THE POTENTIAL NEED FOR FUSION IN THE U.S. ENERGY SYSTEM

E. BEARDSWORTH AND J. POWELL

September 1977

DEPARTMENT OF NUCLEAR ENERGY

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ABSTRACT

For fusion to become available for commercial use in the 21st century, R & D must be undertaken now. But it is hard to justify these expenditures with a "cost/benefit" oriented assessment methodology, because of both the timeframe and the uncertainty of the future benefits. Focusing on the factors most relevant for current consideration of fusion's commercial prospects, i.e., consumption levels and the outcomes for fission, solar, and coal, many possible futures of the U.S. energy system are posited and analyzed under various assumptions about costs. The "Reference Energy System" approach was modified to establish both an appropriate degree of detail and explicit time dependence, and a computer code used to organize the relevant data and to perform calculations of system cost (annual and discounted present value), resource use, and residuals that are implied by the consumptions levels and technology mix in each scenario. Not unreasonable scenarios indicate benefits in the form of direct cost savings, which may well exceed R & D costs, which could be attributed to the implementation of fusion.

PREFACE

This study was undertaken to examine how and what degree fusion might be expected to contribute to the future of the U.S. energy system. We live in a highly complex and uncertain world--a fact more pervasive and significant than is usually acknowledged in much modeling and assessment activity. To know what happened last year is hard enough. To know what will happen fifty or one-hundred years into the future is clearly impossible. The initial phase of our work was centered on establishing an approach and methodology: to develop a framework that would organize any quantification that might be undertaken, and to focus it on issues that could be meaningfully addressed.

The long time scale involved and its attendant high degree of uncertainty became the dominant consideration as each of several existing energy models were considered. Among others, these included the Brookhaven linear programming models BESOM and DESOM and the Institute for Energy Analysis (IEA) Energy Simulation Model. It was decided to develop an accounting model approach which would keep the highly explicit and aggregated features of the IEA work, while overcoming the artificiality of its supply-demand matching procedure. At the same time, economics was also incorporated, though not to the extent of the normative cost-optimization approach of the linear program models.

In earlier work, the static model BESOM had been used to study the impact of district heating applications on fusion implementation. The present study began as a follow-on to that effort, with the recognition that time dependence should be explicitly incorporated, and that a simpler model of the energy system would probably be appropriate.

The Reference Energy System description of energy flows provided an excellent point of departure for the development of an interactive computer program,

a subtask whose successful completion relied totally on the quick and imaginative programming of Gary Goldstein and innumerable insights from Ellen Cherniavsky.

The major variables relevant to fusion were quickly identified--total demand, and the extent and costs of alternative resources. To investigate each of these, the expertise of the National Center for Analysis of Energy Systems (NCAES) was relied upon heavily--Morris Beller, Chaim Braun, and Doug Gunwaldsen were most helpful in discussions about each of the major supply sectors and their respective possible implementation schedules.

At the urging of Ron Kostoff (ERDA), the concept of a "Cost/Benefit" analysis was introduced into the study, beginning with an examination of the state of the art to evaluate its applicability to fusion. If the study was to make a useful contribution in the area of R & D budget priority evaluation, it would have to consider commonly used parlance and concepts at least as a point of departure.

Suggestions from Ken Hoffman were helpful in examining issues of Cost/Benefit analysis. Very helpful and thorough critiques of an earlier draft were done by Dave Behling, Morris Beller, and Ron Kostoff.

Absolutely vital to the entire effort was Pam Walton's cheerful and prompt typing of the far too numerous revisions and additions, and Stan Majeski and Metzi Rappold's attention to the figures and drawings.

SUMMARY AND CONCLUSIONS

This study was undertaken to explore the potential role fusion might play in the future U.S. energy system, especially as interpreted through a Cost/Benefit Analysis, and as it might bear on current R & D decisions.

Purposes of the Study

- . To determine the conditions under which fusion could contribute significantly to long range U.S. energy needs, and
- . To apply Cost/Benefit Analysis so as to examine its suitability, limitations, and relevance to the case of fusion.

Approach

To evaluate the potential role of fusion by:

- . Developing a perspective on the issues that can be meaningfully addressed,
- . Developing a methodological framework which sufficiently and appropriately characterizes the U.S. energy system,
- . Identifying the key factors that will bear on the need for fusion,
- . Identifying which quantitative assumptions about the future of energy result in a finding that benefits are indeed attributable to fusion, and
- . Making explicit the consequences imbedded in those assumptions.

Conclusions

- . This study demonstrates the extreme sensitivity of Cost/Benefit Analysis to input assumptions which, because of the time scale of fusion, must be highly arbitrary. The applicability of Cost/Benefit to fusion is therefore questionable.
- . Nevertheless, not unreasonable scenario comparisons, with and without fusion, indicate benefits in the form of direct cost savings which could substantially exceed the projected costs of R & D (depending on the choice

of discount rate); this without an accounting of externalities--the benefits of avoiding pollution and nuclear proliferation, as well as the benefit of the availability of energy itself.

- . Simple arithmetic and common sense provide powerful constraints on allowable or reasonable projections of future total energy use and combinations of energy supply. However, the parameter space of possible energy futures remains large.
- . By mapping out parts of that space, some of the factors critical to the need for fusion have been explored:
 1. the future behavior of total energy consumption, and
 2. the future availability and cost of alternative supplies.
- . In certain regions of that space, significant benefits are attributable to fusion.

The potential benefits of a commercial fusion program are enhanced in a world where: 1) total demand continues to grow, and/or 2) where alternative resources are limited or costly:

- . If imports are restricted,
- . If coal use cannot increase greatly (because of limitations on production capacity, increasing costs, or environmental effects),
- . If fission is not to be greatly expanded and developed in a form which can make more complete use of the resource,
- . If central station solar cannot be made reliable and economic,
- . If the choice of discount rate is not too high, and
- . If fusion can be available earlier and quickly implemented, regardless of initial cost.

An extreme in any of these factors, or any combination of them to a lesser degree indicates the necessity and desirability of substantial reliance on fusion energy in the twenty-first century.

Particulars of the Study

Projections were developed for each of the major supply sectors over the next 100 years, incorporating assumptions regarding possible technical and policy developments for each resource. Levels of total energy consumption were fixed by assumption, distinguishing two cases in the near-term (HIGH and LOW) based on detailed demand analysis, and two cases in the long-term (HIGH and ZEG) based on possible trends. The zero growth cases level off at 115 and 180 Quad respectively, with the high cases reaching 240 to 300 Quad by the year 2075. Scenarios were developed for each total consumption case using various combinations of the different supply projections.

The "Reference Energy System" concept was modified to incorporate a greater degree of aggregation and explicit time dependence, and a computer code was developed to organize the relevant data, to permit interactive user modification of scenarios, and to perform calculations of system costs, resource depletion, and environmental effects. Total annual system cost was calculated in each of the 100 years, based on cost figures which were estimated for the various fuels and capital equipment. Calculations were also done of the cumulative discounted present value using different discount rates and starting dates.

Basic trade-offs among resources were studied, and some sensitivity analyses were done on coal cost, fusion introduction date, and fusion capital cost:

- . Fusion is absolutely required to meet even modest energy demand, in cases involving less optimistic assumptions about alternatives.

- . Very high initial fusion plant capital costs can be tolerated on a system-wide basis, with widescale implementation of fusion to follow only as the ensuing learning curve brings the capital costs down.
- . Early introduction of fusion considerably enhances its cost/benefit picture.

The cases which indicate the greatest relative benefits of fusion (i.e., the difference between the total system cost of two scenarios with and without fusion) are those involving high reliance on coal and high costs for coal. In these cases the use of fusion to replace a major portion of the coal use results in systems savings which can reach a level of \$200 to 500 billion/year out of total annual cost of \$700 to 1100 billion/year. For assumptions leading to lower relative benefits, it must be remembered that only direct costs have been considered. Decisions are more likely to be made on the basis of the less quantifiable externality issues such as health, safety, and the environment. For example, society may make a political (noneconomic) decision against plutonium, or a health decision against expanded coal usage.

Future work should focus on developing alternative methodologies to deal with the question of present society's responsibility for future generations, and help in the decisions which allocate current RD & D expenditures. For example, the range of energy, supply, demand, and cost projections might be handled with a probabilistic approach, as an advance over the use of deterministic single-valued scenarios whose relative likelihood of occurrence can only be implicitly considered. Uncertainty is a key issue--it is one of the reasons discounting is used, and at the same time the reason why a more complex treatment is needed. Keeping energy options open involves the expenditure of resources and the bearing of risk, where the possibility of failure must be weighed against the possibility of immense value if not critical necessity.

Chapter 1

INTRODUCTION

A. Background and Purposes

Fusion energy is released when certain light atomic nuclei undergo nuclear reactions to form heavier elements. For such reactions to occur, extraordinary conditions of temperature and pressure are required, which so far have occurred only in stars and in thermonuclear devices (the hydrogen bomb). The goal of the fusion R & D program is to create such conditions in a reactor, suitable for the generation of useful energy. The relevant physics and engineering for such devices have been widely examined.^{1,2} This study, however, examines the role fusion might play in the U.S. energy system from the standpoint of economics, environment, and resources.³

Fusion R & D is public business because the uncertainty of success, the time scale, and the financial requirements of fusion development prevent the private sector from undertaking it fully. Thus, fusion will require public funding and significant physical and social resources for its development. For these expenditures to be justified over the claims of all the many competing

and urgent problems and programs, fusion must hold some promise of meeting the demonstrable future needs or desires of society in a technically and economically practical manner. Also, our society has begun to learn to evaluate what use will be made of any new technology, and fusion is no exception.

The questions underlying this work are these: On what basis can fusion R & D be justified? Will fusion be needed, or be able to make an important contribution to future energy needs? Will its benefits, in the usual terminology, outweigh its costs?

B. Approach

The central question addressed in this study is somewhat narrower: to identify and analyze the quantitative assumptions about the future of society and energy which relate to judgments about the necessity or desirability of fusion. A corollary concern is the justification of current R & D spending on a Cost/Benefit or other basis, acknowledging the many difficult methodological and philosophical issues involved. With respect to the former, a scenario approach is used to describe alternative futures of the U.S. energy system. For the latter, a dual approach is taken. First, a straightforward Cost/Benefit analysis is performed, but partially reversed from normal procedure. Second, the relevance and applicability of Cost/Benefit Analysis are examined, especially with regard to the long time-scale of fusion. (See Appendix A.) Some modest suggestions are offered about where its relevance might be strengthened and in what directions alternative methodologies might be sought.

The "reversal" of normal Cost/Benefit procedure⁴ involves asking first how big the net benefits of fusion in the twenty-first century would have to be

in order to justify current R & D budgets on a discounted present value basis (depending of course on the choice of discount rate). The normal tendency is to presume that for long time scales, discounting totally obliterates the effect of any future net benefits, so that only immense benefits would result in a non-negligible present value. Interestingly, simple calculations indicate that the required quantities are not so outrageously large when compared with potential cost differences among various scenarios for the U.S. energy system. (The benefits of fusion are taken as the system cost savings brought about by its implementation.) These results are discussed in Chapter 2, and the calculations described in Appendix B. The relevance of Cost/Benefit Analysis and discounting to long-range projects is controversial--some of the arguments often put forth are summarized in Appendix A. It is nevertheless useful to proceed with a Cost/Benefit Analysis because it does provide insights, because alternative methodologies are not widely available or accepted, and finally because various agencies of government insist upon it as a standard means of program evaluation.

C. Methodology

The quantitative descriptions of alternative energy futures were developed using a simplified model of the entire U.S. energy system over the next one hundred years. The major factors which will bear most directly on the need for fusion were identified and examined. Levels of total energy consumption in the U.S. were established, distinguishing two cases in the near-term (HI and LOW) based on detailed demand analysis, and two cases in the long term (HI and ZEG) based on possible trends. Independently, projections were developed to provide several different possible implementation schedules for each of the major supply sectors, incorporating assumptions regarding many possible

technical and policy developments for each resource. Clearly the extent to which fusion will be implemented will depend on total energy demand and on the availability and cost of alternative sources: oil and gas, coal, fission, solar, and of course fusion itself.

Complete scenarios were constructed by selecting from among the various supply schedules to meet each of the demand projections, within a model of the U.S. energy system which was adapted from the "Reference Energy System" concept.⁵ A computer code was developed to organize the relevant data to permit interactive user modification of scenarios and to perform calculations of system cost, resource depletion, and environmental effects. Total annual system cost was calculated in each of the 100 years, based on cost figures which were estimated for the various fuels and capital equipment. The actual behavior over time of the system cost stream offers more detailed information and insight into implications of different energy futures than is provided under discounting. However, the cumulative discounted present value was also calculated using several different discount rates and starting dates.

The intent of developing the model was to provide a convenient means to make explicit the consequences of a given set of assumptions about the future of the energy system. The approach first requires that the scenario ("fuel mix") be self-consistent and reasonable in each of the one-hundred years--totals must add up properly and supply must equal demand, with all conversion efficiencies taken properly into account. Furthermore, each variable must exhibit smooth and reasonable behavior over time. Only then can an assessment be undertaken of the economic, resource, and environmental effects implied by the consumption level and technology mix of a given scenario.

The development of the approach and methodology (the "right tool for the job") constituted a major subtask in itself and is discussed in Chapter 2. Results and analyses of several scenarios are presented in Chapter 3. In addition to the basic question of the potential discounted benefits of fusion, several other issues are explored, such as drastic limits on alternatives, and accelerated development of fusion (early implementation). Chapter 4 offers the philosophical and methodological basis by which the total consumption scenarios were derived. This most basic variable requires different treatments for the near and far-terms. Cost/Benefit Analysis is discussed in Appendix A, where some of its controversial aspects are reviewed. The reader is encouraged to establish his own view of the suitability of cost/benefit to fusion as the application of it undertaken here unfolds.

Several caveats should be noted. First, no attempt is made here at prediction. Rather the study examines future possibilities. Second, no claim is made that the pertinent parameter space has even begun to be explored. The number and variability of outcomes for the U.S. and the world increases greatly as one considers a longer time scale, but only a very few can receive detailed scrutiny. This study has aimed at a useful bracketing of possible ranges of some of the relevant variables.

No attempt is made here to assess the desirability of relative "benefits" of a greater or lesser amount of energy consumption. Nor is any assertion been made as to whether or to what extent GNP growth, or the more relevant but less quantifiable "quality-of-life", will depend on energy in the long run. The discussion of benefits in terms of direct energy system cost savings has the advantage that it can readily be done, although such savings may not, in the final analysis, be the most important consideration in determining the extent of fusion implementation.

Notes to Chapter 1

1. D. Steiner, The Technology Requirements for Power by Fusion, Nucl. Science and Engineering, 58 107-156 (1975).
2. R. F. Post and F. L. Ribe, Fusion Reactors as Future Energy Sources, Science 186, 397, (November, 1974).
3. G. L. Kulcinski, Fusion Power - An Assessment of its Potential Impact in the USA, Energy Policy, p. 104 (June 1974).
4. Ideally a Cost/Benefit assessment would proceed first from an ingenuous and thorough enumeration of all costs and benefits to a later determination of the Cost/Benefit ratio. With so much latitude in the determination of the costs and benefits in the case of fusion, however, such a procedure could not meaningfully be undertaken.
5. Sourcebook for Energy Assessment, M. Beller, ed. BNL Report No. 50483 (December 1975).

Chapter 2
APPROACH AND METHODOLOGY

A. Introduction

Developing the approach and methodology was in one sense a separate sub-task from the analysis and generation of results and conclusions. But there was also give and take between these interdependent means and ends, as both became more clearly defined over the course of the study.

With the general initial objective in mind (see Chapter 1) the first task was to identify the major variables or key factors considered to have the greatest bearing on the potential need for fusion. There then followed the parallel tasks of determining what level of detail was appropriate and choosing a suitable model. Then total energy demand projections were developed together with projections of possible implementation schedules for each of the major supply resources. Scenarios of the energy future of the U.S. were then constructed by selecting various combinations of the different supply

options to meet each of the total demand projections. Total energy system cost was calculated using cost estimates for the several fuels and technologies that were distinguished in the model.

The "benefit" of fusion was taken as the difference in annual system cost for two otherwise comparable scenarios with and without fusion. The first step of the "reversed" cost-benefit approach, however, was the calculation of minimum long range net benefits.

B. Long Range Benefits¹

A straight forward calculation was done to determine the minimum long range net benefits that result in a \$10 billion dollar present value as of 1975. This calculation is presented in detail in Appendix B. The \$10 billion figure represents an approximation of the present value of the projected fusion R & D program cost (expected to total \$20 billion to be spent between now and the year 2000). This is the "cost" to be matched or exceeded by the "benefit" referred to above, if the fusion R & D program is to be justified on this basis.

A net benefit stream was assumed to start in the year 2025, increasing linearly through the year 2075. This "wedge" of savings approximates the general shape of an actual net benefit stream that might result from the difference in system cost between two different scenarios. Table 2-1 shows the annual savings the wedge must reach by 2075, to give the cumulative discounted present value in 1975 of \$10 billion. The total net benefit, or area of the savings wedge, is given in the last column. The extreme sensitivity to discount rate is noteworthy. Going from a 5% to a 10% discount rate increases the required annual benefit in 2075 by over a factor of 50.

Also perhaps surprising, and contrary to the usual supposition, is the fact that these figures for the annual benefit are not astronomical (for some discount rates), but as is demonstrated later are in some cases quite within the range of possible

TABLE 2-1

PRESENT VALUE OF FUTURE BENEFITS

BILLIONS OF DOLLARS

<u>DISCOUNT RATE (%)</u>	<u>PRESENT VALUE</u>		<u>ANN. NET BENEFIT \$/yr. 2075</u>	<u>TOT. NET BENEFIT</u>
	<u>1975</u>	<u>2025</u>		
0	10	10	0.4	10
1		16.4	0.9	23
3		43.6	4.4	110
5		118	20	500
7		307	83	2,080
9		825	330	8,250
10		1,155	550	13,800
15		11,220	11,000	280,000

system cost savings. In any event, the required "benefit" is estimated, whether such amounts are to be found in cost savings, or in estimates of the many less commensurable advantages that might be attributed to the use of fusion.²

C. Time-Scale and Uncertainty

The study approach was in large part dictated by the long time scale involved--a context dominated by uncertainty. Highly detailed characterizations or models of the energy system (technological, economic, and social) were not attempted, as they could not be provided with adequate or meaningful input data for the time-scale under consideration. Furthermore, a broader based description more readily permits the kinds of issues that are of interest to be addressed: these concern the gross features, and not the details, of the overall future of energy over the next 100 years. To that end, the entire U.S. energy system³ from resource supply through conversion to end use was described in terms of five supply and three end use categories with conversion processes and energy flows which connect them specified at a commensurate level of detail. Using this framework, a completed scenario consists of an entire set of energy activity levels specified for each of the 100 years from 1975 to 2075, thus representing one possible future state of the U.S. energy system that might arise from technological developments, resource availability or policy action. For the exploration of economic implications, an optimization or economic (price) deterministic approach was not undertaken, again because of the time scale and uncertainty.⁴ Instead of allowing cost estimates to determine the levels of implementation of the various technologies, the methodology used here first assumes implementation levels exogenously in the form of working hypotheses, and then explores their economic and other implications in a straightforward manner. Environmental effects are calculated from

coefficients input separately, and each scenario is evaluated under several different sets of cost assumptions embodying different possible futures of energy costs.⁵

D. Major Areas of Uncertainty

Whether or not fusion will be needed, and if so to what extent, will depend on several major factors, which can be roughly categorized under supply and demand. A discussion of demand, or consumption,⁶ would include matters such as the rates and nature of the social and technical change which establish our energy needs; the changes in consumption patterns and efficiencies, as affected by environmental concerns, cultural values, technological developments, and the availability of supplies. What will the long-range pattern of energy consumption be? Are there "Limits to Growth?" Under the heading of supply comes a description of the several major resource and supply technology options--the availability, viability, costs, and externalities of coal, oil and gas, fission (including the breeder), renewable (solar), and fusion.

These are the basic and interdependent major variables (here presented as separable issues only to facilitate analysis) that will bear on the future need for fusion. Each is discussed in turn, both as to its general aspects, and to the approach taken to incorporate these aspects into the analysis.

TOTAL ENERGY RESOURCE CONSUMPTION

Twentieth century energy demand levels have been set according to projections in the current literature, where extrapolations of detailed historical and present trends have been performed. Detailed extrapolation would not be suitable to the far term (after 2000). Instead, general possible trends were used to define overall energy consumption levels.

Figure 2-1. Annual resource consumption 10^{15} Btu/Year.

The near-term (20th century) was thus separated from the far-term (21st century) because the methodology appropriate to each one is different. Even with the more exacting approach that can be applied to the 20th century, by the year 2000 the range of variation among different projections is substantial; and two cases were chosen to represent that range. For the 21st century, it was assumed that consumption would level off, and only the advent of some advanced technology would permit renewed growth. Four scenarios were defined for the total annual resource consumption over the 100 year period of the study, as shown in Figure 2-1. The more detailed scenarios which define the complete fuel mix comprising these total demands are labeled LZ, HZ, LH, and HH; referring to Low or High, and Zero Growth or High, in the 20th and 21st centuries respectively. A detailed discussion of these matters appears in Chapter 4.

SUPPLIES

The many factors involved in each of the various supply resources are increasingly discussed in every conceivable forum, from the popular press to academia, government, and the general population. Yet another recitation of these issues is therefore not included here. Instead, two or more scenarios are posited for each major supply category to represent the fundamentally different possible outcomes for each, with quantities and growth rates adapted from the various studies which provided the near-term total consumption projections discussed in Chapter 4.

Oil and Gas, the major fuels today, are eminently exhaustable, even globally, and will not be major long-term sources of energy. For the study, they were combined into a single category, including all domestic and imported resources. Two possibilities are considered. In the first, oil and gas continue to play a major role in the near and mid terms with consumption at about the current

level, implying continued increasing reliance on imports and vigorous secondary recovery in domestic production. A second scenario involves no imports, but domestic production continues even after 2050 (possibly optimistic). See Figure 2-2a.

LWR's and breeders were aggregated to form a single fission category.

Two scenarios are assumed. In the first, without the breeder, fission generation is limited in time (because of uranium resource limitations) and falls off after peaking some time after the year 2000. In the second, fission continues to make a steady state contribution through the use of breeders. However, it is assumed that the difficulties associated with the breeder will limit its acceptability to some degree, constraining its implementation. At issue is whether the public will accept the plutonium economy or not (See Figure 2-2b). A third scenario involves intensive breeder implementation, even though this is considered to be a relatively improbable outcome. Fission, on the threshold of true commercial maturity, is confronted with a now familiar host of problems which involve not its technical feasibility but its social acceptability.

Coal is often cited as the mainstay energy resource of the U.S., but there are considerable problems to be expected from a vastly greater level of use, whether through direct combustion or by conversion to synthetic fuels. The severe environmental impacts involved in every part of the coal fuel cycle will not be readily or cheaply dealt with. In several scenarios, the use of coal was allowed to increase to whatever degree necessary to make up the slack between other resources, and the total resource consumption indicated for the scenarios. In some cases, this resulted in manifestly immense utilization of coal, the total U.S. proven reserves being exhausted within the next century, with annual production levels more than ten times current ones. In other cases, the use of coal was allowed to grow no higher than 50 Quad/yr. (roughly four times the current level), representing

Figure 2-2. Supply schedules.

the situation where either production capability or environmental damage results in such a limitation (see Figure 2-2c).

Fusion is assumed to contribute to national energy needs in the early part of the 21st century, and its growth rate varies from high to very high in order to meet the postulated total energy demand. Fusion, implemented only if breeders are not, is assumed to relieve the pressure on other resources in the 21st century ZEG cases, and to be solely responsible for allowing later growth in the 21st century HIGH cases. Like the other technologies, the fusion power reactor is treated here as a black box, characterized by a few parameters such as cost, efficiency, and environmental emissions. The probability of success of the R & D program and the question of what type of fusion reactor will be developed is not addressed here. Scenarios are simply run with or without fusion.

Solar Energy is separated into two distinct categories. Near-term technology solar thermal application to space conditioning is incorporated into the long-range total demand figures. It simply reduces the total demand for fuels and electricity. On the other hand, advanced solar electric (photovoltaic or thermal), like fusion, is an advanced technology which may or may not be available in the future for electrical power generation, and is characterized by its cost and environmental effects.

RATE CONSTRAINTS

For each of these resources, the rate of change of implementation levels are constrained by several factors which were taken into account in establishing these scenarios. These include:

- Orderly retirement of existing capital equipment. A widely implemented technology with a large investment is not likely to be dropped suddenly. Typical plant life is 30 years, so rates of decline (or replacement) must reflect full utilization of equipment in place.

- Maximum growth rate.⁷ During the early phase of the introduction of a new technology, very high rates (but small absolute numbers) of growth can be maintained. But as the number of plants increase, a lower percentage growth rate is to be expected.
- Ultimate limits. It taxes one's imagination to foresee a full scale power plant on every street corner, or a construction rate corresponding to several new plants per week. Some cognizance must be taken of the realistic scale of things.

E. The Model and Scenarios

The description of the U.S. energy system used in this study specifies supply and demand categories together with the flows connecting them. It is based on the "Reference Energy System" technique⁹ which was devised at BNL. Figure 2-3 shows the RES diagram for the year 1972. Energy resources flow from left to right, undergoing conversion processes to reach demands. Energy quantities are given in Quads (1 Quad = 10^{15} BTU) and are national annual totals.

Figure 2-4 shows the simpler more aggregated version of the RES developed for this study to provide the framework to address the overall features of the energy system. The parameters of this simplified version are aggregated to reflect the major variables defined above, and to permit time dependence to be explicitly and readily treated.

A computer program Time-Phased Reference Energy System Generator (TPRESG) was developed to organize the relevant data, to permit interactive user modification of scenarios, and to perform calculations of the system cost, resource depletion (cumulative and annual), and environmental effects which result from the consumption levels and the technology mix of a given scenario.

Figure 2-3. Reference energy system, year 1972.

TOTAL RESOURCE USE = SUM OF * VALUES
 TOTAL USE = SUM OF FUELS**

() PARENTHESES INDICATE CONVERSION EFFICIENCIES
 v = VARIABLE EFFICIENCY

Figure 2-4. Reference energy system T P R E S G
 (1975 data).

Where the RES treats only one year at a time, in TPRESG each category activity level is exogenously specified over the entire 100 year time period. As the user makes changes to selected activities, the program corrects the value of associated parameters. For example, if coal-steam electric is changed, then corrected values are inserted for coal resource and total electricity, etc. With the time dependence of each variable explicitly displayed, the user can manipulate the scenario until each parameter exhibits smooth and reasonable behavior over time, while maintaining self-consistency at each point in time (i.e., the variables in the RES are all properly arrayed). The final output is a complete set of energy activity levels and their resulting implications for each of the 100 years from 1975 to 2075, and thus can represent any given future course of the U.S. energy system which might arise from technological developments, resource availability, or policy action.

SCENARIOS

The approach taken to establish these complete scenarios involved first choosing a total consumption case, and then selecting from among the individual supply schedules to provide that total amount of energy. Judgment was exercised to limit the rapid escalation in the number of combinations that could result from even the limited number of choices available.⁸ In many cases coal was allowed to take up the slack between other supplies and total consumption. Through the year 2000, the individual supply schedules and technology mix follow closely the more detailed fuel mix described in the Sourcebook "reference" and "future" cases.⁹

SAMPLE TPRESG OUTPUT

Figure 2-5 shows the TPRESG printout for the "HIGH-ZEG" base case. Each group of numbers gives the levels of energy activities for reference years covering the 100-year period. These activities correspond exactly to those shown in the Reference Energy System (Figure 2-4). This output provides various characterizations of the energy system as calculated from the exogenously determined energy activity levels:

- Average annual percentage growth rates for selected activities are shown for the time intervals between reference years. Requiring smooth behavior over time is in effect a second derivative check on the time behavior of the activity. Note, for example, that fission experiences very high growth rates in the near term (23.4% over the next five years).
- The Electrification Ratio is calculated as delivered electricity divided by the sum of all delivered fuels and electricity, making immediately evident any fuel mix assumptions which would imply drastic changes in end-use technology.
- Total Use and Total Resource are the total delivered fuels at the point of end use, and the total annual resource requirement, respectively. The difference between them is simply due to losses in conversion from resource to usable fuel or electricity.
- Cost implications:

Total annual system cost is given. This includes operating and maintenance, annualized capital cost (assuming a 30-year plant life and appropriate plant factors), and fuel and transportation costs. End-use equipment costs were not included.

HIGH-ZEC CASE CASE

FOSSIL RESOURCES				ELECTRIC GENERATION			
TOTAL USE				RESOURCE USE (THERMAL)			
YEAR	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.00	13.37	6.6%	6.48	8.82	1.65	0.00
1980	50.66	18.59	5.6%	6.98	13.03	5.34	0.00
1985	66.50	24.58	6.4%	6.70	14.86	11.33	0.00
1990	66.00	33.91	4.5%	6.15	18.00	23.97	0.00
2000	65.90	53.30	2.5%	5.30	19.14	28.86	0.00
2010	63.20	68.70	.2%	5.00	20.90	33.80	0.00
2020	63.10	70.40	.1%	4.71	22.00	35.80	0.00
2040	63.10	72.30	.0%	4.36	22.90	36.80	0.00
2060	63.10	72.35	0.0%	4.36	22.90	36.80	0.00
2075	63.10	72.35		4.36	22.90	36.80	0.00

ELECTRICAL GENERATION						
YEAR	LIO & GAS	COAL	FISSION	RENEW	CTR	
1975	2.43	3.15	6.7%	1.53	23.4%	0.00
1980	2.30	4.30	3.8%	1.71	15.7%	0.00
1985	2.70	5.20	3.8%	3.74	15.4%	0.00
1990	2.10	6.30	.6%	8.06	2.5%	0.00
2000	1.80	6.70	.9%	10.39	1.6%	0.00
2010	1.70	7.30	.5%	12.20	.8%	0.00
2020	1.60	7.70	.2%	13.20	.1%	0.00
2040	1.50	8.00	0.0%	13.60	0.0%	0.00
2060	1.50	8.00	0.0%	13.60	0.0%	0.00
2075	1.50	8.00	13.60	3.20	0.0%	0.00

COAL TO SYNFUELS				TOTAL ENERGY CARRIERS (DIRECT USE)		
YEAR	LIO & GAS	COAL		LIO & GAS	COAL (IND)	ELECTRICITY RATIO
1975	0.00	0.0%		41.56	4.15	6.51
1980	0.00	0.0%		46.40	5.00	8.47
1985	2.15	20.0%		55.20	6.70	11.27
1990	8.71	0.9%		60.30	9.40	14.80
2000	21.21	3.5%		60.50	12.00	19.80
2010	30.00	1.0%		72.00	13.80	22.40
2020	33.00	.1%		74.20	14.30	23.80
2040	34.00	0.0%		75.20	14.30	24.30
2060	34.00	0.0%		75.20	14.30	24.30
2075	34.00			75.20	14.30	24.30

FINAL CONSUMPTION END USE

LID & GAS				ELECTRICITY			
YEAR	R & C	IND	TRANS	R & C	IND	TRANS	
1975	13.20	9.88	18.49	3.78	2.71	.02	
1980	12.40	14.00	20.00	4.60	3.80	.07	
1985	11.50	20.50	23.20	5.70	5.40	.17	
1990	11.50	22.80	26.00	7.00	7.40	.40	
2000	11.50	26.00	31.00	8.00	10.00	1.00	
2010	11.40	27.70	32.90	9.40	11.30	1.20	
2020	11.40	28.10	34.70	10.30	12.10	1.40	
2040	11.30	28.60	35.30	10.40	12.30	1.60	
2060	11.30	28.60	35.30	10.40	12.30	1.60	
2075	11.30	28.60	35.30	10.40	12.30	1.60	

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94
1980	17.00	22.80	20.17	59.97	85.73
1985	17.20	32.80	23.37	73.37	106.04
1990	18.50	39.60	26.40	84.50	129.82
2000	20.30	48.00	32.00	100.30	155.26
2010	21.30	52.80	34.10	108.20	174.30
2020	21.70	54.50	36.10	112.30	178.44
2040	21.70	55.20	36.90	113.80	181.34
2060	21.70	55.20	36.90	113.80	181.39
2075	21.70	55.20	36.90	113.80	181.39

CIVIL RESOURCE USE

	1975-2024	1995-2044	1975-2075
TOTAL COAL	2414.	3334.	6090.
TOTAL LIO & GAS	3176.	3187.	6395.

Figure 2-5. Energy activity levels national annual totals (E15 BTU).

TOTAL ANNUAL SYSTEM COST (C9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1	148.1	148.1
1980	191.5	191.5	191.5	191.5	191.5
1985	254.2	254.2	254.2	254.2	254.2
1990	333.7	333.7	333.7	333.7	333.7
2000	461.4	461.4	461.4	461.4	461.4
2010	574.5	574.5	574.5	574.5	574.5
2020	639.4	639.4	639.4	639.4	639.4
2040	733.7	733.7	733.7	733.7	733.7
2060	817.5	817.5	817.5	817.5	817.5
2075	880.2	880.2	880.2	880.2	880.2
DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST					
TO 1975					
0%	61238.2	61238.2	61238.2	61238.2	61238.2
5%	7483.0	7483.0	7483.0	7483.0	7483.0
10%	2068.6	2068.6	2068.6	2068.6	2068.6
15%	1691.3	1691.3	1691.3	1691.3	1691.3
TO 1995					
0%	56099.2	56099.2	56099.2	56099.2	56099.2
5%	11660.7	11660.7	11660.7	11660.7	11660.7
10%	5552.2	5552.2	5552.2	5552.2	5552.2
15%	3649.0	3649.0	3649.0	3649.0	3649.0
TO 2010					
0%	48831.6	48831.6	48831.6	48831.6	48831.6
5%	13501.5	13501.5	13501.5	13501.5	13501.5
10%	6957.9	6957.9	6957.9	6957.9	6957.9
15%	4729.4	4729.4	4729.4	4729.4	4729.4
TO 2020					
0%	42766.7	42766.7	42766.7	42766.7	42766.7
5%	14017.7	14017.7	14017.7	14017.7	14017.7
10%	7504.6	7504.6	7504.6	7504.6	7504.6
15%	5145.6	5145.6	5145.6	5145.6	5145.6

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	11.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	329.40	300.12	107.36	67.10	0.00	0.00
2020	356.40	324.72	116.16	72.60	0.00	0.00
2040	367.20	334.56	119.60	74.80	0.00	0.00
2060	367.20	334.56	119.60	74.80	0.00	0.00
2075	367.20	334.56	119.60	74.80	0.00	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SU2 E6 TONS	PART F6 TONS	HIC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.00	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.46	15.21	34.17	30.12	23.49	4.15
2020	10.79	15.99	35.11	30.04	24.28	4.26
2040	10.95	16.26	35.59	31.15	24.38	4.29
2060	10.95	16.26	35.59	31.15	24.38	4.29
2075	10.95	16.26	35.59	31.15	24.38	4.29
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	18.01	1.54	35.51	2.34	.20	
1985	22.94	1.96	45.05	2.94	.36	
1990	30.36	2.36	57.56	3.68	.48	
2000	37.86	3.21	81.87	5.16	.60	
2010	43.93	3.95	101.89	6.40	.71	
2020	45.63	3.92	103.22	6.43	.75	
2040	46.63	4.02	105.07	6.60	.70	
2060	46.64	4.02	105.05	6.60	.70	
2075	46.64	4.02	105.05	6.60	.70	

Figure 2-5. (Continued)

From this annual figure, calculated for each of the 100 years, a cumulative "present value" cost figure is calculated for each of several discount rates and starting dates. The different discount rates bracket the many notions that arise in assessment of social investments, involving issues ranging from interest rates to inter-generational responsibility. The different starting dates allow a glimpse at how the situation will look to future decision makers. This entire matter of discounting is discussed in greater detail in Appendix A.

- Cumulative consumption of key resources is shown for various time intervals.
- Health and Environmental Emissions and Effects are calculated.

F. Cost and Environmental Coefficients

The code TPRESG is equipped to handle five sets of cost assumptions simultaneously. Each set can have costs that are constant or time varying over the 100-year period. It was decided to keep cost data fairly simple. Obviously, the cost parameter space is large; some simplifying assumptions were needed. Most costs were kept constant in time. Exceptions were: 1) coal (at the mine-mouth) whose cost varied linearly from $\$1/10^6$ BTU to $\$4/10^6$ BTU from 1975 to 2075, 2) oil and gas, from \$2.00 to \$5.50 over the same interval, 3) fission fuel, which nearly doubles between now and 2000 and rises more slowly thereafter, and 4) the fusion plant capital cost, discussed below. Table 2-2 summarizes these cost assumptions. Generally, the figures were adapted from cost estimates used in related BNL energy modeling.

FUSION CAPITAL COST AND LEARNING CURVES

The different cost sets in TPRESG were used to study the sensitivity of system cost to different possible time trends of the fusion capital cost.

□

TABLE 2-2

COST ASSUMPTIONS
(1975 Dollars)

Electrical Generation

	Capital (\$/kw)	O + M (\$/10 ⁶ BTUe)
- CTR	(a)	0.40
- Renewable	600(b)	1.00
- Fission	600	0.40
- Coal Steam	450	0.50
- Oil and Gas Steam	300	0.25
- Trans. and Dist.	250	0.52

Resource (\$/10⁶ BTU)

- Coal (at mine)	(\$1.00, 1975), (4.00, 2075)*
Coal Transport	\$0.12
- Oil and Gas	(2.00, 1975), (\$5.50, 2075)*
- Synfuels:	
Capital	\$2.00
O + M	\$0.40
CTR Fuel (\$/10 ⁶ BTUe)	\$0.20
Fission Fuel (\$/10 ⁶ BTUe)	(\$1.25, 1975), (\$2.40, 2000), (\$2.70, 2020)**

(a) See Figure 2-6 and Table 2-3.

* Time varying costs entered as series of points (Amount, Year), connected by straight lines by the program.

** Cost from 2020-2075 is constant at \$2.70.

(b) See Table 2-3 for long-range solar electric cost assumption.

Figure 2-6 shows the values used, based on the premise that the cost of the earliest commercial fusion plants could be very high (HIGH) or only moderately higher than LWR's (LOW), and that the rate of learning, as reflected in a subsequent drop in costs, could be FAST or SLOW. The first three sets apply in the nominal fusion implementation schedule used in most of the scenarios. The last two were reserved for examination of the implications of accelerated availability of commercial fusion. (See Table 2-3)

Figure 2-6. Fusion capital cost learning curves.

No attempt was made to use the various engineering estimates of fusion reactor costs (the "reference designs") because it is far too early to describe in detail the reactors that will actually be build 30 to 100 years from now. Instead a strictly parametric approach was taken. Commercially viable reactors will by definition be approximately competitive.

The Energy Model Data Base (EMDB) provides specific coefficients at the individual process level for various emissions and effects resulting from

TABLE 2-3

Fusion Capital Costs
Learning Curves
 (\$/kw)

Set #	Initial Cost	Learning Curve	Cost (yr)	Cost (yr)	Cost (yr)
Set 1	HI	Slow	\$2400 (2000)	\$1440 (2020)	\$760 (2075)
Set 2	HI	Fast	\$2400 (2000)	\$1000 (2020)	\$650 (2050)
Set 3	LO	Fast	\$1600 (2000)	\$750 (2020)	\$650 (2025)
Set 4	* { HI LO	Fast	\$2400 (1990)	\$1000 (2010)	\$650 (2040)
Set 5		Fast	\$1600 (1990)	\$750 (2010)	\$650 (2040)
Renewable**			\$600 (1975)	\$2000 (2010)	\$2000 (2075)

* Shifted ten years earlier, for accelerated CTR implementation schedule.

**The near term figure reflects Hydropower, while the 21st century figures characterize central station solar electric as a backstop technology of assured feasibility at high cost (Feasibility at competitive costs is not proven).

energy conversion and use activities.¹⁰ These coefficients are in the form of tons of pollutant, or injuries, per BTU of energy flow. Values for the coefficients, presented in Appendix C, were taken from the Data Base with an attempt to select the most representative or reasonable estimates for the more aggregated energy flow activities in TPRESG, but it is not possible to establish truly meaningful coefficients at that level of aggregation because the individual technologies vary greatly in their characteristic emissions. Furthermore, the use of constant coefficients over 100 years is not entirely justified: the extensive deployment of a technology will presumably go hand in hand with improved emissions control. Nevertheless, resulting totals should give an approximate feeling for the relative burdens to the environment imposed in the different scenarios.

Notes to Chapter 2

1. For this particular aspect of the study, methods and results do not bear separating into respective chapters, and are presented together here.
2. This refers to the innumerable points that can be raised such as coal miners lives saved, or reduction of SO_2 emissions, or elimination of plutonium accident risk, or the increased national security of energy independence, etc.
3. The purview might have been broader, introducing complicated issues such as the impact of energy on lifestyle and the economy, but it certainly cannot be narrower. The interconnectedness of energy resource use could not be adequately reflected, say, in an analysis of just the electrical sector, because the degree of electrification is a significant variable.
4. In optimization modeling, the technology mix is mathematically determined according to the criterion of minimum total system cost. Calculations are performed for a set of constraint equations which constitute a model of the energy system, and results are determined by the unit cost coefficients that are input to the model. This has two consequences. First, the number of input variables that have to be estimated is increased. Figures for supply, resource, and technology limits are still needed, in addition to cost figures.

Secondly, the "once-removed" character of the framework, where costs "drive the model", can obscure the fact that the resulting implementation levels have actually been determined by the cost assumptions in a way only slightly less arbitrary than exogenously fixing the implementation levels themselves.

Furthermore, costs, whether in the form of direct figures or elasticities or supply curves, cannot be easily established with any degree of reliability even for the near term, much less the very far term. Costs would, therefore, join with the other variables whose possible ranges require parametric treatment.

5. In this study, some of the possible ranges of both implementation levels and costs were in fact explored, but the distinction is that no formal attempt was made to model their influence on each other.
6. The term "demand" (in economics a quantity which can be different from supply) here is used interchangeably with the term "consumption", the amount of energy consumed in a given year is equal to the amount provided.
7. H. Davitian, private communication.
8. If only two choices are available for each of five variables, this results in $2^5 = 32$ combinations to be considered. Many of these may not be feasible, however, such as cases where supply is not equal to demand, or where extreme or unrealistic situations are involved.

9. Sourcebook for Energy Assessment, M. Beller, ed., BNL Report No. 50483.
10. Energy Model Data Base, User's Manual, Energy Environmental Group, BNL Report No. 19200 and 21545.

Chapter 3

RESULTS AND ANALYSES

A. Introduction

Future scenarios of energy supply and demand are strongly constrained by simple arithmetic--total demand is equal to total supply, which in turn must equal the sum of individual contributing resources. If there are restrictions on one resource, either another resource must make up the difference or a reduced total results. Conversely, additional resources of one type can ease the need for others, or permit expanded total consumption. In the scenarios that follow, total consumption of primary resources was fixed by assumption, and various resource mixes were developed through objective and intuitive judgment. As discussed in Chapter 2(D), each resource was assumed to contribute approximately according to one of its own individual possible supply schedules, the rates of implementation, or retirement already having satisfied several criteria. In addition to the assumptions developed for the total demand and for each resource,

a preselection of resource mix strategies was made.

The scenarios are summarized in Table 3-1. For the first several cases (HZ01-05), coal was allowed to take up the slack, sometimes reaching very high (and probably unattainable) annual consumption levels. In other cases, a limit was set on coal, and either some other resource was selected to take up the slack (HZ-06) or the total demand was reduced (MZ-01) to yield a more believable case.

In no case was fusion commercialized unless the breeder was not. And in most cases the breeder was held to a non-growth schedule. High long-term growth was permitted only if one of the advanced ("inexhaustible") technologies was available. The issue of fusion introduction data was examined under different assumptions about the availability of alternative resources (with and without imports).

B. Resource Trade-offs and Cost/Benefit

In Figure 3-1 the resource levels and total annual system costs are plotted as a function of time for cases HZ-01 through HZ-05 (Detailed printouts appear in Appendix D). As supplies are tightened, if fusion is not introduced (#1 - #3), both the need for coal and the system cost increase. The introduction of fusion (#4 and #5) considerably eases both factors.

Coal Use

Table 3-2 shows the total coal use for all scenarios as compared with the current estimates for U.S. reserves and resources. That resources appear to be more than sufficient is not cause for casual optimism about reliance on coal, however. The immediate and cumulative impacts associated with annual production levels from several to over ten times the current rate would be considerable, even if such rates could be attained.

TABLE 3-1

SUMMARY OF SCENARIOS

SCENARIO	FUSION	IMP	FBR	COAL	COMMENTS
HZ-01	N	Y	Y	unlimited	Base case, with breeder and imports
-02	N	Y	N	unlimited	Base case, but no breeder
-03	N	N	N	unlimited	Base case, no breeder, no imports
-04	Y	Y	N	unlimited	Fusion!
-05	Y	N	N	unlimited	Fusion!
-06	Y	N	N	limited	Fusion, drastic case
-07	Y	Y	N	unlimited	Early Fusion - based on HZ-04
-08	Y	N	N	unlimited	Early Fusion - based on HZ-05
MZ-01	Y	N	N	<60 Quad/yr	All Fusion (Mid-term demand revised from HZ-06)
-02	N	N	N	<60 Quad/yr	All Solar
-03	N	N	Y	<60 Quad/yr	All FBR
HH-01	Y	Y	N	unlimited	High Fusion
-02	Y	N	N	unlimited	V. High Fusion
-03	N	N	N	unlimited	V. High Solar
-04	N	N	N	unlimited	V. High FBR
LZ-01	N	Y	Y		Base case
02	Y	Y	N		Fusion replaces FBR

Figure 3-1. Annual System Cost & Resource Use Hi-Zeg (Hz)

TABLE 3-2

TOTAL CUMULATIVE FOSSIL RESOURCE USE

SCENARIO	TOTAL COAL USE 10 ¹⁸ BTU		TOTAL OIL & GAS USE 10 ¹⁸ BTU	
	1975 - 2025	1975 - 2075	1975 - 2025	1975 - 2075
HZ-01	2.4	6.1	3.2	6.4
-02	2.5	8.0	3.2	6.4
-03	3.7	11.1	1.9	3.0
-04	2.4	5.3	3.2	6.4
-05	3.2	6.6	2.0	3.1
-06	2.5	5.2	1.9	3.0
-07	2.2	4.9	3.2	6.4
-08	2.9	6.0	2.0	3.1
MZ-01	2.3	5.0	1.9	3.0
-02	2.3	5.0	1.9	3.0
-03	2.3	5.0	1.9	3.0
HH-01	2.4	5.3	3.2	6.4
-02	3.2	6.6	2.0	3.1
-03	3.2	6.6	2.0	3.1
-04	3.2	6.6	2.0	3.1
LZ-01	1.7	4.1	2.4	4.5
-02	1.7	4.1	2.4	4.5

U.S. Proved Reserves 9.6

Remaining Recoverable
Resources* 35.0* includes proved reserves
and undiscoverable resources

TABLE 3-3
DISCOUNTED NET BENEFITS
HI - ZEG SCENARIO COMPARISONS

										Net P.V.* Discounted Back to 1975 at:					
										1995		2020			
										5%	10%	5%	10%		
Scenario	Fusion Imports FBR	Coal Quad/yr 2075	Annual System Cost (\$10 ⁹ /yr) 2075	Net Present Value*				5%	10%						
				in 1995		in 2020									
				5%	10%	5%	10%								
H203	n n n	152 - 59	979 - 710					3.4	-13.6	96.	14.			1. Fusion vs no Fusion	
H205 (a)	y n n	= 93	= 269	9	-36	865	126	1.3	-5.4	11.9	1.7			with no Imports, no FBR	
H202	n y n	112 - 49	997 - 779					107.	3.0	171.	100.			2. Fusion vs no Fusion	
H204 (a)	y y n	= 63	= 218	285	8	1541	896	42.	1.2	21.1	12.3			with Imports but no FBR	
H201	n y y	72 - 49	880 - 779					-6.8	-11	57.	52.			3. Fusion vs FBR	
H204 (a)	y y n	= 23	= 101	-18	-29	511	466	-2.7	-4.3	7.0	6.4			with Imports	
H202	n y n	112 - 72	997 - 880					114.	14.	114.	48.			4. FBR vs no FBR	
H201	n y y	= 40	= 117	303	37	1030	430	45.	5.5	14.3	5.9			with imports, no fusion	
H203	n n n	152 - 59	979 - 686					251.	36.	253.	101.			1. (b)	
H205 (b)	y n n	= 93	= 293	666	96	2281	909	99.	14.3	31.	12.5				

* Difference between cases in cumulative discounted total annual system cost, from start year indicated to 2075. (\$10⁹)

(a) Fusion Capital Cost: Learning Curve: HI-Slow

(b) Fusion Capital Cost: Learning Curve: LO-Fast

Cost

In the plot of annual system cost in Figure 3-1, possible trade-offs are apparent. Under the cost assumptions used, these resource mix scenarios show a high system cost late in the next century unless the investment is made to install fusion reactors (This is the investment at the point of commercialization from 2010 on--not the cost of research to be done between now and then.) It is just such an effort, with temporarily higher costs, that may be required to establish the more vast resource base which fusion makes available.

Annual Cost Curves and Discounting

Costs over time are not typically presented. Instead, the possibly complex shape of these curves is collapsed to a single parameter--the discounted present value, which is highly sensitive to the choice of discount rate and which narrowly confines the basis for decision. A discounting approach can indicate a preference for the nonfusion scenarios because they temporarily exhibit lower cost in the nearer timeframe. Of course, this takes no account of ultimately lower cost of a system, which moreover relies on an inexhaustible resource base (nor have the external benefits of avoiding high coal use been considered).

This effect is apparent in Table 3-3, where detailed comparisons among the HZ scenarios are given. For example, HZ-03 vs. HZ-05 compares a fusion vs. no fusion case, assuming no imports and no breeder. The use of fusion saves 93 Quads of coal per year by 2075, and the annual system cost is down by \$269 billion. Discounted net present values are also shown. First, for two starting dates and two values of the discount rate, the net difference is shown in the cumulative discounted system cost, from the start date out to 2075. Finally, those figures are discounted back to 1975, at two different rates, giving for each comparison eight different estimates of the net present value² (of fusion) in 1975.

The most noteworthy feature of these numbers is their extreme variability. The 2020 figures reflect only the large wedge of long-term savings due to fusion, but the 1990 figures are dominated by the temporarily higher costs around 2010. Within each comparison the net benefits can range from minus \$5 to 10 billion to plus \$100 to 200 billion, depending on discount rates. For any one given set of discount rates, the variability among comparisons is somewhat less. A conclusion from this is that the effect of discount rate on results is as great or greater than any effect due to resource mix or cost assumptions, verifying that the level of detail and specificity in the model and data are indeed appropriate, that is to say that they are commensurate with the influence that the discount rate has on results.

The "HIGH-HIGH" cases are shown on Figure 3-2 and compared with the corresponding fusion scenarios of the "HIGH-ZEG" cases. It was assumed that energy growth would be renewed in the twenty-first century only if fusion proved successful. But these high growth rates do begin to press against the realistic scale of things mentioned above. For example, in the scenario with imports (HH01), the fusion electrical generation is 22.5 mQ in 2040 and 49.0 mQ in 2060. This corresponds to 630 and 1370 plants (@ 1500 MW) respectively.³ The 740 plants to be added in those two decades would have to be brought on line at an average rate of three per month! Finding sites alone would be problematic, much less the capital, manpower, and materials. Current U.S. capacity of all types would be equivalent to only 317 plants (@ 1500 MW).

The electrification ratio implied here should be noted. Unless fusion heat can be effectively converted to liquid or gas fuels, this degree of reliance on fusion implies a drastically increased proportion of electrical end-use devices.

Figure 3-2. Annual system cost & resource use High-High (HH).

C. Drastic Limits

A "worst case" with respect to alternatives for energy supply would involve: 1) a limit to annual coal production (not to exceed 60 quad/year, which is 5 times current production), 2) unavailability of oil and gas imports, and 3) a fission system restricted to LWR's and therefore unable to continue to supply energy after the exhaustion of uranium. An attempt to match these supply schedules to the HZ demand case leads to an extraordinary requirement for the introduction of fusion and/or solar technologies. In Figure 3-3 a probably unachievable amount of solar was required to match supply and demand under these assumptions (the HZ-06 case). Instead, a new demand case was indicated, which fortuitously reflected a trend evident in new projections currently under development for Planning and Analysis of ERDA. Figure 3-4 shows this new MZ (M for "middle") demand scenario which has a lower profile in the mid term (1980 - 2025 approximately), though it reaches the same ultimate long-term rate of primary resource consumption (~170 quad/year). Also shown for comparison are preliminary values for the F-2 and F-4 ERDA forecasts.⁴ The MZ demand scenario allows a slightly less drastic growth rate in coal production, and a more reasonable (attainable) schedule for the introduction of solar and fusion.

D. Basic Long-Range Alternatives

There are three basic alternatives for energy supply in the very long term. Only fusion, solar, and breeder fission technologies offer access to resources that are essentially inexhaustible. Each, however, suffers from serious limitations. Fusion has yet to be proven feasible. Solar (central station electric) may be technically feasible but is not economically feasible. Fission carries a now familiar host of acceptability problems, which may far outweigh any possible (though by no means assured) economic advantage.

Figure 3-3. Annual system cost & resource use drastic limits.

Figure 3-4. Total resource consumption.

Figure 3-5 and 3-6 show scenarios in which each alternative long-range technology is taken in turn to provide the bulk of energy supply in the 21st century. Again, simple arithmetic dictates that if one resource is not to be available, another must take its place if a given total consumption is to be maintained. Here the three technologies have not been characterized in any great detail. The principal distinguishing feature in these scenarios is cost, where assumptions are as given in Table 2-3. Solar is described as a backstop technology which will very probably be available at the high cost of \$2000/kW. Fission encounters a gradually rising fuel cost, and the fusion capital cost falls along the learning curves shown previously in Figure 2-6. Additional distinctions are evident in the health and environmental effects, however, detailed conclusions should not be drawn from the totals which result because of the level of aggregation [see Chapter 2(F)].

The total land use result in 2075 is nominally 50×10^6 acre/yr for the MZ cases, and 86×10^6 acre/yr for the HH cases. This figure is increased by 6×10^6 acres and 13×10^6 acres respectively by the dominant use of solar (10^4 and 2×10^4 mi², an area equal to the state of New Hampshire, or New Hampshire and Vermont combined). The effect is not as large as might be expected because electrical transmission and distribution land use dominates the land use by electric utilities.

LAND USE (ACRES/1000 MWe)

	<u>PLANT</u>	<u>TOTAL</u>
Coal Steam	400	17600
Oil Steam	115	17315
Nuclear	314	17514
Fusion	314	17514
Solar	4500	21700
Trans. & Dist.	17200	-----

Figure 3-5. Annual system cost & resource use
 Long range alternatives MZ01 Fusion
 MZ02 Solar
 MZ03 FBR

* 10¹⁵ BTU/year

Figure 3-6. Annual system cost & resource use
Long range alternatives HH02 Fusion
 HH03 Solar
 HH04 FBR

E. Early Implementation of Fusion

Assuming that it might be possible to accelerate the fusion RD & D program so that growth in commercialization could begin earlier, it is interesting to examine the extent of resulting benefits. Figures 3-7 and 3-8 show comparisons between "nominal" fusion introduction, which reaches a significant (10 quads) level by 2010, and "early" fusion, where that same curve is shifted 10 years earlier. For the case with imports (Figure 3 - 7) and without imports (Figure 3 - 8), the earlier fusion energy was used to displace some of the need for coal and fission. In both comparisons a substantially lower system cost results, and this savings depends only slightly on the fusion capital cost learning curve assumption ("HI-FAST" vs. "LO-FAST").

Table 3-4 indicates the differences in discounted present value. The net benefit of early introduction, though of course strongly dependent on the choice of discount rate, is nevertheless robust and may be indicative of current R & D spending levels that would be appropriate to bring about early introduction.

F. Cost Sensitivity

Since coal is assumed to be a major energy supply and the principal alternative to fusion, its cost and utilization levels will have the greatest effect on the total system cost. The sensitivity of results to assumptions made about the future of coal costs was examined.

All scenarios were run under the cost assumptions shown in Table 2-3. The cost of coal was presumed to rise linearly from \$1 in 1975 to \$4 in 2075 ($\$/10^6$ BTU), independently of development rate or cumulative resource depletion. A tool commonly used to describe the possible dependence of cost on such variables is the supply curve, where unit cost is plotted against the cumulative production. Time

Figure 3-7. Annual system cost & resource use
Early implementation of fusion

- - - HZ04 (Nominal)
— HZ07 (Early)

Figure 3-8. Annual system cost & resource use
Early implementation of fusion

--- HZ05 (Nominal)
— HZ08 (Early)

TABLE 3-4

CHANGE IN 1975 DISCOUNTED PRESENT VALUE

EARLY IMPLEMENTATION OF FUSION

[HZ08 (early) minus HZ05 (nominal)] (without imports)

		<u>HI</u>	<u>FAST</u>	<u>LO</u>	<u>FAST</u>
1975	0%	1564		1567	
	10%		3.2**		16.6
1995	5%	101	(268.3)*	138	(366.)
	10%		6.4 (42.9)	18	(121.)
2010	5%	121	(669)	119	(656.6)
	10%		13.3 (369)	14.1	(392.4)

[HZ07 (early) minus HZ04 (nominal)] (with imports)

1975	0%	1059		1056.7	
			5.1		10.6
1995	5%	74.6	(198)	88.6	(235.)
	10%		7.4 (49.6)	11.4	(76.7)
2010	5%	73.4	(405.3)	75.1	(414.8)
	10%		7.8 (216.5)	8.6	(238.9)

* Numbers in parentheses are discounted present values in the designated start year. 1975 values were obtained by straight discounting of this value.

** See Note 2.

is not an explicit variable. Thus, a given cost level will be reached at a given production level and not at some prespecified time.

Figure 3-9 shows the coal supply curves which are implied by the coal use and cost trajectories employed in the above scenarios. Notably, with the cost fixed with respect to time, differing amounts of resource used imply a more sharply rising supply curve for the lower utilization, and a more slowly rising curve for the higher utilization. This can be viewed in several ways. On one hand, it might be argued that this is indeed appropriate: Coal use would indeed be lower precisely when its supply curve rises more sharply. On the other hand, it might be argued that the opposite is true, and the lower coal use should involve lower, not higher costs. This, in fact, is the basis of using a supply curve to fix costs with respect to quantity rather than with respect to time.

Figure 3-9 indicates the effect that fixing the coal cost according to a supply curve has on the total system cost. It is pushed higher in the high coal (high cost) case and lower in the low coal case, when the extrapolated base case supply curve is used to determine the cost of coal.

CTR Capital Cost Learning Curve

The different cost sets in TPRESG were used to study the sensitivity of system cost to different possible time trends of the fusion capital cost. Table 2-3 shows the values used, based on the premise that the cost of the earliest commercial plants could be very high (HIGH) or low (LOW) only moderately higher than LWR's and that the rate of learning, as reflected in a subsequent drop in costs, could be fast or slow. The first three cost sets apply in the nominal fusion implementation schedule used in all the above scenarios. (The last two were used for the examination of accelerated availability of commercial fusion.)

Figure 3-9. Effect on system cost of fixing coal supply curve.

Figure 3-10 gives the annual system cost curves for these different fusion capital cost cases. The advantage of a faster learning curve is more pronounced than the effect of a lower initial cost. This is obvious because implementation is very slight in the beginning. The lesson, however, is that very high initial costs can be tolerated on a system wide basis, with widescale implementation to follow only as the ensuing learning curve makes it appropriate.

Figure 3-10. Effect of capital cost learning curves.

Notes to Chapter 3

1. Sourcebook for Energy Assessment, M. Beller, ed., BNL Report No. 50483 (December 1975).
2. Although the direct integration of the entire cost curve from 1975 to 2075 appears in the computer printout, these are of less interest because resulting 1975 discounted present values are dominated by near-term variations in system cost which are artifacts of the methodology, and not pertinent to the issues in question.
3. $1 \text{ mQ(e)} = 10^{15} \text{ BTU(e)} = 33.4 \times 10^3 \text{ MW} \cdot \text{years/P.F.}$

For a plant factor of 0.8, and if each plant is assumed to have a capacity of 1500 MWe, then 27.8 plants are required to generate 1 mQ(e).

The thermal requirement is approximately 10 plants per mQ(t).

4. Work in progress at the National Center for the Analysis of Energy Systems, Brookhaven National Laboratory, for Planning and Analysis/ERDA.

Chapter 4

PROJECTIONS OF TOTAL ENERGY CONSUMPTION

The long-term pattern of energy consumption will be singularly important in determining whether or not fusion will be necessary. Unfortunately, however, we cannot predict the future. Nor can the complex interdependence of many factors, such as supply, prices, and consumption be adequately taken into account, except in an ad hoc manner. (There is feedback in the real world which is difficult to model and incorporate into analysis.) For example, if the future availability of fusion were assured, we would probably be freer with our use of intermediate resources, and consumption would not be held back as much by supply restrictions. Alternatively, increasing resource scarcity over the period presumably would both lower total demand for energy and increase the price that could be paid for fusion reactors. (Note that with respect to fusion implementation, these two forces work in opposite directions.)

These difficulties of modeling and prediction are circumvented by discussing the future in terms of several scenarios, which are "possible futures" of the energy system and which should effectively bracket the relevant range of possible outcomes. Different methodological approaches are appropriate to the near term (here taken as up to the year 2000) and the long term (75 years into the 21st century), since extrapolation rapidly loses validity the further out ones goes from verifiable data.

A. The Twentieth Century

For the purposes of this study the rest of the twentieth century is called "near term", although in other contexts the year 2000 might be considered mid or long-term. Much can be said in terms of detailed analysis of energy demand and consumption patterns in the near term, but what is of interest here is simply: What will the situation be as the time approaches when fusion might play a meaningful role in the U.S. energy system? How much will energy use grow in the next quarter century? What changes will occur in the pattern of use? Such questions can be answered by specifying demand projections in fairly aggregate terms, appropriate to the level of analysis that can be reasonably undertaken.

Scenario sets to the year 2000 have been generated according to several different criteria. In the BNL Sourcebook¹ a "future" case was distinguished from a "reference" case by the addition of new technologies and moderate conservation efforts. An IEA study³ bracketed the future with high, medium, and low estimates for demands and supplies in all the individual sectors, as did the Ford Foundation,⁴ with its Historical Growth, Technical Fix, and Zero Energy Growth cases. The FEA^{5,6} distinguished cases according to the price of oil and policy (Business as Usual, Conservation, Accelerated Supply, etc.)

within a monumental modeling effort which attempts to overcome some of the aforementioned problems.

Figure 4-1 shows the total resource consumption estimated in these various studies. It is important to note the variability among them. In each study totals were arrived at either by projecting⁷ various "macro" quantities as population, GNP, and Energy/GNP (or energy use per capita), or through detailed consideration of each of the energy supply and demand sectors, working from highly disaggregated demand driven models of the U.S. energy system. Beginning with a population projection (series II or III of the U.S. Census Bureau), values are assumed over time for the number of persons/household, for the unit requirements for space heat, water heat, cooking, and miscellaneous electricity (often distinguished geographically and according to housing type). These unit demand figures, along with end-use device efficiency estimates, and particularly changes in them over time, are arrived at by considering current practices, historical trends, current stocks, likely replacement and addition rates, saturation effects, and technological (physical or engineering) limits.⁸ But there is no rigorous way to establish what values these or any of the other parameters will take on in the future--judgments are made and in many cases different scenarios are set forth to account for different possible trends in future energy use practices.

The derivation of residential energy demand is mentioned above. A similar approach is applied to transportation, where population and some set of parameters such as number of vehicles per person, passenger-miles or vehicle-miles, and device efficiency (miles/gallon) are estimated. A slightly different approach must be used for the energy demands for commerce and industry. Here overall business activity levels must be estimated, together with shifts

Figure 4-1. Total resource consumption (to 2000).

which might occur (for example, from metals to plastics, or durables to services). A typical basis might be projected commercial floor space, or tons of steel produced. Again, unit energy requirements must be arrived at--using data for current practice produces a high estimate of future energy consumption if efficiencies are expected to improve in the future due to higher energy costs.⁹ The various studies cited have already scrutinized the various sections of society and the economy, and have chosen methodologies by which to arrive at total energy requirements.

No mention has been made yet of supply, or fuel choices. The "technological" parameters used above reflect assumptions that given fuels are being used in various proportions, in various devices, to meet the demands in given categories. Future practice may permit wide changes in those proportions, as with the generally held view that the U.S. energy system will become increasingly electrified. It is not sufficient then, to report predictions for demands by sectors alone (i.e., Residential and Commercial, Transportation, and Industry), but the fuels in use must also be specified (i.e., electricity, coal, liquids, gasses).

An important problem is the uncertainty in numerical values assigned both to the disaggregated inputs and to the resulting totals. These numbers can only be taken as "givens", for the purpose of performing "if ... then" kinds of analyses. It is, therefore, legitimate for the purposes of this study to use the aggregate figures resulting from detailed analysis done elsewhere, presuming that they represent a reasonable representation of possible futures, while being aware of assumptions in them which may be arguable. Moreover, it is also appropriate to modify with appropriate caution, the aggregate figures as desired so as to describe a different possible future. No unrealism should result so long as a sense is maintained of what such new aggregate figures would imply on the level of a disaggregated analysis.

The Sourcebook Reference Energy cases project an average annual growth rate in total resource usage of about 2.9% from 1980 to 2000, with electrical generation growing at 4.9%. The "Future" cases indicate a resource growth rate of 2.2% with electricity growing at 2.9% over the same period. Both scenarios involve the same proportional shift to electricity by the year 2000, but result in a very different total resource use and total electrical consumption by the year 2000. This is summarized in Table 4-1. Table 4-2 summarizes

TABLE 4-1

ELECTRIFICATION TRENDS

	<u>Reference</u>		<u>Future</u>	
	'80	'00	'80	'00
Total Resource Use (% Growth Rate)	90 (2.9)	163	88 (2.2)	137
Electricity Delivered (% Growth Rate)	8.0 (4.9)	21.44	7.67 (2.9)	13.75
Coal + Liquid + Gas Delivered	57	82.5	54.6	67
Elec. ÷ (Coal + Liq. + Gas + Elec.)	0.12	0.20	0.12	1.17

in greater detail the structure of energy supply as projected in the various studies plotted in Figure 4-1.

Two scenarios, "HIGH" and "LOW", were established for use in this study. For the HIGH case the Sourcebook "Reference" case total consumption figures were taken as representative of most of the higher current projections of energy use. However, the final demand proportions (i.e., among the different sectors) and the carrier mix were adjusted according to the "Future" case.

TABLE 4-2

FUELS CONSUMPTION PROJECTIONS

10¹⁵ Btu(t) Delivered [Electricity in btu(e)]

	current	1980	1985	1990	2000
<u>SOURCEBOOK^a</u>					
REFERENCE CASE	('72)				
-Tot. Resources	<u>72</u>	<u>90</u>	<u>105</u>	<u>122</u>	<u>162</u>
for { L&G	8.0	7.0	6.7	6.1	5.3
elec { Coal	8.2	11.4	12.3	15.4	19.6
gen { Nuc	-	5.4	13.8	16.9	36.5
-Tot. Electric	5.7	8.0	10.6	13.5	21.4
direct { L&G	43.6	52.1	56.9	62.6	73
use { Coal	4.0	5.0	6.9	7.7	9.6
-Fuels*	48	57	64		83
FUTURE CASE					
-Tot. Resources		<u>88</u>	<u>98</u>	<u>113</u>	<u>137</u>
for { L&G		6.3	5.8	4.3	1.9
elec { Coal		10.9	9.5	12.2	8.4
gen { Nuc	"	5.4	13.2	16.7	24.3
-Tot. Electric		7.7	9.9	11.8	13.8
direct { L&G		50.9	49.8	51.8	55.6
use { Coal		3.7	5.7	9.0	11.4
-Fuels		55	55	61	67
<u>FEA-76^b</u>					
ALL SCENARIOS	('74)				
-Tot. Resources	<u>73</u>	<u>80-85</u>	<u>91-105</u>	<u>113-121</u>	
\$13 REFERENCE CASE					
-Tot. Resources	<u>73</u>	<u>82</u>	<u>98</u>	<u>114</u>	
for { L&G	7.0	6.6	5.8	5.9	
elec { Coal	8.5	11.4	15.4	19.6	(none)
gen { Nuc	1.2	3.1	8.7	13.3	
-Tot. Electric	5.8	7.8	10.3	13.2	
direct { L&G	48.4	51.7	60	67	
use { Coal	4.7	4.2	5.1	6.3	
-Fuels*	53	56	65	73	
<u>FORD ENERGY POLICY PROJECT^c</u>					
HISTORIC GROWTH	('73)				
-Tot. Resources	<u>73</u>		<u>116</u>		<u>186</u>
Electricity	6.4		12.9		27.1
Fuels	55.8		78.6		113.7
TECHNICAL FIX					
-Tot. Resources		(none)	<u>91.3</u>	(none)	<u>124</u>
Electricity	"		8.0		11.4
Fuels			68.1		93.2
ZERO ENERGY GROWTH					
-Tot. Resources			<u>88.1</u>		<u>100</u>
Electricity	"		7.9		11.5
Fuels			65.2		68.9
<u>BUMINES^d</u>					
-Tot. Resources	('74)	<u>73.1</u>	<u>87.1</u>	<u>103.5</u>	<u>163.4</u>

a - ref 1 c - ref 4
b - ref 6 d - ref 7

*Total Coal, Liquids & Gases used directly (not for elec. gen)

The LOW case was defined following 8 to 10% below the Sourcebook "Future" scenario, but leveling off in the last decade at about 115 Quad, in a fashion similar to the Ford Foundation ZEG scenario but not at quite so drastically low a level. Until 1990 then, this LOW case will fall within the lower FEA projections. The demand proportions and carrier mix will again be similar to the Sourcebook Future case. Table 4-3 summarizes the LOW and HIGH 20th century energy scenarios which result in two alternative starting points for the next century, when fusion could begin to play a significant role.

Some examination of such figures reveals an important (and somewhat alarming) fact. It is a matter of "ands", not "ors", to provide energy in the quantities suggested through the course of the next 25 years. The "HIGH" scenario (which isn't very high compared with projections put forth a few years ago) calls for a huge increase in coal production, and a vigorous nuclear program, and continued high oil and gas imports, and aggressive implementation of coal synfuels. There are no "ors"--all are needed. And this aspect is only slightly less troubling in the case of the "LOW" scenario.

The picture of life in the U.S., with regard to energy demand, is projected in the HIGH case on the assumption that current consumption patterns continue, with no significant improvement in residential, commercial, or industrial end-use. However, it is assumed that a 40% improvement in automobile efficiency will be realized by 1980, because of a shift to smaller cars. It is basically a "no new initiatives" scenario, using census projections for population and housing mix; 4 to 5% growth rates in industrial activities, and some modest recognition of saturation and leveling effects in the latter part of the next quarter century.

The LOW case on the other hand follows the philosophy behind EPP's technical fix scenario out to 1990. A level of energy consumption is set

TABLE 4-3

FUELS CONSUMPTION PROJECTIONS(this study - approximate supply mix)

	1975	1980	1985	1990	2000
"HIGH" CASE					
-Tot. Resources	<u>71</u>	<u>86</u>	<u>105</u>	<u>123</u>	<u>152</u>
for { L&G	6.5	7.0	6.7	5.8	5.3
elec { Coal	8.2	13.0	14.9	17.1	19.1
gen { Nuc	1.6	5.3	11.3	22.8	25.8
Tot. Electric	6.5	8.5	11.3	14.1	19.8
direct { L&G	41.6	46.4	55.2	57.3	68.5
use { Coal	4.5	5.0	6.7	8.9	12.0
-Fuels	46	51	62	66	80
"LOW" CASE					
-Tot. Resources	<u>71</u>	<u>81</u>	<u>95</u>	<u>110</u>	<u>115</u>
for { L&G		6.6	6.0	5.2	4.0
elec { Coal		12.3	13.3	15.3	14.5
gen { Nuc		5.0	10.1	20.4	19.6
-Tot. Electric		8.0	10.1	12.6	15.0
direct { L&G		43.9	49.5	51.3	51.9
use { Coal		4.7	6.0	8.0	9.1
-Fuels		49	56	59	61

which provides essentially the same level and quality of services, but which assumes the adoption of specific energy saving technologies, most obviously through the elimination of waste. In the last decade the scenario changes to incorporate the idea of a zero rate of growth--energy consumption reaches a constant level which can sustain a satisfactory economy and society through technological and social change. A lowered standard of living may be implied by ZEG, however, if the gains made on the utilization end are wiped out by increased energy costs of extracting more dilute and inaccessible resources.

B. The Twenty-first Century

In the discussion of twentieth century energy consumption projections, the obvious impossibility of prediction was stressed. In its place scenarios were defined to bracket the potentialities of various possible trends, as constrained by the starting point which is established by current reality. In considering the twenty-first century, there is less to go on than in the near or mid-term, and characterizations of lifestyle, population, technology, and society must be parametric, not predictive. Alternative views of the future range from the wildest technological optimism of science fiction, to faith that "good old-fashioned" technological and economic progress will continue to improve man's condition, to the grim pessimism of some social commentators¹⁰, to "paradigm shifted" outlooks,¹¹ where human values gain center stage and smaller "human"scale technology¹² replaces megalithic devices and institutions. In considering the implications of fusion, these aspects deserve considerable attention. However, in this study a more modest objective is approached more quantitatively, insofar as it is possible.

To establish the necessary framework in which to evaluate the impact of fusion, energy consumption patterns in the 21st century must be posited, but there is no "real" way to determine them. One can, however, set them forth somewhat arbitrarily, with the help of certain available guideposts.

Population is a key parameter. The U.S. Bureau of the Census¹³ projects several series for the structure and size of the U.S. population. These are shown in Figure 4-2. Except for series-I, the widely acknowledged viewpoint is well represented here that eventually population must level off, even if gradually. By looking at various possible values for energy use per capita, some feeling can be gotten for the magnitudes involved in the long-term future of energy. Table 4-4 offers some perspective on this. Data for World and U.S. population per capita energy consumption, and total energy consumption are given under varying sets of assumption.

Currently, the U.S. per capita energy use is 345 MMBTU/capita, far exceeding the world level of 63 MMBTU/capita (MMBTU = 10^6 BTU).

Note that U.S. projections for the year 2000 show nearly a doubling of the per capita energy use. And further, the LOW year 2000 energy use of 115 Quad. could maintain the U.S. Census Bureau II-X (no population growth) series year 2080 population of 270×10^6 people with only a modest reduction in per capita consumption.

The world figures given are those of H. Kahn who presents them as to optimistic view of the world over the next 200 years,¹⁴ where the standard of living throughout the world is foreseen reaching present western standards with the advanced nations maintaining a per capita GNP (and energy use) of from 3 to 5 times that of the world average. Much higher estimates are shown in

Figure 4-2. United States population - Projections to 2050.

TABLE 4-4

FUTURE U.S. AND WORLD POPULATION AND ENERGY USE

	Population (10 ⁶)	Per Capita Energy Use (10 ⁶ BTU/Cap.)	Total Energy (10 ¹⁵ BTU)
<u>U.S.</u> 1974	212	(345)	73.1
<u>World</u> ^a			
1975	4,000	(63)	250
2075	14,600	(164)	2,400
2175	15,000	(240)	3,600
"20-20" Scenario ^b	20,000	600	(12,000)
<u>U.S.</u> 2000			
Sourcebook, Fut. & Ref.	249-262 }	(520-650)	{ 137-163
U.S. Census II-X, & II			
"LOW" - this study		(440-460)	115
<u>U.S.</u> 2050			
U.S. Census II-X	270	240p	(65)
"		345p	(93)
"		500p	(135)
"		(426)	115
U.S. Census I	500	600p	(300)

a Reference 14.

b 20 billion people, 20 kw/person, reference 15.

() Parentheses indicate a derived value.

p Indicates that the value of the parameter was assumed.
Other entries from references.

the "20-20" scenario, where 20 billion people all reach a high per capita consumption of 20 kw/person--nearly twice current U.S. levels.¹⁵

To provide the necessary contexts for this analysis, a twenty-first century LOW case is defined as having constant annual U.S. energy consumption, following the philosophy of the twentieth century LOW case of zero energy growth. If a modest increase to population is projected, it is assumed to be supported in an ever improving standard of living through more efficient use of a constant energy budget.

Over the last several years, the downward trend in long-range energy projections is unmistakable. No longer need anyone discuss the consequences of some everlasting percentage growth rate, as the lessons of exponential mathematics are gradually absorbed, and the scale and nature of the problems perceived.

To establish an upper bound to the possible long-range future of energy use, a twenty-first century HIGH growth case is defined according to the premises (1) that very real difficulties can be foreseen for supplying energy at high growth rates in the next twenty or thirty years, and (2) that a later renewed upturn in the rate of increase of energy use could only result from the use of new technologies which cannot be expected to provide substantial quantities in the near to mid terms (namely, solar and fusion). Coupling this to the two 20th century cases then results in plateaus of constant energy use until the introduction of these advanced technologies. The detailed shape of these time trends will vary according to the dates and rate of introduction of fusion (or solar).

A limit is set at ~300 Quad./yr. as the highest total resource use allowed in any scenario through the year 2075.

Figure 4-3 summarizes the overall time trends of annual energy consumption established for this study.

Figure 4-3. Annual resource consumption 10^{15} Btu/Year.

Notes to Chapter 4

1. Sourcebook for Energy Assessment, B. Beller, ed., BNL Report 50483, December, 1975. Projections in the Sourcebook are essentially the same as scenarios 0 to V in ERDA-48 (Ref. 2).
2. A National Plan for Energy Rd & D, ERDA-48, June, 1975.
3. "The IEA Energy Simulation Model, A Framework for Long-Range U.S. Energy Analysis", C. Whittle and D. B. Reister, January, 1975.
4. A Time to Choose, Report of the Ford Foundation Energy Policy Project, Ballinger Publishing Company, 1974.
5. Project Independence Report, Federal Energy Administration, November, 1974.
6. National Energy Outlook, F.E.A., February, 1976.
7. U.S. Energy Through the Year 2000 (Revised), Bureau of Mines, Department of Interior, W. G. Dupree and J. S. Corsentino, December, 1975.
8. Efficient Use of Energy: A Physics Perspective, American Physical Society Study Group, Physics Today, August, 1975. This study argues that the technological limits for conservation measures offer far more opportunity than is currently acknowledged in most analyses.
9. The role of costs play in determining future consumption levels is exceedingly difficult to predict in detail. Historical elasticities can be used*, or as in the Project Independence FEA Demand Model (Ref. 5, Appendix A, pg. 55) capital equipment investment decisions are assumed to be made according to fuel price changes, with a consequent gradual lagged adjustment in demand. (*See for example "The Effect of Price on Demand for Electric Energy During the Rest of the 20th Century", D. Chapman, A.A.A.S., pg. 68, February, 1975).
10. R. L. Heilbroner, An Inquiry Into the Human Prospect.
11. For example, see Hazel Henderson: "Nudging Society off its Macho Trip", Science, Vol. 190, pg. 862, November, 1975.
12. E. F. Schumacher, Small is Beautiful, Economics as if People Mattered, Harper and Row, 1973.
13. Statistical Abstracts of the United States, 1975, U.S. Department of Commerce, Bureau of the Census.
14. H. Kahn, et. al., The Next 200 Years, Wm. Morrow and Company, Inc., New York, 1976.
15. P. F. Palmedo, Private Communication.

Chapter 5

CONCLUSIONS

This study was undertaken to explore the potential role fusion might play in the future U.S. energy system, especially as interpreted through cost/benefit analysis, and as it might bear on current R&D decisions; also to develop perspectives and methodologies for long-range R&D planning and justification; and to examine cost/benefit analysis for its suitability, limitations, and relevance to fusion.

The potential need for fusion was evaluated by first developing a perspective on what issues can be meaningfully addressed: Questions must first be asked before they can be answered. A methodological framework was needed which sufficiently and appropriately characterized the U.S. energy system. The study

then proceeded by identifying the key factors that will bear on the need for fusion, identifying the quantitative assumptions about the future of energy which result in a finding that benefits are indeed attributable to fusion, and making explicit the consequences imbedded in those assumptions.

One conclusion that emerges is that cost/benefit analysis, as presently understood and applied, is of questionable applicability to fusion R & D. The extreme sensitivity to assumptions undermines any confidence one might hope to have in quantitative results. Furthermore, the assumptions themselves can be little more than conjecture, because of the time scale involved.

However, that fact does not prevent one from asking: "Very well, I won't believe the numbers, but tell me how big they are anyhow, if I assume this value for this and that value for that"? In the results of this study not unreasonable scenario comparisons, with and without fusion, indicate that benefits in the form of direct cost savings could in fact exceed R & D costs (depending on the choice of discount rate); this without an accounting of externalities--the benefits attached to avoiding pollution and proliferation, as well as the benefit of the availability of energy itself.

Simple arithmetic and common sense provide powerful constraints on allowable or reasonable projections of total future energy use and combinations of supply, but the parameter space nevertheless remains very large. By mapping out parts of that space, some of the factors critical to the need for fusion have been examined. The most important of these are:

1. The future behavior of total energy consumption, and
2. The future availability and cost of alternative supplies.

The study has outlined some of the regions of that space where significant benefits are attributable to fusion.

Basic trade-offs among resources were studied, and some sensitivity analyses were done on coal cost and fusion capital cost. On a system-wide basis, very high initial fusion plant capital costs can be tolerated, with widescale implementation of fusion to follow only as the ensuing learning curve brings the capital costs down. The cases which indicate the greatest relative benefits of fusion (i.e., the difference between the total system cost of two scenarios with and without fusion) are those involving high reliance on coal and high costs for coal. In these cases the use of fusion to replace a major portion of the coal use results in systems savings which can reach the \$200 to 500 billion/year mentioned above, out of total annual cost of \$700 to 1100 billion/year. For assumptions which lead to lower relative benefits, it must be remembered that only direct costs have been considered. Decisions are more likely to be made on the basis of the less quantifiable externality issues such as health, safety, and the environment. For example, society may make a political (noneconomic) decision against plutonium.

Total Resource Consumption

In Chapter 1 any attempt in this study to characterize the benefits of greater or lesser energy consumption per se was specifically disavowed. Without some characterization of the linkage between energy, the economy, and quality of life, however, it is difficult to represent quantitatively the expected benefits of fusion with respect to their variation with future total energy consumption. Certain elements are obvious, however. If more energy is to be consumed, the resource must come from somewhere.

In Figure 5-1 scenarios are presented together--all of which involve the use of fusion and imports, but no breeder. As the total consumption picture increases, there are strong reasons to hesitate presuming that either fission or

Figure 5-1. Annual system cost & resource use
Total consumption comparisons

LZ02

HZ04 Fusion, imports, no breeder

HH01

the fossil fuels could be extended much beyond the levels shown to meet the total requirement. As seen previously in the discussion of long-range alternatives, there are but three basic choices: fusion, the breeder, or solar.

If high or only moderately high energy use is to be even possible in the next century, the role fusion must play and the urgency of its availability are readily apparent. For the case of lower total consumption, the urgency of fusion may be less compelling. However, its absence would still have to be made up by one of the other resources. In the cases shown, imports have been assumed available--their removal would increase the pressure on alternatives.

The potential benefits of a commercial fusion program are enhanced in a world where total demand continues to grow, and/or where alternative resources are limited or costly.

- . If imports are restricted,
- . If coal use cannot rise greatly (because of limitations on production capacity, increasing costs, or environmental effects),
- . If fission is not to be greatly expanded, and developed in a form which can make more complete use of the resource,
- . If central station solar cannot be made reliable and economic,
- . If the choice of discount rate is not too high, and
- . If fusion can be available earlier and quickly implemented, regardless of initial cost.

An extreme in any of these factors, or any combination of them to a lesser degree, indicates the necessity and desirability of substantial reliance on fusion energy in the twenty-first century.

Future work should focus on developing alternative methodologies to facilitate an accounting of the noncommensurable externalities, to deal with the question of present society's responsibility for future generations, and to help in the decisions which allocate current RD & D expenditures. For example, the range of energy, supply, demand, and cost projections might be handled with a probabilistic approach, as an advance over the use of deterministic single-valued scenarios whose relative likelihood of occurrence can only be implicitly considered. Uncertainty is a key issue--it is one of the reasons discounting is used, and at the same time the reason why a more complex treatment is needed. Keeping energy options open involves the expenditure of resources and the bearing of risk, where the possibility of failure must be weighed against the possibility of immense value if not critical necessity. Fusion offers potential access to one of the very few perpetuable energy resources.

Notes to Chapter 5

1. In the HH scenarios, the increase from 150 quads in 2000 to 300 quads in 2075 corresponds to an average annual growth rate of only $\sim 1\%$.

APPENDIX A COST/BENEFIT ANALYSIS

Cost Benefit Analysis is the name given to the set of techniques used to evaluate the desirability of investments, especially projects and programs undertaken by governments in the public interest. It is based on the fundamental premise of "economic efficiency", which asserts that the general social welfare will be maximized when optimal use is made of resources.¹ Thus the value of outputs of a project should maximally exceed the value of resources used (i.e., diverted from other projects). Projects can be ranked and chosen according to this criterion of greatest net benefit.

Cost/Benefit Analysis is used to make such determinations. Simply stated, it involves the identification of all the impacts of a project, both favorable and unfavorable, and the valuation of these impacts, where possible, in monetary terms. The favorable impacts (benefits or outputs) might be valued according to the amount the gainers of the project are willing to pay, and the unfavorable in terms of the amount of compensation due those who are adversely affected.²

Though very straightforward in concept, Benefit/Cost Analysis turns out to be very much more difficult in practice. The foremost difficulty is that of establishing prices for the valuation of costs and benefits.³

PRICES

One looks to the private sector (the "free market") to see what prices are being paid there for equivalent commodities or services. This is presumed to be the best available measure of the value attached to them by society. But government programs come into being specifically to fill gaps left by market imperfections, and they also have benefits which are frequently less tangible and may not have equivalents in the free market. There are incommensurables or socially

valued activities for which price or monetary value simply do not enter in. A "willingness-to-pay" approach to setting values is treacherous and difficult--non-market social interactions may not obey the same logic as market interactions. Pricing is not the only difficulty. There are numerous other complexities in identifying all the effects of programs.

Externalities are side-effects for which no compensation can be or is paid to the losers (or paid by the gainers). Pollution and environmental disruption are examples; the polluter is taxed, but there is no way payment can be made to all the individuals who are adversely affected. Secondary Impacts and Non-Efficiency Objectives: a project may have no net effect on the economy but may cause, for example, a boom in one place at the expense of surrounding areas. These effects are often ignored despite their potential significance. Also, there is the danger that only one side will be noted, as the gainers (or losers) can be highly localized while the losers (or gainers) are dispersed. The recipients of benefits may not be the ones who incur the costs--a project can have important income redistribution effects whose suitability to social equity goals is not easy to assess. Objectivity is hard to maintain when almost everyone has a stake of one kind or another. It is unrealistic to expect an advocate not to emphasize benefits and minimize costs. And this can occur in full sincerity, realizing the difficulty in even identifying all the effects of an undertaking. Present Value: An investment invariably involves incurring costs at one time and realizing benefits at some other time. An investment is made now with the expectation of a return in the future (or the opposite--go now, pay later). The present value of a cost (or benefit) to be realized at a future time is less by some percentage than a cost (or benefit) right now. Discounting is the term given the

technique used to collapse a stream of costs and benefits over time to permit them to be compared in terms of their "present value".

$$PV(T_0) = \sum_{t=T_0}^T B(t) \frac{1}{(1+R)^{t-T_0}} \quad (1)$$

Equation (1) shows the summation of an annual benefit stream $B(t)$ to calculate its total present value evaluated at time T_0 . If a decision were to be made between receiving a benefit equal to PV now, as against the benefits $B(t)$ spread out over future years, equation (1) would define the point of indifference between the two choices, once the discount rate R has been defined.

THE DISCOUNT RATE

The present value is extremely sensitive to the choice of discount rate, making it a crucial and thus highly controversial parameter. The discount rate is usually set equal to the "opportunity cost of capital," which is the rate of return that would be obtained if the resources were invested in the private sector rather than in the project under consideration. It is the "price" of investment capital, and thus shares some of the same valuation difficulties as do the costs and benefits themselves. There are many different rates of return in the economy; ideally then different discount rates should be applied to different parts of a project, depending on which economic sector resources are being diverted from.

RISK

Higher returns are earned by investments when the level of risk is higher. Should "risky" or "riskless" rates be used to discount government projects? Some argue that the higher return, on average, just compensates the investor for his higher proportion of loss, so the lower riskless rate is the real rate

of return. Others argue that a failed investment only hurts the investor and not society (the equipment and buildings still exist). Therefore, all investments are already riskless from society's point of view and the higher return is real, representing real growth to the economy. This argument remains unresolved in the economics literature.

SOCIAL DISCOUNT RATE

A distinction is often suggested between the standard investment discount rate, and a "social" discount rate, which it is felt should reflect a broader set of issues and values than just economic ones. However, there is little agreement on what it should be. What follows is a summary of the main arguments frequently heard on the subject. No attempt is made at resolution, but rather to set forth the major points at issue.

FOR LOW DISCOUNT RATES

Arguments for low (even negative) discount rates and against high rates (or discounting itself) emphasize several points:

An Emphasis on the Near-Term results from normal discounting, leading to choices which may be suboptimal from a long-term perspective.⁴ For example, R & D for advanced technologies has a very long lead time. But choosing short-term solutions instead may lead to serious consequences if inadequate preparation is made for the eventual exhaustion of the resources on which we now depend.

Grandchildren: people constantly forgo current consumption for altruistic or noneconomic reasons. This is real and commonplace social behavior that is simply not addressed by discounting methodology, though it may bear considerable relevance to long-term social issues.

The Transcendence of Values Over Money in part summarizes some of the arguments against discounting and cost/benefit analysis. Some people simply find the setting of prices on social values to be offensive and impertinent, despite the oft-made statement that a choice nevertheless implies a price (the value or price of the next thing one could have done with the resources) through revealed preference. There are incommensurables and social values which perhaps should be handled explicitly, and not incorporated into an economic efficiency framework through the assignment of a price.

FOR HIGH RATES

The arguments for discounting, with rates figures according to the opportunity cost of capital, likewise center around a few main points.

The Economic Efficiency Criterion would be violated by the use of a low rate. Using too low (or high) a rate will reduce the general social welfare by allowing unprofitable projects to be undertaken--absorbing resources which could have been put to better use.

Future Society, from all indications, will be richer and smarter than we are. To what extent should we sacrifice our own well-being for their comfort or convenience? Conversely, that future bounty may in fact depend on present investments. But how many of the very pressing needs around the world today do we put off so as to prepare for future generations? The whole question of intergenerational responsibility is immensely hard to deal with.

Of Uncertainty we can be certain. Circumstances will change and prognostications may or may not be proven accurate. If in 1876 the U.S. had projected the future demand for whale oil through the year 1900, huge government investments in whales might have been made. Obviously such efforts would have been unnecessary, and would have diverted funds from other more productive uses. One can only wonder what unexpected developments await us.

Conclusion

Is a given project worthy of public funds? To the extent that it is appropriate to evaluate a project in terms of its readily enumerable inputs and outputs and its desirability as a monetary investment, cost-benefit analysis and discounting provide the information for that assessment. However, the methodology is not without limitations, complexities, and controversies. Hopefully, future theoretical work will augment and expand the relevance and applicability of cost-benefit analysis; in the meantime its conclusions must be carefully relegated to their appropriate place in the making of decisions.

FOOTNOTES

1. It might be noted that this philosophical premise, and its modern economic interpretation, are not universally agreed upon.
2. When the benefits cannot be evaluated, but are acknowledged as a "public good" (i.e., defense, space, etc.), then cost effectiveness is invoked. The objective is to be accomplished in the most economical manner possible.
3. This controversy, as well as many of the other points raised here, are discussed in more detail in Public Expenditures & Policy Analysis, ed. R. H. Haveman, Markham Publishing Company, 1970.
4. Hopefully, the present value would not be used as a ranking criterion, without considering the more detailed behavior over time of the cost and benefit streams. A preference based solely on the relative magnitude of present values might not be the choice that would be made were the larger picture examined. A course of action with near-term payoff is inevitably preferred on a present value basis even if its long-term consequences are disastrous.

APPENDIX B MINIMUM LONG-RANGE NET BENEFITS

With a few simplifying assumptions, it is possible to calculate easily the present value in 1975 of a given net benefit stream that might result from the introduction of an advanced technology during the next century.

Figure B-1. Net benefit stream.

The essential elements are represented in Figure B-1 where the net benefit stream is shown as beginning 50 years from now, in 2025, and increasing linearly through 2075. This "wedge" would correspond to the savings, or difference in overall energy system cost, that might result from fusion. The use of a linear function allows direct calculation of discounted present values while approximating the curve likely to result from a more detailed treatment where quantitative estimates for energy quantities and costs are used. The parameter b , the net annual savings in 2075, can be varied to test different magnitudes of savings.

$$PV(T_0) = \sum_{t=T_0}^T B(t) \frac{1}{(1+R)^{t-T_0}} \quad (1)$$

Equation (1) gives the general formula for calculating the present value of the annual benefit stream $B(t)$.

In integral form, this can be written

$$PV(T_o) = \int_{T_o}^T B(t) e^{-\alpha(t-T_o)} dt \quad (2)$$

where $\alpha = \ln(1 + R)$

Applying this to the curve in Figure (B-1)

$$\begin{aligned} PV(1975) &= e^{-50\alpha} PV(2025) \\ &= e^{-50\alpha} \int_0^{50} \frac{b}{50} t \cdot e^{-\alpha t} dt \end{aligned}$$

This integral is easily done:

$$\int_0^T t e^{-\alpha t} dt = \frac{1}{\alpha^2} \left[1 - e^{-\alpha T} (1 + \alpha T) \right]$$

Therefore:

$$\begin{aligned} PV(2025) &= \frac{b}{50} \cdot \frac{1}{\alpha^2} \left[1 - e^{-50\alpha} (1 + 50\alpha) \right] \\ \frac{PV(2025)}{b} &= \frac{50}{A^2} \left[1 - e^{-A} (1 + A) \right] \end{aligned} \quad (3)$$

where $A = 50\alpha$

TABLE B-1

RESULTS FOR DIFFERENT DISCOUNT RATES

R(%)	α	A	e^{-A}	<u>PV(2025)</u> b	<u>PV(1975)</u> b	$b(10^9\$)$, for $PV(1975) = \$10 \times 10^9$
1	0.0995	.498	.608	18.0	10.94	0.9
3	0.0296	1.48	.228	9.92	2.26	4.4
5	0.0488	2.44	.087	5.88	0.51	20
7	0.0677	3.38	.034	3.7	0.12	83
9	0.0862	4.31	.013	2.5	0.03	330
10	0.0953	4.77	.0085	2.1	0.018	550
15	0.140	6.99	.00092	1.02	0.0009	11,000

Table B-1 gives results from equation (3) for different discount rates R. The minimum 2075 annual savings b which results in a \$10 billion present value in 1975 is shown in the last column. Two aspects are noteworthy--these figures are not so large, and secondly they are extremely sensitive to the discount rate.

Savings of \$300 to 500 billion/yr are on the order indicated in the fusion scenarios as compared with high coal scenarios (see Chapter 3.) (These savings, moreover, reflected only actual production costs and none of the numerous externalities that will be attributable to high coal usage.)

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APPENDIX C TIME PHASED REFERENCE ENERGY SYSTEM GENERATOR*

TPRESG is an interactive computer program written for use on the INTERCOM system of the Brookhaven National Laboratory Central Scientific Computing Facility. It is based on the Reference Energy System methodology, a diagrammatic description of energy flows in the U.S. energy system, with the addition of explicit incorporation of the time dimension.

The purpose of TPRESG is to provide a convenient framework in which to specify quantitatively the flows in the U.S. energy system over time (the next 100 years) in such a way that each energy activity variable varies smoothly and reasonably over time, while bearing a consistent relationship to the other energy flows at each point in time. Then, once a given scenario is defined, several of its attributes and implications are readily calculated and output in a convenient format.

Basic Structure

Figure C-1 shows the simplified reference energy system. Data values appearing on the various links are annual total energy flows for the U.S. energy system in 1975. Efficiencies are indicated where a conversion or distribution process entails some loss of energy. Figure C-2 shows the diagram again but with "activity" indexes indicated. Each energy activity has been assigned an index number (i.e., total distributed electricity is activity #20, total coal mined is #11, electricity generated by coal steam is #9). The activities in heavy circles are those whose values are printed in the final output. (see Figure C-5)

Initial Data Set

A complete, consistent set of data must be specified to initialize TPRESG. This consists of values for each of 10 reference years. This initial data set

* A newer version has since been written called PRESTO, based on the same ideas but with considerably expanded capabilities. Its operational details are also quite different.

TOTAL RESOURCE USE = SUM OF * VALUES
 TOTAL USE = SUM OF FUELS **

() PARENTHESES INDICATE CONVERSION EFFICIENCIES
 v = VARIABLE EFFICIENCY

Figure C-1. Reference energy system T P R E, S G
 (1975 data)
 (10¹⁵ Btu/Year)

Figure C-2. Reference energy system T P R E S G
Energy flow activity variable indexes.

must already exhibit self-consistency in each reference year. For example:

$$X_{14} = X_4 + X_{21}$$

and

$$X_{19} = X_6 + X_7 + X_8 + X_9 + X_{10}.$$

Table C-1 shows the base case specification (HZ01) developed for the HIGH-ZEG cases. Once this initial data set is established, a series of interactive commands enable the user to make changes in the energy totals.

Activity Level Changes

Activity level changes are specified in the format:

IACT1, IYEAR, AMT, IACT2

where - IYEAR must be one of the 10 reference years

- AMT is a floating point number specifying a change to be made (in Quads)
- IACT1 }
- IACT2 } are activity variable indexes

When only IACT1 is entered (enter IACT2 = 0) the amount AMT is added to variable # IACT1 for the year IYEAR. If a value for IACT2 is entered then the amount AMT is deducted from variable # IACT1 and added to variable # IACT2. In other words, that amount is transferred from IACT1 to IACT2.

When any change is made that affects adjoining variables, corrected values are computed for those variables so that consistency of the flow network is maintained in that reference year. For example, a change in one of the electrical generation modes (IACT1 = 6 - 10) with IACT2 = 0 will result in a change in the total electric generation--so variables # 19, 20, and # 23, 24, and 25 are recomputed. (The final demand changes are allocated in proportion to the already

TABLE C-1
BASE CASE DATA SET

<u>ACTIVITY</u> <u>VARIABLE #</u>	<u>REFERENCE YEAR</u>									
	1975	1980	1985	1990	2000	2010	2020	2040	2060	2075
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3.12	3.14	3.63	5.14	7.20	8.60	9.14	9.14	9.14	9.14
3	1.65	5.34	11.33	23.97	28.86	33.80	35.80	36.80	36.80	36.80
4	8.82	13.03	14.86	18.00	19.14	20.90	22.00	22.90	22.90	22.90
5	6.48	6.98	6.70	6.15	5.30	5.00	4.71	4.36	4.36	4.36
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	1.04	1.10	1.38	1.80	2.52	3.00	3.20	3.20	3.20	3.20
8	.53	1.71	3.74	8.06	10.39	12.20	13.20	13.60	13.60	13.60
9	3.15	4.30	5.20	6.30	6.70	7.30	7.70	8.00	8.00	8.00
10	2.43	2.30	2.20	2.10	1.80	1.70	1.60	1.50	1.50	1.50
11	13.37	18.59	24.58	33.91	53.30	68.70	70.40	72.30	72.35	72.35
12	52.80	58.66	66.50	66.80	65.90	63.20	63.10	63.10	63.10	63.10
13	13.37	18.59	22.43	28.25	32.10	35.77	37.42	38.35	38.35	38.35
14	12.97	18.03	21.76	27.40	31.14	34.70	36.30	37.20	37.20	37.20
15	0.00	0.00	2.15	8.71	21.21	30.00	33.00	34.00	34.00	34.00
16	0.00	0.00	1.40	5.66	13.79	19.50	21.45	22.10	22.10	22.10
17	48.04	53.38	60.50	60.79	60.01	57.50	57.46	57.46	57.46	57.46
18	48.04	53.38	61.90	66.45	73.80	77.00	78.91	79.56	79.56	79.56
19	7.15	9.41	12.52	16.26	21.41	24.20	25.70	26.30	26.30	26.30
20	6.51	8.47	11.27	14.80	19.80	22.40	23.80	24.30	24.30	24.30
21	4.15	5.00	6.70	9.40	12.00	13.80	14.30	14.30	14.30	14.30
22	41.56	46.40	55.20	60.30	68.50	72.00	74.20	75.20	75.20	75.20
23	3.78	4.60	5.70	7.00	8.80	9.90	10.30	10.40	10.40	10.40
24	2.71	3.80	5.40	7.40	10.00	11.30	12.10	12.30	12.30	12.30
25	.02	.07	.17	.40	1.00	1.20	1.40	1.60	1.60	1.60
26	13.20	12.40	11.50	11.50	11.50	11.40	11.40	11.30	11.30	11.30
27	9.88	14.00	20.50	22.80	26.00	27.70	28.10	28.60	28.60	28.60
28	18.49	20.00	23.20	26.00	31.00	32.90	34.70	35.30	35.30	35.30
29	16.98	17.00	17.20	18.50	20.30	21.30	21.70	21.70	21.70	21.70
30	16.73	22.80	32.80	39.60	48.00	52.80	54.50	55.20	55.20	55.20
31	18.51	20.17	23.37	26.40	32.00	34.10	36.10	36.90	36.90	36.90
32	52.22	59.97	73.37	84.50	100.30	108.20	112.30	113.80	113.80	113.80
33	70.94	85.73	106.04	129.82	155.26	174.30	178.44	181.34	181.39	181.39

existing proportions, subject to later reallocation if desired). If coal steam is changed, not only will the downstream (demand) variables be corrected, but so will the upstream (supply) variables: # 14, 13, and 11.

Allowed values for IACT1 and IACT2 are as follows:

	<u>IACT1</u>	<u>IACT2</u>
	6	0, 7, 8, 9, 10
Change Electric	{ 7	0, 6, 8, 9, 10
Generation Mix		0, 6, 7, 9, 10
or Total		0, 6, 7, 8, 10
		0, 6, 7, 8, 9
	10	
	18	0 (See Discussion)
Change Direct Coal Use	21	0
Change Direct Oil and Gas	22	0 (See Discussion)
Reallocate	{ 23	24, 25
Electricity		23, 25
		23, 24
Reallocate	{ 26	27, 28
Oil and Gas		26, 28
		26, 27

A decision structure for these corrections is incorporated into the program to permit rapid interactive changes to be made while the program automatically maintains the consistency requirement. The demand allocation has already been mentioned. In the case of oil and gas, a change to variables #10 or # 22 will result in a change to variable # 18. If the effective change in variable # 18 (total delivered oil and gas) is to lower it, the impact is passed back to lower the liquid and gas resource (# 12 and # 17). If the change is an increase in # 18, the concomitant change is made instead to coal synfuels (variables # 16, 15, and 11). The special command # 18 was provided to reverse this allocation when desired; oil and gas demand can thus be increase by transferring from synfuels to the direct oil and gas resource category.

The initial data set determines some of the characteristics of these re-allocations. The proportion of each fuel to each final demand category is kept the same unless specifically changed. Three of the electric generation categories have their efficiencies calculated according to the initial values of input fuel and output generation in each reference year, so a change in efficiency over time can be simulated.

Time Dependence

As changes are made to activity levels in the various reference years, the user must aim towards developing reasonable time-series in each variable. If one activity in one year is altered, the adjoining years' values will likely also require adjustments to maintain smooth variation in time. Experience is helpful in anticipating the disruptions to associated variables when some change is made. That is, a change in one variable may disrupt the time-series of some other variable. For example, when one resource is to be gradually phased out, another must be brought in to replace it if the total resource consumption is to be maintained

constant. This procedure can be less than straightforward, however, because of the interdependencies which the program's decision structure are keeping consistent. The user will have to tune the quantities until all variables exhibit satisfactory time-series.

There is one additional command which scales every activity variable in a given reference year: if $IACT1 = 0$, then all activities in the reference year IYEAR are multiplied by AMT. This command is useful as the first step in making large changes in the overall level of energy resource consumption.

Interpolation

On command TPRESG will interpolate values for all variables in all of the 100 years, based on the 10 reference year values that have been set for each variable.

Figure C-3. Reference years.

This procedure results in a specification of every energy activity variable in every one of the 101 years. (A library cubic spline interpolation routine is used.)

Calculation of Effects

Once a satisfactory scenario is completed, the user can instruct TPRESG to calculate the "effects". Each energy activity in each year is then multiplied by appropriate coefficients, to tally total annual system cost, and health and environmental emissions and effects for that scenario.

TABLE C-2

COST COEFFICIENTS

Associated Energy Activity Variable #			Cost Cost Set Coeff.									
			#	#	\$	YR.	\$	YR.	\$	YR.		
Fusion		6	c	1	1	2400.	2000	1440.	2020	760.	2075	
Renew.	Capital Cost	7	c	1	2	600.	1990	2000.	2010			
Fission		8	c	1	3	600.						
Coal		9	c	1	4	450.						
Oil & Gas		10	c	1	5	300.						
	O&M	6	e	1	6	0.4						
		7	e	1	7	1.0						
"		8	e	1	8	0.4						
		9	e	1	9	.05						
		10	e	1	10	0.25						
Trans & Dist Cap.		20	c	1	11	250.						
Trans & Dist O&M.		20	e	1	12	0.52						
Fusion fuel		6	e	1	13	0.2						
Fission fuel		8	e	1	14	1.25	1975	2.40	2000	2.70	2020	
Coal (at mine)		11	t	1	15	1.00	1975	4.0	2075			
Coal Transport		13	t	1	16	0.12						
		--	t	1	17	0.0						
Synfuel Cap.		16	t	1	18	2.0						
Synfuel O&M.		16	t	1	19	0.4						
Oil & Gas		17	t	1	20	2.00	1975	5.50	2075			
				2	1	2400.	2000	1000.	2020	650.	2050	
				3	1	1600.	2000	750.	2020	650.	2050	
				4	1	2400.	1990	1000.	2010	650.	2040	
				5	1	1600.	1990	750.	2010	650.	2040	

c - \$/kW
e - \$/10⁶ BTU Electric
t - \$/10⁶ BTU Thermal Output

TABLE C-3

HEALTH & ENVIRONMENTAL EMISSIONS AND EFFECTS COEFFICIENTS

Energy Activity	Index Number	6	7	8	9	10	11	16 (b)	21	12	26	27	28
<u>RADIATION</u>													
Population Exposure	10^3 man-rem	27.0	---	27.0	---	---	---	---	---	---	---	---	---
Kr ⁸⁵ Production	10^6 curies	---	---	24.6	---	---	---	---	---	---	---	---	---
Tritium Production	10^5 curies	1.63	---	8.8	---	---	---	---	---	---	---	---	---
Hi Rad Waste	10^3 ft ³	---	---	5.5	---	---	---	---	---	---	---	---	---
Spent Blanket	10^3 ft ³	55.0	---	---	---	---	---	---	---	---	---	---	---
<u>AIR POLLUTION</u>													
CO ₂	10^6 tons	---	---	---	356	302	0.1	---	112.	---	85	85	75
CO	10^3 tons	---	---	.008	65	0.7	4.0	2.	38	2.5	18	13.4	400
NO _x	"	---	---	1.3	1174	1320	4.8	130.	290	80	43	200	45
SO ₂	"	---	---	---	643	1138	3.4	47.2	603	21.3	113	393	15
Particulates	"	---	---	0.6	66	97	17.2	-11.5	1240	2.9	36	77	62
Hydrocarbons	"	---	---	0.03	19.6	33	2.6	-1.7	19.1	24	18	10	47
Land Use	10^6 acre·yr	0.89	1.07	0.89	0.88	0.87	0.26	-0.05	.0008	0.08	---	---	---
Deaths	#	0.17	---	6.4	4.8	2.4	81	-91	0.4	0.6	---	---	---
Injuries	10^3	0.017	---	0.2	0.44	0.2	1.6	-0.9	0.03	0.05	---	---	---
Man Days Lost	10^3	0.33	---	11.2	17.4	8.9	112	-89.	1.05	2.3	---	---	---
Solid Waste	10^6	---	---	3.4	58.7	---	1.0	8.6	.003	0.04	---	---	---

a) Units are per 10^{15} BTU per year

b) Negative coefficients give credit for coal transportation effects included in #11 but which do not apply for synfuel production

Table C-2 gives the cost information that must be provided to the program. 1) If a single cost number is given (e.g., cost coefficient # 4 = \$450,) and no year is specified, then that cost is treated as constant in time. 2) If two or three pairs of cost-year coordinates are specified, a straight line interpolation is performed for times between the points that are given. In cases where the points given do not cover the entire time period from 1975 to 2075 (e.g., # 14 stops at 2020) the constant value is extended through those years outside the given range.

Up to five distinct "sets" of costs can be used simultaneously. Each successive cost set is the same as the previous one, with any number of changes specified. In the case shown in Table C-2, cost set # 2 is the same as # 1, but with the fusion capital cost (cost coefficient # 1) having a different value. In this example, only coefficient # 1 has been varied in each of the five different sets of costs.

Cost Calculation

In each of the 101 years, the annual energy system cost is computed by multiplying each of the energy activity variables by an appropriate cost coefficient and adding. This is done separately for each cost set. Capital costs (coefficient # 1 - 5, and 11) are first annualized, assuming 30-year plant life (capital recovery factor CRF = 15% and a plant factor PF of 0.8).

$$\text{Annualized Capital Cost } \left(\frac{\$}{10^6 \text{ BTU}} \right) = \text{Capital Cost } \left(\frac{\$}{\text{kW}} \right) \times \frac{\text{CRF}}{29.9 \times \text{PF}}$$

Cumulative discounted present value of these annual costs streams are also calculated

$$\text{DPV}(R, Y_0) = \sum_{y=Y_0}^{2076} C(y) \frac{1}{(1 + R)^{y-Y_0}}$$

where $C(y)$ is the annual system cost in the year y , Y_0 is the starting year for the calculation, and R is the discount rate. Four different start years (1975, 1995, 2010, and 2020) and four different discount rates (0, 5, 10, and 15%) are applied for each cost set (see Figure C-5). Outputs for costs are in billions of dollars. Note that $\$1/10^6 \text{ BTU} = \$10^9/10^{15} \text{ BTU}$, therefore:

$$\text{Total Annual System Cost } \left(\frac{\$10^9}{\text{year}} \right) = \sum_i \text{Energy}_i \left(\frac{10^{15} \text{ BTU}}{\text{year}} \right) \times \text{Cost}_i \left(\frac{\$}{10^6 \text{ BTU}} \right)$$

Health and Environmental - Emissions and Effects

Coefficients are shown in Table C-3. The Energy Modeling Data Base (EMDB) provides highly specific coefficients at the individual process level for various emissions and effects resulting from energy conversion and use activities.* These coefficients are in the form of amount of pollutant, or number of injuries, per BTU of energy flow. Coefficients were taken from the Data Base with an attempt to select the most representative or reasonable estimates for the more aggregated energy flow activities in TPRESG. Resulting totals should give an approximate feeling for the relative burdens to the environment imposed in the different scenarios. It should be noted, however, that it is not possible to establish truly meaningful coefficients at that level of aggregation because the individual technologies vary greatly in their characteristic emissions. (Base case fuel allocations in more detailed studies** were used to arrive at prorated coefficients for the highly aggregated TPRESG energy activity variables.)

* Energy Modeling Data Base, User's Manual, Energy Environmental Group, M. Goldberg, BNL Report No. 19200.

** Sourcebook, BNL Report No. 50483.

The Program Flow Chart is shown in Figure C-4. After reading the input data, the user can choose from among eight interactive commands. Most are self-explanatory. The Activity Change (# 1) stays within its own loop for successive instructions, until a command is given with IACT1 = -1. The restart (# 5) permits a fresh start under the initial conditions, if needed. The Selected Print (# 7), which was used to type Table C-1, allows any number of variables to be printed quickly, and the full output (# 4) has an option to print various (any from among the four) subsections of the full output. (Figure C-5)

The Interpolate (# 2) and Effects (# 3) must be used prior to any Print-out or Output File Write (# 6), during which a line of test can be input as the case title. Figure C-5 gives the complete printout which results from the print command (# 4). Several additional features are:

1) Average annual percentage growth rates implied by the change in the activity variable from that reference year to the next reference year. For example, the increase of coal from 13.37 Quad in 1975 to 25.80 Quad in 1980 represents an average annual % growth rate of 13.1% over that five-year period.

2) The electrification ratio given in the third row, adjacent to total delivered electricity, is calculated thus:

$$\text{Electrification Ratio} = \frac{\text{Electricity}}{\text{Liq. \& Gas.} + \text{Coal} + \text{Electricity}}$$

where all fuels are as delivered (variables # 22, 21, and 20.)

3) Total resource and fuel use are defined as variables # 33 and 32, respectively, and are defined on Figure C-2.

Figure C-4. TPRESG program flow chart.

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11201 HIGH-ZEG BASE CASE

FOSSIL RESOURCES TOTAL USE

ELECTRIC GENERATION RESOURCE USE (THERMAL)

YEAR	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(6.6%)	6.48	8.82	1.65	0.00
1980	58.66	18.59	(5.6%)	6.98	13.03	5.34	0.00
1985	66.50	24.58	(6.4%)	6.70	14.86	11.33	0.00
1990	66.80	33.91	(4.5%)	6.15	18.00	23.97	0.00
2000	65.90	53.30	(2.5%)	5.30	19.14	28.86	0.00
2010	63.20	68.70	(.2%)	5.00	20.90	33.80	0.00
2020	63.10	70.40	(.1%)	4.71	22.00	35.80	0.00
2040	63.10	72.30	(.0%)	4.36	22.90	36.80	0.00
2060	63.10	72.35	(0.0%)	4.36	22.90	36.80	0.00
2075	63.10	72.35		4.36	22.90	36.80	0.00

ELECTRICAL GENERATION

YEAR	LIO & GAS	COAL	FISSION	RENEW	CTR
1975	2.43	3.15 (6.2%)	5.33 (23.4%)	1.04 (1.1%)	0.00 (0.0%)
1980	2.30	4.30 (3.8%)	1.71 (15.7%)	1.10 (4.5%)	0.00 (0.0%)
1985	2.20	5.20 (3.8%)	3.74 (15.4%)	1.38 (5.3%)	0.00 (0.0%)
1990	2.10	6.30 (.6%)	8.06 (2.5%)	1.80 (3.4%)	0.00 (0.0%)
2000	1.80	6.70 (.9%)	10.39 (1.6%)	2.52 (1.7%)	0.00 (0.0%)
2010	1.70	7.30 (.5%)	12.20 (.8%)	3.00 (.6%)	0.00 (0.0%)
2020	1.60	7.70 (.2%)	13.20 (.1%)	3.20 (0.0%)	0.00 (0.0%)
2040	1.50	8.00 (0.0%)	13.60 (0.0%)	3.20 (0.0%)	0.00 (0.0%)
2060	1.50	8.00 (0.0%)	13.60 (0.0%)	3.20 (0.0%)	0.00 (0.0%)
2075	1.50	8.00	13.60	3.20	0.00

YEAR	COAL TO SYNFUELS	TOTAL ENERGY CARRIERS (DIRECT USE)	ELECTRICITY	ELECTR	
		LIC & GAS	COAL (IND)	RATIO	
1975	0.00 (0.0%)	41.56	4.15	6.51 (5.3%)	.12
1980	0.00 (0.0%)	46.40	5.00	8.47 (5.7%)	.14
1985	2.15 (28.0%)	55.20	6.70	11.27 (5.4%)	.15
1990	8.71 (8.9%)	60.30	9.40	14.80 (2.9%)	.18
2000	21.21 (3.5%)	68.50	12.00	19.80 (1.2%)	.20
2010	30.00 (1.0%)	72.00	13.80	22.40 (.6%)	.21
2020	33.00 (.1%)	74.20	14.30	23.80 (.1%)	.21
2040	34.00 (0.0%)	75.20	14.30	24.30 (0.0%)	.21
2060	34.00 (0.0%)	75.20	14.30	24.30 (0.0%)	.21
2075	34.00	75.20	14.30	24.30	.21

FINAL CONSUMPTION END USE

YEAR	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	12.40	14.00	20.00	4.60	3.80	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.80	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	28.10	34.70	10.30	12.10	1.40
2040	11.30	28.60	35.30	10.40	12.30	1.60
2060	11.30	28.60	35.30	10.40	12.30	1.60
2075	11.30	28.60	35.30	10.40	12.30	1.60

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94 (3.8%)
1980	17.00	22.80	20.17	59.97	85.73 (4.3%)
1985	17.20	32.80	23.37	73.37	106.04 (4.0%)
1990	18.50	39.60	26.40	84.50	129.82 (1.8%)
2000	20.30	48.00	32.00	100.30	155.26 (1.2%)
2010	21.30	52.80	34.10	108.20	174.30 (.2%)
2020	21.70	54.50	36.10	112.30	178.44 (.1%)
2040	21.70	55.20	36.90	113.80	181.34 (.0%)
2060	21.70	55.20	36.90	113.80	181.39 (0.0%)
2075	21.70	55.20	36.90	113.80	181.39

CUM. RESOURCE USE 1975-2024 1995-2044 1975-2075

TOTAL COAL	2414.	3334.	6090.
TOTAL LIO & GAS	3176.	3187.	6395.

Figure C-5. Energy activity levels
national annual totals (E15 BTU).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1	148.1	148.1
1980	191.5	191.5	191.5	191.5	191.5
1985	254.2	254.2	254.2	254.2	254.2
1990	333.7	333.7	333.7	333.7	333.7
2000	461.4	461.4	461.4	461.4	461.4
2010	574.5	574.5	574.5	574.5	574.5
2020	639.4	639.4	639.4	639.4	639.4
2040	733.7	733.7	733.7	733.7	733.7
2060	817.5	817.5	817.5	817.5	817.5
2075	880.2	880.2	880.2	880.2	880.2

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST					
TO 1975					
0%	61238.2	61238.2	61238.2	61238.2	61238.2
5%	7483.0	7483.0	7483.0	7483.0	7483.0
10%	2868.6	2868.6	2868.6	2868.6	2868.6
15%	1691.3	1691.3	1691.3	1691.3	1691.3
TO 1995					
0%	56099.2	56099.2	56099.2	56099.2	56099.2
5%	11660.7	11660.7	11660.7	11660.7	11660.7
10%	5552.2	5552.2	5552.2	5552.2	5552.2
15%	3649.0	3649.0	3649.0	3649.0	3649.0
TO 2010					
0%	48831.6	48831.6	48831.6	48831.6	48831.6
5%	13501.5	13501.5	13501.5	13501.5	13501.5
10%	6957.9	6957.9	6957.9	6957.9	6957.9
15%	4729.4	4729.4	4729.4	4729.4	4729.4
TO 2020					
0%	42766.7	42766.7	42766.7	42766.7	42766.7
5%	14017.7	14017.7	14017.7	14017.7	14017.7
10%	7504.6	7504.6	7504.6	7504.6	7504.6
15%	5145.6	5145.6	5145.6	5145.6	5145.6

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARC)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	17.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	329.40	300.12	107.36	67.10	0.00	0.00
2020	356.40	324.72	116.16	72.60	0.00	0.00
2040	367.20	334.56	119.68	74.80	0.00	0.00
2060	367.20	334.56	119.68	74.80	0.00	0.00
2075	367.20	334.56	119.68	74.80	0.00	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.46	15.21	34.17	30.12	23.49	4.15
2020	10.79	15.99	35.11	30.84	24.28	4.26
2040	10.95	16.26	35.59	31.15	24.38	4.29
2060	10.95	16.26	35.59	31.15	24.38	4.29
2075	10.95	16.26	35.59	31.15	24.38	4.29

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	18.01	1.54	35.51	2.34	.28
1985	22.94	1.96	45.05	2.94	.36
1990	30.36	2.36	57.56	3.68	.48
2000	37.06	3.21	81.87	5.16	.60
2010	43.93	3.95	101.89	6.40	.71
2020	45.63	3.92	103.22	6.43	.75
2040	46.63	4.02	105.07	6.60	.78
2060	46.64	4.02	105.25	6.60	.78
2075	46.64	4.02	105.95	6.60	.78

Figure C-5. (Continued)

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APPENDIX D

SCENARIO PRINTOUTS

1970 HIGH-7FC BASE CASE

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(6.6%)	6.48	8.82	1.65	0.00
1980	58.66	18.59	(5.6%)	6.98	13.03	5.34	0.00
1985	66.50	24.58	(6.4%)	6.70	14.86	11.33	0.00
1990	66.80	33.91	(4.5%)	6.15	18.00	23.97	0.00
2000	65.90	53.30	(2.5%)	5.30	19.14	28.86	0.00
2010	63.20	68.70	(.2%)	5.00	20.90	33.80	0.00
2020	63.10	70.40	(.1%)	4.71	22.00	35.80	0.00
2040	63.10	72.30	(.0%)	4.36	22.90	36.80	0.00
2060	63.10	72.35	(0.0%)	4.36	22.90	36.80	0.00
2075	63.10	72.35		4.36	22.90	36.80	0.00

YEAR	ELECTRIC GENERATION					
	LIO & GAS	COAL	FISSION	RENEW		CTR
1975	2.43	3.15	(6.2%)	1.53	(23.4%)	0.00
1980	2.30	4.30	(3.8%)	1.71	(15.7%)	0.00
1985	2.20	5.20	(3.8%)	3.74	(15.4%)	0.00
1990	2.10	6.30	(.6%)	8.66	(2.5%)	0.00
2000	1.80	6.70	(.9%)	10.39	(1.6%)	0.00
2010	1.70	7.30	(.5%)	12.70	(.8%)	0.00
2020	1.60	7.70	(.2%)	13.26	(.1%)	0.00
2040	1.50	8.00	(0.0%)	13.60	(0.0%)	0.00
2060	1.50	8.00	(0.0%)	13.60	(0.0%)	0.00
2075	1.50	8.00		13.60		0.00

YEAR	COAL TO SYNGASELS		TOTAL ENERGY CARRIERS (DIRECT USE)			ELECTRICITY RATIO
	LIO & GAS	COAL (IND)				
1975	0.00	(0.0%)	41.56	4.15	6.51	(5.3%)
1980	0.00	(0.0%)	46.40	5.00	8.47	(5.7%)
1985	2.15	(20.0%)	55.20	6.70	11.27	(5.4%)
1990	8.71	(8.9%)	68.30	9.40	14.80	(2.9%)
2000	21.21	(3.5%)	68.50	12.00	19.80	(1.2%)
2010	30.00	(1.0%)	72.00	13.80	22.40	(.6%)
2020	33.00	(.1%)	74.20	14.30	23.80	(.1%)
2040	34.00	(0.0%)	75.20	14.30	24.30	(0.0%)
2060	34.00	(0.0%)	75.20	14.30	24.30	(0.0%)
2075	34.00		75.20	14.30	24.30	

FINAL CONSUMPTION END USE

YEAR	LIO & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.69	3.78	2.71	.02
1980	12.40	14.00	20.00	4.60	3.80	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.00	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	28.10	34.76	10.30	12.10	1.40
2040	11.30	28.60	35.30	10.40	12.30	1.60
2060	11.30	28.60	35.30	10.40	12.30	1.60
2075	11.30	28.60	35.30	10.40	12.30	1.60

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.72	18.51	52.22	70.24
1980	17.00	22.80	20.17	59.97	85.73
1985	17.20	32.80	23.37	73.37	106.04
1990	18.50	39.60	26.60	84.50	129.82
2000	20.30	48.00	32.00	100.30	155.26
2010	21.30	52.00	34.10	107.40	174.30
2020	21.70	54.50	36.10	112.30	178.44
2040	21.70	55.20	36.90	113.80	181.34
2060	21.70	55.20	36.90	113.80	181.39
2075	21.70	55.20	36.90	113.80	181.39

CUM. RESOURCE USE

1975-2076 1995-2044 1975-2075

TOTAL COAL	2414.	3334.	6090.
TOTAL LIO & GAS	3176.	3187.	6395.

Figure D-1. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (\$9 DOLLARS)

YEAR	COST ASSUMPTIONS \$/TS		
	SC11	SC12	SC13
1975	148.1	148.1	148.1
1980	191.5	191.5	191.5
1985	254.2	254.2	254.2
1990	333.7	333.7	333.7
2000	461.4	461.4	461.4
2010	574.5	574.5	574.5
2020	639.4	639.4	639.4
2040	733.7	733.7	733.7
2060	817.5	817.5	817.5
2075	880.2	880.2	880.2

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975				
0%	61238.2	61238.2	61238.2	
5%	7483.0	7483.0	7483.0	
10%	2868.6	2868.6	2868.6	
15%	1691.3	1691.3	1691.3	
TO 1995				
0%	56099.2	56099.2	56099.2	
5%	11660.7	11660.7	11660.7	
10%	5552.2	5552.2	5552.2	
15%	3649.0	3649.0	3649.0	
TO 2010				
0%	48831.6	48831.6	48831.6	
5%	13501.5	13501.5	13501.5	
10%	6957.9	6957.9	6957.9	
15%	4729.4	4729.4	4729.4	
TO 2020				
0%	42766.7	42766.7	42766.7	
5%	14017.7	14017.7	14017.7	
10%	7504.6	7504.6	7504.6	
15%	5145.6	5145.6	5145.6	

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP C3	KR-HS C6	TRIT C5	RAD WASTE C3	SPENT BLANKET C3	(SPARE)
	MAN REM CU FT	CURTIES CU FT	CURTIES CU FT	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	329.40	300.12	107.36	67.10	0.00	0.00
2020	356.40	324.72	116.16	72.60	0.00	0.00
2040	367.20	334.56	119.68	74.80	0.00	0.00
2060	367.20	334.56	119.68	74.80	0.00	0.00
2075	367.20	334.56	119.68	74.80	0.00	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.46	15.21	34.17	30.12	23.49	4.15
2020	10.79	15.99	35.11	30.84	24.28	4.26
2040	10.95	16.26	35.59	31.15	24.38	4.29
2060	10.95	16.26	35.59	31.15	24.38	4.29
2075	10.95	16.26	35.59	31.15	24.38	4.29
YEAR	LAND USE E6 ACRES	DEATHS C3	INJURIES C3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	18.01	1.58	35.51	2.34	.20	
1985	22.94	1.96	45.05	2.94	.36	
1990	30.36	2.36	57.56	3.68	.48	
2000	37.86	3.21	81.87	5.16	.60	
2010	43.93	3.95	101.89	6.40	.71	
2020	45.63	3.92	103.22	6.43	.75	
2040	46.63	4.02	105.87	6.60	.78	
2060	46.64	4.02	105.95	6.60	.78	
2075	46.64	4.02	105.95	6.60	.78	

Figure D-1. Continued.

H201 HIGH-ZEG BASE CASE

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(6.6%)	6.48	8.82	1.65	0.00
1980	58.66	18.59	(5.6%)	6.98	13.03	5.34	0.00
1985	66.50	24.58	(6.4%)	6.70	14.86	11.33	0.00
1990	66.80	33.91	(4.5%)	6.15	14.00	23.97	0.00
2000	65.90	53.30	(2.5%)	5.30	19.14	28.86	0.00
2010	63.20	68.70	(.2%)	5.00	20.90	33.80	0.00
2020	63.10	70.40	(.1%)	4.71	22.00	35.80	0.00
2040	63.10	72.30	(.0%)	4.36	22.90	36.80	0.00
2060	63.10	72.35	(0.0%)	4.36	22.90	36.80	0.00
2075	63.10	72.35		4.36	22.90	36.80	0.00

ELECTRICAL GENERATION							
YEAR	LIO & GAS	COAL	FISSION	RENEW			CTR
1975	2.43	3.15	(6.2%)	.53	(23.4%)	1.04	(1.1%)
1980	2.30	4.30	(3.8%)	1.71	(15.7%)	1.10	(4.5%)
1985	2.20	5.20	(3.8%)	3.74	(15.4%)	1.38	(5.3%)
1990	2.10	6.30	(.6%)	8.06	(2.5%)	1.80	(3.4%)
2000	1.80	6.70	(.9%)	10.39	(1.6%)	2.52	(1.7%)
2010	1.70	7.30	(.5%)	12.20	(.8%)	3.00	(.6%)
2020	1.60	7.70	(.2%)	13.20	(.1%)	3.20	(0.0%)
2040	1.50	8.00	(0.0%)	13.60	(0.0%)	3.20	(0.0%)
2060	1.50	8.00	(0.0%)	13.60	(0.0%)	3.20	(0.0%)
2075	1.50	8.00		13.60		3.20	

COAL TO SYNFUELS				TOTAL ENERGY CARRIERS (DIRECT USE)			
YEAR	LIO & GAS	COAL		LIO & GAS	COAL	IND	ELECTRICITY RATIO
1975	0.00	(0.0%)		41.56	4.15	6.51	(5.3%)
1980	0.00	(0.0%)		46.40	5.00	8.47	(5.7%)
1985	2.15	(28.0%)		55.20	6.70	11.27	(5.4%)
1990	8.71	(8.9%)		60.30	9.40	14.80	(2.9%)
2000	21.21	(3.5%)		68.50	12.00	19.80	(1.2%)
2010	30.00	(1.0%)		72.00	13.80	22.40	(.6%)
2020	33.00	(.1%)		74.20	14.30	23.80	(.1%)
2040	34.00	(0.0%)		75.20	14.30	24.30	(0.0%)
2060	34.00	(0.0%)		75.20	14.30	24.30	(0.0%)
2075	34.00			75.20	14.30	24.30	

FINAL CONSUMPTION END USE						
YEAR	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	12.40	14.00	20.00	4.60	3.80	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.80	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	28.10	34.70	10.30	12.10	1.40
2040	11.30	28.60	35.30	10.40	12.30	1.60
2060	11.30	28.60	35.30	10.40	12.30	1.60
2075	11.30	28.60	35.30	10.40	12.30	1.60

TOTALS						
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE	
1975	16.98	16.73	18.51	52.22	70.94	(3.8%)
1980	17.00	22.80	20.17	59.97	85.73	(4.3%)
1985	17.20	32.80	23.37	73.37	106.04	(4.0%)
1990	18.50	39.60	26.40	84.50	129.82	(1.8%)
2000	20.30	48.00	32.00	100.30	155.26	(1.2%)
2010	21.30	52.80	34.10	108.20	174.30	(.2%)
2020	21.70	54.50	36.10	112.30	178.44	(.1%)
2040	21.70	55.20	36.90	113.80	181.34	(.0%)
2060	21.70	55.20	36.90	113.80	181.39	(0.0%)
2075	21.70	55.20	36.90	113.80	181.39	

CUM. RESOURCE USE			
1975-2024	1995-2044	1975-2075	
TOTAL COAL	2414.	3334.	6090.
TOTAL LIO & GAS	3176.	3187.	6395.

Figure D-2. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS		
	SET1	SET2	SET3
1975	148.1	148.1	148.1
1980	191.5	191.5	191.5
1985	254.2	254.2	254.2
1990	333.7	333.7	333.7
2000	461.4	461.4	461.4
2010	574.5	574.5	574.5
2020	639.4	639.4	639.4
2040	733.7	733.7	733.7
2060	817.5	817.5	817.5
2075	880.2	880.2	880.2

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	61238.2	61238.2	61238.2
5%	7483.0	7483.0	7483.0
10%	2868.6	2868.6	2868.6
15%	1691.3	1691.3	1691.3
TO 1995			
0%	56099.2	56099.2	56099.2
5%	11660.7	11660.7	11660.7
10%	5552.2	5552.2	5552.2
15%	3649.0	3649.0	3649.0
TO 2010			
0%	48831.6	48831.6	48831.6
5%	13501.5	13501.5	13501.5
10%	6957.9	6957.9	6957.9
15%	4729.4	4729.4	4729.4
TO 2020			
0%	42766.7	42766.7	42766.7
5%	14017.7	14017.7	14017.7
10%	7504.6	7504.6	7504.6
15%	5145.6	5145.6	5145.6

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	329.40	300.12	107.36	67.10	0.00	0.00
2020	356.40	324.72	116.16	72.60	0.00	0.00
2040	367.20	334.56	119.68	74.80	0.00	0.00
2060	367.20	334.56	119.68	74.80	0.00	0.00
2075	367.20	334.56	119.68	74.80	0.00	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.46	15.21	34.17	30.12	23.49	4.15
2020	10.79	15.99	35.11	30.84	24.28	4.26
2040	10.95	16.26	35.59	31.15	24.38	4.29
2060	10.95	16.26	35.59	31.15	24.38	4.29
2075	10.95	16.26	35.59	31.15	24.38	4.29
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	18.01	1.58	35.51	2.34	.28	
1985	22.94	1.96	45.05	2.94	.36	
1990	30.36	2.36	57.56	3.68	.48	
2000	37.86	3.21	81.87	5.16	.60	
2010	43.93	3.95	101.89	6.40	.71	
2020	45.63	3.92	103.22	6.43	.75	
2040	46.63	4.02	105.87	6.60	.78	
2060	46.64	4.02	105.95	6.60	.78	
2075	46.64	4.02	105.95	6.60	.78	

Figure D-2. Continued.

HZ02 IMPORTS, ALLOWED, NO FUSION, NO FBR

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(6.6%)		6.48	8.82	1.65	0.00
1980	58.66	18.59(5.6%)		6.98	13.03	5.34	0.00
1985	66.50	24.58(6.4%)		6.70	14.86	11.33	0.00
1990	66.80	33.91(4.5%)		6.15	18.00	23.97	0.00
2000	65.90	53.30(2.5%)		5.30	19.14	28.86	0.00
2010	63.20	68.13(1.9%)		5.00	23.19	31.58	0.00
2020	63.10	82.20(1.4%)		4.71	33.43	24.95	0.00
2040	63.10	107.76(.1%)		4.36	57.25	4.33	0.00
2060	63.10	110.71(.1%)		4.36	60.11	1.62	0.00
2075	63.10	112.48		4.36	61.83	.00	0.00

YEAR	ELECTRICAL GENERATION					
	LIQ & GAS	COAL	FISSION	RENEW	CTR	
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)	0.00(0.0%)	
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)	0.00(0.0%)	
1985	2.20	5.20(3.8%)	3.74(15.4%)	1.38(5.3%)	0.00(0.0%)	
1990	2.10	6.30(.6%)	8.06(2.5%)	1.80(3.4%)	0.00(0.0%)	
2000	1.80	6.70(1.9%)	10.39(.9%)	2.52(1.7%)	0.00(0.0%)	
2010	1.70	8.10(3.7%)	11.40(-2.1%)	3.00(.6%)	0.00(0.0%)	
2020	1.60	11.70(2.7%)	9.20(-8.7%)	3.20(0.0%)	0.00(0.0%)	
2040	1.50	20.00(.2%)	1.60(-4.9%)	3.20(0.0%)	0.00(0.0%)	
2060	1.50	21.00(.2%)	.60(****%)	3.20(0.0%)	0.00(0.0%)	
2075	1.50	21.60	.00	3.20	0.00	

YEAR	COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECT RATIO
	LIQ & GAS	COAL(IND)	ELECTRICITY		
1975	0.00(0.0%)	41.56	4.15	6.51(5.3%)	.12
1980	0.00(0.0%)	46.40	5.00	8.47(5.7%)	.14
1985	2.15(28.0%)	55.20	6.70	11.27(5.4%)	.15
1990	8.71(8.9%)	60.30	9.40	14.80(2.9%)	.18
2000	21.21(3.5%)	68.50	12.00	19.80(1.2%)	.20
2010	30.00(1.0%)	72.00	13.80	22.40(.6%)	.21
2020	33.00(.1%)	74.20	14.30	23.80(.1%)	.21
2040	34.00(0.0%)	75.20	14.30	24.30(0.0%)	.21
2060	34.00(0.0%)	75.20	14.30	24.30(0.0%)	.21
2075	34.00	75.20	14.30	24.30	.21

FINAL CONSUMPTION END USE

YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	12.40	14.00	20.00	4.60	3.80	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.00	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	28.10	34.70	10.30	12.10	1.40
2040	11.30	28.60	35.30	10.40	12.30	1.60
2060	11.30	28.60	35.30	10.40	12.30	1.60
2075	11.30	28.60	35.30	10.40	12.30	1.60

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.8%)
1980	17.00	22.80	20.17	59.97	85.73(4.3%)
1985	17.20	32.80	23.37	73.37	106.04(4.0%)
1990	18.50	39.60	26.40	84.50	129.82(1.8%)
2000	20.30	48.00	32.00	100.30	155.26(1.0%)
2010	21.30	52.80	34.10	108.20	171.51(.4%)
2020	21.70	54.50	36.10	112.30	179.39(.1%)
2040	21.70	55.20	36.90	113.80	184.33(.0%)
2060	21.70	55.20	36.90	113.80	184.57(.0%)
2075	21.70	55.20	36.90	113.80	184.72

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL	2523.	4042.	7998.
TOTAL LIQ & GAS	3176.	3187.	6395.

Figure D-3. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS		
	SET1	SET2	SET3
1975	148.1	148.1	148.1
1980	191.5	191.5	191.5
1985	254.2	254.2	254.2
1990	333.7	333.7	333.7
2000	461.4	461.4	461.4
2010	570.9	570.9	570.9
2020	654.4	654.4	654.4
2040	800.1	800.1	800.1
2060	912.3	912.3	912.3
2075	997.4	997.4	997.4

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST			
TO 1975			
0%	65368.8	65368.8	65368.8
5%	7597.1	7597.1	7597.1
10%	2874.1	2874.1	2874.1
15%	1691.7	1691.7	1691.7
TO 1995			
0%	60228.9	60228.9	60228.9
5%	11962.6	11962.6	11962.6
10%	5588.5	5588.5	5588.5
15%	3654.2	3654.2	3654.2
TO 2010			
0%	52981.9	52981.9	52981.9
5%	14152.3	14152.3	14152.3
10%	7134.7	7134.7	7134.7
15%	4796.4	4796.4	4796.4
TO 2020			
0%	46887.0	46887.0	46887.0
5%	15047.7	15047.7	15047.7
10%	7934.5	7934.5	7934.5
15%	5392.5	5392.5	5392.5

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	307.80	280.44	100.32	62.70	0.00	0.00
2020	248.40	226.32	80.96	50.60	0.00	0.00
2040	43.20	39.36	14.08	8.80	0.00	0.00
2060	16.20	14.76	5.28	3.30	0.00	0.00
2075	.00	.00	.00	.00	0.00	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.74	15.26	35.11	30.63	23.53	4.17
2020	12.22	16.30	39.86	33.45	24.74	4.36
2040	15.22	17.18	49.83	38.99	25.78	4.62
2060	15.58	17.26	51.02	39.64	25.89	4.65
2075	15.79	17.31	51.73	40.03	25.96	4.66

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	18.01	1.58	35.51	2.34	.28
1985	22.94	1.96	45.05	2.94	.36
1990	30.36	2.36	57.56	3.68	.48
2000	37.86	3.21	81.87	5.16	.60
2010	43.77	3.90	101.17	6.34	.75
2020	48.66	4.87	123.06	7.78	.99
2040	55.73	6.87	165.49	10.64	1.48
2060	56.48	7.11	170.45	10.98	1.54
2075	56.94	7.25	173.42	11.18	1.57

Figure D-3. Continued.

HZ03 NO IMPORT, NO FBR, NO FUSION -- ULTRA HIGH COAL

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.5%)		6.48	8.82	1.65	0.00
1980	49.98	26.32(8.3%)		6.98	13.03	5.34	0.00
1985	49.45	39.84(6.3%)		6.70	14.86	11.33	0.00
1990	47.79	54.48(3.2%)		6.15	18.00	23.97	0.00
2000	41.99	74.96(3.0%)		5.30	19.14	28.86	0.00
2010	27.14	101.60(1.4%)		5.00	23.19	31.58	0.00
2020	26.11	117.19(1.1%)		4.71	33.43	24.95	0.00
2040	20.29	146.84(.1%)		4.36	57.25	4.33	0.00
2060	20.29	150.81(.1%)		4.36	60.11	1.62	0.00
2075	20.29	152.06		4.36	61.83	.00	0.00

YEAR	ELECTRICAL GENERATION						CTR
	LIQ & GAS	COAL	FISSION	RENEW			
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)		0.00(0.0%)	
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)		0.00(0.0%)	
1985	2.20	5.20(3.8%)	3.74(15.4%)	1.38(5.3%)		0.00(0.0%)	
1990	2.10	6.30(2.6%)	8.06(2.5%)	1.80(3.4%)		0.00(0.0%)	
2000	1.80	6.70(1.9%)	10.39(.9%)	2.52(1.7%)		0.00(0.0%)	
2010	1.70	8.10(3.7%)	11.40(-2.1%)	3.00(.6%)		0.00(0.0%)	
2020	1.60	11.70(2.7%)	9.20(-8.7%)	3.20(0.0%)		0.00(0.0%)	
2040	1.50	20.00(.2%)	1.60(-4.9%)	3.20(0.0%)		0.00(0.0%)	
2060	1.50	21.00(.2%)	.60(****%)	3.20(0.0%)		0.00(0.0%)	
2075	1.50	21.60	.00	3.20		0.00	

YEAR	COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY RATIO
	LIQ & GAS	COAL(IND)	LIQ & GAS	COAL(IND)	
1975	0.00(0.0%)		41.56	4.15	.12
1980	0.00(0.0%)		38.50	12.50	.14
1985	2.15(28.0%)		39.70	21.70	.16
1990	8.71(8.9%)		43.00	26.40	.18
2000	21.21(5.7%)		46.70	33.00	.20
2010	37.69(1.8%)		44.20	38.80	.21
2020	45.31(.7%)		48.50	36.30	.22
2040	52.46(.3%)		48.20	34.30	.23
2060	55.54(.2%)		50.20	32.30	.23
2075	57.08		51.20	30.30	.23

FINAL CONSUMPTION END USE

YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.70	5.40	.17
1990	8.20	16.26	18.54	7.00	7.40	.40
2000	7.04	17.73	21.13	8.80	10.00	1.00
2010	7.00	17.00	20.20	9.90	11.30	1.20
2020	7.45	10.37	22.68	10.30	12.10	1.40
2040	7.24	18.33	22.63	10.40	12.30	1.60
2060	7.54	19.09	23.56	10.40	12.30	1.60
2075	7.69	19.47	24.03	10.40	12.30	1.60

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.6%)
1980	14.09	27.92	16.66	59.47	84.78(4.1%)
1985	13.97	41.84	16.86	72.67	104.25(4.6%)
1990	15.20	50.06	18.94	84.20	131.38(1.5%)
2000	16.64	60.73	22.13	99.50	153.01(1.0%)
2010	16.90	67.10	21.40	105.40	168.92(.5%)
2020	17.75	66.77	24.08	108.60	177.39(.1%)
2040	17.64	64.93	24.23	106.80	180.60(.0%)
2060	17.94	63.69	25.16	106.79	181.86(-.0%)
2075	18.09	62.07	25.63	105.79	181.49

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL	3683.	5691.	11150.
TOTAL LIQ & GAS	1949.	1411.	3019.

Figure D-4. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS		
	SET1	SET2	SET3
1975	148.1	148.1	148.1
1980	184.1	184.1	184.1
1985	239.5	239.5	239.5
1990	321.9	321.9	321.9
2000	439.3	439.3	439.3
2010	548.9	548.9	548.9
2020	638.1	638.1	638.1
2040	779.9	779.9	779.9
2060	896.4	896.4	896.4
2075	979.2	979.2	979.2

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST			
TO 1975			
0%	63669.0	63669.0	63669.0
5%	7327.8	7327.8	7327.8
10%	2768.8	2768.8	2768.8
15%	1634.1	1634.1	1634.1
TO 1995			
0%	58728.1	58728.1	58728.1
5%	11555.0	11555.0	11555.0
10%	5367.1	5367.1	5367.1
15%	3501.3	3501.3	3501.3
TO 2010			
0%	51806.7	51806.7	51806.7
5%	13784.2	13784.2	13784.2
10%	6929.7	6929.7	6929.7
15%	4650.0	4650.0	4650.0
TO 2020			
0%	45903.7	45903.7	45903.7
5%	14704.9	14704.9	14704.9
10%	7747.8	7747.8	7747.8
15%	5264.5	5264.5	5264.5

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	E3 CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	307.80	280.44	100.32	62.70	0.00	0.00
2020	248.40	226.32	80.96	50.60	0.00	0.00
2040	43.20	39.36	14.08	8.80	0.00	0.00
2060	16.20	14.76	5.28	3.30	0.00	0.00
2075	.00	.00	.00	.00	0.00	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	0.32	18.08	14.12	8.36	2.73
1980	6.73	7.96	21.54	20.05	18.90	2.75
1985	8.16	8.47	25.99	27.16	30.75	2.96
1990	9.31	9.54	29.54	31.43	37.67	3.16
2000	10.39	10.95	32.73	36.23	45.75	3.31
2010	11.31	10.96	35.87	40.39	53.18	3.08
2020	12.62	12.19	40.46	41.98	50.79	3.24
2040	15.30	12.74	49.72	46.15	49.27	3.28
2060	15.59	13.14	50.91	46.04	47.02	3.33
2075	15.66	13.30	51.32	45.45	44.66	3.33

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	19.34	2.20	47.64	3.19	.29
1985	25.56	3.19	69.02	4.63	.37
1990	34.20	4.02	89.98	5.95	.50
2000	41.59	4.96	115.90	7.55	.62
2010	49.36	6.15	149.10	9.59	.83
2020	54.41	6.96	170.59	10.92	1.09
2040	61.88	8.93	215.61	13.87	1.62
2060	62.80	9.06	220.35	14.14	1.70
2075	63.07	9.07	221.54	14.20	1.74

Figure D-4. Continued.

H204 IMPORTS ALLOWED, FUSION

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(6.6%)		6.48	8.82	1.65	0.00
1980	58.66	18.59(5.6%)		6.98	13.03	5.34	0.00
1985	66.50	24.58(6.4%)		6.70	14.66	11.33	0.00
1990	66.80	33.91(4.5%)		6.15	18.00	23.94	.03
2000	65.90	53.30(2.5%)		5.30	19.14	28.53	.34
2010	63.20	68.70(-.2%)		5.00	20.90	31.58	2.29
2020	63.10	67.48(-.3%)		4.71	19.14	24.95	14.29
2040	63.10	63.50(-1.3%)		4.36	14.31	4.33	42.86
2060	63.10	48.74(0.0%)		4.36	0.00	1.62	60.00
2075	63.10	48.74		4.36	0.00	.00	61.71

YEAR	ELECTRICAL GENERATION					
	LIQ & GAS	COAL	FISSION	RENEW		CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)		0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)		0.00(0.0%)
1985	2.20	5.20(3.8%)	3.74(15.3%)	1.38(5.3%)		0.00(0.0%)
1990	2.10	6.20(.6%)	8.05(2.4%)	1.80(3.4%)		.01(24.8%)
2000	1.80	6.70(.9%)	10.27(1.0%)	2.52(1.7%)		.12(19.0%)
2010	1.70	7.30(-.9%)	11.40(-2.1%)	3.00(.6%)		.80(18.3%)
2020	1.60	6.70(-1.5%)	9.20(-8.7%)	3.20(0.0%)		5.00(5.5%)
2040	1.50	5.00(0.0%)	1.60(-4.9%)	3.20(0.0%)		15.00(1.7%)
2060	1.50	0.00(0.0%)	.60(***%)	3.20(0.0%)		21.00(.2%)
2075	1.50	0.00	.00	3.20		21.60

YEAR	COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY RATIO
	LIQ & GAS	COAL(IND)	LIQ & GAS	ELECTRICITY	
1975	0.00(0.0%)		41.56	6.51(5.3%)	.12
1980	0.00(0.0%)		46.40	8.47(5.7%)	.14
1985	2.15(28.0%)		55.20	11.27(5.4%)	.15
1990	8.71(8.9%)		60.30	14.80(2.9%)	.18
2000	21.21(3.5%)		68.50	19.80(1.2%)	.20
2010	30.00(1.0%)		72.00	22.40(.6%)	.21
2020	33.00(.1%)		74.20	23.80(.1%)	.21
2040	34.00(0.0%)		75.20	24.30(0.0%)	.21
2060	34.00(0.0%)		75.20	24.30(0.0%)	.21
2075	34.00		75.20	24.30	.21

FINAL CONSUMPTION END USE

YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.70	2.71	.02
1980	12.40	14.00	20.00	4.60	3.00	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.80	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	20.10	34.70	10.30	12.10	1.40
2040	11.30	28.60	35.30	10.40	12.30	1.60
2060	11.30	28.60	35.30	10.40	12.30	1.60
2075	11.30	28.60	35.30	10.40	12.30	1.60

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.8%)
1980	17.00	22.80	20.17	59.97	85.73(4.3%)
1985	17.20	32.80	23.37	73.37	106.04(4.0%)
1990	18.50	39.60	26.40	84.50	129.82(1.8%)
2000	20.30	48.00	32.00	100.30	155.27(1.2%)
2010	21.30	52.80	34.10	108.20	174.37(.3%)
2020	21.70	54.50	36.10	112.30	178.96(.1%)
2040	21.70	55.20	36.90	113.80	182.93(-.0%)
2060	21.70	55.20	36.90	113.80	182.60(.0%)
2075	21.70	55.20	36.90	113.80	182.69

CUM. RESOURCE USE			
	1975-2024	1995-2044	1975-2075
TOTAL COAL	2386.	3168.	5263.
TOTAL LIQ & GAS	3176.	3187.	6395.

Figure D-5. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS		
	SET1	SET2	SET3
1975	148.1	148.1	148.1
1980	191.5	191.5	191.5
1985	254.2	254.2	254.2
1990	333.8	333.8	333.7
2000	462.5	462.5	461.9
2010	579.3	578.2	575.5
2020	649.6	635.8	628.0
2040	735.6	695.5	687.7
2060	752.2	713.3	713.3
2075	779.0	764.1	764.1

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST			
TO 1975			
0%	59642.4	57717.6	57408.3
5%	7490.3	7417.0	7390.1
10%	2873.2	2868.2	2864.7
15%	1692.4	1691.9	1691.2
TO 1995			
0%	54501.8	52577.0	52268.6
5%	11678.1	11483.7	11413.5
10%	5581.4	5547.6	5525.2
15%	3664.4	3655.9	3646.2
TO 2010			
0%	47212.0	45289.1	44992.3
5%	13507.3	13105.3	12975.2
10%	7037.2	6898.5	6827.5
15%	4792.4	4725.9	4680.3
TO 2020			
0%	41061.3	39192.3	38951.5
5%	13917.6	13327.8	13186.5
10%	7569.6	7288.7	7194.2
15%	5218.8	5045.8	4976.3

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.03	70.86	44.28	.55	0.00
2000	280.53	252.64	90.57	56.49	6.60	0.00
2010	329.40	280.44	101.62	62.70	44.00	0.00
2020	383.40	226.32	89.11	50.60	275.00	0.00
2040	448.20	39.36	38.53	8.80	825.00	0.00
2060	583.20	14.76	39.51	3.30	1155.00	0.00
2075	583.20	.00	35.21	.00	1188.00	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.46	15.21	34.17	30.12	23.49	4.15
2020	10.44	15.91	33.92	30.19	24.16	4.23
2040	9.88	16.03	32.01	29.19	24.03	4.21
2060	8.10	15.65	26.07	25.93	23.44	4.07
2075	8.10	15.65	26.07	25.93	23.44	4.07

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	18.01	1.58	35.51	2.34	.28
1985	22.94	1.96	45.05	2.94	.36
1990	30.36	2.36	57.56	3.68	.48
2000	37.86	3.21	81.85	5.15	.60
2010	43.93	3.95	101.75	6.39	.71
2020	44.88	3.65	97.40	6.04	.68
2040	44.37	3.22	88.33	5.43	.56
2060	40.58	1.99	62.41	3.68	.24
2075	40.58	1.99	62.30	3.67	.24

Figure D-5. Continued.

H205 NO IMPORTS, NO FBR, FUSION

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.80(8.7%)		6.98	13.03	5.34	0.00
1985	49.45	39.84(5.9%)		6.70	14.86	11.33	0.00
1990	47.79	53.45(3.2%)		6.15	18.00	23.94	.03
2000	39.79	73.93(1.9%)		5.30	19.14	28.53	.34
2010	37.58	89.22(-.9%)		5.00	20.90	31.58	8.00
2020	26.11	81.41(-.6%)		4.71	19.14	24.95	37.14
2040	23.36	72.74(-1.1%)		4.36	14.31	4.33	74.29
2060	20.29	58.74(0.0%)		4.36	0.00	1.62	95.14
2075	20.29	58.74		4.36	0.00	.00	96.86

ELECTRICAL GENERATION					
YEAR	LIQ & GAS	COAL	FISSION	RENEW	CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)	0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)	0.00(0.0%)
1985	2.20	5.20(3.8%)	3.74(15.3%)	1.38(5.3%)	0.00(0.0%)
1990	2.10	6.30(.6%)	8.05(2.4%)	1.80(3.4%)	.01(24.8%)
2000	1.80	6.70(-.9%)	10.27(1.0%)	2.52(1.7%)	.12(31.5%)
2010	1.70	7.30(-.9%)	11.40(-2.1%)	3.00(.6%)	2.80(15.4%)
2020	1.60	6.70(-1.5%)	9.20(-8.7%)	3.20(0.0%)	13.00(3.5%)
2040	1.50	5.00(0.0%)	1.60(-4.9%)	3.20(0.0%)	26.00(1.2%)
2060	1.50	0.00(0.0%)	.60(****%)	3.20(0.0%)	33.30(.1%)
2075	1.50	0.00	.00	3.20	33.90

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECT
YEAR		LIQ & GAS	COAL(IND)	RATIO
1975	0.00(0.0%)	41.56	4.15	6.51(5.3%)
1980	0.00(0.0%)	38.50	12.00	8.47(5.7%)
1985	2.15(28.0%)	39.70	21.70	11.27(5.4%)
1990	8.71(8.9%)	43.00	25.40	14.80(2.9%)
2000	21.21(3.7%)	44.70	32.00	19.80(2.0%)
2010	30.77(2.3%)	49.20	35.80	24.25(2.5%)
2020	38.69(.2%)	44.20	22.30	31.21(.5%)
2040	40.15(.5%)	43.00	17.30	34.46(.2%)
2060	44.00(0.0%)	42.70	14.30	35.66(0.0%)
2075	44.00	42.70	14.30	35.66

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.70	5.40	.17
1990	8.20	16.26	18.54	7.00	7.40	.40
2000	7.50	16.97	20.23	8.80	10.00	1.00
2010	7.79	18.92	22.49	10.72	12.23	1.30
2020	6.79	16.74	20.67	13.51	15.87	1.84
2040	6.46	16.35	20.18	14.75	17.44	2.27
2060	6.42	16.24	20.04	15.26	18.05	2.35
2075	6.42	16.24	20.04	15.26	18.05	2.35

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.4%)
1980	14.89	27.42	16.66	58.97	84.26(4.3%)
1985	13.97	41.84	16.86	72.67	104.25(4.5%)
1990	15.20	49.06	18.94	83.20	130.35(1.4%)
2000	16.30	58.97	21.23	96.50	149.79(1.6%)
2010	18.51	66.95	23.79	109.25	174.98(.2%)
2020	20.30	54.91	22.51	97.72	178.75(.1%)
2040	21.21	51.10	22.45	94.76	183.86(.0%)
2060	21.68	48.59	22.39	92.66	184.93(.0%)
2075	21.68	48.59	22.39	92.66	185.03

CUM. RESOURCE USE			
	1975-2024	1995-2044	1975-2075
TOTAL COAL	3194.	3917.	6571.
TOTAL LIQ & GAS	2031.	1503.	3134.

Figure D-6. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS		
	SET1	SET2	SET3
1975	148.1	148.1	148.1
1980	183.4	183.4	183.4
1985	239.5	239.5	239.5
1990	320.4	320.4	320.4
2000	432.7	432.7	432.1
2010	579.3	575.4	566.2
2020	664.2	628.4	608.0
2040	728.2	658.7	645.1
2060	713.3	651.6	651.6
2075	709.8	686.4	686.4

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	58035.0	54626.9	53943.4
5%	7275.6	7129.1	7065.3
10%	2768.0	2756.7	2748.3
15%	1630.8	1629.5	1628.1
TO 1995			
0%	53116.6	49708.5	49025.4
5%	11446.1	11057.3	10888.6
10%	5402.8	5326.4	5271.1
15%	3508.9	3487.7	3465.1
TO 2010			
0%	46158.4	42757.6	42105.7
5%	13549.7	12749.6	12436.9
10%	7127.5	6817.5	6633.5
15%	4864.6	4702.3	4577.5
TO 2020			
0%	39889.1	36642.3	36154.7
5%	13840.0	12724.0	12424.4
10%	7622.0	7047.2	6839.0
15%	5285.3	4910.6	4752.6

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.03	70.86	44.28	.55	0.00
2000	280.53	252.64	90.57	56.49	6.60	0.00
2010	383.40	280.44	104.88	62.70	154.00	0.00
2020	599.40	226.32	102.15	50.60	715.00	0.00
2040	745.20	39.36	56.46	8.80	1430.00	0.00
2060	915.30	14.76	59.56	3.30	1831.50	0.00
2075	915.30	.00	55.26	.00	1864.50	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	8.16	8.47	25.99	27.16	30.75	2.96
1990	9.20	9.50	29.25	30.82	35.81	3.14
2000	10.12	10.53	31.94	35.22	44.36	3.18
2010	11.09	11.72	35.05	38.92	49.59	3.37
2020	8.92	10.34	29.13	29.25	32.26	2.67
2040	7.63	9.79	25.22	24.79	25.69	2.41
2060	5.49	9.24	18.44	19.72	21.34	2.13
2075	5.49	9.24	18.44	19.72	21.34	2.13

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	19.20	2.16	46.80	3.13	.29
1985	25.56	3.19	69.02	4.63	.37
1990	33.93	3.94	88.30	5.84	.50
2000	41.15	4.87	114.09	7.43	.62
2010	48.98	5.56	133.48	8.61	.73
2020	52.49	4.43	114.86	7.20	.72
2040	53.18	3.58	97.79	6.02	.60
2060	50.38	2.19	70.63	4.13	.31
2075	50.38	2.18	70.52	4.12	.31

Figure D-6, Continued.

HZ06 DRASTIC LIMITS--UNREALISTIC NEAR-TERM TOT. CONSUMPTION

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(19.3%)		6.48	8.82	1.65	0.00
1980	47.78	35.03(5.2%)		6.98	13.03	5.34	0.00
1985	47.25	45.48(.3%)		6.70	14.86	11.33	0.00
1990	45.95	46.11(2.1%)		6.15	15.42	23.93	.03
2000	39.79	56.83(.7%)		5.30	15.43	33.25	.34
2010	27.14	61.06(-.9%)		5.00	12.31	31.58	8.00
2020	26.11	55.90(-.4%)		4.71	4.86	24.95	37.14
2040	23.36	51.84(-.1%)		4.36	0.00	4.33	74.29
2060	20.29	52.59(0.0%)		4.36	0.00	1.62	95.14
2075	20.29	52.59		4.36	0.00	.00	96.86

ELECTRICAL GENERATION						
YEAR	LIQ & GAS	COAL	FISSION	RENEW		CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)		0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)		0.00(0.0%)
1985	2.20	5.20(.8%)	3.74(15.3%)	1.38(22.7%)		0.00(0.0%)
1990	2.10	5.40(0.0%)	8.05(4.0%)	4.30(6.8%)		.01(24.8%)
2000	1.80	5.40(-2.3%)	11.97(-.5%)	8.52(6.1%)		.12(31.5%)
2010	1.70	4.30(-9.3%)	11.40(-2.1%)	15.75(-3.4%)		2.80(15.4%)
2020	1.60	1.70(0.0%)	9.20(-8.7%)	11.20(-1.6%)		13.00(3.5%)
2040	1.50	0.00(0.0%)	1.60(-4.9%)	8.20(-4.7%)		26.00(1.2%)
2060	1.50	0.00(0.0%)	.60(****%)	3.20(0.0%)		33.30(.1%)
2075	1.50	0.00	.00	3.20		33.90

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)			ELECTRICITY RATIO
YEAR		LIQ & GAS	COAL(IND)	ELECTRICITY	
1975	0.00(0.0%)	41.56	4.15	6.51(5.3%)	.12
1980	9.23(-2.1%)	42.50	12.00	8.47(5.7%)	.13
1985	8.31(-.9%)	41.70	21.20	11.27(9.4%)	.15
1990	7.94(8.1%)	40.82	21.60	18.07(3.5%)	.22
2000	17.83(4.1%)	42.50	22.40	25.72(2.6%)	.28
2010	26.92(1.4%)	37.20	20.80	33.27(.2%)	.36
2020	31.00(.5%)	39.20	19.30	33.99(.1%)	.37
2040	34.00(.5%)	39.00	17.30	34.46(.2%)	.38
2060	37.85(0.0%)	38.70	14.30	35.66(0.0%)	.40
2075	37.85	38.70	14.30	35.66	.40

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	11.36	12.83	18.31	4.60	3.80	.07
1985	8.69	15.48	17.53	5.70	5.40	.17
1990	7.78	15.44	17.60	8.54	9.04	.49
2000	7.13	16.14	19.23	11.43	12.99	1.30
2010	5.89	14.31	17.00	14.71	16.78	1.78
2020	6.02	14.85	18.33	14.71	17.28	2.00
2040	5.86	14.83	18.30	14.75	17.44	2.27
2060	5.82	14.72	18.16	15.26	18.05	2.35
2075	5.82	14.72	18.16	15.26	18.05	2.35

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(5.0%)
1980	15.96	28.63	18.38	62.97	91.29(3.3%)
1985	14.39	42.09	17.70	74.18	107.69(3.5%)
1990	16.32	46.07	18.09	80.48	128.31(1.9%)
2000	18.56	51.53	20.53	90.62	154.55(1.1%)
2010	20.60	51.89	18.78	91.27	172.78(.2%)
2020	20.73	51.43	20.33	92.49	176.10(.0%)
2040	20.61	49.57	20.57	90.75	177.25(.0%)
2060	21.08	47.07	20.51	88.66	178.78(.0%)
2075	21.08	47.07	20.51	88.66	178.88

CUM. RESOURCE USE		
1975-2024	1995-2044	1975-2075
TOTAL COAL	2509.	2774.
TOTAL LIQ & GAS	1890.	3022.

Figure D-7. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS		
	SET1	SET2	SET3
1975	148.1	148.1	148.1
1980	204.1	204.1	204.1
1985	251.6	251.6	251.6
1990	319.3	319.3	319.2
2000	469.9	469.9	469.3
2010	663.5	659.6	650.4
2020	687.7	651.8	631.4
2040	706.2	636.8	623.2
2060	681.8	620.2	620.2
2075	675.6	652.2	652.2

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST			
TO 1975			
0%	58327.9	54919.8	54236.3
5%	7651.7	7505.2	7441.4
10%	2931.2	2919.8	2911.5
15%	1725.9	1724.6	1723.2

TO 1995			
0%	53222.1	49814.0	49130.9
5%	12088.9	11700.1	11531.4
10%	5826.5	5750.0	5694.7
15%	3791.9	3770.6	3748.1

TO 2010			
0%	45554.4	42153.6	41501.7
5%	13916.9	13116.8	12804.1
10%	7546.3	7236.3	7052.2
15%	5248.7	5086.4	4961.6

TO 2020			
0%	38697.3	35450.6	34962.9
5%	13628.7	12512.8	12213.1
10%	7593.1	7018.2	6810.0
15%	5305.1	4930.3	4772.4

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.03	70.86	44.28	.55	0.00
2000	326.43	294.46	105.53	65.84	6.60	0.00
2010	383.40	280.44	104.88	62.70	154.00	0.00
2020	599.40	226.32	102.15	50.60	715.00	0.00
2040	745.20	39.36	56.46	8.80	1430.00	0.00
2060	915.30	14.76	59.56	3.30	1831.50	0.00
2075	915.30	.00	55.26	.00	1864.50	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	7.00	8.71	22.63	20.64	18.59	2.81
1985	8.26	8.83	26.54	27.38	30.30	2.96
1990	8.27	8.87	26.49	27.48	30.78	2.92
2000	8.40	9.59	26.92	28.05	31.97	2.87
2010	7.37	8.52	23.98	25.40	29.54	2.37
2020	6.40	8.81	20.83	23.04	27.51	2.31
2040	5.53	8.59	18.10	20.62	24.79	2.15
2060	5.17	8.42	17.27	18.82	21.03	2.01
2075	5.17	8.42	17.27	18.82	21.03	2.01

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	21.12	2.36	56.06	3.63	.35
1985	26.65	3.28	74.32	4.90	.41
1990	33.78	3.38	76.42	5.04	.44
2000	43.59	3.69	88.22	5.69	.52
2010	51.94	3.48	88.42	5.58	.50
2020	50.26	2.79	76.26	4.70	.36
2040	48.90	2.23	65.75	3.95	.25
2060	48.98	2.05	64.39	3.79	.27
2075	48.98	2.05	64.28	3.79	.27

Figure D-7. Continued.

H207 ACCEL. FUSION (IMPORTS ALLOWED) BASED ON H204

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(6.6%)	6.48	8.82	1.65	0.00
1980	58.66	18.56	(5.3%)	6.98	13.00	5.34	.03
1985	66.50	24.23	(6.7%)	6.70	14.72	11.33	.14
1990	66.80	33.91	(4.4%)	6.15	18.00	23.61	.34
2000	65.90	52.43	(1.3%)	5.30	18.28	27.42	2.34
2010	63.20	59.87	(.0%)	5.00	15.17	25.49	14.29
2020	63.10	60.11	(-.5%)	4.71	12.00	18.17	28.57
2040	63.10	54.64	(-.6%)	4.36	5.72	1.62	54.29
2060	63.10	48.74	(0.0%)	4.36	0.00	0.00	61.71
2075	63.10	48.74		4.36	0.00	.00	61.71

YEAR	ELECTRICAL GENERATION							
	LIO & GAS	COAL	FISSION	RENEW	CTR			
1975	2.43	3.15 (6.2%)	1.53 (23.4%)	1.04 (1.1%)	0.00 (0.0%)			
1980	2.30	4.29 (3.7%)	1.71 (15.7%)	1.10 (4.5%)	.01 (32.2%)			
1985	2.20	5.15 (4.0%)	3.74 (15.1%)	1.38 (5.3%)	.05 (17.5%)			
1990	2.10	6.30 (.2%)	7.94 (2.2%)	1.80 (3.4%)	.12 (19.2%)			
2000	1.80	6.40 (-1.9%)	9.87 (-.7%)	2.52 (1.7%)	.82 (18.1%)			
2010	1.70	5.30 (-2.3%)	9.20 (-3.2%)	3.00 (.6%)	5.00 (6.9%)			
2020	1.60	4.20 (-3.7%)	6.70 ****%	3.20 (0.0%)	10.00 (3.2%)			
2040	1.50	2.00 (0.0%)	.60 (0.0%)	3.20 (0.0%)	19.00 (.6%)			
2060	1.50	0.00 (0.0%)	0.00 (0.0%)	3.20 (0.0%)	21.60 (0.0%)			
2075	1.50	0.00	.00	3.20	21.60			

YEAR	COAL TO SYNFUELS		TOTAL ENERGY CARRIERS	(DIRECT USE)	ELECT
			LIO & GAS	COAL (IND)	RATIO
1975	0.00	(0.0%)	41.56	4.15	6.51 (5.3%) .12
1980	0.00	(0.0%)	46.40	5.00	8.47 (5.7%) .14
1985	2.15	28.0%	55.20	6.70	11.27 (5.4%) .15
1990	8.71	8.9%	60.30	9.40	14.80 (2.9%) .18
2000	21.21	3.5%	68.50	12.00	19.80 (1.2%) .20
2010	30.00	1.0%	72.00	13.80	22.40 (.6%) .21
2020	33.00	.1%	74.20	14.30	23.80 (.1%) .21
2040	34.00	(0.0%)	75.20	14.30	24.30 (0.0%) .21
2060	34.00	(0.0%)	75.20	14.30	24.30 (0.0%) .21
2075	34.00		75.20	14.30	24.30 .21

FINAL CONSUMPTION END USE

YEAR	LIO & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	12.40	14.00	20.00	4.60	3.80	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.80	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	28.10	34.70	10.30	12.10	1.40
2040	11.30	28.60	35.30	10.40	12.30	1.60
2060	11.30	28.60	35.30	10.40	12.30	1.60
2075	11.30	28.60	35.30	10.40	12.30	1.60

TOTALS

YFAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94 (3.8%)
1980	17.00	22.80	20.17	59.97	85.72 (4.2%)
1985	17.20	32.80	23.37	73.37	105.83 (4.1%)
1990	18.50	39.60	26.40	84.50	129.81 (1.8%)
2000	20.30	48.00	32.00	100.30	155.29 (1.0%)
2010	21.30	52.80	34.10	108.20	171.44 (.4%)
2020	21.70	54.50	36.10	112.30	179.09 (.1%)
2040	21.70	55.20	36.90	113.80	182.79 (-.0%)
2060	21.70	55.20	36.90	113.80	182.69 (-.0%)
2075	21.70	55.20	36.90	113.80	182.69

CUM. RESOURCE USE			
	1975-2024	1995-2044	1975-2075
TOTAL COAL	2217.	2835.	4881.
TOTAL LIO & GAS	3176.	3187.	6395.

Figure D-8. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	SET1	SET2	SET3	SET4	SET5
1975				148.1	148.1
1980				191.5	191.5
1985				254.3	254.1
1990				334.8	334.2
2000				464.6	461.9
2010				563.3	555.4
2020				619.2	608.7
2040				659.2	659.2
2060				712.0	712.0
2075				764.1	764.1

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO	0%	5%	10%	15%
1975				
		56658.8	7346.5	7303.2
			2862.9	2854.1
			1692.2	1689.7
1995				
		51509.8	11286.0	11178.5
			5497.9	5448.5
			3642.4	3614.9
2010				
		44235.5	12700.1	12560.4
			6682.0	6588.6
			4581.5	4512.7
2020				
		38323.3	12909.5	12805.0
			7045.1	6964.4
			4881.6	4816.1

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3 MAN REM	KR-85 E6 CURIES	TRIT E5 CURIES	RAD WASTE E3 CU FT	SPENT BLANKET E3 CU FT	(SPARE)
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.44	42.07	15.06	9.41	.55	0.00
1985	102.33	92.00	32.99	20.57	2.75	0.00
1990	217.62	195.32	70.07	43.67	6.60	0.00
2000	288.63	242.80	64.19	54.29	45.10	0.00
2010	383.40	226.32	89.11	50.60	275.00	0.00
2020	450.90	164.82	75.26	36.85	550.00	0.00
2040	529.20	14.76	36.25	3.30	1045.00	0.00
2060	583.20	0.00	35.21	0.00	1188.00	0.00
2075	583.20	.00	35.21	.00	1188.00	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.10	16.71	9.96	3.01
1985	7.71	10.62	25.35	21.12	12.89	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.68	14.23	31.54	27.61	20.76	4.03
2010	9.74	15.04	31.78	28.80	23.20	4.09
2020	9.55	15.72	30.95	28.56	23.86	4.16
2040	8.81	15.80	28.44	27.24	23.68	4.13
2060	8.10	15.65	26.07	25.93	23.44	4.07
2075	8.10	15.65	26.07	25.93	23.44	4.07
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	18.01	1.58	35.45	2.33	.28	
1985	22.85	1.93	44.47	2.90	.35	
1990	30.36	2.36	57.54	3.67	.48	
2000	37.63	3.13	80.26	5.05	.58	
2010	41.65	3.21	86.37	5.34	.57	
2020	42.99	3.03	84.09	5.15	.52	
2040	42.09	2.48	72.70	4.37	.37	
2060	40.58	1.99	62.30	3.67	.24	
2075	40.58	1.99	62.30	3.67	.24	

Figure D-8. Continued.

H206 ACCEL.FUSION NO IMPORTS, NO FBR (BASED ON H205)

FOSSIL RESOURCES				ELECTRIC GENERATION			
TOTAL USE				RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.77(8.6%)		6.98	13.00	5.34	.03
1985	49.45	39.69(6.0%)		6.70	14.72	11.33	.14
1990	47.79	53.45(2.7%)		6.15	18.00	23.61	.34
2000	39.79	70.10(1.0%)		5.30	15.43	24.64	8.06
2010	37.58	77.42(-1.1%)		5.00	9.45	14.96	36.57
2020	26.11	69.63(-.7%)		4.71	7.71	14.10	60.00
2040	23.36	60.94(-.2%)		4.36	2.86	1.62	88.57
2060	20.29	58.74(0.0%)		4.36	0.00	0.00	96.86
2075	20.29	58.74		4.36	0.00	.00	96.86

ELECTRICAL GENERATION						
YEAR	LIQ & GAS	COAL	FISSION	RENEW		CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)		0.00(0.0%)
1980	2.30	4.29(3.7%)	1.71(15.7%)	1.10(4.5%)		.01(32.2%)
1985	2.20	5.15(4.0%)	3.74(15.1%)	1.38(5.3%)		.05(17.5%)
1990	2.10	6.30(-1.5%)	7.94(1.1%)	1.80(3.4%)		.12(31.6%)
2000	1.80	5.40(-4.9%)	8.87(-5.0%)	2.52(1.7%)		2.82(15.1%)
2010	1.70	3.30(-2.0%)	5.40(-.4%)	3.00(.6%)		12.80(5.0%)
2020	1.60	2.70(-5.0%)	5.20(***%)	3.20(0.0%)		21.00(1.9%)
2040	1.50	1.00(0.0%)	.60(0.0%)	3.20(0.0%)		31.00(.4%)
2060	1.50	0.00(0.0%)	0.00(0.0%)	3.20(0.0%)		33.90(0.0%)
2075	1.50	0.00	.00	3.20		33.90

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)			ELECTRICITY RATIO
YEAR		LIQ & GAS	COAL(IND)	ELECTRICITY	
1975	0.00(0.0%)	41.56	4.15	6.51(5.3%)	.12
1980	0.00(0.0%)	38.50	12.00	8.47(5.7%)	.14
1985	2.15(28.0%)	39.70	21.70	11.27(5.4%)	.16
1990	8.71(8.9%)	43.00	25.40	14.80(2.9%)	.18
2000	21.21(3.7%)	44.70	32.00	19.80(2.0%)	.21
2010	30.77(2.3%)	49.20	35.80	24.25(2.5%)	.22
2020	38.69(.2%)	44.20	22.30	31.21(.5%)	.32
2040	40.15(.5%)	43.00	17.30	34.46(.2%)	.36
2060	44.00(0.0%)	42.70	14.30	35.66(0.0%)	.38
2075	44.00	42.70	14.30	35.66	.38

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.70	5.40	.17
1990	8.20	16.26	18.54	7.00	7.40	.40
2000	7.50	16.97	20.23	8.00	10.00	1.00
2010	7.79	18.92	22.49	10.72	12.23	1.30
2020	6.79	16.74	20.67	13.51	15.87	1.84
2040	6.46	16.35	20.18	14.75	17.44	2.27
2060	6.42	16.24	20.04	15.26	18.05	2.35
2075	6.42	16.24	20.04	15.26	18.05	2.35

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.4%)
1980	14.89	27.42	16.66	58.97	84.26(4.3%)
1985	13.97	41.84	16.86	72.67	104.25(4.5%)
1990	15.20	49.06	18.94	83.20	130.34(1.4%)
2000	16.30	58.97	21.23	96.50	149.79(1.6%)
2010	18.51	66.95	23.79	109.25	175.13(.2%)
2020	20.30	54.91	22.51	97.72	178.98(.1%)
2040	21.21	51.10	22.45	94.76	183.63(0.0%)
2060	21.68	48.59	22.39	92.66	185.03(0.0%)
2075	21.68	48.59	22.39	92.66	185.03

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL 2924: 3402: 6001:
TOTAL LIQ & GAS 2031: 1503: 3134:

Figure D-9. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	SET1	SET2	COST ASSUMPTIONS SET3	SET4	SET5
1975				148.1	148.1
1980				183.5	183.5
1985				239.9	239.6
1990				321.5	320.9
2000				441.9	432.6
2010				552.6	532.6
2020				598.1	576.2
2040				606.7	606.7
2060				650.3	650.3
2075				686.4	686.4

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975		
0%	53063.1	52376.0
5%	7034.2	6929.9
10%	2753.5	2731.7
15%	1631.8	1625.9
TO 1995		
0%	48131.6	47452.7
5%	10789.0	10522.6
10%	5283.5	5150.2
15%	3495.7	3416.3
TO 2010		
0%	41118.6	40627.1
5%	12080.6	11780.3
10%	6448.7	6241.1
15%	4454.4	4297.4
TO 2020		
0%	35327.2	35055.5
5%	12055.0	11855.0
10%	6639.7	6483.2
15%	4626.9	4498.5

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3 MAN REM	KR-85 E6 CURIES	TRIT E5 CURIES	RAD WASTE E3 CU FT	SPENT E3 BLANKET CU FT	(SPARE)
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.44	42.07	15.06	9.41	0.55	0.00
1985	102.33	92.00	32.99	20.57	2.75	0.00
1990	217.62	195.32	70.07	43.67	6.60	0.00
2000	315.63	218.20	82.65	48.79	155.10	0.00
2010	491.40	132.84	68.38	29.70	704.00	0.00
2020	707.40	127.92	79.99	28.60	1155.00	0.00
2040	853.20	14.76	55.81	3.30	1705.00	0.00
2060	915.30	0.00	55.26	0.00	1864.50	0.00
2075	915.30	0.00	55.26	0.00	1864.50	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.60	7.94	21.38	19.74	18.27	2.74
1985	8.14	8.47	25.93	27.13	30.74	2.96
1990	9.20	9.50	29.24	30.82	35.81	3.14
2000	9.65	10.43	30.39	34.37	44.21	3.15
2010	9.66	11.41	30.29	36.30	49.12	3.26
2020	7.50	10.03	24.37	26.64	31.79	2.56
2040	6.21	9.49	20.46	22.18	25.22	2.30
2060	5.49	9.24	18.44	19.72	21.34	2.13
2075	5.49	9.24	18.44	19.72	21.34	2.13
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	19.19	2.16	46.75	3.13	.29	
1985	25.52	3.18	68.76	4.61	.37	
1990	33.93	3.94	88.28	5.84	.50	
2000	40.16	4.55	107.17	6.96	.54	
2010	45.95	4.54	111.80	7.15	.46	
2020	49.46	3.43	93.59	5.77	.46	
2040	50.15	2.60	77.03	4.62	.35	
2060	50.38	2.18	70.52	4.12	.31	
2075	50.38	2.18	70.52	4.12	.31	

Figure D-9. Continued.

11/02 ALL SOLAR LONG RANGE SUPPLY (BASED ON 11/01)

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(13.1%)	6.48	8.82	1.65	0.00
1980	49.98	25.80	(7.9%)	6.98	13.03	5.34	0.00
1985	49.45	38.29	(1.9%)	6.70	14.86	10.12	0.00
1990	45.95	42.16	(2.1%)	6.15	14.28	18.88	0.00
2000	39.79	51.78	(1.6%)	5.30	13.43	26.53	0.00
2010	27.14	61.06	(-.9%)	5.00	12.31	31.58	0.00
2020	26.11	55.90	(-.4%)	4.71	4.86	24.95	0.00
2040	23.36	51.84	(-.1%)	4.36	0.00	4.33	0.00
2060	20.29	52.59	(0.0%)	4.36	0.00	1.62	0.00
2075	20.29	52.59		4.36	0.00	.00	.03

ELECTRIC GENERATION							
YEAR	LIO & GAS	COAL	FISSION	RENEW		CTR	
1975	2.43	3.15	(6.2%)	1.04	(1.1%)	0.00	(0.0%)
1980	2.30	4.30	(3.0%)	1.10	(4.5%)	0.00	(0.0%)
1985	2.20	5.20	(-.0%)	1.30	(10.3%)	0.00	(0.0%)
1990	2.10	5.00	(-.6%)	2.31	(7.0%)	0.00	(0.0%)
2000	1.00	4.70	(-.9%)	4.64	(6.4%)	0.00	(0.0%)
2010	1.70	4.30	(-9.3%)	8.80	(8.8%)	0.00	(0.0%)
2020	1.60	1.70	(0.0%)	21.20	(2.4%)	0.00	(0.0%)
2040	1.50	0.00	(0.0%)	34.20	(.3%)	0.00	(0.0%)
2060	1.50	0.00	(0.0%)	36.50	(.1%)	0.00	(0.0%)
2075	1.50	0.00		37.09		.01	

TOTAL ENERGY CARRIERS (DIRECT USE)							ELECT. RATIO	
YEAR	COAL TO SYNTH	LIO & GAS	COAL (IND)	ELECTRICITY				
1975	0.00	(0.0%)	41.56	4.15	6.51	(5.3%)	.12	
1980	0.00	(0.0%)	38.50	12.00	8.47	(5.1%)	.14	
1985	2.15	(21.8%)	39.70	20.20	10.91	(5.5%)	.15	
1990	6.40	(9.3%)	39.82	20.40	14.34	(3.2%)	.19	
2000	16.29	(5.0%)	41.50	21.00	19.80	(2.0%)	.24	
2010	26.92	(1.4%)	37.20	20.80	24.25	(2.5%)	.29	
2020	31.00	(.5%)	39.20	19.30	31.21	(.5%)	.35	
2040	34.00	(.5%)	39.00	17.30	34.46	(.2%)	.38	
2060	37.05	(0.0%)	38.70	14.30	35.66	(0.0%)	.40	
2075	37.05		38.70	14.30	35.66		.40	

FINAL CONSUMPTION END USE							
YEAR	R & C	LIO & GAS	IND	TRANS	R & C	IND	TRANS
1975	13.20		9.88	18.49	3.78	2.71	.02
1980	10.29		11.62	16.59	4.60	3.80	.07
1985	8.27		14.74	16.69	5.52	5.23	.16
1990	7.59		15.06	17.17	6.78	7.17	.39
2000	6.96		15.76	18.78	8.00	10.00	1.00
2010	5.89		14.31	17.00	10.72	12.23	1.30
2020	6.02		14.85	18.33	13.51	15.87	1.84
2040	5.86		14.83	18.30	14.75	17.44	2.27
2060	5.82		14.72	18.16	15.26	18.05	2.35
2075	5.82		14.72	18.16	15.26	18.05	2.35

TOTALS						
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE	
1975	16.98	16.73	18.51	52.22	70.94	(3.4%)
1980	14.89	27.42	16.66	58.97	84.26	(3.7%)
1985	13.79	40.17	16.85	70.81	101.49	(2.3%)
1990	14.38	42.63	17.56	74.57	113.59	(1.6%)
2000	15.76	46.76	19.78	82.30	133.36	(.8%)
2010	16.61	47.34	18.30	82.25	144.92	(1.4%)
2020	19.53	50.02	20.17	89.72	167.53	(.3%)
2040	20.61	49.57	20.57	90.75	177.24	(.0%)
2060	21.08	47.07	20.51	88.66	178.79	(.0%)
2075	21.08	47.07	20.51	88.66	178.88	

CUM. RESOURCE USE			
	1975-2024	1995-2044	1975-2075
TOTAL COAL	2344.	2719.	5063.
TOTAL LIO & GAS	1911.	1432.	3343.

Figure D-10. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (C9 DOLLARS)

YEAR	COST ASSUMPTIONS				
	SET1	SET2	SET3	SET4	SET5
1975	140.1	140.1	140.1		
1980	183.4	183.4	183.4		
1985	234.2	234.2	234.2		
1990	281.8	281.8	281.8		
2000	395.0	395.0	395.0		
2010	515.2	515.2	515.2		
2020	692.1	692.1	692.1		
2040	848.2	848.2	848.2		
2060	915.4	915.4	915.4		
2075	952.7	952.7	952.7		

DISCOUNTED PRESENT VALUE OF CIRC. SYSTEM COST

TO 1975				
0%	65098.0	65097.9	65097.9	
5%	7120.3	7120.3	7120.3	
10%	2643.1	2643.1	2643.1	
15%	1574.9	1574.9	1574.9	
TO 1995				
0%	60491.1	60491.1	60491.1	
5%	11420.5	11420.5	11420.5	
10%	5044.1	5044.1	5044.1	
15%	3190.2	3190.2	3190.2	
TO 2010				
0%	54254.4	54254.4	54254.4	
5%	14548.2	14548.2	14548.2	
10%	7204.4	7204.4	7204.4	
15%	4747.0	4747.0	4747.0	
TO 2020				
0%	48322.7	48322.6	48322.6	
5%	15959.1	15959.1	15959.0	
10%	8531.9	8531.9	8531.9	
15%	5022.0	5022.0	5022.0	

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	WASTE E3	SPIRIT E3	(SPARK)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	90.10	82.16	29.39	18.37	0.00	0.00
1990	171.45	156.21	55.88	34.93	0.00	0.00
2000	277.29	252.64	90.38	56.49	0.00	0.00
2010	307.80	280.44	100.32	62.70	0.00	0.00
2020	248.40	226.32	80.96	50.60	0.00	0.00
2040	43.20	39.36	14.08	8.80	0.00	0.00
2060	16.20	14.76	5.28	3.30	0.00	0.00
2075	.27	.00	.02	.00	.55	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PAHT E6 TONS	HC E6 TONS
1975	5.67	8.32	10.00	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	7.99	8.41	25.55	26.26	28.86	2.93
1990	7.92	8.60	25.36	26.26	29.14	2.86
2000	7.91	9.28	25.37	26.52	30.04	2.79
2010	7.37	8.52	23.90	25.40	29.54	2.37
2020	6.40	8.01	20.83	23.04	27.51	2.31
2040	5.53	8.59	18.10	20.62	24.79	2.15
2060	5.17	8.42	17.27	18.82	21.03	2.01
2075	5.17	8.42	17.27	18.82	21.03	2.01
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	19.20	2.16	46.80	3.13	.29	
1985	24.80	3.06	66.42	4.45	.37	
1990	28.80	3.14	70.45	4.66	.39	
2000	35.94	3.36	80.36	5.18	.46	
2010	42.01	3.48	88.38	5.58	.50	
2020	49.39	2.79	76.04	4.69	.36	
2040	53.58	2.22	65.31	3.94	.25	
2060	54.97	2.05	63.82	3.78	.27	
2075	55.08	2.04	63.70	3.78	.27	

Figure D-10. Continued.

M201 20TH CENT TOT. CONSUMPTION REVISED FOR DRASTIC LIMITS

FOSSIL RESOURCES				ELECTRIC GENERATION			
TOTAL USE				RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.80(7.9%)		6.98	13.03	5.34	0.00
1985	49.45	38.29(1.9%)		6.70	14.86	10.12	0.00
1990	45.95	42.16(2.1%)		6.15	14.28	18.88	.03
2000	39.79	51.78(1.6%)		5.30	13.43	28.53	.34
2010	27.14	61.06(-.9%)		5.00	12.31	31.58	8.00
2020	26.11	55.90(-.4%)		4.71	4.86	24.95	37.14
2040	23.36	51.84(-.1%)		4.36	0.00	4.33	74.29
2060	20.29	52.59(0.0%)		4.36	0.00	1.62	95.14
2075	20.29	52.59		4.36	0.00	.00	96.86

ELECTRICAL GENERATION					
YEAR	LIQ & GAS	COAL	FISSION	RENEW	CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)	0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(13.4%)	1.10(4.5%)	0.00(0.0%)
1985	2.20	5.20(-.8%)	3.34(12.8%)	1.38(10.2%)	0.00(0.0%)
1990	2.10	5.00(-.6%)	6.35(4.8%)	2.30(6.8%)	.01(24.8%)
2000	1.80	4.70(-.9%)	10.27(1.0%)	4.52(7.8%)	.12(31.5%)
2010	1.70	4.30(-9.3%)	11.40(-2.1%)	6.00(3.1%)	2.80(15.4%)
2020	1.60	1.70(0.0%)	9.20(-8.7%)	8.20(0.0%)	13.00(3.5%)
2040	1.50	0.00(0.0%)	1.60(-4.9%)	8.20(-4.7%)	26.00(1.2%)
2060	1.50	0.00(0.0%)	.60(****%)	3.20(0.0%)	33.30(.1%)
2075	1.50	0.00	.00	3.20	33.90

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)			ELECT
YEAR		LIQ & GAS	COAL(IND)	ELECTRICITY	RATIO
1975	0.00(0.0%)	41.56	4.15	6.51(5.3%)	.12
1980	0.00(0.0%)	38.50	12.00	8.47(5.1%)	.14
1985	2.15(21.8%)	39.70	20.20	10.91(5.5%)	.15
1990	6.40(9.3%)	39.82	20.40	14.34(3.2%)	.19
2000	16.29(5.0%)	41.50	21.00	19.80(2.0%)	.24
2010	26.92(1.4%)	37.20	20.80	24.25(2.5%)	.29
2020	31.00(.5%)	39.20	19.30	31.21(.5%)	.35
2040	34.00(-.5%)	39.00	17.30	34.46(.2%)	.38
2060	37.85(0.0%)	38.70	14.30	35.66(0.0%)	.40
2075	37.85	38.70	14.30	35.66	.40

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.52	5.23	.16
1990	7.59	15.06	17.17	6.78	7.17	.39
2000	6.96	15.76	18.78	8.80	10.00	1.00
2010	5.89	14.31	17.00	10.72	12.23	1.30
2020	6.02	14.85	18.33	13.51	15.87	1.84
2040	5.86	14.83	18.30	14.75	17.44	2.27
2060	5.82	14.72	18.16	15.26	18.05	2.35
2075	5.82	14.72	18.16	15.26	18.05	2.35

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.4%)
1980	14.89	27.42	16.66	58.97	84.26(3.7%)
1985	13.79	40.17	16.85	70.81	101.49(2.3%)
1990	14.38	42.63	17.56	74.57	113.59(1.6%)
2000	15.76	46.76	19.78	82.30	133.35(.8%)
2010	16.61	47.34	18.30	82.25	144.92(1.4%)
2020	19.53	50.02	20.17	89.72	167.53(.3%)
2040	20.61	49.57	20.57	90.75	177.25(.0%)
2060	21.08	47.07	20.51	88.66	178.78(.0%)
2075	21.08	47.07	20.51	88.66	178.88

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL 2344. 2719. 5012.
TOTAL LIQ & GAS 1911. 1432. 3043.

Figure D-11. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	183.4	183.4	183.4		
1985	234.2	234.2	234.2		
1990	281.9	281.9	281.8		
2000	395.8	395.8	395.2		
2010	512.6	508.8	499.5		
2020	641.2	605.4	585.0		
2040	706.2	636.8	623.2		
2060	681.8	620.2	620.2		
2075	675.6	652.2	652.2		

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	55177.8	51769.7	51086.2
5%	6827.2	6680.7	6616.9
10%	2626.1	2614.8	2606.5
15%	1573.6	1572.3	1570.8
TO 1995			
0%	50570.1	47162.0	46478.9
5%	10641.8	10253.0	10084.3
10%	4928.8	4852.3	4797.1
15%	3174.0	3152.8	3130.2
TO 2010			
0%	44319.9	40919.1	40267.3
5%	12910.6	12110.5	11797.8
10%	6695.9	6386.0	6201.9
15%	4512.0	4349.7	4224.9
TO 2020			
0%	38574.3	35327.5	34839.9
5%	13513.7	12397.8	12098.1
10%	7479.5	6904.6	6696.4
15%	5193.1	4818.3	4660.4

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3 MAN REM	KR-85 E6 CURIES	TRIT E5 CURIES	RAD WASTE E3 CU F1	SPENT BLANKET E3 CU F1	(SPARE)
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	90.18	82.16	29.39	18.37	0.00	0.00
1990	171.72	156.21	55.90	34.93	.55	0.00
2000	280.53	252.64	90.57	56.49	6.60	0.00
2010	383.40	280.44	104.88	62.70	154.00	0.00
2020	599.40	226.32	102.15	50.60	715.00	0.00
2040	745.20	39.36	56.46	8.80	1430.00	0.00
2060	915.30	14.76	59.56	3.30	1831.50	0.00
2075	915.30	.00	55.26	.00	1864.50	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	7.99	8.41	25.55	26.26	28.86	2.93
1990	7.92	8.60	25.36	26.26	29.14	2.86
2000	7.91	9.28	25.37	26.52	30.04	2.79
2010	7.37	8.52	23.98	25.40	29.54	2.37
2020	6.40	8.81	20.83	23.04	27.51	2.31
2040	5.53	8.59	18.10	20.62	24.79	2.15
2060	5.17	8.42	17.27	18.82	21.03	2.01
2075	5.17	8.42	17.27	18.82	21.03	2.01

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	19.20	2.16	46.80	3.13	.29
1985	24.80	3.06	66.42	4.45	.37
1990	28.79	3.14	70.45	4.66	.39
2000	35.92	3.36	80.36	5.18	.46
2010	41.51	3.48	88.42	5.58	.50
2020	47.05	2.79	76.26	4.70	.36
2040	48.90	2.23	65.75	3.95	.25
2060	48.98	2.05	64.39	3.79	.27
2075	48.98	2.05	64.28	3.79	.27

Figure D-11. Continued.

M202 ALL SOLAR LONG RANGE SUPPLY (BASED ON M201)

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIO & GAS	COAL		LIO & GAS	COAL	FISSION	CTR
1975	52.80	13.37 (13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.80 (7.9%)		6.98	13.03	5.34	0.00
1985	49.45	38.29 (1.9%)		6.70	14.86	10.12	0.00
1990	45.95	42.16 (2.1%)		6.15	14.28	18.88	0.00
2000	39.79	51.78 (1.6%)		5.30	13.43	26.53	0.00
2010	27.14	61.06 (-.9%)		5.00	12.31	31.58	0.00
2020	26.11	55.90 (-.4%)		4.71	4.86	24.95	0.00
2040	23.36	51.84 (-.1%)		4.36	0.00	4.33	0.00
2060	20.29	52.59 (0.0%)		4.36	0.00	1.62	0.00
2075	20.29	52.59		4.36	0.00	.00	.03

YEAR	ELECTRICAL GENERATION						
	LIO & GAS	COAL	FISSION	RENEW			CTR
1975	2.43	3.15 (6.2%)	.53 (23.4%)	1.04 (1.1%)			0.00 (0.0%)
1980	2.30	4.30 (3.8%)	1.71 (13.4%)	1.10 (4.5%)			0.00 (0.0%)
1985	2.20	5.20 (-.8%)	3.34 (12.8%)	1.38 (10.3%)			0.00 (0.0%)
1990	2.10	5.00 (-.6%)	6.35 (4.8%)	2.31 (7.0%)			0.00 (0.0%)
2000	1.80	4.70 (-.9%)	10.27 (1.0%)	4.64 (6.4%)			0.00 (0.0%)
2010	1.70	4.30 (-2.3%)	11.40 (-2.1%)	8.80 (8.8%)			0.00 (0.0%)
2020	1.60	1.70 (0.0%)	9.20 (-8.7%)	21.20 (2.4%)			0.00 (0.0%)
2040	1.50	0.00 (0.0%)	1.60 (-4.9%)	34.20 (.3%)			0.00 (0.0%)
2060	1.50	0.00 (0.0%)	.60 (****)	36.50 (.1%)			0.00 (0.0%)
2075	1.50	0.00	.00	37.09			.01

YEAR	COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECT. RATIO
	LIO & GAS	COAL (IND)	LIQ & GAS	ELECTRICITY	
1975	0.00 (0.0%)		41.56	6.51 (5.3%)	.12
1980	0.00 (0.0%)		38.50	8.47 (5.1%)	.14
1985	2.15 (21.8%)		39.70	10.91 (5.5%)	.15
1990	6.40 (9.3%)		39.82	14.34 (3.2%)	.19
2000	16.29 (5.0%)		41.50	19.80 (2.0%)	.24
2010	26.92 (1.4%)		37.20	24.25 (2.5%)	.29
2020	31.00 (.5%)		39.20	31.21 (.5%)	.35
2040	34.00 (.5%)		39.00	34.46 (.2%)	.38
2060	37.85 (0.0%)		38.70	35.66 (0.0%)	.40
2075	37.85		38.70	35.66	.40

FINAL CONSUMPTION END USE

YEAR	LIO & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.52	5.73	.16
1990	7.59	15.06	17.17	6.78	7.17	.39
2000	6.96	15.76	18.78	8.80	10.00	1.00
2010	5.89	14.31	17.00	10.72	12.23	1.30
2020	6.02	14.85	18.33	13.51	15.87	1.84
2040	5.86	14.83	18.30	14.75	17.44	2.27
2060	5.82	14.72	18.16	15.26	18.05	2.35
2075	5.82	14.72	18.16	15.26	18.05	2.35

TOTALS

YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94 (3.4%)
1980	14.89	27.47	16.66	58.97	84.26 (3.7%)
1985	13.79	40.17	16.85	70.81	101.49 (2.3%)
1990	14.38	42.63	17.56	74.57	113.59 (1.6%)
2000	15.76	46.76	19.78	82.30	133.36 (.8%)
2010	16.61	47.34	18.30	82.25	144.92 (1.4%)
2020	19.53	50.02	20.17	89.72	167.53 (.3%)
2040	20.61	49.57	20.57	90.75	177.24 (.0%)
2060	21.08	47.07	20.51	88.66	178.79 (.0%)
2075	21.08	47.07	20.51	88.66	178.88

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL	2344.	2719.	5012.
TOTAL LIO & GAS	1911.	1432.	3043.

Figure D-12. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	183.4	183.4	183.4		
1985	234.2	234.2	234.2		
1990	281.8	281.8	281.8		
2000	395.0	395.0	395.0		
2010	515.2	515.2	515.2		
2020	692.1	692.1	692.1		
2040	848.2	848.2	848.2		
2060	915.4	915.4	915.4		
2075	952.7	952.7	952.7		

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	65098.0	65097.9	65097.9
5%	7120.3	7120.3	7120.3
10%	2643.1	2643.1	2643.1
15%	1574.9	1574.9	1574.9
TO 1995			
0%	60491.1	60491.1	60491.1
5%	11420.5	11420.5	11420.5
10%	5044.1	5044.1	5044.1
15%	3198.2	3198.2	3198.2
TO 2010			
0%	54254.4	54254.4	54254.4
5%	14548.2	14548.2	14548.2
10%	7204.4	7204.4	7204.4
15%	4747.0	4747.0	4747.0
TO 2020			
0%	48322.7	48322.6	48322.6
5%	15959.1	15959.1	15959.0
10%	8531.9	8531.9	8531.9
15%	5822.8	5822.8	5022.0

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	90.18	82.16	29.39	18.37	0.00	0.00
1990	171.45	156.21	55.88	34.93	0.00	0.00
2000	277.29	252.64	90.38	56.49	0.00	0.00
2010	307.80	280.44	100.32	62.70	0.00	0.00
2020	248.40	226.32	80.96	50.60	0.00	0.00
2040	43.20	39.36	14.08	8.80	0.00	0.00
2060	16.20	14.76	5.28	3.30	0.00	0.00
2075	.27	.00	.02	.00	.55	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.60	7.94	21.39	19.75	18.27	2.74
1985	7.99	8.41	25.55	26.26	28.86	2.93
1990	7.92	8.60	25.36	26.26	29.14	2.86
2000	7.91	9.28	25.37	26.52	30.04	2.79
2010	7.37	8.52	23.98	25.40	29.54	2.37
2020	6.40	8.81	20.83	23.04	27.51	2.31
2040	5.53	8.59	18.10	20.62	24.79	2.15
2060	5.17	8.42	17.27	18.82	21.03	2.01
2075	5.17	8.42	17.27	18.82	21.03	2.01

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	19.20	2.16	46.80	3.13	.29
1985	24.80	3.06	66.42	4.45	.37
1990	28.80	3.14	70.45	4.66	.39
2000	35.94	3.36	80.36	5.18	.46
2010	42.01	3.48	88.38	5.58	.50
2020	49.39	2.79	76.04	4.69	.36
2040	53.58	2.22	65.31	3.94	.25
2060	54.97	2.05	63.82	3.78	.27
2075	55.08	2.04	63.70	3.78	.27

Figure D-12. Continued.

MZ03 ALL FBR LONG RANGE SUPPLY (BASED ON MZ01)

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(13.1%)	6.48	8.82	1.65	0.00
1980	49.98	25.80	(7.9%)	6.98	13.03	5.34	0.00
1985	49.45	38.29	(1.9%)	6.70	14.86	10.12	0.00
1990	45.95	42.16	(2.1%)	6.15	14.28	18.91	0.00
2000	39.79	51.78	(1.6%)	5.30	13.43	31.64	0.00
2010	27.14	61.06	(-.9%)	5.00	12.31	47.65	0.00
2020	26.11	55.90	(-.4%)	4.71	4.86	73.77	0.00
2040	23.36	51.84	(-.1%)	4.36	0.00	88.22	0.00
2060	20.29	52.59	(0.0%)	4.36	0.00	91.53	0.00
2075	20.29	52.59		4.36	0.00	67.80	.00

ELECTRICAL GENERATION							
YEAR	LIQ & GAS	COAL	FISSION	RENEW		CTR	
1975	2.43	3.15	(6.2%)	1.53	(23.4%)	1.04	(1.1%)
1980	2.30	4.30	(3.8%)	1.71	(13.4%)	1.10	(4.5%)
1985	2.20	5.20	(-.8%)	3.34	(12.9%)	1.38	(10.2%)
1990	2.10	5.00	(-.6%)	6.36	(5.8%)	2.30	(4.3%)
2000	1.80	4.70	(-.9%)	11.39	(4.1%)	3.52	(-1.6%)
2010	1.70	4.30	(-9.3%)	17.20	(4.6%)	3.00	(.6%)
2020	1.60	1.70	(0.0%)	27.20	(.9%)	3.20	(11.1%)
2040	1.50	0.00	(0.0%)	32.60	(.2%)	3.20	(0.0%)
2060	1.50	0.00	(0.0%)	33.90	(-.0%)	3.20	(0.0%)
2075	1.50	0.00		33.90		3.20	.00

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY		ELECT RATIO
YEAR		LIQ & GAS	COAL (IND)			
1975	0.00	(0.0%)	41.56	4.15	6.51	(5.3%)
1980	0.00	(0.0%)	38.50	12.00	8.47	(5.1%)
1985	2.15	(21.8%)	39.70	20.20	10.91	(5.5%)
1990	6.40	(9.3%)	39.82	20.40	14.34	(3.2%)
2000	16.29	(5.0%)	41.50	21.00	19.80	(2.0%)
2010	26.92	(1.4%)	37.20	20.80	24.25	(2.5%)
2020	31.00	(.5%)	39.20	19.30	31.21	(.5%)
2040	34.00	(.5%)	39.00	17.30	34.46	(.2%)
2060	37.85	(0.0%)	38.70	14.30	35.66	(0.0%)
2075	37.85		38.70	14.30	35.66	.40

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.52	5.23	.16
1990	7.59	15.06	17.17	6.78	7.17	.39
2000	6.96	15.76	18.78	8.80	10.00	1.00
2010	5.89	14.31	17.00	10.72	12.23	1.30
2020	6.02	14.85	18.33	13.51	15.87	1.84
2040	5.86	14.83	18.30	14.75	17.44	2.27
2060	5.82	14.72	18.16	15.26	18.05	2.35
2075	5.82	14.72	18.16	15.26	18.05	2.35

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.90	16.73	18.51	52.22	70.94 (3.4%)
1980	14.89	27.42	16.66	58.97	84.26 (3.7%)
1985	13.79	40.17	16.85	70.81	101.49 (2.3%)
1990	14.38	42.63	17.26	74.57	113.59 (1.6%)
2000	15.76	46.76	19.78	82.30	133.27 (.8%)
2010	16.61	47.34	18.30	82.25	144.42 (1.3%)
2020	19.53	50.02	20.17	89.72	164.92 (.2%)
2040	20.61	49.57	20.57	90.75	172.57 (.0%)
2060	21.08	47.01	20.51	88.66	173.55 (-1.0%)
2075	21.08	47.07	20.51	88.66	149.82

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL 2344: 2719: 5012:
TOTAL LIQ & GAS 1917: 1432: 3043:

Figure D-13. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	183.4	183.4	183.4		
1985	234.2	234.2	234.2		
1990	281.8	281.8	281.8		
2000	392.1	392.1	392.1		
2010	475.5	475.5	475.5		
2020	571.9	571.9	571.9		
2040	641.2	641.2	641.2		
2060	693.0	693.0	693.0		
2075	726.3	726.3	726.3		

*DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	52850.4	52850.4	52850.4
5%	6586.5	6586.5	6586.5
10%	2594.3	2594.3	2594.3
15%	1567.9	1567.9	1567.9
TO 1995			
0%	48243.6	48243.6	48243.6
5%	10004.0	10004.0	10004.0
10%	4715.6	4715.6	4715.6
15%	3083.3	3083.3	3083.3
TO 2010			
0%	42144.7	42144.7	42144.7
5%	11772.0	11772.0	11772.0
10%	6040.5	6040.5	6040.5
15%	4072.8	4072.8	4072.8
TO 2020			
0%	36959.4	36959.4	36959.4
5%	12379.4	12379.4	12379.4
10%	6710.5	6710.5	6710.5
15%	4625.7	4625.7	4625.7

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	90.18	82.16	29.39	18.37	0.00	0.00
1990	171.72	156.46	55.97	34.98	0.00	0.00
2000	307.53	280.19	100.23	62.65	0.00	0.00
2010	464.40	423.12	151.36	94.60	0.00	0.00
2020	734.40	669.12	239.36	149.60	0.00	0.00
2040	880.20	801.96	286.88	179.30	0.00	0.00
2060	915.30	833.94	298.32	186.45	0.00	0.00
2075	915.30	833.92	298.31	186.44	.05	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	7.99	8.41	25.55	26.26	28.86	2.93
1990	7.92	8.60	25.36	26.26	29.14	2.86
2000	7.91	9.28	25.38	26.52	30.04	2.79
2010	7.37	8.52	23.99	25.40	29.55	2.37
2020	6.40	8.81	20.86	23.04	27.52	2.31
2040	5.53	8.59	18.14	20.62	24.81	2.15
2060	5.17	8.42	17.31	18.82	21.05	2.01
2075	5.17	8.42.	17.31	18.82	21.05	2.01
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	19.20	2.16	46.80	3.13	.29	
1985	24.80	3.06	66.42	4.45	.37	
1990	28.79	3.14	70.45	4.66	.39	
2000	35.74	3.36	80.58	5.20	.46	
2010	40.97	3.51	89.54	5.65	.52	
2020	46.15	2.90	79.64	4.90	.42	
2040	48.00	2.42	71.51	4.29	.35	
2060	48.98	2.26	70.48	4.16	.38	
2075	48.98	2.26	70.48	4.16	.38	

Figure D-13. Continued.

HH01 IMPORTS ALLOWED, HIGH FUSION

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(6.6%)		6.48	8.82	1.65	0.00
1980	58.66	18.59(5.6%)		6.98	13.03	5.34	0.00
1985	66.50	24.58(6.4%)		6.70	14.86	11.33	0.00
1990	66.80	33.91(4.5%)		6.15	18.00	23.94	.03
2000	65.90	53.30(2.5%)		5.30	19.14	28.53	.34
2010	63.20	68.70(-.2%)		5.00	20.90	31.58	2.29
2020	63.10	67.48(-.3%)		4.71	19.14	24.95	17.14
2040	63.10	63.50(-1.3%)		4.36	14.31	4.33	64.29
2060	63.10	48.74(0.0%)		4.36	0.00	1.62	140.00
2075	63.10	48.74		4.36	0.00	.00	178.86

ELECTRICAL GENERATION					
YEAR	LIQ & GAS	COAL	FISSION	RENEW	CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)	0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)	0.00(0.0%)
1985	2.20	5.20(3.8%)	3.74(15.3%)	1.38(5.3%)	0.00(0.0%)
1990	2.10	6.30(.6%)	8.05(2.4%)	1.80(3.4%)	.01(24.8%)
2000	1.80	6.70(.9%)	10.27(1.0%)	2.52(1.7%)	.12(19.0%)
2010	1.70	7.30(-.9%)	11.40(-2.1%)	3.00(.6%)	.80(20.1%)
2020	1.60	6.70(-1.5%)	9.20(-8.7%)	3.20(0.0%)	6.00(6.6%)
2040	1.50	5.00(0.0%)	1.60(-4.9%)	3.20(0.0%)	22.50(3.9%)
2060	1.50	0.00(0.0%)	.60(****%)	3.20(0.0%)	49.00(1.6%)
2075	1.50	0.00	.00	3.20	62.60

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)			ELECTRICITY RATIO
YEAR		LIQ & GAS	COAL(IND)	ELECTRICITY	
1975	0.00(0.0%)	41.56	4.15	6.51(5.3%)	.12
1980	0.00(0.0%)	46.40	5.00	8.47(5.7%)	.14
1985	2.15(28.0%)	55.20	6.70	11.27(5.4%)	.15
1990	8.71(8.9%)	60.30	9.40	14.80(2.9%)	.18
2000	21.21(3.5%)	68.50	12.00	19.80(1.2%)	.20
2010	30.00(1.0%)	72.00	13.80	22.40(1.0%)	.21
2020	33.00(.1%)	74.20	14.30	24.73(1.2%)	.22
2040	34.00(0.0%)	75.20	14.30	31.23(2.4%)	.26
2060	34.00(0.0%)	75.20	14.30	50.17(1.4%)	.36
2075	34.00	75.20	14.30	62.18	.41

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	12.40	14.00	20.00	4.60	3.80	.07
1985	11.50	20.50	23.20	5.70	5.40	.17
1990	11.50	22.80	26.00	7.00	7.40	.40
2000	11.50	26.00	31.00	8.80	10.00	1.00
2010	11.40	27.70	32.90	9.90	11.30	1.20
2020	11.40	28.10	34.70	10.70	12.57	1.45
2040	11.30	28.60	35.30	13.37	15.81	2.06
2060	11.30	28.60	35.30	21.47	25.40	3.30
2075	11.30	28.60	35.30	26.61	31.47	4.09

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.8%)
1980	17.00	22.80	20.17	59.97	85.73(4.3%)
1985	17.20	32.80	23.37	73.37	106.04(4.0%)
1990	18.50	39.60	26.40	84.50	129.82(1.8%)
2000	20.30	48.00	32.00	100.30	155.27(1.2%)
2010	21.30	52.80	34.10	108.20	174.37(.4%)
2020	22.10	54.97	36.15	113.22	181.81(.6%)
2040	24.67	58.71	37.36	120.74	204.36(1.3%)
2060	32.77	68.30	38.60	139.67	262.60(.9%)
2075	37.91	74.37	39.39	151.67	299.84

CUM. RESOURCE USE			
1975-2024		1975-2075	
TOTAL COAL	2386.	3168.	5263.
TOTAL LIQ & GAS	3176.	3187.	6395.

Figure D-14. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	191.5	191.5	191.5		
1985	254.2	254.2	254.2		
1990	333.8	333.8	333.7		
2000	462.5	462.5	461.9		
2010	579.3	578.2	575.5		
2020	661.2	644.6	635.2		
2040	810.7	750.5	738.8		
2060	989.0	898.2	898.2		
2075	1078.0	1034.9	1034.9		
DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST					
TO 1975					
0%	67749.8	64166.1	63764.9		
5%	7661.4	7548.4	7515.9		
10%	2880.3	2873.6	2869.6		
15%	1692.9	1692.3	1691.6		
TO 1995					
0%	62608.6	59024.9	58624.8		
5%	12131.8	11831.9	11746.7		
10%	5628.4	5583.1	5557.5		
15%	3672.7	3662.2	3651.7		
TO 2010					
0%	55325.0	51742.9	51352.8		
5%	14457.2	13835.5	13672.7		
10%	7240.4	7053.0	6967.4		
15%	4865.9	4782.5	4729.1		
TO 2020					
0%	49126.0	45606.5	45280.6		
5%	15407.1	14469.8	14285.3		
10%	8027.5	7632.5	7512.3		
15%	5433.9	5206.7	5119.7		

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.03	70.86	44.28	.55	0.00
2000	280.53	252.64	90.57	56.49	6.60	0.00
2010	329.40	280.44	101.62	62.70	44.00	0.00
2020	410.40	226.32	90.74	50.60	330.00	0.00
2040	650.70	39.36	50.76	8.80	1237.50	0.00
2060	1339.20	14.76	85.15	3.30	2695.00	0.00
2075	1690.20	.00	102.04	.00	3443.00	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.53	9.10	21.19	16.91	9.96	3.02
1985	7.73	10.62	25.42	21.16	12.90	3.46
1990	8.80	11.99	28.80	24.56	16.77	3.71
2000	9.79	14.25	31.90	27.81	20.79	4.04
2010	10.46	15.21	34.17	30.12	23.49	4.15
2020	10.44	15.91	33.92	30.19	24.16	4.23
2040	9.88	16.03	32.01	29.19	24.03	4.21
2060	8.10	15.65	26.07	25.93	23.44	4.07
2075	8.10	15.65	26.07	25.93	23.44	4.07
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	18.01	1.58	35.51	2.34	.28	
1985	22.94	1.96	45.05	2.94	.36	
1990	30.36	2.36	57.56	3.68	.48	
2000	37.86	3.21	81.85	5.15	.60	
2010	43.93	3.95	101.75	6.39	.71	
2020	45.77	3.65	97.41	6.04	.68	
2040	51.04	3.22	88.45	5.43	.56	
2060	65.50	2.00	62.89	3.69	.24	
2075	77.07	1.99	63.00	3.69	.24	

Figure D-14. Continued.

HH02 NO IMPORTS, VERY HIGH FUSION

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.80(8.7%)		6.98	13.03	5.34	0.00
1985	49.45	39.84(5.9%)		6.70	14.86	11.33	0.00
1990	47.79	53.45(3.2%)		6.15	18.00	23.94	.03
2000	39.79	73.93(1.9%)		5.30	19.14	28.53	.34
2010	37.58	89.22(-.9%)		5.00	20.90	31.58	8.00
2020	26.11	81.41(-.6%)		4.71	19.14	24.95	40.00
2040	23.36	72.74(-1.1%)		4.36	14.31	4.33	94.29
2060	20.29	58.74(0.0%)		4.36	0.00	1.62	172.29
2075	20.29	58.74		4.36	0.00	.00	212.57

ELECTRICAL GENERATION					
YEAR	LIQ & GAS	COAL	FISSION	RENEW	CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)	0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)	0.00(0.0%)
1985	2.20	5.20(3.8%)	3.74(15.3%)	1.38(5.3%)	0.00(0.0%)
1990	2.10	6.30(.6%)	8.05(2.4%)	1.80(3.4%)	.01(24.8%)
2000	1.80	6.70(.9%)	10.27(1.0%)	2.52(1.7%)	.12(31.5%)
2010	1.70	7.30(-.9%)	11.40(-2.1%)	3.00(.6%)	2.80(16.1%)
2020	1.60	6.70(-1.5%)	9.20(-8.7%)	3.20(0.0%)	14.00(4.3%)
2040	1.50	5.00(0.0%)	1.60(-4.9%)	3.20(0.0%)	33.00(3.0%)
2060	1.50	0.00(0.0%)	.60(****)	3.20(0.0%)	60.30(1.4%)
2075	1.50	0.00	.00	3.20	74.40

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY RATIO
YEAR		LIQ & GAS	COAL(IND)	
1975	0.00(0.0%)	41.56	4.15	.12
1980	0.00(0.0%)	38.50	12.00	.14
1985	2.15(28.0%)	39.70	21.70	.16
1990	8.71(8.9%)	43.00	25.40	.18
2000	21.21(3.7%)	44.70	32.00	.21
2010	30.77(2.3%)	49.20	35.80	.22
2020	38.69(.2%)	44.20	22.30	.33
2040	40.15(.5%)	43.00	17.30	.40
2060	44.00(0.0%)	42.70	14.30	.52
2075	44.00	42.70	14.30	.56

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.09	5.70	5.40	.17
1990	8.20	16.26	18.54	7.00	7.40	.40
2000	7.50	16.97	20.23	8.80	10.00	1.00
2010	7.79	18.92	22.49	10.72	12.23	1.30
2020	6.79	16.74	20.67	13.91	16.34	1.89
2040	6.46	16.35	20.18	17.52	20.71	2.70
2060	6.42	16.24	20.04	25.93	30.68	3.99
2075	6.42	16.24	20.04	31.27	36.99	4.82

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.4%)
1980	14.89	27.42	16.66	58.97	84.26(4.3%)
1985	13.97	41.84	16.86	72.67	104.25(4.5%)
1990	15.20	49.06	18.94	83.20	130.35(1.4%)
2000	16.30	58.97	21.23	96.50	149.79(1.6%)
2010	18.51	66.95	23.79	109.25	174.99(.4%)
2020	20.70	55.38	22.56	98.64	181.61(.6%)
2040	23.98	54.36	22.88	101.22	203.86(1.3%)
2060	32.35	61.22	24.03	117.60	262.08(.9%)
2075	37.69	67.53	24.86	130.08	300.74

CUM. RESOURCE USE			
	1975-2024	1995-2044	1975-2075
TOTAL COAL	3194.	3917.	6571.
TOTAL LIQ & GAS	2031.	1503.	3134.

Figure D-15. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS				SET5
	SET1	SET2	SET3	SET4	
1975	148.1	148.1	148.1		
1980	183.4	183.4	183.4		
1985	239.5	239.5	239.5		
1990	320.4	320.4	320.4		
2000	432.7	432.7	432.1		
2010	579.3	575.4	566.2		
2020	675.8	637.2	615.2		
2040	798.2	710.0	692.8		
2060	941.6	829.9	829.9		
2075	1005.2	953.9	953.9		

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	65853.6	60853.0	60082.4
5%	7439.5	7255.1	7185.8
10%	2774.8	2761.8	2753.0
15%	1631.4	1629.9	1628.5
TO 1995			
0%	60934.6	55934.1	55164.0
5%	11880.4	11391.0	11208.0
10%	5447.8	5360.4	5302.1
15%	3517.0	3493.8	3470.4
TO 2010			
0%	53982.9	48989.2	48248.8
5%	14459.7	13449.9	13105.8
10%	7322.7	6966.2	6767.9
15%	4936.2	4757.5	4624.9
TO 2020			
0%	47664.2	42833.6	42265.8
5%	15263.3	13816.3	13475.7
10%	8057.7	7374.5	7141.7
15%	5490.4	5064.0	4889.4

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3 CU FT	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	E3 CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.03	70.86	44.28	.55	0.00
2000	280.53	252.64	90.57	56.49	6.60	0.00
2010	383.40	280.44	104.88	62.70	154.00	0.00
2020	626.40	226.32	103.78	50.60	770.00	0.00
2040	934.20	39.36	67.87	8.80	1815.00	0.00
2060	1644.30	14.76	103.57	3.30	3316.50	0.00
2075	2008.80	.00	121.27	.00	4092.00	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	8.16	8.47	25.99	27.16	30.75	2.96
1990	9.20	9.50	29.25	30.82	35.81	3.14
2000	10.12	10.53	31.94	35.22	44.36	3.18
2010	11.09	11.71	35.05	38.92	49.59	3.37
2020	8.92	10.34	29.13	29.25	32.26	2.67
2040	7.63	9.79	25.22	24.79	25.69	2.41
2060	5.49	9.24	18.44	19.72	21.34	2.13
2075	5.49	9.24	18.44	19.72	21.34	2.13

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	19.20	2.16	46.80	3.13	.29
1985	25.56	3.19	69.02	4.63	.37
1990	33.93	3.94	88.30	5.84	.50
2000	41.15	4.87	114.09	7.43	.62
2010	48.98	5.56	133.48	8.61	.73
2020	53.38	4.43	114.87	7.20	.72
2040	59.41	3.58	97.91	6.03	.60
2060	74.41	2.19	71.09	4.14	.31
2075	86.42	2.19	71.21	4.13	.31

Figure D-15. Continued.

HH03 NO IMPORTS SOLAR ONLY

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.80(8.7%)		6.98	13.03	5.34	0.00
1985	49.45	39.84(5.9%)		6.70	14.86	11.33	0.00
1990	47.79	53.45(3.2%)		6.15	18.00	23.94	0.00
2000	39.79	73.93(1.9%)		5.30	19.14	28.53	0.00
2010	37.58	89.22(-.9%)		5.00	20.90	31.58	.00
2020	26.11	81.41(-.6%)		4.71	19.14	24.95	0.00
2040	23.36	72.74(-1.1%)		4.36	14.31	4.33	0.00
2060	20.29	58.74(0.0%)		4.36	0.00	1.62	0.00
2075	20.29	58.74		4.36	0.00	.00	.00

ELECTRICAL GENERATION					
YEAR	LIQ & GAS	COAL	FISSION	RENEW	CTR
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)	0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)	0.00(0.0%)
1985	2.20	5.20(3.8%)	3.74(15.3%)	1.38(5.4%)	0.00(0.0%)
1990	2.10	6.30(.6%)	8.05(2.4%)	1.81(3.8%)	0.00(0.0%)
2000	1.80	6.70(-.9%)	10.27(1.0%)	2.64(7.9%)	0.00(0.0%)
2010	1.70	7.30(-.9%)	11.40(-2.1%)	5.80(10.9%)	.00(0.0%)
2020	1.60	6.70(-1.5%)	9.20(-8.7%)	17.20(3.7%)	0.00(0.0%)
2040	1.50	5.00(0.0%)	1.60(-4.9%)	36.20(2.8%)	0.00(0.0%)
2060	1.50	0.00(0.0%)	.60(****%)	63.50(1.3%)	0.00(0.0%)
2075	1.50	0.00	.00	77.60	.00

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY RATIO
YEAR		LIQ & GAS	COAL (IND)	
1975	0.00(0.0%)	41.56	4.15	.12
1980	0.00(0.0%)	38.50	12.00	.14
1985	2.15(28.0%)	39.70	21.70	.16
1990	8.71(8.9%)	43.00	25.40	.18
2000	21.21(3.7%)	44.70	32.00	.21
2010	30.77(2.3%)	49.20	35.80	.22
2020	38.69(.2%)	44.20	22.30	.33
2040	40.15(.5%)	43.00	17.30	.40
2060	44.00(0.0%)	42.70	14.30	.52
2075	44.00	42.70	14.30	.56

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.80	.07
1985	8.27	14.74	16.69	5.70	5.40	.17
1990	8.20	16.26	18.54	7.00	7.40	.40
2000	7.50	16.97	20.23	8.80	10.00	1.00
2010	7.79	18.92	22.49	10.72	12.23	1.30
2020	6.79	16.74	20.67	13.91	16.34	1.89
2040	6.46	16.35	20.18	17.52	20.71	2.70
2060	6.42	16.24	20.04	25.93	30.68	3.99
2075	6.42	16.24	20.04	31.27	36.99	4.82

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.4%)
1980	14.89	27.42	16.66	58.97	84.26(4.3%)
1985	13.97	41.84	16.86	72.67	104.25(4.5%)
1990	15.20	49.06	18.94	83.20	130.35(1.4%)
2000	16.30	58.97	21.23	96.50	149.79(1.6%)
2010	18.51	66.95	23.79	109.25	174.95(.4%)
2020	20.70	55.38	22.56	98.64	181.61(.6%)
2040	23.98	54.36	22.88	101.22	203.86(1.3%)
2060	32.35	61.22	24.03	117.60	262.08(.9%)
2075	37.69	67.53	24.86	130.08	300.74

CUM. RESOURCE USE			
	1975-2024	1995-2044	1975-2075
TOTAL COAL	3194.	3917.	6571.
TOTAL LIQ & GAS	2031.	1503.	3134.

Figure D-16. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	183.4	183.4	183.4		
1985	239.5	239.5	239.5		
1990	320.3	320.3	320.3		
2000	431.9	431.9	431.9		
2010	581.8	581.8	581.8		
2020	730.6	730.6	730.6		
2040	978.5	978.5	978.5		
2060	1364.5	1364.5	1364.5		
2075	1613.5	1613.5	1613.5		

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975				
0%	82249.3	82249.3	82249.3	
5%	7845.4	7845.4	7845.3	
10%	2795.3	2795.3	2795.3	
15%	1632.9	1632.9	1632.9	
TO 1995				
0%	77331.5	77331.5	77331.5	
5%	12958.5	12958.5	12958.5	
10%	5587.6	5587.5	5587.5	
15%	3544.5	3544.5	3544.5	
TO 2010				
0%	70392.7	70392.7	70392.7	
5%	16719.6	16719.6	16719.6	
10%	7933.4	7933.4	7933.4	
15%	5200.0	5200.0	5200.0	
TO 2020				
0%	63876.7	63876.7	63876.7	
5%	18709.3	18709.3	18709.3	
10%	9360.3	9360.3	9360.3	
15%	6219.5	6219.5	6219.5	

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.35	198.03	70.84	44.28	0.00	0.00
2000	277.29	252.64	90.38	56.49	0.00	0.00
2010	307.83	280.44	100.32	62.70	.05	0.00
2020	248.40	226.32	80.96	50.60	0.00	0.00
2040	43.20	39.36	14.08	8.80	0.00	0.00
2060	16.20	14.76	5.28	3.30	0.00	0.00
2075	.03	.00	.00	.00	.05	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	8.16	8.47	25.99	27.16	30.75	2.96
1990	9.20	9.50	29.25	30.82	35.81	3.14
2000	10.12	10.53	31.94	35.22	44.36	3.18
2010	11.09	11.72	35.05	38.92	49.59	3.37
2020	8.92	10.34	29.13	29.25	32.26	2.67
2040	7.63	9.79	25.22	24.79	25.69	2.41
2060	5.49	9.24	18.44	19.72	21.34	2.13
2075	5.49	9.24	18.44	19.72	21.34	2.13
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	19.20	2.16	46.80	3.13	.29	
1985	25.56	3.19	69.02	4.63	.37	
1990	33.93	3.94	88.30	5.84	.50	
2000	41.17	4.87	114.09	7.43	.62	
2010	49.49	5.56	133.43	8.61	.73	
2020	55.90	4.43	114.64	7.20	.72	
2040	65.35	3.58	97.35	6.01	.60	
2060	85.26	2.18	70.06	4.12	.31	
2075	99.81	2.18	69.94	4.11	.31	

Figure D-16. Continued.

HH04 NO IMPORTS, FISSION ONLY (FBR)

YEAR	FOSSIL RESOURCES TOTAL USE			ELECTRIC GENERATION RESOURCE USE (THERMAL)			
	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37(13.1%)		6.48	8.82	1.65	0.00
1980	49.98	25.80(8.7%)		6.98	13.03	5.34	0.00
1985	49.45	39.84(5.9%)		6.70	14.86	11.33	0.00
1990	47.79	53.45(3.2%)		6.15	18.00	23.97	0.00
2000	39.79	73.93(1.9%)		5.30	19.14	28.86	0.00
2010	37.58	89.22(-.9%)		5.00	20.90	39.34	0.00
2020	26.11	81.41(-.6%)		4.71	19.14	62.92	0.00
2040	23.36	72.74(-1.1%)		4.36	14.31	93.64	0.00
2060	20.29	58.74(0.0%)		4.36	0.00	164.43	0.00
2075	20.29	58.74		4.36	0.00	148.80	.00

YEAR	ELECTRICAL GENERATION					CTR
	LIQ & GAS	COAL	FISSION	RENEW		
1975	2.43	3.15(6.2%)	.53(23.4%)	1.04(1.1%)		0.00(0.0%)
1980	2.30	4.30(3.8%)	1.71(15.7%)	1.10(4.5%)		0.00(0.0%)
1985	2.20	5.20(3.8%)	3.74(15.4%)	1.38(5.3%)		0.00(0.0%)
1990	2.10	6.30(.6%)	8.06(2.5%)	1.80(3.4%)		0.00(0.0%)
2000	1.80	6.70(.9%)	10.39(3.1%)	2.52(1.7%)		0.00(0.0%)
2010	1.70	7.30(-.9%)	14.20(4.9%)	3.00(.6%)		0.00(0.0%)
2020	1.60	6.70(-1.5%)	23.20(2.0%)	3.20(0.0%)		0.00(0.0%)
2040	1.50	5.00(0.0%)	34.60(2.8%)	3.20(0.0%)		0.00(0.0%)
2060	1.50	0.00(0.0%)	60.90(1.3%)	3.20(0.0%)		0.00(0.0%)
2075	1.50	0.00	74.40	3.20		.00

YEAR	COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY RATIO
	LIQ & GAS	COAL(IND)	LIQ & GAS	ELECTRICITY	
1975	0.00(0.0%)		41.56	6.51(5.3%)	.12
1980	0.00(0.0%)		38.50	8.47(5.7%)	.14
1985	2.15(28.0%)		39.70	11.27(5.4%)	.16
1990	8.71(8.9%)		43.00	14.80(2.9%)	.18
2000	21.21(3.7%)		44.70	19.80(2.0%)	.21
2010	30.77(2.3%)		49.20	24.25(2.8%)	.22
2020	38.69(.2%)		44.20	32.14(1.2%)	.33
2040	40.15(.5%)		43.00	40.93(2.0%)	.40
2060	44.00(0.0%)		42.70	60.60(1.2%)	.52
2075	44.00		42.70	73.08	.56

FINAL CONSUMPTION END USE

YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	10.29	11.62	16.59	4.60	3.00	.07
1985	8.27	14.74	16.69	5.70	3.40	.17
1990	8.20	16.26	18.54	7.00	7.40	.40
2000	7.50	16.97	20.23	8.80	10.00	1.00
2010	7.79	10.92	22.49	10.72	12.23	1.30
2020	6.79	16.74	20.67	13.91	16.34	1.89
2040	6.46	16.35	20.18	17.52	20.71	2.70
2060	6.42	16.24	20.04	25.93	30.68	3.99
2075	6.42	16.24	20.04	31.27	36.99	4.82

TOTALS

YFAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94(3.4%)
1980	14.89	27.42	16.66	58.97	84.26(4.3%)
1985	13.97	41.84	16.86	72.67	104.25(4.5%)
1990	15.20	49.06	18.94	83.20	130.35(1.4%)
2000	16.30	58.97	21.23	96.50	149.78(1.5%)
2010	18.51	66.95	23.79	109.25	174.74(.3%)
2020	20.70	55.38	22.56	98.64	179.58(.5%)
2040	23.96	54.36	22.00	101.22	198.88(1.2%)
2060	32.35	61.22	24.03	117.60	252.60(-.4%)
2075	37.69	67.53	24.86	130.08	236.97

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL	3194.	3917.	6571.
TOTAL LIQ & GAS	2031.	1503.	3134.

Figure D-17. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	183.4	183.4	183.4		
1985	239.5	239.5	239.5		
1990	320.3	320.3	320.3		
2000	431.6	431.6	431.6		
2010	562.7	562.7	562.7		
2020	637.1	637.1	637.1		
2040	758.1	758.1	758.1		
2060	961.7	961.7	961.7		
2075	1116.6	1116.6	1116.6		
DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST					
TO 1975					
0%	65250.5	65250.5	65250.5		
5%	7316.7	7316.7	7316.7		
10%	2758.7	2758.7	2758.7		
15%	1628.7	1628.7	1628.7		
TO 1995*					
0%	60332.6	60332.6	60332.6		
5%	11555.7	11555.7	11555.7		
10%	5341.2	5341.2	5341.2		
15%	3474.6	3474.6	3474.6		
TO 2010					
0%	53434.4	53434.4	53434.4		
5%	13850.2	13850.2	13850.2		
10%	6959.2	6959.2	6959.2		
15%	4695.5	4695.5	4695.5		
TO 2020					
0%	47424.4	47424.4	47424.4		
5%	14663.7	14663.7	14663.7		
10%	7618.7	7618.7	7618.7		
15%	5164.8	5164.8	5164.8		

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	BLANKET CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	46.17	42.07	15.05	9.41	0.00	0.00
1985	100.98	92.00	32.91	20.57	0.00	0.00
1990	217.62	198.28	70.93	44.33	0.00	0.00
2000	280.53	255.59	91.43	57.15	0.00	0.00
2010	383.40	349.32	124.96	78.10	0.00	0.00
2020	626.40	570.72	204.16	127.60	0.00	0.00
2040	934.20	851.16	304.48	190.30	0.00	0.00
2060	1644.30	1498.14	535.92	334.95	0.00	0.00
2075	2008.80	1830.22	654.71	409.19	.05	0.00
CO2 CO NOX SO2 PART HC						
YEAR	E9 TONS	E6 TONS	E6 TONS	E6 TONS	E6 TONS	E6 TONS
1975	5.67	8.32	18.08	14.12	8.36	2.73
1980	6.68	7.94	21.39	19.75	18.27	2.74
1985	8.16	8.47	25.99	27.16	30.75	2.96
1990	9.20	9.50	29.25	30.82	35.81	3.14
2000	10.12	10.53	31.94	35.22	44.36	3.18
2010	11.09	11.72	35.05	38.92	49.59	3.37
2020	8.92	10.34	29.15	29.25	32.27	2.67
2040	7.63	9.79	25.26	24.79	25.71	2.41
2060	5.49	9.24	18.52	19.72	21.38	2.14
2075	5.49	9.24	18.54	19.72	21.39	2.14
LAND USE DEATHS INJURIES MAN DAYS SOLID WASTE						
YEAR	E6 ACRES	E3	E3	LOST E6	E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	19.20	2.16	46.80	3.13	.29	
1985	25.56	3.19	69.02	4.63	.37	
1990	33.93	3.94	88.31	5.84	.50	
2000	41.15	4.87	114.12	7.43	.62	
2010	48.98	5.57	133.99	8.64	.74	
2020	53.38	4.51	117.44	7.35	.77	
2040	59.41	3.79	103.95	6.38	.71	
2060	74.41	2.57	82.12	4.79	.51	
2075	86.42	2.65	84.82	4.94	.56	

Figure D-17. Continued.

LZ01 LOW-ZEG BASE CASE

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37 (5.3%)		6.48	8.82	1.65	0.00
1980	55.14	17.47 (4.7%)		6.56	12.25	5.02	0.00
1985	59.85	22.12 (5.8%)		6.03	13.37	10.20	0.00
1990	56.78	29.62 (2.7%)		5.23	13.56	20.37	0.00
2000	48.14	38.63 (1.3%)		3.92	14.16	21.36	0.00
2010	41.71	44.00 (.4%)		3.30	14.37	22.72	0.00
2020	40.77	45.71 (.1%)		3.04	14.41	23.13	0.00
2040	40.35	46.23 (.0%)		2.79	14.64	23.53	0.00
2060	40.37	46.28 (0.0%)		2.79	14.65	23.54	0.00
2075	40.37	46.28		2.79	14.65	23.54	0.00

ELECTRICAL GENERATION						
YEAR	LIQ & GAS	COAL	FISSION	RENEW		CTR
1975	2.43	3.15 (5.0%)	.53 (22.2%)	1.04 (1.1%)		0.00 (0.0%)
1980	2.16	4.04 (2.9%)	1.61 (14.8%)	1.10 (4.8%)		0.00 (0.0%)
1985	1.98	4.68 (.3%)	3.37 (14.2%)	1.40 (1.8%)		0.00 (0.0%)
1990	1.79	4.75 (.4%)	6.85 (1.2%)	1.53 (2.0%)		0.00 (0.0%)
2000	1.33	4.96 (.1%)	7.69 (.6%)	1.86 (.6%)		0.00 (0.0%)
2010	1.12	5.02 (.0%)	8.20 (.4%)	1.98 (.2%)		0.00 (0.0%)
2020	1.03	5.04 (.1%)	8.53 (.1%)	2.03 (.0%)		0.00 (0.0%)
2040	.96	5.12 (0.0%)	8.70 (0.0%)	2.05 (0.0%)		0.00 (0.0%)
2060	.96	5.12 (0.0%)	8.70 (0.0%)	2.05 (0.0%)		0.00 (0.0%)
2075	.96	5.12	8.70	2.05		0.00

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)			ELECT
YEAR		LIQ & GAS	COAL (IND)	ELECTRICITY	RATIO
1975	0.00 (0.0%)	41.56	4.15	6.51 (4.2%)	.12
1980	0.00 (0.0%)	43.62	4.70	8.02 (5.0%)	.14
1985	1.94 (26.8%)	49.68	6.03	10.28 (5.6%)	.16
1990	7.40 (7.5%)	51.26	7.99	13.57 (.8%)	.19
2000	15.70 (2.3%)	50.09	8.08	14.65 (.3%)	.20
2010	19.80 (.7%)	47.52	9.11	15.11 (.2%)	.21
2020	21.32 (.1%)	47.94	9.24	15.40 (.0%)	.21
2040	21.74 (.0%)	48.09	9.14	15.54 (0.0%)	.21
2060	21.75 (0.0%)	48.11	9.15	15.54 (0.0%)	.21
2075	21.75	48.11	9.15	15.54	.21

FINAL CONSUMPTION END USE						
YEAR	R & C	LIQ & GAS IND	TRANS	R & C	ELECTRICITY IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	11.66	13.16	18.80	4.36	3.60	.07
1985	10.35	18.45	20.88	5.20	4.93	.15
1990	9.78	19.38	22.10	6.42	6.79	.37
2000	8.41	19.01	22.67	6.51	7.40	.74
2010	7.52	18.28	21.71	6.68	7.62	.81
2020	7.37	18.16	22.42	6.67	7.83	.91
2040	7.23	18.29	22.57	6.65	7.87	1.02
2060	7.23	18.30	22.58	6.65	7.87	1.02
2075	7.23	18.30	22.58	6.65	7.87	1.02

TOTALS					
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE
1975	16.98	16.73	18.51	52.22	70.94 (2.6%)
1980	16.01	21.46	18.87	56.34	80.78 (3.5%)
1985	15.55	29.41	21.03	65.99	96.17 (2.9%)
1990	16.19	34.16	22.47	72.82	111.14 (.2%)
2000	14.92	34.49	23.41	72.82	113.46 (.1%)
2010	14.20	35.01	22.52	71.73	114.11 (.1%)
2020	14.03	35.23	23.33	72.59	115.40 (.0%)
2040	13.88	35.30	23.60	72.78	115.95 (.0%)
2060	13.88	35.31	23.61	72.80	116.04 (0.0%)
2075	13.88	35.31	23.61	72.80	116.04

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL 1731: 2198: 4089:
TOTAL LIQ & GAS 2439: 2126: 4500:

Figure D-18. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	COST ASSUMPTIONS SETS				
	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	180.4	180.4	180.4		
1985	229.8	229.8	229.8		
1990	284.6	284.6	284.6		
2000	338.2	338.2	338.2		
2010	378.8	378.8	378.8		
2020	413.4	413.4	413.4		
2040	469.3	469.3	469.3		
2060	523.0	523.0	523.0		
2075	563.1	563.1	563.1		

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	41099.1	41099.1	41099.1
5%	5774.8	5774.8	5774.8
10%	2456.8	2456.8	2456.8
15%	1527.2	1527.2	1527.2
TO 1995			
0%	36539.0	36539.0	36539.0
5%	7926.5	7926.5	7926.5
10%	3920.5	3920.5	3920.5
15%	2642.5	2642.5	2642.5
TO 2010			
0%	31346.7	31346.7	31346.7
5%	8714.6	8714.6	8714.6
10%	4510.9	4510.9	4510.9
15%	3074.7	3074.7	3074.7
TO 2020			
0%	27400.8	27400.8	27400.8
5%	9002.4	9002.4	9002.4
10%	4829.9	4829.9	4829.9
15%	3316.2	3316.2	3316.2

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
	MAN REM	CURIES	CURIES	CU FT	CU FT	
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	43.47	39.61	14.17	8.86	0.00	0.00
1985	90.99	82.90	29.66	18.54	0.00	0.00
1990	184.95	168.51	60.28	37.68	0.00	0.00
2000	207.63	189.17	67.67	42.30	0.00	0.00
2010	221.40	201.72	72.16	45.10	0.00	0.00
2020	230.31	209.84	75.06	46.92	0.00	0.00
2040	234.90	214.02	76.56	47.85	0.00	0.00
2060	234.90	214.02	76.56	47.85	0.00	0.00
2075	234.90	214.02	76.56	47.85	0.00	0.00
YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	0.32	18.08	14.12	8.36	2.73
1980	6.14	0.56	19.92	15.90	9.36	2.83
1985	6.96	0.56	22.87	19.04	11.61	3.12
1990	7.27	10.16	23.78	20.50	14.23	3.15
2000	7.11	10.40	23.22	19.97	14.34	2.94
2010	6.97	10.04	22.78	20.00	15.50	2.74
2020	7.00	10.34	22.76	19.97	15.69	2.75
2040	7.00	10.40	22.76	19.92	15.59	2.75
2060	7.01	10.40	22.77	19.93	15.60	2.75
2075	7.01	10.40	22.77	19.93	15.60	2.75
YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS	
1975	14.17	1.14	26.12	1.71	.20	
1980	17.00	1.48	33.37	2.20	.26	
1985	20.82	1.76	40.54	2.65	.32	
1990	25.48	2.07	49.94	3.20	.38	
2000	27.75	2.31	59.24	3.72	.45	
2010	28.95	2.50	65.22	4.08	.48	
2020	29.56	2.55	67.08	4.18	.49	
2040	29.83	2.57	67.70	4.22	.50	
2060	29.84	2.57	67.77	4.22	.50	
2075	29.84	2.57	67.77	4.22	.50	

Figure D-18. Continued.

LZ02 FUSION REPLACES FBR

FOSSIL RESOURCES TOTAL USE				ELECTRIC GENERATION RESOURCE USE (THERMAL)			
YEAR	LIQ & GAS	COAL		LIQ & GAS	COAL	FISSION	CTR
1975	52.80	13.37	(5.3%)	6.48	8.82	1.65	0.00
1980	55.14	17.47	(4.7%)	6.56	12.25	5.02	0.00
1985	59.85	22.12	(5.8%)	6.03	13.37	10.20	0.00
1990	56.78	29.62	(2.7%)	5.23	13.56	20.34	.03
2000	48.14	38.63	(1.3%)	3.92	14.16	21.03	.34
2010	41.71	44.00	(.4%)	3.30	14.37	15.79	7.14
2020	40.77	45.71	(.1%)	3.04	14.41	12.28	11.43
2040	40.35	46.23	(.0%)	2.79	14.64	1.89	22.86
2060	40.37	46.28	(0.0%)	2.79	14.65	.81	24.00
2075	40.37	46.28		2.79	14.65	.00	24.86

ELECTRICAL GENERATION									
YEAR	LIQ & GAS	COAL	FISSION	RENEW		CTR			
1975	2.43	3.15	(5.0%)	1.53	(22.2%)	1.04	(1.1%)	0.00	(0.0%)
1980	2.16	4.04	(2.9%)	1.61	(14.8%)	1.10	(4.8%)	0.00	(0.0%)
1985	1.98	4.68	(.3%)	3.37	(14.2%)	1.40	(1.8%)	0.00	(0.0%)
1990	1.79	4.75	(.4%)	6.84	(1.0%)	1.53	(2.0%)	.01	(24.8%)
2000	1.33	4.96	(.1%)	7.57	(2.8%)	1.86	(.6%)	.12	(30.4%)
2010	1.12	5.02	(.0%)	5.70	(2.3%)	1.98	(.2%)	2.50	(4.7%)
2020	1.03	5.04	(.1%)	4.53	(9.3%)	2.03	(.0%)	4.00	(3.5%)
2040	.96	5.12	(0.0%)	.70	(-4.2%)	2.05	(0.0%)	8.00	(.2%)
2060	.96	5.12	(0.0%)	.30	(****%)	2.05	(0.0%)	8.40	(.2%)
2075	.96	5.12		.00		2.05		8.70	

COAL TO SYNFUELS		TOTAL ENERGY CARRIERS (DIRECT USE)		ELECTRICITY		ELECT RATIO	
YEAR	LIQ & GAS	COAL(IND)	COAL(IND)	COAL(IND)	COAL(IND)		
1975	0.00	(0.0%)	41.56	4.15	6.51	(4.2%)	.12
1980	0.00	(0.0%)	43.62	4.70	8.02	(5.0%)	.14
1985	1.94	(26.8%)	49.68	6.03	10.28	(5.6%)	.16
1990	7.40	(7.5%)	51.26	7.99	13.57	(.8%)	.19
2000	15.70	(2.3%)	50.09	9.08	14.65	(.3%)	.20
2010	19.80	(.7%)	47.52	9.11	15.11	(.2%)	.21
2020	21.32	(.1%)	47.94	9.24	15.40	(.0%)	.21
2040	21.74	(.0%)	48.09	9.14	15.54	(0.0%)	.21
2060	21.75	(0.0%)	48.11	9.15	15.54	(0.0%)	.21
2075	21.75		48.11	9.15	15.54		.21

FINAL CONSUMPTION END USE						
YEAR	LIQ & GAS			ELECTRICITY		
	R & C	IND	TRANS	R & C	IND	TRANS
1975	13.20	9.88	18.49	3.78	2.71	.02
1980	11.66	13.16	18.80	4.36	3.60	.07
1985	10.35	18.45	20.88	5.20	4.23	.15
1990	9.78	19.34	22.10	6.42	6.79	.37
2000	8.41	19.01	22.67	6.51	7.40	.74
2010	7.52	18.28	21.71	6.68	7.62	.81
2020	7.37	18.16	22.42	6.67	7.83	.91
2040	7.23	18.29	22.57	6.65	7.87	1.02
2060	7.23	18.30	22.58	6.65	7.87	1.02
2075	7.23	18.30	22.58	6.65	7.87	1.02

TOTALS						
YEAR	R & C	IND	TRANS	TOT USE	TOT RESOURCE	
1975	16.98	16.73	18.51	52.22	70.94	(2.6%)
1980	16.01	21.46	18.87	56.34	80.78	(3.5%)
1985	15.55	29.41	21.03	65.99	96.17	(2.9%)
1990	16.19	34.16	22.47	72.82	111.14	(.2%)
2000	14.92	34.49	23.41	72.82	113.47	(.1%)
2010	14.20	35.01	22.52	71.73	114.32	(.1%)
2020	14.03	35.23	23.33	72.59	115.98	(.1%)
2040	13.88	35.30	23.60	72.78	117.17	(.0%)
2060	13.88	35.31	23.61	72.80	117.31	(.0%)
2075	13.88	35.31	23.61	72.80	117.36	

CUM. RESOURCE USE
1975-2024 1995-2044 1975-2075

TOTAL COAL 1731. 2198. 4089.
TOTAL LIQ & GAS 2439. 2126. 4500.

Figure D-19. Energy activity levels national annual totals (E15 Btu).

TOTAL ANNUAL SYSTEM COST (E9 DOLLARS)

YEAR	SET1	SET2	SET3	SET4	SET5
1975	148.1	148.1	148.1		
1980	180.4	180.4	180.4		
1985	229.8	229.8	229.8		
1990	284.7	284.7	284.7		
2000	339.3	339.3	338.7		
2010	393.7	390.2	382.0		
2020	424.5	413.5	407.2		
2040	479.0	457.6	453.4		
2060	520.2	504.7	504.7		
2075	550.1	544.1	544.1		

DISCOUNTED PRESENT VALUE OF CUM. SYSTEM COST

TO 1975			
0%	41500.3	40514.6	40250.6
5%	5829.7	5782.5	5752.3
10%	2465.3	2461.1	2456.4
15%	1528.8	1528.2	1527.3
TO 1995			
0%	36941.8	35956.1	35691.3
5%	8073.7	7948.4	7867.5
10%	3979.3	3950.9	3918.5
15%	2669.9	2660.6	2645.4
TO 2010			
0%	31673.8	30697.9	30475.0
5%	8931.5	8682.4	8563.7
10%	4652.8	4547.2	4469.3
15%	3179.6	3119.1	3060.9
TO 2020			
0%	27586.4	26676.7	26532.9
5%	9166.9	8844.6	8756.7
10%	4945.1	4777.4	4716.5
15%	3402.0	3292.5	3246.4

HEALTH & ENVIRON - EMISSIONS & EFFECTS

YEAR	POP EXP E3	KR-85 E6	TRIT E5	RAD WASTE E3	SPENT BLANKET E3	(SPARE)
1975	14.31	13.04	4.66	2.92	0.00	0.00
1980	43.47	39.61	14.17	8.86	0.00	0.00
1985	90.99	82.90	29.66	18.54	0.00	0.00
1990	184.95	168.26	60.21	37.62	.55	0.00
2000	207.63	186.22	66.81	41.64	6.60	0.00
2010	221.40	140.22	54.24	31.35	137.50	0.00
2020	230.31	111.44	46.38	24.92	220.00	0.00
2040	234.90	17.22	19.20	3.85	440.00	0.00
2060	234.90	7.38	16.33	1.65	462.00	0.00
2075	234.90	.00	14.18	.00	478.50	0.00

YEAR	CO2 E9 TONS	CO E6 TONS	NOX E6 TONS	SO2 E6 TONS	PART E6 TONS	HC E6 TONS
1975	5.67	8.52	18.08	14.12	8.36	2.73
1980	6.14	8.56	19.92	15.90	9.36	2.83
1985	6.96	9.56	22.87	19.04	11.61	3.12
1990	7.27	10.16	23.78	20.50	14.23	3.15
2000	7.11	10.40	23.22	19.97	14.34	2.94
2010	6.97	10.04	22.78	20.00	15.49	2.74
2020	7.00	10.34	22.76	19.97	15.69	2.75
2040	7.00	10.40	22.75	19.92	15.58	2.75
2060	7.01	10.40	22.76	19.93	15.60	2.75
2075	7.01	10.40	22.76	19.93	15.60	2.75

YEAR	LAND USE E6 ACRES	DEATHS E3	INJURIES E3	MAN DAYS LOST E6	SOLID WASTE E9 TONS
1975	14.17	1.14	26.12	1.71	.20
1980	17.00	1.48	33.37	2.20	.26
1985	20.82	1.76	40.54	2.65	.32
1990	25.48	2.07	49.93	3.20	.38
2000	27.75	2.31	59.22	3.72	.45
2010	28.95	2.49	64.76	4.05	.47
2020	29.56	2.53	66.35	4.14	.48
2040	29.83	2.52	66.24	4.13	.47
2060	29.84	2.52	66.24	4.13	.47
2075	29.84	2.52	66.18	4.13	.47

Figure D-19. Continued.