Drilling for Oil and Gas in Our Buildings

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Over 40% of U.S. oil imports, or nearly 20% of U.S. oil demand, is provided by Arab and Iranian sources.[1] The vulnerability of these supplies has been dramatized by the political upheaval in Iran and by the recent Senate Foreign Relations Committee prediction that Saudi Arabian production in 1985 will fall several million barrels of oil per day short of previously expected production levels. Because of this supply security problem, rising oil demand, and the difficulties of increasing domestic production, a U.S. oil supply shortfall measured in millions of barrels of oil per day is a very real possibility for the mid 1980's. How can we avert this potential crisis: Gasoline rationing? Further speed limit reductions? Mandatory thermostat setbacks in winter? Further tens of billions in energy industry subsidies? We have a different proposal: to "drill" the giant oil and gas field represented by our buildings and recover the oil and gas now wasted. A successful effort could, by the mid to late 1980's, save half the energy now consumed for space heating, equivalent to 2½ million barrels of oil per day or two thirds of our present dependence on Arab and Iranian oil.[2]

THE POTENTIAL FOR SAVING FUEL

A combination of measures involving added insulation, caulking and weatherstripping, window improvements, and furnace modifications could reduce the fuel needed to heat a typical residence by 50 to 75 percent, without loss of comfort. (Indeed comfort may be improved near exterior walls and windows.) Similar gains could be made in our schools, office buildings, stores, and other commercial buildings;[3] however, this paper focuses on residential buildings.*

*The detailed calculations in this paper apply mainly to residences heated with oil and gas. However, the policies are applicable to residences heated by any fuel.

A goal to reduce fuel consumption for space heating 50 percent or more in existing residences by the mid to late 1980's is technologically, economically and institutionally feasible.* This goal is far greater than the 4 percent savings potential estimated by the Department of Energy.[5] Our estimate is much larger for three reasons: first, greater reductions of space heating fuel requirements than most people think are practical are achieveable with relatively simple measures; second; our estimate is based on a concept of economic feasibility which differs from the one commonly used; and third, we propose institutional innovations that could lead to a high level of implementation.

The Technical Potential

It is possible to achieve remarkable improvements in the energy efficiency of existing residences. Recently, for example, a team of Princeton University researchers introduced some fuel conservation measures in a townhouse in the neighboring community of Twin Rivers and reduced the townhouse's annual fuel requirements for space heating by 2/3.[6] This achievement is especially remarkable in light of the fact that the house was already "well insulated" before the improvements were made: it had double glazing and ceiling and wall insulation. The "retrofits" introduced by the Princeton group included measures such as extensive caulking to reduce unwanted air leaks, insulation around the perimeter of the basement, and the installation of indoor shutters to be placed over large windows at night.

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*Potential savings are even greater in new buildings - 75% or more. For an excellent analysis of the technical opportunities, economics, and institutional issues associated with energy conservation in residences more generally (for both new and existing residences) see ref. 4.

In another effort the installation of more conventional conservation measures (storm windows, wall, floor, and ceiling insulation) by a National Bureau of Standards team lead to nearly a 60% reduction in the heating requirements of a large wood frame rambler (the Bowman House) in suburban Washington, D.C. (see Table 1).[7]

Our Economic Criterion

The conventional approach to evaluating conservation investments is to see if the payback period is "acceptable." The payback period is the number of years it would take to pay off the investment through the user's savings on fuel purchases. The judgment is usually made that the payback period must be less than 3 to 5 years to be acceptable. In contrast, our approach is to invest in conservation measures for a given energy consuming activity to the point of minimizing the total cost to the nation: the cost of energy (evaluated at its replacement cost) consumed over the expected life of the investment plus the cost of the conservation investments.* The critical terms here are "expected life" and "replacement cost." The expected life of almost all conservation investments is more than 3-5 years; so by our criterion fuel savings are credited for a longer period. In our approach fuel savings are also credited at a higher value, since the replacement cost is the cost of energy from new sources and facilities, a cost which is significantly higher than present energy prices. The value one places on energy saved by making a conservation investment depends on one's choices. For the individual consumer who must choose between a conservation investment and increased energy purchases, the estimated price of energy averaged over the life of the investment is the appropriate value. But for the nation as a whole,

*In economic jargon the present value of these costs should be minimized.

Table 1. Economics of Saved Energy for the Bowman House

Conservation Measure	Investment($)[a]	Savings(%)[a,b]	Cost of Saved Energy (1978 $/barrel)[c]
1. Storm Windows	780	25	14
2. Wall Insulation	840	20	18
3. Floor Insulation	480	7.5	28
4. Attic Insulation[d]	550	6	39
1+2	1620	45	16
1+2+3	2100	52.5	17
1+2+3+4	2650	58.5	20

Notes

(a) Based on ref. 7.

(b) The savings are relative to a pre-retrofit annual consumption level of 23.6 barrels of oil. The furnace efficiency is 55%.

(c) For a 12% home improvement loan with a 15 year term. (The corresponding "real" interest rate is 6%. See note 8.)

(d) The relatively high cost of saving energy with attic insulation arises from the fact that there was already 3½ inches of insulation in the ceiling before the retrofits were made.

faced with a choice between a conservation investment and an investment in supply expansion, the replacement cost is the appropriate value for energy saved. Our economic criterion, which represents the national perspective, results in many more investments being economically justified than is the case with conventional analysis. Our approach minimizes the overall cost to the nation, while the conventional approach does not.

To illustrate our approach to the economics of energy conservation it is useful to introduce the concept of the "cost of saved energy." Consider the \$780 investment in storm windows for the Bowman house (see Table 1) - an investment which saves 5.9 barrels of oil per year. If this investment were paid for with a 12% home improvement loan having a 15 year term (a term comparable to the expected life of the investment), the annual loan payment (in constant dollars) would be \$80.[8] The "cost of saved energy" is simply this annual cost divided by the annual savings:

\$80/5.9 barrels = \$14/barrel.

The cost of saved energy associated with each of the Bowman house investments is shown in Table 1.

Our conservation investment criterion is that an investment is cost justified if the cost of saved energy for that investment is less than the replacement cost for energy. Starting with the most cost effective investment, one would pursue further investments until the cost of saved energy for the last investment (the marginal cost of saved energy) is equal to the replacement cost for energy. What is the replacement cost for energy to residential customers? We estimate that for liquids and gases it is between \$30 and \$40 per barrel of oil (in 1978 dollars).[9] These replacement costs are considerably greater than the actual prices paid by residential customers in 1978: about \$21/barrel for heating oil and \$15/barrel (of oil equivalent energy) for natural gas.[11]

The cost of saved energy associated with the Bowman house investments should be compared to these replacement costs (see Figure 1).* The first three investments (which give rise to a 52% fuel savings) are clearly justified by our criterion. The last investment (for ceiling insulation) may or may not be cost justified, because it is uncertain whether the replacement cost is higher or lower than $39/barrel.

Because present energy prices are so much lower than replacement costs, however, the typical consumer would usually invest only in the first one or two investments shown in Table 1, and thereby capture less than the full savings which are justified on the basis of the replacement cost criterion.** The challenge for public policy is to motivate the homeowner to make his investment decisions in accord with the national goal of minimizing overall costs.***

Level of Implementation

The fact that energy prices are not equal to replacement costs is just one of several institutional obstacles to achieving a 50-75% reduction in the

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*Good economic data on retrofits are available for the Bowman house. However, the Bowman house is not typical, because initially it was very air-tight.[7] For most houses a given level of investment would yield greater savings. Specifically, in many houses fuel savings of 15-20% can be achieved at very low cost by eliminating anomalous heat losses associated with unwanted air flows that bypass insulation.[19] We estimate that for a more typical house a 50% fuel savings could be achieved for an investment of about $1500, corresponding to an average cost of saved energy of $15/barrel of oil (compared to $20/barrel for the Bowman house).[12]

**Specifically, suppose the homeowner expected that fuel prices would rise no faster than general inflation. Then only the first investment would be cost-justified from his perspective if the heating fuel were gas, and only the first two investments would be cost justified with oil heat.

***The criterion that investments be pursued to the point where the marginal cost of saved energy equals the replacement cost of fuel would have only a relatively minor effect on the consumer's total energy bill (cost of fuel plus loan payment) in practice, because the minimum in the total energy bill as a function of the fuel savings is usually very broad. Consider the total energy bill for the Bowman house (see Figure 1). At 1978 fuel prices the minimum fuel bill would arise for a $1620 investment, which would save 10.6 barrels per year. An investment of $2650, which would lead to a 30% greater fuel savings, would give rise to a total monthly energy bill only 9% higher.

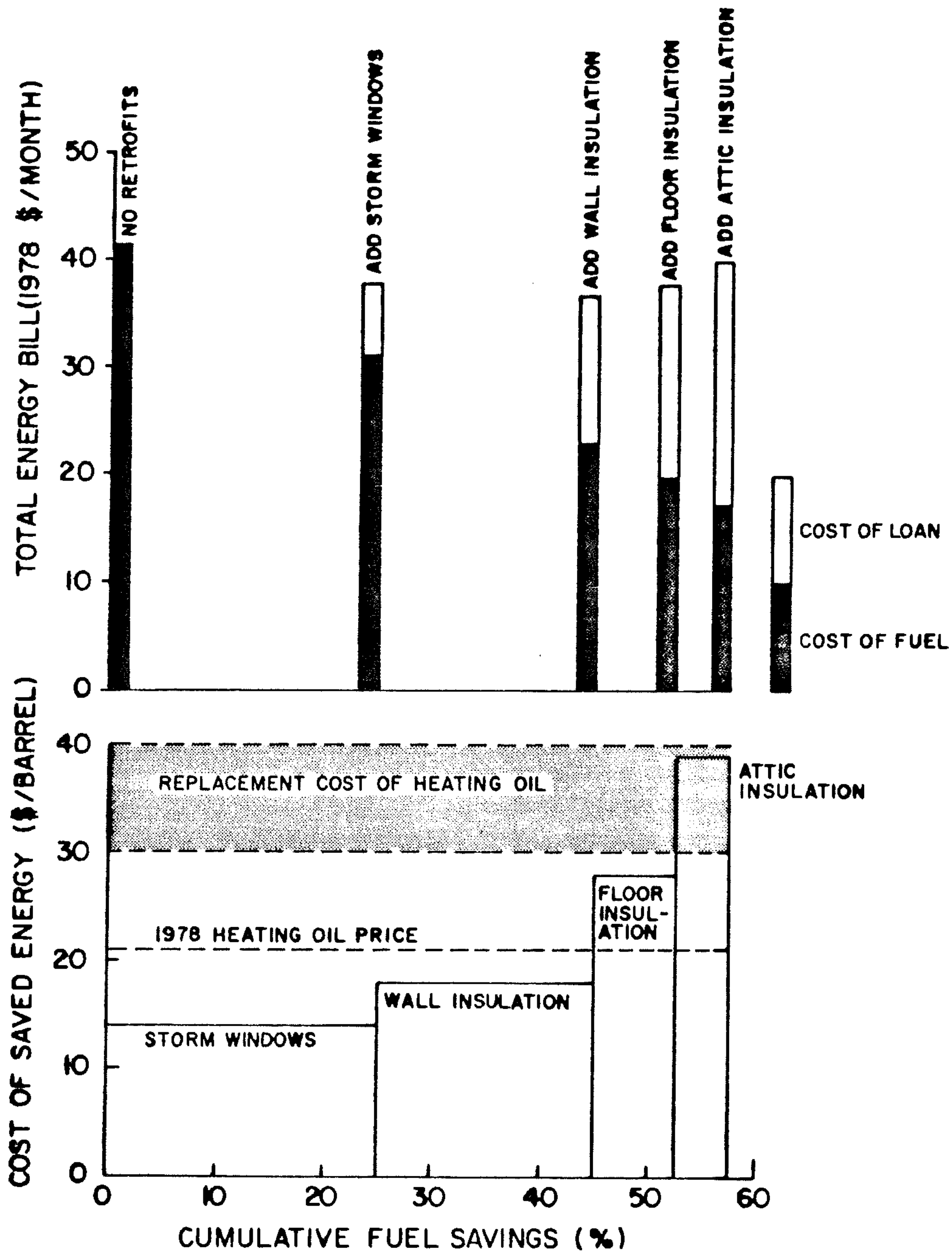

Figure 1: The Economics of Saved Energy for the Bowman House. The monthly bill shown at the top is based on the 1978 oil price of $21/barrel. All other data are from Table 1.

use of fuel for space heating. Other obstacles include the lack of technical capabilities to achieve highly efficient heating of residences, the low incentives for improving those rental buildings for which the fuel bill payer is someone other than the building owner, and the fact that the Department of Energy has set as its goal the capture of energy savings costing only $10 per barrel of oil equivalent energy in its Residential Conservation Service program.[13] These obstacles will not go away by themselves, but we are persuaded that, because the economics of improved housing energy performance are so compelling, these obstacles could be overcome with acceptable public policy changes. In what follows we sketch the outlines of a new policy which could lead in a few years time to saving half the fuel the nation uses for space heating. This policy involves retrofit pilot projects, the training of house "doctors," and innovative financing measures that would encourage a high level of implementation.

A PROPOSED POLICY FOR ENERGY CONSERVATION IN HOUSING

Retrofit Pilot Projects

Pilot projects are essential because the nation's responsible professionals don't yet understand household energy performance well enough. If on the average $1500 per house or apartment is to be invested in conservation, it is essential to know what steps would be most effective and to be able to estimate the fuel savings that would probably occur. Handbooks and computer programs are now widely available to provide just that information. The trouble is that they are often wholly inadequate to provide the optimal advice for making conservation investments. Building "models" assume that a building is like an idealized box, but a real building cannot always be treated that way. The pathways for heat flow are often complex. The magnitude of the problem is illustrated by the escape of warm air into the attics of houses - heat flow that bypasses the ceiling insulation. It has been estimated that heat losses through "attic insulation bypasses" in one and two story single family wood frame houses account for about 20% of total U.S. residential space heating energy use.[14]

A recent investigation showed that, for 40 houses tested in various parts of the Northeast, actual heat losses to the attic were 3 to 7 times greater than the theoretical heat losses (calculated for the heat flow through the ceiling insulation.)[15] Various pathways for warm air to flow into the attic can cause such heat losses: an open shaft around a flue that extends from the basement to the attic, plumbing vent pipes, stairwells, spaces within walls, unsealed walls behind dropped ceilings, etc.

Because of these pathways, handbooks or computer programs will usually fail to give people advice that will minimize the cost of improving the energy performance of their houses. Because of insulation bypasses a homeowner who follows advice to add more ceiling insulation is likely to get only 1/3 to 2/3 of the fuel savings claimed for the insulation job.[15] While this savings may be cost effective, the homeowner could often be saving much more for the same level of investment if the bypasses were blocked first. And the insulation job may make it much more difficult in the future to find and plug up the bypass heat flows.

To reduce such heat losses it is necessary first to identify them. Unfortunately this problem has not been widely studied in the United States. Most housing types still have not been tested, and even measurement techniques for quickly identifying such heat losses are not yet fully developed. What is needed are pilot projects involving the intensive investigation of heat losses for <u>thousands of individual houses and apartments</u> representing all the major housing types in every region of the country. These investigations should be conducted by competent housing researchers, and regional programs should perhaps be coordinated by an agency with the needed technical skills, such as the National Bureau of Standards. In each case inspection and measurement, analysis, retrofit, and performance evaluation is needed. If the post-retrofit evaluation shows the performance improvement much less than expected, the sequence should be repeated. The goal should be to identify in each case a set of measures which, if carried out routinely, would minimize overall costs. As suggested above, in typical cases these retrofits should reduce energy use for space heating 50 to 75%.

While this process may sound complicated, the total amount of time needed per house would at most be only a few man-weeks of professional investigation. A solid experimental basis for retrofitting most housing types in the nation to achieve the fuel savings goals set forth here could probably be achieved in 2-4 years with a total research budget amounting to 50-100 million dollars.

It would not be necessary to wait until the research were completed on all housing types before proceeding with the next phase of the overall retrofit program, however. As research results are obtained on a particular housing type, they could be immediately utilized in the retrofit effort for that type. The payoff from this effort could thus begin within a year or less of initiating the overall program. This is in sharp contrast with R&D projects for conventional energy supply technologies, where the initial payoffs occur at the very least many years after project initiation.

Training of House Doctors

In general, building owners do not know how best to spend money on conservation investments. They need expert advice. Builders typically do not have the technical skills to design an optimal housing retrofit. What is needed to deal with this lack of knowledge is a new profession of "house doctors."[16,17] The house doctor is a person who understands housing from a thermal standpoint, can identify by direct inspection the important thermal attributes of a small building, and is thoroughly familiar with effective retrofits on most housing types in the region. Every community needs house doctors who can function as housing inspectors or auditors, as installers of conservation materials, and as vocational instructors who would train such auditors and installers. We focus here on the housing auditor. The house doctor as auditor would make "house calls" to diagnose the needs of houses from a thermal standpoint.*

The institutional framework for a nationwide program of housing audits already exists. The 1978 National Energy Conservation Policy Act requires that public utilities provide to building owners on request a building audit that would result in a set of recommendations for conservation investments.

The primary strength of the law is that it is universal; in principle utilities can service nearly all buildings. The principle weakness of the present law is that it does not have a strong enough technological basis. Under the law "well-trained" auditors would understand how "ideal" houses would work, but they might not learn how "real" houses work.

This shortcoming of the present housing auditor program is not an intrinsic difficulty but is amenable to solution. A training program is needed which is firmly rooted in experience.

One strategy for improving the competency of house auditors would be to establish regional training and certification programs in conjunction with the regional housing retrofit pilot projects. Because this combined research and training program would involve extensive measurements for typical housing types, detailed measurements could be avoided in subsequent routine audits, and audit costs could thereby be controlled. The house doctor's training should thus enable a competent diagnosis on the basis of rapid inspection.

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*The house doctor as auditor should also be prepared to provide advice to remedy other energy ills of the house as well - suggesting flow restrictor shower heads, water heater insulation, the installation of heat recovery devices, etc.

Prospective house doctors should perhaps be "certified" before they could practice. Because it would be necessary for house doctors to keep abreast of the fast moving developments in the housing research programs over the next few years, it may be desirable to require house doctors to take short (one week, say) refresher courses and be recertified annually.

The house auditor's responsibilities for a given house must not end with a single diagnosis. Rather the auditor should follow through with a "post operation checkup" to see if his "patient is cured." The success of the conservation efforts would be measured in part by comparing fuel bills both before and after retrofits. If post-retrofit performance is generally much less than expected, the advice of a "specialist" on the particular housing type should probably be sought, both to achieve a cure and to establish that the thermal properties of the type of house in question are adequately understood.

The Department of Energy has estimated that an audit in its proposed Residential Conservation Service program would require 2½ man hours and cost about $60.[18] A high quality audit like that proposed here would cost more - but the increased savings would more than justify the cost. Housing conservation researchers L. Becker and G. Dutt at Princeton University have proposed a combined audit/partial retrofit strategy that would make the more costly audit very attractive. Their proposal is that the auditors should perform on-the-spot partial retrofits, involving some furnace efficiency improvements and the reduction of "bypass" heat losses. Many such losses can be reduced or eliminated rather quickly using a few simple materials such as small sheets of plastic, tape, or small quantities of insulation. (This remarkable possibility arises because many bypass heat losses involve unwanted air flows through relatively small areas, the reduction of which is intelligence intensive but not nearly so labor and materials intensive as the more conventional conservation measures.) It is estimated that these audit/partial retrofits would require about 4 man hours and cost perhaps twice as much as the DOE audit. But the partial retrofit alone could typically save 15-20% of space heating fuel.[19]

Financing

An all out effort to retrofit buildings heated by oil and gas to improve their energy performance could require on the order of $15 billion per year of capital investment.[20] This level of investment is economically justified because the cost of saving energy even to the high degree proposed here would be less than the cost of the energy supply investments which would thereby be made unnecessary. This is a staggering investment rate, but it is only about 15% of the value of building construction contracts[21] and about 25% of the level of energy supply investments in 1977.[22]

The financing problem for such conservation investments is not one of finding the capital - it is one of motivating tens of millions of consumers to invest in conservation and of channeling capital available in capital markets to these conservation projects. The financing opportunities differ, depending on whether the space heating fuel is electricity, gas or oil.

Electricity and Gas Conservation Investments: Electric and gas utilities provide a particularly promising institutional framework for financing building investments that save electricity and gas. Involving these utilities could lead to a high level of conservation investment in just a few years. The unique advantages of these public utilities are the following:

- These utilities are accustomed to raising large amounts of capital. (In 1977 they accounted for about ¼ of all new plant and equipment expenditures in the U.S. economy.)[22]
- Utilities offer an existing administrative structure for channeling the needed capital to nearly all households and commercial buildings.

- Utility financing provides a natural institutional framework for valuing saved energy on a replacement cost basis. (Utilities, unlike the customers they serve, would be faced with an investment choice between conservation and supply expansion.)

- Utility financing provides a mechanism that could facilitate the evaluation of conservation investments on a lifecycle cost basis. (The customer could be charged on his utility bill the loan payment for the conservation investment. If the loan had a long term comparable to the 10-20 year financial lifecycle of most conservation investments* the customer, upon receiving advice on a range of investment opportunities, could approximately minimize lifecycle costs by investing to the level such that his total monthly utility bill would be minimized.)

Regulatory changes are probably needed to assure that utilities are motivated to evaluate conservation projects fairly, however. Because most utilities are allowed by state regulatory commissions to make a profit only on the energy supply capital they own, conservation investments would not, in today's regulatory climate, be treated on an equal footing with supply investments.

One arrangement designed to motivate the utilities to make conservation investments has been instituted in the state of Oregon, where electric utilities are allowed to finance conservation investments (for residential electric heating customers) and introduce them into the rate base.[23] An electric heating customer may request an audit of his dwelling. Subsequently the utility will offer to finance and contract for that part of the work recommended by the auditor which the homeowner actually wants done. Since the cost of the conservation investment goes into the rate base, the homeowner does not pay for the retrofit outright; rather the customer would repay the utility the cost of the conservation investment (without interest), only if and when the house is sold.

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*Utilities often have access to capital for long term loans - for example, from institutional investors such as insurance companies.

The Oregon plan has a number of attractive features. Not only does it provide a mechanism for achieving the optimal level of investment, but most important, it should lead to a high level of participation. While conventional conservation investments often lead to dollar as well as fuel savings, the resulting reduction of the consumer's total energy bill based on lifecycle costs (the cost fo fuel plus the loan payment) would often not be large enough to be a compelling incentive to invest (see Figure 1). The Oregon plan does provide a compelling incentive. The energy bill for participating consumers should drop markedly, since the interest payments on the investments are spread over all customers. It is a startling fact, however, that this arrangement would not penalize non-participating customers. Utility expenditures for conservation would be approximately balanced by the savings to the utility in deferring new supply investments. In other words, even though the utility would provide "free" retrofits to some customers, the price of electricity would rise only about as fast as it would have without the conservation program.* This remarkable result arises because the cost of saving energy is expected to be much less than the cost of expanding energy supply. In the case of Oregon's Pacific Power and Light utility, for example, the criterion specified for justifying conservation investments is:[24]

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*In the Appendix we show that for a typical U.S. utility putting conservation investments for electric heating customers into the rate base would not increase the price of electricity relative to what it would be with the equivalent amount of supply expansion.

> "The test will be whether, in each instance, the cost of "producing" the energy to be saved through installation of insulation or weatherization is sufficiently less than the cost of producing equivalent energy through new production, to provide long term benefits to all rate-payers. This test will be uniformly and objectively applied and cost-effective installation will be available to all qualified customers who meet the test."

Another attractive feature of this plan is that it provides the basis for protecting low income groups against the impacts of rising energy prices. The poor spend a much larger fraction of their income directly on energy than do higher income groups.[25] Thus rising energy prices can place an especially heavy burden on low income groups. This problem has led to proposals for "lifeline rates" and other measures to keep energy prices low for low consumption levels.[26] Unfortunately, however, such measures to protect low income groups often end up subsidizing the energy consumption of middle and upper income consumers as well, and they reduce the incentive to conserve. In contrast, utility financing of conservation investments would protect participating low income households without reducing the incentive to conserve.

An additional virtue of this plan is that it provides a direct mechanism for encouraging conservation in renter occupied buildings. A formidable obstacle to conservation investments in such circumstances is that the building owner has no significant incentive to make conservation investments if he does not pay the energy bills. Putting conservation investments for rental properties into the rate base, however, is an attractive arrangement for renter and utility, which does not place a burden on the landlord, except by increasing the sale price of the building.

Putting gas heating conservation investments into the gas utility rate base could lead to especially large space heating fuel savings, because natural gas accounts for nearly half of space heating fuel use. In this case putting conservation investments into the rate base would slow the introduction of costly new gas sources, which eventually will cost residential customers about twice what they now pay for gas.[9]

Gas utilities should be attracted to this proposal because it would provide substantial opportunities for rate base expansion for the new era of slow growth in the gas supply. Not only would the conservation investments themselves add to the rate base, but also the saved gas could be used for other customers. Saving half of the gas we now use for space heating would free up gas supplies equivalent to 40% of the total amount of oil used today by industry. Thus gas saved in buildings could be used to substantially reduce industry's dependence on oil. (A particular gas utility today may be reluctant to seek such savings, however, for fear that the saved gas might be reallocated to another utility. It is clearly in the national interest to eliminate such disincentives from the nation's gas allocation policy.)

Of course the Oregon plan or its equivalent for gas utility is not perfect. While the plan provides substantial rewards to participating customers, it would not significantly benefit other ratepayers. A variant of the Oregon plan which may be more attractive in this respect, and therefore more palatable politically, would be a utility financed conservation program in which only part of the investment would go into the rate base (as in the Oregon plan) while the remainder would be charged to participants via a long term loan paid on the utility bill.

The Oregon plan, or some variant upon it, appears to us to be a promising arrangement for achieving a high level of space heating fuel savings in a relatively short time. Yet the 1978 National Energy Conservation Policy Act explicitly prohibits utility financing of conservation investments. (The Oregon plan, which was initiated before the passage of the Act, may continue because of a "grandfather clause" in the Act.) It is possible for the Secretary of Energy to waive this prohibition:[27]

> Waiver - The Secretary may, upon petition of a public utility supported in the case of a regulated utility by a Governor, waive in whole or in part the prohibitions contained in subsection (a) with respect to the utility if such utility demonstrates to the satisfaction of the Secretary that, in carrying out prohibited activities under subsection (a), fair and reasonable prices and rates of interest would be charged and the Secretary finds, after consultation with the Federal Trade Commission, that such activities would not be inconsistent with the prevention of unfair methods of competition and the prevention of unfair or deceptive acts or practices.

In light of the large stakes involved and the urgency for setting a major housing conservation program in motion, substantial efforts should be made to make use of this waiver, to have this prohibition repealed with new legislation, or to identify some alternative financing arrangements that are as promising as the Oregon plan.

Oil Conservation Investments: Unfortunately the utility financing model cannot be easily applied directly to oil heating customers. Yet since our energy crisis is mainly an oil crisis and since oil heat accounts for over 2 million barrels of oil per day, a financing arrangement that will lead to a high participation rate and a high fuel savings rate is badly needed for oil heating conservation investments.

One way to create the same incentives for oil heating customers as the utility financing scheme described above creates for electric and gas heating customers would be to set up energy conservation financing corporations to make investment capital available for heating oil conservation projects. Such corporations could perhaps organize the housing audits and arrange for installation as well. These corporations could obtain capital either from institutional investors (such as insurance companies) or from the sale of bonds. Participating customers would pay nothing directly for these investments, but would be required to pay off the investment at the time the house is sold. Interest on these investments would be paid by the government. One way to obtain the needed revenues would be to levy a tax on heating oil. We estimate that the interest could be paid on loans covering all residential investments with a tax that would increase from about 1½¢/gallon in the first year to about 20¢/gallon at the end of the ten year program and would then would be reduced in half every five years thereafter.[29] Alternatively the interest could be paid for with revenues from the windfall profits tax associated with the decontrol of oil prices. A recent Congressional Budget Office estimate is that the cumulative windfall profits through 1985 would total $135 billion and that President Carter's windfall profits tax proposal would yield revenues of $72 billion.[30] We estimate that the total interest payments on residential oil heating loans would total $26 billion.[28]

CONCLUSION

The housing retrofit program we have outlined is very ambitious. It could not be realized if one or more of the three program components were slighted - the retrofit pilot projects, the house doctor training programs, or the financing measures. But the effort could in just a few years significantly reduce our dependence on insecure sources of foreign oil; it would help stabilize energy prices; it would lead to the creation of over 200,000 jobs for conservation installers[31] and many more jobs for the manufacturing and marketing of the needed materials and hardware; it would be much less costly and much more effective in helping to rapidly close the oil supply/demand gap than a synthetic fuels strategy; and the effort would be far preferable to the imposition of draconian energy rationing measures.

Notes and References

1. In 1978 U.S. oil consumption averaged 18.7 million barrels of oil per day, while total imports averaged 8.2 million barrels per day. Arab and Iranian sources accounted for 3.5 million barrels of oil per day. See <u>Monthly Energy Review</u>, published by the Energy Information Administration, U.S. Department of Energy, March 1979.

2. In 1975 oil and gas use for space heating amounted to 6.7 Quads in the residential sector (see E. Hirst and J. Carney, <u>Residential Energy Use to the Year 2000: Conservation and Economics</u>, Oak Ridge National Laboratory report ORNL/CON-13, September 1977) and 3.5 Quads in commercial buildings (see J.R. Jackson and W.S. Johnson, <u>Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use</u>, Oak Ridge National Laboratory report ORNL/CON-14, February 1978). Thus saving 1/2 of oil and gas used for space heating would be equivalent to saving the energy equivalent of about 2½ million barrels of oil per day. Although about half this space heating fuel is gas, gas saved in buildings could be used to displace oil used by industry, so that saving a Btu of space heating fuel is equivalent to saving a Btu of oil.

   Further fuel savings could be achieved in buildings heated with electricity and other fuels (for which consumption totalled 2.35 Quads of primary energy in 1975). In the case of electricity the percentage reduction in space heating energy requirements that could be achieved with economical conservation measures may be less than in oil or gas heated buildings, because electrically heated buildings are usually thermally tighter to begin with.

3. The potential percentage reduction in space heating fuel requirements should be at least as great for commercial as for residential buildings. One would expect lower heating requirements for a unit area of commercial space than for a unit area of residential space, because there is less building "skin" for a unit area of a commercial building on the average. However, the reports cited in note (2) show that in 1975 commercial buildings consumed, on the average, 40% more fuel for space heating per square foot than did residential buildings.

4. Office of Technology Assessment, <u>Residential Energy Conservation</u>, volumes I and II, July 1978, Washington, D.C. Also for an excellent analysis of the energy and dollar savings opportunities for a variety of household appliances see D.B. Goldstein and A.H. Rosenfeld, "Energy Conservation in Home Appliances through Comparison Shopping: Facts and Fact Sheets," Lawrence Berkeley Laboratory Report LBL-5910, March 1978.

5. The Department of Energy estimate of the impact of implementing the Residential Conservation Service (RCS) program established in Title II of the National Energy Conservation Policy Act (PL 95-619) is that 7% of households will request an audit each year, that 75% of audits will be followed up by conservation retrofits, and that the completed program will result in energy savings of 0.38 Quads per year, which is less than 4 percent of residential space and water heating energy consumption in 1975. To estimate the expected savings for participating households, note that with a 5 year program about 26% of houses would be retrofitted, so that energy savings for space heating and water heating would average

about 13% for the customers who would act on the advice of the household audit. See Department of Energy, "Residential Conservation Service Program: Proposed Rulemaking and Public Hearing," p. 16577, Federal Register, Part II, March 19, 1979.

6. Frank W. Sinden, "A Two Thirds Reduction in the Space Heat Requirement of a Twin Rivers Townhouse," Energy and Buildings, vol. 1, number 3, April 1978. See also Saving Energy in the Home: Princeton's Experiments at Twin Rivers, edited by Robert H. Socolow, Ballinger, Cambridge, 1978.

7. The Bowman house (2054 ft^2) initially had insulation only in the attic ($3\frac{1}{2}$ inches) and double glazing only on a living room picture window; all other windows had single glazing. Before the storm windows and insulation were added efforts were made to reduce air infiltration by caulking, weatherstripping, etc. This effort (which cost $190) resulted in no measurable savings. This is probably because the house was quite air tight to begin with - having an air exchange rate of 0.2-0.6 air exchanges per hour. A more typical house has 1-2 air exchanges per hour. See D.M. Burch and C.M. Hunt, "Retrofitting an Existing Wood-Frame Residence for Energy Conservation - an Experimental Study," NBS Building Science Series 105, July 1978.

8. The annual payment P on a loan L with an interest rate i and a term of N years is

$$P = \frac{iL}{1-(1+i)^{-N}}.$$

For i = 0.12 and N = 15 this becomes

$$P = 0.147 L.$$

Thus if L = \$780, P = \$115 per year. For an annual savings of 5.9 barrels of oil the cost of saved energy is \$19.4/barrel. This cost of saved energy, which would be the same in each year over the life of the loan, is to be compared to the average price of oil over this period. During this period the price of the oil would be increasing. Suppose the price of oil escalated at the general inflation rate (which we assume averages 6%/year). If the initial price of heating oil is the average 1978 price to residential customers (\$21/barrel - see Monthly Energy Review, note 1) then the oil price would be \$28/barrel in 5 years, \$38 in 10 years, \$50/barrel in 15 years.

To facilitate the comparison between the cost of saved energy and the cost of oil, the cost of saved energy can be corrected for inflation. With 6% inflation, a 12% interest rate in current dollars corresponds to a 6% interest rate in constant dollars. Thus in constant dollars, with i = 0.06 and N = 15 years,

$$P = 0.103L$$

The resulting cost of saved energy for the case considered here ($13.60/ barrel) is to be compared to an average oil price (in constant dollars) over the life of the investment of $21/barrel. If the price of oil escalated faster than general inflation, the average price of oil over the life of the investment (in constant dollars) would be greater than $21/barrel.

9. In the case of oil we consider two measures of the replacement costs: oil imports and synthetic liquids from coal. As of July, 1979 oil imports cost about $20 per barrel. To get the replacement cost for residential customers one must add the cost of overseas transport (about $1/barrel in 1978) and the refining/marketing mark-up (about $8 in 1978). Thus for imports the present replacement cost is about $29/barrel. For synthetic liquids from coal production costs have been estimated (see ref.10) to be $25-$35 per barrel (in 1978 dollars), corresponding to a residential customer price of $33-$43 per barrel.

   In the case of natural gas the most discussed sources of new gas are unconventional sources of natural gas (from tight sands, deep formations, Devonian shale, coal beds, geopressurized reservoirs) and synthetic high Btu gas from coal. It has been estimated that unconventional gas will cost $15-$30 per barrel of oil equivalent energy, while synthetic high Btu gas will cost $20-$25 (see ref.10). To this one must add about $10/barrel (roughly the difference between the residential price of gas and the gas production cost in 1978), so that the replacement cost of gas to residential customers would be $25-$40 per barrel for unconventional natural gas sources and $30-$35 per barrel for high Btu gas from coal.

10. Department of Energy transmittal to the Senate Natural Resources Committee, March 23, 1979.

11. According to <u>Monthly Energy Review</u> (see note 1) the average price of residential heating oil was about $21 in 1978, and the average price of residential gas was $15 per barrel of oil equivalent energy.

12. For a typical house a 50% fuel savings (59 million Btu or 10 barrels of oil equivalent energy per year) could be achieved for about $1500 invested according to the recommendations of a competent "house doctor" trained to contend with bypass as well as conventional heat losses. For this investment the cost of saved energy (see note 8) would be

$$\frac{(0.103 \times \$1500)/\text{year}}{10 \text{ barrels/barrel}} = \$15/\text{barrel}.$$

13. The Department of Energy estimates that the RCS program would result in homeowner investments totalling $6.7 billion and would lead to fuel savings of 180,000 barrels/day (see note 5). The cost of saved energy implicit in this effort is (see note 8):

$$\frac{0.103 \times (\$6.7 \times 10^9)}{(365 \text{ days}) \times (0.18 \times 10^6 \text{ bbls/day})} = \$10/\text{barrel}.$$

   Clearly a much higher investment level is cost justified.

14. G.S. Dutt and J. Beyea, "Hidden Heat Losses in Attics - Their Detection and Reduction," Center for Energy and Environmental Studies Report No. 77, Princeton University, May 1979.

15. G.S. Dutt, J. Beyea, F.W. Sinden, "Attic Heat Loss and Conservation Policy," paper presented at the Energy Technology Conference and Exhibition, sponsored by the Technology and Society Division of the American Society of Mechanical Engineers, November 5-9, 1978.

16. A sophistocated "commercial building doctor" program is also needed. A pioneering program along these lines is being developed by a group at Iowa State University. See "Manual of Procedures for Authorized Class A Energy Auditors in Iowa," prepared by the Engineering Research Institute, Iowa State University, for the Iowa Energy Policy Council, April 1979 (second edition).

17. The house doctor concept was originally proposed by Robert Socolow of Princeton University. See R. H. Socolow, "Energy Conservation in Existing Residences: Your Home Deserves a House Call," paper presented at the conference Energy Efficiency as a National Priority, Washington D.C., sponsored by Public Citizen, Inc., May 20, 1976.

18. See ref. (5) p.16581.

19. L.J. Becker and G.S. Dutt, "Will the Residential Audit Program Save Energy?" testimony for the U.S. DOE Proposed Rulemaking and Public Hearings on the Residential Conservation Service Program, April 24, 1979.

20. An average investment might be $1500/house or $90 billion for all oil and gas heated households. Perhaps another $50 billion would be needed for the commercial sector. We assume this program is carried out over 10 years.

21. In 1977 the value of building construction contracts in the U.S. amounted to $61.4 billion for residential and $35.3 billion for non-residential buildings. See Statistical Abstract of the United States-1978, p. 782.

22. The total investment in energy supply in 1977 was $52.7 billion: $2.0 billion in coal mining, $27.7 billion in electric utilities, $4.4 billion in gas utilities, and $18.5 billion in oil and gas. Sources: Energy Information Administration, Annual Report to Congress: Volume II, 1977, April 1978, p. 50; "1979 Annual Statistical Report," Electrical World, March 15, 1979. Energy supply investments accounted for nearly 40% of new plant and equipment expenditures in 1977 (see "Economic Indicators," prepared for the Joint Economic Committee by the Council of Economic Advisors, May 1979).

23. "Oregon Utilities Can Put Home Insulation in Rate Base: Sound Economics," Electrical Week, July 17, 1978.

24. "Application for Approval of Proposed Tariff Rider and Associated Accounting and Rate-Making Treatment," submitted by C.P. Davenport, Vice President, Pacific Power and Light, to the Public Utility Commission of Oregon, in the matter of the Proposed Residential Energy Efficiency Rider of Pacific Power and Light, April 14, 1978.

25. D.K. Newman and D. Day, The American Energy Consumer, a report to the Energy Policy Project of the Ford Foundation, Ballinger, Cambridge, 1975.

26. See, for example, "Panel on Lifeline Rate Proposals," page 333 in Compilation of Statements of Witnesses Before the Subcommittee on Energy and Power, March/April 1976, Electric Utility Rate Reform and Regulatory Improvement, Hearings Before the Subcommittee on Energy and Power of the Committee on Interstate and Foreign Commerce, U.S. House of Representatives, April 1976.

27. See 216(e), "Supply, Installation, and Financing by Public Utilities: Waiver," Public Law 95-619, National Energy Conservation Policy Act, November 9, 1978.

28. We assume that the retrofits on the nation's 16 million oil heated houses are carried out at a constant rate over 10 years. Thus for a \$1500 investment per house and a 12% interest rate the interest payment required in the year t (in current dollars) would be

$$I(t) = 0.12 \times (\$1500/\text{house}) \times E(t) \times (1.6 \times 10^6 \text{ houses/year}) \times \beta(t) \quad \text{for } t \leq 10$$

$$I(t) = 0.12 \times (\$1500/\text{house}) \times E(10) \times (1.6 \times 10^6 \text{ houses}) \times \beta(10) \times e^{-t/\tau} \quad \text{for } t > 10.$$

Here

$E(t) = \dfrac{e^{it} - 1}{e^{i} - 1}$ = investment escalation factor in the year t for inflation rate i ($i = 0.06$).

$\beta(t) = \dfrac{\tau}{t}(1 - e^{-t/\tau})$ = fraction of the retrofitted houses with outstanding loans in the year t.

τ = average number of years between the sales of a dwelling unit (7 years).

(For a derivation of the expression for $\beta(t)$ see the appendix.)

Using these expressions we estimate that the required interest is \$12 billion for the first ten years and \$26 billion over all time.

29. Since residential heating accounted for 21 billion gallons of oil in 1975 the heating oil tax in the year t would be

$$T(t) = \frac{I(t)}{(1-t/20)\ (21 \times 10^9 \text{ gallons})} \text{ dollars/gallon for } t \leq 10 \text{ years.}$$

and

$$T(t) = \frac{I\ (t)}{(10.5 \times 10^9 \text{ gallons})} \text{ dollars/gallon for } t > 10 \text{ years.}$$

The I(t) in these expressions is given in note 28 for these two time periods. Thus we obtain the following tax schedule:

Year	Tax (¢/gallon)	Year	Tax (¢/gallon)
1	1.3	7	11.3
2	2.7	8	13.6
3	4.2	9	16.3
4	5.7	10	19.4
5	7.4	15	9.5
6	9.2	20	4.6

30. Congressional Budget Office, "The Effect of the June 26 OPEC Price Increase on the Decontrol of Domestic Crude Oil," July 13, 1979.

31. A typical retrofit in housing might require about 7 man days. Thus one man could do about 350 retrofits over 10 years, and about 160 thousand jobs would be needed to carry out retrofits on the entire stock of oil and gas heated housing over 10 years. Perhaps 80 thousand additional jobs would be needed for retrofits in the commercial sector.

APPENDIX: The Effect of Conservation vs. Supply Expansion on Electricity Rates

In this Appendix we describe the impact on the average price of electricity of putting residential space heating conservation investments into the rate base of electric utilities, as an alternative to electricity supply expansion.

The average price of electricity for a utility having only electricity supplies in the rate base is

$$P_{EO} = \frac{rC_{CO}}{H} + C_{FO} \quad \text{dollars per delivered kwh,} \qquad (A.1)$$

where

C_{CO} = current value (original value less depreciation) of the installed physical plant, in dollars per average delivered kilowatt

C_{FO} = fuel cost, in dollars per delivered kwh

r = annual capital charge rate (for investor owned electric utilities r averaged 0.148 in 1976*).

H = number of hours in the year (8766)

(In this analysis we neglect operation and maintenance costs other than fuel.)

If new capacity is added the average price becomes

$$P_E = \frac{r}{8766}[\alpha_0 C_{CO} + \alpha_1 C_{C1}] + \alpha_0 C_{FO} + \alpha_1 C_{F1} \qquad (A.2)$$

where

C_{C1} = capital cost of the new plant

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*The average annual capital charge rate for electric utilities is the ratio

$$r \equiv \frac{(\text{Operating Revenues}) - (\text{Operation and Maintenance Expenses})}{\text{Net Electric Utility Plant}}$$

obtained from Tables 51S and 52S of Edison Electric Institute, Statistical Yearbook of the Electric Utility Industry for 1976, October, 1977.

C_{F1} = fuel cost for the new plant

α_0 = fraction of generation from "old" plants

α_1 = fraction of generation from "new" plants.

Suppose that instead of expanding supply capacity an investment is made in the equivalent amount of "saved energy" costing C_S (dollars per kw saved at the point of end use). If the cost of this investment is folded into the average price of electricity one gets instead of P_E,

$$P_S = \frac{r}{8766}\left[C_{C0} + \frac{\beta\alpha_1 C_S}{1-\alpha_1\beta}\right] + C_{F0} \qquad (A.3)$$

Thus

$$P_S - P_E = \alpha_1 \left[\frac{r}{8766}\left(\frac{\beta C_S}{1-\alpha_1\beta} - \Delta C_C\right) - \Delta C_F\right] \qquad (A.4)$$

where

$\Delta C_C = C_{C1} - C_{C0}$

$\Delta C_F = C_{F1} - C_{F0}$.

β = fraction of the conservation investments remaining in the rate base.

The fraction β occurs here because a conservation investment is removed from the rate base when the house is sold. Here we shall assume that all conservation investments to reduce space heating fuel use are made over a 10 year period. Since the average house is sold every 7 years, β will be significantly less than 1 at the end of this 10 year investment period.

We now evaluate the various parameters shown in (A.4).

<u>The β factor</u>: If N is the number of retrofits in the rate base then

$$\frac{dN}{dt} = P(t) - \frac{N}{\tau} \qquad (A.5)$$

where

P = number of retrofits added in the year t.

τ = average length of time between house sales (7 years).

For simplicity we assume a constant retrofit rate.

Thus

$$N(t) = \tau P \ (1-e^{-t/\tau}) \qquad (A.6)$$

and

$$\beta(t) = \frac{N(t)}{tP} = \frac{\tau}{t} \ (1-e^{-t/\tau}) \qquad (A.7)$$

At the end of the retrofit program

$$\beta(10) = 0.53$$

<u>The cost of saved energy</u>: We have estimated that the cost of reducing oil and gas use for space heating 50% would be \$1500 per household. Since there were 57.2 million oil and gas heated households in 1975 and about 63% of the fuel burned is delivered as useful heat (see D.L. O'Neal, "Energy and Energy Cost Analysis of Residential Heating Systems", Oak Ridge National Laboratory Depart ORNL/CON-25, July 1978), the cost of saved energy is

$$C_S = \frac{(\$1500/\text{house}) \times (57.2 \times 10^6 \text{ houses}) \times (3413\text{Btu/kwh}) \times (8766 \text{ hours})}{0.5 \times 0.63 \times (6.7 \times 10^{15} \text{ Btu})}$$

$$= \$1220 \text{ per kw of delivered heat.}$$

<u>The current value of the present electrical system</u>: In 1976 the installed generating capacity of investor owned utilities was 415.8×10^6 kw, with a net value of $\$141.4 \times 10^9$ (see Tables 1S and 51S <u>Statistical Yearbook of the Electric Utility Industry for 1976</u>. Since the average capacity factor was 43.4% in 1976 (see Tables 1S and 7S, <u>Statistical Yearbook</u>) and since losses in transmission and distribution amount to 9%, the average cost of delivered electricity was

$$C_{CO} = \frac{\$141.4 \times 10^9}{0.434 \times 0.91 \times (415.8 \times 10^6 \text{kw})} = \$860/\text{kw}.$$

The replacement cost for electricity: To estimate the average replacement capital cost we note that the peak demand for electricity in 1976 was 1.59 times the average electrical demand (see Table 6S, Statistical Yearbook).

For the baseload component of this replacement cost we assume a nuclear plant costing \$800/kw(e) (see C.L. Rudasil, "Coal and Nuclear Generating Costs", Electric Power Research Institute Report EPRI PS-455-SR, 1977) operating with a 65% average capacity factor. Its cost per average delivered kw(e) is thus

$$\frac{\$800/\text{kw}}{0.65 \times 0.91} = \$1352/\text{kw}.$$

For peaking units we assume a capital cost of \$280/kw (see Office of Technology Assessment, Application of Solar Energy to Today's Energy Needs, vol I, p. 170, June 1978) and that all capacity operates at 80% of capacity at the time of the system peak. Thus per kw of average produced power one needs

$$\frac{1}{0.80}\left[1.59 - \frac{80}{65} \times 1.0\right] = 0.45 \text{ kw(e) of peaking capacity.}$$

The peaking capacity cost per delivered kw is thus

$$\frac{0.45 \text{ kw} \times (\$280/\text{kw})}{0.91} = \$138/\text{kw}.$$

The cost of distribution has been estimated to be \$157/kw (see Application of Solar Energy to Today's Energy Needs, vol II, p. 721), while in 1972 the total transmission and distribution capital cost was estimated to be 2.2 times the distribution cost (see M.L. Baughman and D.J. Bottaro, "Electric power Transmission and Distribution Systems: Costs and Their Allocation", Center for Energy Studies, The University of Texas at Austin, July 1975). We assume this ratio holds for the replacement cost as well. Thus T & D costs per kw of delivered electricity are approximately

$$\frac{2.2 \times 1.59 \times \$157}{0.91} = \$604/\text{kw}.$$

Thus the average replacement cost is

baseload plant	1352
peaking plant	138
transmission and distribution	604
	$2094/kw

The Fuel Cost in the Present Plant: The generation of electricity by source and fuel cost in the U.S. was the following in 1976:

Source	Percentage	Fuel Cost(mills/kwh)
Hydro	14.0	-
Coal	46.4	9.2
Oil	15.7	21.4
Gas	14.5	11.0
Nuclear	9.4	3.8
	100	

(Sources: All fuel costs but nuclear are obtained from Tables 13.1S, 41S, and 42S of Statistical Yearbook of the Electric Utility Industry for 1976. Nuclear costs are for 1975 from D.L. Phung, "Cost Comparison Between Base Load Coal - Fired and Nuclear Plants in the Midterm Future (1985-2015)", Paper 2 in Economic and Environmental Implications of a U.S. Moratorium, 1985-2010, vol III, Institute for Energy Analysis, September 1976.)

Fuel Cost for the New Plants: We assume the new plants are nuclear and peaking plants which add to the above mix. We assume the same fuel cost for the new as for the existing peaking plants. For the new baseload nuclear plants we assume a fuel cost of 5.9 mills/kwh (see H.A. Feiveson, F. von Hippel, and R.H. Williams, "An Evolutionary Strategy for Nuclear Power", Center for Energy and

Environmental Studies Report No. 67, Princeton University, September 1978).
We now estimate what fraction of the present electricity supply comes from baseload plants. Much of the present oil and capacity (along with hydro) is used for peaking and load following purposes, as the following 1977 U.S. average data show:

Source	Capacity Factor (%)
Nuclear	70
Coal	57
Gas Steam	52
Oil Steam	43
Hydro	43
Gas and Oil Turbines and Combined Cycles	9

(See National Electric Reliability Council, "8th Annual Review of Overall Reliability and Adequacy of the North American Bulk Power Systems", August 1978.)

We shall assume the baseload power in 1977 consisted of nuclear, coal, 1/2 the oil-steam, and 2/3 the gas-steam electricity produced. For these sources, which provided 73% of the total electricity generated, the average cost of electricity in 1976 was 10.1 mills/kwh. Thus the difference between the delivered fuel cost for "new" and "old" electricity is

$$\Delta C_F = \frac{0.73}{0.91} [0.0059 - 0.0101] = -\$0.0034/\text{kwh}.$$

<u>Summary</u>: The following is a summary of our results:

$r = 0.148$

$\beta(10) = 0.53$

$C_S = \$1220/\text{kw}$

$\Delta C_C = \$2100 - \$860 = \$1240/\text{kw}$

$\Delta C_F = -\$0.0034/\text{kwh}$

Thus at the end of the 10 year investment period (1979-1989):

$$P_S - P_E = \alpha_1 \left[\frac{0.0109}{1-0.53\alpha_1} - 0.0175 \right] \text{ dollars/kwh} \tag{A.8}$$

In this period the electric utility industry projects that electricity demand will grow @ 4.0%/year to 3104 billion kwh in 1989 ("29th Annual Electrical Industry Forecase," Electrical World, September 15, 1978).

If residential conservation investments for today's electric space heating customers were pursued instead of the equivalent amount of power generation, electricity demand in 1989 would be reduced by 66 billion kilowatt hours (half the electric space heating demand in 1978), assuming that on the average the conservation effort would lead to a 50% reduction in space heating electricity consumption. Thus by 1989

$$\alpha_1 = \frac{66}{3104} = 0.021$$

and

$$P_S - P_E = 0.021 \ [0.0110 - 0.0175] = -\$0.00014/\text{kwh}. \tag{A.9}$$

This calculation shows the remarkable result that non participating customers would not be penalized by putting conservation investments into the rate base (indeed there may even be a tiny benefit of about 0.1 mill/kwh or 0.4% of the 1978 average electricity price).

One uncertainty in this calculation is the cost of saved energy for electric heating customers. Our estimate ($1220/kw) is based on what is achievable with oil and gas heated houses. One might argue that the cost would be greater for electrically heated houses, which are usually thermally tighter to begin with. Data are inadequate to make a judgment as to whether or not our cost estimate is appropriate. However, even if the cost of saved energy were twice as large for electric heating, one would obtain instead of

(A.9):

$$P_S - P_E = 0.021 \; [0.0220 - 0.0175] = +\$0.000095/\text{kwh}, \qquad (A.10)$$

which is still a null effect.