusted for land-owner types.

Researchers from the Pacific Northwest Research Station of the U.S. Forest Service developed these estimating techniques, based on studies of 518 random freshly harvested sites in Washington, Oregon and Idaho, 120 sites in Montana, and 57 sites in Southeast Alaska.

The research team estimated the volume of residue piles by formulas based on their resemblance to one of four basic geometric shapes, and then tested the estimates by measuring the piled material. Bark-to-wood ratios were derived, to include the energy potential of bark. Material samples were taken to help determine the product potential.

The estimates do not address actual collection and use of the biomass. Those issues are site-specific and depend on geography, roads, competing uses, land-management goals, environmental issues and cost.

Logging Residue in Southeast Alaska

Special logging-residue estimator ratios were derived from the earlier studies for use with coastal Alaska's Sitka spruce and Western hemlock stands, and published in 1986. They reflect the isolation and ruggedness of the Alaska coast and islands. The resource survey was considered crucial for studying new residue markets, planning land-clearing for replanting,

and utilizing low-grade timber. Wood energy, possibly by means of wood-fired central generation, was considered a market target.

In 1989 the Pacific Northwest Research Station of the U.S. Forest Service published a single reference book consolidating estimator data for the five states. This compilation assessed two types of application:

- current opportunities for logging residue; and
- prospects for whole-tree harvesting of small-diameter stands.

The data were presented in tabular format.

Data categories include total land area and commercial forest area by owner class, and forest type, site and size, and others.

Landsat Biomass Mapping

The Oregon Department of Energy program sponsored a satellite biomass-mapping project in 1985 to see if Landsat-3 land-cover data were convertible to biomass resource information, as a primary data source for a statewide automated biomass mapping system.

The research was done by the University of Oregon's Environmental Remote Sensing Applications Laboratory. It related Landsat data to permanent inventory plots in the Deschutes National Forest.

The project found definite associations between Landsat data classes and biomass resource classes, with a potential for use in a computerized geographic information system. Landsat data cover more than 10 million acres of national forests in Oregon.

Idaho Mapping Study

The Idaho Department of Water Resources tested the potential for computerized biomass assessment with a pilot mapping and data collection study in 1985. Existing forest-residue data for a test plot were classified and stored for analysis and manipulation in a simulated assessment of resources. The study was done by the department's Image Analysis Facility.

Woody Biomass Plantations

A final report on a five-year study of tree plantations as a long-term energy supply was issued in 1985 by Seattle City Light. The report was financed by the Regional Bioenergy Program. The project involved native red alder and black cottonwood in a variety of planting densities. The crops were fertilized, weeded and irrigated for maximum production. However, the highest growth rates were observed in an untreated, mixed-species plot.

Coppice regeneration was attempted, but suffered 75 percent mortality with alder and 15 percent mortality with cottonwood.

Tree farming was judged to be technically feasible, though not economic in the current Pacific Northwest energy market. Fuel costs indicated that a minimum 10-year rotation cycle would be needed to produce 26 oven-dried tons (ODT) tons/acre/yr to fuel a 25 MW steam plant.

Forest-Residue Supply Curves

Simple estimates of amounts of residue in the woods are little help in weighing commercial bioenergy proposals, which need reliable data about long-term fuel availability and cost.

A study by Envirosphere Co., commissioned by the Regional Bioenergy Program in 1985, provided site-specific marginal-cost curves for the 84 principal timber counties of the Pacific Northwest, and all of southeast Alaska²¹. The data were formatted for a Lotus 1-2-3TM spreadsheet and published on floppy disks.

Marginal costs were estimated through 1990, and supply and demand trends for another 15 years were discussed.

Worksheets and step-by-step directions carry the reader through the estimating process.

A planner could use the marginal-cost curves to estimate total delivered cost of a specific annual fuel requirement. The task is analogous to asking, "How many tons of residue will be available from logging sites within a radius of 10 miles? 20 miles? 30 miles?," until the

²¹For southeastern Alaska, a flat 20 percent of the harvest volume is estimated; county-by-county curves were not available.

necessary quantity is accumulated.

The number of acres harvested annually in a county is multiplied by the typical volume of residue per acre for that region. The number of acres is factored by type of ownership (public/private) and method of harvest (clearcut/partial). Residue yield per acre is also factored by piece size, terrain slope and yarding distance.

A final equation computes the delivered cost per cubic foot by combining the costs of recovery, processing and transportation.

Using the worksheets and data, the report estimates fuel costs for four hypothetical cases from distinctive geographic zones.

These are:

- Shelton, Wash., for the Olympic Peninsula;
- Pendleton, Ore., for the ponderosa pine area of central Oregon;
- Lewiston, Idaho, in the Intermountain forest zone between the Rockies and the Cascades; and
- Eugene, Ore., in Oregon's Willamette Valley.

Resource Development: Economics

Industrial Wood-Fuel Market

The potential for increased industrial wood-fuel utilization in Washington was examined by the Washington State Energy Office in 1987.

They found that only 18 percent of non-users have investigated wood fuel, and 40 percent wanted information about vendors, economics, technologies, fuel availability and environmental issues.

The study sought to identify market potential for the more-than three million tons of forest residues produced annually in the state and mainly disposed of by slashburning. These fires create air pollution, and waste an estimated 34 trillion Btu's of heat, in a state whose industry pays about \$505 million annually for fossil fuel.

The study inquired about operators' standards for capital-investment decisions, barriers to wood-fuel use, and changes needed to encourage its adoption.

The state has 6,000 manufacturers in 347 industries. A first cut eliminated industries without technical capacity for wood heat. It retained 155 industries that use appropriate forms of energy, such as high process heat, steam, hot air or hot water.

The shortened list was then sorted by firms according to fuel consumption; and firms with fewer than 20 employees or annual fuel costs estimated at less than \$100,000 were eliminated. This left 1,276.

The 300 largest fuel users of the remaining candidate facilities were sent surveys. Of the 54 percent responding, 32 percent spent less than \$100,000 per year on fuel, and 22 percent spent more than \$1 million.

Rate of return was the capital-investment decision method preferred by 47 percent and 33 percent preferred to calculate simple payback. Their principal wood-fuel concerns were about economic or technical feasibility, supply stability and capital availability.

The energy office concluded that the growth potential is substantial.

Residential Wood Heating

Wood consumption for home heating has been studied by a number of agencies, to satisfy the needs of energy planners, timber managers and air pollution authorities.

Oregon used questionnaires and stove-sales reports to derive consumption estimates. Washington inventoried users, county by county.

Idaho's Department of Water Resources commissioned a statewide study. Based on a mail survey of a random sample of households, the study found that 28 percent of respondents used wood as a primary heat source, and 29 percent as a secondary source.

Average annual consumption for wood-heated Idaho homes was found to be 3.77 cords, for a state total estimated at 660,000 cords. If all householders who said they intended to install woodstoves did so, another 200,000 cords would be required annually, according to the survey. Economics was the strongest motive reported for wood heating, followed by esthetics.

The ultimate consumption projection was prepared by Omni Environmental Services and published by the Regional Bioenergy Program in 1988.

Based on data from 15 state and federal sources, the report concluded that wood usage in the Columbia River watershed will be essentially flat for two decades.

The number of wood-heated households was expected to rise to 3.17 million in 1985 from 4.43 million. Consumption was estimated at 4.2 million cords in 1985 and 4.5 million cords in 2005, given no technological or price disruptions. The most sensitive decision factor was reported to be fuel price.

Home weatherization was predicted to reduce per-household fuel use by 22 percent, but population growth will keep overall demand constant.

High-technology woodstoves can reduce demand by 6 to 17 percent, with their greater efficiency. Pellet-fed stoves were not expected to affect the cordwood market in the near term because their fuel is manufactured. Catalytic afterburners were expected to reduce total consumption by no more than 11 percent.

Resource Development: Recovery Technology

"Doghair" Studies

A primary resource-recovery task of the Regional Bioenergy Program is developing and demonstrating improved recovery technology.

One important improvement opportunity lies in the bulk harvesting of small-diameter, low-value stands to allow reclamation by replanting. A five-year project partly sponsored by the regional program has demonstrated reliable, affordable machinery for that purpose. It is a versatile, cost-effective system for self-financed stand conversion. Unwanted trees are processed in the woods into marketable fuel and fiber products.

Development began in 1983, in an experiment launched by the Quilcene Ranger District of the Olympic National Forest.

Hermann Brothers Logging and Construction Co. of Port Angeles, Wash., contracted to clear a vast, overpopulated "doghair"²² stand of stunted conifers for replanting.

Many such submarginal tracts occupy valuable land on the Olympic Peninsula, where they sprouted lushly in the debris of fires that swept the peninsula from 1891 to 1925.

Hermann Brothers agreed to harvest 20,000 acres, charging \$13 an acre and keeping all the trees, processing them into any product that could be sold. Every tree over 1 inch in diameter and 10 feet high was to go — as many as 20,000 scrawny firs, hemlocks and cedars per acre.

Each year, Hermann Brothers and cooperating equipment builders refined the equipment and production system. The final versions were tested in 1986. The product mix was adjusted from year to year, to maximize the benefits of new equipment or to match the changing market. Products included sawlogs, lumber, paper chips and hogfuel.

The Pacific Northwest Research Station of the U.S. Forest Service participated in the trials. The Regional Bioenergy Program joined the venture in 1985 by underwriting development of a bulk harvesting, chipping, hogging and log-salvage system designed by Hermann Bros.

Five research reports have come out of the Quilcene project under the umbrella title, "Harvesting Overstocked Stands of Small Diameter Trees." They dealt with harvesting and processing equipment, stem density, biomass distribution, chemical composition with site-fertility implications, and energy values.

Tree-Farm Residues

Kinzua Corp. operates a 175,000-acre tree farm with a sawmill, chipping plant and 9.7 MW wood-fired cogeneration plant at Heppner, Ore. The preferred boiler fuel is mill residues, but residue price, quantity, and availability are

subject to production changes and market conditions, while thinnings and slash from tree-farm silviculture are available year-around.

A study of ways to optimize the forest-residue recovery system was made in 1987-88, commissioned by Kinzua Corp. and the regional program.

The study is based on eastern Oregon operations, but its findings are pertinent throughout the Intermountain Region, from the Cascade Range to the Continental Divide.

The report documents the economics and applicability of several options for recovering small, unmerchantable understory trees taken before logging white-fir stands, thinnings from overstocked young ponderosa pine stands, and logging slash.

The cogeneration plant burns 71,500 BDU/yr²³ of residues annually. Mill residues were plentiful during the study period, 1987-88, so only 7,000 BDU/yr of forest-residues were needed.

The report is in six sections:

- a state-of-the-art survey of equipment for handling small logs and residues;
- analysis of Kinzua recovery methods and economics;
- analysis of processing methods;
- margin and risk comparisons of selected recovery options;
- discussion of policy issues affecting resource availability and mechanized recovery on delicate soils; and
- recommended growth strategy.

Good lumber market or bad, the study found, the ongoing forestry generates enough residues for 25,000 ODT²⁴ of pulp chips and 12,000 ODT of fuel byproduct annually.

It recommended a cautious expansion of residue recovery, beginning with in-the-woods flail processing of pulp logs, chipping of pine

²² "Doghair" is logger jargon in the Pacific Northwest for dense stands where the trees grow "as close as hair on a dog's back".

²³ Bone-dry unit—2,400 lbs at 0% moisture

²⁴ Oven-dry ton—2,000 lbs. of wood at 0% moisture

Hermann Bros. in-the-woods small-tree processing system includes debarker/delimer (foreground), boom loader for chipper (left), and shredder and loader with chip vans (rear)

— photo by Craig L. Chase

thinnings for pulp, and recovery of log tops for chipping at the mill. Eventual extension to whole-tree hauling was recommended, for chipping at the mill.

The report also recommended attention to research into the long-term site-productivity impact of residue removal.

Chunkwood

Chunkwood is forest residue reduced to large fuel chips 2.5 to 4.5 inches long, made with chipper-like machines or modified conventional chippers. American and Scandinavian experimenters have been developing the technology for several years. U.S. Forest Service projects were conducted at the North Central Forest Experiment Station at Houghton, Mich., and the Missoula Technology and Development Center, in Missoula, Mont.

Chunks are said to dry well in storage, with much less spontaneous combustion than chips. Chunks are also a more versatile product than chips, since they can be reprocessed into smaller forms such as pulp chips, flakes, or other fiber options, to take advantage of market openings.

A University of Idaho research team conducted a chunkwood study for the Regional Bioenergy Program. Study sites were in the Colville National Forest in northeastern Washington, the University of Idaho Experimental Forest near Moscow, and at the 50 MW woodburning generating station of Washington Water Power Co. at Kettle Falls, Wash.

Some of the findings were reported at a chunkwood conference of the International Energy Agency in Sweden in 1988. A complete report was published later by the Regional Bioenergy Program, dealing with recovery, collection and processing, transportation, total system costs, storage and combustion.

The team found that chunkwood technology is feasible but not currently economic in the Pacific Northwest. With a favorable price and short haul, it could be profitable for thinnings and overstocked timber but not for logging residues, because of greater expense.

A prototype chunker was used: a modified Morbark Model 18 whole-tree chipper powered by a 310 hp Cummins Model 903 diesel engine.

Study elements covered a variety of combinations of the chunker, a feller-buncher, bulldozer and grapple skidders, with several transportation modes.

Production was best with clearcut whole trees skidded to the chunker. Logging-residue and whole-tree machine rates, production rates and costs were comparable.

Chunks were found to be too heavy for conventional pneumatic handling, presenting handling problems throughout the utilization chain, from the woods to the furnace grate.

Combustion was good, however. The study found that chunks would be better fuel than hog fuel for the Kettle Falls boiler because of dryness, reduced conveyor wear, less chute plugging, less vulnerability to freezing, lower burn rate, improved flame stability, less carryover of unburned fuel, less internal erosion, stable superheater temperature and extended turbine life.

Forest Residues

Industry has been slow to include forest residues among energy resources in the Pacific Northwest and Alaska.

Forest residues are remote, scattered and non-uniform. Mill residues, in contrast, often are free or better (by the avoided cost of land-filling). They accumulate close to the boiler, and require little processing.

Prospects for forest-residue utilization were summed up for the Regional Bioenergy Program in a recent study by a team from the Forest Products Department of the University of Idaho.

The report²⁵ describes state-of-the-art transportation, recovery and processing machinery. Investment costs are presented, with estimates of hourly owning and operating costs.

²⁵*Wood Residue Recovery, Collection and Processing*, Leonard R. Johnson.

A model for economic analysis is offered. It begins with delivery costs, since distance is a dominant variable.

In-the-woods processing that increases load density is described. Processed products include chips, hog fuel, chunkwood, cordwood and bales. Alternatively, whole or delimbed trees can be trucked from remote sites for processing, if the road system and tree size allow.

Recovery and collection costs depend on the terrain and type of material. Tree size controls the choice of equipment, the achievable operating efficiency and the kinds of end products. If tree sizes vary widely, machinery selected for big trees may be handicapped in manipulating smaller residue pieces.

Logging and residue processing can be simultaneous, if the proportions of logs and sawtimber are balanced and there is adequate space to operate the equipment efficiently.

If recovery is separate from logging, the operation must cope with odd shapes and sizes, scattered and difficult to bunch, for which there is little specialized equipment because of the low intrinsic value.

Double-Entry Logging

"Double entry" logging, an alternative approach to residue recovery, has demonstrated promise in other forestry studies of reducing costs for timber operators, increasing residue recovery, and improving bioenergy economics.

Conventionally, a site is logged with a single system big enough for the heaviest timber on the site; small or unmerchantable pieces are left for disposal. In double-entry logging, a second pass is made to pick out light logs and large residue pieces with smaller, less labor-intensive equipment.

Two double-entry demonstrations were funded by the Regional Bioenergy Program; one in southwestern Oregon on a typical Bureau of Land Management partial-cut sale of old-growth fir and pine, and the other in Idaho on two clearcut blocks of smaller cedar and fir.

The Oregon project used a big yarder with a five-man crew and a smaller yarder with a crew

of three. The big yarder took logs above 16" diameter, and the smaller one took the remainder down to 4", plus all hardwoods. About half as much residue was left behind as on a conventionally harvested control site.

The conclusion was that the slash reduction was not worth the added cost.

In the Idaho project, 29 percent more sawlogs were recovered and gross volume per acre increased by 63 percent, but per-acre costs were 58 percent higher than for conventional yarding. The conclusion was that double-entry would be effective if it increased volume recovery and a market was available for the residue.

Both studies reported double-entry to be cost effective if the management plan requires removal of small material, the terrain is steep, and the understory is largely unmerchantable residue among large logs.

Residue Processing

Processing logging residue on delivery at the landing can reduce recovery costs, an experimental project in northern Idaho demonstrated. Using a skidder or dozer and a home-made, hydraulic shear, the crew produced cordwood for \$20-\$25 per cord. The shear handled pieces up to 23" in diameter and recycled in 7 seconds. Cost studies showed that the system would be feasible where firewood demand is high.

Pieces unsuitable for firewood were processed in a hydraulic grinder, but the trial found it added no value, either in material handling or transportation.

Orchard Trimmings

"The Jammer," a mammoth compactor that crunches tree limbs and brush into blocky bales of potential fuel has been developed at the University of California, Davis, funded by the Regional Bioenergy Program.

John A. Miles, an agricultural-engineering professor, said the Jammer was first intended to make logging slash more transportable, but it also appears useful for orchard trimmings.

Miles and colleagues modified a standard cotton module box and mounted a knuckle boom on it. The brush is loaded and compacted into two bundles, which are then ejected.

Resource Conversion

Co-firing Wood Chips with Coal

If as little as 10 percent of the coal consumed in interior Alaska were replaced by wood, a use would be created for 142,000 tons of residues a year, and out-of-state fuel purchases would be reduced, and so would fossil-fuel emissions.

Several studies to determine the technical and economic feasibility of co-firing biomass with coal in a major power plant have been conducted by the University of Alaska, Fairbanks, underwritten by the Regional Bioenergy Program. The test site was Fort Wainwright, an Army base near Fairbanks.

Fuels included aspen, white spruce and paper birch. The chip component ranged from 9.9 percent to 21.9 percent of the fuel mixture, by weight. At 21.9 percent, maximum stoker speed was required to maintain steam production. Stack emissions were only slightly improved, but ash production was down 8 to 16 percent.

Wood shipped from as far as 60 miles was found to be less expensive than coal, in cost per heat unit. Only one vendor in interior Alaska was capable of supplying sufficient chips for long-term use.

Biomass Fuel Characterization

The need to reduce reliance on landfills by applying the energy-recovery option is clear and urgent. Energy recovery is a consummate match of waste raw material to energy demand. Yet, commercial acceptance of biomass fuels is slowed by a lack of engineering-quality fuel characterization and specification.

Although woody biomass and MSW are processed in several ways to improve their handling, relatively little is known about optimizing their combustion. Most contemporary woodburning systems are adapted from coalburning technology, and take little advantage

of basic physical and chemical differences among the fuels.

The Regional Bioenergy Program has sponsored a three-year testing project to collect and measure fuel characteristics, both physical and chemical, for use in designing biomass-combustion systems. Its objectives are:

- to test certain fuels, define their co-firing characteristics, and evaluate their co-firing potential;
- to recommend test protocols, standards, and specifications;
- to define, analyze and evaluate typical system modifications for using these fuels; and
- to develop and publish the findings as a supplement to the looseleaf Biomass Project Guidebook.

The fuels have included pellets and hogged fuel of native species, both clean and salt-contaminated, and MSW-derived fuel from all five states in the region. Clean Douglas-fir pellets were characterized for a data baseline. Future tests will characterize multiple-feedstock pellets including waste paper, newsprint, cardboard, yard wastes and straw.

Combustion tests are conducted in a unique test facility at Oregon State University's Department of Mechanical Engineering, which gives precise control of operating conditions for comprehensive combustion profiles. In association with gas chromatography/mass spectroscopy procedures, testing goes beyond combustion data to address a wide range of factors related to public health and safety.

Test methods, procedures and protocols approved by the EPA and American Society for Test and Measurement (ASTM) are specified throughout.

Wood-Boosted Geothermal

Low-quality geothermal aquifers are common in western states; hot, but not enough to generate electricity economically.

The Montana Department of Natural Resources and Conservation evaluated a proposed 15 MW power plant near Ennis Hot

Springs, using a wood-fired boiler to boost brine beyond its 275° F wellhead temperature.

Mill and logging residues were burned for test calculations. Surrounding forests have large quantities of low-quality lodgepole pine and Douglas-fir, should large quantities of fuel be called for.

Three power cycles were compared:

- A conventional wood-fired steam turbine with no geothermal assistance;
- A wood-fired steam turbine with geothermally preheated feedwater, using combustion air for the steam cycle; and
- A two-stage binary engine with geothermally vaporized working fluid, plus geothermal preheating of combustion air for a wood-fired steam turbine.

The geothermal preheater reduced fuel costs 15 percent to 17 percent and the two-stage, binary system reduced costs 27 percent to 20 percent, but neither was judged to be competitive in the present energy market. Continued exploration of geothermal was recommended.

Wood Gasification

The region's biggest consumer of biomass fuel is the forest-products industry. Typically, the fuel is used on site.

It is believed that converting the biomass to low-Btu "producer" gas would broaden its applicability, but lack of standard test techniques and protocols has hampered development.

The most recent trial occurred at North Powder, Ore. An idle gasification unit was available, burning chipped, beetle-killed, lodgepole pine.

Testing was delayed by plant breakdowns, economic uncertainty and changes of ownership. Nevertheless, a sampling and quality assurance plan was developed before FY-1989 funding limitations resulted in termination.

Earlier, a 1980 wood-gasification project in Anchorage attempted to develop a simple generation system for remote, interior Alaska villages. The project was partly sponsored by the

Regional Bioenergy Program. It was terminated in 1985 after a professional evaluation team declared the system inadequate for its mission.

Severe environmental problems remained to be resolved. A hazardous effluent stream from the gasifier was found. Almost 500 gallons of potentially mutagenic liquid was analyzed and about 180 containers of solid and liquid waste and contaminated soil were taken to a hazardous-waste disposal site.

Environmental Protection

MSW-to-Energy

The Regional Bioenergy Program focuses its MSW energy-recovery resources on demonstrations with broad, regional value, environmental benefits, and constructive publicity for the program's purposes.

One example is a renovated, 59-year-old City of Tacoma steamplant that has been converted to burn a three-fuel blend of RDF,²⁶ coal, and wood.

The plant is expected to go online in early 1991 after its environmental-impact process is completed and startup hitches are resolved. It will co-fire 70 tons of fuel per hour composed of about 30 percent RDF, 32 percent wood residues, and 26 percent coal. It will generate a net 45MW of electricity at 3.5 cents/kWh.

Both MSW and wood residue pose near-crisis disposal problems for Tacoma, with about 170,000 residents creating 600 tons of consumer waste daily, and a number of sawmills and other forest-products handlers piling up bark, debris and mill residues.

At the same time, a decade-long regional energy surplus is fading and new, least-cost sources are welcome.

The steam plant, coal-fired when it was first commissioned to back up the municipal hydroelectric supply, later was converted to oil. The plant only ran continuously two times, for a total of 101 days. During the second episode, the

²⁶Refuse-derived fuel (municipal solid waste processed to improve its performance as fuel)

superheaters burned out and the plant was mothballed because new environmental standards required emission controls and a new cooling system.

Conversion to biomass fuel was conceived during the OPEC oil crisis in 1979. The proposal was studied and found to be feasible, but was shelved when market conditions changed.

Also in 1979, the city built a resource-recovery plant to divert solid waste and prolong the life of the municipal landfill. Intended to salvage salable materials including RDF, the resource-recovery unit joined the steam plant in mothballs when the prospective RDF market evaporated.

A private firm offered to lease the steam plant, modify it for co-firing biomass with coal, and sell the power back to Tacoma City Light. The city accepted. When the firm could not find the right kind of financing, Tacoma City Light took over the project.

The repowering consisted of adding two fluidized-bed combustors, converting existing boilers into heat-recovery steam generators, and installing mechanical-draft cooling, a distributed, computerized control system (DCS), and fuel-handling equipment.

Wood wastes will be trucked in around the clock, under supply contracts. RDF will be delivered six days a week. The coal will be barged down from British Columbia and offloaded directly onto the plant's conveyor.

Total cost is about \$44 million. A \$15 million matching grant from the state Department of Ecology covered part of it, and also supported part of a \$3 million upgrading at the RDF facility to improve quality control and fragment sizing. The Regional Biomass Program granted \$308,000 for the original feasibility and market studies.

Tacoma City Light cautions that local supporting factors are important and should be weighed before embarking on similar projects. For Tacoma, these included:

- an idle resource-recovery facility in place;
- idle, low-mileage turbine generators;

- a large site served by a navigable waterway; and
- big residue-generating neighbors.

Otherwise, the plant is technically commonplace with the exception of co-firing three fuels.

Woodstove Study Series

Woodstove pollution is a critical issue in many communities of the region, including Portland, Medford, Klamath Falls, Yakima, Seattle, Spokane, Missoula, Boise and Juneau. The Klamath Falls airshed was recently ranked worst in the nation²⁷ because of woodstoves.

The Regional Bionergy Program has underwritten four significant woodstove studies which yielded a number of reports including this benchmark seven-part series by OMNI Environmental Services:

- *Estimating the Volume of Residential Wood Burning in the Pacific Northwest and Alaska;*
- *Mitigation Measures for Minimizing Environmental Impacts;*
- *Cost/Benefit Analysis of those Mitigation Measures;*
- *Estimating Carbon Monoxide Air Quality Impacts from Woodstoves;*
- *Identification of Factors Which Affect Combustion Efficiency and Environmental Impacts from Woodstoves;*
- *Woodstove Emission Sampling Methods Comparability Analysis and In-Situ Evaluation of New Technology Woodstoves;* and
- *Compendium of Environmental and Safety Regulations and Programs Affecting Residential Wood Heating Appliances.*

Institutional and economic influences are the concern of the two reports on control strategies:

Mitigation Measures for Minimizing Environmental Impacts and Cost/Benefit Analysis of Mitigation Measures.

²⁷January, 1988: 792 micrograms of particulate pollutants per cubic meter of air

The studies appraised the public acceptability of 18 possible control strategies. Those chosen as most likely to succeed were:

1. Catalytic add-on afterburners, provided free;
2. Catalytic devices required, but not free; 70 percent tax credit allowed;
3. Low-emission certification of new stoves, with 33 percent tax credits;
4. Public education about choosing appropriate stove sizes;
5. Old-style stoves banned within 3 years, with 70% tax credit for replacements;
6. Installation permits for new stoves, with fees proportionate to emissions;
7. Require certification of new stoves, without tax credit; and
8. Moratorium on new stoves.

Estimating Carbon Monoxide Air Quality Impacts from Woodstoves addresses the difficulty of identifying sources of carbon monoxide (CO) emissions.

Woodstoves emit eight times more CO (by weight) than they do smoke and other fine particulates. In the atmosphere, the source of a CO component is difficult to identify, yet tracking the source can be urgent because it is a quick-acting poison.

The study observed time patterns and meteorological conditions in residential

Section of portable AWES/Data LOG'r (TM) system for sampling woodstove emissions. Lower section (clockwise from upper right) holds a resin filter, silica gel water trap, oxygen sensor and vacuum pump. —photo by Craig Chase

Summary of Stove Performance and Emission Rates*

Stove Type	Maximum Output (1000 Btu)	Efficiency %	Particulate (Grams /Hr)	CO (Gm/Hr)	NOx (Gm/Hr)	HC (Gm/Hr)	PAH (Mg/Hr)
Conventional	44.4	58.5	26.1	109.3	0.86	111.6	2378
Catalytic	31.1	74.1	2.7	50.6	0.82	20.7	160
Refractory	21.2	74.0	0.3	0.3	1.26	0.2	99
Pellet	23.8	76.8	1.2	1.5	1.49	0.9	362
Pellet boiler	327.6	67.9	38.7	425.0	19.42	2.4	318

*Source: *Environmental Impacts of Advanced Biomass Combustion Systems*, OMNI Environmental Services, Beaverton, OR

neighborhoods of six cities to estimate the probable intensities of woodstove-derived atmospheric CO.

How effective are new-technology stoves, and how accurately do laboratory tests reflect their performance in the real world?

Those questions are examined in *Identification of Factors Which Affect Combustion Efficiency and Environmental Impacts from Woodstoves*. Pellet-burning stoves, add-on pellet feeders and add-on catalytic afterburners were laboratory operated. All the pellet systems performed at least as well as catalyst-equipped traditional stoves, with high thermal efficiencies.

For real-world comparison, computerized sampling and recording devices were attached to stoves in five homes. They showed that some emission rates were actually lower than they had been in the laboratory, indicating that operating technique may be a major emission-rate variable.

The automated testing system was referenced against two conventional EPA procedures in the final emission study, in parallel evaluations of several new-technology stoves. These were made with operating patterns typical of Portland and New England.

The report is *Woodstove Emission Sampling Methods Comparability Analysis and In-Situ Evaluation of New Technology Woodstoves*.

The three methods gave statistically comparable readings on particulate emissions. The automated OMNI system, which uses a more efficient trap for semi-volatile organics, got higher readings for that group.

Detailed descriptions of laws, rules and programs on residential wood combustion in the United States at the time (1985) are given in *Compendium of Environmental and Safety Regulations and Programs Affecting Residential Wood Heating Appliances*.

The report was intended for planners, regulators and the woodstove industry.

Environmental Impacts of Advanced Residential and Institutional, (Woody) Biomass Combustion Systems was aimed at the lack of test

standards and documentation which has hindered woodstove performance comparisons²⁸.

The study was commissioned to extend environmental evaluation to emissions that are not covered in woodstove certification, complex compounds including some mutagenic polycyclic aromatic hydrocarbons (PAH).

So-called "advanced technology" woodstoves, including the highly regarded forced-air pellet stove, employ a variety of design stratagems to reduce specific harmful emissions and qualify for certification. If a confused consumer makes an inappropriate selection, air quality can suffer; thus, good consumer information is desirable.

PAH's are generated during the typical incomplete, uneven combustion of hand-stoked, air-starved woodstoves. The PAH's enter the atmosphere entrained in flue gases, or are released indoors as fugitive emissions when the stove is opened or inadequately closed.

The study measured flue-gas concentrations of 18 PAH's listed by the U.S. Environmental Protection Agency's (EPA) Integrated Air Cancer Project and the Oregon Department of Environmental Quality (DEQ) source-profile program. Those compounds are:

• Acenaphthene	• Dibenzo[ah]anthracene
• Acenaphthalene	• Fluoranthene
• Anthracene	• Fluorene
• Benzo[a]anthracene	• Indeno[1,2,3-cd]pyrene
• Benzo[a]pyrene	• Naphthalene
• Benzo[b]fluoranthene	• Phenanthrene
• Benzo[ghi]perylene	• Pyrene
• Benzo[k]fluoranthene	• 2-methyl naphthalene
• Chrysene	• 3-methylcholanthrene

The tests were conducted on four stoves in a laboratory and a commercial pellet-fired boiler in use in a high school.

²⁸Commercial boilers operate within narrow efficiency "envelopes" under steady conditions, while home woodstoves are batch-fed through open doors and then operated as oxygen-starved chambers.

None of the stoves was completely clean of toxic particulates; each had a vulnerable burn rate at which mutagens were detectable, either definitely or marginally.

All the advanced-technology devices were found to burn cleaner than the traditional stove, but improvement in one component did not predict a gain in the others. Generally, particulate and carbon monoxide emission were improved by two or three orders of magnitude, and volatile organic compounds decreased by one to two orders of magnitude.

The refractory and pellet stoves were generally lowest in pollutants and bioassay responses, but they emitted more NO_x than the others, probably because of hotter fires. NO_x rates were comparable to those of common oil or gas furnaces.

The report warned that the results need verification and replication because wood combustion is highly variable, even under standard test conditions.

Low emission levels from the refractory stove and pellet burner were credited to metered, continuous fuel feed and hot fires, plus long high-temperature particle-residence times in the refractory stove chamber. Relatively high PAH and mutagen output from the pellet stove was ascribed to on-off thermostatic modulation of fuel feed and combustion air, which allowed smoldering on low-burn cycles.

The stove with the catalytic afterburner had lower CO and organic emissions than the traditional stove, but not as low as the pellet and refractory stoves. This was blamed on swamping of the afterburner by high particulate volumes after batch fueling.

The pellet-fed stove performed generally well, with indications that fine-tuning could improve emissions and efficiency.

Slashburning

Since 1981, the Regional Bioenergy Program has supported a series of studies of ways to minimize emissions from broadcast burns and reduce their impact on populated or protected

areas. Some of the most sensitive populated areas are Washington's Puget Sound corridor and Oregon's Willamette Valley, which both lie west of the Cascade Range.

Computer modeling has credited industry with almost a 30 percent reduction in slashfire emissions there, mainly through increased removal of harvest residues for pulp chips,

Slashfire tests use emission samplers suspended over burn sites to sample rising particulates. Research crew member and portable data recorder are shown at test site.

— photo by Craig L. Chase

cordwood, or hog fuel. But this hypothesis was found to be over-generous when tested in 1986 and 1987, in studies conducted to increase the model's precision. The new studies found more residue left behind than before.

The improved precision of the 1987-88 model did, however, reduce the total emission charge against slashfires, despite increased fuel loading. The model now credits Oregon slashfires with 20 percent less emissions than previously, and Washington with 7 percent less.

The earlier models estimated fuel consumption, character and strength of pollutants, and trace-gas emissions. Subsequent studies in 1983 and 1984 by the Pacific Northwest Research Station of the Forest Service had quantified the air-quality effects of increased residue removal, and of scheduling fires for favorable weather. A series of 12 test fires measured and characterized a number of emitted compounds. Similar studies began in 1985 in eastern Oregon and Washington, where forest, meteorological and population conditions are different.

Forest Depletion

Scientists are reviewing conventional wisdom about managing the region's uniquely productive forests for sustained growth. They fear inadvertent, cumulative damage by intensive management, risking future productivity.

They are mindful that the long crop cycle, typically 80 years per rotation, hinders direct observation of cumulative effects, so that even the most conscientious foresters have had only indirect evidence for evaluating management practices.

One invaluable set of paired, second-growth control plots is available for cause-and-effect comparisons because of the foresight of a pioneer U.S. Forest Service fire researcher, the late Bill Morris. A recent study of 44 "Morris pairs," funded by the Regional Bioenergy Program, is reported in *Effects of Burning Old-Growth Logging Slash in the Cascade Range of Western Washington and Oregon*.

Test plots of second-growth forest, set aside four decades ago, allow researchers a rare opportunity to compare regrowth on land subjected to slashburning, and land cleared by other means.

The authors concede that logging residue is a hazard and a reforestation problem, yet they recommend lopping foliage and branches and scattering them on the site because they contain most of a tree's nutrients.

They urge that site deficiencies should be taken strongly into account in prescribing rotation periods, with special care for shallow, rocky sites that are low in nutrients and humus, with more nutrients at the surface than in the soil. Yarding should be minimal to reduce soil damage, they suggest. Rotation cycles on especially fragile sites should be as long as 200 years, to maintain soil nitrogen and humus on steep, eroding sites.

More intensive production would be appropriate on robust sites where nitrogen and organic material are plentiful, mineral soils are deep and well-drained, the climate is favorable, and fast-growing secondary vegetation restores nutrients quickly.

Herbicide can be preferable to fire for vegetation control on some sites, the report says. Supplemental nutrients should be evaluated in areas of intense utilization and short rotation, because essential soil microorganisms may require a sustained nutrient supply.

The study's conclusions are applicable to about 40 percent of the commercial forest west of the Cascades, according to the authors. The test plots will be revisited at 10-year intervals to expand benchmark data through subsequent rotations.

Technology Transfer

A broad-based technology transfer effort has evolved in the Regional Bioenergy Program.

Target audiences have been identified, publications evaluated, and new initiatives extended to key target groups.

Key issues today include public attitudes toward MSW, the credibility of bioenergy as a local solution to local needs, and the development of effective audiovisual and video presentations.

Bioenergy Seminar

An international, five-day seminar on biomass energy will be held March 18-22 in Coeur d'Alene, Idaho.

The keynote, "Bioenergy for a Clean Environment," embraces the role of biomass fuels in coping with global warming, and the efficiency of bioenergy systems compared to other human energy activities that impact the biosphere.

The seminar is intended to increase communication within the bioenergy community. Economic development based on local biomass resources, and attraction of capital for new or expanded bioenergy ventures are among the goals.

Most discussion topics will be down-to-earth, rather than matters of global policy. They will range from the latest equipment for woody biomass and MSW energy-recovery processes, to reports on producer gas and alcohol-fuel development.

The gathering will be funded under a technology-transfer grant of the Regional Bioenergy Program and cosponsored by the Idaho Department of Water Resources. It is the first such conference in this changing field since 1984, when a similar meeting was held in Portland, Ore.

More than 50 speakers and panelists are scheduled. They will be academic, industrial, governmental and political specialists. They will include users, vendors and regulators.

Papers will discuss the environmental mandates and the economics of biomass resources, including hogfuel, chips, sawdust, whole-tree chips, and chunkwood.

Sessions on densified fuels, whether wood, bark, field residues or MSW, will be on the program. Biogas digestors, gasifiers and other conversion technologies for gases and liquid fuels are also topics.

An open poster session and vendor exhibits are planned, and a number of technical tours. The Coeur d'Alene area is rich in biomass resources and bioenergy applications.

Bioenergy Bulletin

The *Bioenergy Bulletin*, journal of the Regional Bioenergy Program since 1979, carries reports on program activities, policies and announcements, illustrated with tables, graphs and pictures. It now is included in *Biologue*, a periodical of the National Wood Energy Association.

When the *Bioenergy Bulletin* began, the Pacific Northwest & Alaska program was the only regional bioenergy effort. Now, *Bioenergy Bulletin* appears alongside news of the four other regional programs, which represent the other continental states' bioenergy activities.

Bioenergy Project Guidebook

A plain-language guidebook for people considering biomass energy projects has been published by the Pacific Northwest & Alaska Regional Bioenergy Program.

The thick, looseleaf volume has first produced in 1988 with nine major sections and 10 case histories. Another four sections were added in 1989.

The chapters are organized to be used independently, or in sequence as project-planning steps. Most are aimed at a nontechnical, managerial audience; the plant managers, financial officers and project sponsors who need a general understanding on which to base their judgments of the feasibility of a proposal.

Three chapters, however — on fuels, energy-conversion methods and plant specifications — are written for engineers.

Chapter topics are:

- planning for the fuel supply;
- fuel characteristics, storage and use;
- selecting a conversion technology;
- conversion technologies;
- environmental considerations;
- economics of biomass projects
- financing biomass projects, including computer modeling, spreadsheets and sensitivity analyses;

- plant-specific descriptions (selecting the hardware);
- bioenergy glossary;
- fuel contracting;
- forest residues;
- agricultural residues; and
- small-to-medium-sized modular combustion systems.

A gate-fold flow chart outlines four phases of planning for a bioenergy project, from the first discussion of the idea through start-up and integration into the everyday operations.

Problems are described candidly, sometimes in detail.

The cases include:

- North Powder, Ore.; the first commercial gasifier in the region (and first one in the U.S. to drive a generator). Fuel was forest and mill residue from a salvage operation in beetle-killed lodgepole pine.
- Biomass One, a hog-fueled cogenerator in Medford, Ore., with twin boilers and turbine generators producing 22.5 MW of electricity and 110,000 lbs of process steam.
- Kinzua Cogeneration Limited Partnership, a 10 MW cogeneration plant at Heppner, Ore., fueled with forest and mill residues.
- Stoltze-Connor Lumber Co., a shavings-fired boiler at Darby, Mont., built of recycled equipment, supplying 20,000 lb/hr of process steam to kilns.
- Ogden Martin Corp., an MSW mass burner for Marion County, Ore.; a 550-ton-per-day facility that produces 11 MW of electricity for sale and provides a reliable disposal solution.
- Cassia County, Idaho, a prefabricated, two-unit modular MSW incinerator that burns 50 tons/day of MSW and generates 10,000 lbs/hr of steam for a nearby potato-processing plant.
- Marindale Dairy, at Novato, Calif.; a demonstration of a prototype plug-flow anaerobic manure digester for a 320-cow dairy.
- Modoc Lumber Co., Klamath Falls, Ore.; a pilot wood-pelletizing plant using pine planer shavings.

ENERGY-COST RANGES FOR CROP RESIDUES

Small rectangular bale burner	\$4,000/100,000 Btu/hr
Home or shopping-heating installation, air-to-water heat exchanger, hot-water heat storage, purchase and installation except for bale storage	
Round bale burner Purchase cost only	\$15,000/million Btu/hr
Biomass boiler Purchase + installation	\$37,000-\$57,000/million Btu/hr
Gasifier Purchase cost	\$12,000-\$17,000/million Btu/hr
Engine/generator With controls and utility interconnects	\$1,200-\$2,000/Kw

NOTE: Total systems, installed and ready for operation, are generally 210%-450% of purchase price of the conversion unit. Extras may include installation, building, utilities, heat-transfer facilities, blowers and pumps, conveyors and emission-control equipment.

Typical table from Bioenergy Project Guidebook chapter on agricultural residues

- B.C. Forest Products; a wood-fired, space-heating and kiln-heating system using thermal fluid instead of steam, at Grande Cache, Alberta.
- Maple Lane School, Centralia, Wash.; conversion of central boilers to wood pellets to solve air-pollution problems from local high-sulphur coal.

Yearbooks

Program yearbooks have been published since 1986, documenting technical accomplishments, issues and considerations relating to resource development and planned activities. This important technology-transfer medium has been the central journal and historical record of the Regional Bioenergy Program among the state, federal, academic, political, and professional people who participate.

Bioenergy Glossary

The program published a 64-page glossary for nontechnical people in 1986. From "acetone" to "YUM," the authoritative booklet explains terms that are likely to stop a lay reader.

It includes photographs, line drawings and charts, and a source bibliography for more extensive inquiries.

Networking

The Regional Bioenergy Program participates extensively in professional, industry and trade associations. It also exchanges information and plans with other publicly funded institutions, and provides technical reports to the National Technical Information Service, industry journals and trade association publications.

Future Directions

Recent international events have added urgency to efforts aimed at increasing the use of bioenergy. Changes in the economy create new opportunities. And the biosphere, itself, presents new arguments for reduced reliance on a system of extracting fossil fuel from one hole in the earth while burying potential biomass fuel in another one.

While the Regional Bioenergy Program is adjusting to meet national and regional change, it continues to focus on its mandated mission: To expand the use of biomass energy, emphasizing cost-effective, environmentally sound options.

The program's strategic plan covers 1991-1993, to provide planning continuity in dealing with the region's most pressing bioenergy issues, and in exploiting its principal opportunities.

Activities are in four categories:

- technology transfer, information and education;
- biomass fuel combustion;
- biomass-derived liquid fuels; and
- municipal solid waste derived fuels.

Technology Transfer, Information and Education

Activity 1: Identification and description of regional program services and information resources

Descriptions of the program's data resources and technical, professional and information services will be developed, aimed at potential user industries, governmental policy makers, technical users, educators, journalistic media and special interest groups.

The Alaska Energy Authority will be the lead agency, assisted by other Task-Force agencies.

Activity 2: Consolidation of the Regional Bioenergy Program's information resources

A permanent, uniform system for public and Task Force access to program publications will be developed. It will serve Task Force inquiries, bioenergy researchers working on applications, and businesses, agencies and other interested bodies.

The project will insure that all of the region's publications are available to national data centers. It will link libraries and databases within the regional program, coordinate exchanges between Task Force members, keep track of state projects, and develop mailing lists and media directories.

The Regional Bioenergy Program management will be the lead agency, assisted by other Task Force agencies.

Activity 3: Industry, agency, and interest-group access to information and technology-transfer services

A systematic technology-transfer and technical-assistance program will be formed to develop printed material, demonstration tours, conferences, increased representation in regulatory and environmental affairs, and cooperative government-industry advisory groups.

Target audiences will be the wood-products, MSW and agricultural industries, the environmental and state regulatory agencies, and environmental interest groups.

Tasks will be divided among state members of the Task Force and the Regional Bioenergy Program management.

Activity 4: Improving communications with the national and other regional programs

Mutual awareness of program activities and public support for national laboratory programs will be enhanced by:

- establishing links between this Regional Bioenergy Program, the Solar Energy Research Institute and the Oakridge National Laboratory on specific technologies of regional interest;
- arranging for pertinent DOE publications to be circulated to Task Force members;
- circulating quarterly reports of other regional programs to Task Force members; and
- sending all reports and publications of this Regional Bioenergy Program to other regional program managers.

The Regional Bioenergy Program management will be the lead agency, assisted by assigned Task Force agencies.

Activity 5: Media support plan

This project will provide technical and textual assistance to Task Force agencies for use in publicizing bioenergy activities.

It will include producing generic slide shows, writing and printing material for information packets, producing videotapes and recruiting speakers for a bioenergy speakers bureau.

The Regional Bioenergy Program management will be the lead agency, assisted by Task Force agencies and support contractors.

Biomass Fuel Combustion

Activity 6: Residential Wood-Energy-Use Education

A woodstove users' educational program modeled on a highly successful project of the Klamath County (Ore.) Health Department will be established in six communities of each of the region's five states.

The Neighborhood Energy Information Programs will apply commercial marketing strategies and techniques to neutralize skepticism and motivate supporters of voluntary air-quality measures. It will include educational materials, moisture meters, demonstration videotapes, XEDAR infra-red compliance-survey cameras and laptop computers, pollution weather bulletins and public service announcements.

Educational emphasis will be on wood seasoning, health, neighborhood baseline pollution surveys and pollution-level targets.

The Oregon Department of Energy will be the lead agency, assisted by Task Force agencies.

Activity 7: Pellet-stove testing and technology transfer

Emission testing and demonstration of residential pellet-stove heating will continue in Medford and Klamath Falls. These two Oregon communities each have non-attainment airsheds

Schematic of AWES/Data LOG'r (TM) system for in-situ detection of woodstove emissions. Wood heating will be a study target.

in the winter, and traditions of residential wood heating.

Pellet stoves are acknowledged to burn more efficiently than conventional stoves: the demonstration will dramatize the difference. It will report test results and exempt pellet-burners from mandated shutdowns during air-pollution episodes, supporting a community strategy of rewarding efficient wood heating.

The tests will continue to investigate suspected emission differences between high-altitude and low-altitude installations.

Activity 8: Efficiency improvements in wood combustion to reduce PM-10 emissions and allow for industrial development

Particulate air pollution in Libby, Mont., exceeds EPA and state standards and has resulted in sanctions on industrial growth. The pollutants are mainly road dust and woodstove emissions.

The Regional Bioenergy Program will join a state-federal-private plan to reduce pollution by substituting electric heat for wood heat. Electricity generated by an existing biomass-fueled steam plant will be dedicated for home heating. Consumers will be encouraged to pay their electric-heating bills with cordwood, reducing the impact on household cash flow for residents who cut their own wood, a local tradition.

The offset from reduced stove emissions will be credited to the application for a new sawmill. Residues from that mill and others will be burned in the steam plant, reducing the landfill waste stream and generating additional revenue in tipping fees.

The DOE contribution will underwrite meetings of the major parties and an economic study of the project. The lead agency will be the Montana Department of Natural Resources and Conservation.

Activity 9: Biomass-fuel combustion testing and characterization

Testing and characterizing of refuse-derived fuel, mixed waste paper and wood samples will

be completed. Test methods, procedures and protocols will be proposed. The materials will be combined with each other and with straw. A final report will be completed and distributed.

The work may lead to energy uses for substances that are now wasted: paper, grass straw and yard residues.

The lead agency will be the Regional Bioenergy Program management.

Biomass-Derived Liquid Fuels

Activity 10: Technology assessment MSW-to-ethanol

A waste-to-ethanol project will be designed, using biochemical or thermochemical processes. Sponsors will be identified and selected, and a location chosen. The activity will be coordinated with the Solar Energy Research Institute (SERI).

The lead agencies will be the Montana Department of Natural Resources and Conservation and the Washington State Energy Office.

Activity 11: Vegetable-oil fuel demonstration in diesel engines

Vegetable-oil fuel concepts developed at Montana State University and the University of Idaho will be tested on a medium-speed railroad diesel engine, in cooperation with oil producers and researchers. The test will identify critical areas including emissions, engine efficiency, and climatic considerations. Results will be reported to railroad, energy and trucking trade associations.

The lead agency will be the Montana Department of Natural Resources and Conservation.

Municipal Solid Waste Derived Fuels

Activity 12: Energy recovery

Effects of forthcoming changes in EPA new-source standards will be evaluated and reported to known sponsors of energy-recovery projects. A project demonstration will be arranged, based on EPA's provisions for modest-scale conversion

Biomass fuel testing and characterization will be completed, using Oregon State University's unique Biomass Combustion Unit.

of problem wastes such as waste oil and tires. Landfill-gas regulations will be studied and state energy offices will nominate sites and make feasibility studies for demonstrations.

The lead agency will be the Washington State Energy Office.

Activity 13: Public information/education

Information activities of other organizations will be studied for improved ways to provide inform the public about solid-waste management, and an action plan will be prepared.

The lead agency will be the Washington State Energy Office.

Activity 14: Recycling

Model rural recycling programs that have succeeded elsewhere will be studied and demonstrated in a host community. A marketing handbook for local governments and recyclers will be prepared, as will a case-study book on successful rural programs to be a text for a series of workshops. The lead agency will be the Idaho Department of Water Resources.

Activity 15: Legislation

An ongoing information exchange among states and regions will be established to track changes in solid-waste management regulation. State energy offices will follow developments in their jurisdictions, to be shared among the state and regional programs.

Federal regulation will be monitored, as well. The purpose is timely awareness of restrictions, to ensure that the program's positions are represented and considered.

Activity 16: Risk communications

Risk-communication guidelines will be developed for public officials to use in evaluating and discussing environmental risks associated with solid-waste disposal. The guidelines will be distributed in two sets of papers, one for decision-makers presenting the information, and the other for the public evaluating it. The project will be follow recommendations published in *Managing Municipal Solid Waste: A Comparative Risk Analysis of Landfill and Resource Recovery Facilities*, by the Northeast Regional Bioenergy Program.

The lead agency will be the Regional Bioenergy Program management.

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Envirosphere Co.; *Final Report, Regional Logging Residue Supply Curve Project*, Bellevue, WA, August 1986.

Howard, James O.; *Biomass Estimates for Five Western States*, U.S. Forest Service, Pacific Northwest Research Station, Portland, October 1990.

Howard, James O. and Setzer, Theodore S.; *Logging Residue in Southeast Alaska*, U.S. Forest Service, Pacific Northwest Research Station, Portland, February 1988.

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