Economic Evaluation of Eucalypt Energy Plantations[1]

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Abstract: An analysis is made of the break-even price at a 6 percent and 10 percent real interest rate for "intensive" and "minimally managed" scenarios for managing eucalypt energy plantations. The break-even price is greater than the average stumpage price reported for firewood and chipwood by the State Board of Equalization. However, a conversion surplus approach shows that eucalypt firewood plantations are profitable for both the intensive and minimally managed scenario. For plantations producing chips for energy, only the minimally managed scenario, with yields greater than 58 dry tons per acre at harvest, appears to be profitable, assuming delivered chip prices of $35 per bone dry ton. The benefit-cost ratio for a commercial planting of eucalypts at the Concord Naval Weapons Station, California, showed that a return of at least 10 percent on establishment costs was highly probable with proper choice of species.

An evaluation of the economic feasibility of investment in a eucalypt energy plantation must involve an assessment of the costs of the various cultural practices (planting, weed control, irrigation), the costs of processing the standing tree into a usable form (logging costs, transportation costs, chipping, cutting to firewood length) and the returns expected from the sale of the processed product (firewood, chips), all compounded or discounted to a constant point in time at an interest rate selected on the basis of management objectives.

Presented below are two different analyses of eucalypt energy plantations. First, two possible management scenarios are presented, drawn from a survey of planting and cultural practices throughout California, and a "break-even" price is calculated. This break-even price is the necessary return on a cord of firewood or ton of chips, to earn a given rate of return on money invested in the plantation. The second analysis calculates a benefit-cost ratio from an actual case study of a commercial planting of eucalypts at the U.S. Naval Weapons Station in Concord, California, using actual cost and return data from early trials by the USDA Forest Service's Institute of Forest Genetics.

BREAK-EVEN PRICE ANALYSIS

With the new flurry of interest in planting eucalypts, there have been many proposed management scenarios statewide. These range from the use of intensive agronomic practices such as cultivation, irrigation and fertilization, to a more extensive "wildland" type of planting, with little management input after initial tree planting. For the purpose of this analysis, two theoretical cases were developed to represent the range of management proposals. Table 1 presents the cost data for two different levels of management, namely intensively managed and minimally managed eucalypt energy plantation. The cost data presented are based on some average figures for actual eucalypt plantations in California and some general costs derived from managed plantations of other tree species (Klonsky et al, 1983; Rose et al, 1981). All costs and returns in this analysis are in constant 1982 dollars, and the interest rates used are real interest rates (net of inflation).

Methods

The objective of the analysis was to calculate a break-even price for a eucalypt energy plantation for the two levels of management. The first step in the process was to discount all costs back to the present time at a 6 percent and 10 percent real interest rate using equation 1 below. Costs were assumed to occur at the beginning of the year.

$$DC = C/((1+i)\exp(n-1)) \qquad (1)$$

where: DC = discounted cost
C = actual cost
i = interest rate
n = year when cost occurs.

An 8-year rotation length was chosen for this analysis because it is near the point of culmination of mean annual increment for several species reported in the literature (FAO, 1981; Metcalf, 1924). Because many eucalypt species coppice readily from the stump following harvest, no additional investment in stand establishment costs are

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Table 1--Costs per acre for intensively and minimally managed eucalypt energy plantations in California. 1st rotation assumed to be 8 years and the 2nd and 3rd rotations assumed to be 7 years.

		Cost/Acre (1982 Dollars)		Discounted Cost (1982 Dollars)			
		Intensive	Minimal	Intensive		Minimal	
Cultural Practice	Year(s)	Management	Management	6 pct.	10 pct.	6 pct.	10 pct.
Site Preparation[1]	1	150.00	50.00	150.00	150.00	50.00	50.00
Pre-emerg5nt Herbicide	1	27.00	27.00	27.00	27.00	27.00	27.00
Seedlings[2]	2	363.00	204.00	342.45	330.00	192.45	185.45
Planting Labor	2	62.40	35.36	58.49	56.36	33.96	32.73
Irrigation[3]	Annual	100.00	--	620.98	533.49	--	--
Initial Watering	2	--	200.00	--	--	188.68	181.82
Weed Control	2	40.00	40.00	37.74	36.36	37.74	36.36
Fertilization[4]	2	30.00	--	28.30	27.27	--	--
	3-8	56.00	--	294.93	247.85	--	--
Management Costs	Annual	5.00	5.00	31.05	26.67	31.05	26.67
Land Rental	Annual	150.00	40.00	931.47	800.24	248.39	213.40
TOTAL DISCOUNTED COSTS-- 1 Rotation				2522.41	2235.24	809.27	753.43
TOTAL DISCOUNTED COSTS-- 3 Rotations				4009.51	3111.58	1071.70	908.08

[1]Intensive-- Disc and rip; Minimal-- Disc only
[2]Intensive-- 1210 seedlings/acre at $.30/each; Minimal--680 seedlings/acre
[3]Includes labor, depreciation, water
[4]76 lbs.-N 1st year, 152 lbs.-N subsequent years

needed for at least the next two or three harvests. In subsequent rotations, some replanting may be necessary to replace stumps which fail to coppice (Fahraeus, 1974). For this analysis, the break-even price was calculated on the basis of 3 rotations. The second and third rotations were assumed to be 1 year shorter than the first rotation because the well-developed root system of the coppiced trees will allow full site occupancy more quickly than occurs with seedling trees. The total period for the 3 rotations is 22 years. The discounted costs for the first rotation were summed up, and the results are shown in table 1. It was assumed that all costs except stand establishment costs (site preparation, seedlings, planting labor) would remain the same for the second and third rotations. These costs were also discounted back to the present, and table 1 shows the total discounted cost for the 3 rotation period.

Based on the costs presented in table 1, the break-even price is calculated for the sale of eucalypt stumpage for the intensive and minimally managed scenarios, at the 6-percent and 10 percent real interest rate. Break-even price has been defined as the necessary price per unit required to earn a given rate of return on money invested in the plantation. To solve for this value, the discounted costs are set equal to the discounted returns.

$$DC = DR \quad (2)$$

where: DC = discounted costs
DR = discounted returns.

Since the discounted returns can be expressed as:

$$DR = (YxBEP)/((1+i)exp(r)) \quad (3)$$

where: DR = discounted returns
Y = yield
BEP= break-even price
i = interest rate
r = rotation length.

then equation 2 can be transformed to:

$$DC= (YxBEP)/(1+i)exp(8)+ (YxBEP)/(1+i)exp(15)+ (YxBEP)/(1+i)exp(22). \quad (4)$$

This equates the discounted costs from the three rotations to the discounted returns from the three rotations (occurring in years 8, 15, and 22 respectively). Equation 4 is transformed to:

$$DC = YxBEP((1+i)exp(-8)+ (1+i)exp(-15)+(1+i)exp(-22)). \quad (5)$$

Because the merchantable yields for these management scenarios are not precisely known, the break-even price (BEP) is calculated for a range of potential yields. For each assumption about merchantable yield, the break-even price was calculated using equation 6.

$$BEP = DC/Y((1+i)exp(-8)+ (1+i)exp(-15)+(1+i)exp(-22)). \quad (6)$$

Table 2--Break-even stumpage price per cord and per dry ton for intensive and minimal management of eucalypt biomass plantations based on merchantable yield and interest rate. Rotation length for the first rotation is 8 years and 7 years for the second and third rotations.

Merch. Yield at Rotation			Intensive Management				Minimal Management			
			6 pct.		10 pct.		6 pct.		10 pct.	
Cubic Ft.	Cords[1]	Dry Tons[2]	$/cord	$/Ton	$/cord	$/Ton	$/cord	$/Ton	$/cord	$/Ton
1360	16	29					50	28	68	38
2720	32	58					25	14	34	19
4080	48	86	63	35	78	43	17	9	23	13
5440	64	115	47	26	59	33	13	7	17	10
6800	80	144	38	21	47	26				
8160	96	173	32	18	39	22				

[1]Assumes 85 cubic feet of solid wood per cord
[2]Assumes 1.8 Tons per cord

Results

The results of the analysis are shown in table 2. For example, for a merchantable yield of 64 cords of firewood at the end of an 8-year rotation (or 7-year coppice rotation) using the intensive management scenario, the grower needs $47 per cord for firewood stumpage to receive a 6 percent real return on the planting investment, or $59 per cord to receive a 10 percent real return on the investment. For comparison, under the minimally managed strategy, with yields only half of the intensive management option, or 32 cords, then table 2 shows one would only need to receive $25 for a 6 percent return on investment and $34 for a 10 percent return. Table 2 also shows the break-even price per dry ton for individuals selling eucalypt trees on that basis of measure.

The differences between the break-even price for the intensive and minimally managed cases points out that one must carefully evaluate whether the intensive cultural costs and the resulting yields would really give an acceptable return on a tree planting investment.

Assessing Market Prices

Once the break-even price for an investment in eucalypts has been calculated, an assessment is needed of how this compares with the actual market price being received for stumpage in an area. Many owners are looking at the delivered firewood prices being paid in metropolitan areas in the state, and assuming they will receive the same price for their standing trees. This does not consider the considerable costs involved in getting a standing tree harvested, processed into firewood, and transported to a market. Owners who consider marketing chips to a biomass cogeneration facility need to assess the costs of harvesting, chipping, and transportation.

Firewood

Since the California Yield Tax applies to harvested firewood, the California State Board of Equalization (SBOE) annually collects information on the average stumpage price received for firewood statewide, and reports the figures in the Harvest Value Schedules to serve as the basis for the yield tax owed by the landowner. In the most recent Harvest Value Schedule, the average stumpage value for hardwood fuelwood was $15 per cord, and $8 per cord for non-hardwood fuelwood (SBOE, 1982). It is quite obvious that for the relationships shown in table 2, only the minimally managed management scenario at yields greater than 48 cords per acre would be close to this statewide average for fuelwood stumpage. These figures, however, tend to be collected mainly from commercial forest areas of the state, and due to the rugged terrain, which results in high harvesting costs, and the long distance to market, the Harvest Value Schedule values may be lower than individuals would receive for planting eucalypts on fairly level terrain, close to the eventual firewood market.

To get a better idea as to what market price might be possible, we worked backward from a final delivered firewood price to arrive at a stumpage value using a "conversion surplus" approach.

In general the final market price for any wood product can be expressed as:

$$SP = STP + HC + PC + TC + MPR \qquad (7)$$

where:
SP = selling price
STP = stumpage price
HC = harvesting cost
PC = processing cost
TC = transportation cost
MPR = margin for profit & risk.

Table 3 gives the result of a study of firewood harvesting and processing carried out in New England (Dammann and Andrews, 1979). The study calculated the most efficient mix of equipment for a firewood harvest based on the average log skidding distance and the annual production of the firewood harvesting/manufacturing firm. The average harvesting, processing, and transportation cost, including a 15 percent margin for profit and risk (HC, PC, TC, MPR terms in equation 7) ranged from $33 to $48 per cord for a 20-mile one-way distance to market, and from $66 to $94 per cord for a 90 mile one-way distance to market.

Table 3-Contract harvesting, processing and transportation costs for firewood, 15 percent margin for profit and risk (1982 dollars). Source: Dammann and Andrews, 1979.

Transportation Distance	Cost/Cord[1]	Equipment Type[2]
20 miles	$33-48	Chainsaw; Ground Skidder; Splitter; Loader
90 miles	$66-94	Dump Truck

[1] Cost varies based on skidding distance, yearly production, and type of equipment.

[2] Type of equipment chosen on basis of skidding distance and yearly production to minimize total harvesting, processing and transportation costs.

If we assume a final selling price of $150 per cord (SP term in equation 7) for firewood, then by subtracting these figures in table 3, we can get an idea as to the conversion surplus left for firewood stumpage. For a 20-mile haul, the maximum possible value for stumpage using these harvesting and processing costs would be $102 to $117 per cord. This would require a commercial firewood planting located in very close proximity to a major market center such as Sacramento, the San Francisco Bay Area, or Los Angeles. It can be seen that the conversion surpluses exceed the break-even price figures in table 2, and thus the return on planting would exceed the 6 to 10 percent real interest rates used in the analysis.

It is much more likely, based on the high land prices of areas surrounding the major market centers, that eucalypt planting would be distributed 90 miles from a final market center. If this were the case, the conversion surplus left after subtracting the harvesting, processing and transportation costs from the firewood selling price would be $56 to $84 per cord, which also appears feasible at our expected levels of yield.

Biomass Chips

The California State Board of Equalization (SBOE) also reports the average stumpage price for chipwood in its Harvest Value Schedule. The most recent schedule reports average stumpage for hardwood and softwood chipwood as $1 per green ton, which would convert to $2 per bone dry ton, assuming a moisture content of 100 percent on an oven-dry basis. This average stumpage price is far below the break-even prices reported per dry ton in table 2.

We used the conversion surplus approach to calculate the residual value left after harvesting, processing, transportation, and a margin for profit and risk were subtracted from the delivered price for chips at a biomass cogeneration facility. According to a recent Pacific Gas and Electric (PG&E) report, there are currently 13 biomass cogeneration facilities in California, and another 15 facilities projected to be in operation in the near future (PG&E, 1982). To date, these plants mainly operate on residue from wood product and agricultural processing industries. Some residue from orchard prunings and urban tree removals are also purchased. A survey of several of these purchasers shows that the delivered prices paid by the facilities ranges from $22 to $35 per bone dry ton.

Table 4 shows the costs of harvesting, processing, and transporting biomass chips to a cogeneration facility. These data were collected from various studies. All the reports calculated costs on the basis of approximately 2000 hours of equipment use per year, which means that a considerable acreage would be needed to justify the capital expense of purchasing the equipment.

At the $35 per bone dry ton for delivered chips, and $22 per ton for harvesting, chipping, and transportation on level terrain with a high level of mechanization, then the conversion surplus for stumpage would be $13 per ton. Table

Table 4--Contract harvesting, processing and transportation costs for wood chips, 20 mile haul, 15 percent margin for profit and risk (1982 dollars).

Costs ($/Dry Ton) 1	Terrain	Equipment Type	Reference
$21.95-28.70	level to rolling	Feller buncher, grapple skidder, chain flail, whole tree chipper, chip van	Arola & Miyata, 1981
$19.56-24.45	level to rolling u	same as above	Rose, Ferguson, et al, 1981
$34.50	>50% slope	Snyder feller buncher, Skyline yarder,	Scheiss, 1982
$47.15	>50% slope	Chainsaw, accumulator, Pewee yarder,	Scheiss, 1982

[1] Range in price due to different average tree diameters and volume per acre harvested.

Table 5--Costs for establishment of eucalypt plantations with contract labor at Concord Naval Weapons Station (Data on file at USDA Forest Service Pacific Southwest Forest and Range Experiment Station).

Operation	Year	Current Costs($)		Discounted Costs($)					
				Interest Rate/Seedlings per Acre					
		Seedlings per Acre		5 pct.		6.2 pct.		10 pct.	
		435.6	810	435.6	810	435.6	810	435.6	810
Site Preparation									
Discing	1	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Spraying	1	44.00	44.00	44.00	44.00	44.00	44.00	44.00	44.00
Discing	2	20.00	20.00	19.05	19.05	18.83	18.83	18.18	18.18
Spraying	2	44.00	44.00	41.90	41.90	41.43	41.43	40.00	40.00
Planting									
Seedlings	2	130.68	243.00	124.46	231.43	123.05	228.81	118.80	220.91
Planting	2	56.63	97.20	53.93	92.57	53.32	91.53	51.66	88.36
Cultivation									
Spraying	3	44.00	44.00	39.91	39.91	39.01	39.01	36.36	36.36
Irrigation									
Monthly	3	178.60	332.13	162.00	301.25	158.35	294.48	147.60	274.49
TOTAL				505.25	790.11	497.99	778.09	476.6	742.30

2 shows $13 per ton to be greater than the break-even price for only the minimally managed scenario at yields greater than 2720 cubic feet (58 dry tons) per acre. At $22 per bone dry ton for delivered chips, then only the costs of harvesting, chipping, and transportation are covered, which means no price could be paid to the landowner for stumpage.

In Washington on very steep terrain for mechanized harvesting of biomass, preliminary studies shown in table 4 indicate that the costs of harvesting, chipping, and transportation alone are greater than the delivered price of wood chips.

It is anticipated that as more biomass conversion facilities come on line, and as the real price of energy continues to increase, competition will drive the real price of wood chips up, although it is difficult to predict to what level. Our analysis shows the sensitivity of a eucalypt energy plantation to the delivered price for wood chips.

CASE STUDY-- CONCORD NAVAL WEAPONS STATION

Our objective in this section is to evaluate the economic viability of a eucalypt planting program at the Concord Naval Weapons Station by dividing present value of benefits by present value of costs, both discounted at various interest rates. The benefit-cost ratio is useful to determine if a project is returning an acceptable return on the public resources invested.

Actual costs of the various cultural operations required to establish eucalypts at Concord refer to contract labor, and include a margin for profit and risk (table 5). Experience at Concord indicates that the site requires intensive cultivation for eucalypt production. The planting site should be disced and sprayed with herbicide for one year before planting, at the time of planting, and one year after planting. Summer irrigation by tank truck is budgeted for the first year. Two planting densities were considered, namely 435.6 seedlings per acre, which was-the density used for species trials at Concord, and 810 seedlings per acre, which should produce a well-stocked stand even after considerable mortality.

Methods

The analysis reported here was completed in 1980 and is reported in 1980 dollars. All costs were discounted to the (then) present time using equation 1 at a 5 percent, 6.2 percent, and 10 percent real interest rate. The bulk of evidence suggests that 5 percent is the rate most commonly applied to public investments (D.E. Teeguarden, pers. comm.). The rate actually used by the Forest Service in its analyses under the Resources Planning Act is 6.2 percent. The 10 percent rate was chosen because it was felt to be closer to the

Table 6-- Yields and current value for 9-year-old eucalypt plantations at Concord Naval Weapons Station. Source: King and Krugman, 1980.

Species	Survival (pct.)	Trees (#/acre)	Volume (cords/acre)	Green Weight (tons/acre)	Current Value: Firewood ($25/cord)	Current Value: Chips ($8/ton)
E. dalrympleana	60	261	25.86	77.58	646.50	620.64
E. grandis	91	396	24.21	72.63	605.25	581.04
E. nitens	94	409	26.60	79.80	665.00	638.40
E. viminalis	75	327	15.98	47.94	399.50	383.52

Table 7--Benefits per acre on a 9-year coppice rotation for E. dalrympleana (D) and E. viminalis (V) fuelwood at Concord Naval Weapons Station (Assuming stumps will coppice 4 times before replanting is necessary.

Cutting Cycle	Year	Value at Harvest[1] ($/acre)		Present Value ($/acre)				
				D			V	
		D	V	5 pct.	6.2 pct.	10 pct.	5 pct.	6.2 pct.
1	11	761.54	470.59	467.52	417.30	293.61	288.89	257.87
2	20	870.74	538.07	344.58	277.67	142.37	212.93	171.53
3	29	995.60	615.22	253.97	184.76	69.04	156.94	114.17
4	38	1138.36	703.44	187.19	122.93	33.48	115.67	75.97
5	47	1301.58	804.31	137.96	81.80	16.23	25.25	50.55
TOTAL				1391.22	1084.46	554.73	859.68	670.14

[1] Assuming a real price increase of 1.5 percent per year and a current stumpage of $25 per cord.

rate of return for private investors. Table 5 gives the actual and discounted costs per acre in 1980 for the two planting densities.

Data from a eucalypt species trial at Concord (King and Krugman, 1980) were used to estimate yields (table 6). These yield data were collected from trees planted at the 435.6 seedling density level and reduced by natural mortality. Mean annual increment was probably at a maximum around 8 to 9 years.

In one respect the yield data could be considered inflated: trees were planted in small plots (16 trees) and because of mortality in adjacent plots, trees of the successful species were relatively free of competition at the plot edge. On the other hand, it is now obvious that these early trials were not planted with the best seed sources and current tests indicate that yields could well be doubled with proper choice of seed. Furthermore, yields were certainly underestimated for the coppice rotations. The eucalypt species mentioned here, with the exception of shining gum (Eucalyptus nitens Maid.), will sprout back readily after cutting, and regeneration by sprouting is anticipated for at least four cutting cycles. The sprout generations should grow more rapidly than the initial seedling generation because they begin on an established root system. Because there was no way to estimate the increased growth, yields were assumed to be the same as those for the first generation, giving a conservative estimate of returns.

For the higher planting density, there was no data to evaluate yields. Volume per tree will likely be less at the higher density, but volume per acre may well increase, particularly at rotations as short as 9 years. The higher density option was included because it is a commonly used spacing in eucalypt plantations around the world. For our analysis we used a conservative assumption; i.e., that yields at the closer spacing would be the same as yields at the wider spacing. Although we do not have a good estimate of the benefits of closer spacing, the scenario may have importance in evaluating the profitability of a high planting density when high mortality is expected. Plantings on a large scale and at various spacings are needed to develop better estimates of yield, but on balance, the present estimates seem to be conservative.

The discounted benefits (returns) from 5 cutting cycles for mountain and manna guns (E. dalrympleana Maid. and E. viminalis Labill.) are shown in table 7. As the previous section pointed out, it is difficult to assess the stumpage price for eucalypt energy products. Our analysis assumed a stumpage price of $25 per cord, which is close to the stumpage price of $8 per ton for chips. Since stumpage prices for wood products in general are projected to increase at about 1.5 percent annually in real dollars (Haynes, Connaughton, Adams, 1980), a real price increase was included in the calculation of the benefits.

Results

Table 8 shows the benefit/cost ratio, determined by dividing the discounted benefits in table 7 by the discounted costs in table 5. It appears that planting mountain gum on Navy land will return at least 6.2 percent on the investment (the B/C ratio is greater than 1), and even 10 percent at the low planting density. It will not return 10 percent on the investment at the high planting density (the B/C ratio is less than 1), at least with our conservative estimates of yield and liberal estimates of costs.

Table 8--Benefit/Cost ratio for plantations of E. dalrympleana and E. viminalis at the Concord Naval Weapons Station using contract labor.

Seedlings per acre	E. dalrympleana			E. viminalis	
	5 pct	6.2 pct.	10 pct.	5 pct.	6.2 pct
435.6	2.75	2.18	1.16	1.70	1.35
810.0	1.76	1.39	0.75	1.09	0.86

In general, the economic returns used in these calculations were probably conservative. Yields will be higher because coppice growth is more rapid than seedling growth; biologic productivity is probably not maximized at the 435.6 seedling density level which is the limit of this data; and selection within species can be used to improve yields (Ledig, this proceedings). Contract costs are often higher than in-house costs, so the benefit-cost ratios reported may be higher if in-house labor is used. All of these factors suggest the economic outlook for eucalypt production is even better than that summarized in table 8, yet even the present scenario indicates that eucalypt culture is quite profitable.

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