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Energy Conservation and the Consumer

A tax placed on energy and adjusted to wage levels would ease a change to a more labor intensive economy.

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In this article I seek to explain what is known about the connections among consumer activities, the direct and indirect demands of these activities for energy and employment, and the consumer's options for energy conservation. When the consumer's activities demand employment, they require the consumer's own services, but when they demand energy they require the stored energy resources of the earth. This fact underpins the three dilemmas of energy conservation that I will discuss in detail. The consumer's control over the energy he uses to heat, cool, and light his residence or fuel his auto will not be discussed; the methods for conservation in these areas are well understood.

Individual control over energy use is viewed as an alternative to governmental assumption of that control. Energy conservation is necessary because of (i) the environmental effects of unbridled consumption; (ii) the long lead time and massive capital allocations necessary for future increases in energy supply; (iii) the instabilities associated with a large dependence on foreign energy supplies; (iv) the need for an enduring national goal that unifies the nation and does not require massive new economic growth; and (v) because energy is a fundamental ingredient in any economic system. This last point indicates the necessity to focus on the conservation of energy rather than steel, for example. A proper plan to conserve energy would conserve steel. In general, capital can be recycled but, of course, energy can not. Labor can not only be recycled, it can be multiplied.

During the industrial revolution in the United States there has been an unprecedented thrust to substitute the energy from fossil fuels for human labor to accomplish material transformations (toolmaking) and to achieve mechanization. From the worker's and consumer's view, this substitution has generally meant less drudgery in the work place, greater buying power, and more leisure. To the industrialist, the substitution of tools and energy for labor has provided a means to control and predict production costs and, consequently, profits.

Material and energy costs have been low, relative to labor, as well as predictable for almost 50 years. Machines and fuels are incapable of striking for higher wages. Economic growth seems to have absorbed those workers displaced by mechanization. Thus technology, material and energy use, and employment and economic growth appear to be intimately linked. But now the finiteness of resources comes into view as this nation's striving for a better life spreads internationally. We are beginning to understand the links among heavy consumption, environmental damage, and degradation of the quality of life. We are beginning to see the need for one more adaptive act of humankind, the need for a group morality.

It should be within the reach of each individual consumer to perceive that he must forgo certain forms of energy consumption now in order to ensure their availability to his offspring or to his own generation in the future. As the human body eventually reaches a condition of zero growth, then so must that population as a whole. Such an achievement, however, would require our casting out such mathematically impossible maxims as "the greatest good for the greatest number" and substituting, perhaps, "life-styles of elegant frugality." Then we would act to preserve the knowledge of how to live healthfully, limit our numbers, and minimize our per capita consumption of resources, particularly energy. We would recognize that, because people's wants are infinite and because resources are finite, only relative wants are important; and that economic growth increases the disparity in relative wants, eases our severe interpersonal and interindustry competition, and increases the uncertainty of future events.

Economic growth and development will probably continue until the assured available energy is almost entirely demanded for maintenance of the society. Stabilization of economic growth now is often argued as being a means of reducing the inevitable future trauma of living on an energy budget. There would obviously be problems, however, with the egalitarian national life-style that would be required to achieve stabilization now. We would have to recognize that the rising world population will result in the rising collision of individual and national freedoms as well as in the accelerated depletion of stored energy; and that the concept of individual and corporate ownership, apparently an adaptation to resource shortages, will probably give way to public or societal ownership, as the shortages worsen. It is unclear whether a totally democratic society could exist with severe shortages. If it could not, smaller and smaller fractions of the population would participate in resource allocation decisions. How to control the decision-makers would then become a problem. As long as the population at large could perceive an equitable distribution of the dwindling resources then,

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presumably, the society could remain stable. Plato's concept of leaders or "guardians" deprived of all physical wealth and steeped in leadership seems an appropriate model for controllers of a stable society with limited resources.

Before we plan to conserve energy or to increase our energy supplies, we must understand the total energy and employment cost of every good and service. Only then will we be able to determine the energy conserved by consuming one good or service instead of another, or the energy cost of substituting a new technology, a new manufacturing process, for example, for another. The changes that may have to be made in order to reduce our energy consumption can be thought of as efficiency improvements in our current life-style. As I shall show, many such changes may be resisted and, unless they are fully understood, they may not provide significant net energy savings.

To calculate the energy cost of one unit of an item, one must determine the direct inputs of goods and services required to produce that item. Because each of these inputs has its own set of inputs, and so on, one obtains such a multitude of small inputs that leaving off the next round does not significantly change the total energy requirements of the original item. I have used the economic input-output data published by the U.S. Department of Commerce (*1*), and the data of Herendeen (*2*), to calculate the direct and indirect energy and employment demands of a number of personal consumption activities and to analyze trade-offs between human and mechanical energy.

Substituting Energy for Labor: The First Dilemma

If conserving energy or any material resource is judged to be the main path to our survival, the impact of such a path on employment must be known. Since we, as laborers, decide our future, and since we have repeatedly increased our wages and controlled the cost of the resource base, the potential redistribution of labor resulting from a conservation program is of primary importance.

Let us observe the problem from the point of view of an industrial decision-maker. He compiles his current capital, materials, labor, and energy costs and projects them on the basis of his expectations of the future. Trend analyses would have shown that his raw materials and energy costs are either stable, unless his product is derived from agriculture, or declining, as in the case of electricity, his principal energy substitute for labor. In terms of dollars, tool costs would have been rising primarily because of their labor content, but the most rapidly rising, and the most unpredictable, costs would have been those for manual labor. An important factor in the industrialist's decision-making process would be his anticipated relative unit costs of energy and of labor. The ratio of these two costs are formed into an index (wage divided by price of electricity) and plotted for the years 1926 to 1973 in Fig. 1. In that period the ratio grew by a factor of 10. It grew by 230 percent between 1950 and 1970, during which time electrical machinery costs increased by about 54 percent (current dollars). The curve in Fig. 1 shows a leveling to a declining trend during recession periods, possibly indicating an attempt of the economic system to equilibrate resource and labor costs.

Total costs of electricity relative to total product costs are small. In 1963, one average dollar of industrial sales caused only about 2.5 cents of electricity sales (*3*), and about 65 cents went for wages, directly and indirectly (*4*). As shown in Fig. 1, the rapidly rising cost of capital since 1950 has probably deterred a more rapid switch to a more electric, less labor intensive production system. Since 1950, the marginal productivities of labor and capital have been rising relative to that of electricity, while the ratio of the marginal productivities of labor and capital has been relatively neutral. This capital cost, however, contains the cost of building and heating machinery which cannot be considered a substitute for labor. The generally higher cost of capital should therefore aid in the return to a more labor, less electric intensive system. The point is twofold: the cost of electricity has failed to represent its importance in the marketplace, and the situation has grown worse with time.

If we take energy, labor, and capital to be factors required for production, then, as the cost of energy is increased relative to the cost of labor, the economic system will adjust, in theory, such that the marginal productivity (a change in gross national product resulting from a unit change in factor use) of energy will increase relative to that of labor. If the wage levels and labor productivity are constant, this change means lower energy use. In other words, Fig. 1 indicates that the productivity of labor has, historically, increased more rapidly than, and at the expense of, electrical energy productivity. To reverse this process, the price of electricity must rise relative to wages. This same phenomenon appears to be true for overall energy and labor use (*5, 6*).

The overall effects of economic growth on energy and labor demand were suggested by an investigation (*7*) in which it was demonstrated that if, in 1963, the economic sectors had been allowed to grow at the proportional expense of all the remaining sectors, most industries would have become more energy demanding and less labor demanding. In a special case study (*8, 9*) it was shown that the system that produces beverages would be less energy demanding and more labor demanding if the beverages were delivered in refillable rather than throwaway containers. Most important was the type of labor that would be involved in the change. Jobs would be lost in the highly organized, high-wage

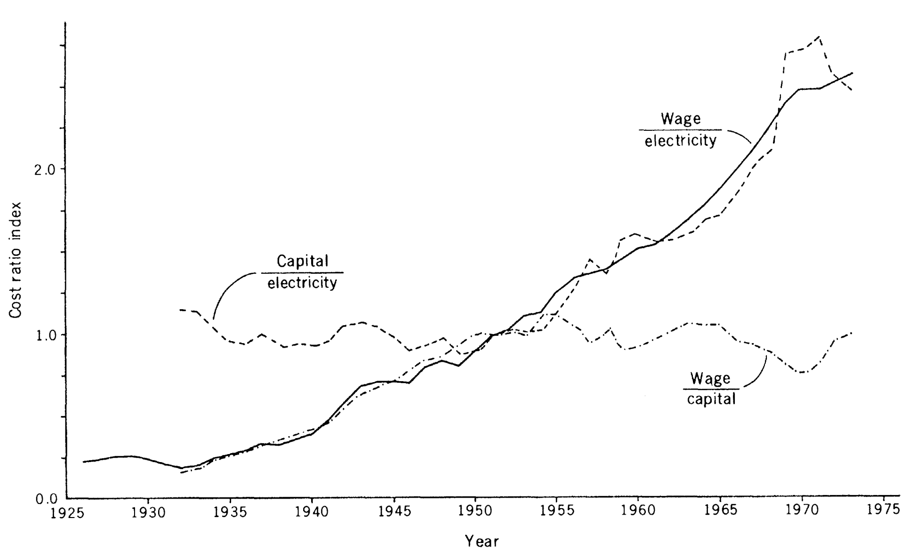

Fig. 1. Industrial labor, electricity, and capital cost ratios in the United States, 1926 to 1973, in current dollars. Based on manufacturing worker's hourly wages, the industrial price of a kilowatt-hour of electricity, and the yields on AAA corporate bonds (1951 = 1.0). Data from the Department of Commerce (*1*), Edison Electric Institute (*21*), and Moody's *Industrial Manual* (*22*).

paying, can-maker's plants and would be gained in the low-wage paying, relatively nonorganized, retail sector. The lack of acceptance of this plan was the direct result of opposition from organized labor and intensive lobbying by can- and bottle-making interests.

Another example of increasing energy and decreasing labor utilization is found in a comparison of the energy and employment costs of protein production (*3*). The production of a unit of milk protein requires about 2.7 times as much energy as a unit of cheese protein, and yet requires only about one-fifteenth as many jobs. This result derives from the nature of the different processes: milk contains mostly water and it must be homogenized, pasteurized, and trucked, each of which operations is an energy but not labor intensive process.

Herein lies the first dilemma. Energy conserving policies would increase overall employment in general by decreasing the number of high-wage jobs and increasing the number of low-wage jobs, but the people holding the former belong to the most highly organized unions. Thus organized labor, after struggling to achieve reasonable wages and personal dignity in the marketplace, and having slowly relinquished much dignity because of the inevitable relationship between high wages and assembly lines, for example, would now have to be asked to forgo their higher wages in order to avoid the general unemployment induced by declining energy supplies. Such a situation would be tenable only if prices and profits were thoroughly controlled. It also follows that technological developments have, historically, resulted in jobs being denied to marginally employed workers.

Income and Energy Use: The Second Dilemma

The relation between personal income and energy use can best be introduced by asking three questions:

1) What fraction of total energy use does the U.S. consumer control (directly and indirectly) through his purchase of goods and services?

2) How does this direct and indirect fraction vary with income?

3) How might consumers proceed to change their purchasing habits so as to reduce their energy dependence?

The first question is answered in Table 1, in which the data indicate the importance of personal consumption expenditures. Such expenditures demanded two-thirds [one-third of this amount for the automobile (*10*)] of all U.S. energy and 62 percent of all employment in 1963. Government activities accounted for about 13 percent of all energy consumption and employed about 21 percent of the total labor force. Capital formation demanded about 10 percent of all energy and 12 percent of all employment. Exports accounted for most of the remaining energy (coal) and labor consumed. The fractions of the various energy types allocable to personal consumption is surprisingly constant, except for coal. Most coal was consumed in steelmaking and electrical generation and about 16 percent was exported (directly and indirectly) in 1963. In the near future it will be possible to compare the data of Table 1 with similar data from 1967.

Figure 2 provides the answer to the second question. Family income after taxes is plotted against the direct, indirect, and total energy demand associated with the spending of that income (*10*). For example, the poor generally traveled by bus (when they traveled) and the rich usually traveled by plane. Both are indirect energy uses. Middle income people traveled by auto, which represents a direct energy use. The rate of direct energy use slowed as income increased, but the rate of indirect energy use did not. Together they yielded a total energy demand that was nearly linear with income. Here we find the second dilemma: spending money in any way demanding energy, and the extra dollar spent required almost the same energy when spent by a poor family as it did when spent by a rich one. It appears that the only way to save energy is to reduce income, unless the variation of energy consumption about the "total" line is very large. However, as I shall show in the next section, saving energy means saving dollars and that leads to additional energy use.

From the supporting data for Fig. 2 (*10*), it is evident that the average family used about 55 percent of its total energy directly. It is also evident that two-thirds of the lowest income group's total energy use was direct. Just the opposite is true of the upper income group: two-thirds of its total energy use was indirect. A further examination of these data shows that modification of the behavior of the upper middle income class would be the most fertile area for energy conservation. Herendeen is now investigating the energy-income redistribution effects in view of the slight nonlinearity of the total energy line in Fig. 2.

The third question is more difficult to answer. Consumer spending patterns would appear to be a function of income level. That is, as family income increases, buying patterns change. For example,

Table 1. Percentages of energy and labor (direct and indirect) for final demand activities, during 1963. The data are from Hannon and Abbott (*15*). The definitions of the activities are from (*1*).

Activity	Energy type: Coal	Crude oil	Refined petroleum	Electricity	Gas	Total primary energy	Labor*
Personal consumption expenditures	53.2	71.3	70.8	69.2	72.2	66.6	62.2
Gross private fixed capital formation	14.9	8.6	7.3	10.5	10.5	10.3	12.1
Net inventory change	1.2	1.3	1.5	0.9	1.0	1.3	0.9
Exports†	15.9	6.6	7.7	4.9	5.0	9.0	3.6
Federal government purchases, defense	6.6	5.6	6.1	6.5	4.7	5.9	8.4
Federal government purchases, other	1.0	0.9	0.9	0.4	0.9	0.9	2.5
State and local government purchases, education	2.4	1.8	1.6	3.0	2.0	2.0	4.6
State and local government purchases, health, welfare, and sanitation	1.0	0.8	0.7	1.1	0.9	0.8	1.5
State and local government purchases, safety	0.2	0.3	0.3	0.2	0.2	0.2	0.9
State and local government purchases, other	3.6	2.9	3.1	3.3	2.5	3.1	3.3
Total final demand	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Man-year basis: includes household and government workers but not military personnel. †Dollar value of imports not used.

meat becomes a larger part of the diet; travel is more frequent and by faster modes; and more investments are made. As income rises, more goods and services are consumed, resulting in rising indirect energy demands.

As an example of the utility of Fig. 2, let us consider a person living in New York. It was reported in 1973 (*11*) that the average New Yorker is much less energy demanding than the average U.S. citizen, even though his personal income is 25 percent higher than average. This, it was assumed, was because New Yorkers live in apartments and use mass transit heavily. But the data of Fig. 2 suggest that if a person has a 25 percent higher than average income, then his energy use is also nearly 25 percent higher than average. It is apparently difficult and expensive in both dollars and energy to service people living in a city. Or, perhaps living in a city induces a more frenetic, consequently more costly, pattern of behavior.

Figure 3 with the enlargement of its central portion shows the relative (direct and indirect) energy and labor cost per 1963 dollar of personal consumption on each of the 83 different consumption categories of the U.S. Department of Commerce. In general, the services, except transportation, seem to be distributed along a roughly horizontal (constant energy intensity) line with high-wage services on the left and low-wage services to the right (for example, physicians on the left, hospitals on the right). Goods and transportation services are distributed along a roughly vertical line which joins the service line at about its lower-third point. The energy purchases are, logically, highest on this line.

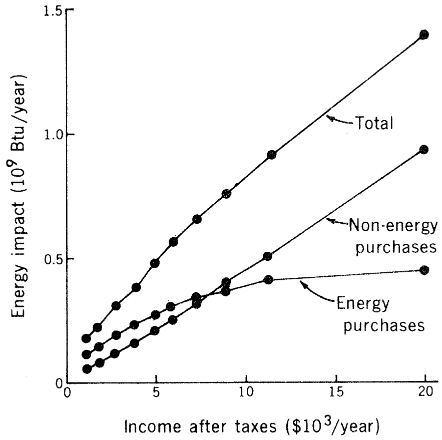

Fig. 2. Direct, indirect, and total family energy impact plotted against family income, 1960 to 1963. From Herendeen (*10*).

The possible lack of independence among some of the personal consumption items is demonstrated by the averaged point "owning and operating an auto" in the upper-center portion of Fig. 3, and by comparing this point with the points "gasoline and oil," "new and used cars," "auto repair," "auto insurance," and "tires." Knowledge of the individual auto expenditures could guide the consumer on the energy and employment effects of his marginal dollar expenditures, but the overall effect of owning an auto is given by the "average" point.

Figure 3 gives the total energy and employment effects produced by the spending of a consumer dollar on the 83 different consumption categories. The figure does not show the secondary effects. Suppose, for example, that you purchase a new car. The energy and employment effects shown in the figure represent only those effects which occur in the web of industries which supply the auto industry (including the fabricating, transporting, and retailing). These effects do not include the energy and employment demands created by the personal consumption of the workers who receive your new car money from the manufacturer, nor the energy and labor demanded by the workers of the producers of these goods as they too spend their wages. As money passes through each new set of hands, some is saved and taxed and eventually the effect dies out. If one assumes that for every dollar spent on a new car, two more are spent via the multiplier effect on average personal consumption, then each new car dollar spent, which represents one dollar of growth in the gross national product, demands 60,000 British thermal units (new car) and 172,000 Btu (two average 1963 personal consumption expenditure dollars) for a total of 232,000 Btu (1 Btu is equivalent to 1055 joules). The expansion from 60,000 to 232,000 Btu demonstrates the effects of the growth dollar on energy demand. It has a similar effect on employment demand.

Table 2. Selected results on the total dollar, energy, and labor impacts of consumer options in transportation during 1971. Data are expressed in terms of the requirements to move a million passengers 1 mile (1.6 km) (NA, not applicable).

Transportation mode	Load factor	Thousands of dollars (1971)	Energy* 10^6 Btu	Energy* Direct (%)	Jobs
		Intercity transportation			
Car	2.9 people	55	5900	51	3.7
Plane	53% full	58	9800	73	3.8
Bus	47% full	39	2700	51	3.1
Train	37% full	44	4000	58	7.2
Electric commuter†	31% full	128	9900	11	8.5
		Urban transportation			
Car‡	1.9 people	69	8900	58	4.2
Bus‡	12.0 people	105	5300	57	8.3
Motorcycle	1.1 people	57	4200	49	1.55
Bicycle	1.0 people§	26§	1300	59§	1.7‖
Walking	1.0 people	NA	710	51	0.7

*Vehicle transportation fuel only. †The "PATH" commuter system, New York–New Jersey, 1971 [see Penner (*16*)]. Other intercity data from Sebald and Herendeen (*17*). ‡Data from Hannon and Puleo (*18*). §From Hirst (*19*). ‖Center for Advanced Computation estimate based on Hirst (*19*).

Table 3. Intercity transportation. The energy that would be saved by shifting from each transportation mode to another. Plus or minus signs preceding numbers indicate, respectively, an increase or a decrease in energy use; plus or minus signs after the numbers indicate, respectively, an increase or decrease in dollar cost. Calculated from Table 2.

Shifting from	Shifting to: Car	Plane	Bus	Train
Car		+355,000+	−200,000−	−633,000−
Plane	−355,000−		−374,000−	−414,000−
Bus	+200,000+	+374,000+		+260,000+
Train	+633,000+	+414,000+	−260,000−	

Respending Dollars Saved: The Third Dilemma

Let us now look more deeply into the energy and labor needed to supply an entire service. Herendeen (*2*) has shown that all transportation consumed (directly and indirectly) about 42 percent of the U.S. energy in 1963, with the personal auto accounting for half of this demand. Such knowledge prompted us at this laboratory to investigate energy use and transportation options. Table 2 shows the dollar, energy, and employment costs of ten alternative passenger modes. The intercity modes were developed for an approximate 300-mile (482.7-kilometer) intercity distance in order to allow the five modes to be considered competitive. All costs are very sensitive to load factors. In terms of dollars and energy, the plane is easily the most expensive, and the train is the most employment intensive. The intercity bus costs the least in dollars and in energy.

The urban passenger has a variety of modes to choose from, as shown in Table 2. These modes are increasingly unpopular but decreasingly energy expensive as one moves down the list. Energy consumed in walking was that used to supply the food consumed by the average person for the energy used in excess of that used by the body in the resting position.

It has been pointed out by Bullard (*12*) that the important factor in energy conservation is the rate at which energy is saved on the transfer from one activity to another. Tables 3 and 4 show rates of energy savings (British thermal units saved per dollar saved) for shifts from each transportation mode to the other. The rates vary from about 17,000 to 633,000 Btu per dollar. In all cases except in the urban transportation shifts from car to bus, dollars are saved if energy is saved, and vice versa. For example, the traveler who switched from urban bus to bicycle would save energy (and dollars) at the rate of 51,000 Btu per dollar. If he were not careful to spend his dollar savings on an item of personal consumption which had an energy intensity greater than 51,000 Btu per dollar then his shift to the bicycle would have been in vain.

It is easy to notice that in every instance, a change in transportation mode that would conserve energy would also save dollars (except in the case of changing from urban car to bus transportation).

Table 4. Urban transportation. The energy that would be saved by shifting from each transportation mode to another. Plus or minus signs preceding numbers indicate, respectively, an increase or a decrease in energy use; plus or minus signs after the numbers indicate, respectively, an increase or decrease in dollar cost. Calculated from Table 2.

Shifting from	Shifting to: Car	Bus	Motorcycle	Bicycle	Electric commuter
Car		−100,000+	−392,000−	−177,000−	+ 17,000+
Bus	+100,000−		0	− 51,000−	+200,000+
Motorcycle	+392,000+	0		− 61,000−	+ 80,000+
Bicycle	+177,000+	+ 51,000+	+ 61,000+		+ 84,000+
Electric commuter	− 17,000−	−200,000−	− 80,000−	− 84,000−	

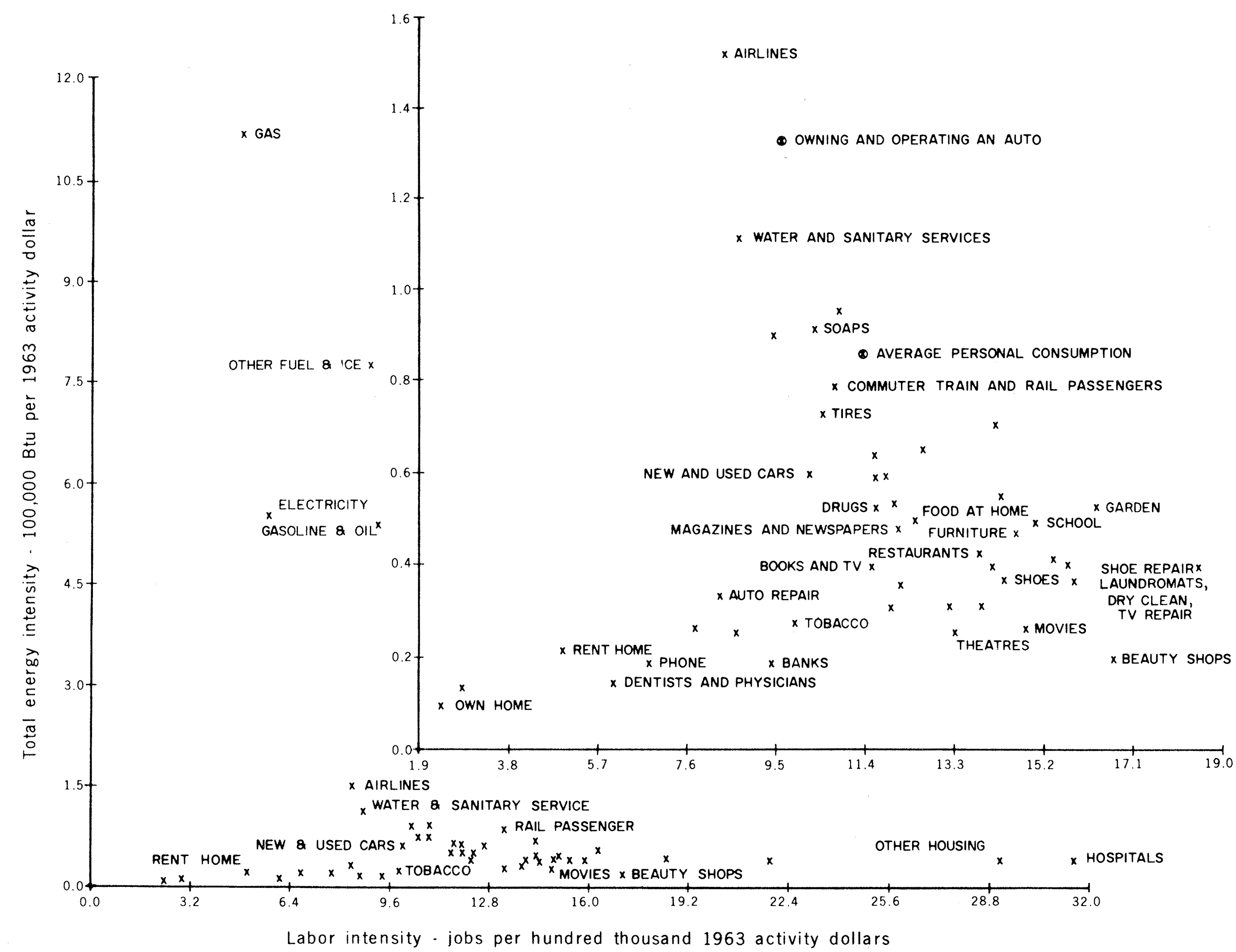

Fig. 3. The total energy and labor (direct and indirect) intensity of various personal consumption activities, 1963. From the Center for Advanced Computation's energy-employment model, August 1974. The inset is an enlargement of the central portion of the data.

This provides us with the third dilemma: that is, what does the consumer do with the dollars he saves after he has shifted to a cheaper mode of transportation? He can spend it or save it. In either case, energy will be required to provide for this freed expenditure. The second dilemma indicates that the consumer will adjust to increasing wealth through a change in purchasing habits, and his total energy use will rise proportionately to his income. However, armed with certain information, the consumer can purposefully direct his income so that he does save energy on balance. It should be clear, however, that he can never save more energy by redirecting certain portions of his income than he can by becoming that much poorer.

Table 5 is a rank order listing by energy intensity of the top 20 (in terms of dollars) personal consumption activities. Data on the activities of owning an auto and owning a home are listed so that they can be compared with the energy intensity of the average personal consumption dollar. Labor intensities are also given so that the interested reader may determine the impact of his own respending on the labor situation.

In the above example, the bus passenger turned bicycle rider (see Table 4) could spend his dollar savings on anything below and including "private investment" in the activity list of Table 5, and save some energy. The net energy is found by subtracting the number in Table 5 from the transfer savings of Table 4. If, for example, his savings were spent on "restaurants," the net energy savings would be 51,000 minus 32,400, which equals 18,600 Btu per dollar saved. Also from Tables 2 and 5, one can calculate the net impact on labor at four jobs gained for every million dollars saved on the bus to bicycle transfer.

Most of the savings rates are so large in Tables 3 and 4 that they could be overcome only if the consumer spent his savings directly on electricity or gasoline and oil. However, the consumer must be aware that the purchase of an extra car, for example, means greater purchases of gasoline and oil as well.

An interesting case arises in the shift from urban car to bus. Here the consumer saves 100,000 Btu per extra dollar spent on bus transportation. This extra dollar must be produced by reducing expenditure on other things, since urban bus transportation is more expensive than car (Table 2). Suppose the extra dollars came from a reduction in average personal consumption spending; then from Table 5, the total energy savings rate would be 170,000 Btu per dollar.

Table 6 shows the same phenomena as Tables 2 to 4. But in this case, home appliance alternatives are compared. The annual total dollar, energy, and employment costs were compiled for manufacturing, operating, and maintaining each appliance. From these data the energy savings rate can be calculated and compared to the data of Table 5 to determine the net energy savings.

Significant energy savings rates are obtainable if fewer appliances are used and if gas is used instead of electricity in stoves, dryers, and water heaters. This savings rate is reduced, if not reversed, by the energy demands of the alternative consumption activity.

Table 5 shows that the federal tax dollar and the private investment dollar are relatively low in energy intensity. This fact indicates that shifts from average personal consumption to federal spending or investment would reduce energy demands. However, many of these activities, for example, building highways or power plants, foster accelerated energy use and lower employment demands than personal consumption. Heavy construction programs can therefore be viewed as energy-wasteful disemployment programs. It is tempting for the energy conservation policy-maker to devise methods to divert the personal consumption dollars into federal spending or private capital formation. If such a procedure were followed for the purpose of conservation, it would be truly deceptive not to focus these dollars on processes which lead to a lowering of the average national energy intensity [see (*13*) for example].

In general, if all consumers were to make such carefully precalculated consumption shifts as outlined above, national income would be preserved, the energy intensity of personal consumption would be lowered, and employment would be maintained if not increased—and it would certainly be redistributed. However, the amount of net energy savings might be small because of the respending effect, and because of the fact that people will not want or need a sufficient quantity of the lower energy goods and services, and because of the likelihood of too few people actually being aware of their options. In any event, there is a limit to the savings that can be realized by such life-style changes which preserve national income.

Conclusion: Resolving the Three Dilemmas

The problem of energy conservation by the consumer has been examined in terms of three dilemmas: First, when wages increase relative to costs, then energy use increases through the process of mechanization. Second, energy use and income are linearly connected such that the spending of an average additional dollar of income demands nearly the same amount of energy, regardless of one's income level. Thus, doubling one's income doubles one's energy use so that the phenomenon of "rising expectations," so ingrained in the

Table 5. The energy and labor intensity of the 20 activities in which personal consumption expenditures (PCE) are highest in terms of dollars. Ranked in order of decreasing energy intensity during 1971. From Hannon and Puleo (*18*).

PCE sector description	Energy intensity (Btu per dollar)	Labor intensity (jobs per $1000)	PCE sector description	Energy intensity (Btu per dollar)	Labor intensity (jobs per $1000)
Electricity	502,500	0.0436	(Federal taxes)	(36,300)	(0.082)
Gasoline and oil	480,700	0.0729	Women's and children's clothing	38,100	0.1000
(Housing)	(144,000)	(NA)	Restaurants	32,400	0.0875
(Auto ownership)	(111,500)	(.081)	Men's and boys' clothing	31,400	0.0984
Cleaning preparations	78,100	0.0733	Religious and welfare activity	27,800	0.0863
(Average PCE)	(70,000)	(0.080)	Private hospitals	26,100	0.1718
Kitchen and household appliances	58,700	0.0551	Automobile repair and maintenance	23,500	0.0483
New and used cars	55,600	0.0775	Financial interests except insurance	21,500	0.0784
Other durable house furniture	54,600	0.0894	Tobacco products	19,800	0.0585
(Private investment)	(45,600)	(0.066)	Telephone and telegraph	19,000	0.0585
Food purchases	41,100	0.0852	Rented home	18,300	0.0350
Furniture	36,700	0.0917	Physicians	10,700	0.0325
			Own home	8,300	0.0167

American worker, is limited by the amount of available energy. Third, saving energy usually means saving money, the respending of which reduces, if not eliminates, the energy first thought saved. Not respending the savings means a reduction in national income (gross national product) and money saved too quickly means a reduction in employment. But this last effect is somewhat abated by the general increase in labor intensity that is associated with the lower average energy intensity. This effect could also be thwarted by each worker agreeing to work fewer hours. Both solutions, that is, not respending one's savings and working fewer hours, would eventually result in decreased per capita wealth. It should also be pointed out that convenience demands energy, for example, high speed autos and airplanes, and one-way packaging. Giving up convenience is the equivalent of the consumer's accepting a lower implicit wage, and saving energy.

There probably are no popularly acceptable solutions to these three dilemmas. If wages, as well as proprietor's incomes, were reduced relative to the cost of energy, or if the population decreased, or both, net energy consumption would be reduced without creating widespread unemployment. However, strong labor unions attest to the irreversibility of wage rates.

Table 6. The dollar, energy, and labor impacts of consumer activities in the home during 1971 (including manufacturing, operating, and maintaining the home). Herendeen and Sebald (*20*).

Type or number of appliances	Requirement per year: Dollars (1971)	10^6 Btu	Hundredths of a job	Energy savings rate* (Btu per dollar)
	Kitchen appliance sets†			
Spartan (4 appliances)	152.50	64.9	1.09	+304,000
Moderate (11 appliances)	252.50	95.3	1.85	+254,000
Plush (20 appliances)	337.90	117.0	2.47	
	Clothes dryer			
Gas	27.6	8.1	0.23	+500,000
Electric	39.4	14.0	0.27	−383,000
Outdoor	3.4	0.2	0.03	
	Stove			
Gas	33.5	13.4	0.26	+198,000
Electric	50.7	16.8	0.36	
	Refrigerator (12 cubic feet‡*)*			
Conventional	45.0	11.1	0.35	+608,000
Frost-free	55.7	17.6	0.40	
	Water heating			
Gas	46.0	37.7	0.22	+325,000
Electric	104.0	56.6	0.50	
	Electronic media			
Black and white television	21.7	5.4	0.18	+ 79,000
Color television	67.2	9.0	0.63	−120,000
Radio	4.1	1.2	0.03	

*When the activity is compared with the next one down the list; plus and minus signs mean, respectively, increases or decreases in energy use and dollar cost. †Including a stove, clothes dryer, and water heater all run on gas. ‡Twelve cubic feet are equivalent to 0.33 cubic meter.

Perhaps an initial energy resource tax, geared proportionately to the wage level, could be placed on fuels, particularly on those used to make electricity. Such a tax would thrust our most important resource into a position in the marketplace competitive with its chief substitute, manpower. The tax revenue could be used to reward those who reduced their energy use or those who were severely disadvantaged by the tax. In effect, this money could be used to cover the initial costs of converting to a life-style with lower energy demands. With energy costing more, the severance tax revenue would generally be spent in a manner compatible with reducing our energy requirements. Also, in the long run, the tax would imply lower real wages because of its demanding a lower labor productivity through the substitution of labor for energy.

It is appropriate that an already energy intensive nation take steps to increase its productivity per unit of energy expended. Raising the cost of energy relative to the cost of its substitute appears to be the best way for us to achieve such an increase in that it induces through the market mechanism the change to a more labor intensive technology. The tax approach might also give us time and revenue to redirect technology into improving productivity from available energy and into easing the transition to lower labor productivity. While this relative cost change would probably be produced by an economic recession, through a reduction in the average real wage, the uncontrolled wage reduction that might result under such conditions could also cause much unemployment unless the technology of production could very rapidly become more labor intensive. The ratio of the energy tax to wages should be increased at a rate which maximally increases productivity from energy without creating an unacceptable level of unemployment.

The impact on prices of the two basic types of energy taxes (one based on the unit of energy, the other on the dollar value of energy) were estimated by Bullard (*6*). The tax based on the British thermal unit is preferred by those favoring energy conservation because it does not discriminate against small energy users who normally pay a higher unit price for energy than do large users.

Another method that would conserve energy, and that is more fundamental than taxation, would be energy rationing through the use of coupons. Energy storage would be guaranteed to the consumer by his being given coupons that could be used for different types of energy, such as gasoline or electricity, at different exchange rates. Thus the consumer would have the option of conserving energy through the process of ownership of a stored versatile fuel. This concept implies the existence of an energy interest rate that depends on consumer decisions to forgo present energy consumption in order to ensure a future supply. The energy coupons would be purchased from the federal government which consequently would need to "own" the energy resources. Such an ownership would allow the society to jointly set a national energy interest rate which would dictate how rapidly the proved energy reserves of the society could be consumed.

In the long run, we must adopt energy as a standard of value (*7*) and perhaps even afford it legal rights (*14*). For energy, like no other entity, cannot be recycled or multiplied. It flows from the sun and from the energy inventories of the earth. Shall we live off the flux or the storage? How fast and under what circumstances shall we draw it from storage? We would answer these fundamental questions correctly if we set energy as the basis of value and structured our economic and legal system accordingly.

As a final point, we must consider the major problem related to the veracity of the energy crisis. Is the crisis contrived or real? The conservative approach is to believe that it is real and act accordingly. If the crisis is real, we shall be viewed by future generations as terribly wise; if the crisis is false, we shall have had an instructive relief from the dancing mirage of our manifest destiny.

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Evolution of a Gene

Multiple genes for LDH isozymes provide a model of the evolution of gene structure, function, and regulation.

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In the beginning, living systems were relatively simple and depended upon only a small number of macromolecules for metabolic activity and continued existence. Evolutionary progress entailed the acquisition of new macromolecules and metabolic processes, eventually resulting in the great variety and biochemical complexity of the life forms that exist today.

Early biological evolution required the creation of new metabolic machinery encoded in new deoxyribonucleic acid (DNA). However, much subsequent evolutionary change has depended primarily upon the modification and elaboration of preexisting components, particularly the DNA (*1, 2*), as indeed the term evolution implies. Thus, large portions of the genetic information (the DNA) are internally homologous within single organisms and also between organisms, even between those that are only distantly related (*3*). Correspondingly, protein molecules engaged in similar tasks, either in the same or in different organisms, are likely to be truly homologous.

Unfortunately, the historical process of biochemical diversification based on the evolution of genes cannot be examined directly since the biochemical record of the past has been largely obliterated. However, the probable course of gene evolution can be reconstructed by examining a wide spectrum of related organisms with reference to the synthesis and activity of specific proteins. For example, the extensive analysis of the primary structure (amino acid sequence) of the cytochrome c molecules of a large number of animals, plants, and protists has revealed that all of these proteins are, indeed, very similar to one another (*4, 5*). These data have allowed the construction of a phylogenetic tree for cytochrome c and a simulation of the evolutionary history of the gene locus encoding this protein (*6*). It is possible, by using these procedures of reconstruction, to document indirectly the number, variety, and timing of mutational events experienced by this gene during its evolution and thereby to explain the array of cytochrome c molecules characteristic of living organisms today.

During the course of evolution, new metabolic functions and new protein molecules have come into existence. Since a sequence of about 1000 nucleotides is required to encode an average-sized protein, the probability of a functional protein arising anew seems infinitely small. In contemporary organisms it is highly unlikely that the random generalization of a new sequence of nucleotides would result in the transcription of a functional messenger ribonucleic acid (mRNA), let alone lead to the production of a protein having any metabolic significance. Novel nucleotide sequences must have been generated and tested billions of years ago during the earliest evolution of biological systems, but the creation of totally new sequences of nucleotides can scarcely be a significant mechanism for generating new information in highly complex and integrated organisms such as those existing today. Far more likely now is the derivation of new genetic information by duplication and subsequent modification of previously existing information, that is, from functioning genes (*7, 8*). Such a duplication of genes coding for specific proteins could be followed by mutational changes eventually resulting in proteins of somewhat different structure and, therefore, different function. A duplicated gene coding for a specific enzyme, for example, could gradually be changed

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