Notes

Individual Purchase Criteria for Energy-Related Durables: The Misuse of Life Cycle Cost

*Harry Chernoff**

INTRODUCTION

Life cycle cost is one of the most widely advocated methods for evaluating energy-related durables. The analysis method, its standard assumptions, and its rationale are well known. The costs and benefits of a durable are calculated over its lifetime and discounted at a market rate of interest for the individual. The investment with the lowest life cycle cost is preferred to all others.

Although life cycle costing is standard among economists, the results of most analyses bear no relationship to the behavior of individuals. Discount rates inferred from observations of purchases are much higher than routinely assumed by economists. This note contends that the disparity between life cycle decisionmaking and individual decisionmaking is not the result of irrational behavior by individuals but the result of inappropriate assumptions about individual discount rates by economists.

THE DISCOUNT RATE OF THE INDIVIDUAL

The most important component of a life cycle analysis is the discount rate. This rate is variously called the individual discount rate, the market discount rate, the implied discount rate, and the implicit discount rate. Regardless of nomenclature, this rate measures (or should measure) the individual's financial requirements and the sum of market imperfections and risks the individual faces or perceives. Most life cycle analysts, however, ignore the imperfections and risks and assume a discount rate based on the individual's interest rate for borrowing or lending (Ruegg, 1975; Sedmak and Zampelli, 1979; Reid et al., 1977; Lunde, 1982). Such a rate assumes that buying an energy-related durable is as safe and secure as putting money in a perfectly liquid, perfectly controllable, insured bank account. As obser-

The Energy Journal, Vol. 4, No. 4

* Economist, Science Applications, Inc., 1710 Goodridge Drive, McLean, Virginia 22102.

Table 1. Implicit Discount Rates for 1978 Purchases of Energy-Related Durables by Single-Family Homeowners

Furnaces	
Electric	54%
Gas	40
Oil	40
Room air conditioner	48
Central air conditioner	17
Water heater	
Electric	163
Gas	457
Oil	61
Refrigerator	83
Freezer	101
Range/oven	
Electric	77
Gas	64
Clothes dryer	
Electric	13
Gas	27

Source: U.S. Department of Energy (1982), p. 48.

vations of durables prices and purchases make clear, this discount-rate assumption *could hardly be farther from the truth.*

In a 1979 article, Hausman observed discount rates of 20 percent on average for purchases of energy-efficient air conditioners. In a comment on Hausman's study, Gately (1980) compared the sales prices of otherwise identical energy-efficient and energy-inefficient refrigerators and estimated discount rates (based on sales prices alone) ranging from 45 to 300 percent.

In a comprehensive study of durables purchases, researchers at Oak Ridge National Laboratories calculated very high implicit discount rates. As Table 1 shows, rates of 50 to 100 percent were typical.

High discount rates, of course, imply short payback periods. It is thus not surprising that consumers—most of whom have no understanding of discount rates—uniformly demand short payback investments. For example, in an extensive survey of home improvers (questioned about passive solar improvements), researchers concluded that "respondents expected passive solar features and sunspace additions to pay for themselves in five or less years. Respondents more knowledgeable or aware of passive solar were more likely to consider a larger payback period acceptable than those with no knowledge of passive solar. Older respondents were less likely to consider even a three-year payback period acceptable than younger respondents" (Market Facts Inc., 1981c, p. I-22).

It is noteworthy that the respondents in this survey were not average homeowners but were prime solar buyers—college-educated, aged 30 to 55, with annual incomes above $20,000. Among less stratified samples, rapid payback is even more important.

In another survey (Science Applications, Inc., 1981), San Diego homebuilders, lenders, and HVAC distributors were questioned about upper-income homebuyers' criteria for buying photovoltaic systems. These individuals solidly agreed that a five-year payback would be necessary. No one expressed any interest in life cycle cost.

Significantly, these diverse observations of high discount rates (and short payback periods) are consistent with economic theory. Economists have long recognized that market imperfections, uncertainty, risk, and a host of other variables increase discount rates. As applied to energy-related durables, discount rates far above market rates should be expected for a number of reasons:

1. An investment in a consumer durable is illiquid. At a given discount rate, an individual will prefer to hold a liquid financial asset to an illiquid consumer durable. To entice the individual to forgo liquidity, a liquidity premium must be added to the discount rate.
2. The market rate of interest (or opportunity cost of money) assumed in standard life cycle analyses is ordinarily based on a riskless rate (e.g., the individual's lending or borrowing rate). An investment in a durable is not riskless and must therefore carry a risk premium.
3. The value of energy efficiency depends on the price of energy. To the average consumer, U.S. energy policy, if it exists at all, is hopelessly confused. With energy supplies and energy prices fluctuating wildly from year to year, an uncertainty premium must be added to the discount rate.
4. The capital markets in which the individual functions are less efficient than is generally assumed. For example, in a 1980 study of the willingness of New Jersey consumers to invest in energy conservation, the most frequently mentioned reason for not making improvements with rapid paybacks was "I don't have the money to invest right now!" (New Jersey Department of Energy, 1981). In an efficient capital market, the individual would borrow to invest in measures that are defined as attractive. The individual's inability or unwillingness to borrow implies a high personal discount rate.
5. The possibility of rapid obsolescence and technological change also raises the discount rate. If consumers expect solar system prices to fall or refrigerator efficiency to rise, they may incur an economic penalty for not waiting until the improved model is available.
6. The possibility that the individual will not be able to internalize future benefits of the durable further raises the discount rate. Life cycle analysts evaluate costs and benefits over the physical life of the durable. Individuals, however, evaluate costs and benefits over the period they expect to own the durable. Since market discount rates are higher for used durables than for new durables (no warranty, uncertain seller claims, unknown maintenance and repair history, etc.), there is little reason to expect energy efficiency to have much effect on the sales price of a used durable. Indeed, for many durables, efficiency is only the third or fourth most sought after characteristic. With refrigerators, for example, efficiency ranks behind initial price, size, and color (Davis and Perry, 1982; McNeill and Wilkie, 1979). With the average homeowner moving every five to seven years, energy-related benefits 10 to 20 years in the future have little present value.

7. Finally, to evaluate energy efficiency, the consumer must obtain and evaluate information that would otherwise be of little value. This task imposes a search cost on the buyer. If the individual does not expect the energy savings to be worth the costs of the search, or if the individual is unable to evaluate conflicting claims for costs and benefits, he has no economic basis for searching (Jacoby et al., 1976). For the typical decisionmaker, the precision and accuracy implied by the life cycle analyses' all-inclusive list of costs and benefits is deceptive. Few individuals use any formal decision process, let alone one so complex as life cycle cost (Olshavsky and Granbois, 1979; OR/MS Dialogue, 1980).

The futility of trying to convince individuals to use sophisticated life cycle methods has even been recognized by proponents of life cycle cost. Lunde (1982), for example, recently proposed a variation of traditional life cycle cost which he termed "alternative equivalent lifecycle payback time." He suggested this procedure as a way to "help force the user to the proper conclusions of a life cycle analysis." Why the need for such a method? As Lunde states, "current techniques are evidently too complicated for most situations. . . . Invariably, all the customer wants to know is the payback of the system" (p. 197).

CONCLUSION

The use of life cycle cost to evaluate energy-related durables is widely recommended by economists and equally widely ignored by individuals. As one advocate of life cycle cost admits, "all the customer wants to know is the payback of the system." In reality, however, the issue is not analysis methods but discount rates. At a high enough discount rate, a 20-year life cycle analysis is the same as a three-year payback. Empirical evidence suggests that actual risk- and uncertainty-adjusted discount rates for energy-related durables are far higher than the risk-free market rates most economists assume. Although a precise discount rate is difficult to specify, economic theory offers multiple justification for very high rates. For the typical individual, these high discount rates neatly translate into short payback periods. Life cycle analyses that rely on low discount rates simply do not reflect the market.

POSTSCRIPT: SOCIAL COSTS

Many economists have commented on the socially inefficient short-run investment path of the individual. Indeed, the inability or unwillingness of individuals to make socially optimal or efficient purchases of energy-efficient durables is one of the principal arguments for appliance efficiency standards, appliance labeling, and government and utility financing of residential conservation and solar measures.

On economic grounds, many of these utility and government programs are commendable. Utility-designed programs, in particular, show great promise. By substituting their longer-run purchase criteria for the individual's criteria, utilities have been able to invest in conservation at less cost than new generating capacity. This substitution benefits everyone—utilities, ratepayers, and society—and should be encouraged.

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The Real Price of Imported Oil Revisited

*Michael J. Coda and John E. Jankowski, Jr.**

In a 1980 *Energy Journal* article, an examination was made of the effects of inflation and exchange rate adjustments on imported oil prices in some selected countries (Dunkerley and Jankowski, 1980). This showed that "real" inflation and exchange-rate adjusted) prices, after rising threefold between 1973 and 1974, generally declined between 1974 and 1978. This decline was due to high rates of inflation and in some cases the weakness of the dollar in terms of local currency. A similar examination of the period following the second oil price rise between 1978 and 1980 shows somewhat different results. In this period, despite relative stability in nominal prices, the real prices of imported oil continued to rise through mid-1982.

The movement in real prices of imported oil is given in Table 1 for 14 oil-importing countries, seven OECD members, and seven developing countries. These indices were derived by converting the average dollar price of Saudi Arabian oil (f.o.b. Ras Tanura) for each year to national currencies at the average exchange rates prevailing during that year. These prices were deflated by the Consumer Price Index in each oil-importing country. The same calculations were done for May 1982, the last month for which data were available. The resulting prices are listed in index form with 1974 equal to 100. Countries are ordered from top to bottom according to how much oil import prices have increased since 1974, with those facing the largest real price increases at the top. Not surprisingly, changes in the indices reflect the general movement of world oil prices with steep increases in 1974 and 1979–80. However, real oil import prices have increased much more rapidly in some countries than others, with Korea experiencing a 66.7-percent price increase since 1974 compared with India's 157.4-percent rise. In addition, other contrasts are reflected in the column showing the percentage change since 1978. Some countries—for example, Turkey, Kenya, and West Germany—have been hit with price increases approximately twice the size of those felt in such nations as the Philippines and Jamaica during this period. Many of those in the first group faced declining real prices after the first oil price rise.

The Energy Journal, Vol. 4, No. 4.

* Resources for the Future, Inc., 1755 Massachusetts Ave., N.W., Washington, D.C. 20036.

The authors wish to thank Joy Dunkerley for her advice and comments.

Table 1. Index of Real Price of Imported Oil[a] (1974 = 100)

	1973	1974	1978	1979	1980	1981	May 1982	% Increase Since 1978
India	34	100	122	151	222	260	257.4	130
Turkey	33	100	88	95	186	226	237.7	170
Brazil	32	100	95	124	224	218	213.9	125
Germany	31	100	86	100	160	212	212.4	163
Portugal	34	100	114	127	189	214	207.3	82
Italy	30	100	95	108	155	198	201.4	112
Thailand	35	100	102	124	176	189	194.2	90
France	28	100	79	89	132	170	184.3	133
Philippines	37	100	113	119	174	185	182.7	62
Jamaica	30	100	102	136	182	182	179.3	76
United States	31	100	98	118	176	180	175.5	79
Kenya	27	100	67	76	139	172	173.4	159
Japan	32	100	69	92	149	157	167.8	143
Korea	27	100	84	100	171	162	166.7	149
Average	32	100	94	112	175	194	196.7	109

Source: International Monetary Fund, *International Financial Statistics* (various issues).

[a]Imported oil price is that of Saudi oil (Ras Tanura). This price is adjusted for changes in exchange rates and domestic inflation to yield the index of real price of imported oil.

Table 2 explains these variations. The key variables are the changes in the values of national currencies relative to the dollar and the various rates of inflation. If a currency has depreciated in relation to the dollar, this will have the effect of increasing real oil import prices because a country has to offer more of its currency for each dollar of oil purchased. If a country has a high inflation rate, this will also slow down increases in the real price.

The changes in real oil import prices from 1978 to 1982 can be broken into two periods, pre- and post-1980. Before 1980, the increase in real prices was primarily the result of the jump in world oil prices, which rose 125 percent, from $12.70 to $29 per barrel. No consuming country could avoid this and real prices rose everywhere. However, movements in exchange rates varied substantially between countries, with slight appreciations (relative to the dollar) in four countries and depreciations in the remaining nations listed. As a result, some countries, such as Japan and Brazil, faced much larger real price increases than others.

From 1980 until May 1982, a period in which nominal prices rose 16.6 percent, exchange-rate fluctuations were critical in determining the direction of real prices. In France, Germany, Italy, Turkey, and Kenya, currencies depreciated at a rate well over that of inflation, causing price increases of more than 30 percent. Meanwhile, inflation and/or stable exchange rates held real prices steady in Jamaica, Brazil, Korea, and the Philippines.

For a portion of this period, nominal world oil prices were generally falling—a trend not reflected in the Saudi benchmark price. For this reason, Table 3 was constructed. In it, the world oil price is a weighted average of prices in nine oil-exporting states as reported in the U.S. Department of Energy's *Monthly*

Table 2. Percentage Changes in Real Price, Nominal Prices, Exchange Rates, and Inflation Rates

	1974–1978 30.1% Nominal Price Increase			1978–1980 125.7% Nominal Price Increase			1980–May 1982 16.2% Nominal Price Increase		
	Real Change in Oil Prices (%)[a]	Change in Exchange Rates (%)[b]	Change in General Prices (%)[c]	Real Change in Oil Prices (%)	Change in Exchange Rates (%)	Change in General Prices (%)	Real Change in Oil Prices (%)	Change in Exchange Rates (%)	Change in General Prices (%)
India	22	1.1	8.2	83	−4.0	18.5	16	18.0	18.4
Turkey	−12	74.3	158.3	112	213.3	233.4	28	97.5	79.3
Brazil	−5	166.1	264.6	136	191.7	179.3	−4	203.5	269.4
Germany	−14	−22.4	18.0	87	−9.4	9.5	31	42.2	26.4
Portugal	14	72.9	96.9	65	13.9	55.8	10	40.8	49.0
Italy	−5	30.5	79.2	64	0.9	39.2	30	49.5	33.9
Thailand	2	0.0	27.3	73	0.6	31.5	10	12.3	18.5
France	−16	6.2	45.9	68	−6.2	25.7	31	42.2	26.4
Philippines	13	8.6	24.7	53	1.8	49.8	5	12.1	24.0
Jamaica	6	57.9	93.3	71	24.2	63.9	−2	0.0	18.7
United States	−2	n.a.	32.3	79	n.a.	26.3	0	n.a.	16.3
Kenya	−21	8.3	78.0	76	−4.0	22.9	24	41.9	32.7
Japan	−32	−28.0	37.1	117	7.7	11.9	13	4.2	7.6
Korea	−16	19.2	83.7	102	36.3	52.1	−3	9.9	31.0

Source: Derived from International Monetary Fund, *International Financial Statistics* (various issues).

[a] The percentage changes in real price can be computed with the following equation: $R \times ((1 + N)(1 + E)/(1 + I)) - 1$, where R is the change in the real imported oil price, N is the change in the nominal price of imported oil, and I is the inflation rate. Totals may be affected by rounding.

[b] A negative figure denotes an appreciation in the value of local currency relative to the dollar.

[c] As represented by local consumer price index.

Table 3. Percentage Change in Real Prices During Period of Nominal Price Fall, January–June 1981 to July–May 1982

	Percentage Real Price Change
United States	−10.0
Jamaica	−9.2
Philippines	−8.5
Korea	−8.3
Portugal	−6.6
Brazil	−6.1
$ Price of Oil	−4.9
Germany	−1.5
France	−1.2
Italy	−0.8
Thailand	−0.4
India	0.3
Japan	1.5
Kenya	1.7
Turkey	5.6

Source: Department of Energy, *Monthly Energy Review*, August 1982; International Monetary Fund, *International Financial Statistics* (various issues).

Note: Oil price was obtained by taking weighted price of oil exported by nine countries. To derive percentage changes, average prices, exchange rates, and inflation rates were used for the two periods.

Energy Review.[1] The average price of oil exports from these countries in the first six months of 1981, $34.63, was approximately 5 percent above the $32.95 average price in the second half of 1981 and the first five months of 1982. (This drop was a good deal smaller than that which many newspaper reports based on spot market trends indicated.) As Table 3 shows, however, this price decline never reached several importing countries which had exchange-rate depreciations in excess of their inflation rate. For Turkey, a 5-percent nominal price decrease became a 6-percent real price increase. These exchange-rate fluctuations have prevented any significant fall in the price of oil imports in some key importing countries—Japan, Germany, France—a factor that has undoubtedly placed downward pressure on oil import consumption. However, a decline in U.S. interest rates could lead to a drop in the value of the dollar, thus exaggerating instead of offsetting any further decline in nominal world oil prices.

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Comment on International Energy Agency's World Energy Outlook

*David M. Kline and John P. Weyant**

The International Energy Agency's *World Energy Outlook* (1982) reports on the results of an ambitious and comprehensive international energy study. The report represents a major step forward in the coordination and communication of energy policy analyses among the 21 IEA member countries. A major conclusion of the study is that the current softness of the world oil market is not likely to last out the current decade, particularly without fundamentally new policy initiatives on the part of the major oil importers. One could argue with the various assumptions and analyses that are employed to arrive at this conclusion, but on the whole the IEA's analysis appears to be carefully and consistently done, particularly for a study involving a high degree of cooperation between analysts from countries who are basically allies, but often have goals and objectives that differ in particular areas.

Although we are in broad agreement with the conclusions of the analysis that is at the foundation of the World Energy Outlook, in our opinion the policy recommendations that are drawn from them are incomplete. The IEA argues that since the world oil market will eventually tighten, policy measures designed to reduce the level of oil imports should be high on the energy policy agenda of the member nations. Nowhere though, is an attempt made to evaluate these import reductions, and thus important questions remain unanswered. If fewer oil imports are better, are none best? Are all import reductions equally desirable?

The concept of an import premium could have been exploited to focus the discussion on import-reduction policies and provide some guidance for national policy in this area.

As defined by Kline (1981), for example, the import premium measures the difference between the total cost of oil to importing countries and the world price. Estimates of the premium value thus provide guidance in how far governments should be willing to go in encouraging import-reducing activities. The IEA report is unnecessarily vague in this regard.

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* Energy Modeling Forum, Terman Engineering Center, Stanford University, Stanford, Calif. 94305.

The import-premium methodology developed by Kline (1981) could also be used to amplify one of the central policy concerns of the IEA book. Since it aggregates benefits and costs over time, the premium measure could be used to illustrate the point that despite appearances, profligate energy use policies are exactly the wrong response to currently soft oil prices.

A more fundamental problem with the policy recommendations drawn from the IEA analysis is the lack of emphasis on contingency planning measures as a response to the oil vulnerability problem. This is a particularly serious problem because the benefits of an oil import-reduction program may be a long time coming. As acknowledged by IEA Executive Director Ulf Lantzke, "Clearly, it will take time before these policy guidelines can be implemented fully. Although the problem is long term, policy-making in most countries is, naturally, oriented towards the short term. It may well take one or two decades before a reasonable balance among energy supplies can be achieved on a lasting basis."

Since 1979 a number of books, reports, and articles devoted to oil policy in general and oil security policy in particular have appeared (e.g., Deese and Nye, 1981; Plummer, 1982; Horwich and Mitchell, 1982; Bohi and Montgomery, 1982; Lewis, 1980; Rowen, 1980; National Petroleum Council, 1981; Energy Modeling Forum, 1982; Plummer, 1981; Alm, 1981; Adelman, 1982; Schlesinger et al., 1982; Rowen and Weyant, 1982). These works have ranged from highly theoretical economic and optimal control analyses to timely and pragmatic policy evaluations. A review and evaluation of this literature reveals a handful of insights that are difficult to argue with.

Among the most important lessons that can be extracted from the spate of energy security policy analyses is that there is a difference between dependence on oil imports and vulnerability to oil supply interruptions. "High" oil prices are painful if dependence is great, but if supplies are cut off suddenly, the effects of the adjustment of the economy to the shortage can be catastrophic. This is why stockpiles have been such a popular energy security policy option. They focus on the vulnerability problem directly by reducing the extent of any sudden interruption in supplies. In addition to directly substituting for imports that are cut off, the stocks can provide valuable time for importers to adjust to the new price regime. And since stockpiles can be built up much more rapidly than the comparable effects of any import reduction effect could be felt, the stockpile option (perhaps augmented by a fuel-switching program of some sort) has dominated the energy security policy debate—see, e.g., Hogan (1981) for more on the relative advantages of stockpiles compared with import reductions as an energy security policy.

Thus, if there is a danger that the current slackness of the world oil market will lead to fewer import reductions than are desirable, there is an even greater danger that it will lead to less contingency planning than is desirable. Failure to implement import reduction policies could be costly in 10 to 20 years, but failure to prepare for oil supply interruptions now could be even more costly in the short to intermediate term.

To help emphasize this point, we've used some of our recent short-to-intermediate-term oil price projections (Weyant and Kline, 1982) to update an oil stockpile analysis published in *The Energy Journal* (Rowen and Weyant, 1982). Our world oil projections are similar in spirit to the IEA scenarios, but we avoid gaps between

Table 1. Minimum and Maximum Duration Oil Glut

	1984	1987	1990	1993
Maximum Duration Glut				
World oil price (1983$/bbl)	$25	$23	$27	$35
World oil demand (Mmbd)	42	44	48	50
OPEC production (Mmbd)	20	23	25	27
Minimum Duration Glut				
World oil price (1983$/bbl)	$27	$30	$36	$42
World oil demand (Mmbd)	43	47	49	50
OPEC production (Mmbd)	22	25	27	27

supply and demand by fixing supply and demand conditions and solving for equilibrium prices. We construct a Minimum Duration Glut Scenario by combining conditions that uniformly lead to higher demands and lower supplies at any price, and a Maximum Duration Glut Scenario by combining low and high supply conditions. The price and oil consumption projections for these two cases are shown in Table 1.

Next, we redo the stockpile breakeven analysis described in Rowen and Weyant (1982). The shock oil market conditions of the 1980s affect both the benefits *and* costs of an oil stockpiling program. Benefits are lower because of more slack in the world oil market and fewer barrels of imports on which to pay a higher price during an oil supply interruption. Costs are lower because of lower carrying costs and a lower propensity for stockpile acquisitions to put upward pressure on world oil prices.

We consider three interruption events involving the complete cessation of oil exports from: Saudi Arabia and the entire Persian Gulf. Using the oil supplies, demands, and prices for the two oil price projections as initial conditions we compute stockpile benefits and costs as described by Rowen and Weyant (1982). The breakeven probabilities for various U.S. stockpile fill rates are shown in Table 2

Table 2. Breakeven Probabilities for Alternative U.S. Stockpile Fill Rates

Market Conditions Prior to Interruption	Stockpile Fill Rates (barrels per day)	Saudi Arabia 1985	Saudi Arabia 1990	Persian Gulf 1985	Persian Gulf 1990
1980 oil market conditions	200,000	0.03	0.08	0.01	0.01
	300,000	0.03	0.10	0.01	0.01
	400,000	0.04	0.14	0.01	0.01
Minimum duration glut	200,000	0.04	0.08	0.02	0.01
	300,000	0.04	0.10	0.02	0.01
	400,000	0.04	0.14	0.02	0.01
Maximum duration glut	200,000	0.07	0.05	0.02	0.01
	300,000	0.08	0.05	0.02	0.01
	400,000	0.08	0.06	0.01	0.01

Because the cost of oil stockpiling during the current oil glut has declined by about as much as its benefits, the breakeven probabilities for the two glut scenarios are not very different from those calculated assuming the world oil market conditions of 1980 persisted throughout the 1980s. And according to the probability assessments of most observers, the current full rate of the Strategic Petroleum reserve is too low, rather than too high.

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Acknowledgments

All manuscripts submitted to *The Energy Journal* are sent to anonymous referees for screening and review. Without their efforts, the standards of the Journal could not possibly be maintained. Since July 1982 the following referees volunteered their time and talents to *The Energy Journal*. The editors welcome this chance to thank them publicly for their help and dedication.

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