FEASIBILITY OF GENERATING ELECTRIC POWER FROM FOREST RESIDUE

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by

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Short Reference Abstract:

The general feasibility of generating electric power from logging residue was examined in a preliminary investigation using the Mount Hood National Forest in western Oregon as an example. Raw material supply, restricting regulations, and the interface between forest industries and the power industry are explored. These industries operate in different time frames and different markets, and it is difficult for them to coordinate efforts in producing electricity from wood fuel.

Keywords: Energy, electric power generation, forest residue

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I. SUMMARY AND CONCLUSIONS

The general feasibility of generating electric power from forest logging residue was examined in a case study of a hypothetical situation. Institutional factors--such as the need for a long-term dependable supply of raw material, regulatory aspects, and the way public timber is sold and harvested--were explored. Projected costs and a discussion of environmental factors are presented.

A basic problem of fuel availability is that the amount of logging residue fluctuates from year to year, depending on the amount of logging activity and on market forces for Utility grade (pulp logs) and other cull logs and also on demand for firewood by commercial cutters or by individuals.

The portion of the Mount Hood National Forest tributary to Estacada, Oregon, was selected as the location for a hypothetical case study in an actual area of logging activity. The unutilized 1978 logging residue was estimated sufficient to supply a 25-MW (megawatt) powerplant. By 1980 the pulp industry increased use of Utility grade logs to offset reduced levels of mill residue caused by the housing slump, and the demand for firewood increased sharply. This resulted in nearly total utilization of accessible residue material over 8 inches in diameter on most of the Mount Hood National Forest.

Estimated capital cost[1/] of a 25-MW powerplant would be $47.4 million by 1985, plus $5.9 million for a fuel processing plant and storage yard.

The estimated energy cost[2/] from a 25-MW biomass wood-burning electrical generating plant using forest residue as the fuel has been

1/ Glossary of terms is on page 49

2/ At a 75 percent annual capacity factor calculated for facilities with assumed initial commercial operation dates of 1985, 1990, and 1995 (appendix C). The fuel cost varies from one-third to one-half the total energy cost over the life of the plant. Estimated energy costs for the initial operating year are:

Year of commercial operation	Energy cost for initial year of operation
	Mills per kWh
1985	81
1990	106
1995	138

Several institutional constraints have been identified that create both practical and economic difficulties. Some of these relate to laws and regulations affecting operations of BPA and the USDA Forest Service, others to Federal and State utility regulatory policies.

Long-term assured fuel supply is a major concern in the planning and operation of a powerplant. Investors and regulatory commissions may not readily accept a sustained yield timber harvest as an adequate assurance of fuel supply. It is not clear what additional assurance the timber industry could give.

Additionally, residue from other ownerships and some mills would probably be available within an economic hauling distance of the plant. These sources, as well as the feasibility of constructing a larger plant or several smaller plants, are not covered in this report.

A determination of environmental consequences, as mandated by the National Environmental Policy Act (NEPA) (83 Stat. 852), would be necessary before any proposal for Federal participation could be implemented. Compliance with State and local environmental standards and regulations would be necessary to obtain permits needed for construction and operation of a wood-fired powerplant.

Utilizing forest logging residue will augment land management and provide environmental benefits in addition to electrical energy. For example, there would generally be improved site preparation for regeneration, cleaner ground for future management, reduced fire hazard, and savings from reduced expenditures for slash disposal. On the other hand, adverse effects could include disturbance of soil or wildlife habitat, reduction of nutrient levels, and increased truck traffic on forest roads.

The cogeneration option should be specifically addressed in any new studies of wood energy potential. Cost analyses of cogeneration facilities indicate that electric power energy costs are significantly lower than the energy costs reported in this study.

II. INTRODUCTION

Projections of regional load growth prepared by electric utilities indicate there may be deficits in both peaking capability and ability to meet total electrical loads in the Pacific Northwest over the next 10 years. These deficits will occur if water conditions in the Federal Columbia River Power System are critical or near critical. Since large baseload conventional generation, such as from coal or nuclear fuels, cannot be installed in time to meet these deficits during the 1980's, other near-term resources must be considered. One such alternative is forest logging residue, for which a powerplant could be constructed in from 3 to 5 years.

This report documents the efforts of the Bonneville Power Administration (BPA) and the USDA Forest Service to investigate the feasibility of using forest logging residue (slash) as fuel to generate electricty. For the purpose of this study, the Clackamas River drainage area in the vicinity of Estacada, Oregon, was chosen to illustrate a hypothetical location for a plant that could be fueled largely by residues from a National Forest.

In 1978 the unused logging residue from the Mount Hood National Forest within a 60-mile radius from Estacada was judged sufficient to supply a 25-MW powerplant, but by 1980 nearly all of this material was used either as Utility grade logs for pulp chips or as firewood removed by commercial cutters or individuals under permit for personal use. This rapid turn of events makes it clear that, even though a sufficient amount of residue-type material may be produced, it may be diverted to other uses by market forces. A powerplant enterprise must therefore be prepared to meet price competition from other uses and should probably include plans for additional or standby fuel sources, such as residue from other landownerships, hardwoods, thinnings, brush removal, or mill residue. The Mount Hood National Forest has a large demand for fuelwood because of its location near a large metropolitan area. Supply areas a greater distance from large population centers would have less competition from fuelwood cutters.

Several other areas on National Forests and other ownerships in western Oregon and western Washington produce quantities of logging residue comparable to that on the Mount Hood National Forest. Analysis of fuel supply problems, institutional constraints, and environmental concerns reported in this study will be applicable, for the most part, to other potential plant locations over the entire BPA service area: Oregon, Washington, Idaho, and western Montana.

In these States, the USDA Forest Service currently spends approximately $27 million annually for slash disposal, and in many areas, timber purchasers spend about an equal amount under the terms of timber sale contracts. Increased utilization of residue for energy could reduce, but not completely eliminate, the need for slash burning in some areas.

Using forest residue to generate electrical power would help reduce the volume of slash burned or otherwise treated and would also produce land management benefits. Such benefits include reduced fire hazard, reduced habitat for destructive forest insects, better site preparation for reforestation, improved access for subsequent management, and a favorable effect on air quality from less slash burning.

Benefits of power generation from this source or other new sources include not only the incremental benefit as a strategic supplement to the regional power supply but also first-hand experience in developing this supply source and the logistics necessary for a viable operation.

A 20-percent net overall plant thermal efficiency is based on the wood fuel heat input to the net energy output of the plant with a deduction for all inplant power consumption. An annual capacity factor of 75 percent is used in this report.

III. CONCEPTUALIZED 25-MW PLANT

A. Plant Description. This study conceptualizes a 25-MW plant to derive the capital, fixed annual, operating and maintenance, and total energy costs of a typical biomass wood-burning generating plant. Commonly available "state of the art" commercial equipment has been used for estimates of capital costs.

This 25-MW plant, along with its auxiliary systems and a 60-day processed fuel supply, could be accommodated on a 15-acre plant site, together with a 20-acre log yard and fuel processing site. One factor in site selection is the desirability of being close to additional fuel sources on U.S. Department of the Interior, Bureau of Land Management, State, and private forest lands. This would broaden and diversify the fuel supply base as protection against increasing demands on the National Forests for pulpwood, home firewood, or other products. Other criteria for selecting a site include availability of water, labor force, support services, projected duration of land occupancy, and the various environmental considerations described later in this report.

Chip delivery by belt conveyors to outdoor storage piles and recovery from beneath the piles could be accomplished with conventional systems. The fuel could be screened and oversized material hogged prior to its introduction into the boiler.

The wood-fired boiler, turbine generator, and auxiliary systems considered in this study are essentially of standard design. Turbines in a power generating plant are generally the condensing type, exhausting to 3 inches of mercury back pressure, with suitable extraction points for driving auxiliary mechanical equipment.

Capital cost estimates are based on the assumption that particulates in stack gas will be removed in a two-stage, multicyclone collector, followed by a low-energy wet scrubber. Cooling water from the turbine exhaust steam condenser could be circulated through a cooling tower or cooling ponds. Ash is assumed to be handled by wet collection from the boiler grate, multicyclones, and wet scrubber. After it is dewatered, the slurry will contain about 75 percent solids. The resultant wood ash or char may be a marketable byproduct of the process. Without such a market it would be hauled to an approved land fill area. Cooling tower blowdown of about 1 percent prevents buildup of solids in the circulating water, and can normally be discharged with minimal treatment. Amounts of SO_2 would be negligible, and equipment for removal of such material should not be necessary.

Any subsequent studies relating to specific locations should also examine the feasibility of 5 or 10-MW plants located closer to the logging activity to reduce the distance for residue to be transported. Although operations of a small plant may be affected by adverse weather in remote locations, smaller generating plants have the advantage of not requiring as much land area at any one location. The fuel storage area for smaller plants can be reduced in proportion to fuel consumption, but only moderate reductions in other space requirements would be necessary. On balance, economies of scale would probably favor the larger 25-MW plant. The actual design and size of a plant and its supporting fuel processing system recommended for any particular location would depend on a more detailed engineering study based on data for a specific site.

B. Capital Costs and Annual Operating and Maintenance Costs. The estimated construction costs based on 1978 dollars for three plants of different sizes range from $24,773,000 for a 25-MW plant to $9,826,300 for a 5-MW plant. Construction cost estimates, based on data prepared by Schuchart & Associates, Inc., Seattle, Washington, are contained in table 1 (appendix A).

The payroll for the operation of a 25-MW plant is estimated at $1,040,000 per year, based on 1978 dollars and assuming $40,000 per person per-year for wages, payroll taxes, insurance, and other payroll related costs. The payroll cost for the smaller plants is not expected to be reduced significantly. Annual maintenance and supply costs, based on 1978 dollars, are estimated at 2 percent of the capital investment, or $495,000 for the 25-MW plant and $196,500 for the 5-MW plant.

C. Institutional Constraints. These constraints are primarily regulatory or related to financial arrangements for funding construction of the facility. If a generating plant were constructed and operated by an electric utility, all the regulatory requirements of that industry would apply.

1. Public regulations, assured fuel supply, and transmission lines. Electric utilities must have their proposed generating plants approved by appropriate Federal, State, and county agencies. These approvals may be difficult to obtain if the utility does not have an assured fuel supply or if the lack of long-term fuel contracts reduces the term of the financing and thus increases the project's unit energy costs. Moreover, a utility must have legal access to transmission line rights-of-way over the land it occupies or crosses. If transmission lines cannot be constructed, no plant can be considered, no matter how desirable.

2. High cost power in disfavor. Regulatory agencies would probably not allow generation costs higher than acceptable alternatives into a private utility's rate base as a regular procedure since this is contrary to their purpose of protecting the consumer. Public agencies would not plan to construct a generating plant or purchase power from a plant constructed by others unless the cost of the energy were equal to, or less than, the cost of energy from other sources. If there is a lack of an assured long-term fuel supply, the length of the financing normally available to a private utility or a public agency could be substantially reduced. Any reduction in the term of financing would adversely affect the unit cost of energy. Public agencies and private utilities will plan to acquire energy from generating facilities that have the lowest energy cost providing that other requirements, such as environmental acceptability, are met.

D. Environmental Considerations. To comply with NEPA requirements and State and local environmental standards and regulations, an environmental analysis would be required. Considerations necessary for environmental assessment include:

1. Air quality. All powerplants in Oregon must meet State and Federal air pollution requirements, including those limiting the emissions of particulates, sulfur compounds, and other pollutants. In addition, the plant must be shown not to cause degradation of existing air quality beyond the applicable "prevention of significant deterioration" limits. Preconstruction monitoring for baseline data and postconstruction monitoring and reporting of factors relating to air quality may be required by the State Department of Environmental Quality. Research in the following areas would be required to comply with the existing regulations: meteorology, appropriate air pollution control devices, predictive dispersion modeling, and ecological effects of changes in air quality.

2. Water quality and consumption. Permits dealing with water rights, consumptive versus nonconsumptive uses, and quantity of water needed would be required for the use of water for cooling, scrubber operation, boiler feedwater, and for the discharge of water from the plant. Discharge of water to sewers would require permission from the local agency providing this service. Water quality standards limit the quantity of pollutants that can be discharged to a body of water, but in Oregon, the requirement that "highest and best" control technology be applied would probably preclude any discharge of water from the plant to surface waters. This would require water to be treated instead and recirculated within the plant. The cost data in this report include water treatment. Predictive analysis in the following areas is needed to comply with existing laws and regulations: aquifer depletion, seepage from plant sources, characterization of water that is withdrawn or discharged, and any potential erosion.

3. Noise. The plant would be required to meet noise standards established by the State Department of Environmental Quality. Existing and predicted noise levels must be analyzed and corrective measures recommended.

4. Solid waste. If an approved disposal site nearby is available and suitable to handle the wastes produced, it may be used. If a separate waste disposal site is required, a permit must be obtained. Special consideration would relate to any possible toxicity of the waste and the potential for leaching, drainage, and flooding at the waste disposal site. If the waste is classified as hazardous, much more stringent requirements are imposed. Monitoring wells may be required to ensure that any leaching can be detected. Before a permit can be issued for disposal of solid waste, a geological survey of the site must be performed and predicted losses from leaching and wind analyzed. Measures to limit these losses must be planned.

5. Land use. The plant would be required to comply with local and State land use plans and ordinances or to obtain appropriate variances. In addition, the plant must comply with land use goals in the particular State's land use laws, which include preservation of forest, recreational, historic, scenic, and agricultural lands.

6. Impact of transmission lines. Any new transmission lines from scattered small plants in the National Forests could have an undesirable impact on the local environment. If the site is closer to an electrical load center, the environmental impact and transmission line costs would be less.

7. Socioeconomic impacts. The social and economic impacts of the plant must be assessed in terms of employment, taxes, housing, transportation, and community services, such as schools, health care, and police and fire protection.

IV. FUEL SUPPLY LOGISTICS

A. Residue Volumes, Harvesting Methods, and Costs. Estimates were made of available logging residue from the Clackamas, Estacada, and Zigzag Ranger Districts, and portions of Columbia Gorge and Bear Springs Ranger Districts, which are all tributary to Estacada (appendix B, table 2). For the purpose of this example, it is assumed that yarding of unutilized material (YUM) would be required on all clearcut areas and on 60 percent of partial cut and salvage areas.

Volumes were estimated for two size classes of residue: material at least 8 inches in diameter by 10 feet long, and material 3 to 8 inches in diameter by 6 or more feet in length. Annual available logging residue in the study area after other uses are discounted is 173,000 oven-dry tons in the larger size class and 22,000 tons in the smaller. The 173,000 tons alone would provide sufficient fuel for a 25-MW plant.

The larger residue pieces would be yarded with the yarding equipment used for the merchantable logs. This feature of timber sales is commonly called YUM yarding. This larger material can be hauled in standard log trucks or in short truck and trailer (mule train) combinations. Small pieces of residue would come out in a separate relogging operation, using smaller, mobile equipment that generally has a shorter reach or operating radius than equipment used in the main logging. These smaller pieces would be more costly to load and haul, either in log form or as chips from mobile chippers located at the landing.

Much of the larger residue is presently yarded to the roadside landing as a required measure for managing slash and its yarding would not be chargeable to power generation costs. Any cost of yarding the smaller material, however, would have to be borne by the power generation operation or other interests benefiting from its removal and use.

Other possible fuel sources include residue from lumber and plywood mills and salvage material or residue other than from logging--from either the National Forest or from other ownerships. The latter could include thinnings, hardwoods, scattered mortality, or material from land-clearing operations. These could be especially important during the winter when operations on the National Forest are curtailed.

The cost of forest residue delivered to Estacada and processed into pulpwood-size chips or hogged fuel, as developed in this study, would be from $23 to $51 per ovendry ton, 1978 prices (appendix B, table 6). These costs are based on an average hauling distance of 45 miles.

B. Institutional Constraints.

1. Competing uses of residue material. There is a high degree of uncertainty regarding the availability of residue volumes, discussed in the preceding section, for power generation. The pulp industry is the major industrial competitor for low grade logs not meeting specifications for lumber or plywood use. Historically, when sufficient mill residue exists, relatively few Utility grade logs come to market and most are left as logging residue. When the volume of mill residue declines, however, such as during a slump in housing construction, more Utility grade logs are used. Utility grade or cull logs are used by other forest industries and some are exported. Increasing competition for such logs would have to be met continually by the power industry as markets change.

In addition, the demand for home firewood has increased sharply in the last 3 years, especially on the Mount Hood National Forest. On the more accessible portions of this Forest, nearly all suitable logging residue is currently being removed for firewood, either by commercial firewood cutters or by individuals for home use.

Mill residue, on the other hand, is generally a lower cost raw material than logging residue; and the power industry itself might logically seek to use a maximum of mill residue in lieu of logging residue. In some cases, this could put the power industry in direct competition for hogged fuel used in the forest product industry.

All things considered, the forest industries would probably welcome the power industry as a partner but could be hostile if the power industry were seen only as a competitor. Moreover, active participation in generating electric power by the forest industries to provide firm power as a portion of the regional power supply could add a major new dimension to integrated forest industries and the structure of their timber harvesting operations.

2. No guarantee of long-term timber supply. Usually the USDA Forest Service sells timber in individual sales with a 2 to 5-year cutting period. The forest industries have preferred competitive sales rather than timber allocation and have adjusted to what is often an extremely competitive situation. Their long-term assurance of supply comes from the Forest Service's legal requirement for sustained yield, with a steady supply of timber sales competitively available.

3. Disposal of logging residue. Timber sales on the National Forests presently take the form of stumpage sales, giving the purchaser the right to cut and remove designated timber. Logging residue is a joint product, produced with the material that is removed and used. It may also contain dead and down material that existed before logging. The margin of what is economic for the forest industries to remove and utilize may change rapidly, especially for Utility grade or other cull logs that might be suitable for energy use. The USDA Forest Service does not conduct commercial logging operations, nor does it operate sorting yards from which various classes of material could be sold to different parties.

The forest industries that purchase National Forest timber would probably welcome a market for "energy wood" but, in all likelihood, would want to control the logging and sorting of all timber on their sale areas, seeking the best market at any given time for various classes of material.

Accurate identification of Utility grade or cull logs would require a qualified log scaler to inspect each log. This can create scaling problems for logs in the middle of a truckload of mixed grade logs, or for borderline logs whose grade and best use is not certain to the loader operator.

The initial timber purchaser has first rights to the logging residue created. Under present practice, substandard material on clearcut areas may be removed by the purchaser in any amount without charge, subject to agreement on deposits for road maintenance and use. This is an incentive to encourage greater utilization of material on west-side sales. Utility grade logs are generally included in timber sales on a lump sum basis, which means, in effect, that the timber purchaser has paid for such material and has a contractual right to remove it until the expiration date of the sale.

4. <u>Removal of residue</u>. The USDA Forest Service usually does not require removal of logging residue nor Utility grade logs or hardwoods from the sale area if there is no market for such material. Although the Forest Service can require removal of unutilized material to a stockpiling or sorting area on the National Forest, it generally lacks suitably developed sites and the workers and other resources needed to operate a sorting yard.

Generally speaking, the Forest Service utilization policy states that the total appraised stumpage value of a timber tract will not be reduced to obtain utilization of a species, size, or class of material (Forest Service Manual, Section 2403.25). This means that total appraised stumpage value in a timber sale will not be reduced to offset the extra costs of removing residue material that costs more to remove than it is worth.

5. Slash disposal. Deposits are generally required from timber purchasers to pay the cost to the USDA Forest Service for slash disposal beyond the amount accomplished by timber purchasers. Burning, piling, or other physical treatment are generally the most cost-effective methods of slash disposal.

In theory, the required deposits for slash disposal could be reduced or eliminated to the extent that treatment would not be required. This could give incentive for removal of residue. It would be difficult, however, to specify how much additional residue would have to be removed to reduce treatment needs by a given amount and to measure for compliance.

C. Environmental Considerations.

1. Beneficial effects of residue removal. A number of benefits result from removing logging residue from the forest because management practices are better when the forest is cleaned up after logging operations:

a. After the larger material has been removed, the resulting lighter burn will be less costly and less likely to cause soil damage than a heavier burn, since burning time and soil temperature will be reduced.

b. Slash fires will create less smoke after residue is removed, because there will be less material consumed. Also, burning can be done when it might not otherwise be possible if the large residue material were still on the ground. Thus, burning for site preparation followed by prompt reforestation could occur in the same season as the main logging.

c. Reforestation is benefited since more planting or seeding spots will be available. Planting access will be improved. Future thinning and management of the new stand will benefit from improved access for workers and equipment if large residue material is removed.

d. Aesthetic appearance can be enhanced by removal of the residue material, thus eliminating an appearance of waste and contributing instead to a visual impression of careful management and stewardship.

e. Stream protection can be enhanced by removal of large logs and debris that might otherwise clog stream channels causing potential erosion or washouts.

2. Adverse effects of residue removal. There appear to be no major disadvantages from removal of larger residues from the forest. The desired level of residue to be achieved on each area can be specified in presale interdisciplinary planning to consider the various resources involved and their needs. Minor adverse effects, however, might include the following:

a. Excessive soil disturbance can occur on steep, fragile soils or heavy, wet soils, and tractor yarding on wet ground can result in undesirable soil compaction.

b. Removal of residue could have an adverse effect on wildlife habitat if all snags and large material were eliminated. Also, winter operations might disturb big game animals on critical winter range. Present policy is to maintain habitat diversity adequate for a stable population of wildlife.

c. Nutrient recycling can be interrupted if too much residue is removed. Nutrients are concentrated in the foliage and branches; only a small amount is in the main stem of the tree. Leaving the tops and material under 3 inches in diameter should adequately provide for most nutrient recycling.

d. Hauling of residue would add to the truck traffic on the Clackamas River highway and its feeder roads. A 25-MW powerplant would require about 50 truckloads of wood fuel every day. Hauling on weekdays only during the logging season could mean up to 90 loads per day. Existing traffic is now about 200 truckloads per day.

V. ENERGY COSTS

Estimates of cost for electric power from a 25-MW generating plant using forest residue as the fuel have been developed for each year of a 30-year operating life. These costs include annual fixed and variable production costs. They represent cost of producing electricity at the plant; they do not include transmission and distribution costs.

Estimated costs for generating plants with initial operation dates of 1985, 1990, and 1995 are as follows:

Year of initial operation and capacity factor	Plant capital cost	Production Costs		
		Fixed	Variable	Total
	Dollars/kW	--Mills/kWh--		
1985:				
65 percent[3/]	1896	57	31	88
75 percent	1896	51	30	81
1990:				
75 percent	2404	66	40	106
1995:				
75 percent	3052	84	54	138

Detailed annual costs (as of 1978) and data for the life of the facility are given in appendix C.

3/ A 65 percent capacity factor for a plant coming on line in 1985 is shown for comparison.

Fixed annual costs included principal and interest payments on borrowed capital, equipment replacements, insurance, fixed operation and maintenance costs, administrative and general costs, and taxes (or in lieu of tax payments) on the fixed cost items. The variable production costs include fuel costs, variable operation and maintenance costs, and taxes (or in lieu of tax payments) on the variable cost items.

The plant model represents a hypothetical project financed, constructed, and operated by an Oregon public agency. All necessary capital is assumed to come from 30-year tax-exempt revenue bonds at 7.25-percent interest. All projects are assumed to be designed for baseload operation.

One of the major concerns to the utilities is the possibility that the usual 30-year financing might not be available because of the apparent lack of an assured long-term fuel supply. The following tabulation depicts comparative energy costs for a 1985 plant with a 75 percent capacity factor for the 1st year of operation under different financing periods:

Costs	10-year financing	20-year financing	30-year financing
	- - - -	Mills per kWh	- - - -
Fixed	70	55	51
Variable	30	30	30
Total	100	85	81

It is assumed that the heating value of dry wood is 8500 Btu/lb; the capacity factor for the plant is 75-percent; and a 20-percent net overall plant thermal efficiency can be obtained based on the wood fuel heat input to the net output of the plant with a deduction for all inplant power consumption.

Capital cost estimates include escalation to the assumed date of commercial operation. Annual operating costs, including equipment replacement, insurance, administrative and general, and operation and maintenance, were escalated according to the following schedule, recognizing that estimates of net inflation rates are uncertain:

	Percent
1977-80	6.0
1981-85	7.0
1986-95	5.0
After 1995	4.0

The capital cost estimates for the 25-MW wood-fired plant, based on 1978 dollars, are discussed under "Conceptualized 25-MW Plant." Capital costs were developed for a 5-year planning and construction period. These costs are escalated to their date of expenditure. The accumulation of expenditures over the 5-year period, plus interest during construction, yields the total current capital cost as of the date the plant is placed in commercial operation. The current capital cost is estimated to be $1896/kW in 1985, rising to $3052/kW by 1995.

VI. FURTHER EFFORT REQUIRED

A. Better Cost Information. All the cost data developed in this study are best estimates--not from actual experience of using forest logging residue as fuel. Additional work is required to refine the cost estimates, particularly for the variable production costs. These variable costs will be affected by fuel costs (collecting, transporting, chipping, and stumpage if applicable), overall plant efficiency, and operation and maintenance costs for the emission control equipment.

B. Cost Data For Near-Term Alternative Energy Sources. Since the Pacific Northwest utilities have projected energy deficits for each year to 1990 the region needs to compare wood-fired generation of electrical power with other near-term energy sources that are commercially viable during the 1980's. Better information is needed on the costs of these other sources.

C. Net Energy Balance. The amount of energy used in harvesting and converting forest residue to a usable fuel for an electrical generating plant should be determined and compared with the amount and value of energy produced. For example, would society be better off using the energy input directly to meet the demand for other uses, rather than converting to electricity through harvesting and burning of forest residue? One source states that the energy consumed in timber harvesting in the West averages 0.58 million Btu per dry ton, compared with a gross heat value of 17.7 million Btu per dry ton.[4/]

This estimate of energy consumed in timber harvesting refers to regular log harvest; the energy expended to harvest logging residue would certainly be greater. The total energy used in collecting, transporting, processing, and converting residue to electricty should be specifically examined and compared with the net energy produced.

D. Fuel Supply. Several constraints that limit the USDA Forest Service from making logging residue available for a demonstration project have been identified in section IV, "Fuel Supply Logistics." Some of the conflicts with other uses can be mitigated or reduced by existing laws, policies, and procedures. Other constraints identified could be overcome with new laws, regulations, and policies.

4/ John A. Bergvall, Loren Gee, and William Koss, 1978. Wood Waste for Energy Study, Inventory Assessment and Economic Analysis. Wash. Dep. Nat. Resour., Olympia. 193 p.

On timber sales presently covered by contracts between the purchaser and the USDA Forest Service, the purchaser has control and priority use of all wood in the sale until voluntarily released or until the sale is terminated. In such cases, negotiation with the purchaser may be the only way to make the logging residue available.

A power company or power agency contemplating building a wood-fueled powerplant may be able to find a long-term dependable fuel supply by negotiating with a few well-established purchasers of National Forest timber for a major portion of powerplant needs and supplementing the supply by short-term contracts with smaller suppliers.

The USDA Forest Service may need new authority to require removal of logging residue to a specified off-forest site. Operation of a storage area or sorting yard for residue may require additional personnel and appropriated funds. Thorough analysis of the feasibility of such an operation is needed. Perhaps private entrepreneurs could be encouraged to operate such a facility on a commercial basis or by contract with the Forest Service. The Forest Service should continue to examine other possible benefits that could accrue to the land, water, and air resources by removal of this residue.

The multibenefit concept needs further investigation to explore whether the value of land management or environmental benefits might be taken into account to help offset the costs of collecting, transporting, and preparing forest residue. Examples of the various benefits are less smoke from reduced volume of slash burned, reduction of wildfire hazard and insect infestation, more rapid reforestation, and improved ground access for workers and equipment.

It is unrealistic to think that, in a free economy where market costs and prices determine resource allocation, the total cost of residue removal and transportation to an energy plant should be borne by the logging and land management operation. Some further incentives for removal must come from a reasonable price which an energy plant is willing to pay for raw material. Investment credits or other tax advantages may be needed.

Collecting and hauling large volumes of residue may conflict with other established land uses, especially roads used by timber sale purchasers and recreationists. In some cases, agreements covering reconstruction, maintenance, hauling restrictions, and administration costs of roads will need to be examined and perhaps modified.

E. Conceptualizing the Powerplant. A closer examination is needed to evaluate possible plant sites and to determine optimum plant size; i.e., a single large plant or several smaller plants located closer to logging areas. Firewood cutting has increased on the Mount Hood National Forest, and it may be desirable to consider plant locations farther from large metropolitan areas.

The various combinations of prospective ownership of generation plants and the fuel supply facilities must be evaluated. Some examples are: (1) electric utility owning both, (2) forest products industry owning both, (3) electric utility owning plant and forest industry owning fuel, or (4) a combination of electric utility, forest products industry and government. The electric utility could be investor owned, publicly owned, a cooperative, or under joint ownership.

F. Cogeneration. The opportunity to utilize cogeneration as an alternative to a full condensing steam turbine powered electrical generation plant has some definite advantages. These are most evident in the forest industry; however, cogeneration reduces the electrical generating output to 30 to 50-percent of a full condensing turbine, even though the thermal efficiency is two to three times greater.

The forest industry, by its very nature, lends itself well to cogeneration and small power production--cogeneration because of the need for various forms of process steam and small power production because of the forest industry's close involvement with a potential fuel supply. Forest residue could be brought in as part of regular logging operations, and in a sawmill operation the mill residue (hogged fuel) could be used. If a cogeneration facility were part of the plant, costs would be lower for shop and yard equipment, labor, utilities, and overhead expenses.

For cogeneration to be truly viable, however, the cogenerating forest industry would require a dependable market for both the electric power and steam, at a price sufficient to cover its cost. The participating power industry, which markets the power would in turn require a dependable supply of power at a reasonable cost compared with power from alternative sources. Also, there would need to be sufficient demand for process steam.

G. Public Participation. Finally, public participation should be a specific element of the planning process in any definite proposal for a given area. This includes a consideration of alternatives and a review of environmental and economic impacts on the community and surrounding area.

APPENDIX A

Table 1--Capital cost estimates for construction of wood-fired plant[1/]
(Based on '78 Dollars)

ITEM	25 MEGAWATT	10 MEGAWATT	5 MEGAWATT
		($ x 1000) --- Thousand dollars---	
FUEL HANDLING FACILITIES Truck dumps, screening, hogs, conveyors, stacker, reclaimer, rolling stock	2,969.4	1,719.9	1,131.9
BOILER Furnace, grates, fans, auxiliary burner, feedwater pumps, continuous chemical feed	6,060.0	3,510.0	2,310.0
FEED WATER TREATMENT Pumps, filters, demineralizer, deaerator, blowdown exchanger condensate polish	363.6	210.6	138.6
ASH HANDLING FACILITIES Collection hopper, crusher, eductors, dewatering, settling tank	686.8	397.8	261.8
TURBINE-GENERATOR Condensing turbine-generator extraction ports, lube oil system, primary switchgear, unit substation, step-up transformer, controls	6,120.6	3,545.1	2,333.1
HEAT REJECTION EQUIPMENT Condenser, cooling tower, circulating pumps, hot well pumps	929.2	538.2	354.2
EMISSION CONTROL Mechanical, collector, venturi, scrubber, recirculating pumps	282.8	163.8	107.8
LAND and BUILDING[2/] Land, scale house, maintenance building, garage, boiler house, turbine room, foundations	2,787.6	1,614.6	1,062.6
TOTAL COST for PLANT and EQUIPMENT (A) Equipment, building foundations, installation. includes construction, administrative, and markup	20,200.0	11,700.0	7,700.0
ENGINEERING (B) At 8, 10, and 12.5 percent, of item A above	1,616.0	1,170.0	962.5
FREIGHT (C) at 5-percent on material (approximately 50-percent of item A above)	505.0	293.5	193.5
SPARE PARTS (D) at 2-percent on material (approximately 50-percent of item A above)	202.0	117.0	77.0
CONTINGENCY 10-percent on A, B, C, D above	2,250.0	1,328.0	893.3
TOTAL (excluding IDC)[3/]	24,773.0	14,608.5	9,826.1

1/ Figures taken from Rocket Research Company's "Prefeasibility Study for 5-MW, 10-MW, and 25-MW Wastewood Burning Electric Power Generating Facilities," November 15, 1978 (prepared by Schuchart & Associates, Inc., Seattle, Washington)

2/ If this project is built by the Federal Government and located on USDA Forest Service land, the cost of the land would be deducted.

3/ IDC is interest during construction which is a variable depending on ownership and method of financing.

APPENDIX B--Fuel inventory and costs

Table 2--Estimate of 1978 logging residue on Mount Hood National Forest tributary to Estacada, Oregon 1/

Ranger District and type of cut	Large residue 8" X 10' and larger 2/		Small residue 3"-8" X 6' and longer		Total
	Old growth	Second growth 3/	Old growth	Second growth 3/	All ages
	Thousand ovendry tons				
Glackamas:					
Glearcut	107	--	13	--	120
Partial cut	14	--	2	--	16
Salvage	2	1	4/	4/	3
Total	123	1	15	--	139
Estacada:					
Glearcut	49	7	5	1	62
Partial cut	30	10	5	2	47
Salvage	3	1	1	4/	5
Total	82	18	11	3	114
Zigzag:					
Glearcut	25	--	3	--	28
Partial cut	--	4/	--	4/	4/
Salvage	--	--	--	--	--
Total	25	--	3	--	28
Golumbia Gorge:					
Glearcut	--	--	--	--	--
Partial cut	--	--	--	--	--
Salvage	13	1	1	4/	15
Total	13	1	1	4/	15
Bear Springs:					
Glearcut	15	--	2	--	17
Partial cut	11	--	2	--	13
Salvage	--	--	--	--	--
Total	26	--	4	--	30
Grand Total	269	20	34	3	326

1/ Includes all of Glackamas, Estacada, and Zigzag Ranger Districts, one-third of Golumbia Gorge Ranger District, and one-half of Bear Springs Ranger District, with assumption that residue pieces 8 inches x 10 feet and larger would be yarded to the landing on all clearcut areas and on 60 percent of partial cut and salvage areas. Smaller residue pieces down to 3 inches in diameter and to 6 feet in length are included in the estimate, unyarded, for 50 percent of all cutting areas. Estimates include only yardable material that can be brought to the landing.
2/ Standard specifications for required yarding of unutilized material.
3/ Timber under 140 years of age.
4/ Less than 500 overdry tons.

Table 3--Costs of high lead yarding plus loading and hauling for removal of residue material 8 inches by 10 feet and larger, 1978[1/]

Item	Residue removal cost: Dollars per thousand board feet, gross. Scribner log scale	Dollars per green ton[2/]	Dollars per ovendry ton[3/]
High-lead yarding	14.60	2.92	5.31
Depreciation	2.30	.46	.84
Logging overhead	6.00	1.20	2.18
Fire protection	.40	.08	.15
Equipment move-in	.85	.17	.31
Total	24.15	4.83	8.79
Loading[4/]	9.70	1.94	3.53
Hauling, average 45 miles[5/]	24.70	4.94	8.99
Total	58.55	11.71	21.31

1/ Yarding costs developed from USDA Forest Service, Pacific Northwest Region Timber Appraisal Handbook; loading and hauling costs are estimated. Data may not add to totals due to rounding.

2/ At 10,000 pounds, or 5 green tons per thousand board feet, Scribner scale.

3/ At factor 1.82 for 45-percent moisture content, wet basis.

4/ Based on $350 per day for 8 loads at 4,500 board feet or 22.5 green tons per load.

5/ Based on $250 per truck per day for 2.25 loads per day, at 4,500 board feet or 22.5 green tons per load.

Table 4--Costs of tractor yarding plus loading and hauling for removal of residue material 8 inches by 10 feet and larger, 1978[1/]

Item	Dollars per thousand board feet, gross. Scribner log scale	Dollars per green ton[2/]	Dollars per ovendry ton[3/]
Tractor yarding	8.45	1.69	3.08
Depreciation	1.75	.35	.64
Logging overhead	6.20	1.24	2.26
Fire protection	.45	.09	.16
Equipment move-in	.60	.12	.22
Total	17.45	3.49	6.06
Loading[4/]	9.70	1.94	3.53
Hauling, average 45 miles[5/]	24.70	4.94	8.99
Total	51.85	10.37	18.58

1/ Yarding costs developed from USDA Forest Service, Pacific Northwest Region Timber Appraisal Handbook; loading and hauling costs are estimates. Data may not add to totals due to rounding.

2/ At 10,000 pounds, or 5 green tons per thousand board feet, Scribner scale.

3/ At factor 1.82 for 45-percent moisture content, wet basis.

4/ Based on $350 per day for 8 loads at 4,500 board feet or 22.5 green tons per load.

5/ Based on $250 per truck per day for 2.25 loads per day, at 4,500 board feet or 22.5 green tons per load.

Table 5--Costs for processing forest residue, 1978

Item	Annual cost	Cost per day[1]	Cost per ovendry ton[2]
	- - - - - - - - - -	Dollars	- - - - - - - - - -
Whole-log chip mill:[3]			
Fixed costs--			
Amortization and Interest	330,480		
Insurance, 0.35-percent of initial investment	14,000		
Taxes, 1.25-percent of initial investment	50,000		
Repairs and maintenance, 2-percent of initial investment	80,000		
Land lease, 20 acres at $700 per acre per year	14,000		
Total	488,480	2,079	
Operating costs--			
Electricity, 25,000 kWh/day at 10 mills/kWh		250	
Fuel for mobile equipment (estimated)		130	
Labor, 6 persons at $13 per hour $6 per hour payroll overhead		624	
Direct supervision, 15-percent of labor costs		94	
Total		1,098	
Total for whole-log chip mill		3,177	10.31
Mobile chipper[4]			15.46

1/ At 235 operating days per year.

2/ At 35 200-cubic foot units per hour or 308 ovendry tons per day.

3/ Consisting of large and small ring debarker, large capacity disk or drum chipper, hog mill, storage area for logs and chips, plus equipment for loading, unloading, and materials handling. Initial cost of chip mill is estimated at $4 million, to be amortized over 30 years at 7.25-percent interest.

4/ Estimated at 1.5 x cost for whole log chip mill

Table 6--Total cost of forest residue fuel for electric power generation, 1978.

Item	Large residue, 8" x 10' and larger	Small residue, 3"-8" x 6' and longer
	YUM yarded1/	Unyarded2/
	- - Dollars per ovendry ton - -	
High-lead yarding:		
Yarding	--	17.58
Loading	3.53	7.06
Hauling, average 45 miles	8.99	10.79
Fuel processing--		
By chip mill	10.31	--
By mobile chipper	--	15.46
	22.83	50.89
Tractor yarding:		
Yarding	--	12.12
Loading	3.53	7.06
Hauling, average 45 miles	8.99	10.79
Fuel processing--		
By chip mill	10.31	--
By mobile chipper	--	15.46
	22.83	45.43
Equivalent fuel cost:	- - - Mills per kWh3/ - - -	
High-lead yarding	23	51
Tractor yarding	23	46

1/ YUM = yarding of unutilized material.

2/ For small residue, yarding and loading costs are estimated at 2.0 x cost for large residue; hauling cost is estimated at 1.2 x cost for large residue.

3/ Based on 8,500 Btu per ovendry pound or 17 million Btu per ovendry ton of wood, at 20-percent net energy efficiency of steam and electric power generation, and 3,413 net Btu per kWh.

APPENDIX C

CASE 1 ELECTRICAL ENERGY COST FOR A 25-MW WOOD-FIRED PLANT

1985--YEAR OF INITIAL COMMERCIAL OPERATION

75-PERCENT CAPACITY FACTOR

Bonneville Power Administration--Thermal Power Branch

General Information:
This program estimates the cost of energy for a 25-MW wood residue powerplant, 100 percent of which is owned by a typical but undefined public agency.

Assumptions:

1. Capital Requirements, 1985 in-service date:

A)	Direct construction cost	$28,200,000
B)	Indirect construction cost	11,300,000
C)	Interest during construction	7,300,000
D)	Initial fuel	600,000
E)	Total plant investment	47,400,000

2. Variable fuel cost (mills/kWh):

Year	1985	1990	1995	2000	2005	2010	2014
Value	26.2	35.1	46.9	62.8	84.0	112.4	142.0

3. Financing rates:

A)	Capital 30-year bonds issued at	7.250 percent
B)	Fixed cost of fuel inventory 5-year bonds issued at	7.250 percent
C)	Interest on reinvesting reserves	7.000 percent

4. Escalation rates for A) operation and maintenance, B) interim replacements, C) insurance, and D) administrative and general costs:

Time Period	1977-80	1981-85	1986-95	1996-2050
Rate	6 percent	7 percent	5 percent	4 percent

5. Project operating data:
   - A) Designed for baseload operation
   - B) Annual capacity factor--75 percent
   - C) Amortized plant line--30 years

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Case 1 (Continued)

WOOD RESIDUE POWERPLANT

PUBLIC AGENCY ANNUAL ENERGY COST

Operating Years	1	10	20	30
General Information				
1 Percentage ownership, public	100	100	100	100
2 Date of commerical operation	12/01/85	12/01/85	12/01/85	12/01/85
3 Net plant capacity (MW)	25	25	25	25
4 Net capacity (MW) to public	25	25	25	25
5 Annual capacity factor (percent)	75	75	75	75
6 Annual generation public (million kWh)	164.2	164.2	164.2	164.2
7 Finance rate (percent), public	7.25	7.25	7.25	7.25
8 Variable fuel rate (mills/kWh)	26.2	44.3	79.3	142.0
9 Fixed cost on fuel inventory (mills/kWh)	8.5	8.5	8.5	8.5
Capital Cost (Million Dollars)				
10 Direct construction cost	28.2	28.2	28.2	28.2
11 Total plant investment	47.4	47.4	47.4	47.4
Fixed Annual Costs ($1,000/Yr)				
12 Interest and amortization	3,916.2	3,916.2	3,916.2	2,224.0
13 Interim replacements	99.0	153.6	229.5	339.8
14 Insurance	101.0	156.7	234.2	346.6
15 Operation and maintenance	2,029.8	3,148.8	4,705.9	6,965.8
16 Administration and general	496.4	770.1	1,150.9	1,703.6
17 Fixed annual taxes	456.8	541.0	658.1	726.7
18 Fixed cost on fuel inventory	1,396.1	1,396.1	1,396.1	1,396.1
19 Subtotal (12-18)	8,495.3	10,082.5	12,290.8	13,702.6
Variable Production Costs ($1,000/Yr)				
20 Fuel expenditure	4,303.3	7,270.4	13,020.2	23,317.2
21 Operation and maintenance	390.8	606.3	906.1	1,341.2
22 In lieu of property tax	262.9	441.1	779.9	1,380.9
23 Subtotal (20-22)	4,957.0	8,317.8	14,706.2	26,039.3
Credits Toward Project ($1,000/Yr)				
24 Interest earnings on reserves	118.5	118.5	118.5	0.0
Total Annual Bus Bar Energy Cost				
$1,000/Yr	13,333.8	18,281.8	26,878.5	39,741.9
Mills/kWh	81.2	111.3	163.6	242.0

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Case 1 (Continued)

WOOD RESIDUE POWERPLANT

SUMMARY REPORT

	Fixed Cost		Variable Production Cost		Total Annual Cost	
Yr	$1000/Yr	Mills/kWh	$1000/Yr	Mills/kWh	$1000/Yr	Mills/kWh
1985	8,376.8	51.0	4,957.0	30.2	13,333.8	81.2
1990	9,172.2	55.8	6,608.1	40.2	15,780.3	96.1
1995	10,187.3	62.0	8,810.5	53.6	18,997.8	115.7
2000	11,203.8	68.2	11,708.7	71.3	22,911.9	139.5
2005	12,439.3	75.7	15,569.4	94.8	28,008.7	170.5
2010	13,943.2	84.9	20,714.4	126.1	34,657.6	211.0
2014	13,702.6	83.4	26,039.3	158.5	39,741.9	242.0

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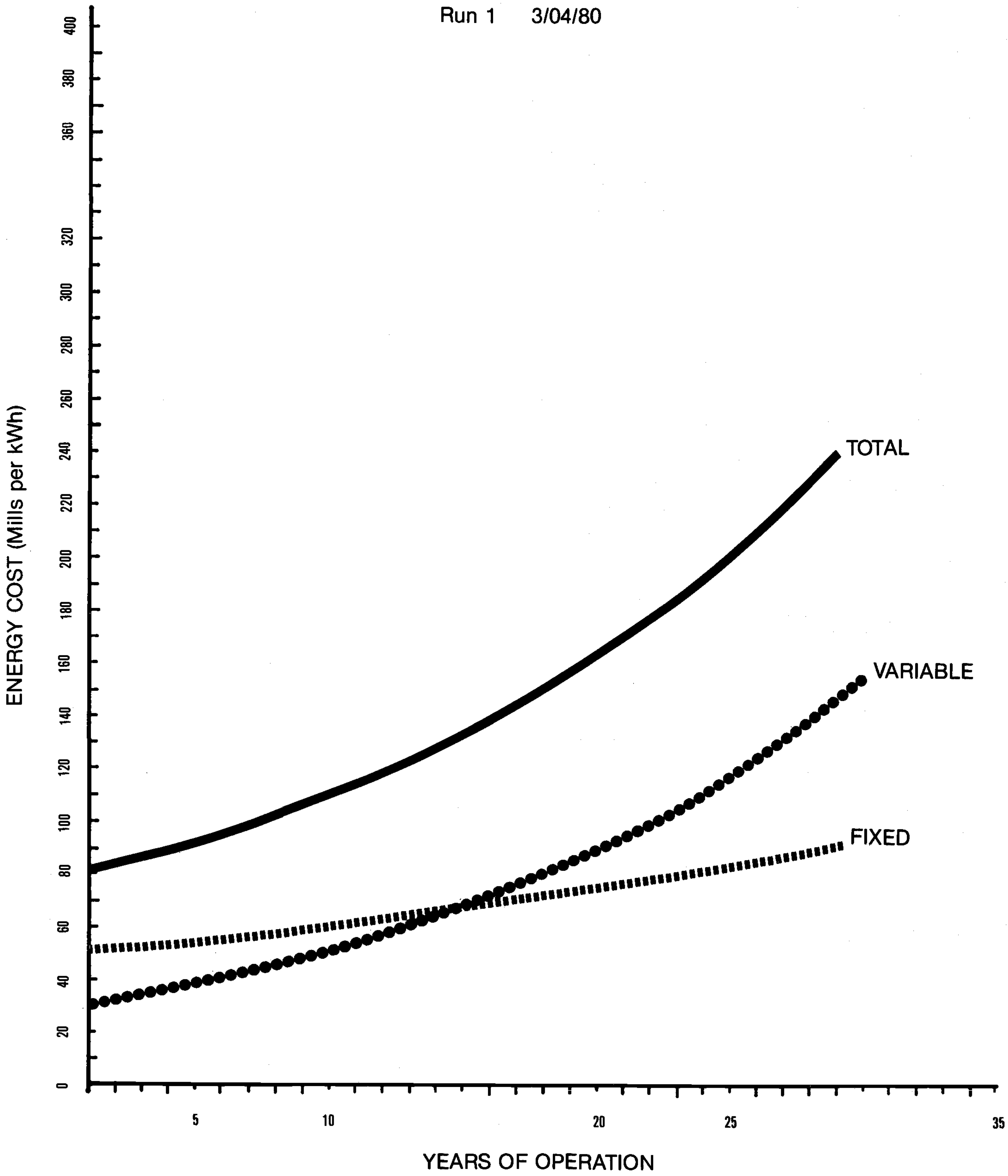
25-MW-CASE 1
WOOD RESIDUE POWERPLANT
ENERGY COST AND YEARS OF OPERATION
1985 Year of Initial Commercial Operation
75-percent Capacity Factor
Financing, 30 years at 7.25 percent
Run 1 3/04/80



CASE 2

ELECTRICAL ENERGY COST FOR A 25-MW WOOD-FIRED PLANT

1985--YEAR OF INITIAL COMMERCIAL OPERATION

65-PERCENT CAPACITY FACTOR

Bonneville Power Administration--Thermal Power Branch

General Information:
This program estimates the cost of energy for a 25-MW wood residue powerplant, 100 percent of which is owned by a typical but undefined public agency.

Assumptions:

1. Capital Requirements, 1985 in-service date:

A)	Direct construction cost	$28,200,000
B)	Indirect construction cost	11,300,000
C)	Interest during construction	7,300,000
D)	Initial fuel	600,000
E)	Total plant investment	47,400,000

2. Variable fuel cost (mills/kWh):

Year	1985	1990	1995	2000	2005	2010	2014
Value	26.2	35.1	46.9	62.8	84.0	112.4	142.0

3. Financing rates:

A)	Capital 30-year bonds issued at	7.250 percent
B)	Fixed cost of fuel inventory 5-year bonds issued at	7.250 percent
C)	Interest on reinvesting reserves	7.000 percent

4. Escalation rates for A) operation and maintenance, B) interim replacements, C) insurance, and D) administrative and general costs:

Time period	1977-80	1981-85	1986-95	1996-2050
Rate	6 percent	7 percent	5 percent	4 percent

5. Project operating data:
   A) Designed for baseload operation
   B) Annual capacity factor--65 percent
   C) Amortized plant line--30 years

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Case 2 (Continued)

WOOD RESIDUE POWERPLANT

PUBLIC AGENCY ANNUAL ENERGY COST

Operating Years	1	10	20	30
General Information				
1 Percentage ownership, public	100	100	100	100
2 Date of commerical operation	12/01/85	12/01/85	12/01/85	12/01/85
3 Net plant capacity (MW)	25	25	25	25
4 Net capacity (MW) to public	25	25	25	25
5 Annual capacity factor (percent)	65	65	65	65
6 Annual generation public (million kWh)	142.3	142.3	142.3	142.3
7 Finance rate (percent), public	7.25	7.25	7.25	7.25
8 Variable fuel rate (mills/kWh)	26.2	44.3	79.3	142.0
9 Fixed cost on fuel inventory (mills/kWh)	8.5	8.5	8.5	8.5
Capital Cost (Million Dollars)				
10 Direct construction cost	28.2	28.2	28.2	28.2
11 Total plant investment	47.4	47.4	47.4	47.4
Fixed Annual Costs ($1,000/Yr)				
12 Interest and amortization	3,916.2	3,916.2	3,916.2	2,224.0
13 Interim replacements	99.0	153.6	229.5	339.8
14 Insurance	101.0	156.7	234.2	346.6
15 Operation and maintenance	2,029.8	3,148.8	4,705.9	6,965.8
16 Administration and general	496.4	770.1	1,150.9	1,703.6
17 Fixed annual taxes	446.4	530.6	647.7	716.3
18 Fixed cost on fuel inventory	1,210.0	1,210.0	1,210.0	1,210.0
19 Subtotal (12-18)	8,298.7	9,885.9	12,094.3	13,506.0
Variable Production Costs ($1,000/Yr)				
20 Fuel expenditure	3,729.6	6,301.0	11,284.2	20,208.3
21 Operation and maintenance	390.8	606.3	906.1	1,341.2
22 In lieu of property tax	230.7	386.8	682.7	1,206.8
23 Subtotal (20-22)	4,351.1	7,294.1	12,872.9	22,756.3
Credits Toward Project ($1,000/Yr)				
24 Interest earnings on reserves	118.5	118.5	118.5	0.0
Total Annual Bus Bar Energy Cost				
$1,000/Yr	12,531.4	17,061.5	24,848.7	36,262.3
Mills/kWh	88.0	119.9	174.6	254.7

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Case 2 (Continued)

WOOD RESIDUE POWERPLANT

SUMMARY REPORT

Yr	Fixed Cost		Variable Production Cost		Total Annual Cost	
	$1000/Yr	Mills/kWh	$1000/Yr	Mills/kWh	$1000/Yr	Mills/kWh
1985	8,180.2	57.5	4,351.1	30.6	12,531.4	88.0
1990	8,975.6	63.1	5,797.2	40.7	14,772.8	103.8
1995	9,990.7	70.2	7,725.4	54.3	17,716.1	124.5
2000	11,006.7	77.3	10,256.6	72.1	21,263.2	149.4
2005	12,242.7	86.0	13,626.2	95.7	25,868.9	181.7
2010	13,746.6	96.6	18,113.9	127.2	31,860.5	223.8
2014	13,506.0	94.9	22,756.3	159.9	36,262.3	254.7

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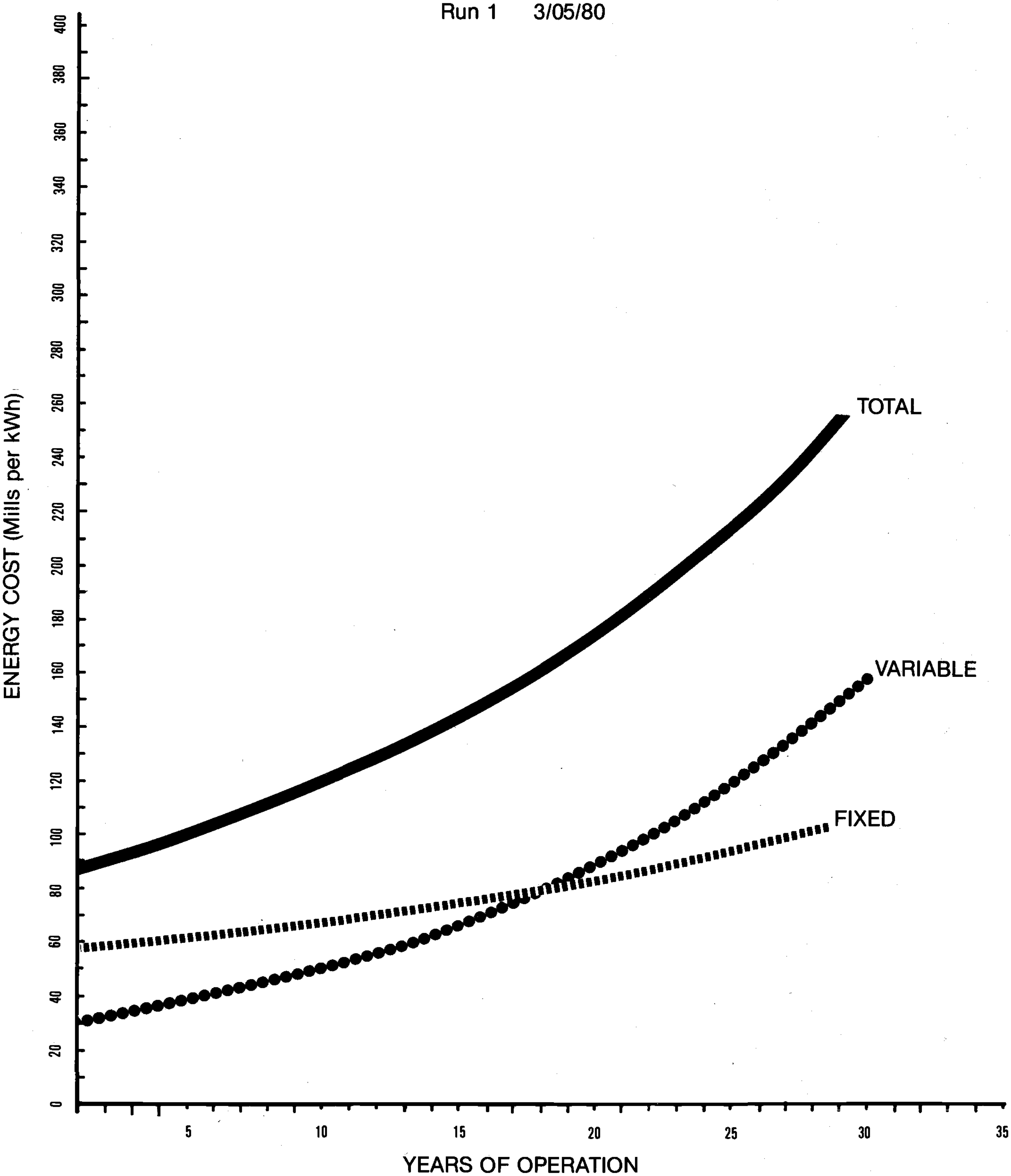
25-MW-CASE 2
WOOD RESIDUE POWERPLANT
ENERGY COST AND YEARS OF OPERATION

1985 Year of Initial Commercial Operation
65-percent Capacity Factor
Financing, 30 years at 7.25 percent
Run 1 3/05/80



CASE 3

ELECTRICAL ENERGY COST FOR A 25-MW WOOD-FIRED PLANT

1990--YEAR OF INITIAL COMMERCIAL OPERATION

75-PERCENT CAPACITY FACTOR

Bonneville Power Administration--Thermal Power Branch

General Information:
This program estimates the cost of energy for a 25-MW wood residue powerplant, 100 percent of which is owned by a typical but undefined public agency.

Assumptions:

1. Capital Requirements, 1990 in-service date:

A)	Direct construction cost	$35,800,000
B)	Indirect construction cost	14,300,000
C)	Interest during construction	9,200,000
D)	Initial fuel	800,000
E)	Total plant investment	60,100,000

2. Variable fuel cost (mills/kWh):

Year	1990	1995	2000	2005	2010	2015	2019
Value	35.1	47.0	62.9	84.1	112.6	150.6	190.2

3. Financing rates:

A)	Capital 30-year bonds issued at	7.250 percent
B)	Fixed cost of fuel inventory 5-year bonds issued at	7.250 percent
C)	Interest on reinvesting reserves	7.000 percent

4. Escalation rates for A) operation and maintenance, B) interim replacements, C) insurance, and D) administrative and general costs:

Time period	1977-80	1981-85	1986-95	1996-2050
Rate	6 percent	7 percent	5 percent	4 percent

5. Project operating data:
   - A) Designed for baseload operation
   - B) Annual capacity factor--75 percent
   - C) Amortized plant line--30 years

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Case 3 (Continued)

WOOD RESIDUE POWERPLANT

PUBLIC AGENCY ANNUAL ENERGY COST

Operating Years	1	10	20	30
General Information				
1 Percentage ownership, public	100	100	100	100
2 Date of commerical operation	12/01/90	12/01/90	12/01/90	12/01/90
3 Net plant capacity (MW)	25	25	25	25
4 Net capacity (MW) to public	25	25	25	25
5 Annual capacity factor (percent)	75	75	75	75
6 Annual generation public (million kWh)	164.2	164.2	164.2	164.2
7 Finance rate (percent), public	7.25	7.25	7.25	7.25
8 Variable fuel rate (mills/kWh)	35.1	59.3	106.2	190.2
9 Fixed cost on fuel inventory (mills/kWh)	11.4	11.4	11.4	11.4
Capital Cost (Million Dollars)				
10 Direct construction cost	35.8	35.8	35.8	35.8
11 Total plant investment	60.1	60.1	60.1	60.1
Fixed Annual Costs ($1,000/Yr)				
12 Interest and amortization	4,965.4	4,965.4	4,965.4	2,819.9
13 Interim replacements	125.0	186.6	276.3	408.9
14 Insurance	128.0	191.1	282.9	418.8
15 Operation and maintenance	2,590.6	3,867.9	5,725.4	8,475.0
16 Administration and general	633.6	945.9	1,400.2	2,072.7
17 Fixed annual taxes	586.1	682.1	821.7	899.8
18 Fixed cost on fuel inventory	1,872.4	1,872.4	1,872.4	1,872.4
19 Subtotal (12-18)	10,901.1	12,711.6	15,344.4	16,967.5
Variable Production Costs ($1,000/Yr)				
20 Fuel expenditure	5,765.2	9,740.1	17,443.1	31,238.0
21 Operation and maintenance	498.8	744.7	1,102.4	1,631.8
22 In lieu of property tax	350.8	587.2	1,038.5	1,840.7
23 Subtotal (20-22)	6,614.8	11,072.0	19,584.1	34,710.5
Credits Toward Project ($1,000/Yr)				
24 Interest earnings on reserves	150.3	150.3	150.3	0.0
Total Annual Bus Bar Energy Cost				
$1,000/Yr	17,365.6	23,633.3	34,778.2	51,678.0
Mills/kWh	105.7	143.9	211.7	314.6

Case 3 (Continued)

WOOD RESIDUE POWERPLANT

SUMMARY REPORT

Yr	Fixed Cost $1000/Yr	Fixed Cost Mills/kWh	Variable Production Cost $1000/Yr	Variable Production Cost Mills/kWh	Total Annual Cost $1000/Yr	Total Annual Cost Mills/kWh
1990	10,750.8	65.5	6,614.8	40.3	17,365.6	105.7
1995	11,765.3	71.6	8,819.4	53.7	20,584.7	125.3
2000	12,780.6	77.8	11,720.6	71.4	24,501.2	149.2
2005	14,015.8	85.3	15,585.4	94.9	29,601.2	180.2
2010	15,518.7	94.5	20,735.8	126.2	36,254.5	220.7
2015	17,347.2	105.6	27,602.0	168.0	44,949.2	273.7
2019	16,967.5	103.3	34,710.5	211.3	51,678.0	314.6

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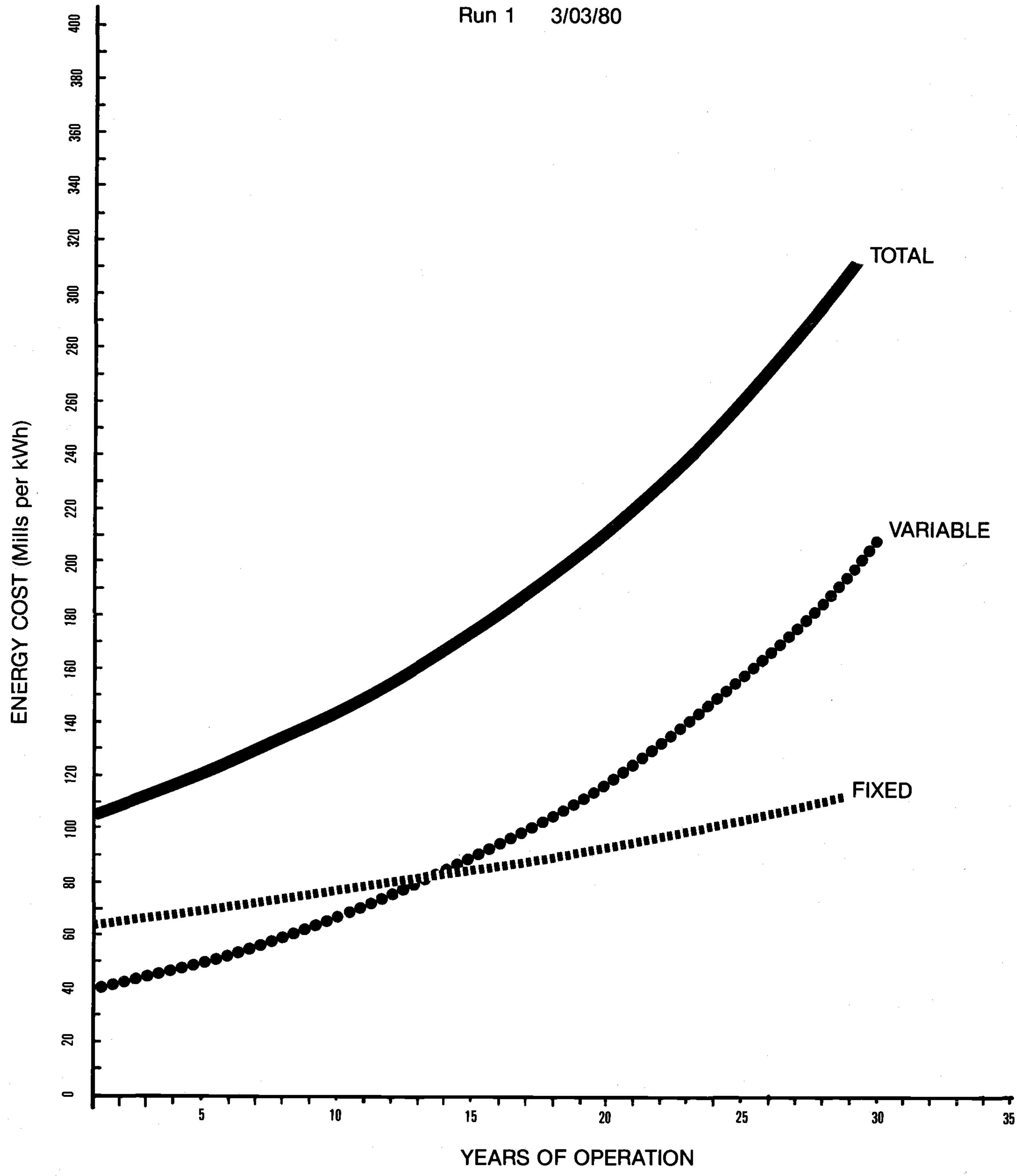
25-MW-CASE 3
WOOD RESIDUE POWERPLANT
ENERGY COST AND YEARS OF OPERATION

1990 Year of Initial Commercial Operation
75-percent Capacity Factor
Financing, 30 years at 7.25 percent
Run 1 3/03/80



CASE 4

ELECTRICAL ENERGY COST FOR A 25-MW WOOD-FIRED PLANT

1995--YEAR OF INITIAL COMMERCIAL OPERATION

75-PERCENT CAPACITY FACTOR

Bonneville Power Administration--Thermal Power Branch

General Information:
This program estimates the cost of energy for a 25-MW wood residue powerplant, 100 percent of which is owned by a typical but undefined public agency.

Assumptions:

1. Capital Requirements, 1995 in-service date:

A)	Direct construction cost	$45,300,000
B)	Indirect construction cost	18,200,000
C)	Interest during construction	11,700,000
D)	Initial fuel	1,100,000
E)	Total plant investment	76,300,000

2. Variable fuel cost (mills/kWh)

Year	1995	2000	2005	2010	2015	2020	2024
Value	47.0	62.9	84.2	112.6	150.7	201.7	254.7

3. Financing rates:

A)	Capital 30-year bonds issued at	7.250 percent
B)	Fixed cost of fuel inventory 5-year bonds issued at	7.250 percent
C)	Interest on reinvesting reserves	7.000 percent

4. Escalation rates for A) operation and maintenance, B) interim replacements, C) insurance, and D) administrative and general costs:

Time period	1977-80	1981-85	1986-96	1996-2050
Rate	6 percent	7 percent	5 percent	4 percent

5. Project operating data:
   A) Designed for baseload operation
   B) Annual capacity factor--75 percent
   C) Amortized plant line--30 years

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Case 4 (Continued)

WOOD RESIDUE POWERPLANT

PUBLIC AGENCY ANNUAL ENERGY COST

Operating Years	1	10	20	30
General Information				
1 Percentage ownership, public	100	100	100	100
2 Date of commerical operation	12/01/95	12/01/95	12/01/95	12/01/95
3 Net plant capacity (MW)	25	25	25	25
4 Net capacity (MW) to public	25	25	25	25
5 Annual capacity factor (percent)	75	75	75	75
6 Annual generation public (million kWh)	164.2	164.2	164.2	164.2
7 Finance rate (percent), public	7.25	7.25	7.25	7.25
8 Variable fuel rate (mills/kWh)	47.0	79.4	142.2	254.7
9 Fixed cost on fuel inventory (mills/kWh)	15.2	15.2	15.2	15.2
Capital Cost (Million Dollars)				
10 Direct construction cost	45.3	45.3	45.3	45.3
11 Total plant investment	76.3	76.3	76.3	76.3
Fixed Annual Costs ($1,000/Yr)				
12 Interest and amortization	6,303.9	6,303.9	6,303.9	3.580.0
13 Interim replacements	159.0	226.3	335.0	495.9
14 Insurance	162.0	230.6	341.3	505.2
15 Operation and maintenance	3,306.3	4,705.9	6,965.8	10,311.1
16 Administration and general	808.6	1,150.9	1,703.6	2,521.7
17 Fixed annual taxes	752.0	857.1	1,026.9	1,115.0
18 Fixed cost on fuel inventory	2,496.6	2,496.6	2,496.6	2,496.6
19 Subtotal (12-18)	13,988.3	15,971.2	19,173.1	21,025.6
Variable Production Costs ($1,000/Yr)				
20 Fuel expenditure	7,719.7	13,042.4	23,356.9	41,828.6
21 Operation and maintenance	636.6	906.1	1,341.2	1,985.4
22 In lieu of property tax	468.0	781.1	1,383.1	2,453.6
23 Subtotal (20-22)	8,824.3	14,729.6	26,081.2	46,267.6
Credits Toward Project ($1,000/Yr)				
24 Interest earnings on reserves	190.8	190.8	190.8	0.0
Total Annual Bus Bar Energy Cost				
$1,000/Yr	22,621.8	30,510.8	45,063.5	67,293.1
Mills/kWh	137.7	185.8	274.4	409.7

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Case 4 (Continued)

WOOD RESIDUE POWERPLANT

SUMMARY REPORT

Yr	Fixed Cost		Variable Production Cost		Total Annual Cost	
	$1000/Yr	Mills/kWh	$1000/Yr	Mills/kWh	$1000/Yr	Mills/kWh
1995	13,797.5	84.0	8,824.3	53.7	22,621.8	137.7
2000	14,812.4	90.2	11,727.2	71.4	26,539.6	161.6
2005	16,047.1	97.7	15,594.2	94.9	31,641.3	192.6
2010	17,549.4	106.8	20,747.6	126.3	38,296.9	233.2
2015	19,377.1	118.0	27,617.8	168.1	46,994.8	286.1
2020	21,600.8	131.5	36,779.7	223.9	58,380.5	355.4
2024	21,025.6	128.0	46,267.6	281.7	67,293.1	409.7

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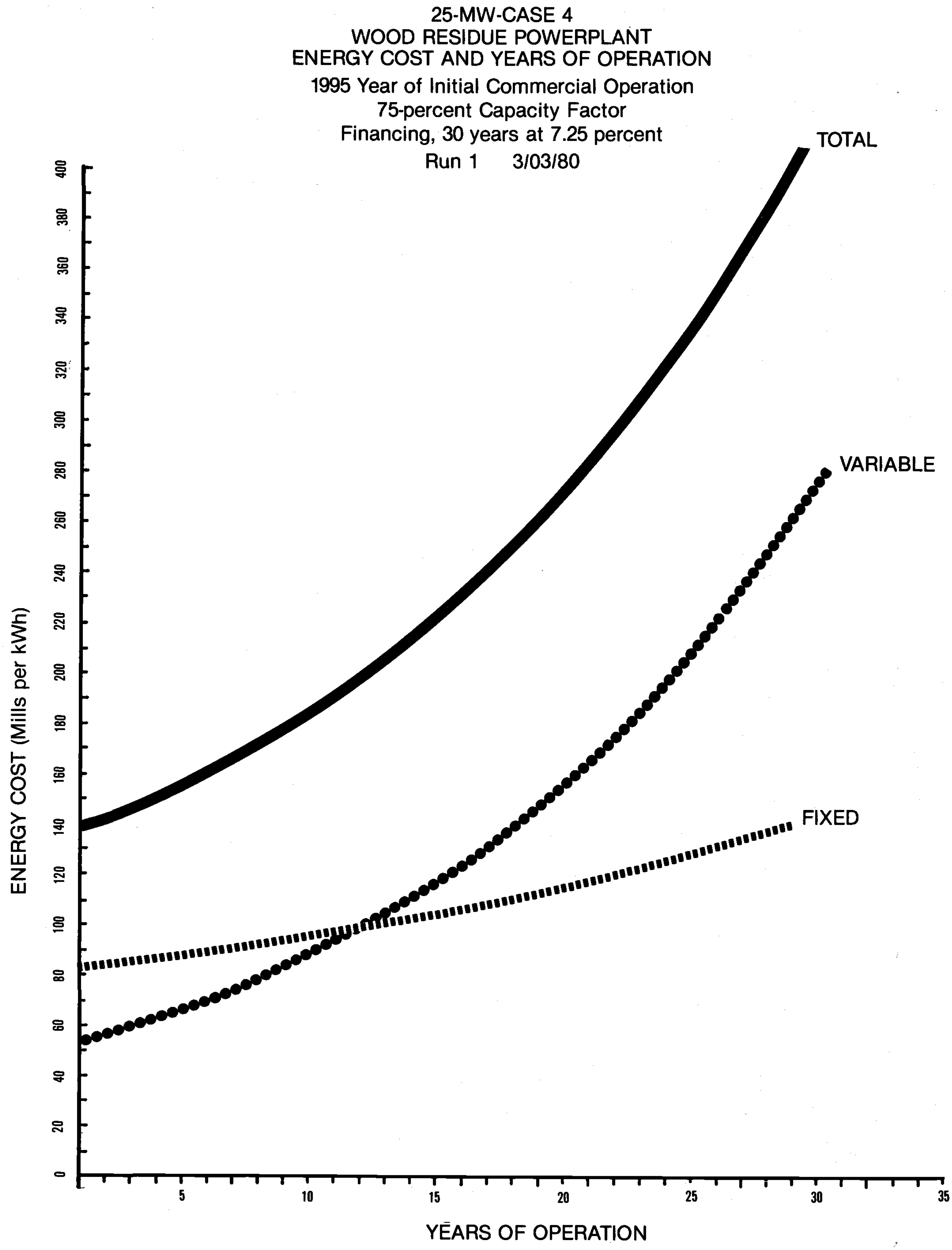
25-MW-CASE 4
WOOD RESIDUE POWERPLANT
ENERGY COST AND YEARS OF OPERATION
1995 Year of Initial Commercial Operation
75-percent Capacity Factor
Financing, 30 years at 7.25 percent
Run 1 3/03/80
TOTAL
VARIABLE
FIXED
ENERGY COST (Mills per kWh)
YEARS OF OPERATION
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
5
10
15
20
25
30
35

Appendix D

Glossary of Terms

Annual capacity factor--the ratio of the average output of a generating resource (in a year's time) to its name plate capacity rating expressed in percent.

Baseload--the minimum load in a power system over a given period of time.

Baseload plant--a powerplant normally operated to carry the baseload.

Capital cost--the total investment necessary to complete a project and bring it to a commercially operable status; includes costs for planning, design, engineering, construction, financing, interest during construction, licensing and other indirect costs, and initial fuel inventory.

Cogeneration--the sequential use of energy to yield usable electrical or mechanical energy and thermal process energy for industrial and other uses.

Condensing system--generally means a steam system where no use is made of the reject steam other than its condensation for recycling as working fluid that is returned to the boiler.

Energy cost--the total cost of producing a unit of energy, usually expressed as mills per kilowatthour.

Load factor--the ratio of the average load to the peak load over a given time period.

Logging residue--woody forest debris, including logs, chunks, bark, branches, tops, and uprooted stumps and trees left on the ground after logging.