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Another Look at Energy Conservation

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While "moral war" and "national will" have become associated with energy conservation during the past year, there remains only one really important reason to think about how we use energy: it costs less to conserve energy than to produce from any new energy sources. If social and environmental cost and benefits are counted the impetus to conserve would be even greater. What do we mean by conservation of energy? Why all the controversy?

I. WHAT IS CONSERVATION?

Conservation is a response to exogeneous changes in relative costs, including possibly external costs. While conservation has many political, social or environmental connotations I identify conservation with economic efficiency(1,2):

a) Conservation means substituting less costly resources or production factors for energy--mainly capital, but also information, materials, and labor. Capital equipment and processes are thereby changed in the medium and long term. Conservation means minimization of the present value of capital and operating costs. (See Fig. 1 and 2)

b) Conservation means short term changes in consumer behavior towards a few key energy intensive activities--driving, heating, cooling, hot water use. Existing capital is used. To the consumer the value of the saved energy exceeds the perceived cost of making the change. See Fig. 3

c) Conservation can appear through structural change, either as the cause, or, more likely as the effect. Changes in the market basket of non-energy intensive goods, changes in the use of land, or long-term changes in behavior and preferences can effect energy use greatly. Other things being equal the ratio of energy consumed/GNP would change.

Of these effects, the first has its greater effect in the medium term, as existing capital is replaced. Here more energy is saved per dollar invested than in retrofit. The second reaction can have a marked effect on existing consumption patterns. The third can lead to enormous changes in the energy requirements of the economy through structural shifts.

In all cases it is resource use and consumer amenity satisfaction that is being optimized, not simply energy use per unit of output. Owing to the relative rise in most energy prices, however, economic efficiency will reduce energy intensities in the long run compared to what would have obtained had energy prices continued their historic fall.

It is extremely important that energy elasticities, energy use, and energy conservation itself be carefully measured. Aggregate performance measures like energy/GNP are almost worthless for analysis since structure, intensity, and behavior are mixed together. Energy use/output in specific, well defined processes, factor analysis for well defined processes, or energy costs/total costs for specific processes are far more suitable as measures of performance. While energy/output for the entire paper industry mixes many processes and output, energy use per ton of pulp (which can be further subdivided by pulping process) more accurately measures performance. Similarly busses and autos are not equivalent "processes" except in special cases and should be disaggregated separately from "passenger transport". Ultimately conservation can be measured as reduction in energy/output, energy's factor share, or energy costs/total costs.

II. HOW MUCH TO CONSERVE

Contrary to some views that conservation is a one time option or the implication that conservation is an all-or-nothing proposition (as implied by President Carter's impatient speechwriters), conservation is a continuous process. In fact, energy/output has fallen in most manufacturing industries gradually for decades because of technological progress.

It is sometimes said that such conservation implies labor intensive practices of lower productivity. To be sure Berndt and Woods' pioneering work(3,4) suggested that capital and energy were complements while the capital-energy bundle and labor were substitutes. Other evidence(2,5) suggested that there was some substitutability between energy and capital, while more recent investigations(6) confirm this more directly. Newer, more labor-productive heavy industry requires less energy/product as well as less labor/product than older(6,7) (See Table 1). This substitution of capital for labor increased the ratio of energy/labor if labor costs increased while energy prices declined.

A. Manufacturing

With energy costs now rising, industries will plan new equipment so as to minimize costs. This will reduce energy intensities considerably compared to today's uses, at a very small increase in capital. The full cost of capital services/unit of output, while possibly higher now than would have been the case had energy costs continue to fall, will be lower than if no measures are taken to reduce energy intensities. Berndt and Wood suggest that this might stimulate the substitution of capital-energy for labor even further, but it is hard to see how this increased capital intensity could remove more than a small part of the energy savings per unit of output "won" by conservation. This is particularly important since newer equipment uses less energy/output than older.

Most of the energy savings will be process heat, not labor saving motive power, and there is no indication anywhere that "labor" intensive practices will return. Heat recovery, more efficient combustion, and process controls will simply replace energy at the margin. It is improper to label these substitutions as deleterious to productivity, since industries that conserve will cut costs. The loss in total productivity comes about through the exogenous rise in the cost of one factor of production, energy.

How far will intensities fall in the future? That depends on the development of energy prices, a sensitive issue. Given price rises that have already occurred and the potential increases due to marginal cost pricing (= decontrol) as well as expected inflation in all energy costs, new facilities can be designed to produce raw materials on 20-60% less energy than existing plant averages. The expected incremental capital cost of these savings will be small, both compared to the value of new industrial equipment and compared to the cost (at the margin) of producing the equivalent amount of new energy supplies. Whether the savings are captured depends critically on how aware industrial decision makers are of present and future marginal energy costs. It will probably be many years beyond the arrival of marginal cost pricing before the full value of conservation is routinely captured in industrial plants.

International comparisons of energy use, suitably disaggregated and adjusted, also hint at how much energy can be saved at various energy prices(8). If production function analyses are suitably disaggregated these technical hints can be understood in economic terms, as Carlsson or Long et al show. Thus capital substitues for energy in steel production in Japan (vs the US), while paper, cement, and steel are produced for less energy/ton in higher price energy lands like Japan, Sweden, or Germany, compared with the US. Table 2 summarizes the US-Swedish comparison.

Thus it is not suprising that the US cement industry is actively moderning its facilities (NY TIMES, Dec. 25, 1977) by substituting larger European dry kilns for smaller, ancient wet kilns. These modernizations improve productivity of labor while cutting energy use by nearly 50% per ton of output, in part due to the larger size of new dry kilns. Moreover the new kilns use coal and "eat" the sulfur produced. How fast new kilns will replace old of course depends on overall demand for cement and the point at which the marginal cost of a ton of klinker from an old factory--due mainly to operating costs exceeds the capital and operating costs of new equipment. Here the price of energy plays a key role, as Carlsson showed. This time factor is important--energy savings to date in all US industry are based retrofit of older equipment. Future gains will be greater, unless the price of energy suddenly falls, an unlikely event in my own judgement.

Finally, thermodynamic limits to energy use in production are still a long way from today's intensities. Paper mills that produce all necessary heat and power from wood wastes have been projected; many processes can now valuably sell waste heat rather than discharging it to the environment; electric power and heat can be cogenerated. Technology and relative prices will be the deciding factors, not nature's laws. In all the link between energy and production, like the link between other factors and production, is extremely flexible in the long run. This is the meaning of energy conservation in the production sector.

B. Buildings

In 1970 when real energy prices reached their historical minimum the present value of energy "conservable" in new structures--up to 40% of existing heat and cooling--exceeded the capital costs of saving this energy with rates of return of around 10% or more. Many institutional barriers hindered the efficient use of resources(10). Evidence exists that larger structures could have been built for less capital cost per area and far less energy use per area but again institutional factors hindered the efficient allocation of resources.

The future will be different. Even before new building codes and techniques appeared consumers began buying insulation in record amounts, spurred by cold winters and higher energy costs. At LBL we estimate that retrofits allow reduction of 20-80% of heating loads and 20% of cooling loads in homes with rates of return of better than 10%. For commercial buildings existing plants can be modified for about a 25% saving, again with an attractive rate of return(11).

In new structures and equipment the savings are even more dramatic. Compared to today's energy intensities, new refrigerators, water heaters, building shells require (60%, 80%, 20-70%) of today's energy use with incremental investments of the order (10-20%, 10%, 5-1%) of total system costs, giving rates of return >8%.

Here as in the industrial sector the effect of price controls, average rather than marginal costing, or subsidies to energy producers (such as the investment tax credit for utilities), is important. In California, for example, present residential natural gas prices (less than $2/GJ) justify attic insulation and some retrofit wall insulation, as well as clock thermostats, saving 20-40% of existing energy use with rates of return greater than 10% (1). At parity prices (about $3/GJ) wall insulation and double windows are profitable in many homes, while at marginal prices (electric heat or synthetic fuels at $6/GJ delivered) homes would require very little energy for heating at all. Indeed it is less expensive to eliminate nearly all of the heating load in the "sunny" part of the country than to capture most of the load with solar heat. If electric and fuel prices rise to replacement costs, however, solar water heating will become the least expensive source of this important amenity, and solar space heat should penetrate the heat market somewhat.

C. Transportation (9)

In the transportation sector, important energy saving technical changes have been occurring in autos, trucks, and airplanes. On the other hand, modal changes (cars to busses or rail, airplanes to rail and busses, truck freight to rail) seem very unlikely simply as energy conservation measures. This is evidenced by experience in Europe and a multitude of economic and attitude surveys regarding the rise--and fall--of transit. However mass transit, railroads and busses have other important benefits that far outweigh the energy savings of these modes.

While autos have shrunk, they have also become more efficient technically--i.e., energy consumption per unit of passenger space has fallen. Since 1973 a combination of changes in auto buying habits, shrinking of individual models of cars, and improvements in the efficiency of each model have caused energy intensity to fall by more than 25%.

Of course given the drop in real gasoline prices since the initial rise in 1974, consumers might balk at buying small cars, and some retrenchment has occurred. Moreover low gasoline prices combined with efficient cars reduces the marginal cost of travel considerably, thus stimulating the increased use of the car or substitution of auto for bus/mass transit in marginal cases. Clearly the continued "enforcement" of MPG standards depends on society's attitude towards the value of reducing energy use per mile. Higher gasoline prices, or taxes on the MPG or weight of cars, more common in Europe, should be considered to support these goals, especially if short term conditions force gasoline prices downward.

While the ultimate results of a concerted effort to reduce the energy intensity of auto transport may be dramatic--30+ MPG fleet averages--the changes expected in trucks and airplanes are also important. New powerplants and wind-designs should increase truck effectiveness, as will changes in rules for hauling practices.

The European Airbus already shaves total costs and fuel costs in the medium-haul air market, but American manufacturers are reportedly close behind. As the energy intensity of all modes are lowered, the energy-related shifts in modes becomes even less important, an effect worth remembering when the auto and bus are compared.

To summarize the prospects--for energy conservation I have gathered in Table 3 the findings of the Demand and Conservation Panel of the Committee of Nuclear and Alternative Energy Systems of the National Academy of Sciences(11). Shown are the energy intensities of the most important uses of energy, relative to present (1975) practices, for a variety of price and policy futures. The intensities shown represent averages for all systems in place in 2010, and including the effect of retrofit on existing plant and structures. Of course the newest equipment is always the least energy intensive, usually considerably less so than the averages given. These findings reflect estimates of economic effectiveness--the measures that reduce intensities cost less than those that would increase supplies, especially when capital outlays are considered. In the Panel's judgement these intensities lie near the economic optima for the price futures considered.

III. LESSONS AND MYTHS

The CONAES Demand Panel results as well as many other investigations of processes in the US and in other countries reveal the same message--a great degree of technical and economic flexibility in the use of energy exists. Given changes in relative prices for energy, modest developments in technology and a few key policies regarding standards, other resources will be profitably substituted for energy. The demand for energy depends critically on this elasticity of substitution, as well as upon the income and price elasticities of various energy intensive amenities, such as driving or space comfort. Many investigations are underway determining both substitution elasticities and the behavioral oriented elasticities.

Unfortunately many myths still survive. It is widely alleged that the flexibility discussed herein is illusory, the counter evidence usually offered in the form of regressions of energy use and GNP over time or across countries or states. Such work is of little value since structure, price, geography, climate, policy, and the state of the art of energy conservation is omitted. The CONAES study focused carefully on substitution, with only a few changes in behavior or preferences factored in. Certainly it is possible that new energy intensive technologies or habits will appear, but the rising price of energy makes this less likely, while at the same time new technologies or lifestyles not contemplated by CONAES might reduce energy intensities. Moreover the most important uses of energy--space conditioning and automobiles--are near saturation, while "new uses", such as calculators, hi-fi, hospitals, or hamburger cookers, use insignificant amounts of energy/output and probably reduce the energy/GNP ratio compared to the mix of goods and services prominent in the 1950's.

In my view, then, the link between energy and GNP is a flexible one, and that flexibility is being tested now. International comparisons bear these conclusions out--gains in energy efficiency have been seen in most industrialized countries since 1973, and indeed in the decades previous. Since energy conservation does not threaten labor productivity or lifestyle--we would not conserve energy where that was the case--there seems little need to worry about the "sacrifices" called forth in President Carter's speeches.

IV. THE ISSUE OF PRICE

The key link between energy and the economy appears to be the price of energy. As mentioned above, energy costs play an important role in determination of the optimum balance between energy and other resources. Unfortunately our government and many groups have insisted on a variety of measures that lower the cost of energy to below replacement levels: price controls, tax subsidies, subsidies for new supply systems, and in some cases offsetting subsidies for certain conservation measures. Are we not in an era when the long run cost of energy will rise continuously? My own view is yes: all substitutes for domestic or imported oil and gas will ultimately cost more than these conventional fuels, and the economy must begin adjusting to that situation. Legitimate distributional questions, especially the impact of higher energy costs on the poor, ought to be handled as such, rather than by keeping the price of energy low.

Of course it is often argued that the world price for oil is controlled upward by the OPEC Cartel. This may be true in the short run, but examination of all alternatives, which are more expensive, suggests that at some time in the near future the market price for world energy supplies, pushed up by growing demand and the high marginal cost of new supplies, will rise above the OPEC price, which has stayed nearly constant in real terms for several years. Including environmental costs in the price of energy, not always an easy task analytically or politically, would raise the price of energy even more. Ignoring environmental costs, or subsidizing the new energy sources beyond their normal development stages, would only lead society to overconsume energy (and the environment) relative to other resources.

V. INTERVENTION?

Will the correct prices "solve" our energy problems? In my view energy prices should represent full social costs of producing and using energy, but this change in pricing policy may not be sufficient to bring about changes in the energy system. Supply experts have made it clear (See the supply report of the CONAES study) that massive government intervention in all areas of energy supply will be necessary if energy supplies are to double by the near 2010. This intervention will doubtlessly include suppression of environmental standards.

But the government could pay attention to the demand for energy. Many kinds of market failures, related to lack of information, lack of access to capital or lack of influence over the design and operation (or ownership) of energy using facilities have created true economic waste in the buildings sector. Auto MPG standards already on the books have influenced greatly the choice of technologies now employed in automobiles. Industry, on the other hand, is not targeted for end use regulation, at least as far as energy intensity is concerned.

Is acceleration of the progress of energy conservation politically or socially acceptable? Can we change the maze of building codes or appliance buying habits of consumers and home builders? It seems to me that these difficulties, hard as they are to quantify, must be compared with the enormous difficulties inherent in bringing any new major energy supply options to the market place. Given the environmental uncertainties of all supply options, I would first opt for a minimum of firm, carefully optimized regulations to insure that new buildings, appliances, and homes are built more carefully than in the past. In California, for example, insulation requirements are carefully attuned to the price of energy: no one "forced" to buy insulation is losing money when reasonable interest rates are considered. Remember that the alternative to optimal insulation in a new home is expansion of energy supply at far greater total cost, at least until pricing policies are changed and environmental costs included in the calculation of the optimum level of insulation based on the marginal cost of new supply.

Perhaps the most important reason for including key regulations in any policy is a fundamental lack of two other resources: time and certainty. We have made a political judgement that we must hurry to reduce our dependence on imports--dollar for dollar, barrel for barrel, conservation does this faster than new supplies. But both conservation and new supplies have tremendous uncertainties in practice. Building codes would act to minimize uncertainty over the pace and success of conservation in buildings, and as I have observed in Sweden and California, generally speed up the pace of technological change. Regulations on behavior, on the other hand, whether in the form of maximum temperatures, gasless Sundays, bans on production of certain goods and services, or forms of energy rationing, have no place in any economic system accustomed to at least some degree of freedom of choice. Moreover, such mandatory conservation measures hardly contribute to significant energy savings. Note that I do not consider building codes "mandatory" energy saving measures because they affect capital equipment, not people.

Unfortunately, energy policy discussions have been dominated in the past by supply interests. There had been little interest in looking towards more effective energy use as a "source" of energy, even though reinsulation of an attic "supplies" energy to another user willing to pay a higher price. If we take a symmetric view of conservation as part of any energy supply picture, however, and understand how great the potential for energy conservation really is, we should be able to shed the fears of "caves and candles" promised by utility company ads a few years back. As Kenneth Boulding once remarked, "Conservation is just thinking before using energy".

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Table 1. Energy (Btu x 10^{-3}) per 1967 \$ shipments[a] and energy per unit labor (Btu per production man hour);[b] representative energy-intensive industries (1954-67).

SIC CODE	INDUSTRY	1954		1958		1962		1967	
		E/\$	E/L	E/\$	E/L	E/\$	E/L	E/\$	E/L
2011	Meat packing plants	9.7	0.318	8.3	0.326	7.0	0.322	6.5	0.371
2042	Prepared feeds	11.4	0.313	9.9	0.364	11.1	0.528	12.4	0.793
2812	Alkalies and chlorine	422.0	5.37	415.4	6.67	388.6	8.64	371.6	10.49
2818	Industrial organic chemicals N.E.C.	163.8	3.27	157.8	3.91	152.4	5.50	149.3	7.54
2911	Petroleum refining	147.5	7.96	146.4	9.90	142.5	13.62	128.3	17.17
3221	Glass containers	118.1	1.02	114.5	1.01	108.7	1.05	100.2	1.14
3241	Hydraulic cement	438	5.74	426	6.46	431	7.97	413	9.81
3312	Blast furnances and steel mills	179.9	2.96	187.6	3.31	171.1	3.52	164.4	3.81
3313	Electrometallurgical products	214.2	4.08	300	4.66	269.6	7.00	280	7.61

[a] From: The conference board, Energy Consumption in Manufacturing, Ballinger, Cambridge, Mass. (1974).

[b] From Reference 4.

Table 2. Sweden/U.S. contrasts in energy use.

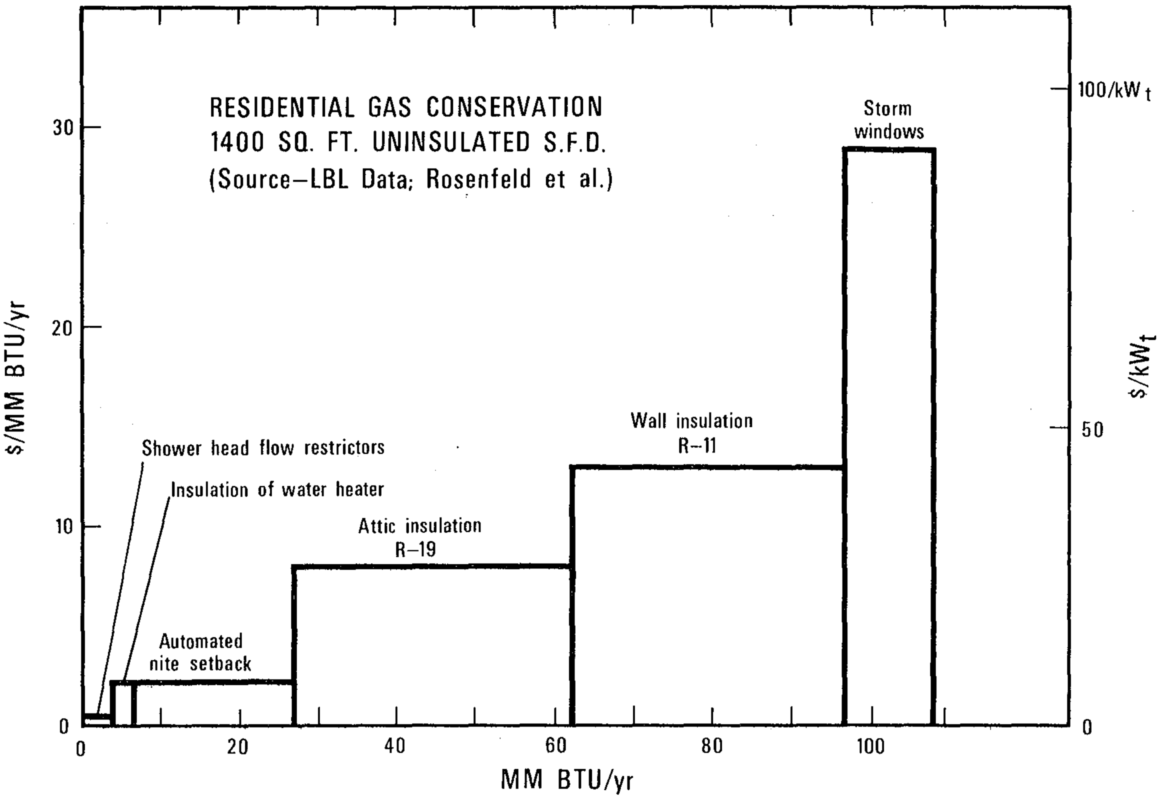
		Per capita demand	Intensity	Total energy use	Notes
Autos		0.6	0.6	0.37	Swedish 24 M.P.G. driving cycle uses less energy
Mass transit trains, bus		2.9	0.80	2.35	Mass transit takes 40% of passenger miles in trips under 20 km in Sweden
Urban truck		0.95	0.3	0.28	Swedish trucks smaller, more diesels
Residential space heat (energy/deg day x area)		(1.7 x 0.95)	0.5	0.81	Sweden 9200 deg days vs 5500 U.S. deg days
Appliances		?	?	0.55	U.S. more, larger appliances
Commercial total/sq ft		1.3	0.6	0.78	Air conditioning important in U.S. only
Heavy industry (physical basis)	Paper	4.2	0.6-0.9	0.92	Sweden more electric intensive due to cheap hydroelectric power. Also Swedish cogeneration
	Steel	1.1			
	Oil	0.5			
	Cement	1.35			
	Aluminum	0.5			
	Chemicals	0.6			
Light industry ($ V.A.)		0.67	0.6	0.4	Space heating significant in Sweden
Thermal generation of electricity		0.3	0.75	0.23	Swedish large hydroelectric, cogeneration

STRUCTURE AND INTENSITY. The demand column gives the ratio of final demand in Sweden to that in the U.S. for important energy uses, the Intensity column the relative energy intensities. It can be seen that both factors influence total energy use. In industry structure in Sweden is more energy demanding than in the U.S., but individual energy intensities are lower. Ultimately lower energy intensities in Sweden account for about 2/3 of the difference in per capita energy use.

Table 3.

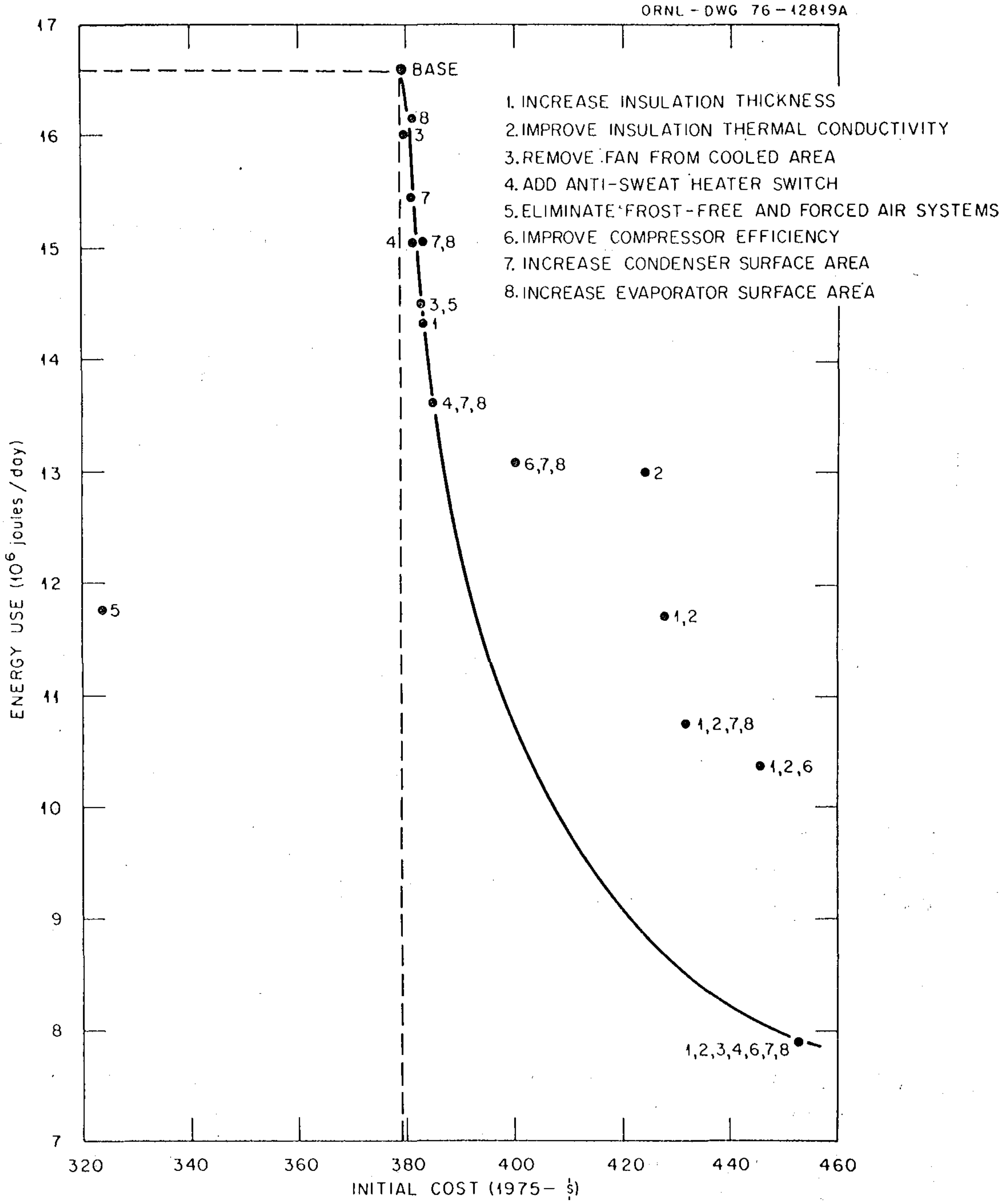
USE	(in 2010) ENERGY INTENSITY, 1975 = 1.00		
	II	III	IV
Thermal Integrity Residential	0.63	0.63	0.76
Commercial	0.42	0.6	0.7
Govt., Education	0.35	0.45	0.5
Space Conditioning--Air	0.66	0.75	0.94
Electric Heat	0.52	0.63	0.9
Gas/Oil Heat	0.72	0.75	0.8
Refrigeration, Freezing	0.58	0.68	0.92
Lighting	0.60	0.70	0.7
Agriculture	0.85	0.85	0.95
Aluminum	0.55	0.63	0.80
Cement	0.60	0.63	0.75
Chemicals (excl. feedstocks)	0.74	0.78	0.84
Construction	0.58	0.65	0.73
Food	0.66	0.76	0.86
Glass	0.69	0.76	0.82
Iron/Steel	0.72	0.76	0.83
Paper	0.64	0.71	0.76
Other	0.57	0.75	0.85
Auto	(37 mpg)	(27 mpg)	(20 mpg)
Lite Truck	(30 mpg)	(21 mpg)	(16 mpg)
Freight Truck	0.6	0.8	0.9
Air Passenger	0.42	0.45	0.5

TABLE 3. Energy Intensities in 3 Conaes Demand/Conservation Panel Futures. Average Energy Prices (use weighted) were 4x, 2x, 1x 1975 levels in Scenarios II, III, IV respectively. For details see Ref. 11. The year is 2010.



XBL7612-10742

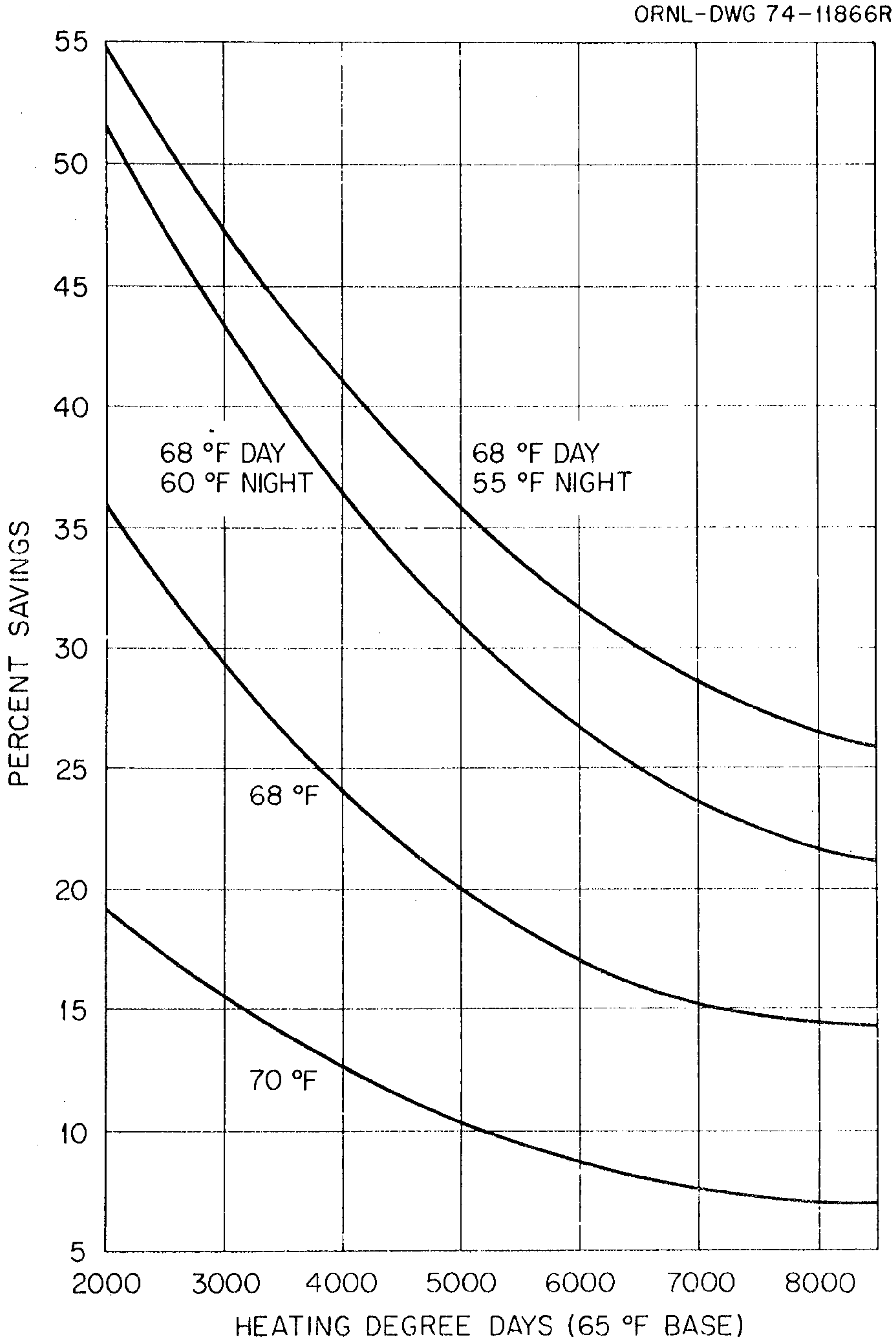
Fig. 1. Investment in conservation as energy supply. This graph plots investment/energy unit on the vertical axis and energy units on the horizontal axis, both quantities normalized to yearly use. The investments required to save energy can be compared with investments in supply; alternatively, the investment can be compared with the value of energy saved (for various prices) and the rate of return on investment read off. Data from Rosenfeld et al., Lawrence Berkeley Laboratory, assembled in Schipper and Darmstadter, 1978.



Energy use vs. retail price for various design changes for a 0.45 m^3 (16 ft^3) top-freezer refrigerator.

XBL 7611-9945

Fig. 2. Energy use vs retail price for a variety of 16 ft^3 refrigerators. Investment in conservation technologies brings quick payback. Data from Hoskins and Hirst, as cited in Schipper and Darmstadter.



XBL 759-8024

Fig. 3. Predicted energy savings for several thermostat settings (72°F is the reference setting and night setback is from 10 P.M. to 6 A.M.).

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