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Intergenerational Equity and Conservation

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ABSTRACT

The issue of intergenerational equity in the use of natural resources is discussed in the context of coal mining conversion. More precisely, the authors attempt to determine if there is a clear-cut benefit to future generations in setting minimum coal extraction efficiency standards in mining. It is demonstrated that preserving fossil fuels beyond the economically efficient level is not necessarily beneficial to future generations even in terms of their own preferences. Setting fossil fuel conservation targets for intermediate products (i.e. energy) may increase the quantities of fossil fuels available to future generations and hence lower the costs, but there may be serious disadvantages to future generations as well. For example, the use of relatively inexpensive fossil fuels in this generation may result in more infrastructure development and more knowledge production available to future generations. The value of fossil fuels versus these other endowments in the future depends on many factors which we cannot possibly evaluate today. Thus, since we have no idea of whether we are helping or harming future generations, the authors recommend that intergenerational equity not be used as a factor in setting coal mine extraction efficiency standards, or in establishing requirements.

CONTENTS

SECTION I

INTRODUCTION

An important consequence of the increased national awareness regarding energy scarcity is that the public is questioning whether the current usage rate of non-renewable energy sources is socially desirable. This interest is basically attributable to two concerns: (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, both these issues are important to whether the actual rate of fossil energy use is close to the socially desirable rate.

The issue addressed in this paper is whether this country is pursuing conservation and non-renewable fuels (especially coal), in a desirable fashion. The impetus for studying this issue arises from a project the Jet Propulsion Laboratory is performing for the Department of Energy concerning 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 which are 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 lease 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? What value systems (efficiency vs. equity) are employed in resolving the issue of what is a socially desirable rate of consumption? Each of these questions has been considered in turn, with a concluding discussion of how these considerations apply to the narrower issue of whether coal extraction systems are achieving a socially desirable level of conservation.

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*This work was done for the Fossil Fuel Extraction Division, United States Department of Energy under Interagency Agreement No. ET-76-I--01-9036 with the National Aeronautics and Space Administration.

SECTION II

CONSERVATION

The term conservation can be defined in the broadest context as using less of a natural resource. Within this framework, however, 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 analysis.

In Figure 2-1, an upward shift in the coal supply function from S_1 to S_2 arises because of more stringent health and safety standards in coal extraction. It costs more to produce at any level of coal output which results in conservation of ΔQ units of coal. 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. The industry supply curve tends to shift upwards if the constraint is binding in coal fields exploited without the standard.

Conservation can also occur as the result of a downward shift in demand (D_1 to D_2) for coal, as shown in Figure 2-2. Two factors can contribute to such a downward shift: (1) a technological improvement of a coal substitute, or (2) newly instituted environmental controls on coal conversion which increase cost.

Attitude change is still another factor that can lead to a decrease in demand for coal. Companies concerned about their image may avoid burning coal even when they are able to meet environmental standards, if the risk of doing so is an unfavorable public attitude.

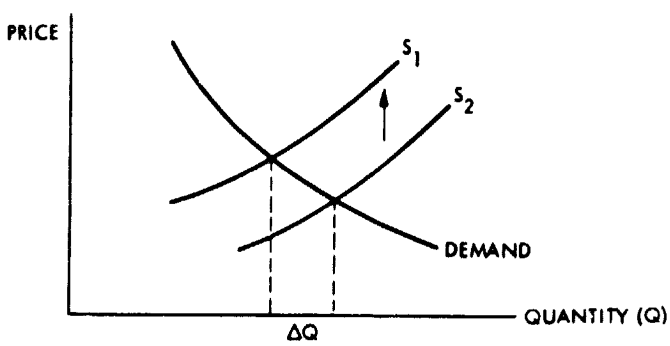

Figure 2-1. Type I Conservation: Upward Shift of Supply Curve for Raw Coal

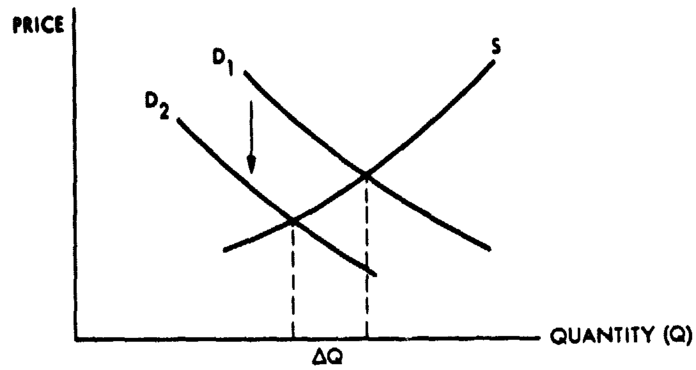

Figure 2-2. Type II Conservation: Downward Shift in Demand for Raw Coal

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 Btus, but rather units of work and that energy is a derived demand. Given the premise that demand is for net energy, the following figures describe what would happen. Figure 2-3 shows a conversion technology with 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 and NQ_2. If these net energy demands are translated into gross energy demands*, 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 feedstocks such as coal.

*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.

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

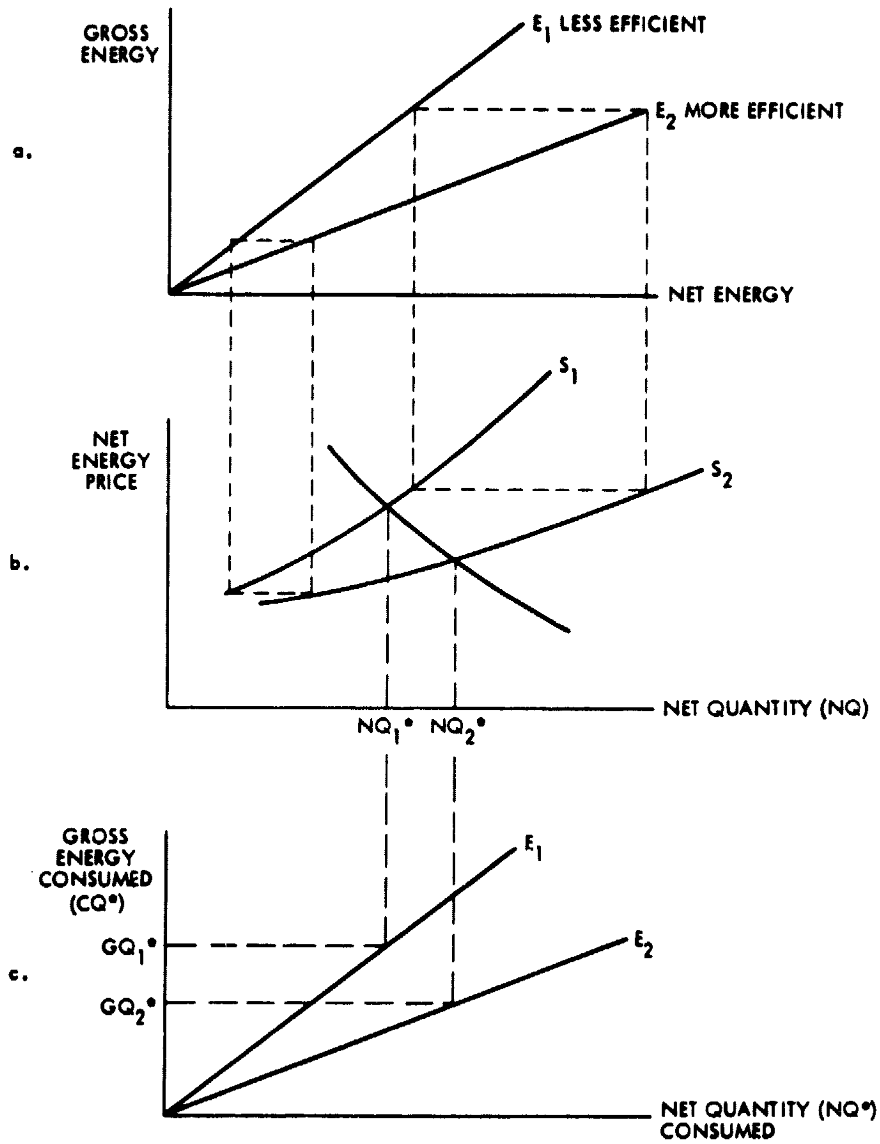

Figure 2-3. Type III Conservation: Improved End-Use Efficienc;

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 2-4 is the result of a government-placed limit on Federal coal leasing. The illustration implies that the constraint is binding; that is, the equilibrium quantity demanded equals the supply limit. In this case, ΔQ is conserved for future use over what the free market would have saved. Given these four interpretations of conservation, we can view the issue of intergenerational equity and conservation with a more precise understanding of the meaning intended.

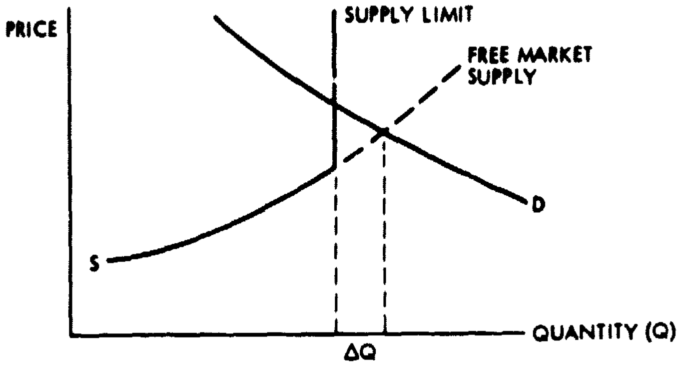

Figure 2-4. Type IV Conservation: Resource Limitations

SECTION III

RENEWABLE ENERGY SOURCES

After much consideration, the term "non-renewable energy source," as used in this paper, was selected over alternatives such as "depletable" and "exhaustible." The basis for this choice is the belief that fossil fuels will never be depleted in a physical sense. Before this point is reached, society will substitute other forms of energy which become cost effective. Already, the technical means exist to convert to a society based entirely on renewable energy sources. However, the cost of this conversion would be much higher than using fossil fuels and is unnecessary at this time. It is clear, however, that the cost of extraction and refinement of some of the physical fossil energy stock is higher than the renewable alternatives; this implies that society will substitute new forms of energy for fossil fuels before they are exhausted. Thus, in discussing fossil conservation, the consideration is not one of leaving a distant generation without a source of energy. In order to accept the contention that cost distribution among generations is the essence of this issue, it must be believed that either we have the knowledge or will have the knowledge to convert to a renewable society. Many technical documents support the view that the technology exists today for such a transition.

The problem of allocation arises with respect to fossil fuels because the earth has been endowed with a stock of stored solar energy in the form of hydrocarbons (non-renewables), which are considerably less costly than current systems, to collect the flow of solar energy (renewables). Thus, a key issue implicit in the question of desirable fossil fuel conservation is how this relatively inexpensive stock of fossil fuels should be allocated among generations.

SECTION IV

EQUITY vs EFFICIENCY

Two dimensions of resource allocation which economists find useful in explaining the salient issues are efficiency and equity considerations. The former area has been analyzed extensively by economists and yields operational decision rules for using resources if certain assumptions prevail (Section IV-A). For example, one must accept as given the distribution of income and wealth. Equity considerations deal with the distribution of income and wealth both across and between different generations of people. Since there is no scientifically meaningful way to compare the satisfaction levels of different individuals, economists cannot tell whether one income or consumption distribution is better than any other.* This is true not only for different individuals in one time period (what is usually referred to as "welfare economics") but also for individuals in different time periods (the intergenerational issue). Section IV-B examines the issues concerning intergenerational equity and suggests that saving fossil fuels may not benefit future generations even in terms of their own preferences.

A. COMMON ASSUMPTIONS OF ECONOMIC ANALYSIS

To gain a clear picture of the workings of the market system, economists usually make several assumptions which simplify the economic analysis with a minimal distortion of results. While the length of this list varies, the assumptions generally fall into four broad categories:

(1) Price-Taker Assumption: This assumes a large number of relatively mobile buyers and sellers for each product, so that an 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 added cost and additional 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.**

*For a discussion of the problems of making equity judgments between individuals or generations see Appendix A.

**Recent experimental work suggests that as little as 25 percent of the consumers being well informed in a given market is enough to lead to competitive results.

(3) Well-Defined Markets: Markets exist for all commodities; even those which are normally considered undesirable. This rules out externalities, which are persistent divergencies between private and social costs. An example would be a polluting firm which does not consider the damage inflicted on the surrounding community among its costs. Because the firms's costs are lower than the total social costs (including the pollution) a non-optimal amount (i.e., too much) of the firms's output is produced.

(4) The Income Distribution and Preference Patterns Remain the Same: The premise here is that the income profile does not change, either among members of the current population or at different time periods. This avoids irreversibility problems which are caused by changing tastes. (For example, future generations may decide that they prefer the scenic waterways that our generation has turned into electric power producers.)

The first three assumptions are called "efficiency" assumptions; by assuring the existence of a market, squeezing out undue profits, and assuming away risk, they guarantee that, with a given distribution of income and ownership, resources are allocated in the most efficient manner. By "efficient" economists mean that no one in the society can be made better off by shifting to some other level of production without hurting another member of the society.

Of course some people can be made better off at the expense of others. By removing the "given the distribution of income and ownership" caveat, we are brought to the realm of the fourth, or "equity", assumption. Instead of making the best use of a given resource distribution, as is done under the efficiency considerations, the equity assumption attempts to find the best resource distribution. 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, leaving a choice among income distributions to voters or legislators.

This distinction between equity and efficiency issues is readily apparent in the literature on allocation of depletable resources over time. Economists have had a great deal to say about the three efficiency criteria. Since non-renewable resource owners have substantial market power and are subject to many government regulations (such as favorable tax treatment, production controls, and import quotas), the assumption of a competitive market is not met. This creates a misallocation of resources; for example, Sweeny et al. (Ref. 1), found that the depletion allowance depresses current resource prices and increases present consumption at the expense of future users. In other words, in Figure 2-1 the incentives for that type of conservation are decreased since the supply curve shifts downward in response to production subsidies, resulting in lower costs of production and larger quantities supplied and demanded. Also, given a high degree of risk or uncertainty, resource depletion is biased toward the present. In effect, a risk premium is added to required rates of return on these projects, which reduces the value of any benefits far into the future. Society as a whole, on the other hand, would benefit if these decisions were made in terms of the expected values. From a societal point of view, risk tends to be neutralized by spreading the risk over the large number of individuals in society.

Finally, the third efficiency criterion requires that the existence of externalities (such as pollution) cause a non optimal amount of the resource (such as oil refining) to be developed. This is so because the full costs of production are not recognized by either the producer or buyer. If these costs were "internalized" the supply curve would shift up (as in Figure 2-1) resulting in fewer resources being consumed.

When there are a large number of residents subject to the externality with small costs to each, however, organization is expensive; no collective action is taken and the misallocation often persists (see Mishan (Ref. 2), for a full exposition of the post-war literature on externalities).

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. Current policy is moving toward making the private market for coal efficient. Subsidies in tax practices such as the depletion allowance have been removed. 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 an elastic demand* for coal must result in fewer coal resources being used.** Therefore, the message of this section is that we are moving toward a desirable level of conservation based solely on efficiency grounds.

The efficiency considerations summarized above have received much attention in the economic literature. Equity considerations, especially across time, have been studied much less. The next section explores some concepts concerning the allocation of natural resources among different generations.

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*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.

**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 2-3).

B. EQUITY CONSIDERATIONS

Using renewable energy sources now will presumably leave a larger stock of non-renewables for future generations. The issue is whether that is necessarily "good". A highly pertinent issue is, of course, "good" for whom? This paper takes the position that it is impossible to predict that leaving large stocks of non-renewable energy sources is necessarily better for future generations, even in terms of their own preferences. The basis for 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) generations of individuals leave a collection of legacies to future generations which are not all independent. Implicit throughout this section on equity is that conservation of type IV (Supply Constraint) is imposed.

The basis of the first point, concerning the value of "saved" non-renewable energy sources in the future, is simply that the possibility exists that they may have little or no value. As long as technological change is possible (and probable in this case) the possibility certainly exists that a major technical breakthrough could occur and significantly reduce the utility 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 one spreads the use of the stock of stored energy, the greater the probability that a social loss will occur through obsolescence of that energy form. Had the Egyptians decided to conserve blocks of granite for the use of future generations in building pyramids, the sentiment would have been appreciated, but there would have been little value in their conservation ethic. Looking to a similar period in the 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 energy form as yet unknown is developed inexpensively. The outcome would be socially wasteful, with this generation having been denied the use of cost-effective resources in order to save them for another, uncertain time. 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 than other energy forms, will descendents be grateful for the non-renewable energy we save? The answer to this rhetorical question is "perhaps" which 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 an infrastructure from which they can derive direct benefits and a stock of knowledge upon which they can build. In the longer-run, the former endowment must be

*Conservation is used here to mean saving resources beyond that implied by efficient private markets. An example of this type of conservation is a supply limit as illustrated in Figure 2-4.

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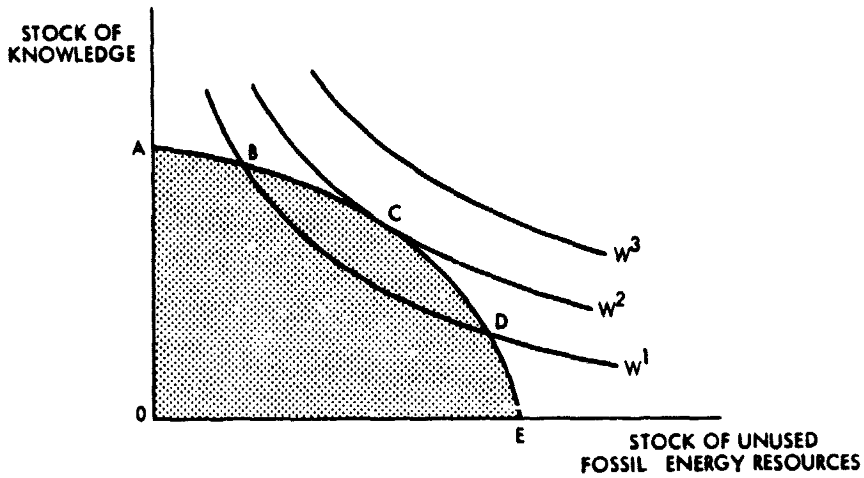

Figure 4-1. Trade-Off of Intergenerational Legacies

replaced, 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 4-1.

The shaded area (ABCDE) represents the feasible set of legacies which can be left as of some future date. The set is convex 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 large reduction in energy left for the future occurs between points C and B, while only a small increase in knowledge occurs. 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 intensive farming industry which is complementary to energy. Given this efficiency in food production, the remaining 95 percent of the workforce 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 availability of inexpensive energy, has been the diversion of resources to the production of knowledge. We have been able to move from point E along the frontier of the feasible set.*

*In reality we are probably somewhere inside the frontier, given the 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 they would like to achieve the highest level of well-being possible in terms of their own preferences. 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 (Figure 4-1). The problem is that we have no idea what their preference ordering (W) will indicate; it is dependent upon the substitutes for fossil fuel and the quality of knowledge we leave them. 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 little fossil fuels, is the best combination of legacies (Figure 4-2a). Of course, preferences which indicate the other extreme (points near E) are also possible.

In the latter case, fossil energy is extremely valuable. It takes large increases in the stock of knowledge (b) to compensate for even small reductions in the stock of fossil fuels. Would we, for instance, be happy to pay double the real cost of energy we pay now if earlier generations had also left us 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, the industrialization of the west has freed major human resources to pursue activities which are not tied directly to subsistence.

The essence of the arguments presented is that the concept of replacing non-renewable energy resources with renewable ones 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 of substitutes is crucial to the question of equity to future generations.

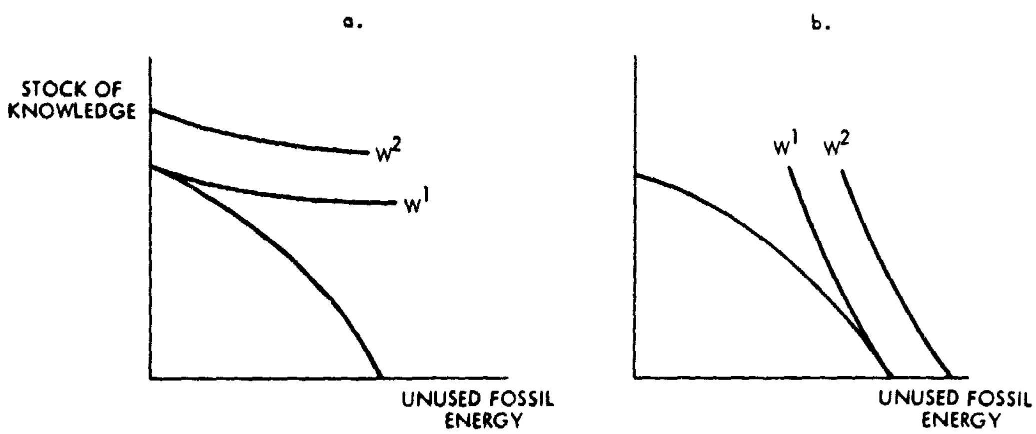

Figure 4-2. Intergenerational Legacies

There appears to be some consensus within the scientific community that renewable energy resources will be demonstrated to be able to provide virtually all of the United States' fossil-derived energy at a cost which is perhaps two-to-three times the projected cost of the fossil alternatives in the 2000 time period. Of course, some advocates are much more optimistic than this would indicate, and in some applications (e.g., water heating in the Southwest) they are probably justified. But even if the real cost is a factor of three more expensive in the long run, is it inhumane 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. 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. Such an effort may save fossil fuels, but these resource savings may not even be valuable to posterity.

SECTION V

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 useful observations and possible studies which would help lead to the 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.*

Precedents do exist for federal actions on intergenerational equity grounds. For example, much of the debate on nuclear waste concerns future generations, and park lands have been set aside in perpetuity for future enjoyment. However, there is the problem discussed earlier of whether future generations would benefit, in terms of their own preferences, if they were endowed with cheaper energy at the expense of infrastructure and knowledge.

Because of this uncertainty about the energy-knowledge combinations, it appears that posterity would not consider intergenerational equity as ample justification for starting 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; the existence of 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, thus it should be politically easier to enact efficiency changes. In this 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 is not well known. One negative aspect of this policy, however, is that a

*Paul Thomas, "Evaluation of Conservation Performance in Coal Systems by a Dynamic Model of Waste," unpublished working paper, JPL, January 1979.

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). Figure 5-1 shows the trade-off of deaths versus cost as curve 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 us to move along RR' within certain limits; no decrease in safety can lower cost beyond $\bar{C}$ and no expenditure on safety can reduce D below $\bar{D}$. Within this range there is a trade-off where 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). Thus far, we have reduced "advanced" to points beneath the RR' curve, but it can be bound further.

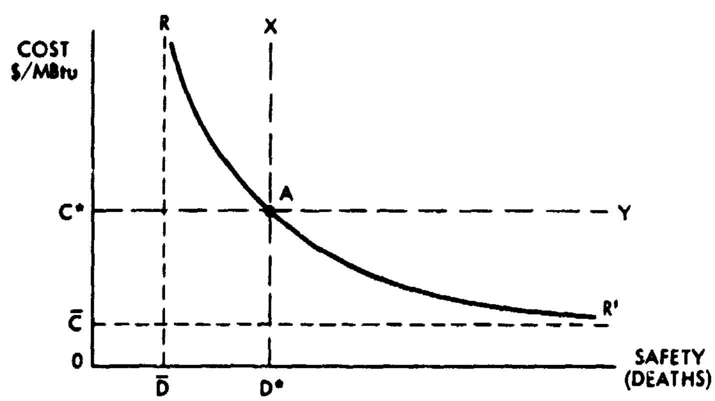

Figure 5-1. Cost-Safety Trade-Off

If one could derive society's indifference curve (locus of combinations of safety and cost among which sciety is equally satisfied) it would have the shape of $\tilde{C}A\tilde{D}$. 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 our 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 we have now. This is not completely intuitive: it suggests that advanced systems may have higher costs or less safety than is associated with existing techniques. The region C*AD* represents technologies where there is an increase in safety, but with no increase in extraction cost. Alternatively, the section of C*AD* from A to D* implies that no decrease in safety is justified no matter how large the cost reduction. Although both these outcomes are possible regulatory solutions, they may not be optimal from a societal viewpoint. 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 $\tilde{C}A\tilde{D}$ is preferable to point A, even though not all of these points represent combinations where both costs and deaths are reduced.

An accurate estimate of $\tilde{C}A\tilde{D}$ 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. To empirically

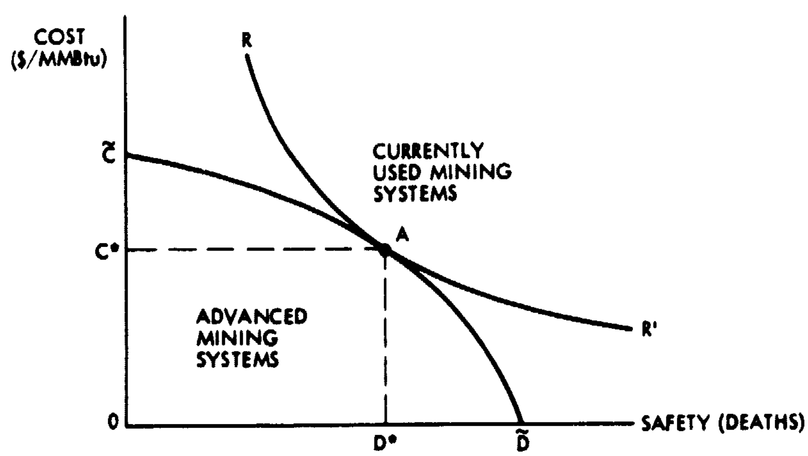

Figure 5-2. Advanced Coal Extraction Systems

estimate $\tilde{C}A\tilde{D}$ one would first need to determine 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 we are not on the verge of resolving this question with any precision, the next twenty years should give us 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. We have the capability of waiting this long for more information without using a major portion of the physical coal reserve. Acknowledging that both over-conservation and under-conservation involve cost to society, the danger of acting on limited information is very high.

In view of these considerations, 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 therefore be evaluated on the basis of cost, safety, and environmental considerations.

SECTION VI

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APPENDIX A

THE EQUITY LITERATURE

There have traditionally been two approaches to measuring a project's value. The most common measure has been Net Present Value (NPV) where projects are chosen to maximize the stream of benefits, discounted by an appropriate time rate (so that benefits in different periods are treated in the same fashion). This criterion has often been criticized as unfair to future generations on efficiency grounds: it does not adequately deal with intangible items such as pain and suffering; imperfect competition and government regulations cause the benefits stream to be over or under-estimated; the discount rate used is too high because risk and uncertainty is included, causing present estimates of benefits to be lower than they actually are; and externalities tip the balance toward present consumption. However, only a few authors have argued against the NPV criterion on equity grounds; some authors, such as Baumol (Ref. 1), Solow (Ref. 2), Arrow (Ref. 3), and Rawls (Ref. 4) have questioned the whole discounting procedure: Is it really true, as NPV implies, that future benefits are worth less than current ones?

The second approach to the problem, pioneered by John Ferejohn and Talbot Page (Refs. 5 and 6) has been called the Dominance Rule. Following the reasoning of Chakravarty (Ref. 7) they assume an infinite number of generations, since there is no satisfactory way to determine which generation is the last, and even if a final period is chosen, the analysis must continue ahead one more period in order to evaluate the terminal stock. Given an infinite time horizon, they propose four basic conditions that any social choice mechanism must satisfy if it is to reflect the preferences of the individuals within the society:

(1) Transitivity (T)--If project A is preferred to project B and project B is preferred to C, C cannot be preferred to A.

(2) Unanimity (U)--If everybody prefers project A to project B, the social choice mechanism should choose A over B.

(3) Independence of Irrelevant Alternatives (IIA)--The social preferences about projects A and B depend only on people's opinions about A and B, and not on their judgments of other alternatives.

(4) Nondictatorship (N)--Social choices are not controlled by one individual or one generation.

Hansson (Ref. 8) has shown that with an infinite time horizon there are an unlimited number of social choice patterns that satisfy all four conditions. These voting criteria all have the following ("dominance") property; if a finite number of generations prefer A to B and all other generations prefer B to A then the social choice mechanism chooses B over A. In other words, even if a thousand generations would benefit from a project, it should not be undertaken if all other generations oppose it.

Page and Ferejohn then compare this Dominance Rule to the net present value criterion, using a theoretical basis introduced by Koopmans (Ref. 9). Koopmans found a set of five axioms (see Page and Ferejohn, pp 10-12, for a discussion of these axioms) which allowed him to derive the mathematical formula for net present value. One of these is the Stationarity axiom, and it is intuitively interpreted as follows: If in the first time period two programs (A and B) are identical, but A is preferred to B because of subsequent benefits, then the social ordering will still rank A preferred to B after the first period is completed. This axiom plays a very important role in deriving the present value formula, but it is inconsistent with the assumptions made in the Dominance Principle. "Inconsistency" means that the axioms of the Dominance Principle and the Stationarity assumption cannot hold at the same time; if a social choice criteria has U, IIA, and Stationarity, then one of the generations (the first) must dictate what projects are undertaken.

This result has important implications for intertemporal equity: if a society makes welfare decisions based on "sensible" criteria (T, U, IIA) then the addition of the Stationarity axiom (which is a by-product of the discounting rule) requires the first generation to be a dictator. This is a disturbing conclusion; if social choice is to be consistent, it cannot be democratic. Using this result Page and Ferejohn suggest that discounting is unacceptable as a social choice rule on the grounds of intertemporal equity. They recommend that a search be started for "broader principles of social choice" which "incorporate ideas of intertemporal equity", rather than spending too much time searching for "the" appropriate discount rate or the "right" measure of costs and benefits.

However, the moral to be drawn from this research may not be as disturbing as it first appears to be. Some of the conditions for the Dominance Principles are more restrictive than they seem; these problems are discussed below.

One unappealing feature is the non-finite planning horizon. Some projects (disposal of nuclear wastes, greenhouse effects caused by fossil fuel combustion, ozone depletion, etc.) do have consequences far into the future; but even the planet this future scenario will occur on will not remain forever. And once the assumption of a non-finite time horizon is given up, the Dominance Principle also becomes dictatorial; all four of its criteria cannot be met by any social choice mechanism when the planning horizon is less than infinite.

Another source of criticism is the axioms themselves, particularly the third one (Independence of Irrelevant Alternatives). Very often the presence of other choices does affect decisions; IIA does not allow for this, or the possibility that strength of feelings may differ among individuals. For example, suppose opinion is split equally between citizens who believe that a billion dollars should be spent on aid to the elderly rather than pollution control, and citizens who believe the opposite. According to IIA, these two choices are "tied"; preferences for both programs are the same. But those who favor aid to the elderly may feel that this is the best possible use to which the funds can be put, whereas those who favor pollution control might find other uses of the money (such as public transportation or cancer research) more desirable. Also, people who favor aid may feel their alternative is much more desirable than pollution control, while those who advocate pollution control feel that it is only slightly better than aid. Given either possibility, a "reasonable" society might choose to use the money for aid to the elderly; IIA would view such a choice as irrational.

The Transitivity axiom can also be invalidated; the majority rule voting mechanism we use in the U.S. can be shown to violate transitivity in the following example:

	Projects		
Person	1st Choice	2nd Choice	3rd Choice
1	A	B	C
2	B	C	A
3	C	A	B

Suppose there are three projects: A. (busing in public schools) B. (no busing in public schools), and C. (no public schools). One person prefers "integrated" schools to segregated schools, and any school to no school. The second prefers "community control": public schools with no busing are the first choice, and no public schools at all are preferred to busing. The third person or group voted for Proposition 13; they prefer no schools at all but might prefer busing if there were schools. If the vote were between projects A and B, A would win, because the first and third voters prefer it; similarly, B would win over C, and C could win over A. But this choice pattern is not transitive; A is preferred to B, B is preferred to C, but C is preferred to A. Thus a "rational" set of individual preferences can upset the transitivity assumption.

Another criticism of the Dominance Principle is that it gives a list of choice (C and D are better than E but they are worse than A and B) rather than a single choice. Gibbard and Satterthwaite (Ref. 10) have replaced IIA with a different axiom, so that a single choice is made; but they still run into the problem of having the first generation dictate preferences. Much work is still being done in this area in an attempt to find a consistent choice mechanism.

So what is left? Page and Ferejohn have shown that NPV is not a very good choice rule, because it cannot meet a few basic preference criteria and still incorporate democratic choice procedures. This paper examined Page and Ferejohn's Dominance Rule criteria and found that they also contain many flaws. Must we stop using these choice rules because of the misgivings we have about them, or is there some middle ground available? What can we say about decisions that must be made now, which have their effects far into the future?

One possible compromise method of evaluating projects would be a "Partitioned" approach. The time horizon of a project would be divided into sections: the first five years, the next five years, the next twenty years, etc. Within these time segments the worth of a project would be evaluated by discounting, and would incorporate our best estimates of benefits, costs, risks, or changes in technology. As the time segments drift farther into the future, the weight given any discounting decreases; this reflects the larger uncertainty we have about the future's tastes and the technological means by which they will deal with problems. These project segments would be compared with the corresponding segments of alternatives. If a project benefits the current generation, but all the risks and costs are borne by future generations, this pattern of gains is made apparent by the Partitioning approach.

This method is an improvement over NPV because it adds some important additional information--who pays and who benefits. If two projets result in the same present benefits, they are indistinguishable under NPV. However, the Partitioning Rule enables individuals to differentiate between projects that benefit most generations to some extent, and projects that serve the present generation at posterity's expense. Under Partitioning, compensation to injured generations becomes possible; if the greatest costs for a project occur in the fiftieth through the seventieth years of operation, those generations which benefit might provide some form of recompense to the generations that are around in those two decades.

Partitioning also has advantages over the Dominance Principle. The partitions need not extend into infinity, although an infinite time horizon can be used. Partitioning also results in a unique choice of projects, rather than a list of possibilities. Finally, the method is understandable and easily used by contemporary decision makers.

An example of the controversy over intergenerational equity would be useful here. It is often argued that the development of nuclear energy is more unfair to the future than expanded coal usage, because radioactive waste disposal creates hazards that many hundreds of future generations must face, long after the benefits of increased energy production have been enjoyed by their forebears. This reasoning does not address several issues, which are discussed below.

One issue involves "long-term risks": Even if we develop incredibly safe storage areas for nuclear wastes, who can guarantee that some natural accident won't occur during the tens of thousands of years that waste is still dangerously radioactive? Since coal doesn't have such long-lived effects, why not scrap nuclear power in favor of coal? This statement fails to note that coal usage also has "long-term risks"; burning massive amounts of coal increases the amount of carbon dioxide in the air. Scientists are unsure whether this accumulating CO_2 will result in "greenhouse effects" that heat up the environment, or block out additional sunlight so that we are thrown into another Ice Age. In either case, there are dangers to increased coal usage; ignoring the long-term risks of coal, while focusing on those of nuclear technology, is arbitrary and short-sighted.

Another issue concerns present benefits: Why not leave nuclear wastes at the reactor site until we have a safe method of waste disposal? Since the present generation is reaping the gains from nuclear power, why not give it an incentive to provide safe disposal? This line of reasoning ignores the increased hazards to all generations; leaving nuclear wastes near the reactor site not only increases the possibility of leakage and health hazards, but it also runs greater risks of theft and terrorism.

Partitioning can address both issues. Underground storage is preferable to reactor site accumulation because it represents greater benefits (less theft and leakage) for all generations. Nuclear and coal usage options may be compared across time to see if one method benefits only a small number of generations. In addition, the method includes long-range risks (such as waste disposal and greenhouse effects) to future generations, at least to the extent that we can predict them. However, these later benefits or costs are discounted, because future events grow more uncertain with distance and we cannot know for sure what preferences posterity will have or what technological innovations they will have created to deal with these problems. The approach has an intuitive appeal; it gives the most weight to those time periods and issues we have the best grasp of, yet it also includes a measure of what effects those actions have on future generations.

In general, economists cannot say as much about equity issues as they can about efficiency arguments; it is difficult to compare the preference patterns of different individuals and different generations. However, a carefully prepared comparison of projects, using Partitioning Rules, can at least begin to explore the efficiency and equity considerations in projects which greatly effect the future and whose decisions must be undertaken now.

APPENDIX

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