ENVIRONMENTAL IMPACTS AND PUBLIC POLICY IMPLICATIONS OF INCREASED COAL USE

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Introduction

The United States has entered an extraordinarily dangerous period in its history. Its ability to survive as an advanced industrial nation has become dependent to an alarming degree on external and not particularly dependable resources. Although it has taken the better part of a decade to get the American people to recognize the nature of this danger, we appear to be on the verge of committing ourselves to significant measures to address our predicament. The increased use of coal, both in direct combustion (for electricity and process heat and steam) and as a source of synthetic premium fuels, clearly is going to be an important part of this commitment.

Part of this increase in coal use is now pretty much a "fait accompli". As of September, 1978, more than 150,000 megawatts of new coal-fired electric power capacity was either planned or under construction to be added to our present base of about 220,000 megawatts. Although some of these plants may be deferred or dropped altogether, electric utility annual coal consumption should increase by 1985 to at least 200 million (more probably 300 million) tons over the 1977 value of 475 million tons. Beyond 1985, a vigorous promotion of a synthetic fuel industry, further expansion of coal-fired electricity and greatly increased industrial use of coal and coal exports could drive coal production levels to as high as 2 billion tons per year by 2000, versus 689 million tons in 1977.

An increase of this magnitude cannot occur without a substantial consensus within American society about the desirability of using coal as the American "escape hatch" from energy dependence and shortages. And in turn, this consensus cannot be achieved unless the society believes that any damage to the environment resulting from the increased coal use will not be so great as to counterbalance the energy benefits the nation will derive. This discussion will focus on

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the nature of the environmental impacts that may occur and the problems that will arise — and that already exist — that complicate the formation of any consensus on coal use and the environment.

The Shape of the Future

An assessment of the impacts of increased coal development should begin with a prediction about the nature of the development foreseen, the regulatory climate in which it occurs, and the extent to which control technology and techniques have kept pace with deployment of new mining and energy conversion methods. Because this assessment will be rather broad and qualitative, the above factors will be dealt with fairly briefly.

As noted in the introduction, coal production levels conceivably could reach two billion tons per year by 2000 (versus 689 million tons in 1977) if coal were to become the centerpiece of U.S. energy policy. This level of production could be especially credible if electrification and synthetic fuels production were encouraged and if the coal export scenario proposed by the recently published report of the World Coal Study *(Coal-Bridge to the Future*, Caroll L. Wilson, et al., Ballinger Publishing Company, Cambridge, Massachusetts, 1980) was vigorously pursued.

This scenario envisions a massive worldwide trade in coal, with the U.S. a major exporter. The two billion ton level of production should be viewed, however, as something of an upper bound because of the multiple stumbling blocks of environmental opposition, serious weaknesses in our coal transportation infrastructure, the current slowdown in the rise of electric power demand, and other factors.

In bare bones fashion, a high coal future might be characterized by:

- Expansion of mining in all producing regions, especially underground mining in Appalachia, the Midwest and the West, and surface mining in the West.
- Significant coal exports to Europe, Japan, and Asia.
- Widespread industry use of coal, probably in fluidized bed boilers.
- Startup of a large synthetic fuels industry.
- Conversion or shutdown of most oil and gas-burning powerplants.
- Electrification of much space-heating, some industry, possibly some transportation.

Although it is impossible to forecast the regulatory climate that would accompany such a shift to coal, it seems likely that some sort of expediting authority for environmental permits would accompany the rapid buildup needed. It is highly uncertain whether any substantial relaxation of environmental standards might occur. There certainly is sentiment in some quarters for such a relaxation, and a worsening of the oil supply/price squeeze could add to this sentiment. On the other hand, it is also quite evident that the American public places a very high value on environmental quality, and any attempt to lighten the coal industry's burden of regulation is more likely to appear as a federal-to-state shift of responsibility (to take advantage of the pro-development sympathies of many coal states) than as an outright weakening of standards.

Finally, it is quite possible that the rapid pace of development will outstrip control technology in two areas — in the control of effluents from synthetic fuel plants, and in the reclamation of Western surface mines.

Impacts and Issues

If coal does stage the comeback that has been forecast, it will return to prominence in a manner vastly different from the way it dominated national energy use in the past. The availability of pollution controls, better combustion techniques, and new mining methods, coupled with enforcement of a wide range of environmental protection requirements, should prevent a repetition of much of the environmental degradation — soot-laden cities, scarred landscapes, ruined and discolored streams — that accompanied coal development in the past. However, despite the laws and new equipment and techniques, large-scale coal development may still be accompanied by substantial environmental impacts. Some of these impacts could result from inadequacies in the enforcement of the laws or in the environmental controls.

Other impacts may result from the failure to regulate a damaging pollutant or to specify an adequate level of protection from a regulated pollutant. These kinds of failures usually result from inadequate knowledge: the inability to recognize a subtle but important impact, to connect a known impact to its correct source, or to determine properly the quantitative relationship between impact and source.

Air Quality

The most controversial — and most expensive to control — area of environmental impact from coal development is air pollution. Despite the air quality standards and emission limitations promulgated under the federal Clean Air Act, air pollution problems are likely to remain a major issue associated with continued coal development. There are a number of reasons for this:

1. The current regulatory framework does not appropriately account for the long distance effects of pollution. The National Ambient Air Quality Standards, and the State Implementation

Plans that enforce them, focus on maintaining air quality within local regions. They tend to reward controls — like tall stacks — that diffuse pollution and minimize local air quality. Thus, many large sources of air pollution have lenient control requirements because their local impact is small. An excellent example of this is the several large power plants in the Ohio River Basin that burn high sulfur coal with no controls, yet are in compliance with their local control requirements — despite the fact that these plants are strongly implicated in degradation of air quality and production of acid rain in the Northeast. Other provisions of the Clean Air Act, such as the Prevention of Significant Deterioration regulations, are limited in effectiveness by our currently inadequate capabilities for modeling the effects of long-range transport of pollution.

2. Current standards may be focusing on the wrong pollutants and are not addressing suspected problem pollutants such as fine particulates, sulfates and nitrates, etc. A primary cause of this shortcoming is the inadequacy of our current understanding — and base of sound evidence — concerning actual pollutant health and ecological impacts.

3. National emission standards for new plants are limited by the availability of adequate controls. The current lack of efficient controls for nitrogen oxides, for example, means that a substantial increase in coal use will lead to significant increases in NO_x emissions unless new controls are developed.

If there are no major new breakthroughs in air pollution control technology and no significant changes in control regulations, a large scale increase in coal-fired electric generation will cause significant increases in national emissions of nitrogen oxides and fine particulates and a gradual increase in sulfur emissions. The development of a synthetic fuel industry may add other pollutants, especially hydrocarbons, to previously clean airsheds. But the level of uncertainty surrounding the impacts of these plants is very high.

The health and ecological consequences of the above emissions changes remain a subject of considerable controversy because of the tentative quality of much of the evidence. The nature of this controversy provides an excellent example of the "What constitutes proof?" problem discussed later.

The major ecological problem expected from increased nitrogen and sulfur oxide emissions is an increase in the acidity of rainfall and subsequent damage to aquatic habitats (as well as man-made materials) and possible damage to forests and agricultural crops. Pollution-caused acidity in rainfall is caused by the oxidation of sulfur and nitrogen oxides into sulfate and nitrate aerosols. When these are scrubbed from the air by rain, the raindrops become a dilute mixutre of sulfuric and nitric acids.

Each link in the acid rain chain between "increased emissions from power plants" to "disappearance of fish from susceptible lakes" has been challenged. For example, while scientists like Gene Likens of Cornell will state unequivocably (for example, in his Scientific American article of October, 1979, Volume 241, No. 4) that the acidity of rain and snow has increased sharply in recent decades, others such as Ralph Perhac of the Electric Power Research Institute point to the poor data base to deny that a sound basis for such a statement exists.

Similar disagreements exist about the relationship between emissions in one region and acid rain in another; about the extent to which reductions in emissions will result in reduced levels of acidity; and the extent to which acid rain is the actual cause of the observed changes in aquatic environments. However, in the opinion of the author, the weight of evidence indicates that the likely result of increased coal development and nitrogen and sulfur oxide emissions will be an increase in both rainfall acidity and actual environmental damages.

Even greater controversy surrounds the possible health effects of increased emissions from coal development. The major suspected culprits are the sulfate products of sulfur oxide emissions and, possibly, the directly emitted fine particulates (particulates of less than about 3 microns in size, containing disproportionately high levels of toxins adsorbed on their surfaces, and capable of being inhaled deeply into the lungs) that are not efficiently controlled by most existing control systems.

A series of epidemiologic analyses of the relationship between mortality rates and air pollution in several American cities has linked current levels of sulfate and fine particulate concentrations to tens of thousands of premature deaths yearly in this country. These analyses suffer from problems with poorly measured pollution exposures, multiple pollutants that may interfere or act synergistically with each other, and inadequate data on those population characteristics that might affect the death rate.

A recent study by scientists from the Harvard School of Public Health (reported in *The Direct Use of Coal*, Office of Technology Assessment, 1979) concludes that these problems are not sufficient evidence to reject these analyses, however. It remains a distinct possibility that existing levels of coal-related air pollution are causing significant numbers of deaths and that increased development may add to this burden.

An additional impact of increased sulfate and fine particulate pollution — an especially serious one in the Western "Big Sky" country — is degradation of visibility. Although preservation of visibility is an explicit objective of the Clean Air Act Amendments of 1977, poor modeling capabilities as well as strong development pressures will make degradation of visibility difficult to prevent.

Finally, the greatest long-term danger from an increase in the use of coal and other fossil fuels may come, not from the pollutants discussed above, but from carbon dioxide, which at current and expected ambient levels displays no direct or immediate adverse impacts on human health or on the biota. Fossil fuel combustion over the past century appears to be a major cause of increasing concentrations of CO_2 in the earth's atmosphere (deforestation may be another cause); CO_2 levels have increased 5 percent since 1958 alone. Some predictions show CO_2 concentrations as doubling by the middle of the next century.

This could present a substantial risk of significant climatic change, because CO_2 in the earth's atmosphere has a "greenhouse effect," allowing incoming sunlight to warm the Earth's surface but trapping outgoing heat radiation. Effects of such a climate change, if it occurred, could include massive shifts in the productivity of farmlands as well as partial melting of the polar icecaps and flooding of coastal cities. Current gaps in our understanding of how climate is regulated and how CO_2 is cycled between its sources and reservoirs leave this issue surrounded by considerable uncertainty. However, the problem is widely perceived by the scientific community as a serious one.

Land and Water Quality

In the past, coal development in general, and mining in particular, were often devastating to both land and water ecosystems. The major damage from mining was caused by the acid drainage from both underground and surface mines, the lack of adequate restoration of surface-mined land, and the subsidence of lands overlying underground mines. Ecological damage also resulted from the heating of surface waters by powerplant cooling systems and improper disposal of waste materials.

All of these impacts are now addressed by federal legislation. As a result, some problems — in particular, acid mine drainage from large active mines, and powerplant thermal pollution — have been virtually eliminated as significant problems for future development. All of the others have been reduced, although substantive problems of enforcement and/or availability of effective controls remain. Also, some new problems may result from the regional shift of coal production to areas where little experience can guide new operations, from the generation of waste products from air pollution control measures, and from the waste products of new processes, especially synthetic fuel processing.

Approximately 60 percent of national coal production comes from surface mines. The proportion will not rise much. The use of new mining methods that integrate reclamation into the mining process and enforcement of the Surface Mine Control and Reclamation

Act (SMCRA) should reduce the importance of reclamation as a critical national issue. However, concern remains that the combination of development pressures and inadequate knowledge may lead to damage in particularly vulnerable areas — alluvial valley floors in the West, prime farmland in the Midwest, and hardwood forests, steep slope areas, and flood-prone basins in Appalachia. Although most of these areas are afforded special protection under SMCRA, the extent of any damage will depend on the adequacy of enforcement of the new strip-mining legislation.

Areas of Appalachia whose economies strongly depend on coal mining have placed strong pressures on Congress to give them relief from stringent federal enforcement, and in some cases have looked with sympathy on attempts to circumvent the regulations. Also, some doubts still remain about the long term success of some Western reclamation, and large scale mining in this region must be watched carefully.

Assuming strong regulatory enforcement, no major problems with acid mine drainage from active surface and underground mines should result from increased coal development. However, inactive mines may still present some technical control problems. Although a small percentage of active surface mines may suffer from acid seepage, problems with underground mines should be the primary problem. Despite a long history of federal and state efforts aimed at controlling acid drainage from inactive underground mines, some mining situations do not allow adequate permanent control once active mining and water treatment cease.

A significant percentage of the mines that are active at present, or that will be opened in this century, will present acid drainage problems on closure. This problem may taper off as shallower reserves are exhausted and new mines begin to exploit coal seams that are deeper than the water table. Many of these mines will be flooded, allowing the seams to be shut off from the oxidation that creates the acid drainage.

Another impact of underground mining that will not be fully controlled is subsidence of the land above the mine workings. Unfortunately, there are no credible estimates of potential subsidence damage from future underground mining. Subsidence, like acid drainage, is a long-term problem. However, SMCRA does not hold the developers responsible for sufficient time periods to ensure elimination of the problem, nor does it specifically hold the developer responsible to the surface owner for subsidence damage.

The major "control" for subsidence is to leave a large part of the coal resources — up to 50 percent or more — in place to act as a roof support. There is obviously a conflict between subsidence prevention and removal of the maximum amount of coal. Moreover, the supports can erode and the roof collapse over a long period of time. The resulting intermittent subsidence can destroy the value of the land for development.

Although all types of mining have the potential to severely impact ground water quantity and quality by physical disruption of aquifers and by leaching or seepage into them, this problem is imperfectly understood. The shift of production to the West, where groundwater is a particularly critical resource, will focus increased attention on this impact. As with other sensitive areas, SMCRA affords special protection to groundwater resources, but the adequacy of this protection depends on the state of knowledge about the problem and on the level of enforcement. The law is likely to be severely tried if mining is combined with various *in situ* conversion methods for coal gasification or oil shale; these methods may severely impact ground water quality.

The proliferation of new coal conversion facilities is likely to create problems both with water quantity and quality. All conversion facilities consume large quantities of water: coal fired powerplants, between 20,000 and 30,000 acre-feet per year for a 3000 MW plant; a water-efficient Lurgi gasification plant, 3000-6000 acre-feet per year for a 250 million cubic feet per day plant; a 50,000 barrel per day Synthoil plant may consume 5000-6000 acre-feet per year (Gold, Harris, et al., *Water Requirements for Steam-Electric Power Generation and Synthetic Fuel Plants in the Western United States*, EPA-600/7-77-037, April, 1977). If a number of these plants are built in the arid portions of the West, their water requirements could aggravate existing water problems in several river basins — for example, in the Upper Colorado and Yellowstone Basins.

The major potential water quality problems from conversion facilities arise from their need to dispose of large quantities of moderately toxic wastes and, in the case of synfuels plants, of smaller quantities of dangerous, possibly carcinogenic wastes. Coal-fired powerplants, for example, will need to dispose of huge quantities of ash and scrubber sludge, both of which pose problems of leaching to groundwater. Coal liquefication processes liberate a variety of toxic substances — such as biphenyls — from coal, and these inevitably appear in effluent streams. As noted above, the *in situ* gasification processes also offer serious threats to groundwater quality. The Resource Conservation and Recovery Act (RCRA) contains important controls on the disposal of hazardous materials, but RCRA may be difficult to enforce and strong pressures are being brought to bear on EPA to limit its application of RCRA's strongest provisions.

Other Impacts

A variety of other impacts, including a rise in occupational health problems, coal transportation problems, secondary development effects, and possible hazards from the handling and use of synthetic fuels will accompany large-scale coal development. Although these problems will not be dealt with in detail here, a few highlights may illuminate their nature.

- Although great strides have been made in reducing the dangers of coal mining, high risks of accidents and lung disease remain, especially in underground mining. Large increases in Eastern underground mining caused by coal conversions as well as a burgeoning synfuels industry will pose difficult occupational health problems. Also, there is a significant possibility that occupational exposures to cancer-causing materials will create continual housekeeping problems at synthetic fuels plants.

- Long distance transportation of coal — for example, from the Northern Great Plains to the Midwest (or to the West Coast for export) — will create extremely heavy traffic flows on main lines that will disrupt towns through which these lines pass. One likely outcome will be a significant increase in crossing accidents.

- Synthetic fuels from oil shale and coal are not perfect substitutes for crude oil or refined products. Initial tests of these fuels indicate that they may pose substantially increased cancer hazards to the fuel users — the general public. The ability of refinery processes to eliminate this hazard is currently uncertain.

- Studies of Western coal development have consistently indicated that the ecological effects of the secondary development that accompanies the energy development — the great influx of construction and operating workers, families, support personnel, etc. — are likely to be as significant as the direct ecological effects. These secondary effects stem from the greatly increased hunting and other recreational pressure, urban sprawl, inadequate sewage treatment, and other adverse conditions that almost always accompany rapid, large scale development.

The Difficulties of Achieving Consensus

As noted in the introduction, little of this coal development is likely to take place unless some broad consensus can be reached about the tradeoffs to be made between development and environment. One possibility for achieving such a consensus is a disastrous energy crisis that simply eliminates most environmental concerns as a significant factor. A more rational approach would require some true balancing of costs and benefits. As can be seen by the rather uncertain picture of expected impacts drawn above, there are going to be some real difficulties in achieving a consensus by this means.

There are three reasons why a consensus will be hard to reach. First, there is no agreement in the scientific community — and there cannot be an agreement at the present time — about the precise nature of the environmental impacts that will flow from increased coal use. (This is why the above description of impacts is so fuzzy.) Although decades of research and many millions of dollars have been poured into research on these effects, major uncertainties still exist.

These uncertainties arise from a variety of causes: many of the technologies that will be employed have yet to be built in sufficient scale to measure impacts; critical environmental processes such as long range transport and transformation of air pollutants are not now well understood; the impacts of the mining portion of the fuel cycle are critically dependent on the behavior of the mining companies and the efficiency of government surveillance, rather than primarily on technology, and these are basically unpredictable; and many of the impacts are very site-specific and therefore critically dependent on future market decisions.

Achieving a *scientific* consensus is made more difficult by the lack of any basic agreement about what constitutes "proof" in an environmental assessment. Biological systems — the "receptors" of the chemical effluents and physical forces generated by the coal fuel cycle — respond stochastically, or probabilistically, to external forces...in other words, the impacts of pollutants on single organisms must be described in terms of statistical probabilities, and an understanding of environmental processes can be gained only by taking multiple measurements and evaluating them statistically.

For a variety of reasons — ranging from the complexity of the systems being measured to poorly conceived research designs — environmental measurements rarely offer the levels of statistical certainty that most physical scientists are comfortable with. As a consequence of the ambiguous nature of much environmental data, many environmental relationships that are generally accepted as "proven" by one segment of the scientific community are rejected by another segment. The link between coal-fired powerplants, acid rain, and acidification of mountain lakes is such a relationship. A more widely known relationship of this sort is the link between smoking and lung cancer, especially as it was understood a decade or so ago.

The second difficulty is the failure of the scientific community and the information media to successfully communicate what is known about coal impacts to the public. The amount of misinformation in the news media about physical impacts as well as control capabilities and costs is at times quite breathtaking. The public is continually being told that acid rain is known to be destroying forests and agricultural crops (e.g., the New York Times Business Section, July 20, 1980), that SO_2 scrubbers never work but that if they did they would bury us in sludge, that coal smoke is known to kill 100,000 people each year, etc. etc.

Our news media are not giving us a consistent and sophisticated view of what is and is not known about the coal fuel cycle, and our scientists are not combating media misinformation. Added to this misinformation is the confusion generated by the staggering amount of information — in wildly varying units using different scenarios of future development, assuming different regulations and industry response to that regulation — with which the public is bombarded.

The third difficulty is that an agreement on the nature of the physical impacts — if this could be achieved — would be an insufficient basis upon which to reach a consensus because people place such drastically different values both on the economic amenities to be gained from increasing coal use and on the environmental amenities that would be lost. So many of the important policy disputes existing in American life today have as their basis these fundamental disagreements about values that it seems unnecessary to describe this problem in further detail.

Policy Implications

Large-scale coal development is going to entail some very substantial risks to the environment. There are significant disagreements among scientists about the nature and extent of the risks. In some cases where there is agreement, the agreement is only about how limited our state of knowledge is. In many cases, the public does not understand what the scientific community is saying, and in some cases, the public doesn't trust what they are saying. And in any case, people's perceptions and values would be wildly variable even if their understanding of objective reality was uniform. What do we do to escape paralysis in the face of all this?

I have never encountered any sweeping solutions to this set of problems. Instead, they have to be nibbled at until they are gnawed down to manageable size. The following is a list of options that may be worth discussing. They are not recommendations. They focus on problems of air quality in the interests of brevity and because this certainly is the area of greatest concern.

1. *Stamp out misinformation.*

It would be a big step forward if the public — or at least the interested part of the public — were arguing about the same set of technical issues that the science community was. It would help, for example, if the public knew that coal-related air pollution might be killing thousands of people, that acid rain might be affecting forests, and that CO_2 might eventually cause a warming of the earth. In the same vein, but from the opposite perspective, it would be nice for the public to understand that satisfying local air quality standards does not guarantee that no further damage is being done. There are a lot of mechanisms for improving the public debate about coal. These include: better science teaching; availability of qualified, syndicated science writers to improve the quality of science reporting in small newspapers; cooperation between local colleges and newspapers (and other media) to improve their science reporting, or simply to provide a means to review such reporting; widespread distribution of state-of-the-art reviews (extensively reviewed for objectivity and expertly written for clarity) of controversial science issues by organizations such as the Office of Technology Assessment; and a host of others.

2. *Use flexible means to reduce emissions from existing coal-fired plants.*

An important reason why an expansion of coal use provokes so much worry is that the emissions from new coal conversion facilities — although held to low levels dictated by the national New Source Performance Standards — will be piggy-backed on top of the very substantial level of emissions from existing coal-fired powerplants. As noted previously, many of these older plants are not controlled despite their apparent contribution to long range pollution problems. Forcing these plants to comply with the national standards would be very expensive (retrofitting scrubbers can be two or more times as expensive as incorporating them as part of the original plant design). However, a flexible policy of requiring emission reductions, using low sulfur coal, coal washing and partial scrubbing, and based on site specific examinations of the cost and effectiveness of the alternatives and the plants' contribution to pollution problems, could lead to a substantial lessening of the overall impact of coal development. An emissions tax might be a method to achieve such a flexible control approach without extensive federal interference.

3. *Accelerate the EPA NO_x control program.*

Nitrogen oxides are the only "criteria pollutant" (air pollutant officially controlled by national ambient standards) expected to increase substantially by the year 2000. This increase appears likely to aggravate problems of acid rain as well as oxidant formation.

EPA has a moderate-sized research program aiming primarily at controlling NO_x during combustion. This program may be deserving of a rise in status to highest priority and a substantial increase in funding and manpower. Full commercialization and deployment of low NO_x burner technology and other controls at an early date can sharply reduce the projected levels of NO_x emission.

4. *Set national emission and/or ambient standards for fine particulates.*

Emissions of the smaller — and more dangerous — particles under 3 microns are likely to increase with an acceleration of coal burning. EPA has been reluctant to promulgate standards on fine particulates because the evidence concerning health and ecological damages is inadequate. However, the known physical properties of these particles may be considered by many to be justification for their explicit control. If EPA were to set emission standards, new coal-fired plants would almost certainly install baghouse controls to comply.

5. *Reduce infrastructure/investment decisions that lock society into coal-based synfuels and other coal use.*

The U.S. — and the world — is faced with the competing requirements of increasing its ability to use coal while maintaining the ability to rapidly reduce fossil fuel use if the postulated relationship between such use and climate warming from increased levels of atmospheric CO_2 is proven to be correct.

Concern over CO_2 emissions and possible climatic effects add to arguments that energy conservation and non-fossil energy production — including nuclear energy — should be of higher priority than expansion of coal use. It is arguable, however, whether sufficient proof of climate effects will be forthcoming in the next decade or two, and expensive decisions based on risk avoidence only may not be forthcoming. It may be possible, however, to direct coal development in ways that will reduce the eventual cost of retooling the energy system if this becomes necessary.

There are complex tradeoffs to be made in the design of any development plan that seeks to minimize the future cost of switching from fossil fuels while maintaining high efficiency of current fossil fuel use. For example, a stress on electricity production and use in transportation may be warranted because electricity can be produced from nuclear (including, eventually, fusion) and solar energy while gasoline and other fuels cannot. However, the effect of such a strategy on current overall use of coal must be examined lest we accelerate coal use now in order to be able to reduce it later. A less problematical action might be to stress coal conversion processes that produce methanol, because large quantities of methanol can alternatively be produced from our wood resources (see *Energy from Biological Processes*, Office of Technology Assessment, 1980).

Except for the first option, all of these options share the common characteristic that they represent risk avoidance rather than damage avoidance...that is, most of the impacts that they strive to reduce or avoid are not well-proven. This is not surprising, because the U.S. has a comprehensive set of environmental legislation that, at the least, deals with most of the proven impacts of coal development (or at least those impacts where a good case for cause-and-effect can be made). These options, then, reflect the nature of major policy problems facing coal development — what is an acceptable risk, and how much money are we willing to spend to reduce risks?