TESTS OF ENERGY CONSERVATION: AN ECONOMIC APPRAISAL*

by

John F. Scoggins
Research Fellow

Public Utility Research Center
University of Florida

September 12, 1991

*This study provides an overview of methodologies used to evaluate energy conservation programs. It was prepared in support of a project on Energy Efficiency Incentives for the Florida State Energy Office. Sanford Berg provided helpful comments on earlier drafts.

Energy conservation is a goal pursued by most public service commissions across the country. Since consumers and utility companies may be affected differently by a conservation program, most public service commissions use several different tests by which to measure the likely effect of proposed programs.[1] This report analyzes the four different tests used by the Florida Public Service Commission: total resource cost test, participants test, rate impact test and utility cost test.

From an economist's point of view, the rationale for each test is *ad hoc*. The benefits of a proposed program may be greater than the costs, according to one test, but not according to the other three. Since the different tests often give conflicting results, it would be helpful to assess the four tests using a single theoretic paradigm. A likely candidate for such a paradigm is something economists call "economic welfare," a long established concept that relies on theories of optimal economic behavior.

This report is organized into three main sections. The first section explains the concept of economic welfare and its relevance in the assessment of energy conservation programs. The second section analyzes each of the four tests used by the Florida Public Service Commission. The final section analyzes the "snap-back effect" controversy in the assessment of energy conservation programs.

1. Economic Welfare

1.1 The Competitive Standard

Approximations of economic welfare can be obtained by using empirical estimates of demand curves and of opportunity costs.[2] The basic technique is to use a consumer's demand for a quantity of a good, which is dependent on the good's price, to reveal how much the consumer values different quantities of that good. Analogously, the quantity of a good that a producer is willing to produce for

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[1] Tests used by different regulatory commissions across the country are very similar. See Burkhart (1990), Costello and Galen (1985), Einhorn (1985), Hobbs and Nelson (1989), and Norland and Wolf (1985).

[2] See Just, Hueth and Schmitz (1982) for a more complete explanation of economic welfare.

sale is also dependent on the good's price and reveals the cost of producing different quantities of the good. Demand and supply curves convey this information because the assumptions concerning perfectly competitive markets hold. In such markets, the producers strive to maximize their profits and therefore have incentives to minimize their costs. Consumers want to maximize their utility and will refuse to pay more for a good than it is worth to them.

The total value of the quantity of a good bought and sold (as determined by the demand curve) minus the total cost of producing the good (as determined by the supply curve) equals the net benefit to the population of producing the good. This net benefit to the population is referred to as economic welfare.

Events that affect the price of a good (price controls), its quantity sold (rationing), or both, will change economic welfare. Consequently the advisability of a government action is a function of its effect on economic welfare. An action that expands the net benefits (gross benefits minus costs) associated with a commodity increases economic welfare.

Note that the economic welfare derived from the production and consumption of a good can be broken into two parts: consumer's surplus and producer's surplus. Consumer's surplus is the portion of economic welfare enjoyed by consumers while producer's surplus is the portion retained by the producer. Consumer's surplus is represented by the area below the demand curve (representing willingness to pay) and above the price charged. Producer's surplus is the area above the supply curve and below the price charge. Figure 1 shows graphically consumer's surplus and producer's surplus.

1.2. Market Failure

The equilibrium quantity, as determined by the intersection of the demand and supply curves, is the quantity that maximizes economic welfare in a perfectly competitive market. Market failure is the situation where one of the assumptions of perfect competition does not hold for that market.

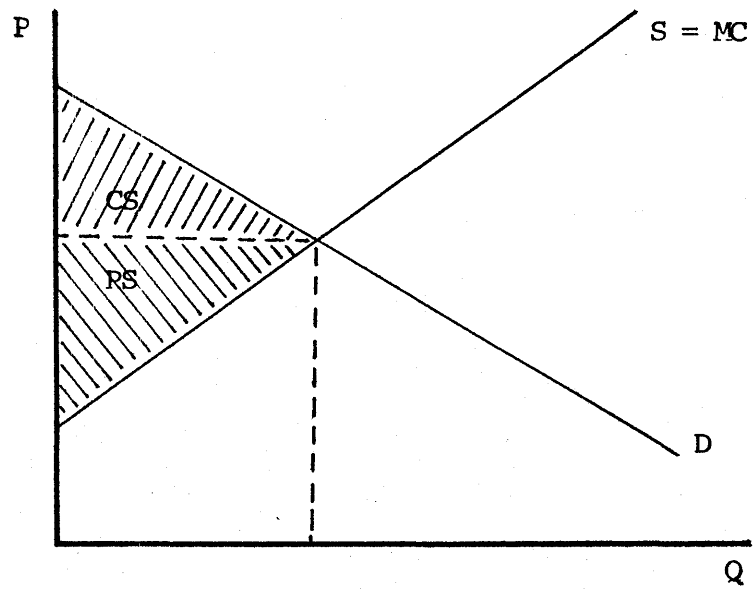

Figure 1
Net Benefits to Production:
Consumers' Plus Producers' Surplus

In that case, the equilibrium quantity will not necessarily maximize economic welfare. Costless government intervention would enhance welfare. The three sources of market failure relevant to tests of energy conservation programs are (1) the under-investment in efficient energy-using durables on the part of consumers; (2) external costs of the use of energy; and (3) pricing below the opportunity cost of electricity.

1.2.1 Under-Investment

Under perfect competition, consumers possess all relevant information and choose their purchases rationally, that is, without obvious error. However, in the purchase of energy-using durables, there is evidence that consumers violate this condition of rationality.[3] By purchasing more expensive but more efficient energy-using durables, many consumers could either enjoy more of the end-use good that the energy-using durable produces (such as cooled air) without an increase in total cost of production or consume the same amount of the end-use good at a lower total cost.

Figure 2 illustrates the above argument. The top graph represents the market for efficient energy-using durables (K); the middle graph represents the market for energy (E); and the bottom graph represents the marginal cost and demand curves for the end-use product--such as comfort or lighting--(Z). Because consumers do not use the least-cost combination of energy-efficient durables and energy, the marginal cost of producing Z (MC_1) is higher than it need be. If consumers would purchase more efficient energy-using durables, their marginal cost curves would shift down to MC_2. Because consumers would be substituting more energy-efficient durables for less energy, the demand for K would shift up from D_{K1} to D_{K2} and the demand for E would shift down from D_{E1} to D_{E2}. By under-investing in efficient energy-using durables, maximum economic welfare is not attained. The point where D_{E2} intersects S_E is where the marginal benefit from the additional energy equals the

[3] See Hausman (1983). Sutherland (1991) finds that a number of alleged barriers to conservation investments are not the result of market failure but reflect rational responses to risky investments which are illiquid and the risk is not easily diversifiable.

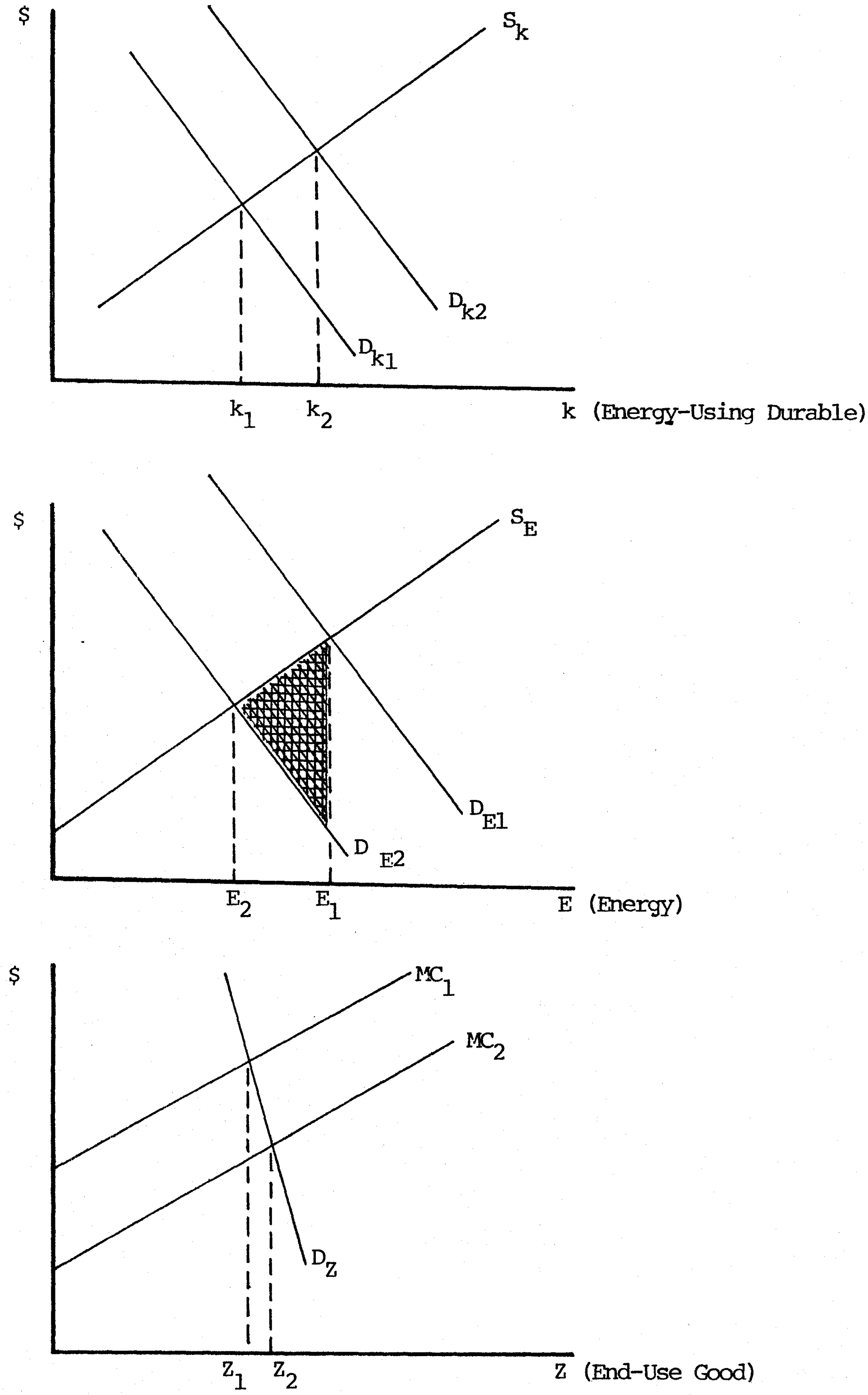

Figure 2
Net Benefits of Increased Investment in
Efficient Energy-Using Durables (With Small Snap-Back Effect)

opportunity cost. Therefore E_2 is the quantity that maximizes the sum of consumer's and producer's surplus. With every extra unit of consumption above E_2, producer's surplus increases but consumer's surplus decreases by a larger amount. If E_1 is the quantity consumed, the loss of the sum of consumer's surplus and producer's surplus is represented by the shaded area in the middle graph.

The increase in end-use consumption from Z_1 to Z_2 caused by the decrease in the marginal cost curve is known as the "snap-back effect." This effect will reduce the possible energy savings of a program that attempts to improve the energy-efficiency of energy-using durables. Notice that the slope of the demand curve for the end-use good (D_Z) in Figure 2 is depicted as being very steep (inelastic). In this case, the snap-back effect is relatively small, and the associated decrease in energy consumption (E_1 - E_2) is relatively large. Conversely, the slope of D_Z at the bottom of Figure 3 is relatively shallow making the snap-back effect large. The decrease in energy demand in Figure 3 is therefore relatively small (E_1 - E_2). Notice that the shaded area in Figure 3, representing the loss of economic welfare from under-investment in efficient energy-using durables, is also relatively small. In general, the smaller the snap-back effect, the greater is the loss of economic welfare from the under-investment in efficient energy-using durables.

Although the stated purpose of an energy conservation program may be to decrease the consumption of energy, economic welfare measures do not weigh a decrease in energy consumption any more than they weigh an increase in end-use good consumption (the snap-back effect). Because of this, the use of economic welfare in the testing of energy conservation programs is potentially controversial. This controversy will be discussed later in greater detail.

1.2.2 External Cost

Another necessary condition for a perfectly competitive market to maximize economic welfare is that all the costs of producing a good are borne by the producers. Otherwise, the supply curve does not represent the social marginal cost of producing the good. If the good is priced at the private

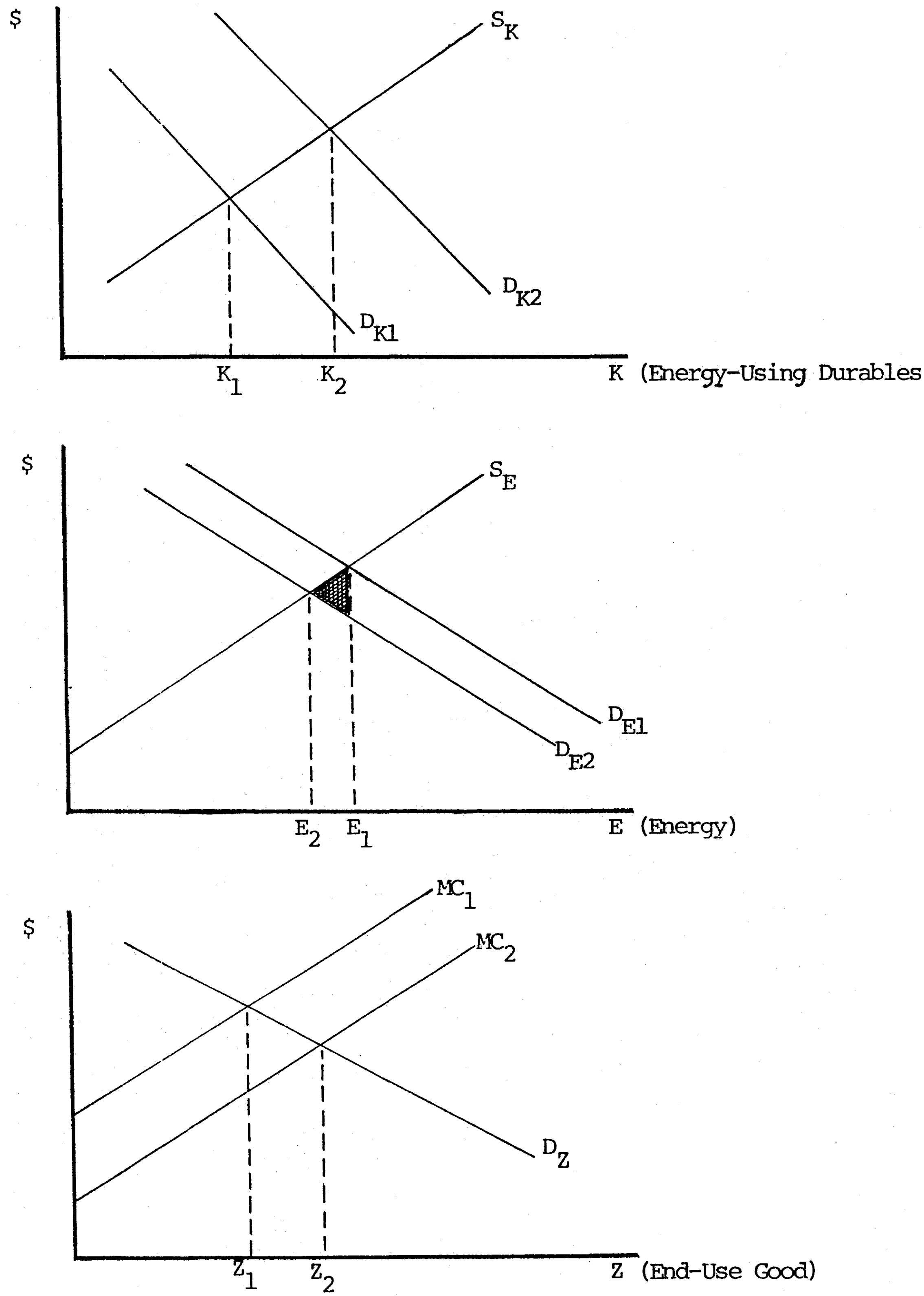

Figure 3
Net Benefits of Increased Investment in
Efficient Energy-Using Durables (With Large Snap-Back Effect)

opportunity cost, the price is low relative to the full costs borne by society when additional units of output are produced.

Pollution is the most frequently cited example of an external cost, and the burning of fossil fuels is a significant source of pollution. Of course, the extent to which the new Acid Rain legislation, the Clean Air Act, and other laws require relatively pollution-free production processes, production costs rise and the externalities are reduced. Another kind of external cost could be a reliance on foreign suppliers of fossil fuels, which could affect national security (and defense expenditure).

Figure 4 is used to illustrate externalities. The marginal cost to society of producing energy is represented by the supply curve $S_E + X$. The economic welfare-maximizing quantity is E_1. However, since only some of the costs of producing the good are borne by the producers, too low a price is charged, and too high a quantity is consumed (E_2). By taxing the good, the consumption of energy could be reduced from E_2 to E_1, and economic welfare could be increased by the amount equal to the shaded area, as the external cost is reduced to where the marginal valuation placed on additional output is just equal to the marginal social cost associated with that unit of output.

The above paragraph is a standard analysis of an external cost's effect on economic welfare. However, in the case of regulated utilities, the situation is a little more involved. It is possible that the external costs of production associated with old productive capacity would be much higher than the external costs associated with new productive capacity. The technology of the new productive capacity might burn fossil fuels more cleanly.

Unfortunately, the exact welfare gain from decreasing energy consumption is difficult to ascertain because the exact external cost of energy production is hard to measure. But the external cost reduction from an energy conservation program should be roughly proportional to the reduction

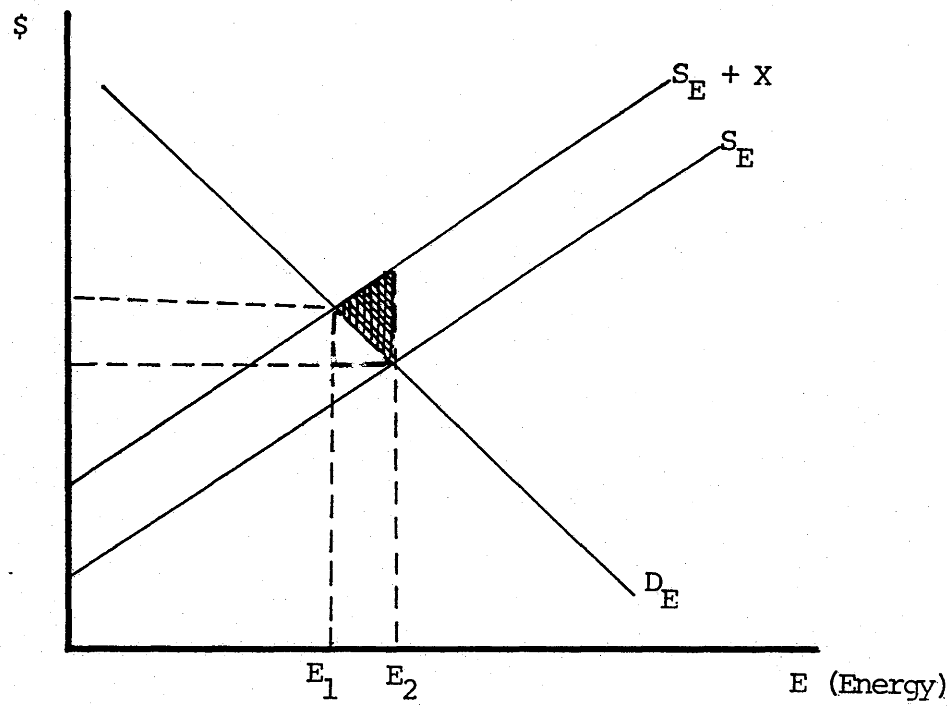

Figure 4
Distortion Caused by an External Cost

in energy consumption: many tests of conservation programs rely solely on reductions in energy production (regardless of the age of the electricity generating unit or actual emission reductions).

1.2.3 Pricing Below Opportunity Costs

The typical utility company is a regulated monopoly.[4] In the multi-firm competitive case the demand and supply (marginal cost) curves intersect such that the marginal firm earns normal profits. This condition does not hold for a monopoly however. It will sometimes be the case that the demand for energy will intersect the average cost curve in the diseconomies of scale region (i.e. the quantities of E where average cost in increasing). This case is illustrated in Figure 5.

In order for the utility to only recoup the cost of producing energy, if it is constrained to a charge uniform price for each unit of output, then price will equal the average cost of production (at E_2). However, economic welfare is maximized when the price is equal to the marginal cost (at E_1). The average-cost price is too low at that quantity of production, and the resulting quantity demanded is too high. The loss of economic welfare is represented by the shaded area in Figure 5.

The reasoning behind this result is that the cost of adding productive capacity is very high relative to the average cost. A conservation program that reduced the demand for energy would increase economic welfare because the avoided capacity and operating costs would be greater than the benefits sacrificed from reduced energy consumption.

Alternatively, if historical capacity costs are low relative to incremental capacity costs, average cost pricing leads to similar "underpricing" of electricity relative to social opportunity costs. Public Service Commissions could provide the correct (higher) price signal to consumers without unduly burdening them if an inverted rate design is adopted. Marginal price would then be greater than the average price, and uneconomic consumption would be discouraged.

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[4] See Berg and Tschirhart (1988).

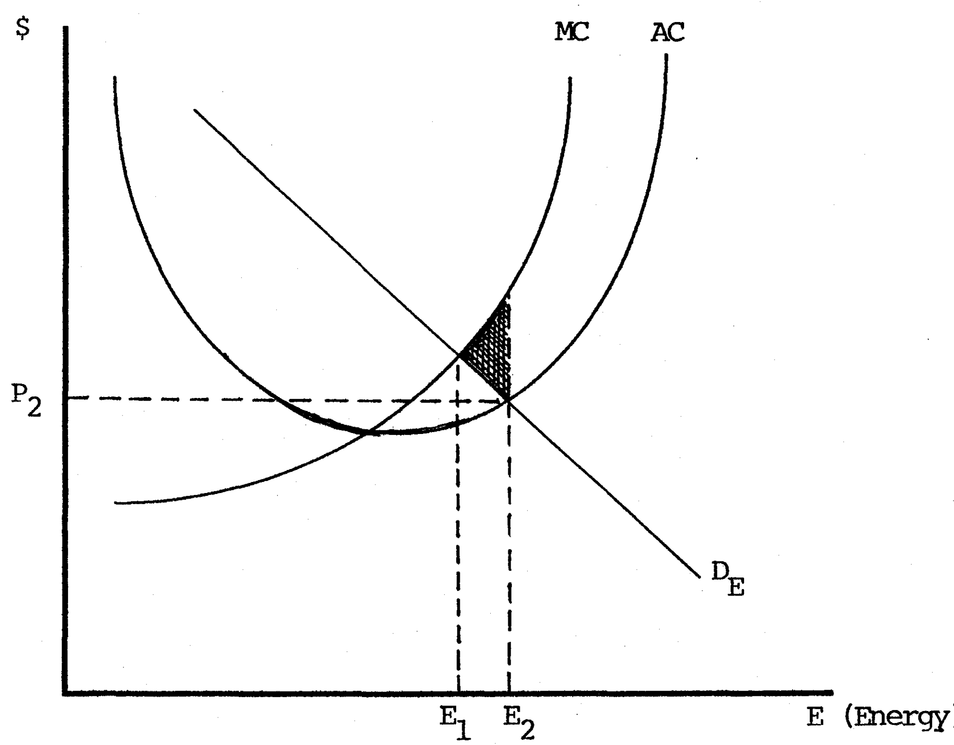

Figure 5
Regulated Monopoly Producing in Diseconomies of Scale Region

To summarize, under-investment in efficient energy-using durables leads to a marginal operating cost curve (for households) that is too high and end-use good consumption that is too low. External costs of energy consumption lead to a marginal cost curve (for utilities) which is too low and end-use consumption that is too high. Operating in the diseconomies of scale region of the long run average cost curve, monopoly regulated to price at average cost charges a price that is too low to maximize economic welfare. All three sources of market failure lead to excessive energy consumption. By increasing the efficiency of energy-using durables, the demand for energy is reduced (although this is partially offset by a reduction in the marginal cost curve for producing comfort, lighting, or other end-use goods). In addition, by internalizing the external costs of energy consumption, more resources would be devoted to end-use good production, and less energy would be consumed. Lastly, a pricing system that equates the price with the marginal cost of production would decrease energy consumption when the regulated monopoly experienced long run diseconomies of scale.

1.3. Distributional (or Equity) Concerns

When a government action increases overall economic welfare, the economic welfare of a particular party is often diminished. An example would be a conservation program that succeeds in increasing energy-efficiency and lowering energy demand. As noted in the explanation of the middle graph in Figure 2, the sum of consumer's surplus and producer's surplus would increase, but producer's surplus would decrease. This potential drop in producer's surplus is a disincentive for utilities to implement conservation programs and is the main reason why so many different tests are used to assess energy conservation programs.[5]

The strict use of consumer's and producer's surplus as a measure of economic welfare implies that a transfer of a dollar from one individual to another would leave economic welfare unchanged.

[5] See Cicchetti (1989).

Because such conclusions require that all individuals have identical preferences, abilities and wealth, economists shy away from making such interpersonal comparisons.

Nevertheless, economists can justify the use of the sum of consumer's and producer's surplus because of a concept called "Pareto efficiency." Simply put, the distributional problem most government actions create can be remedied through a kind of compensation system. An example would be where, instead of allowing consumers to retain all the benefits of a conservation program, the conservation program would be designed to allow the utility to share in the benefits. The net effect on consumer's and producer's surplus would be the same under either policy, but the latter would alleviate the distributional problem.

2. Tests of Energy Conservation Programs[6]

2.1. Rate Impact Test

The benefits in this test are defined as the avoided supply costs as well as any increased revenues. The costs include program costs incurred by the utility, the incentives paid to participants and any increased supply costs. The costs also include any decrease in revenues.

The net benefit of a conservation program as defined by the rate impact test is the same as the change in producer's surplus. As illustrated in Figure 6a, a program that increased investment in efficient energy-using durables would decrease energy consumption from E_1 to E_2 and decrease the price from P_1 to P_2. The utility's revenue falls by the shaded areas A and B. But the utility's cost falls by the shaded area B. Therefore the utility's decrease in profits is represented by the shaded area A.

2.2. Utility Cost Test

The benefits and costs for this test are the same as for the rate impact test except that changes in revenue are excluded. The net benefit of a conservation program as defined by this test

[6] See Florida Public Service Commission (1990).

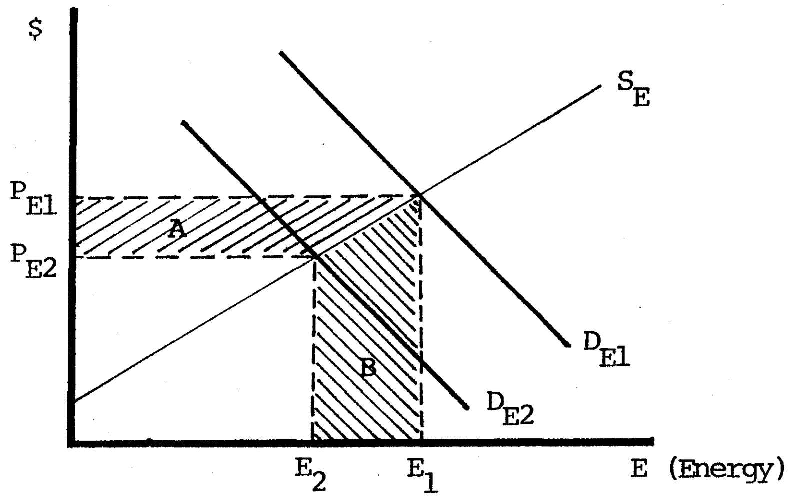

Figure 6a

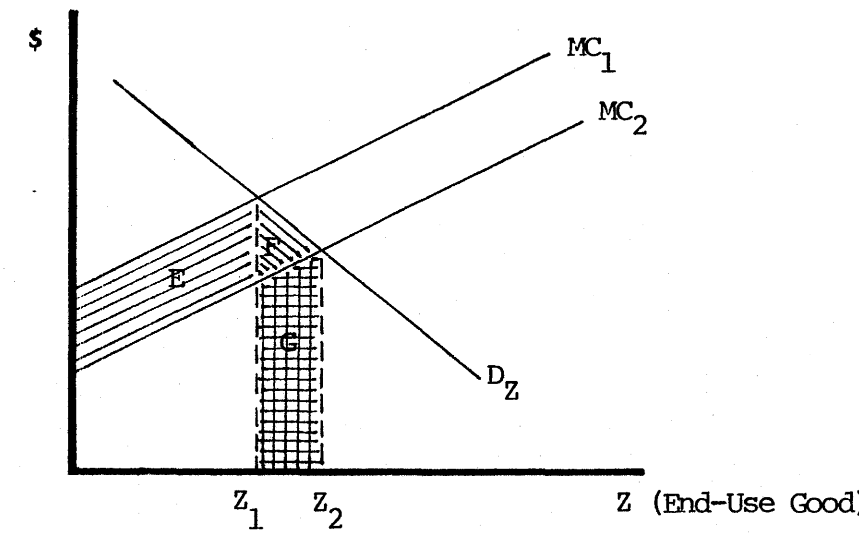

Figure 6b

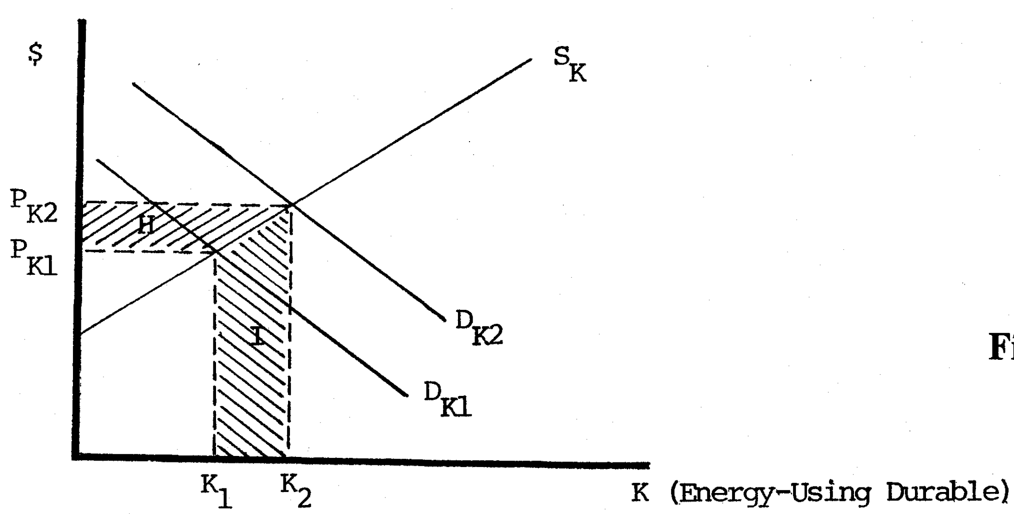

Figure 6c

Impacts of a Conservation Investment

is represented by the shaded area B in Figure 6a. This is equal to the decrease in producer's surplus (area A) minus the decrease in revenue (area A + B). The above illustration indicates that a program that lowers revenue may have positive net benefits according to the utility cost test but negative net benefits according to the rate impact test.

2.3. Participants Test

The benefits for this test include reductions in the consumers' bills, incentives paid by the utility or other third party and any tax credits received. The costs include increases in the participant customers' bills (to pay for the incentives), equipment and materials purchased, ongoing operation and maintenance costs and any equipment removal costs.

According to the definitions, the net benefits for this test equal the change in consumer's surplus excluding the snap-back effect. Figures 6b and 6c illustrate this quantity. The net benefit to consumers of a program that induced them to purchase more efficient energy-using durables would equal the increase in consumers's surplus (area E + F in Figure 6b) minus the increase in expenditures on energy-using durables (area H + I in Figure 6c). The gross benefit of the snap-back effect (ignoring costs) is the value of the increased consumption of Z (area F + G in Figure 6b). The exclusion of the snap-back effect means the net benefits of a conservation program under the participants test is area E - G - H - I. The above illustration indicates that a program that leads to an increase in consumer's surplus may not pass the participants test.

Another concept which is relevant to the participants test is the "free rider" problem.[7] Incentives which are offered to customers to induce them to consume less energy may benefit some customers who do not lower their energy consumption in response to the program. An example is a program that subsidizes the purchase of efficient air-conditioners. Some customers are fully aware of the benefits of efficient air-conditioners and would buy one with or without the subsidy. If the

[7] See Hobbs (1991).

utility company could distinguish between these free riders and the customers who would only buy an efficient air conditioner because of the subsidy, the cost of the program would be greatly reduced, and the decrease in energy consumption would not be affected. In the cases where there are no free riders, the participants test measures benefits as consumer's surplus minus the snap-back effect.

2.4. Total Resource Cost

The net benefits for this test are equal to the sum of consumer's surplus and producer's surplus minus the snap-back effect, which equals the sum of the net benefits for the participants test and the rate impact test. In Figures 6a-6c this amounts to the area A + E - G - H - I.

Remember that for a decrease in energy demand, area A is negative and areas E, G, H and I are positive. The sum of consumer's surplus and producer's surplus is the area A + E + F - H - I. Therefore the sum of the consumer's and producer's surpluses exceeds the net benefits for the total resource test by the area F + G, which is due to the snap-back effect. Accordingly, conservation programs that would lead to an increase in economic welfare (the sum of consumer's surplus and producer's surplus) may not pass the total resource cost test.

3. The Snap-Back Effect Controversy[8]

As mentioned above, the benefits of increased end-use good consumption due to the snap-back effect are excluded from the conservation program tests for the Florida Public Service Commission, as well as for most other state public service commissions. Most economists would argue that if a consumer prefers a higher level of end-use good consumption to an extra dollar, then it would decrease economic welfare to discourage such a transaction.

However, the argument is complicated by the existence of external costs of energy production. Perhaps because they are difficult to accurately measure, external costs and benefits typically are not calculated in the tests for energy conservation programs. If the lowering of external costs was the

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[8] See Khazzoom (1980) and Lovins (1988).

only motivation for energy conservation programs, then this exclusion from the tests would not matter. External cost savings could be assumed to be proportional to energy cost savings and the rankings of potential conservation programs would be unaffected.

If the goal of energy conservation programs is to increase economic welfare, however, the exclusion of external costs from the tests can affect the rankings of potential programs. Moreover if it is impractical to measure external costs, under certain conditions it will sometimes be more accurate to exclude the snap-back effect from the calculation of the net benefit of a program than to include it.

To illustrate this point, the external cost problem is explained using the cost of the end-use good (Z) graph. For simplicity, assume there is no change in producer's surplus nor the amount of money spent on K. Also assume that there is no snap-back effect; making the demand for the end-use product perfectly inelastic. In Figure 7, the inefficient marginal cost curve is represented by MC_1 and the marginal external cost of consuming Z is X_1. The marginal social cost of consuming Z is $MC_1 + X_1$. A change to the efficient energy-using durables would have two benefits. First, it would lower the internal marginal cost of Z from MC_1 to MC_2. Because less energy is used to produce each unit of Z, the marginal external cost of Z is reduced from X_1 to X_2. So using the efficient energy-using durables, the marginal social cost of Z is $MC_2 + X_2$.

A conservation program that induced consumers to purchase efficient energy using durables would score the same net benefits whether the total resource cost test were used or the change in consumer's surplus. This is true because the difference between the change in consumer's surplus and the total resource cost test is the snap-back effect which is zero in this example. Both methods would compute the net benefits to be shaded areas A + B in Figure 7. Neither method would accurately measure the change in economic welfare because neither considers external costs, but relative to each other, they would be equally accurate.

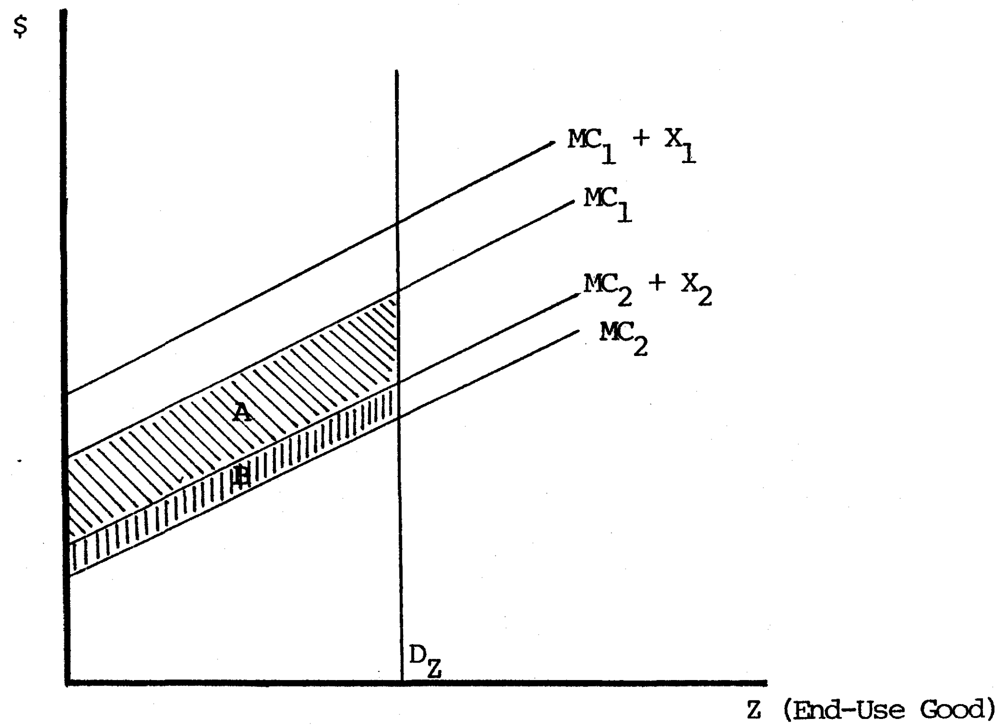

Figure 7
Net Benefit with External Cost
and No Snap-Back Effect

Next consider the case where there are no external costs, but there is a snap-back effect. This is depicted in Figure 8. The reduction in MC (the cost of additional comfort) always leads to an increase in consumer's surplus (area B + C + D + E), but the change in total resource cost (area B + D - F) may be positive or negative depending on the elasticity of demand for Z. In this case, the change in consumer's surplus is the same as the change in economic welfare, and the change in total resource cost is an inaccurate test.

Now consider the case where there is both a marginal external cost of producing Z and a snap-back effect. Looking again at Figure 8, the change in consumer's surplus is still area B + C + D + E, and the change in total resource cost is still area B + D - F. However, the change in economic welfare is no longer equal to the change in consumer's surplus. To compute the change in economic welfare the external costs must be considered. The change in economic welfare is equal to the increase in consumer's surplus, plus the net change in external cost, area A + H - D - E - G. This equals area A + B + C + H - G. Notice that the change in economic welfare can now be greater than or less than the change in consumer's surplus. Although the marginal external cost is decreased from X_1 to X_2, the total external cost can increase if the increase in Z (the snap-back effect) is large. In general, the larger the snap-back effect, the smaller is the increase in economic welfare relative to the change in consumer's surplus.

It is now possible for the change in total resource cost to be a closer approximation of the change in economic welfare than is the change in consumer's surplus. To see this, recall that the total resource cost test (area B + D - F) will always be smaller than the change in consumer's surplus (area B + C + D + E). The difference between these two measures is the net benefit of the snap-back effect (area C + E + F). When there are no external costs, this difference will always lead to an under-measurement of the change in economic welfare on the part of the total cost resource test. However, when there *are* external costs, the net benefit of the snap-back effect can be partially or

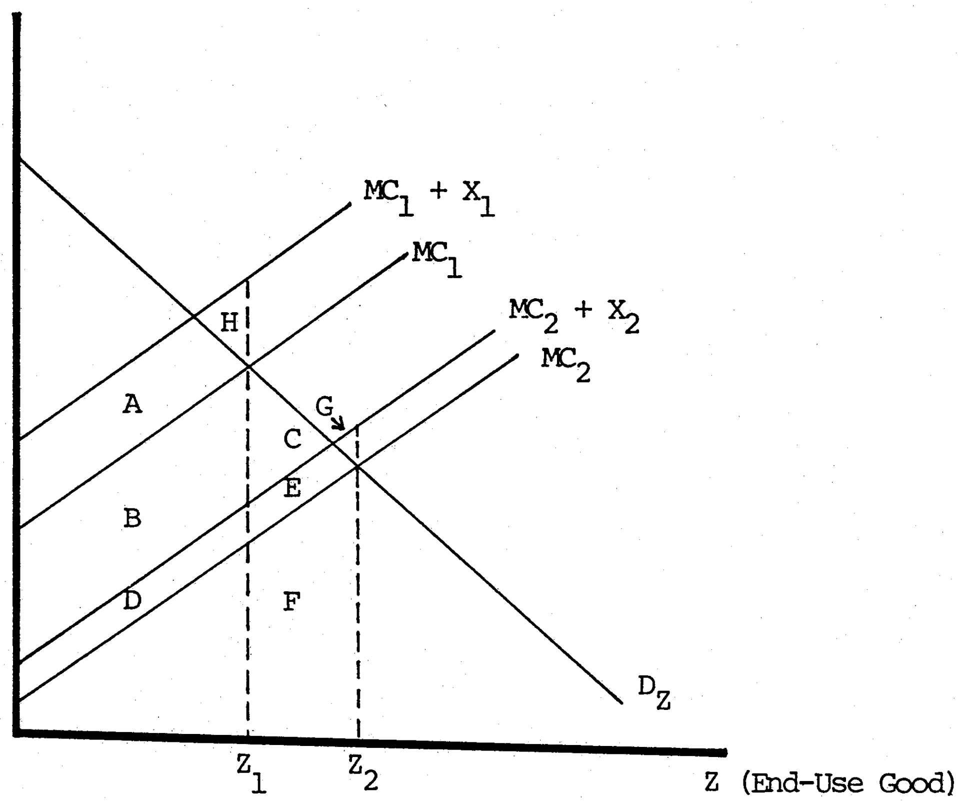

Figure 8
Net Benefit with External Cost
and a Snap-Back Effect

entirely off-set by the change in total external costs, area A + H - D - E - G. If area D + E + G is large relative to area A + H, then total external costs would increase. This condition will be true when the snap-back effect (Z_2 - Z_1) is large and when the initial and ending marginal external costs, X_1 and X_2, are large.

The relevance of this result to the snap-back effect controversy is this: if the primary motivation for energy conservation is the existence of large, but unmeasurable, external costs of energy consumption, then the net benefits of the snap-back effect should not be included in the calculation of costs and benefits. In other words, the total resource cost test would be a better standard than the change in consumer's and producer's surplus. If, however, the primary motivation for energy conservation is the apparent under-investment in efficient energy-using durables, then the change in consumer's and producer's surplus is a better standard than the total resource cost test.

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