Lawrence Berkeley National Laboratory
LBL Publications

Title
THE COST OF CDNSERVED ENERGY AS AN INVESTMENT STATISTIC

Permalink
https://escholarship.org/uc/item/7vb1977x

Author
Meier, A.

Publication Date
1982-11-01

eScholarship.org Powered by the California Digital Library
University of California

LBL-15198
Preprint c.2

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

ENERGY & ENVIRONMENT DIVISION

RECEIVED
LAWRENCE
BERKELEY LABORATORY

FEB 18 1983

LIBRARY AND
DOCUMENTS SECTION

To be published in Harvard Business Review

THE COST OF CONSERVED ENERGY AS AN INVESTMENT STATISTIC

Alan Meier

November 1982

TWO-WEEK LOAN COPY

This is a Library Circulating Copy which may be borrowed for two weeks. For a personal retention copy, call Tech. Info. Division, Ext. 6782.

ENERGY
AND ENVIRONMENT
DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-15198 c.2

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL-15198
EEB-BED 82-16

To be published in Harvard Business Review

THE COST OF CONSERVED ENERGY AS AN INVESTMENT STATISTIC*

Alan Meier
Energy and Environment Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

November 1982

ABSTRACT

The cost of conserved energy (CCE) is an investment statistic that simplifies comparison of conservation measures among themselves and against competing energy supply measures. The cost of conserved energy formula is presented. A conservation measure is cost-effective if its CCE is less than the price of the energy that the measure displaces. The CCE is especially useful when there is uncertainty with respect to future energy prices. An extension of the concept, supply curves of conserved energy, provides a useful technique for characterizing the potential for conservation.

---

* This work was supported by the Assistant Secretary for Conservation and Renewable Energy, Office of Building Energy Research and Development, Building Systems Division of the U.S. Department of Energy under Contract Number DE-AC03-76SF00098.

INTRODUCTION

With the rapid rise in energy prices, energy conservation has become an integral part of many firms' operations. However, conservation investments must compete with other ventures for capital and attention. They frequently lose. This is in part due to a misunderstanding of energy conservation. Most conservation measures improve efficiency, and do not require any sacrifice or reduced service. They improve the efficiency of combustion, heat transfer or recovery. In buildings, typical measures include more efficient motors and lights, more carefully sized and balanced ventilation systems. Even after this initial confusion, a more serious question arises, namely, how should we assess investments in energy efficiency? We present in this article a new investment statistic to provide more realistic consideration of conservation opportunities.

Many firms are now contemplating investments in independent energy supply facilities. These include electricity generation (and cogeneration), use of solar energy, and burning waste materials. Yet even more lucrative energy conservation opportunities are often overlooked simply because their benefits are expressed differently.

Conservation investments are also difficult to integrate into other corporate plans. They are typically proposed <u>after</u> the measures have become cost-effective, which contributes to their awkwardness and adds costs. Leaving space in the design of a boiler complex for installation of a heat exchanger in the eventuality of higher energy prices is very cheap, yet it simplifies conservation enormously.

Conservation investments do not easily fit into the traditional investment analyses. Conservation measures reduce operating costs rather than increase revenues. They are extremely diverse and their risks differ from revenue-generating investments. Energy savings -- hence dollar savings -- will often depend in a very complicated way on the level of production or activity. For example, adding a streamlining device to a truck will save energy whenever the truck is operated. However, the savings are not directly proportional to the distance driven because the savings are greatest at high speeds. Should we install the device or consider another measure, say, switching to radial tires? Finally, should either (or both) measure take precedence over other revenue-generating investments? The cost of conserved energy technique offers insights into these questions.

THE COST OF CONSERVED ENERGY

Most conservation measures require an initial investment. After implementation we can expect the measure to continue saving energy until the piece of equipment wears out. Traditionally we would convert the energy savings into dollar savings and calculate the payback period or return on investment. We ask a different question: namely, what is the cost of saving the energy? Or, put another way, how much must we invest to avoid using that energy?

For example, consider installing extra insulation around a refrigeration unit. It costs $3,000 and is expected to save 75,000 kilowatt-hours in the next ten years. Here the cost of saving 75,000 kilowatt-hours is $3,000. However, it is simpler to express this as the cost of saving a unit of energy. Here the measure saves electricity, so the appropriate unit is the kilowatt-hour. Ignoring, for the moment, the problem of discounting, this yields,

$$\text{cost of saving a kilowatt-hour} = \frac{\$3{,}000}{75{,}000 \text{ kWh}} = 4 \text{ cents/kWh}$$

How is this number interpreted? It means that we have substituted $3,000 capital investment for 75,000 kilowatt-hours of electricity or, on a unit basis, 4 cents for each kilowatt-hour.

Is this a good investment? To answer this question, we must determine the cost of 75,000 kWh from other available sources, usually the local utility company. Utilities typically quote their rates on a per-unit basis which, in this case, would be per kilowatt-hour. In New York, for example, electricity costs about 10 cents/kWh. If this refrigeration unit were located in New York, then saving electricity at 4 cents/kWh appears cheaper than paying the utility 10 cents/kWh for the "real stuff". This conservation measure is a good investment since the refrigerator would be partly operating on electricity obtained at a 60% discount.

Let us view it from another perspective. Suppose a neighboring factory offered to share a cogeneration facility with your firm. In return for a $3,000 investment they would supply you 75,000 kilowatt-hours. Thus, the cogenerated electricity costs 4 cents/kWh. A rational firm would certainly purchase it if the utility rate was 10 cents/kWh.

How does the cogenerated electricity differ from that saved with the insulation? In both cases the \$3,000 investment lowers the utility bill 75,000 kilowatt-hours. There is an element of risk associated with the insulation. If, for some other reason, the refrigerator is turned off or abandoned halfway through its anticipated lifetime, then the investment is prematurely lost. On the other hand, there are similar risks from the cogenerated electricity: the generator may break or the neighboring firm may cease operation. The local utility might also lower rates to below 4 cents/kWh, in which case your firm is committed to the purchase of the more expensive electricity. There are clearly risks with both investments, however we believe most firms would rather choose the alternative offering the maximum independence. Moreover, the risks of a conservation investment depend more on internal operations which are, presumably, better understood. Greater self-reliance and reduced risk favor conservation.

The cost of saved energy calculation above treats investments naively, since it ignores the lag between the initial investment and benefits. We rewrite the formula to include a discount rate and call it the "cost of conserved energy,"

$$CCE = \frac{E}{I} \cdot \frac{d}{1 - (1+d)^{-n}}$$

The right-hand factor is the familiar capital recovery formula. Within it we must now specify the discount rate, d, and the amortization time, n. (To keep the dimensions consistent, the amortization time, discount rate, and energy savings must all be expressed in years.)

Using the refrigerator example above, and assuming a 15% discount rate, we get a cost of conserved energy,

$$CCE = \frac{\$3000}{7500\ \text{kWh/yr}} \cdot \frac{0.15}{1 - (1+0.15)^{-10}} = 8\ \text{cents/kWh}$$

Not surprisingly, the time value of money raises the cost of conserved energy.

There are two investment decision rules associated with the cost of conserved energy. The first rule ranks conservation measures according to their investment worthiness. In other words, how do we compare conservation measures among themselves? The rule is, "Choose the measure with the lowest cost of conserved energy."

The second rule provides a yardstick to compare conservation investments to other "alternative" investments. Here, the "alternative" investment is necessarily in energy supplies -- <u>un</u>conserved energy must be paid for -- such as that provided by the utility or through cogeneration. The cost of energy supplies are typically quoted on a per-unit basis, that is, cents/kWh, dollars/MBtu, etc. The decision rule is, "Implement all conservation measures whose cost of conserved energy is less than the price of the avoided energy." Of course, this ranking may be modified by firms with capital rationing.

For planning purposes, a revised decision rule might be, "Implement all measures whose CCE is less than the energy price, but maintain the capability to implement higher-CCE measures should energy prices unexpectedly rise." In some cases, maintaining this capability will dramatically lower the capital costs of the measure when it is eventually implemented. Also, a firm would be prepared for situations such as recently occurred in Mexico where the government abruptly doubled domestic oil prices.

FEATURES OF THE CCE

One useful feature of the cost of conserved energy is its independence from energy prices. This is best illustrated by an example.

A nation-wide fast-food restaurant chain is considering conservation measures for several hundred virtually identical restaurants. One measure involves replacing the existing motor-compressor in the refrigerator with a more efficient unit. The installation costs and energy savings are the same in every restaurant, namely $1400 and 4000 kWh/year. (These savings are mostly a function of internal loads, not the weather.) The firm expects the units to last at least 20 years, but chooses to amortize it over 8 years. The firm uses a 15% discount rate.

The cost of conserved energy can now be calculated:

$$\text{CCE} = \frac{\$1400}{4000\ \text{kWh/yr}} \cdot \frac{0.15}{1 - (1+ 0.15)^{-8}} \qquad = 7.8\ \text{cents/kWh}$$

Again, the same decision rule applies, namely, implement the measure when its CCE is less than the price of the avoided energy. But how does the firm decide if the measure is economic when their restaurants operate throughout the country? One solution is to compare the CCE to a national average electricity price. The average electricity price for commercial users in late 1981 was 6.48 cents/kWh.[1] In this case, it is cheaper to purchase electricity than save it by improving the refrigerator.

Alternatively, we can compare the CCE to electricity rates paid at each restaurant. In New York City, for example, electricity costs more than 10 cents/kWh, so replacing the motor/compressor would be justified there. The measure would not be justified in Portland, Oregon, where electricity costs less than 5 cents/kWh.

Note that we did not need to recalculate the CCE for the Portland restaurant. In principle, a list of conservation measures and their associated CCE´s could be constructed in the head office. Then the list could be sent to each restaurant´s manager, instructing him (or her) to implement all measures having CCE´s below the local electricity price. Such a list illustrates the geographic "portability" of the CCE statistic. It is independent of local energy prices (even though the determination of economic worthiness requires comparison with the local energy price).

The above example assumes that the costs of implementing a measure, as well as its energy savings, will be constant in each restaurant (or at least suffer from less variation than the energy prices). This applies especially well to some standardized operating equipment, such as lights, refrigerators and ventilation units. A nation-wide CCE fails when there are substantial differences in costs or energy savings. Nevertheless, the example does illustrate how costs of conserved energy are independent of energy prices.

A far more important application will be for a single factory. An energy conservation consultant could prepare a list of conservation measures and their associated CCE´s. The CCE´s do not need to be recalculated as energy prices rise, so the firm has a good plan to respond to the higher prices long after the consultant has departed (and before the prices reach that level).

The CCE also has a kind of fuel portability. Consider a conservation measure that reduces the heat loss of a steam circulation system. Given the cost, energy savings, discount rate and amortization time, we can calculate the CCE. Is this measure economic? The answer depends on the price of the fuel saved. But note that nowhere in the calculation was the fuel type specified. The conservation measure reduced heat loss; the fuel burned to make that heat was not important. The heat may have been generated by burning oil, coal, or natural gas. In fact, boilers are often engineered to burn one of several fuels (depending on which is available or cheapest). Only one CCE for the conservation measure need be calculated. In contrast, one ROI calculation would be needed for each fuel and fuel combination.

SOME COMPLICATIONS

The CCE appears to constrain the analysis to one scenario; namely, "invest now and save a constant amount of energy over the measure's lifetime." Other investment statistics, such as the internal rate of return (IRR) or net present value (NPV), are more flexible. They can easily accommodate periodic operating and maintenance costs, variable energy savings, and a salvage value. However, most of these drawbacks of the CCE can be overcome. We suggest the following approaches. No rules are ironclad; rather, the chief goal should be consistency.

The Measure's Cost. Operating and maintenance costs can be added to the "investment." Likewise, benefits, such as salvage or tax credits can be subtracted. Both future costs and benefits should be discounted prior to incorporation.

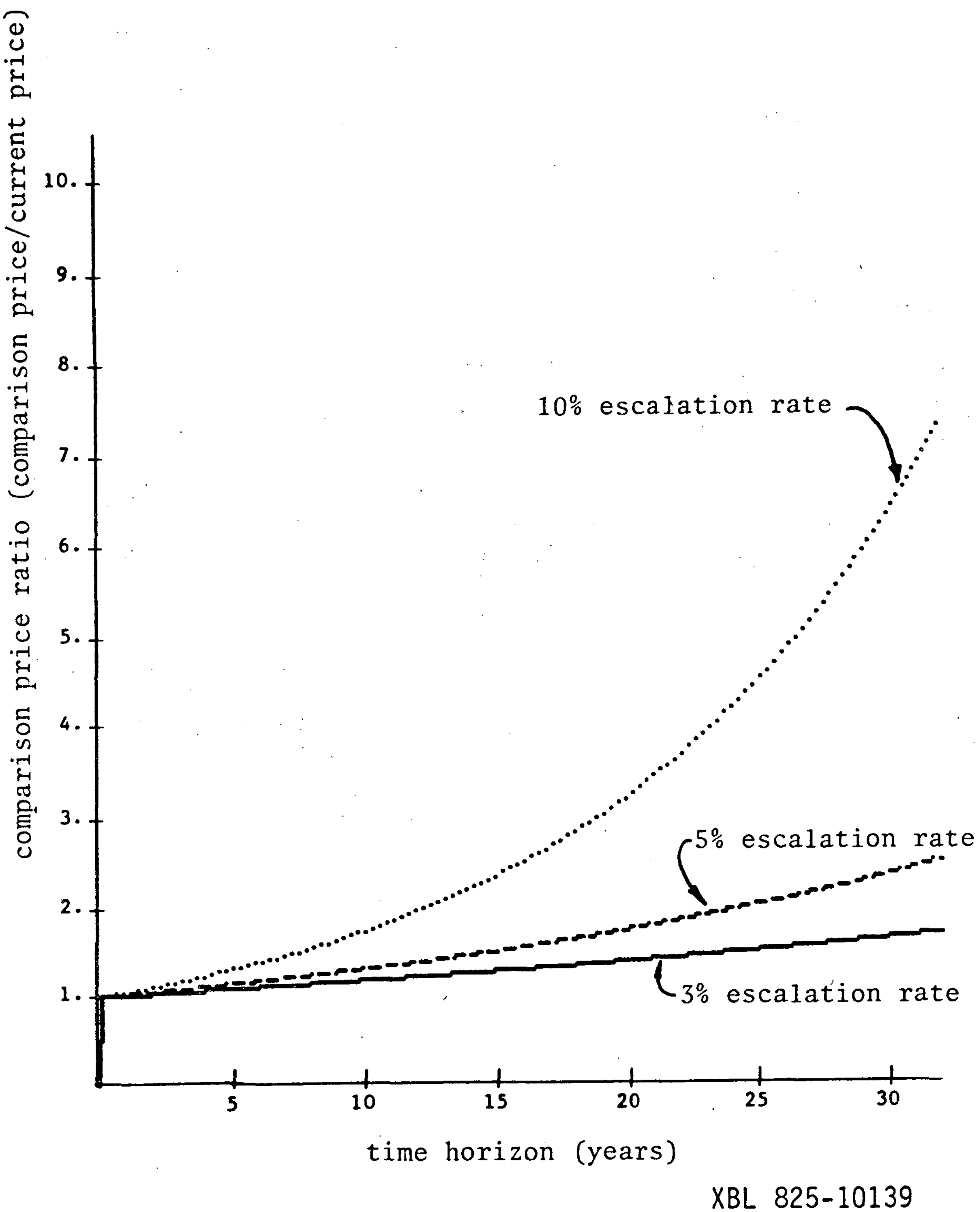
Energy Savings. Use the average annual energy savings. This is the net energy savings. If the measure requires additional energy, such that as to operate new controls, subtract it from the direct savings.[2]

Lifetime. Insert the useful lifetime of the measure. If the measure's performance deteriorates rapidly, reduce the lifetime.

Discount rate. Select the rate appropriate for that level of investment risk. Most off-the-shelf conservation measures will have reliable energy savings and are therefore low-risk.

The comparison energy price. Determine the price of the fuel saved by the conservation measure. Since energy prices will probably change over the measure's lifetime, a weighted average of the energy prices must be used. In spite of the current oil market, the general trend of energy prices is upwards. (This is usually modeled as an exponential increase.) A conservation measure may be economic to implement now even though its CCE is higher than the current energy price because we expect energy prices to rise above the CCE during the measure's lifetime.

We have calculated the comparison price for various fuel price escalation rates. These are plotted in Figure 1. The comparison prices are expressed in terms of the current energy price. For a measure with a 20 year lifetime, and assuming a 5% fuel escalation rate, the graph shows that the comparison price should be about 1.7 times the current energy price. Note that the energy price after 20 years is much higher, about two times the current energy price, but the weighted average will always



XBL 825-10139

Figure 1. If energy prices are expected to rise, then the weighted average of future energy prices should be used in place of the current price. This graph shows the necessary adjustment of the energy price to permit comparison with the cost of conserved energy (CCE) for three fuel escalation rates. Select the time horizon on the X-axis. Read the comparison energy price ratio on the Y-axis for the appropriate escalation rate. Multiply the current energy price by the ratio to obtain the comparison energy price.

be lower.

If the discount rate in the CCE is expressed in real (inflation removed) terms, then the fuel price escalation rate must likewise be expressed in real terms. Alternatively, if a nominal discount rate is used in the CCE, then the fuel price escalation rate must be similarly expressed in nominal (inflation included) terms. We find that it is simpler to work in real dollars. (The low fuel price escalation rates plotted in Figure 1 can be interpreted as either reflecting our prejudice or an optimistic forecast of inflation.)

Note that simply using the current energy price as the comparison price is equivalent to assuming that real energy prices will not rise (or fall) over the lifetime of the measure. Even if real energy prices do rise, the graph shows that the assumption will remain accurate for short lifetimes or low escalation rates. Using the current energy price as the comparison price greatly simplifies the analysis, and might be used for early estimates. However, the implicit assumption of constant energy prices must not be forgotten.

ASSESSING MANY CONSERVATION MEASURES: THE SUPPLY CURVE OF CONSERVED ENERGY

The cost of conserved energy technique can be extended to create "supply curves of conserved energy." (See Figure 2.) The supply curve is a graph of the cumulative energy savings versus the cost of conserved energy. Each conservation measure represents a step on the curve, whose width equals the energy saved and whose height equals its cost of conserved energy. The measures are stacked in order of increasing cost of conserved energy, so the result is a curve resembling familiar supply

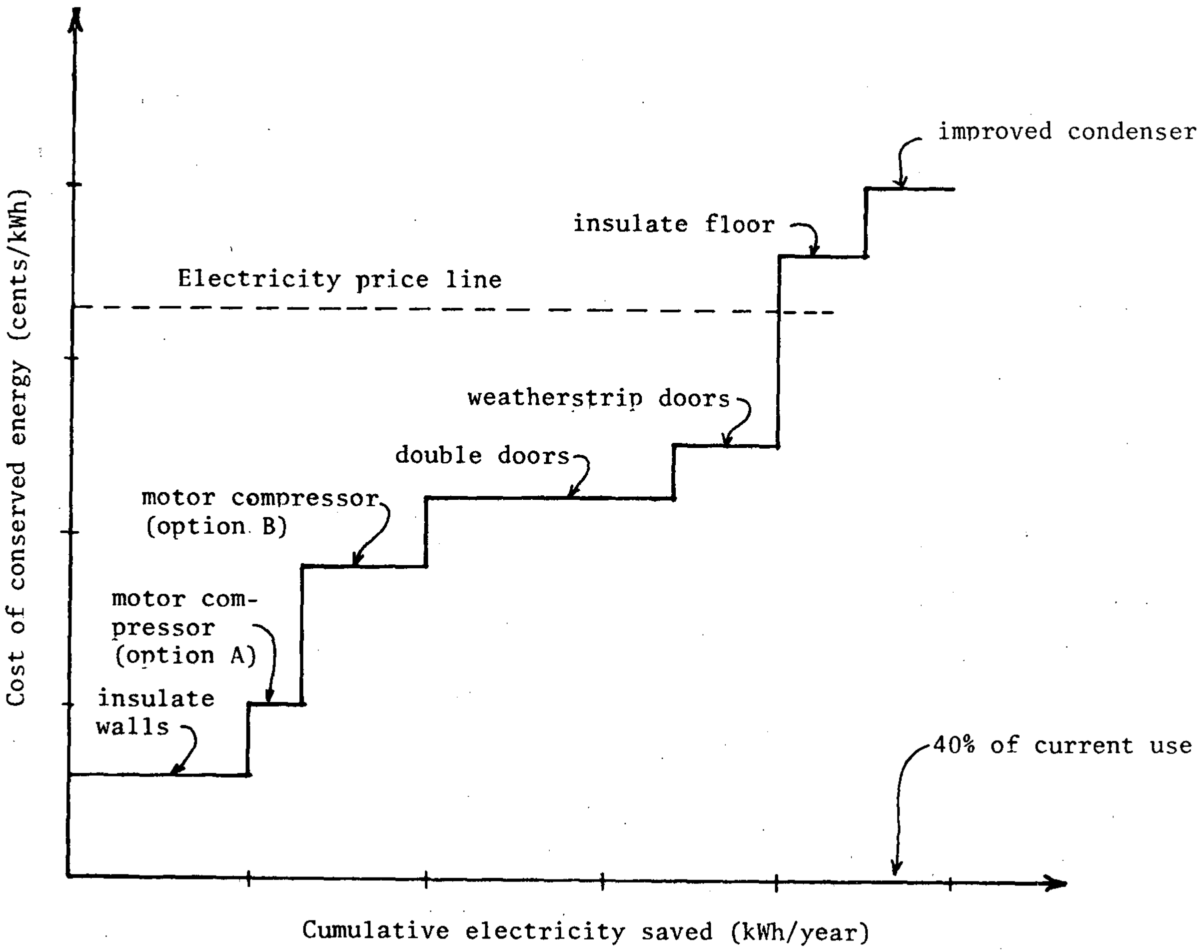


Figure 2. A hypothetical supply curve of conserved energy for a walk-in refrigerator. Each step represents a conservation measure. A step's width indicates the measure's energy savings, the height its cost of conserved energy. All measures below the electricity price line are cost-effective. Should the electricity price rise, then additional measures would become cost-effective.

curves for coal, oil or other resource. Here, however, the resource is conserved energy.

Once again, the price of the avoided energy determines which measures are economic. On a supply curve, this translates into a price line; those measures with CCE's below that line are economic. An increase in energy prices translates into an upward shift in the price line. This results in more measures becoming economic.

The conservation supply curve indicates what measures are already economic at current energy prices, and what will become so at higher energy prices. The curves thus provide important planning information as well. The supply curves are also a useful technique for displaying the potential for conservation. They address the question, "Is it worthwhile devoting significant attention to energy conservation activities?" The arrow denoting "40% of current use" suggests that, at least in this example, suggests that the conservation opportunities are relatively large.

Supply curves of conserved energy can be misleading if certain energy accounting principles are not observed. It is important to avoid double-counting saved energy. This might occur when two alternative measures are considered. For example, two kinds of motor/compressor units might be considered for the refrigerator. Obviously, only one can be installed, so their projected savings must not be added. (Otherwise, we may obtain the embarrassing result that more energy can be saved than the motor/compressor used originally!)

To avoid this problem, while still displaying both measures on the supply curve, we focus on the incremental energy savings and cost. The energy savings and CCE are calculated for each measure as if they were implemented separately. The measure with the lowest CCE would be plotted on the curve. If the alternative also saved less energy, then it would be ignored because, in all cases, the first is preferable. However, if the alternative saved more energy, then a new CCE would be calculated using its incremental cost and energy savings (both above the first measure). This step would be plotted on the curve after the first option. Its CCE would necessarily be higher, but the size of the savings may be either larger or smaller. (It depends upon the circumstances.)

In general, always assume that all earlier measures shown on the curve have been implemented before estimating the energy savings of the next measure. This is, in a sense, a "worst case" situation. If external reasons require a measure to be implemented out of sequence, the energy savings will probably be greater (and CCE lower) than shown on the curve. The magnitude of the overestimate depends on the interdependence of the measures ; but it will never be an underestimate.

It is important know the original energy consumption. Many conservation measures save a percentage of the original energy use, so an error in the original consumption causes errors in estimates of energy savings. An overestimate of initial energy use can lead to saving nonexistent energy!

It is often important to specify the original level of service. The savings from some conservation measures are very sensitive to the level of service. For a building, this would include the inside temperature, and the hours that it must be maintained. The energy saved from insulation, for example, depends on the inside-outside temperature difference; a small error in the inside temperature specification will lead to major errors in savings estimates.

THE CCE AND OTHER INVESTMENT STATISTICS

A list of conservation measures ranked by their cost of conserved energy may differ from similar rankings based on the internal rate of return (IRR) or net present value (NPV).[3] Both the IRR and NPV include energy prices as an input. Thus, changes in energy price assumptions (or even price escalation rates) causes re-ranking of the measures. In contrast, the CCE is independent of energy prices, so new price assumptions will not affect the ranking. Similarly, a supply curve of conserved energy does not change with energy prices (although the cut-off point does).

The CCE is a more compact statement of the costs directly associated with a conservation measure and not cluttered with the excess baggage of energy price assumptions.

CONCLUSIONS

The cost of conserved energy, and its extension, the supply curve, is a convenient technique of expressing the economics of energy conservation. It encourages the comparison conservation investments to those for new energy supplies, or even current energy costs. Finally, the supply curves establish a framework for considering the potential for conservation. It recognizes that the goal is providing specific services, not energy itself, and that more efficient energy use may achieve those more economically.

NOTES AND REFERENCES

1. U.S. Department of Energy, Monthly Energy Review, February 1982, DOE/EIA-0035(82/02)

2. Often the measure saves fuel, but requires additional electricity. This makes the net energy savings awkward to calculate since different fuels are involved. For small increases in electricity use, we suggest conversion of electrical savings to fuel savings at a rate equal to the ratio of their prices. For example, if natural gas costs $5/MBtu and electricity 6 cents/kWh ($17.60/MBtu), then an additional 1 kWh reduces the gas savings by [3415 x (17.6/5) =] 12,000 Btu. This is somewhat higher than the average rate at which thermal power plants convert fuel into electricity, that is, they typically require 11,000 Btu of oil to generate 1 kilowatt-hour.

3. This should come as little surprise since the IRR and NPV rankings often disagree. See, for example, E. J. Mishan, Cost Benefit Analysis, Praeger Publishers, New York, 1971.

This report was done with support from the Department of Energy. Any conclusions or opinions expressed in this report represent solely those of the author(s) and not necessarily those of The Regents of the University of California, the Lawrence Berkeley Laboratory or the Department of Energy.

Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Department of Energy to the exclusion of others that may be suitable.

TECHNICAL INFORMATION DEPARTMENT
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720