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Use of Net Present Value Analysis to Evaluate a Publicly Funded Biomass-to-Ethanol Research, Development, and Demonstration Program and Valuate Expected Private Sector Participation

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ABSTRACT

One of the functions of government is to invest tax dollars in programs, projects, and properties that will result in greater public benefit than would have resulted from leaving the tax dollars in the private sector or using them to pay off the public debt. This paper describes the use of Net Present Value (NPV) as an approach to analyze and select investment opportunities for government money in public research, development, and demonstration (RD&D) programs and to evaluate potential private sector participation in the programs. This approach is then applied to a specific biomass-to-ethanol opportunity in California.

INTRODUCTION

One of the functions of government is to invest tax dollars in programs, projects, and properties that will result in greater social benefit than would have resulted from leaving those tax dollars in the private sector or using them to pay off the public debt. One traditional area for investment by government is research, development, and demonstration (RD&D) of new technology. According to Battelle, US R&D expenditures reached $164.5 billion in 1994, and federal support represented $69.8 billion (42.4% of the total) *(1)*. If invested wisely, these tax dollars could potentially lead to greater social benefit than would be obtained by leaving them in the private sector or using the money to pay off the federal debt. However, if not invested wisely, this could result in less than optimal benefit or, even worse, in less benefit than could be obtained from the other two

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options. The purpose of this paper is to describe an approach to analyzing and selecting investment opportunities for government money in public RD&D programs and valuating expected private sector participation in the programs and to apply this approach to a specific biomass-to-ethanol opportunity in California.

BASICS OF INVESTMENT ANALYSIS

For all investment situations there are five basic variables: costs; revenues or benefits; time; discount rate; and risk. In the analysis of investment opportunities, the opportunities under consideration may have differences with respect to costs and revenue or benefits, project lives, and uncertainties. If the effects of these factors are not quantified systematically, correctly assessing opportunities is very difficult.

Many methods are available to decision makers to systematically evaluate investment opportunities. These methods, described in detail in a variety of books and articles *(2)*, include present, annual, and future value; rate of return; and break-even analysis. The application of each method depends on whether the analysis is for a single opportunity, two mutually exclusive opportunities, or several nonmutually exclusive opportunities.

Net present value (NPV) is the tool of choice for a evaluating all these situations because it is much less time consuming and is straightforward, allows direct comparison between projects between widely differing lives, objectives, and scopes, and allows a rational approach to valuating private sector participation in public programs.

THE NPV APPROACH

To apply NPV to a single opportunity situation, the NPV is calculated by determining the present value of the revenue/benefit stream calculated at the minimum rate of return (hurdle rate) and then subtracting the present value of investment dollars and other costs, also calculated at the rate of return.

$$\text{NPV} = \text{present value revenues @ } i^* \text{—present value costs @ } i^*$$

where i^* is the minimum rate of return. If the NPV is zero, there is enough revenue to cover the costs at a rate of return that is equal to the minimum rate of return required by the investor. Projects with NPV less than zero are dropped from consideration. If the NPV is greater than zero, the NPV represents how many present value dollars will be returned to the investor above and beyond those that will be returned at the minimum rate of return.

To apply NPV to mutually exclusive investments, one calculated the NPV for each potential project. The project with the largest NPV is selected. If neither project has a positive NPV, neither is selected.

A nonmutually exclusive investment situation is one for which more than one investment option can be selected, depending on available capital of budget restrictions. The objective is to select projects that maximize the cumulative profitability of benefit from the available investment dollars. Here the NPV for each project is calculated. Projects with an NPV less than zero are dropped from further consideration because their rate of return is less than the minimum required return. Once the NPV for each project is calculated, the decision maker looks at all possible combinations of projects to determine which combination (whose total investment does not exceed the amount of money available) has the largest cumulative NPV. This is the best possible investment portfolio.

SPECIAL CONSIDERATIONS FOR GOVERNMENT INVESTMENTS

Converting Intangible Benefits and Costs into Dollar Values

A basic tenant of this paper is that to make rational investments of pubic dollars one must have some approximate, quantitative idea of the value of critical costs and benefits. Moreover, as a practical matter, the measure of value must be the same for costs and benefits so that direct comparisons between costs and benefits can be made. The most universal measure of value is the dollar. In the private sector this is the measure of cost and benefit. In the public sector, particularly with respect to RD&D programs, it is the established measure of cost. However, on the benefit side, there is no established measure of value. The authors contend that the dollar should be the measure of benefit so that direct comparisons can be made with costs and so that the established and the well recognized investments analysis methodology previously can be employed in the public sector.

In many cases, converting benefits and costs to dollars is fairly straightforward. For example, the US Department of Energy (DOE) is interested in reducing imported petroleum. The dollar value of the yearly benefit can easily be calculated from the present and projected price of petroleum *(3)*. As another example, the net annual increase or decrease in jobs that results from introducing new technology can be estimated. In addition, placing a dollar value on these jobs is fairly straightforward *(4)*. Other possible costs and benefits are environmental and social, which are more difficult to quantify. However, various agencies such as the US Environmental Protection Agency have studied these issues carefully and have given dollar estimates of health costs associated with various types and levels of pollution, as an example.

Minimal Rate of Return for Public Projects

Establishing a minimal rate of return for public projects requires some special considerations, which have been reviewed extensively by Terry

Heaps *(5)* for Canadian public projects. He concluded that the correct social discount rate for Canada was 3–7%. In another study performed by Wilson Hill Associates *(3)* a discount rate of 7% was used for projects evaluated for the Office of Transportation Programs in the DOE.

SELECTING PUBLIC RD&D PROGRAMS AND VALUATING EXPECTED PARTICIPATION BY THE IMPLEMENTING INDUSTRY

A government R&D program is usually initiated without the private sector, but the private sector is expected to "come on board" at some point to carry the ball forward into the commercial arena. For these situations, the government and the private sector invest in RD&D to obtain what each desires—maximum overall public benefit in the case of government, and profit in the case of the private companies.

Analysis of the value of these programs demands answers to three questions: What portion of the RD&D cost can the private sector incur and still obtain its minimum return from commercializing the technology?; when this private sector cost allowance is subtracted from the total estimated cost to carry out RD&D so as to obtain an estimate of the RD&D cost that must be borne by government, is the estimated government RD&D cost justified given the expected public benefit from implementing the technology?; and if the answer to questions 2 is positive, does the program represent one of government's best opportunities for its limited investment dollars?

The NPV approach to investments provides the answer to all three questions. For example, to answer the first question one calculates the industry NPV. To do this, one estimates over time the capital and operating costs the industry at large will incur to implement a new technology and, using the average minimum interest rate for the industry, calculates the present value of these costs to industry at the initial time of commercialization. One also estimates over time the present value at the time of commercialization of the expected increased revenues or savings the industry should experience from implementing the technology. Subtracting the present value costs from the present value revenues gives the industry NPV at the time when commercialization is expected to begin. If the NPV is negative, the industry cannot afford to contribute to the RD&D effort and cannot afford the capital and/or operating costs of commercialization. As a result, it will not "come on board" and the government should drop the program from consideration. If the industry NPV is zero, industry cannot afford to contribute to the RD&D costs, but can afford the capital and operating costs to commercialize the technology. In this situation, the government will have to incur all the RD&D costs in order for industry to adopt the technology. If the industry NPV is positive, the government can expect the industry to participate in the RD&D costs at a level equivalent to the NPV.

To answer the second question, one calculates the government NPV. To do this, the expected public benefits are estimated over time and dollar values are assigned. Then the present value of these benefits is calculated at the time of commercialization using the social discount factor. Next, the entire RD&D costs over time are estimated and present-valued to the time of commercialization using the social discount factor. Finally, the expected RD&D contribution from industry, calculated above as industry NPV, is subtracted from the entire RD&D costs to obtain the government's expected RD&D costs present valued to the time of commercialization. These present-valued government RD&D costs are then subtracted from the benefits, also present-valued to the time of commercialization, to obtain the government NPV for the program. If the government NPV is less than zero, the program should not be considered for investment of tax dollars. If the government NPV is zero or greater, it should be thrown into the pot of possible government investments.

To answer the third question, government should list all investment options with a NPV greater than zero and select that combination of projects that will maximize the governments cumulative NPV for the amount of funds available.

VALUATING EXPECTED PARTICIPATION BY INDIVIDUAL COMPANIES

If, from the above analysis, the industry NPV is positive, individual companies that are members of the industry can be expected to cost share in the RD&D phase of a program or purchase licensing arrangements. However, the level of cost sharing or license fees will depend on each company's circumstances. The expected level of cost sharing or the licensing fee for a given company can be calculated using company NPV derived from projected revenues and costs a company will experience in implementing the technology in commercial use. If the company NPV is negative, the particular company cannot afford to commercialize the technology even if the technology is provided free. Such a company is not a viable partner to the government program. If the company NPV is zero, the company may be a partner only in the sense that it will implement the government-developed technology if it is free to the company. If the company NPV is positive, the company can afford to cost share the RD&D effort or purchase a licensing arrangement at a level equal to the company NPV.

BIOMASS-TO-ETHANOL OPPORTUNITY IN CALIFORNIA

Background

California is faced with several issues related to how its forest resources are used and managed. In particular, forest fire suppression has caused large quantities of small-diameter and dead and diseased trees and underbrush to accumulate in the forest, which have in turn resulted in severe fuel loads that have led to ever more intense and destructive wildfires. Unabated, this pattern will continue to worsen, and will create greater risk and loss to natural resources, property, and firefighters. In addition, the costs to government for fire suppression and disaster relief will grow at a time when government is trying to curtail costs and reduce budgets. To deal with this issue, the USDA Forest Service, the California Department of Forestry, and local organizations such as the Quincy Library Group have put forth a plan to strategically thin the forests to reduce total wildfire costs and losses. In addition, such a plan would significantly increase the total amount and value of certain assets such as water and timber. However, a key question is what will be done with the forest thinnings once they are removed from the forests. One potential use of the biomass is to convert it into fuel ethanol and cogenerate electricity.

Public Benefits of Thinning Commercial Timberland in California

There are approx 16 million acres of commercial timberland in California. Of this, about 13 million acres are at a slope of 30° or less, which is a requirement for thinning the forest at a reasonable cost *(6)*. Thinning 5% of the 13 million acres each year results in thinning 650,000 acres of forest. The public benefits associated with thinning these acres are: reduced costs of wildfire protection: reduced loss of assets from wildfires: and increased water and timber asset values.

Reduced Costs of Wildfire Protection

Table 1 summarizes the estimated 1993–1994 state, federal, and local government's costs of California's wild land fire protection system. The chart further identifies wild land fire protection phases—initial attack, major fires, and disaster relief—for each level of government.

There are 40 million acres of forest in California. Since 650,000 acres is approx 2% of the acres of forest, we assume that thinning this number of acres will reduce the cost of fire protection by the same percent or $23/acre thinned, and that this effect will last as long as 5 yr after which the effect is lost as the foliage returns.

Reduced Loss of Assets from Wildfires

A primary purpose of wild land fire protection in California is to protect a wide range of assets found in California wild lands. These assets include: timber; range; water and watershed; buildings; human life and safety; air quality; wildlife, plants, and ecosystem health; scenic areas; recreation; and cultural and historic resources. Table 2 shows the total value

Table 1
Wild Land Fire Protection Budgets by Level of Government by Fire Phase *(7)*
($ thousand)

	Initial Attack	Major Fire	Disaster Relief	Total
Total Federal	$132.00	$85.00	$92.00	$309.00
Total State	208.00	45.00	13.00	266.00
Total Local	170.00	1.00	1.00	172.00
Total	$510.00	$131.00	$106.00	$747.00

Table 2
Total California Assets at Risk from Wildfire *(7)*

Asset Type	Total Value
Timber	$105 billion
Range	$138 million/yr.
Water/Watershed •Increased runoff -residential/commercial/industrial use (6 million acre ft.) -agriculture (24 million acre ft.) -hydropower	 $3 billion/yr $1.5 billion/yr $1.6 billion/yr
Structures	$107 billion
Human life/safety	(1)
Air quality	(1)
Wildlife, habitat, plants, ecosystem health	(1)
Scenic resources and recreation	(1)
Recreation	$1.5 billion/yr
Unique sites	(1)

of each of these assets at risk and Table 3 shows the estimated loss on a yearly basis or per-acre burned basis from wildfire. The estimates for loss for each asset on a per-acre burned basis cover a range of values, which depend on the location of the asset. For example, the timber value lost is estimated to range from $2538/acre in the northern interior to $8823/acre on the central coast.

Table 4 shows the estimate for total aggregate asset loss in California on a yearly basis due to wildfire.

As noted earlier, the total forest land in California is 40 million acres. This study assumes that thinning 650,000 acres will reduce asset loss by 2%/yr or $14/acre thinned and that this effect will last as long as 5 yr, after which the effect is lost as foliage returns.

Table 3
Asset Losses in California from Wildfires

Asset	Asset Losses from Fire
Timber	($2,538-$8,823/acre burned)
Range	($8/acre burned)
Water/Watershed -increased residential/commercial/industrial/agricultural water -increased hydropower -reduced reservoir capacity from sediment -sediment removal -water shed rehabilitation	 $3-$12/acre burned (1) $17.50/acre burned (1) ($9-$90/acre burned) ($100-$1,000/acre burned (1) ($230-$400/acre burned) (1)
Structures	$163 million/yr.
Human life/safety	(2)
Air quality	($1-$15,000/acre burned)
Wildlife, habitat, plants, ecosystem, health	(2)
Scenic resources	(2)
Recreation	$5-$107/acre burned
Unique sites	(2)

Table 4
Total Asset Losses Per Year in California Due to Wildfire According to Who Pays *(7)*

Federal	$235 million
State	$54 million
Local	$164 million
Total	$453 million

Increased Water and Timber Asset Values

Thinning forests will probably result in increased water yields. Based on a 1991 report by Ken Turner of the California Department of Water Resources *(8)*, when 75%+ of the vegetation is removed, increased water yields can occur of 0.1 acre feet per acre in areas of 15 in of precipitation annually, up to 0.8 acre feet on acres of 40 in of precipitation annually for the first few years after the vegetation is removed. For the purposes of this report, the average increase is assumed to be 0.25 acre feet per acre thinned.

The value of each new acre foot of water depends on its use. However, on average the value of this water for agricultural, residential, commercial, and industrial use is estimated to be $60 per acre foot and the value for hydropower is estimated to be $70 per acre foot *(7)*. At best, 50% of the increased water yield would be stored for consumption, so the value of the increased water from thinning is estimated to be $16.25/acre thinned. Thus, thinning 650,000 acres will result in $10.5 million in new asset value. Furthermore, this effect is assumed to last as long as 5 yr, after which the effect is low as foliage returns.

Timber growth rates after thinning can return a very high rate of return. Indicators are that annual tree growth can increase by as much as 5–200% or more per acre *(9)*. Although increased timber asset value would clearly be a benefit of thinning, no attempt was made in this study to estimate this increased value.

Expenses and Revenues Associated with Ethanol Facilities That Would Utilize Thinnings from Commercial Timberland in California

Thinning 650,000 acres of forest will yield 3.25 million dry tons of biomass. For this study, we have assumed that this biomass can be converted into 240 million gallons of ethanol. Twelve ethanol plants with an average annual ethanol production capacity of 20 million gallons could produce this amount of ethanol. For this study, certain assumptions were made about the operation and economics of each 20 million gallon per year facility. The key assumptions are: capital costs of $2/annual gallon; O&M costs of $6.1 million/year; and biomass costs at $40/dry ton. These assumptions and others are shown in the block flow diagram in Fig. 1. It is important to note that these assumptions do not presume any particular technology and are not based on detailed engineering and economic analyses.

RD&D Costs

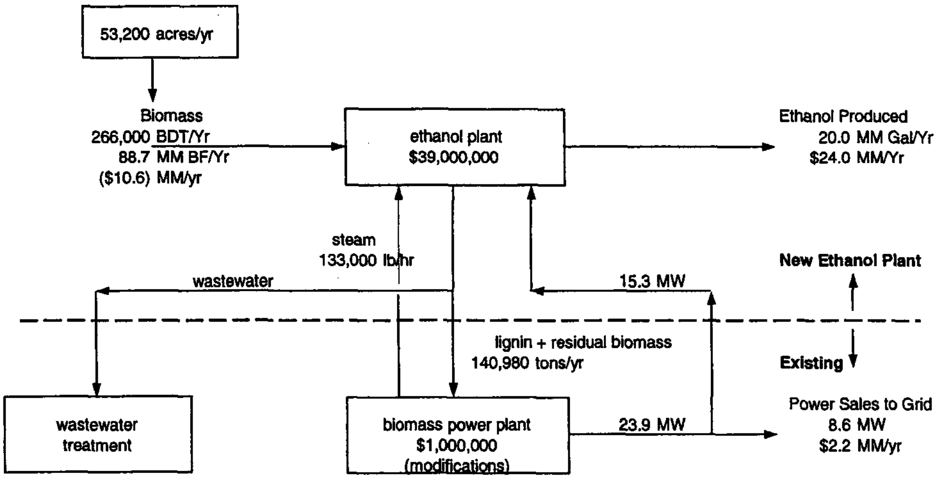
The total RD&D cost is an estimate of the funds needed to extend current knowledge of biomass-to-ethanol technology to the specific opportunity in California. The costs are assumed to be $45 million. The capital contribution to a demonstration plant is an estimate of funds needed to allow the operation of this 20 million gallon per year facility at a 20% rate of return. This contribution is estimated at $20 million. Thinning demonstration costs are funds needed to fully establish thinning methodologies. Total thinning demonstration costs are estimated at $20 million.

Benefits, Revenue, and Cost Streams Over Time

Table 5 shows ethanol and electricity revenue, capital investment, operating costs, increased water values, savings from reduced costs of

BIOMASS TO ETHANOL CONVERSION

Co-location with an Existing Biomass Power Plant and Wastewater Plant in CA



MM = million BDT = bone dry ton BF = board feet

ASSUMPTIONS:	
Biomass conversion rate	75 gal/BDT feedstock
Operating days per year	350 days/year
On-stream %	96 %
Feedstock cost	$40 per dry ton
Ethanol selling price	$1.20 per gallon
Lignin heating value	9,600 MM BTU/lb
Electricity selling price to grid	0.03 per kwh
BDT per 1,000 board feet	3.0 BDT/1000 BF
Biomass power plant efficiency	13,500 BTU/kWh

ETHANOL PLANT INCOME SUMMARY (millions)	
ethanol sales	$24.0
power sales to grid	$2.2
feedstock cost	($10.6)
O&M costs	($6.1)

Fig. 1. Biomass to ethanol conversion. Colocation with an Existing Biomass Power Plant and Wastewater Plant in CA.

wildfire protection, savings from reduced loss of assets from wildfires, and RD&D costs associated with developing and operating 12 biomass-to-ethanol plants in California. The first two commercial plants are completed in yr 0. After that, two commercial plants are brought on stream each year for the next 5 yr, starting in yr 1. As noted earlier, the water yield increase and savings from reduced costs of wildfire and reduced loss of assets from thinning are assumed to last as long as 5 yr, after which the benefit begins to decline. For example, for a given plant, the increased water yield is 12,960 per acre foot for the first year from the thinning operations of that year. For the second year, the increased water yield is that from the first year plus that resulting from the thinning operations of that year. For the second year, and so on until yr 5 is reached. After yr 5, it is assumed that the first thinned acres begin to fill in with biomass and water yields from these areas begin to decrease, thereby negating the effects of new thinning operations that continue to provide increased water yields. Thus, for each plant, water yield increases and savings from reduced costs of wildfire and reduced loss of assets increase each year for

Table 5

Public Benefits, Industrial Revenues, Industrial Costs, and RD&D Costs Associated with a California Biomass-to-Ethanol Industry

Years	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Public Benefits																				
Reduced Wildfire Cost (Million $)						2.5	7.5	15	25	38	50	60	67.5	72.5	75	75	75	75	75	75
Reduced Loss from Wildfire (Million $)						1.5	4.5	9	15	22	30	36	40.5	43.5	45	45	45	45	45	45
Value of Increased Water (Million $)						1.8	5.3	10.5	17.5	26	35	42	47.3	50.8	52.5	52.5	52.5	52.5	52.5	52.5
Total Public Benefit (Million $)						5.8	17.3	34.5	57.5	86	115	138	155.3	166.8	172.5	172.5	172.5	172.5	172.5	172.5
Industrial Revenue																				
Ethanol Revenue (Million $)						48	96	144	192	240	288	288	288	288	288	288	288	288	288	288
Electricity Revenue (Million $)						4.4	8.8	13.2	17.6	22	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4
Total Ethanol & Electricity Revenue (Million $)						52.4	104.8	157.2	209.6	262	314.4	314.4	314.4	314.4	314.4	314.4	314.4	314.4	314.4	314.4
Industrial Costs																				
Capital Investment for 12 Commercial Plants(Million $)					80	80	80	80	80	80										
Operating Costs for Demonstration and Commerciall Plants (Million $)						33.4	66.8	100.2	133.6	167	200.4	200.4	200.4	200.4	200.4	200.4	200.4	200.4	200.4	200.4
Total Commercial Investment & Operating Costs for Demonstration and Commercial Plants (Million $)					80	113.4	146.8	180.2	213.6	247	200.4	200.4	200.4	200.4	200.4	200.4	200.4	200.4	200.4	200.4
R.D&D Costs																				
Technology R&D	10	20	10	5																
Capital Contribution to a Demonstration Plant to Allow the Operator to Obtain a 20% Rate of Return or an NPV = 0			10	10																
Thinning Demonstration	4	4	4	4	4															

Table 6
Industry Net Present Value

	Present Value at Time Zero @ Discount Rate of 20% (Million of $)
Revenue	
• Total ethanol & electricity	943
Costs	
• Total commercial investment for commercial plants and operating costs for 11 commercial plants and demonstration plant	920
Net Present Value = $23 million	

5 yr and then level off. In addition, for this study the public benefits associated with the demonstration plant are ignored.

NPV Analysis

The industry NPV was established by calculating the present value at the end of yr 0 of the total ethanol and electricity revenues at a discount rate of 20% ($943 million) and subtracting the present value at the end of yr 0 of the capital investment for 12 commercial plants and the operating costs for all 12 plants ($920 million). The NPV was +$23 million as shown in Table 6. This means that industry could contribute $23 million to RD&D or construction, or both, of the first demonstration plant and still obtain a 20% return from its commercial operations.

The government NPV was established by calculating the present value of the public benefits produced at a 7% discount rate ($945 million) and then subtracting the present value of the RD&D costs at a 7% discount rate ($95 million) less the expected contribution from industry ($23 million). The government NPV is $873 million as shown in Table 7. In other words, an investment of $72 million ($95 − $23 million) on the part of government and RD&D will potentially provide a 7% return plus $873 million in present value.

Discussion

This NPV analysis suggests that the public benefit realized from thinning the 13 million acres of California's commercial timberland overwhelmingly compensates for the RD&D costs associated with the development of thinning and ethanol production operations. Because not all public benefits were estimated in this analyses, this conclusion might be considered conservation. When other benefits are considered (enhanced

Table 7
Government Net Present Value

	Present Value at Time Zero @ Discount Rate of 7% (Millions of $)
Revenue	
• Public Benefit	945
Costs	
• R&D capital contribution to a demonstration plant to allow it to operate at 20% return, and thinning demonstration costs	95
Net Present Value with Industry Participation = 945-(95-23) = $873 million	
Net Present Value Without Industry Participation = 945-95 = $850 million	

wildlife, habitat and ecosystem balance; increased timber value; jobs; reduced dependence on foreign energy; improved air quality; etc.), the rationale for public investment will become even more compelling.

ACKNOWLEDGMENT

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