

Large-Scale *Eucalyptus* Energy Farms and Power Cogeneration¹

Robert C. Noronla²

The initiation of a large-scale cogeneration project, especially one that combines construction of the power generation facility as well as the establishment of the fuelwood source, is a major undertaking worthy of extensive preliminary investigations.

For the purposes of this paper a large-scale energy farm shall be one in excess of 100 acres. This size of wood producing farm by itself will not support a large commercial cogeneration facility (i.e., 1 mega watt or more), thus it will be assumed that some supplemental fuel source must be sought if the cogeneration facility will consume more fuel than the available acreage will supply.

Because a thorough analysis of fuelwood cost must be an integral part of the overall economic evaluation, all aspects of establishment of a stand, processing and handling of the fuelwood must be investigated.

Seven basic areas of concern must be studied for a complete economic analysis. A detailed discussion of all these is not possible in such a limited paper, however, each will be outlined to indicate specific items which can considerably affect the cost effectiveness of the installation.

Selecting Your Eucalypt Species

Site evaluation -- is extremely important in determining which species will adapt well

¹Presented at the Workshop on Eucalyptus in California, June 14-16, 1983, Sacramento, Calif.

²Manager of Special Projects - Field Operations, Tri-Valley Growers, Modesto, Calif.

Abstract: A thorough evaluation of all factors possibly affecting a large-scale planting of eucalyptus is foremost in determining the cost effectiveness of the planned operation. Seven basic areas of concern must be analyzed:

- | | |
|----------------------|-------------------------------|
| 1. Species Selection | 5. Irrigation |
| 2. Site Preparation | 6. Harvest Planning |
| 3. Planting | 7. Economics of Co-generation |
| 4. Weed Control | |

Only after detailed analysis has been completed, can the decision to move forward with major capital expenditures be made.

Present pay-back is marginal depending on cost of installations, operating expenses and "avoidable rate" payments from utilities.

to the existing conditions. An exhaustive soil analysis is prerequisite to the successful establishment of any stand of trees and should be studied thoroughly to determine what problems if any might exist. The following outline lists several important factors which will weigh heavily on the decision as to the correct eucalypt species for the site in question. These factors are not, however, the only factors which will influence the final selection decision. Each site is a separate case in point and must be treated as such.

- A. Site Evaluation
 - 1. Fertility
 - 2. Slope
 - 3. Water Table
 - 4. Site Specific Problems
 - a. Alkalinity/Acidity
 - b. Clay/Hardpan
 - c. Salt Deposits
 - 5. Soil Type Variability
- B. Species Evaluations
 - 1. Adaptability to Conditions
 - a. Based on Literature
 - b. Existing Site Evaluations
 - c. In-House Evaluations

Species evaluation -- is the next step in the analysis procedure. After the site has been evaluated and the species which are compatible with the specific site are selected, the final decision can be approached as to the one species best suited to the site or the combination of species which would give the best overall performance.

The final selection will be tempered by such influences as seed or seedling availability and cost, macro - or micro-climatic conditions, tree growth habit and other unmentioned site specific problems.

As with any integral part of an economic analysis, the consideration should be the production of the greatest amount of the best quality end product for the least amount of money.

Site Preparation

As with any farming operation, site preparation is first and foremost to assure a successful conclusion. Without proper site preparation, the successive operations of planting, weed control, irrigation and harvesting become at best difficult and at worst impossible. The proper scheme for land preparation is dependent on soil topography and structure. Obviously, certain operations may not be needed if site conditions do not warrant them. The following outline lists the most common operations that might be required prior to planting.

- A. Leveling
 - 1. Planned for irrigation method
- B. Ripping/Chiseling
- C. Plowing/Discing
- D. Seedling Bed Preparation
- E. Pre-Irrigation and Fertilization

Leveling -- may only be needed on sites which are relatively flat and are slated for flood, check or furrow irrigation. Under drip, solid set sprinkler, pull hose, center pivot or other minimal water-use types of irrigation, leveling may be an unneeded [sic] and expensive operation. Rolling or hilly sites may do poorly if leveled due to the depth of cut and the consequent loss of fertility. Thus serious consideration should be given to both the economics and prudence of leveling the site.

Ripping/Chiseling -- again may only be necessary where hard or clay pans exist. Sandy or sandy loam soils generally will produce excellent crops of eucalyptus without the use of deep tillage. Many other soils although tighter than the sandy types will also produce well without the expense and trouble of deep tillage.

Plowing/Discing -- is the generally accepted form of ground preparation in California for most soil types, but may not be needed if alternative methods of competitive plant growth control are used. The economics of discing versus chemical control should be investigated if the present cover is not desired for green mulch.

Seedling Bed Preparation -- is only required when future plans are established for furrow irrigation, mechanical planting or where site specific problems such as salt crusting are present. Flat planting (Direct planting into level surface) under most circumstances is much more desirable than bed planting. Later operations such as weed control and harvesting are simplified by the lack of beds.

Pre-Irrigation and Fertilization -- are very desirable when planting eucalyptus. If planting can be scheduled for fall after first rains have arrived or early spring before the onset of hot

weather, the need for pre-irrigation is eliminated. If planting is conducted where hot dry conditions exist and follow-up irrigation is not immediately available, the planting is almost assured of failure. With most types of potting mixtures the movement of moisture out of the root ball to the surrounding soil occurs within a few hours. If the dry condition is allowed to persist for 8-12 hours a potting mixture with a high percentage of peat will actually resist the infusion of water into the root ball during irrigation. Thus it is essential that adequate moisture be present at planting or immediately thereafter. Fertilization prior to planting can be accomplished in a number of ways, but must be weighed against post-plant fertilization. Economics and availability of equipment are the deciding factors in this instance. Broadcasting a dry fertilizer such as 16-0-0 is a relatively inexpensive means of applying the seedlings initial nitrogen need, but this method is inefficient with respect to placement of the nutrient near the root zone. Banding a dry or liquid fertilizer below and to the side (4 inches and 6 inches respectively) of the seedling will place the nutrients near the root zone but not so near as to burn the lateral root system or displace the tap root. This probably is the most effective application but not the least expensive. Water-running anhydrous ammonia into the irrigation water source would be the least expensive but is relatively short-lived in its effectiveness.

One other important factor that should be considered during site preparation evaluations is the level of pest infestation within the seedling root zone. Most eucalypts are resistant to Fusarium, Phytophthora, nematodes and other common pests, but under severe infestation conditions the performance of the stand could be impaired. If the eucalypt species has a history of susceptibility to an infestation present at the site, an alternate species or an alternate site should be considered.

Planting

The planting costs may vary widely depending on a number of factors. The first decision to be made is whether the seedlings to be planted will be purchased or propagated. If the decision is to purchase, the cost per seedling need merely be multiplied by the requirement for the planting. If self propagation is selected a much more extensive and tedious analysis is required. In most cases the cost of propagation is much lower than purchasing, however, convenience is lost in the process. Some of the precautions that must be considered when preparing seedlings are listed below. These are only precautions to be taken that are over and above those which are necessary to germinate, transplant and grow viable seed spots. It is assumed that a sound basic knowledge of eucalyptus seedling propagation is already at hand.

Seedling preparation -- must include the following important procedures.

1. Hardening of the seedling
2. On-site protection
3. Proper growing media
4. Topping or pruning
5. Container style

The success of the planting may depend upon close attention to the above procedures as well as the proper planting method for the site.

Mechanical versus hand planting -- is an economic decision to be made based on available equipment and labor.

Root ball coverage -- is very important for survival of the seedling during the first days and weeks after planting. Depending on the composition of the growing medium, any exposed portion of the root ball will act as a wick to allow moisture to leave the root zone and dissipate into the atmosphere. Survival of the plant under these conditions is questionable. Total coverage will assure retention of moisture during the all important first year of growth.

Planting density -- is a widely argued point. Many studies have been conducted with claims of tremendous yields per acre made by the investigators. In practice many different tree spacings can produce comparable yields. The important point to remember is the end product desired should dictate the planting density. Cogeneration facilities differ in their fuel requirements, therefore the composition of the fuel to be grown should be manipulated to match the fuel burning equipment.

High moisture contents can be tolerated by some firebox/boiler combinations. In these instances [sic] a very high density planting may be appropriate. High moisture content with a high leaf-to-stump ratio would yield a level of volatile compounds that would increase the BTU per pound and thus the effective output of the cogeneration facility. If very low moisture contents are required by the boiler design, a high stump-to-leaf ratio will be more appropriate.

The planned harvesting method, weed control and irrigation method will all modify the decision-making process. A wealth of publications are available to help a prospective biomass grower decide on an eventual planting pattern and density. Many of these studies have been conducted on the species most adaptable to California conditions and contain valuable statistics. To be prudent one should investigate the method of obtaining the statistics. If extrapolations have been made from single tree samples or very small plots, the results should be viewed with reserve.

Weed Control

Evaluation of weed species -- is the first step in establishing a successful weed control program. Once the full spectrum of weed species has been identified [sic] and the species' growth habits known, a plan for their control can be developed. Many publications are available to assist in species identification, one in particular is the University of California Weed Identification Handbook.

Mechanical versus chemical control -- is a decision to be made early on in the analysis of the entire project. Some soil types do not lend themselves to mechanical weed control, thus it is wise to have an alternative plan that uses either partial or complete chemical control.

Selection of Materials -- should be made with advice of a properly qualified pest control adviser (PCA). Many of the most effective chemicals are restricted materials and therefore cannot be purchased over the counter without proper PCA recommendation or possession [sic] of a commercial applicators certificate.

If farming operations are in existence in the immediate area of the site, it is advisable to ask the operator what materials they have found most effective. Practical experience is worth much in this situation.

Irrigation

For many areas of California irrigation is an absolute necessity. For those areas it is advisable to base the irrigation scheduling on the needs of the trees. There are many types of devices available which will objectively measure soil moisture. Among these are the tensiometers and neutron probes. By the use of these types of devices, the tree's need for moisture can be predicted before it shows any sign of stress. It also allows irrigations to be timed to avoid excessive watering.

Irrigation Method -- is also a very important economic and practical decision to be made. Many sites will only be served well by one type of irrigation method while other sites are adaptable to several types of irrigation systems. In most areas of California irrigation is only needed for the first two or three years of the trees' growth. If plantings can be spaced 3 years apart, the same irrigation equipment can be reused on each successive planting thus reducing the cost per acre for irrigation over the entire planting. This type of planning may preclude the use of the more permanent types of systems such as solid set or underground drip. The cost of the irrigation equipment is of prime concern, however, labor cost and the cost of water and/or pumping will weigh heavily on the eventual selection of the irrigation method to be used. Again, the cost of all components of the irrigation system will determine which system is the most economical.

In some irrigation districts in California the cost of water can be as low as \$3.00 per acre for as much as 6 acre feet per year with very low labor costs to apply the water. In other areas the cost can be as high as \$4.00 per acre for a much lower quantity of water per unit of area. These cost differences make it impossible to recommend one best system for all circumstances. In some cases the high initial cost of a drip system may be quickly offset by the savings in high cost water. In other cases the low cost of water may make it unjustifiable to make any capital expenditures.

The final concern with regard to irrigation is selecting the proper system for the site. The economic concerns mentioned above are in no way the only considerations. If a sprinkler system is to be used, the prevailing wind patterns are a very important consideration. Soil type will also determine the adaptability, to such systems as drip or mist application. Extremely sandy soils will not disperse water well and may require several emitters to give adequate coverage. Topography will determine the initial selection of irrigation equipment. Irrigation specialists are available through the cooperative extension offices to assist in the proper selection of irrigation equipment or, if desired, private consultants can be hired to supply more detailed and specific economic information.

Harvest Planning

The planning of the eventual harvest of the biomass crop is difficult because estimates must be made a minimum of 4 years in advance and in some cases as much as 8 years prior to the first harvest. Several factors are important to consider and are discussed briefly below.

Labor Cost -- is always the first cost input to consider. If the projected wage rate is low enough to offset equipment purchase or rental, the biomass farmer may consider total harvest of the crop by manual means. For large acreages it is unlikely that hand labor can compete with some form of mechanical harvest.

Hauling Cost -- is another cost input that must be estimated far in advance with a high likelihood of error in the estimates. With fuel and labor rates fluctuating as they have in the past 5 years, an accurate estimate of future hauling cost will be extremely difficult. Costs may be reduced or virtually eliminated if the cogeneration facility is located at the farming site, but this sometimes is difficult when cost of land and the eventual point of usage of the power to be generated are conflicting.

Processing Equipment -- is available in several forms. All of the types mentioned below have their proper application, economics and efficiencies being the deciding factors.

1. Tub Grinders - have been adapted from use on hay processing to biomass use with some success. Biomass materials which are brushy and tend to bridge across the tub are not handled well in tub grinders that have no positive feed system. Tub grinders are the least expensive of the systems presently available. Examples: Medallion 905, W.H.O.400NP
2. Hoggers/Chippers - are more adapted to in-field processing where the chips are fed directly into a transport hopper from the hogger. With this type of system the hogger is semi-stationary and has facility for feeding whole trees of the diameter specified by the manufacturer directly into the chipping drum. Again, extremely brushy material is not handled well by this type of equipment, but is very efficient when processing whole trees 3" to 6" in diameter. Example: Nicholson PRC.
3. Down-The-Row Harvesters - are new and experimental at this point, but show a good deal of promise for the future. The only operational unit presently working, to the knowledge of the author, is the Nicholson-Koch mobile chipper. This unit is capable of felling and chipping trees up to 12 inches in diameter at a speed of 1 M.P.H. It is also capable of picking up and chipping previously felled trees up to 19 inches in diameter. The operational production rate is approximately 1 acre per hour on sites yielding 25 tons per acre or green biomass. For very large farms this type of machinery may be worth the investment of \$200,000 to \$300,000.

On-Site Drying or Direct Firing -- of biomass fuel is a decision to be made based on two basic factors.

1. Is the biomass farm located at the cogeneration site?
2. Is the cogeneration plant capable of burning high moisture fuel (40 percent - 60 percent moisture).

If the answer to the first question is positive, the decision to dry the fuel or not stands on its own without consideration for the cost of hauling wet fuel. The decision is then whether to dry the fuel and/or how much to dry it.

The drying process need not be expensive. Proper stacking of the wet fuel will cause internal heat to build in the stack without running the risk of spontaneous combustion. Fuel can be dried to 10 percent to 20 percent by this method. Caution should be exercised in stacking high moisture fuel above 12 feet in height unless the stack can be turned before combustion temperatures are reached.

The simplest of all worlds is to have the biomass fuel source and the cogeneration facility on the same site, and to purchase a firebox/boiler combination that is capable of producing the desired power output using high moisture fuel.

Economics of Cogeneration

Cost of installations--- will vary as with any major cogeneration installation based on the design and location of the facility. Most large cogeneration facilities will cost approximately 1 million dollars per megawatt of power produced if the facility is in the 1 to 20 megawatt range. Beyond the 20 megawatt capacity the cost per megawatt begins to rise rapidly.

Interest costs are a major concern for the cogeneration facility builder. If the return on investment from the sale of the power is not significant on a yearly basis, it may be difficult to repay the debt on construction. To be safe, the interest rate to be paid must be balanced against the revenue to be received using the lowest possible ROI rate for the life of the indebtedness.

Operations Problems -- will in all likelihood [sic] spell the difference between success and failure. Most cost estimations are based on relatively efficient operation of all components of the generation facility, while in actual practice many problems arise that prevent operation of the facility for extended periods of time. A list of recommendations follows that may be helpful in anticipating where problems will occur and how to contend with them.

A. Downtime will be encountered over and above the scheduled yearly maintenance procedures. Knowing that unexpected mechanical failures will occur, protection from income loss during these periods is a necessity. Insurance policies are available to assure income when manufacturer-caused mechanical failures cause loss of income beyond a specified period of time. Depending on premiums paid, a delay in payments from the insurance carrier is made to give the operator time to correct mechanical problems to the best of their abilities. When the more severe failures occur, payments from the insurance carrier will begin after the delay period and will continue for a specified period of time or until the failure is corrected.

B. To abide by the contracts for power production arranged with the utility destined to receive the power, the facility should be designed to operate at the rated output capacity of the generator with the boiler-operating at 75 percent of capacity. If at all possible, the design of the boiler should be such that a partial shutdown of the boiler may be accomplished while continuing to operate at the rated output of the generator. A modular design or multiple cell boiler would accomplish this end.

Contracts being signed at this time have capacity guarantee clauses which allow for higher payments to the energy producer if specified levels of production are adhered to.

C. Consideration must be given to obtaining a sufficient quantity of high yielding fuel to supplement existing supplies. If price movement on fuel supplies appears to be stable or moving up, it would be wise to establish long-term contracts with suppliers. If movement is downward, of course one would want to withhold contracting until the price is more favorable. In any event, the fuel should be well matched to the firebox conditions. Some boilers operate at very high temperatures (2000°F+). In these instances a fuel with a high percentage of ash, especially ash with a low fusing temperature is highly undesirable. The following sample analysis would be very helpful in determining the suitability of the potential fuel to the boiler. Boiler manufacturers can assist in evaluating a potential fuel to assure the proper operation of their equipment, and should be consulted well in advance of facility construction.

Fuel Analysis

Source of Sample:	Biomass Fueled Boiler		
Sampling	November 4, 1980		
Appearance:	Almond Shells (Fines)		
pH of 1% solution in water	11.0		
Moisture	= 5.98 %		
Ignition Loss	= 74.34 %	Ash - 19.68%	
Sulfur (as SO ₃)	= %	(Via BaCl ₂ on aliquot of HCl extract)	
Silicon (as SiO ₂)	= 9.91 %		

The following elements are determined by atomic absorption spectrophotometry on appropriate aliquot portions of a stock solution which contains the hydrochloric acid extraction of the deposit.

Vanadium	(as V ₂ O ₅)	Nil	ppm
Nickel	(as NiO)	48	ppm
Iron	(as Fe ₂ O ₃)	10310	ppm
Copper	(as CuO)	105	ppm
Manganese	(as MnO)	136	ppm
Aluminum	(as Al ₂ O ₃)	60940	ppm
Sodium	(as Na ₂ O)	2700	ppm
potassium	(as K ₂ O)	14060	ppm
Magnesium	(as MgO)	3010	ppm
Calcium	(as CaO)	4206	ppm
Zinc	(as ZnO)		ppm
Cobalt	(as CoO)		ppm
Accounted for: (including Ignition Loss, Sulfur as SO ₃ , and Silicon as SiO ₂).		98.8	%

As can be seen this fuel would be undesirable because of the high ash content and high silicon content in the ash. In high temperature fireboxes this fuel could cause serious problems with fusing of the silicon on the boiler tubes.

- D. Emissions control is of prime concern to any operator, in particular to those who will operate within metropolitan areas. No shortcuts should be considered in this area of concern. Many facilities recently constructed have gone through extensive and costly modifications to meet emission control standards as a result of incomplete consideration during the engineering stages.

Adequate equipment is available to control any emission problem that may arise in a biomass boiler. It would be wise prior to engineering a system to contact as many cogeneration facilities as possible to ascertain what the potential problems might be.

- E. The boiler and firebox are generally trouble free if operated within design limitations. Problems arise in attempting to operate a piece of equipment above its rated capacity.

In the design phase of developing a cogeneration facility, a sufficient amount of excess capacity should be designed in to allow for such eventualities as low B.T.U. fuel, partial loss of heat transfer due to silicon fusing on boiler tubes, low fire temperature due to firebrick or refractory disintegration or mechanical problems in fuel feed systems.

By always assuming that a portion of the boiler system will be inoperable, the chance of not meeting the rated output of the generator will be greatly reduced.

- F. A good deal of consideration should be given to the selection of the turbine and generation equipment. Users of operating facilities should be contacted for their opinions on the performance of the machinery being considered.

Because the entire effort of the operation culminates in the generation of power, an inadequate turbine or generator would be disastrous to the operation. Some typical problems that the manufacturer should be questioned about are:

Turbine

1. Performance history at existing facilities.
2. Seal construction and leakage control.
3. Gearbox reliability.
4. Oil supply and leakage control.
5. Scheduled maintenance shutdown requirements.

Generator

1. Performance history at existing facilities.
2. Bearing life.
3. Scheduled maintenance shutdown requirements.
4. Parts availability and major repair procedures.

Return on Investment -- can be measurably affected by the variable rate of the "avoidable cost" payments from the utility company.

The tables below are taken from the PG&E publication "Cogeneration and Small Power Production Quarterly Report."

PACIFIC GAS AND ELECTRIC COMPANY

PURCHASE PRICES (¢/kWh) FOR ENERGY FROM QUALIFYING FACILITIES FEBRUARY 1980 THROUGH JULY 1983

Seasonal Period *	Time of Delivery Basis			Average Basis
	On-Peak	Partial-Peak	Off-Peak	All kWh
<u>Period B</u>				
February '80 thru April '80	4.496	4.250	3.794	4.121
<u>Period A</u>				
May '80 thru July '80	5.675	5.459	4.700	4.994
August '80 thru September '80	6.100	5.868	5.052	5.368
<u>Period B</u>				
October '80	5.858	5.536	4.943	5.368
November '80 thru January '81	6.226	5.884	5.254	5.706
February '81 thru April '81	6.580	6.219	5.553	6.030
<u>Period A</u>				
May '81 thru July '81	7.783	7.487	6.446	6.850
August '81 thru September '81	8.072	7.765	6.685	7.104
<u>Period B</u>				
October '81	7.752	7.326	6.542	7.104
November '81 thru January '82	7.725	7.302	6.519	7.080
February '82 thru April '82	7.759	7.334	6.548	7.111
<u>Period A</u>				
May '82 thru July '82	6.397	6.102	5.895	6.178
August '82 thru September '82	5.967	5.692	5.499	5.641
<u>Period B</u>				
October '82	6.049	5.912	5.769	5.854
November '82 thru January '83	6.049	5.912	5.769	5.854
February '83 thru April '83	6.209	6.068	5.922	6.009
<u>Period A</u>				
May '83 thru July '83	6.108	5.826	5.629	5.774

* Period A comprises May through September, and Period B, October through April.

PACIFIC GAS AND ELECTRIC COMPANY TIME PERIODS

Seasonal Period A (May 1 through September 30)	Monday through Friday ²	Saturdays ²	Sunday and
On-Peak	12:30 p.m. to 6:30 p.m.		
Partial-Peak	8:30 a.m. to 12:30 p.m. 6:30 p.m. to 10:30 p.m.	8:30 a.m. to 10:30 p.m.	
Off-Peak	10:30 p.m. to 8:30 a.m.	10:30 p.m. to 8:30 a.m.	All Day
<u>Seasonal Period B (October 1 through April 30)</u>			
On-Peak	4:30 p.m. to 8:30 p.m.		
Partial-Peak	8:30 p.m. to 10:30 p.m. 8:30 a.m. to 4:30 p.m.	8:30 a.m. to 10:30 p.m.	
Off-Peak	10:30 p.m. to 8:30 a.m.	10:30 p.m. to 8:30 a.m.	All Day

The tables show that by manipulation of peak production of the cogeneration facility to hours in which the higher rate of return prevails, the amount of return can be significantly increased. Also it is obvious that if a cogeneration facility is planned and returns calculated with "avoidable cost" payments such as were made during August, 1981 through September, 1981, the downward trend in recent payments could render the facility non-profitable.

Another set of factors that weigh heavily on the eventual success of the facility are the variable cost factors. Three of the major factors are listed below and should be given very serious consideration.

1. Labor
2. Materials
3. Fuel

Wherever possible, long-term commitment should be made to guarantee profit for the sup-

plier as well as the cogeneration facility. If possible, contracts for the three factors listed above should be tied closely to fluctuations in "avoidable rate" payments so the facility will remain viable throughout its life.

Misconceptions -- abound in the biomass cogeneration industry. Many assume the return on investment is very high, when in fact it can be marginal to unprofitable. Only the most astute operators can be guaranteed a profit. Systems efficiencies are generally overrated. Fuel sources are estimated to contain more B.T.U.s per pound than they actually contain, boilers are overrated in their efficiency, turbines and generators are generally more prone to maintenance problems than manufacturers will admit and many more exaggerations of performance exist. The potential operator must keep all of these factors in mind to assure a successful conclusion to the establishment of a biomass farm and cogeneration facility.