

BENEFIT-COST ANALYSIS OF A  
REGIONAL ENERGY STRATEGY:  
UMD COAL GASIFICATION

By

JERROLD M. PETERSON & RICHARD W. LICHTY \*

\*The authors are both Associate Professors in the Economics Department  
at the University of Minnesota, Duluth

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Until very recently the choice of energy sources has remained a private decision. Institutions, both private and public, decided on the energy source to provide space heating electric generation or locomotion based on the private benefits and private costs of the alternatives available. The decision maker compared the private benefits and private costs of alternative energy strategies and chose the strategy which provided the greatest benefits for the least cost. Often this decision was based on the profitability of the energy strategy. Recently, it has become apparent that these private decision have externalities which transcend the institutions making the decisions. National and regional energy crises have shown that energy decisions of one institution can, and do, affect many other institutions within society. These energy decisions ought to be evaluated, utilizing benefit-cost analysis before adopting a particular strategy.<sup>1</sup> This paper explores the theory and applications of traditional benefit-cost analysis to a particular regional energy problem.

In this paper the authors explore the problems of using benefit-cost analysis to evaluate the University of Minnesota's decision to install a low BTU coal gasification plant, LBG, to provide gas and oil to fuel its steam boilers and provide space heating at its Duluth Campus. At the present time, UMD uses a combination of natural gas and number five fuel oil to fire its boilers. Unfortunately, Northeast Minnesota faces the dual problem of dwindling natural gas supplies and reduced availability of fuel oil. The natural gas shortage is a

national problem, but the fuel oil shortage is regional. The fuel oil shortage is being caused by Canada's current petroleum export embargo. As a result, the University of Minnesota with the Department of Energy has decided to install a LBG plant to reduce the likelihood of energy interruption for University operation.<sup>2</sup>

The paper itself is divided into three parts. In the first part the authors attempt to identify the private benefits accruing to the University from installing a LBG plant. The second part of the paper attempts to identify the social impacts of this decision. In this section the authors use input-output analysis and SIMLAB to hypothetically measure the social benefits of this energy strategy. In the final section of the paper the authors use benefit-cost analysis to evaluate the overall effectiveness of the LBG energy strategy. The basic goal of this paper is to explore the theoretical and application problems of utilizing benefit-cost analysis to evaluate a regional decision.

#### I. PRIVATE BENEFITS OF LOW BTU COAL GASIFICATION

In theory, any institution, public or private, installing a low BTU coal gasification plant will anticipate receiving at least two direct benefits after the conversion to this energy source. First, the institution will be better able to take advantage of fossil fuel price differentials which occur over time. Once installed, an institution can purchase either coal, natural gas, or petroleum to meet its space heating needs. The purchase of a particular fuel will depend on that fuel's price advantage. Second, the institution will anticipate fewer interruptions in its operation after installation due to energy shortages since the institution has more fuel options from which to choose.

Initially, many private and public institutions considering installing a coal gasification unit will be concerned about the present and future price differentials between gasified coal, natural gas, or petroleum. As natural gas becomes relatively more scarce, the price spread between natural gas and low BTU coal gas should narrow. In 1976 industrial natural gas was selling at an average price of \$1.32/MMBTU while clean LBTU gas was estimated at \$3.55/MMBTU.<sup>3</sup> Although the current price spread between natural gas and LBTU gas seems very unattractive, some of the price differential is tied up in the capital costs of the gasification plant. Estimates suggest that these capital and operating costs on the gasification plant account for about 50 percent of the total cost of the gasification process. The cost of fuel accounts for only 50 percent of the total cost of energy. In fact, if both natural gas and delivered coal prices rise at the same rate while operating costs of LBG plant remain constant, the price differential will dramatically change.

To illustrate the importance of the price differential, a simple mathematical model is developed beginning with Equation 1.<sup>4</sup> In this equation "a"

$$\frac{\partial P}{\partial t} = aP - bP = \lambda P \quad (1)$$

is the percent of growth of the price of gasified coal in MMBTU and "b" is the percent of growth of natural gas prices in MMBTU per unit of time. Here  $\lambda = a - b$  and a, b, and  $\lambda$  are constant. The solution to 1 is given in Equation 2:

$$P = P_{(0)} e^{\lambda t} \quad (2)$$

In this equation  $P_{(0)}$  is the price differential at time  $t = 0$ , say 1975. If a, b, and therefore  $\lambda$  are functions of time, the solution to 2 is Equation 3:

$$P = P_{(0)} \exp \int_0^t \lambda(t) dt \quad (3)$$

If  $\lambda > 0$ , that is if the price change of LBG exceeds the price change of natural gas, the price differential becomes infinite. If  $\lambda = 0$ , the price differential between the LBG and natural gas remains constant. On the other hand, if  $\lambda < 0$ , the growth rate in the price change for natural gas exceeds the price change of coal and the price differential falls to zero, and given enough time, becomes negative.

While no forecast has yet been made which suggests that at any given point in time the price differential between natural gas and LBG will be negative for new LBG plants, it seems likely that under current economic circumstances the price differential will narrow rapidly for plants that are in place. The LBG process is capital and labor intensive with 50 percent of its total cost tied up in labor and capital costs. Suppose all energy prices rise at the same rate so that the price of coal and natural gas both rise at the rate of, say 10 percent per year. For simplicity, assume that all other costs remain constant. In this situation the rate change of the price of LBG would be 5 percent per year, while natural gas would be 10% per year. If LBG gas is 100 percent more expensive than natural gas today, in a little more than 14 years that differential will be near zero. If the rate of growth of natural gas prices is greater than the rate of growth of LBG prices, the LBG process will be less expensive than natural gas at some time in the future. The gap between LBG prices and natural gas narrows more rapidly if the price of natural gas rises more rapidly than coal. If natural gas is in shorter supply than coal, the price of natural gas, if unregulated, seems likely to rise more rapidly than coal under future supply and demand conditions.

Although the narrowing price provides incentive for installation of an LBG plant, private institutions have a second equally important reason for the possible adoption of a LBG plant. The installation of an LBG plant may provide

the institution with protection against interruptions in its operations during severe energy shortages. If the institution can maintain its operations during periods of energy shortages, this continuous operation is likely to be very profitable for a private institution or very beneficial for a public institution. It seems likely, although not assured, that institutions which maintain or increase their activities during shortage periods will provide direct and measurable benefits to society. Institutions, such as; electric utilities, private and public transportation, hospitals, schools, and essential manufacturing facilities, which maintain normal operations during energy shortages, will help to maintain stable economic and social conditions for urban, regional, and national economies. For a private institution these benefits will most likely be reflected in higher profits. While for public institutions these benefits could be measured as social benefits accruing to the recipients of the provided public services.

In the UMD example, if college education is provided uninterrupted during periods of energy shortages, college students will find that they can complete their education within a prescribed time frame and begin their lifetime careers on schedule. The University will find that continuous academic operations are essential to attracting quality students and faculty. It seems likely that students and faculty will be wary of coming to a university that is constantly altering its operations because of energy or other types of disruptions. Collegiate institutions which can maintain their operations during periodic energy shortages will likely be more attractive research and educational institutions. These collegiate institutions ought to be particularly attractive during energy crises. Thus, if the annual net benefits of UMD educational services were typically measured at \$1 million during normal times, the continued provision of these services during an energy shortage would increase in value to, say,

\$2 million. This increase in net benefits occurs because other educational institutions may be forced to curtail or cease their operations. This shortage of educational services would increase the value of UMD's services to society.

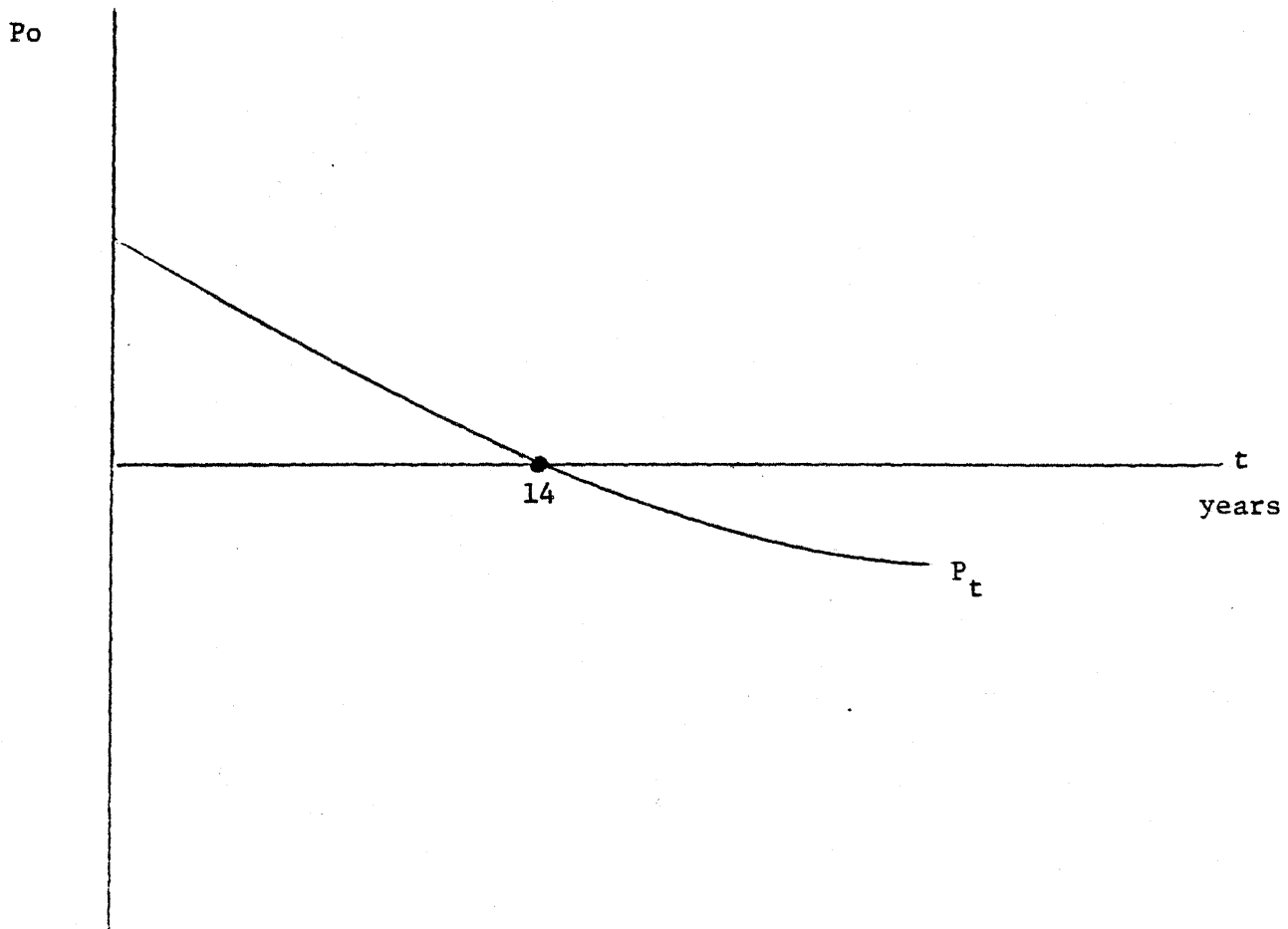
A private institution evaluating an investment in a LBG plant would compare the cost savings from the narrowing price differential and the profit expectations from maintenance of uninterrupted service with the investment in the LBG plant. Before deciding to invest in a LBG plant, a decision maker would attempt to determine the expected value of the investment project. If the LBG plant is built, the institution will experience greater energy costs during normal energy supplies. The benefits or profits of the institution will fall at least during the early years of the investment project. On the other hand, if the LBG plant is built, the institution will experience greater profits or generate greater benefits during energy shortages. Thus, a decision maker needs to know the probability of future energy shortages to calculate the expected values of profits or benefits of this project.

If these probabilities were estimated as .8 for normal energy supplies and .2 for an energy shortage for any given year, a decision maker could develop a decision tree to estimate the expected value of installing a \$3,500,000 gasification plant at UMD. (See Figure 1.)<sup>5</sup> Suppose that for any normal energy year the University has a 60 percent probability of conferring one million dollars in net educational benefits on society and 40 percent probability of conferring a net education loss of one million dollars without the installation of the LBG plant. If the plant is installed, the probabilities of conferring net education benefits fall to 50 percent and the possibility of a loss rises to 50 percent given normal energy supplies. This decline in the probability of conferring educational benefits results from the increased energy costs during the early life of the LBG plant. On the other hand, the University will be

Figure 1

Price Differential  
Between LBG/Natural Gas  
for Plants Installed Today

Price Differential



able to continue operation during an energy shortage. The value of the educational benefits or losses hypothetically rise to \$2 million and the probability of generating these benefits also rises hypothetically to .9 while the probability of losses falls to .1. Under these probabilities the annual expected value of the LBG project is \$320,000 as shown in Figure 2.

If the University were left alone in this decision, they would have to compare this annual expected value of the LBG plant with investment cost of the LBG plant. In essence, the University administration would or should estimate the projects marginal efficiency of investment,  $Mei$ . If these administrators found that  $Mei > r$  were greater than the market rate of interest  $r$ , they should install the LBG plant as all standard capital theory suggests. Naturally, if the  $Mei < r$  these administrators would reject this energy strategy as unprofitable. In Figure 2 the  $Mei = 9.1\%$ . Under these hypothetical conditions the University would install the LBG plant if they could borrow \$3.5 million at an interest rate less than 9.1%. The University might seriously consider rejecting this strategy given the current financial interest rate structure and the University or state government's ability to borrow these funds at favorable interest rates.

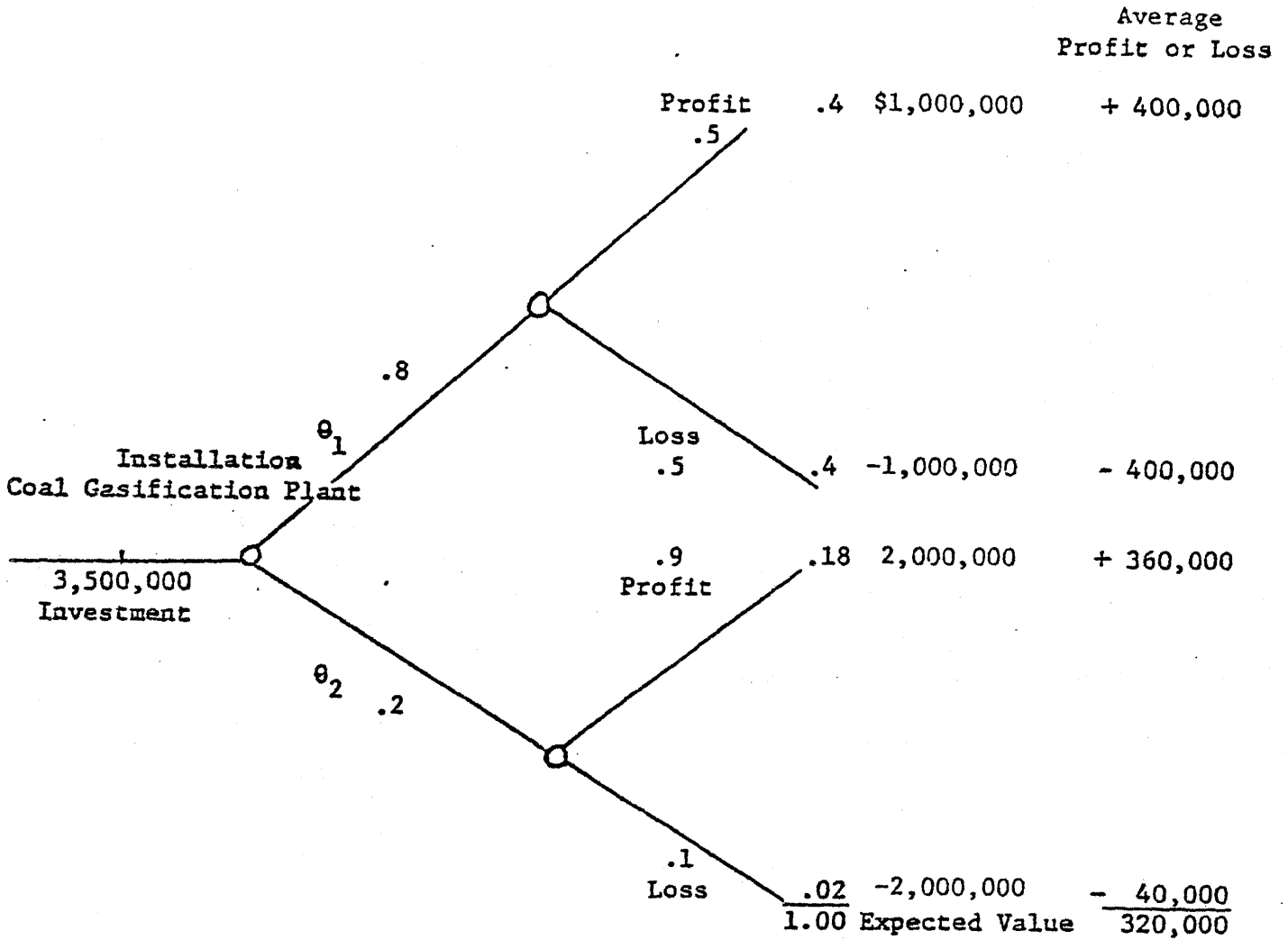
## II. ESTIMATING THE SOCIAL BENEFITS

### OF THE LBG STRATEGY

Before society allows the University to reject the LBG strategy, society should consider the social or indirect benefits of installing an LBG plant at UMD. Society has become increasingly aware of the interdependency of various industries and institutions on particular energy sources. The social benefits of adopting the LBG strategy can be measured as the impacts such a strategy may have on other industries or institutions. Society will find that the continuous

Figure 2

Decision Tree for Private Institution



$$\frac{R}{I_g} = i \quad \frac{320,000}{3,500,000} = .091$$

Present Value of Investment \$3,200,000 =  $\frac{320,000}{.1}$   
 Compared to Cost of Investment

operation of the University will benefit both industries or institutions supplying inputs and demanding outputs. The indirect or social benefits of implementing an energy strategy can be measured in terms of the increased profits or benefits conferred upon industries, firms, or segments of society which have close economic ties to the University. Since the recipient institution would be less vulnerable to energy related slow downs, this institution will not cause serious bottlenecks to develop as the result of energy shortages. Supplying firms will find that their operations are not subject to disruption because of the shut down or slow down of a major customer. These supplying firms will be able to continue operations during energy shortage periods and thus should be able to generate excess benefits for society. At the same time, institutions demanding the recipient institution's output as an input in their production will face less disruption because of the loss of these inputs during periodic energy shortages.

The social benefits of a particular energy policy can be measured in terms of the increased benefits generated by industries supplying inputs or demanding outputs from the recipient industry. These social benefits may be measured as increased profits generated to private firms or increased social benefits generated for the public institutions and may be measured using input-output analysis. Input-output analysis has long been recognized for its capabilities in economic impact assessment, in the analysis of bottlenecks to area economic expansion, and in linking social as well as physical components of large scale simulation models to area economic structure on change.<sup>6</sup> It is certainly less well known as a component of cost-benefit analysis. This latter use of I/O might be quite beneficial, however, as cost-benefit analysis requires measurable estimates of changes in an economy that result from a given policy alternative, and these changes are known to be larger than the direct effects that stem from an assumed policy change.

The input-output methodology would be used in conjunction with a larger analytical data bank system. Such a system could adjust the I/O model through assumed changes in other components of the data bank system or could look at changes in these other components that are linked to changes in the final demand for the region's outputs and that occur on a result of exogenous forces operating on the local economy. In short, the number of measurable effects increase with such data analysis with the added benefits of having consistent projections as between the various identified system components.

One system of this type is that of SIMLAB, currently being developed by Wilbur Maki, University of Minnesota, St. Paul. SIMLAB represents a modular approach to regional simulation, with a potential set of twelve modules--market, demand, production (input-output), investment, value added, employment, labor force, population, household, fiscal, ecology, and energy. The model is based on annual data sources and employs the interconnection of the regional economy and national economic trends for its "all other things equal" projection series.

The input-output component of the SIMLAB system uses a common data base, that of the U.S. input-output system, for all regions for which the system is developed. The derived input-output table is a two-region model that highlights the relationship of the regional economy to the rest of the nation through a detailed set of imports and export matrices.<sup>7</sup> This leads to one of the central concerns of regional analysis and planning, that is the concern about unanticipated side effects of alternative energy development decisions. This is the so-called social cost element of economic life that is rarely measured but is a direct outgrowth of private and public

development decisions. In order to get at these side effects, winners and losers of particular energy allocations need to be identified in advance of actual decisions. This needs to be accomplished in terms of trade-off possibilities and alternative allocation schemes, i.e., through a cost-benefit framework.

SIMLAB is capable of such winner and loser identification and is flexible enough to allow for alternative system analysis. Various impacts are assessed in a simulation format against the "other things equal" or baseline trends of the economy. Gainers and losers are, therefore, identified in terms of their potential under a "do nothing" strategy as well as an absolute or actual basis.

The input-output components of the model itself help to identify the structure of the economy, including the energy component. The input-output coefficients are capable of being converted into energy coefficients, expressed in common BTU units, so that the direct and indirect impacts of alternative developments can be assessed. The baseline series is analyzed on the basis of current and past trends. This series represents the potentials of the economy in the absence of exogenous shocks, such as the curtailment of energy supplies, on the local economy. All "shocks" are measured against this potential. Such a procedure can identify these shocks as a yearly basis for inclusion in the cost-benefit time frame. They may be positive or negative, depending on the chosen alternative on the group being impacted.

There are three time periods that are capable of analysis. The short-range relates to current energy supplies and technologies. The input-output system is particularly good at such a time frame projection set as there is little change in the economy's structure during this time and, therefore, little concern over the restrictive assumptions of an I/O table. The intermediate range encompasses the energy conservation policy potentials as well as the incorporation of existing and known energy production technologies, such as

the UMD coal gasification plant. These technologies will adjust the input-output coefficients according to the new and expected structural changes in the economy. The long-run takes into account the development of new technology and the discovery of new energy sources. The complete restructuring of a simulation system may be required for such long term and unpredictable results.

The SIMLAB model is currently not in operation at the urban level for Duluth and Superior, the region most apt to be impacted by a UMD coal gasification plant. It is being developed, however, for eventual implementation in the analysis of tourism in Northeast Minnesota and for other general planning purposes. Part of that development includes the construction of the two-region input-output model, which has been accomplished at this point in time. This two-region model, although not ideal in many respects, can serve to partially demonstrate the techniques involved in using such models for cost-benefit component identification. The eventual plan is to expand this analysis to incorporate the entire SIMLAB system for short and intermediate term analysis of the coal gasification process and its effects in the Duluth-Superior area.<sup>8</sup>

As an early indication of the impact procedure to be used in a cost-benefit framework, the current impact of UMD was assessed in a related paper. In that paper, it was noted that:

Any institution that is functioning within a regional economy exerts its impacts at many different levels. Each industry, in order to produce its own output, must relate to other industries in the area to secure intermediate products and to sell its own group of semi-finished goods and services.<sup>9</sup>

The direct impact coefficients, the direct dollar impact, and the direct and indirect dollar impact from UMD's operation during the school year 1974-1975 are summarized in Table I. This is based on a UMD budget of \$19,841,991 and a student enrollment of 5,528 students. If the budget allocation is based at all on enrollment, a ratio of students to the budget might be used for the projection of the baseline impacts of UMD on the regional economy.

Table I  
 Projected Interindustry Impact of UMD  
 (all other things equal)

Industry	Direct and Indirect Coefficient	Direct and Indirect Impact (Estimated)
Construction	.0095	\$ 246,443
Food and Kindred	.0249	645,939
Lumber, Furniture	.0005	12,971
Pulp & Paper	.0007	18,159
Printing & Publishing	.0034	88,201
Chemical, etc.	.0008	20,753
Petrol Refine	.0027	70,042
Stone, Clay, Glass	.0002	5,188
Primary Metal	.0001	2,594
Fabricated Metal	.0003	7,782
Machinery	.0008	20,753
Electrical	.0013	33,723
Other Manufacturing	.0011	28,535
Railroad	.0007	18,159
Trucking	.0012	31,130
Other Transportation	.0029	75,230
Communication	.0047	121,924
Electrical Utilities	.0389	1,009,118
Gas Utilities	.0039	101,171
Other Utilities	.0027	70,042
Wholesale	.0375	972,800
Retail	.0201	521,421
FIRE	.0060	155,648
Hotels, Personal Service	.0087	225,690
Business Service	.0094	243,849
Medical, Education	1.0252	26,595,062
Other Services	.0013	33,724
Federal Gov't	.0105	272,384
State, Local	.0067	173,807
<b>TOTAL</b>	<b>1.2266</b>	<b>\$31,822,224</b>

Source See Appendix I

Using the estimate of \$3,590 in budget allocation per student and applying that figure to the official enrollment projection estimates for the institution to the year 1980 (Appendix II) given an anticipated UMD budget for that year of \$25,941,340. Taking that figure times the column of direct and indirect coefficients, as was done before, given a total new impact of \$31,822,224 that is broken down in the matter specified in Table I.

This estimate, then, serves as the baseline against which opportunities gained or lost can be measured. For example, if the reported budget was spread evenly over a twelve month period, the loss to the construction industry that results from a one month energy shortage close down of the school would be  $.0833 \times \$25,941,340 \times .0095$  (the latter number being the direct and indirect education column coefficient for construction), or \$20,537. This leaves the potential annual impacts of UMD on that sector as \$225,906, the corrected baseline projection for that sector.

The social benefits of UMD's LBG plant can be estimated by extending the baseline projections to each of the 28 affected industries shown in Table I. Assuming that an energy shortage closed down UMD for one month, the direct and indirect impacts of this eventually would  $.0833 \times \$31,822,224$  or \$2,650,791. Thus, the social costs of closing UMD down for one month could be estimated at \$2.7 million.

### III. BENEFIT-COST ANALYSIS OF UMD LBG PLANT

The annual net benefits of a particular energy strategy depend on both the direct or private and indirect or public benefits generated by the strategy. As discussed in Section I, the average direct benefits accruing to the recipient institution depend on the profitability of installing the new energy source. Thus, the profitability can be estimated by determining the price differential

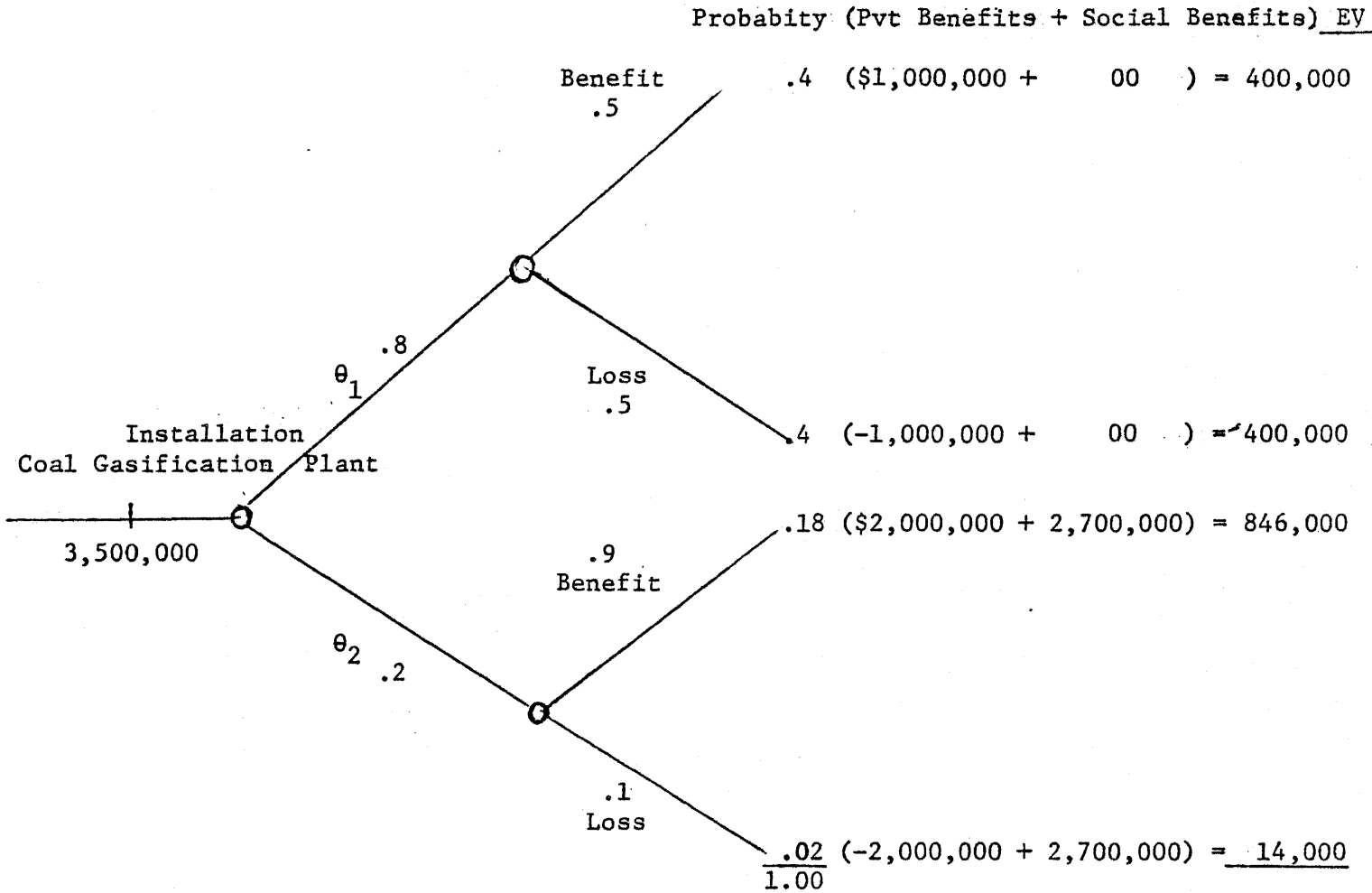
between alternative energy sources and the potential of maintaining operations during an energy crisis. As shown earlier, the price spread between natural gas, oil, and LBG process will most likely narrow and possibly move in LBG's favor sometime in the future for existing LBG plants. If LBG becomes less expensive than natural gas, the price spread will be looked on as an incentive to install the process now. In addition, the unit decision maker will have a second incentive for installing the LBG process. The second incentive is the possibility of reducing operational interruptions during energy shortages. If maintenance of operation during these period shortages is shown to be more profitable or beneficial than interruptable operations, then the decision maker will have further incentive to install the LBG process. However, as suggested in the earlier section, the private decision maker may find that the incentive to install the process while positive may be too weak to make the installation worthwhile.

In addition to these direct benefits, the energy strategy may generate sizable social benefits. As pointed out in the last section, these social benefits may come in the form of the maintenance of operation of auxiliary industries during energy crises. If these industries continue operation during energy shortage, they may be able to generate sizable social benefits. These social benefits will accrue to institutions other than the recipient industry. The recipient industry decision makers, therefore, would ignore these benefits, but society cannot. Society should evaluate the energy strategy based on both the private and social benefits of strategy and the probability that these benefits will materialize.

In the UMD, example the expected value of the social benefits of installing a LBG plant is calculated in Figure 3. In this decision <sup>tree</sup> the probabilities of an energy crisis and profits and losses remain as they were in the previous section.

Figure 3

Hypothetical Decision Tree for Social Benefits



In addition, the private benefits of installation of the LBG plant also remain the same. However, the social benefits which are estimated if an energy crisis occurs are included in this decision tree. Under normal times there are no social benefits of installing the LBG process because energy does not limit UMD's operation. Thus, the expected value of this strategy under normal conditions remains constant.

In an energy crisis, however, the LBG plant being installed at UMD hypothetically could generate \$2.7 million in social benefits as suggested by the SIMLAB projections made in previous section of this paper. These social benefits are generated by assuming UMD maintains its operation during a one month critical period of any energy shortage. By maintaining its operation during this energy shortage, UMD provides benefits both to itself and to many auxiliary institutions. The expected value of these benefits are determined by multiplying the social benefits by an estimated probability of an energy shortage occurring and an estimated probability of the institution providing positive net educational benefits. Using the hypothetical probability that an energy shortage will occur two years out of every ten and the probability that continued operation will generate positive benefits is .9, the UMD gasification plant would generate an average annual expected benefit of \$860,000 (See Figure 4).

Before carrying out the benefit-cost analysis, the annual and total costs of installing the LBG plant must be estimated. In Table 2 the total capital costs are estimated to be \$3.043 million. Annual costs of operation are estimated to be \$1.302 million. These costs include depreciation on the fixed investment of \$122 thousand and interest cost of \$149 thousand (i.e., average investment times 10 percent interest charge). Operating expenses of the plant are \$456 thousand. In addition, the plant will gasify at a 93 percent thermal efficiency 14,383 tons of coal, costing \$575 thousand dollars. At the same

TABLE II

ESTIMATED  
PRIVATE COSTS OF  
INSTALLING LBG PLANT AT UMD

Design and Engineering	336,000			
Construction and Start Up	2,707,000			
<b>TOTAL</b>	<b>\$3,043,000</b>			
<b>Annual Costs</b>	<u>1979</u>	<u>1993</u>	<u>1995</u>	<u>2004</u>
Capital Costs	271,000	271,000	271,000	271,000
Operating Costs	456,000	456,000	456,000	456,000
Coal Costs Est.	<u>575,000</u>	<u>2,300,000</u>	<u>2,753,000</u>	<u>9,788,000</u>
\$40 @ Ton and 14,383 Tons	\$1,302,000	\$3,027,000	\$3,480,000	\$10,515,000
Save 1.62 x 10 <sup>8</sup> scF Natural Gas and 378,880 gallons of No. 5 Fuel Oil plus an 11% increase	<u>732,000</u>	<u>2,928,000</u>	<u>3,540,000</u>	<u>12,587,000</u>
Net 1st Costs	\$ +570,000	\$ 99,000	\$ - 60,000	-2,071,000
and 14th Year				

Sources Division of Coal Conversion and Utilities Dept. of Energy  
"Environmental Impact Assessment of A Low-BTU Gasification  
Facility University of Minnesota Duluth, St. Louis County, Minnesota"  
Nov. 1977 EIA/CCU/77-10 p. 2-17

Russell Bardos "Gasifiers in Industry Program" paper presented at  
4th Annual International Conference on Coal Gasification Liquification  
and Conversion to Electricity Aug. 2-4, 1977 University of Pittsburgh, p.21

1.	Annual Costs Over First 15 Years (\$285) (7.605)	Avg. Annual Benefits Over Last 10 Years (-104) (9,077-7.605)		TOTAL PRESENT COSTS
	<u>\$2,167,710</u>	<u>\$153,100</u>	=	<u>\$2,014,600</u>
		\$2,014,600 - 208	=	<u>\$1,806,000</u>
PV	Average Annual Costs Over 25 Years	\$72,000		

time, UMD will save approximately \$732 thousand in natural gas and No. 5 fuel oil annually. Thus, UMD will incur \$570 thousand in net additional costs the first year of operation.

The cost differential will narrow if the price of coal, natural gas, and fuel oil rise over the next decade. Assuming all fossil fuels rise at the same rate of 10 percent per year while other costs remain constant, the differential will fall to \$99,000 by 1993. In this situation the average cost of installing the LBG plant at UMD over the first 15 years of life is estimated to be \$285,000 per year. However, over the last ten years, LBG becomes less expensive to use since nearly half the costs are fixed. Thus, over the last ten years of life, the LBG plant actually generates a positive average benefit of \$104,000 per year. The present value of the net costs of this plant are \$2.0146 million, estimated over 25 years using a social discount rate of ten percent. (See Footnote 3, Table III). These costs are adjusted for the present value of the return of the original investment at the end of 25 years or \$208,000. Thus, the present value of the total costs of the project adjusted for changes in benefits is \$1,806,000. If these costs are averaged over the 25 plant life, the average annual costs are \$72,000 per year.

The LBG plant then is expected to yield on the average \$788,000 annually in net benefits over costs (See Table III). This strategy is clearly better than no change since the net marginal benefits per year are \$1,488,000 over the "do nothing" strategy. The present value of the annual benefits over the 25 years is \$7,153,000 using a social discount rate of ten percent. The project yields a benefit cost ratio of 2.35. Clearly, installing an LBG plant is a better strategy than doing nothing.

TABLE III

HYPOTHETICAL  
BENEFIT COST ANALYSIS  
OF LBG PLANT  
AT UMD

<u>Policy Evaluated</u>	<u>Avg. Annual Social Benefits</u>	-	<u>Avg. Annual Social Costs</u> 1	=	<u>Net Annual Social Benefits</u>	<u>Benefit Cost Ratio</u> 2
No Change	0	-	\$700,000	=	(700,000)	
LBG Plant	\$860,000	-	72,000 <sup>3</sup>	=	788,000	2.35

1. The annual social costs of no change are estimated by estimating the expected value of benefits of UMD during normal operations of \$160,000 without the additional costs of the gasification plant. This estimate stems from the measured probability of providing net positive educational benefits during normal times hypothetical this probability rise to .6 and losses fall to .4. No educational benefits accrue during an energy crisis thus this policy has an implicit Social Cost of \$860,000. The total Social Costs are estimated by subtracting the increased costs during normal times from the lost educational benefits during abnormal times of 800,000 - 160,000 or a benefit cost ratio of  $\frac{7,153,000}{3,043,000}$ .

2.  $788,000 \times 9.077 = 7,153,000$  (with handwritten annotations)

3. Present Values of Avg. Annual Costs Over First 15 Years Discount Rate 10%  $\$285,000 (7.605) = \$2,167,710$

Present Value of Avg. Annual Benefits Over Last 10 Years of Project  $\$104,000 (9.027-7.605) = -153,100$

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Present Value of Total Costs Over 25 Year Life  $\$2,014,610$

Present Value of Return of Investment at 25 Year of \$3,043,000  $-208,000$   
 $\$1,806,610$

Average Annual Cost for the 25 Years of the Project  $\$72,000$

## SUMMARY

During recent national and regional energy crises, private energy decisions have been shown to have strong external impacts for many societal institutions. The University of Minnesota's decision to install a LBG plant at its Duluth campus affects both the University and regional society. Therefore, the society should use benefit-cost analysis in evaluating this decision. In the B/C analysis society must evaluate both the annual private and annual social benefits of installing a LBG plant.

Evaluating the project's benefits requires the estimation of the expected net benefits of the project during both normal and energy shortage periods. Beyond the normal problems of estimating the social benefits, the project must also determine the probability of an energy crisis occurring. In developing the social benefits of the energy strategy, the project must estimate the net educational benefits which generated by UMD in both normal and shortage periods. Also the analysis must estimate the probability of that UMD will generate positive benefits. The indirect benefits of the project are estimated using SIMLAB to determine the industries affected if UMD should be forced to alter its operation. Beyond this, the project must estimate the duration of the impact of an energy shortage on operation of the campus. Finally, cost data on the operation of a LBG plant and other energy strategies should be collected. Although much of the current information necessary to carry out a complete benefit-cost analysis has not yet been collected, this information is available. An actual benefit-cost analysis can be developed using accurate projections of both the benefits and costs of the LBG strategy. This benefit-cost analysis when carried out may provide some surprising results for both the proponents and critics of the LBG strategy.

## APPENDIX I

TABLE IV

Interindustry Impact of UMD

(Total Budget = \$19,841,991)

	<u>Direct</u> <u>Coefficient</u>	<u>Direct and Indi-</u> <u>rect Coefficient</u>	<u>Direct</u> <u>Impact</u>	<u>Direct and</u> <u>Indirect Impact</u>
Construction	.0076	.0095	150,799	188,499
Food & Kindred	.0223	.0249	442,476	494,065
Lumber, Furniture	0	.0005	0	9,921
Pulp & Paper	0	.0007	0	13,889
Print & Publish	.0025	.0034	49,605	67,463
Chemical, etc.	.0006	.0008	11,905	15,874
Petrol Refine	.0017	.0027	33,731	53,573
Stone, Clay, Glass	0	.0002	0	3,968
Primary Metal	0	.0001	0	1,984
Fabricated Metal	0	.0003	0	5,953
Machinery	.0002	.0008	3,968	15,874
Electrical	.0009	.0013	17,858	25,795
Other Mfg.	.0009	.0011	17,858	21,826
Railroad	0	.0007	0	13,889
Trucking	.0008	.0012	15,874	23,810
Other Transp.	.0017	.0029	33,731	57,542
Communication	.0031	.0047	61,510	93,257
Electrical Util.	.0363	.0389	720,264	771,853
Gas Utilities	.0036	.0039	71,431	77,384
Other Util.	.0025	.0027	49,605	51,589
Wholesale	.0347	.0375	688,517	744,075
Retail	.0184	.0201	365,093	398,824

## APPENDIX I

TABLE IV  
(Continued)

	Direct <u>Coefficient</u>	Direct and Indi- <u>rect Coefficient</u>	Direct <u>Impact</u>	Direct and <u>Indirect Impact</u>
FIRE	.0026	.0060	51,589	119,052
Hotels, Pers. Serv.	.0076	.0087	150,799	172,625
Bus. Serv.	.0078	.0094	154,767	186,515
Medical, Educ.	.0243	1.0252	482,160	20,342,009
Other Service	.0011	.0013	21,826	25,795
Fed. Govt. Ent.	.0095	.0105	188,499	208,341
State-Loc. Ent.	<u>.0054</u>	<u>.0067</u>	<u>107,147</u>	<u>132,941</u>
TOTAL	.1961	1.2266	3,891,012	24,338,185

Source Lichty (9) P. 5.

## APPENDIX II

TABLE V

 UNIVERSITY OF MINNESOTA - DULUTH  
 Fall Quarter Headcounts  
 Second Week - Registration Basis

	1977 Actual	1978 Forecast			1979 Forecast			1980 Forecast		
		High	Point	Low	High	Point	Low	High	Point	Low
<u>Duluth</u>										
Business and Economics	1,051	1,222	1,206	1,190	1,345	1,326	1,307	1,409	1,390	1,371
Education	1,024	1,007	994	981	988	974	960	988	974	960
Fine Arts	331	335	331	327	339	334	329	346	341	336
Letters and Science	3,826	3,914	3,862	3,809	3,947	3,892	3,837	3,985	3,930	3,875
Social Development	110	122	120	118	134	132	130	140	138	136
Medicine	82	96	96	96	96	96	96	96	96	96
Post-MD Fellows	26	26	26	26	26	26	26	26	26	26
Graduate School - Social Dev.	57	60	56	53	60	60	60	60	60	60
- Other	201	228	219	210	235	230	225	240	235	230
Dental Hygiene	36	36	36	36	36	36	36	36	36	36
	6,744	7,046	6,946	6,846	7,206	7,106	7,006	7,326	7,226	7,126

SOURCE Lichty (9), (10) and MPIS 2/1/78

## FOOTNOTES

1. See Assistant Sec (1), Bardos (2), Energy Research (5), AR Prest (19) U.S. Congress (21) for discussion on various evaluations of this energy strategy.
2. Bardos (2), Division of Coal (4), and Maki (13) for discussion of UMD and regional energy problems.
3. Assistant Sect. (1) pp. 25-27. Energy Research (6).
4. Pantell (16) pp. 46-50, Foster Assoc. (7) and Lerhari, D. (8).
5. Bardos (2) p. 21, estimates the costs to be \$3,043,000 to install and start up the UMD coal gasification plant.
6. See Maki (12), (13), and (14), Penn (17) and Penn (18) for discussion of this with relevance to regional and national energy problems.
7. See Maki (12) pp. 1-25.
8. Appendix I contains the Table of Direct and Indirect Impact Coefficients for the Duluth-Superior Growth Center. Appendix II tests the sector and sector definitions that are included in this particular table. A more detailed sector definition is being developed for use in SIMLAB and would be utilized in any actual cost benefit estimation scheme.
9. Lichty (9) p. 4 of draft.
10. The problems of Benefit-Cost Analysis are well described in any number of resources. See, for example, Broadway (3) pp. 361-374 and Prest (19) pp. 683-705.

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