NATURAL RESOURCES JOURNAL

Volume 22
Issue 1 *Winter 1982*

Winter 1982

Intergenerational Equity as It Relates to Conservation and Coal Extraction Standards

R. P. O'Toole

A. L. Walton

By R. P. O'Toole and A. L. Walton*

Intergenerational Equity as it Relates to Conservation and Coal Extraction Standards**

INTRODUCTION

Is the present usage rate of non-renewable energy sources socially desirable? There are two concerns to which current interest can be attributed: (1) that fossil fuels are environmentally damaging, and (2) that using non-renewable energy sources now reduces the stock of stored energy available for future generations. As the subsequent discussion will illustrate, each concern is an important factor in deciding whether the actual rate of fossil energy use is close to the socially desirable rate.

The issue addressed in this paper is whether the United States is pursuing conservation and usage of non-renewable fuels (especially coal) in a desirable fashion. The impetus for this study arises from a project the Jet Propulsion Laboratory is performing for the Department of Energy which focuses upon the development of Advanced Coal Extraction Systems.

One dimension of evaluating advanced systems is their conservation performance. That is, of the total physical stock of coal resources disturbed by an underground mining operation, what proportion is actually extracted? This consideration is especially important for mining on leased federal land where conservation goals are often explicitly included in the leasing agreement. In addressing this subject, some obvious questions arise. What is meant by conservation? What is the difference, if any, among the terms "non-renewable," "exhaustible,"or "depletable" as descriptors of fossil fuels?

There is a second dimension to conservation discussions: what value systems are employed when choosing a socially desirable rate of resource consumption? Choices based upon efficiency criteria will be very different from those based upon equity considerations.

Each of these questions will be considered in turn; a concluding section discusses how these considerations apply to the narrower issue of whether coal extraction systems are achieving a socially desirable level of conservation.

---

*Jet Propulsion Laboratory, California Institute of Technology.

**This work was done for the Fossil Fuel Extraction Division, United States Department of Energy under Interagency Agreement No. ET-7-I-01-9036 with the National Aeronautics and Space Administration.

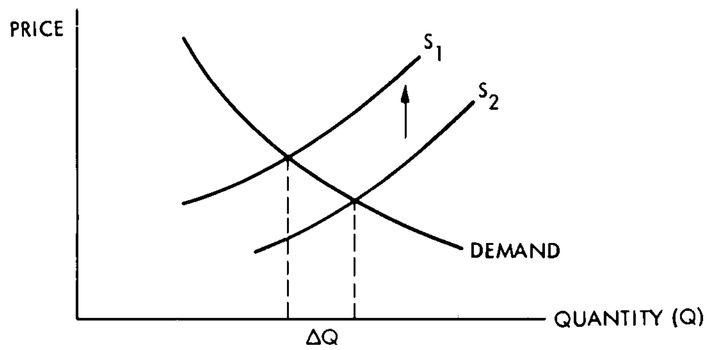
DEFINING CONSERVATION

The term conservation can be interpreted in the broadest context as using less of a natural resource. Within this framework there are at least four ways that conservation can take place. Each of these alternative interpretations is discussed below using simple supply and demand curve analyses.

In Figure 1, the coal supply function shifts upward from S_2 to S_1; this shift may be caused by, for instance, more stringent health and safety standards in coal extraction. Another possible cause of an upward shift in the supply curve is a minimum extraction efficiency standard; i.e., a firm has to extract a specified percentage of the physical coal stock in order to obtain the right to mine, and the constraint is binding in coal fields exploited without the standard. In either case, it costs more to produce at any level of coal output, resulting in conservation of ΔQ units of coal.

FIGURE 1

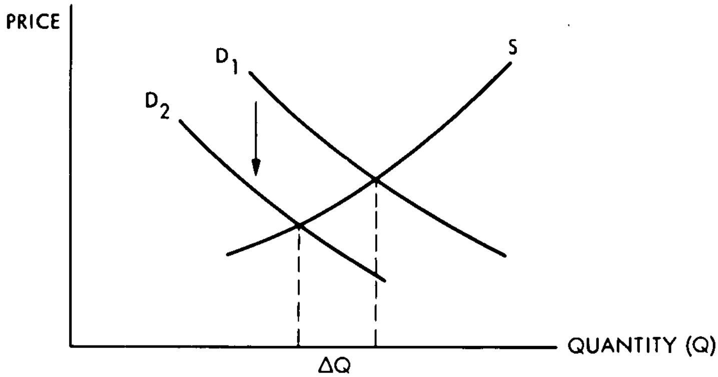
Type I Conservation: Upward Shift of Supply Curve for Raw Coal



Conservation can also occur as the result of a downward shift in demand (D_1 to D_2) for coal, as shown in Figure 2. Several factors can contribute to such a downward shift. A technological improvement may be made in a coal substitute, making it more attractive to users. Alternatively, newly instituted environmental controls on coal conversion may increase the cost of using coal, so that coal users again switch to alternatives. A third factor that can lead to a decrease in demand for coal is attitude change. Companies concerned about their image may avoid burning coal even when they are able to meet environmental standards, if coal usage creates an unfavorable public opinion.

FIGURE 2

Type II Conservation: Downard Shift in Demand for Raw Coal



A third type of conservation occurs when less energy is used because of a technical change which improves end-use efficiency. It is assumed that people do not demand gross Btu but rather units of work, and that energy is a derived demand. Given the premise that demand is for net energy, the diagrams in Figure 3 describe what would happen when end-use efficiency improves. A conversion technology initially has an efficiency E_1. If this efficiency is improved to E_2, as shown in graph "a," it has the impact of shifting the supply curve outward from S_1 to S_2, as shown in graph "b." For any given price, the same amount of gross energy can now provide more net energy at the same price. As the intersection points of supply and demand indicate in graph "b," the net energy demanded (NQ) increases from NQ_1^* to NQ_2^*. However, if these net energy demands are translated into gross energy demands,[1] as shown in graph "c," the equilibrium quantity of gross energy decreases from GQ_1^* to GQ_2^*. Thus, greater end-use efficiency can generate conservation of energy resources.[2]

Finally, conservation can occur when the government imposes a limit on production of a natural resource in order to restrict its consumption. The supply curve shown in Figure 4 is the result of a government-mandated limit on Federal coal leasing. The illustration implies that the constraint is binding; that is, the equilibrium quantity

1. The diagrams in Figures 3a and 3c are identical. Thus, one could determine the gross energy usage implied by the intersection of supply and demand in Figure 3b by using Figure 3a, but this would have resulted in a more complex diagram and perhaps added confusion.

2. An implicit assumption of these diagrammatic results is that the increase in end-use efficiency is costless, althought the results hold under more general conditions.

FIGURE 3

Type III Conservation: Improved End-Use Efficiency

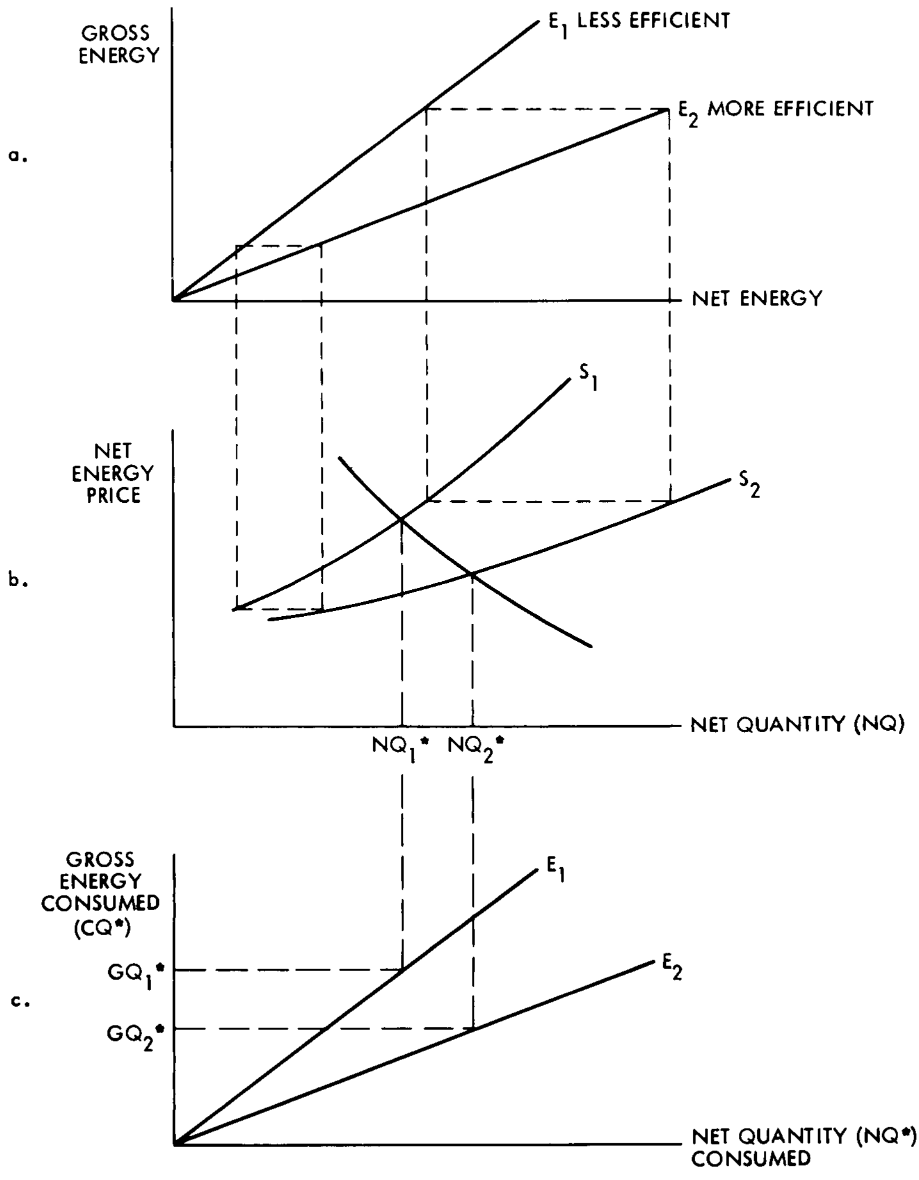
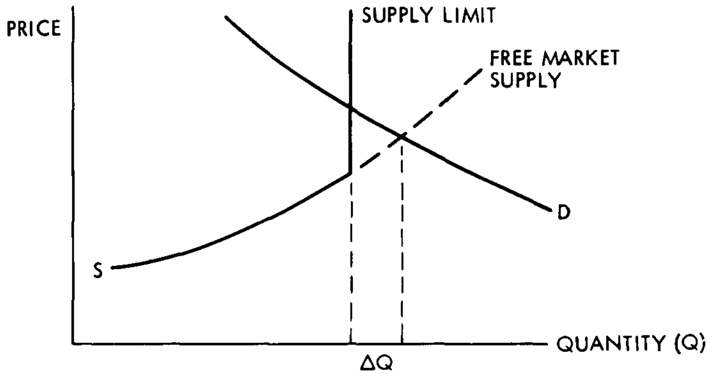


FIGURE 4

Type IV Conservation: Resource Limitations



demanded equals the supply limit. In this case, ΔQ is conserved for future use. Given these four interpretations of conservation, the issue of intergenerational equity and conservation can be discussed with a more precise understanding of the meaning intended.

RENEWABLE AND NON-RENEWABLE ENERGY SOURCES

A second set of distinctions will further clarify the ensuing discussion. In this paper the term "non-renewable energy source" is used when referring to fossil fuels, rather than alternatives such as "depletable" and "exhaustible." The basis for this choice is the belief that fossil fuels will never be depleted or exhausted in a physical sense. Before such a point is reached, society will substitute other forms of energy which become cost effective.[3] The cost of extraction and refinement of *some* of the physical fossil energy stock will be higher than the cost of alternatives; this implies that society will substitute new forms of energy for fossil fuels before fossil energy deposits are exhausted.

Thus, in discussing fossil conservation, the issue is not one of leaving a distant generation without a source of energy, but of allocating the costs of using fossil energy resources among generations.

EQUITY vs. EFFICIENCY

Two value models which may be used to evaluate intergenerational resource allocation are efficiency models and equity models. The

3. W. J. BAUMOL, W. E. OATES, ECONOMICS, ENVIRONMENTAL POLICY AND THE QUALITY OF LIFE 92-118, 136-139 (1979); Nordhaus, *World Dynamics: Measurement Without Data,* 83 ECONOMIC JOURNAL 1156-83 (1973).

former, easily subject to economic analysis, yield operational decision rules for use of resources if certain assumptions prevail. These assumptions are outlined in the next subsection.

One such assumption is that the distribution of income and wealth is given. When this assumption is not valid, choices among resource distributions, based on equity considerations, arise. Equity considerations deal with the distribution of income and wealth within and between different generations. Income and distribution analyses are not easily subjected to economic analysis. This is true not only for individuals in one time period (what is usually referred to as "welfare economics") but also for individuals in different time periods (the intergenerational issue). The analyses which have been used to examine equity issues are described in a second subsection and are used to suggest that saving fossil fuels may not benefit future generations even in terms of their own preferences.

Common Assumptions of Economic Analysis

Economists usually make several assumptions which simplify economic analysis while minimally distorting the results. These assumptions generally fall into four broad categories:

(1) *Price Taker Assumption:* There are a large number of relatively mobile buyers and sellers for each product, so that any individual's actions have little effect on price. This squeezes "excessive" profits (profits greater than an entrepreneur could make elsewhere) out of the product price, and makes price an accurate reflection of the additional costs and benefits inherent in producing the last unit of each good.

(2) *Perfect Information:* Each producer in the marketplace has information on production techniques while consumers have product price and quality information sufficient to make optimal choices.

(3) *Well Defined Markets:* Markets exist for all commodities, even those which are normally considered undesirable. This rules out externalities or other divergences between private and social costs.

(4) *The Income Distribution and Preference Patterns Remain the Same:* The income profile does not change among members of the current population or at different time periods. This avoids irreversibility problems which are caused by changing tastes.

The first three assumptions are "efficiency" assumptions. Utilization of these assumptions assures the existence of a market, squeezes out excessive profits, and assumes away risk. They guarantee that, with a given distribution of income and ownership, resources are allocated in the most efficient manner. "Efficient" indicates that no one in the society can be made better off by shifting to some other level of consumption or production without hurting another member of the society.

Results reached by utilization of the efficiency assumption are unrealistic. Some people are made better off at the expense of others. Removing the "given the distribution of income and ownership" caveat leads to the realm of the fourth, or "equity," assumption.

Instead of arriving at the best use of a given resource distribution, as is done under the efficiency assumptions, equity considerations seek a better distribution of a given resource. Since it is virtually impossible to compare the preferences of different individuals in a consistent manner, economists have had little to say about equity considerations. The choice of possible income distribution is made based on sociological grounds, and this is reflected in the choices made by voters and their elected representatives.

This distinction between equity and efficiency issues is readily apparent in the literature on allocation of depletable resources over time.[4] Economists have had a great deal to say about the three efficiency criteria.[5] First, non-renewable resource owners have substantial market power and are subject to many government regulations, so the assumption of a competitive market is not met. This creates a misallocation of resources. For example, Sweeney[6] found that the depletion allowance depresses current resource prices and increases present consumption at the expense of future users. This analysis was illustrated in Figure 1: since the supply curve shifts downward in response to production subsidies, the incentives for conservation are decreased, resulting in lower costs of production and larger quantities demanded and supplied.

The second efficiency assumption is contradicted by the high degree of risk and uncertainty in resource investment, causing resource usage to be biased toward the present. In effect, a risk premium is added to required rates of return on these projects, reducing the current value of any benefits to be realized far into the future. Yet society as a whole would benefit if these decisions were made in terms

4. The equity-efficiency controversy is summarized in A. M. OKUN, EQUALITY AND EFFICIENCY: THE BIG TRADEOFF (1975). Specific portions of this controversy which relate to depletable resources appear in P. S. DASGUPTA and G. M. HEAL, ECONOMIC THEORY AND EXHAUSTIBLE RESOURCES (1979), and PAGE, TALBOT, CONSERVATION AND ECONOMIC EFFICIENCY (Baltimore, MD: Johns Hopkins, 1977).

5. DASGUPTA, *supra* note 4, particularly ch. 3, 11, 13 and 14.

6. Sweeney, *Economics of Depletable Resources: Market Forces and Intertemporal Bias*, 44 THE REV. OF ECON. STUD. 125-41 (1977).

of the expected values, because risk tends to be neutralized when it is spread over the large number of individuals in society.

Finally, the existence of externalities (such as pollution) invalidates the third efficiency assumption, and causes a non-optimal amount of resource development (such as fossil fuel refining). This is so because the full costs of production are not recognized by either the producer or buyer. If these costs were born by users ("internalized") the supply curve would shift up as in Figure 1, resulting in fewer resources being consumed. However, when there are a large number of residents subject to the externality and little cost imposed upon each, organization is expensive, no collective action is taken and misallocation often persists.[7]

The conclusion which can be drawn from the literature and economic theory is that private markets do induce an efficient amount of conservation if biases are not present.[8] Current policy is moving toward making the private market for coal efficient. Subsidies and tax practices such as the depletion allowance have been reduced. In addition, the social cost of environmental externalities are being internalized to the coal market through regulation. The effect of both these actions is to shift the supply curve for coal upwards, which, coupled with some elasticity in the demand for coal,[9] must result in fewer coal resources being used.[10] This suggests that energy markets are moving toward a desirable level of conservation based solely on efficiency grounds.

The efficiency considerations summarized above have received significant attention in the economic literature.[11] Less attention has been given to the aforementioned equity consideration. The next subsection explores some concepts concerning the allocation of natural resources among different generations. Implicit throughout the discussion of equity is that conservation of type IV (Supply Constraint) is imposed.

---

7. *See* Mishan, *The Postwar Literature on Externalities: An Interpretive Essay,* 19 THE JOURNAL OF ECONOMIC LITERATURE 1-28 (1971), for a full exposition of the postwar literature on externalities.

8. BAUMOL, *supra* note 3, at 114; J. M. GRIFFIN, H. B. STEELE, ENERGY, ECONOMICS AND POLICY 34-39 (1980).

9. As long as the demand for coal is not insensitive to price (demand curve is not vertical). The magnitude of this sensitivity is open to question, since large quantities of coal are supplied through long-term contracts. This suggests that demand may be relatively inelastic in the short run, because users are tied to long-term contracts. However, as these contracts come up for renewal, buyers are probably very price conscious, and demand should have some elasticity.

10. A secondary effect of increasing the cost of coal by internalizing environmental externalities is that the incentives for greater end-use efficiency are increased (Figure 3).

11. DASGUPTA, *supra* note 4, particularly ch. 3, 11, 13, and 14.

Equity Considerations

Using renewable energy sources now would presumably leave a larger stock of non-renewables for future generations. A highly pertinent issue is whether that is necessarily "good," and, if so, "good" for whom? This paper suggests that it is impossible to predict whether leaving large stocks of non-renewable energy sources is necessarily better for future generations, even in terms of their own preferences. This assertion rests on two points: (1) that the value of non-renewable energy sources in the future is a function of the availability and cost of substitutes, and (2) current generations leave a collection of legacies to future generations which are not all independent.

The basis of the first point is this: there may be little or no value to "saved" non-renewable energy sources in the future. As long as technological change is possible (and probable in this case) the possibility certaintly exists that a major technical breakthrough could occur and significantly reduce the value of stocks of fossil fuels. The most obvious example is nuclear fusion which, although a very remote possibility in the short-run, is hard to discount in the long-term (beyond 200 years, for instance). Thus, the longer the time period over which the stock of stored energy is planned to be used, the greater the probability that the need for it will decrease because a more desirable energy form will be developed. Had the Egyptians decided to conserve blocks of granite for future generations to build pyramids, the sentiment would have been appreciated, but there would have been little value in their conservation ethic. Looking to our future, descendents of the present generation may have a similar response to a legacy of a dirty black substance called coal, especially if fusion is perfected, if solar energy is produced cheaply through some new process, or if some other inexpensive energy form as yet unknown is developed. The outcome of this generation having been denied the use of presently cost-effective resources in order to save them for another, uncertain time amounts to a socially wasteful undertaking. However, if these technological advances do not occur, and if that portion of the fossil fuel stock set aside for future generations is less costly to them than other energy forms, will descendants be grateful for the non-renewable energy we save? The answer to this rhetorical question is "perhaps." This leads to the second point about non-renewable energy conservation.

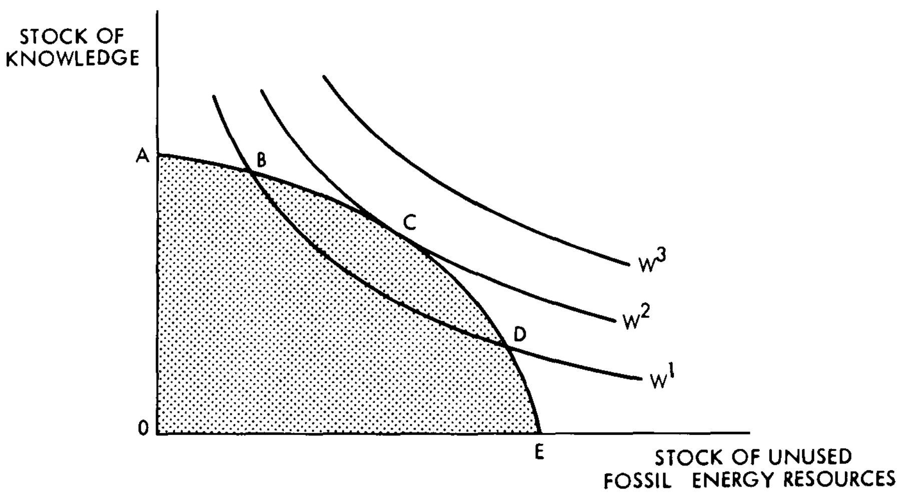
What any generation of people leaves to subsequent generations is a collection of endowments, of which energy is only one dimension. To our children and grandchildren we leave a legacy from which they can derive direct benefits as well as a stock of knowledge upon which they can build. In the long-run, the former endowment may be replaced or decrease in value, but the latter is of enduring value. The essence of this argument is that these endowments are not independent, but in fact have a relationship as depicted in Figure 5.

The shaded area represents the feasible legacies which can be left. The set is concave with respect to the origin because each unit increase in the quantity of either endowment is increasingly expensive in terms of the other. In other words, the first increments in the stock of knowledge are relatively inexpensive in terms of the energy resources which are consumed (i.e., in the range between D and E). A larger reduction in energy left for the future occurs between points C and B, but this energy usage produces a smaller increase in knowledge.

An intuitive explanation of the link between the production of knowledge and the use of energy seems fairly evident in the activities of developed and undeveloped nations. In the United States, for instance, less than five percent of the population produces more than enough food for the country's consumption. This efficiency is made possible by a highly capital and energy intensive farming industry. Given this efficiency in food production, the remaining 95 percent of the labor force is available for other pursuits–one of which is basic research. Nations which have not provided for their fundamental needs do not invest in the basic research which leads to the expansion of the knowledge base. Thus, one of the beneficial by-products of the industrialization of the last century, made possible partly by the avail-

FIGURE 5

Trade-Off of Intergenerational Legacies



ability of inexpensive energy, has been the diversion of resources to the production of knowledge. This knowledge production enables a society to move away from point E along the frontier of the feasible set. (In reality, production tradeoffs are probably somewhere inside the frontier, given government policies which have led to inefficient energy use.)

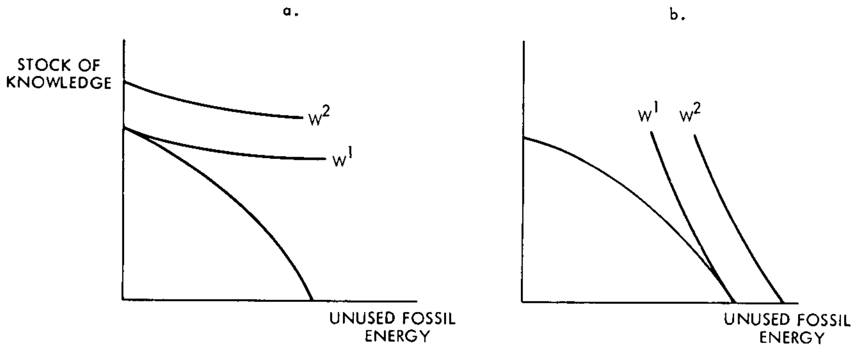
It is impossible to predict the most desirable set of legacies to leave future generations. Obviously, posterity would like to achieve the highest level of well-being possible in terms of its own preferences. In Figure 5, these preferences could be represented by a set of hypothetical indifference curves, denoted W^i. Each curve represents combinations of knowledge and fossil resources among which posterity would be equally satisfied. More of both knowledge and fossil energy is better than less; thus W^3 is a higher level of well-being than W^2, which in turn is better than W^1. But unlike the feasible set of legacies, the set of preferences is probably convex. Convexity assumes that the more posterity has of one good—either knowledge or fossil fuels—the less important (relative to the other good) is an extra unit of that one good. Thus, a future in which there is a greater pool of knowledge than unused fossil fuels (point B) values additions to its energy resources relatively more than a future endowed with large quantities of fossil fuels and relatively little knowledge (point D). Diagrammatically, the slope of W^1 at point B would be greater than at point D.

Indifference curves and the feasible set of legacies may be combined to indicate the combination of knowledge and resources which is most preferred by posterity. In Figure 5, this is point C. C is preferred to points such as B and D because it provides higher levels of satisfaction to posterity, (W^2 is preferred to W^1). Points to the north and east of ABCDE are unobtainable, while points within ABCDE do not provide the same levels of satisfaction as W^2. Thus C is the "best" legacy the present can leave to posterity, in terms of posterity's preferences.

However, the present generation has no idea what posterity's preference ordering (W) will indicate. The shape and location of these preferences depends upon the substitutes for fossil fuel and the quantity of knowledge available. As mentioned earlier, in the extreme case where very inexpensive energy (e.g., fusion) is obtained, the highest preference ordering (W) will intersect the feasible region at point A, indicating that as much knowledge as possible, together with minimal stocks of fossil fuels, is the best combination of legacies. This possibility is shown in 6(a). Of course, preferences which indicate the other extreme (points near E) are also possible, as shown in Figure 6(b). In the latter case, fossil energy is extremely valuable. It takes

FIGURE 6

Intergenerational Legacies



large increases in the stock of knowledge to compensate for even small reductions in the stock of fossil fuels. As an example, the current generation might be willing to pay double the present real cost of energy, if earlier generations had also provided a cure for cancer. The tie between the use of energy and research is a loose one—very little energy is consumed directly in the conduct of basic research. Nevertheless, industrialization has freed significant quantities of human resources to pursue activities which are not tied directly to subsistence.

The essence of the arguments presented is that conserving fossil energy resources is not necessarily socially valuable even to the future generations it is supposed to benefit. Fossil energy has no intrinsic value; it is an intermediate product which provides a service. Thus, the cost and availability of substitutes is crucial to the question of equity to future generations. In some applications, alternatives to fossil fuels appear to be inexpensive and readily available (solar water heating in the southwestern United States, for instance). But even if the real cost is a factor of three more expensive in the long run, is it undesirable to expect future generations to deal with the problem themselves? Probably not. As previously mentioned, technological advance has the potential to greatly soften the impact of this cost increase on the quality of life. Furthermore, the "fairness" problems associated with conservation are bilateral. Productivity growth increases national output and per capita consumption opportunities. Thus, posterity could have higher real incomes, even if energy costs increase. A reasonable question to ask is whether or not the current generation should be expected to forego some of its income by using more expensive renewable energy resources to further increase posterity's wealth.

INTERGENERATIONAL EQUITY AND COAL CONSERVATION

Applying the preceding discussion to the specific issue of extraction efficiency in underground coal mining does not indicate a clear course of action. There is still the problem of separating efficiency and equity issues. Nevertheless, there are the following useful observations and possible studies which could help lead to a socially desirable solution.

One interesting question is whether there is an intergenerational equity rationale for setting a minimum extraction efficiency level on mining done on federally-owned land. The specific case of interest is where private coal companies use technologies such as room and pillar mining where extraction efficiencies are low (e.g., 50 percent) compared to advanced techniques. This choice of technologies is assumed to be rational in that the profit-maximizing technology and extraction efficiency are utilized in response to given mining and market conditions.[12]

Precedents do exist for federal actions on intergenerational equity grounds. As examples, much of the debate on nuclear waste concerns future generations, and wilderness areas have been set aside in perpetuity for future enjoyment. However, there is the problem discussed earlier of whether future generations would prefer to be endowed with cheaper energy at the expense of infrastructure and knowledge. Because of uncertainty about energy-knowledge trade-offs, it is uncertain whether future generations would consider intergenerational equity an ample justification for this generation to start research on conservation of coal.

This does not imply that coal conservation research should not be undertaken. There are many economic efficiency arguments for coal conservation. Incomplete information, price regulation, tax incentives, and environmental externalities all suggest that current coal extraction rates are too high. Thus, a first step would be to look at efficiency conditions in the coal market. By definition, if the market is not efficiently organized, some people can be made better off without making anyone worse off, so it should be politically easier to enact efficiency changes.

12. P. THOMAS, EVALUATION OF CONSERVATION PERFORMANCE IN COAL SYSTEMS BY A DYNAMIC MODEL OF WASTE (January 1979) (Jet Propulsion Laboratory, unpublished report).

In this efficiency context one would want to study the performance and conduct of the existing industry. For example, the government currently leases lands to developers at fairly low rates and then charges them a royalty on each ton of coal extracted. This mechanism has the benefit of reducing risk to the developer by reducing the investment in land when the resource quality and quantity are not well known. One negative aspect of this policy, however, is that a fixed cost (land) has been turned into a variable cost (royalty). Since profit maximizing firms would extract up to the point where price equals marginal cost, this tax would lead to a lower extraction efficiency. Perhaps it would be socially desirable to eliminate the royalty beyond a certain point, to encourage more intensive extraction of a given mine and provide signals for efficient production at the margin. The entire property rights issue is quite pertinent in this context: does the leasing and bidding process provide the proper incentives for research and implementation of more efficient mining methods?

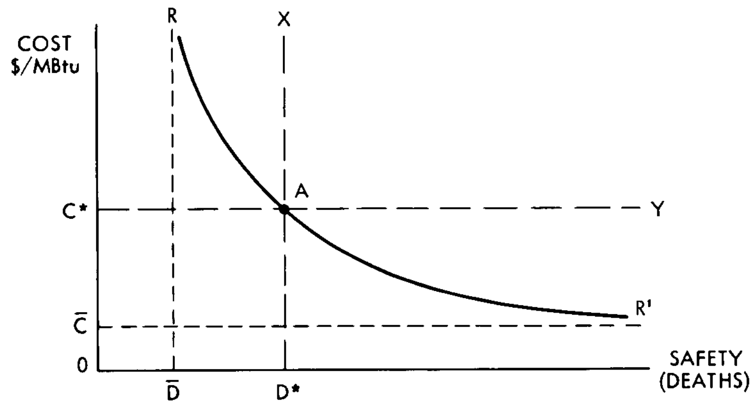
A second area worthy of additional research is how coal use (and hence coal conservation) will be affected by future environmental and safety regulations. One way to approach this problem is to look at the trade-offs among the attributes of cost, safety, and environmental degradation. In order to illustrate the concept with diagrams it will be assumed that there are only two attributes of interest–cost and safety. Curve RR′ in Figure 7 shows the trade-off between safety (number of deaths) and cost. This curve is similar to the legacy curve (ABCDE) in Figure 5, in the sense that it measures possible trade-offs among inputs. However, since these "inputs" (death and dollar costs) have undesirable attributes, the shape of this curve is opposite that in Figure 5: the set of possibilities lies to the northeast of RR′.

The point A is the performance of state-of-the-art conventional technology for a given type of mine. Incremental changes in this technology allow movement along RR′ within certain limits; no decrease in safety can lower cost beyond $\bar{C}$ and no expenditure on safety can improve safety beyond $\bar{D}$. Within this range there is a trade-off: increased safety can be purchased with rising marginal cost, which accounts for the concavity of RR′.

Given this diagram it is obvious that points within OC*AD* would be preferred to the current technology represented by point A, since OC*AD* represents more safety and/or less cost than point A. Similarly, points above and to the right of XAY are less desirable than the current technology. A little less obvious is that the entire area above RR′ represents trade-offs of safety and costs which are inferior to existing technology and its incremental improvements. Movements to any cost safety combination along RR′ are possible from A (the cur-

FIGURE 7

Cost-Safety Trade-Off



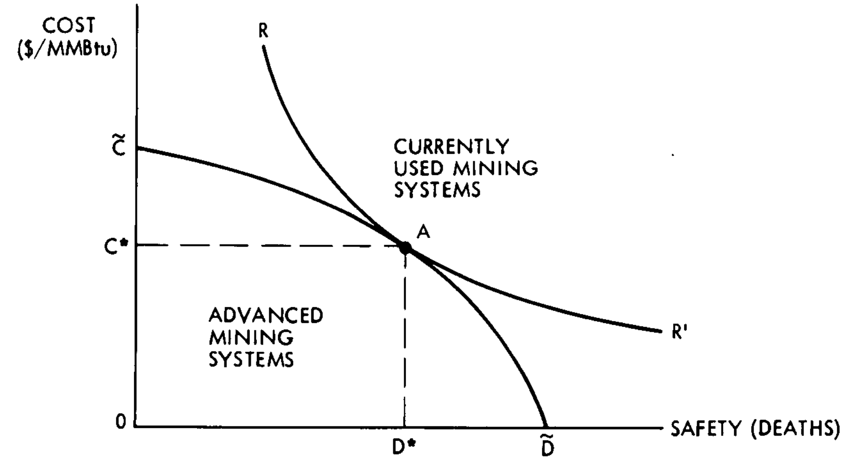
rent technology). Choosing to operate at points within the regions RAX and R'AY are inefficient, because more safety or reduced cost (or both) could be obtained by switching production patterns so that combinations along RR′ are obtained. This analysis reduces the definition of "advanced" to points beneath the RR′ curve, but the possibilities can be bounded further.

If one could derive the combinations of safety and cost among which society is equally satisfied (society's indifference curve) it would probably have the shape of $\tilde{C}A\tilde{D}$ in Figure 8. As safety is decreased moving to the right, larger compensations in terms of cost reduction are required to leave society indifferent, leading to the convex shape of $\tilde{C}A\tilde{D}$. This indifference curve presumably is tangent to RR′ (the locus of technically feasible points) at point A, since this is the current state of technology. If current mining systems are not at this point, changes could be made in existing technology which improve societal satisfaction.

Any system in the region $\tilde{C}A\tilde{D}$ is superior to what exists now. This is not completely intuitive: it suggests that advanced systems may have higher costs or less safety than is associated with existing techniques. However, society may consider technologies which save many lives at a small incremental cost to be worthwhile. Thus, future technology choices may be selected from among the possibilities in $\tilde{C}C^*A$. Similarly, techniques which drastically reduced extraction costs with minor safety losses (combinations in $\tilde{D}D^*A$) might also be preferred to point A. Thus, the entire area below CAD is preferable to point A, even though not all of these points represent combinations where both costs and deaths are reduced.

FIGURE 8

Advanced Coal Extraction Systems



An accurate estimate of C̃AD̃ would be extremely difficult. However, a linear approximation is certainly possible. Such an estimate would improve the understanding of advanced systems and the safety-cost tradeoffs associated with utilizing them. Empirically estimating C̃AD̃ requires a determination of the safety/cost trade-off implicit in other energy systems. Additional constraints could be obtained from regulations which place limits on safety performance in energy and other industries. From this activity a workable definition of "advanced" mining systems could be obtained which considers trade-offs between cost and safety factors.

A vital piece of information in the evaluation of energy trade-offs is the cost of energy to future generations. Although this question cannot be resolved with any precision now, the next twenty years should provide information which can be used to place bounds upon the cost of renewable energy sources. If the real cost (excluding inflation) of utilizing a renewable energy technology is twice that of fossil fuels, then society's view of conserving fossil fuels might be quite different than if the real cost were fifty times as high. Society has the capability of waiting twenty years for more information without using a major portion of the physical coal reserve. Both over-conservation and under-conservation involve cost to society.

Any action taken on the limited information available is very risky. However, it is recommended that further study of conservation for intergenerational equity purposes not be pursued at this time. This does not mean that further study of conservation is undesirable. However, justifications for additional conservation should be based upon efficiency problems (such as price regulation, tax incentives which favor alternative energy sources, lack of information upon which to make production decisions, and externalities imposed upon society by coal production) rather than equity arguments. Advanced coal extraction systems should be evaluated on the basis of cost, safety, and environmental considerations alone–not on equity.