A PUBLIC POLICY DISCUSSION PAPER WITH RECOMMENDATIONS FOR STATE ACTION

Coping With Energy Limitations In Transportation:

Proposals For Michigan

The Michigan Transportation Research Program
Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48109

The Michigan Transportation Research Program

Director

Dr. Charles G. Overberger, Vice President for Research, The University of Michigan.

The Michigan Transportation Research Program Adivsory Committee

Dr. William C. Taylor, Chairman, Department of Civil Engineering, Michigan State University (Co-Chairman)
Dr. Robert L. Hess, Director, Highway Safety Research Institute, The University of Michigan. (Co-Chairman)
Dr. Robert W. Kaufman, Director, Institute of Public Affairs, Western Michigan University.
Dr. James A Kent, Dean, College of Science & Engineering, University of Detroit.
Dr. Tapan Datta, Associate Professor, Department of Civil Engineering Wayne State University.
Mr. Chris M. Kennedy, Manager, Auto Safety Relations, Chrysler Corporation, Detroit, Michigan.
Dr. William D. Drake, Professor of Urban and Regional Planning, School of Natural Resources, The University of Michigan.
Mr. Alvin E. Marshall, Environmental Research Office, Ford Motor Company, Dearborn, Michigan.
Mr. George T. Burton, Jr., Director, Automotive Program, Bendix Research Laboratories, Bendix Centre, Southfield, Michigan.
Mr. Henry F. McKenney, Research Scientist, Environmental Research Institute of Michigan, Ann Arbor, Michigan
Dr. Michael J. Rabins, Chairman, Mechanical Engineering, Wayne State University.
Dr. Sung Lee, Professor of Physics, Keweenaw Research Center, Michigan Technological University.

Public Policy Discussion Paper Task Group

Dr. Donald I. Warren, Chairperson, Department of Sociology and Anthropology, Oakland University.
Dr. Herman E. Koenig, Director, Center for Environmental Quality, Michigan State University.
Mr. Clarence Generette, Transportation Consultant.
Mr. Murray Greyson, Consultant, Environmental Research Institute of Michigan.
Mr. Leonard E. Newland, MTRP Staff Manager, Highway Safety Research Institute, The University of Michigan.
Mr. James L. Dries, MTRP Staff, Highway Safety Research Institute, The University of Michigan.

Ad Hoc Committee for Energy Efficiency Analysis

Dr. Robert W. Kaufman, Chairman, Director, Institute of Public Affairs, Western Michigan University.
Dr. Donald E. Cleveland, Professor of Civil Engineering, The University of Michigan.
Mr. Henry F. McKenney, Mechanical Engineering Consultant, Enviornmental Research, Institute of Michigan, Ann Arbor, Michigan.
Dr. Herman E. Koenig, Director, Center for Environmental Quality, Michigan State University.

COPING WITH ENERGY LIMITATIONS IN TRANSPORTATION: PROPOSALS FOR MICHIGAN

A Public Policy Discussion Paper With
Recommendations for State Action

August 1979

The Michigan Transportation Research Program
Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48109

"This study was funded by the Michigan Department of Transportation. Funds for reproduction were provided by the Michigan Energy Administration, Michigan Department of Commerce."

TABLE OF CONTENTS

LIST OF FIGURES

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UM-HSRI-79-13		

4. Title and Subtitle Coping with Energy Limitations in Transportation: Proposals for Michigan	5. Report Date April 1979 6. Performing Organization Code 8. Performing Organization Report No. UM-HSRI-79-13
7. Author(s) R. Kaufman, H. Koenig, et al.	
9. Performing Organization Name and Address Western Michigan University, Kalamazoo, Michigan Michigan State University, East Lansing, Michigan	10. Work Unit No. (TRAIS) 11. Contract or Grant No. 13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Michigan Transportation Research Program Highway Safety Research Institute The University of Michigan Ann Arbor, Michigan 48109	14. Sponsoring Agency Code

15. Supplementary Notes

MTRP is sponsored by the Michigan Department of Transportation, Lansing, Michigan.

16. Abstract

The transportation energy dependence of Michigan's economy and major industries (auto manufacturing and tourism) is discussed and quantified. For the balance of this century the real cost of energy will rise and its availability will decline. "Net energy" gains are expected to decline as well (the difference between the energy required to extract remaining supplies and the amount of energy supplies that are captured). Alternative energy forms and automotive propulsion systems are surveyed and assessed. Probable economic impacts on Michigan are discussed and the dual pressures of rising transport energy costs and federal regulations on the auto industry are outlined. State action for managing the economic transition which Michigan faces is recommended, and a mechanism for "managing change" is proposed.

17. Key Words	18. Distribution Statement
Transportation Energy Automobiles Petroleum Alternative Fuels Michigan	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
		48	

Preface

The Michigan Transportation Research Program

The Michigan Transportation Research Program (MTRP) is an organization of transportation research specialists and professionals from the fields of economics, engineering, the social sciences, and private commerce.

The program is supported by demonstration and development funds from the Michigan Department of Transportation, administered through the Department's Bureau of Urban and Public Transportation. It is managed by The University of Michigan in Ann Arbor. Dr.Charles G. Overberger, University Vice-President for Research, is the program's director. Dr. Overberger is advised by a Statewide advisory committee consisting of representatives from Michigan's universities, manufacturers, and research firms with interest in transportation.

The program's purpose is to explore transportation issues and recommend actions to the State of Michigan which could result in an expanded base of transportation knowledge for the use of the State's transportation decision-makers.

Pursuant to these purposes MTRP has, through its Ad Hoc Committee for Energy Efficiency, conducted a comprehensive evaluation of reported assessments of our energy resources, along with areas within the transportation sector of our economy wherein significant savings can be effected in both the short and long terms. A preliminary study has also been made of the economic impacts of rising energy costs on the Michigan economy, with recommendations for policy objectives to be pursued and a mechanism for pursuing them.

The Michigan Transportation Research Program is indebted to the Ad Hoc Committee for Energy Efficiency Analysis, under the very effective leadership of its chairman, Dr. Robert Kaufman, for the many hours they have devoted to development of this paper. Finally, special recognition must be given to Dr. Herman Koenig for the lead role he has played in preparing the written document.

COPING WITH ENERGY LIMITATIONS IN TRANSPORTATION:

PROPOSALS FOR MICHIGAN

April 1979

EXECUTIVE SUMMARY

This "white paper" is an outgrowth of deliberations and discussions of the Advisory Committee to the Michigan Transportation Research Program during the past three years. Its focus is on fuels, especially liquid fuels, available for transportation in Michigan's future. This paper analyzes four areas of the energy dilemma: (1) existing supplies of petroleum; (2) the potential for new fuel substitutes; (3) the role of energy conservation; and (4) economic impacts for Michigan. The concluding section makes recommendations for a state action program.

The purpose of this paper is to call attention of policymakers to special characteristics of the national transportation/energy problem that will affect Michigan. Michigan leadership should be alert to changing factors that may require new policies and directions for the future. Appropriate information concerning changes in transportation should be made available to Michigan citizens.

FOSSIL FUEL SUPPLIES

Since the oil embargo of 1973, many studies have assessed national and global petroleum reserves and potential reserves. These estimates have been related to discovery and production rates to reach conclusions on how long reserves will last. Using various assumptions, the investigators reach various conclusions; however, many studies suggest that the turn of the century will bring critical shortages in supplies of petroleum relative to its demand.

Predicting a precise time for this event, however, is less important than beginning now to prepare for the inevitable changes.

The problem facing the United States, and indeed the entire industrialized world, can be simply stated: We are moving from a period of declining real cost of energy and perceived unlimited supplies of natural petroleum and gas to a period of rising real costs of energy and a real decline in the availability of these resources. The gap between historic demand projections and domestic production cannot continue to widen, for both political and economic reasons, even if petroleum is available on the world market.

POTENTIAL NEW FUEL SUBSTITUTES

The nearest substitute in quality and quantity to the fluid fuels is coal, but to utilize coal within the framework of the present energy production, consumption, distribution system, it will be necessary to convert this solid mineral to a refined fluid or gas. Unfortunately, the capital costs of the conversion technology are very high; also, the water resources needed to support the process is a serious limiting factor.

Nuclear energy cannot serve as a portable fuel to drive vehicles required in the present transportation system, agriculture, and many other sectors of the economy. Its practical use will most likely require an electrically based economy.

Biomass in quality is a near substitute for the solid fossil fuels. Like coal, it must be converted to a liquid before it is a primary fuel for the present transportation system. In comparison with coal, it is dilute and geographically dispersed.

It is the dispersed and intermittent quality of most of the various solar forms of energy, rather than absolute quantities, that is the limiting factor in their economic use. Solar-thermal energy is very difficult to store in large quantities, and it is virtually untransportable as heat.

Hydro and wind are primarily work forms of energy which in the past have been used directly at the point of collection to drive grist mills, water pumps, and weaving looms. In the context of a modern economy, this form of solar energy is most likely to be converted to electricity so that it can be transported, integrated and coordinated with other sources of electrical energy.

Net Gain

The divergence in assessments concerning the longevity of natural gas and petroleum reserves stems from many variables in making the calculations. Among these variables are estimated industrial development rates and costs, as well as the availability of alternative resources. The calculations must consider two key concepts: gross energy and net energy. Gross energy is that produced from a given facility during its lifetime. Net energy is the difference between gross energy and the energy used in constructing, operating, and maintaining a given facility during its lifetime.

ROLE OF ENERGY CONSERVATION

Energy conservation in transportation, as presented by the U.S. Secretary of Transportation (1978), identifies three basic ways to improve the energy efficiency of our transportation system: (1) improved management of the existing systems and improved technologies; (2) shifting a portion of travel to more energy-efficient modes; and (3) traveling less.

The recognition of the dominant transportation role of autos and trucks indicates that high priority should be placed on increasing the efficiency of these vehicles and on the conservation of energy in transportation.

The subject of conservation in transportation is closely related to land use policy. In fact, we may conclude that strong ties and relationships exist between transportation, energy, and land use, and that effective plans for them cannot be achieved on a piecemeal basis.

Changes in land use allocations, urban form, and levels of regional economic diversification clearly go hand-in-hand with transportation planning and development. Long lead times are required to design, develop, and modify the transportation system in anticipation of these changes. Further, transportation planning can be a positive force in giving direction to land use allocations and the community structures so as to minimize transportation requirements.

ECONOMIC IMPACTS FOR MICHIGAN

The Michigan economy, dominated as it is by the automotive industry, must expect serious impacts on its employment, income, and tax revenues unless special and unusual cooperation is established between the federal and state governments and the transportation industry in carrying out certain critical transitions in our economy. Michigan is heavily dependent upon low-cost, reliable, and versatile transportation to support its industry. Historically, the state has played a pre-eminent role in developing the present system. Our resource base is clearly changing, and the evolution of our transportation systems must now take on new directions.

Unfortunately, most of the components of energy conservation in transportation imply major reductions in employment opportunities in the automotive industry in the medium and long terms. In the long term, conservation measures will prolong the life of the low-cost natural fluid fuels. Also in the long term, increases in the cost of energy relative to labor will motivate the development of production technologies in all sectors of the economy that are relatively more labor-intensive than they are now.

The relationship between the domestic auto industry and government, particularly at the federal level, is adversarial in approach and is characterized largely by mutual distrust and suspicion. This situation must be modified to one of cooperation and mutual trust built around sober and realistic understandings of the nature of the problems we face and the difficult steps that must be taken to deal with them.

Of particular interest is the impact of the evolving regulatory controls on the auto industry in Michigan. Recent independent studies have indicated that the impact of federal regulations is affecting the auto industry in critical areas such as: (1) premature obsolescence of production equipment; (2) new capital formation; (3) reduction in jobs in Michigan by forcing the industry to import production equipment and/or automotive parts from foreign producers; (4) magnifying existing differences between U.S. automakers by applying "equally difficult standards to unequal companies"; and (5) possibly creating, from the above impacts, annual price increases that will "exceed rates of inflation of growth in consumer income."

The State of Michigan must recognize this potential revolution within its most important industrial base and assist in every way possible to ease this transition and its adverse effects on the Michigan economy.

In pursuit of this objective, it is recommended that a special task force of representative leaders be established to:

1) facilitate improved cooperation between the various agencies of the federal government and the Michigan transportation industry in achieving nationally established goals in energy conservation, environmental standards, and safety in transportation; and

2) define specific areas of research and development where coordinated and integrated developments in commerce, transportation, and human settlements can significantly reduce the short- and long-term impact of rising energy costs on the economy of Michigan and its citizens.

I. INTRODUCTION

It is now a historical fact that the peak of production in conventional natural gas and petroleum in the continental United States occurred in the early 1970s. World production of oil reportedly is expected to peak between 1985 and the year 2000 if present trends continue. The fluid fossil fuels are a particular concern, not only because of their rate of depletion, but because the economy of the United States is so heavily dependent upon these fuels as a primary source of energy. The transportation system, in particular, depends critically upon petroleum for 95% of its energy.

If the reported assessments of future petroleum supplies are valid, the potential impact on the Michigan economy is of deepest concern to all of its citizens. Michigan has historically played a pivotal role in the national transportation industry. Employment, income, and tax revenues of the state are tied intrinsically to the existing highway system.

The state faces a particularly difficult dilemma. On the one hand, the Michigan economy (80% of total production) is heavily dominated by durable products, the vast majority of which are petroleum-driven machines with or without wheels. On the other hand, its economy also depends upon a low-cost, reliable transportation system to support its economy and provide energy resources.

- 80% of Michigan production is exported.
- 60% of the economic consumption within the state is imported.
- 50% of the foods consumed within the state are shipped in.
- The second largest industry in the state is tourism.
- 90% of the energy used in the state is imported.

Any long-term adaptations in the structure of the transportation system in the state and nation to reduce the dependence on petroleum-driven motor vehicles obviously will have both positive and negative impacts on the overall economy in both the medium and long terms. But, given the heavy dependence of the Michigan economy on the automotive industry, negative impacts are potentially much greater than positive impacts.

The purpose of this paper is essentially fourfold:

a) to provide a critical evaluation of reported assessments of conventional non-renewable resources and the potential availability and cost of alternatives,
b) identify principles and areas in adaptation wherein the energy intensity and cost of the transportation system can be reduced,
c) identify the primary areas of economic impact that must be considered in policies directed at energy conservation in transportation,
d) identify specific policy directions and recommend specific mechanisms for pursuing them.

II. ENERGY RESOURCE LIMITATIONS: A CRITICAL EVALUATION OF REPORTED ASSESSMENTS

Steps are in progress to improve the energy efficiency of the transportation system and other components of the economy, and much remains to be done in this regard. But, beyond improving the efficiency of the transportation system as it now exists, we are still faced with the inescapable fact that, compared to the time scale required for structural changes in the transportation system, conventional forms of natural gas and oil are rapidly being depleted the world over and as yet there are no foreseeable future substitutes in quality and quantity at comparable prices. Further, the potential impact of acid rains resulting from changes in the composition and heat balance of the earth's atmosphere are of increased concern.

In retrospect, it is now clear that the extent of the geological reserve of conventional petroleum in the continental United States has been known at least since 1956, when M. King Hubbert predicted with remarkable accuracy that the peak of the U.S. petroleum production cycle would occur in the early 1970s. Historically, this was also the year in which then President Eisenhower approved the National Interstate Highway System, which committed this nation to the development of a very versatile transportation mode.

These events are significant because (1) they illustrate that this nation can and has taken long-term perspectives in planning the basic structure of important sectors of our economy, and (2) they illustrate the fragmented nature of the understanding surrounding some of our most important planning efforts. In principle, information was available in 1956 from which to anticipate a possible overdependence of the proposed transportation system on petroleum.

The oil embargo of 1973 touched off a seemingly endless series of detailed studies directed at reassessing and refining earlier assessments of national and global reserves and their probable discovery and production rates in the decades ahead. Not only oil but all fossil fuels are now the subject of many investigations, assessments, and conflicting predictions and debates on how much exists, how long it will last, and what the possibilities are for the development of nuclear, solar, and other alternative sources of energy as replacements. (See examples in references cited at the end of this paper.)

The time cycle for liquid hydrocarbon production as presented by the American Petroleum Institute is indicated in Figure 1. The gap between historic demand projections and domestic production illustrated in this figure cannot continue to widen for both political and economic reasons, even if petroleum is available on the world market.

The nearest substitute in quality and quantity to the fluid fossil fuels is coal. But to utilize coal within the framework of the present energy production, consumption, and distribution system, it will be necessary to convert this solid mineral to a refined fluid or gas. It is the only way that this resource can be utilized in the present transportation system. The conversion of this resource to refined fluids under the best of conditions can probably only take place with efficiencies of 55-65%. Unfortunately, the capital costs of the conversion technology is very high and water resources to support the process a serious limiting factor. Under present economic conditions, synthetic fuels derived from coal will cost 3 to 5 times as much as current natural fuels.

It is possible, of course, to utilize coal resources directly for the generation of electricity, which in turn can be reconverted back to both work and heat. But to do so will require extensive modification of

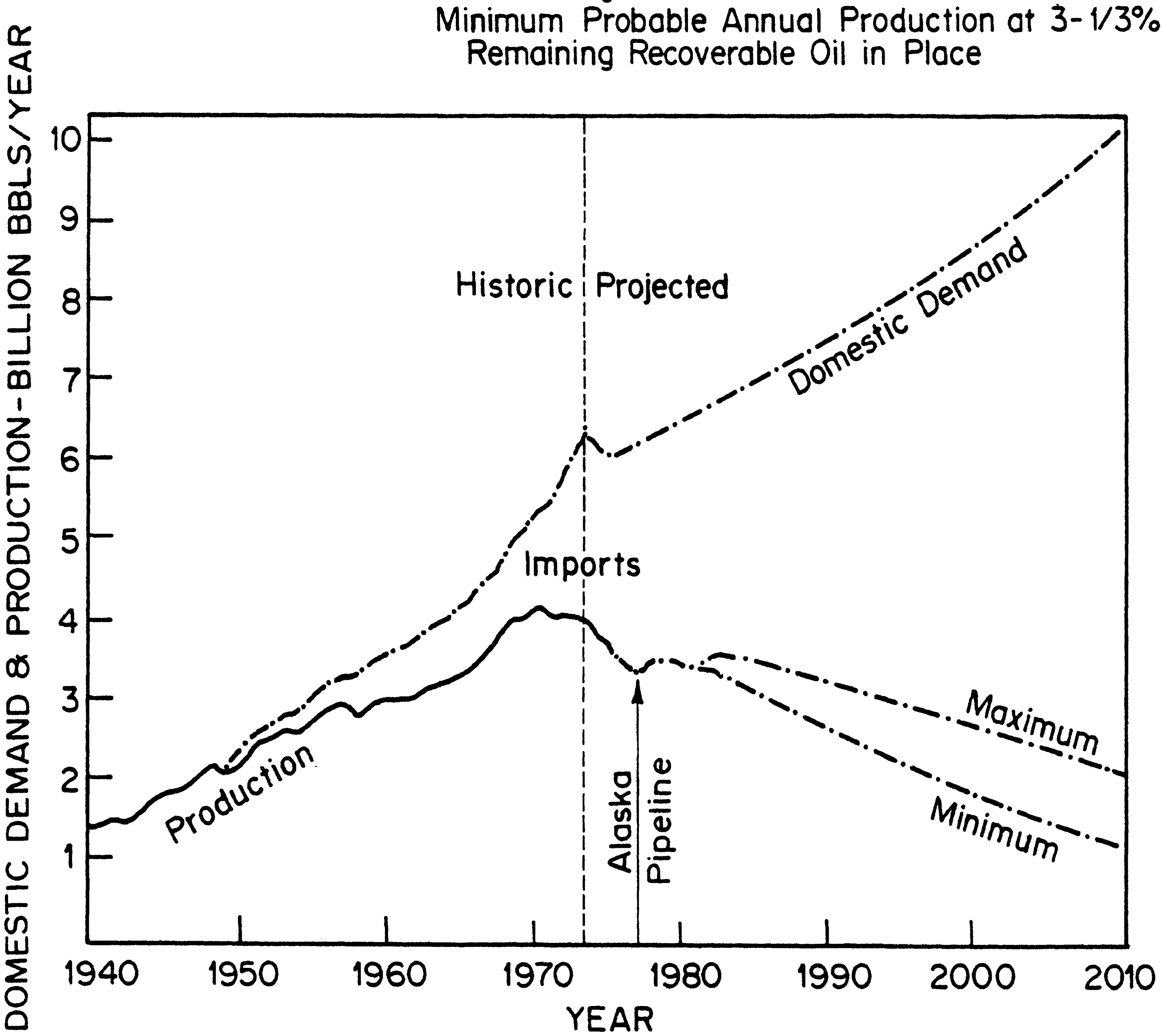
Figure 1

FORECAST OF U.S. LIQUID HYDROCARBON PRODUCTION & DEMAND

Sources: American Petroleum Institute Published Data (1976)
U.S. Geological Survey, Circular 725 (1975)

Resource Base	Maximum	Minimum
Conterminous U.S.	126.679	81.679
Alaska	66.307	25.307
Natural Gas Liquids	34.350	23.350
(As of 1/1/75)	227.336	130.336

Projections Based On: Consumption at Zero Per Capita Increase
1.5% Annual Population Increase
Alaska Pipeline Capacity
Maximum Probable Annual Production at 2% of Remaining Recoverable Oil in Place
Minimum Probable Annual Production at 3-1/3% of Remaining Recoverable Oil in Place



existing power generating facilities to avoid excessive environmental damage, and it will require fundamental and massive changes in the structure of our transportation system to utilize the electrical form of energy. In this sense, coal is not a universal primary fuel. It cannot be regarded as a complete substitute for the fluid fuels.

Nuclear energy has somewhat similar characteristics. It cannot serve as a portable fuel to drive mobile vehicles required in the present transportation systems, agriculture, and many other sectors of the economy. Its practical use will most likely require an electrically based economy. For these and other reasons, the physical and technical structure of an economy (including transportation) based primarily on nuclear fuel will be substantially different from the structure of an economy based on fluid fossil fuels or a combination of the two.

Biomass in quality is a near substitute for the solid fossil fuels. Like coal it must be converted to a liquid before it is a primary fuel for the present transportation system. Unlike coal, it has not been concentrated in time and space by natural geophysical processes. In comparison to coal, it is dilute and geographically dispersed.

Solar-thermal energy is also diffused and dilute. In addition, it is intermittent. It is very difficult to store in large quantitites and it is virtually untransportable as heat. Therefore, it must be developed primarily as a decentralized source in very close proximity to the end use or converted to electrical form.

Hydro and wind are primarily work forms of energy which in the past have been used directly at the point of collection to drive grist mills, water pumps, weaving looms, etc. In the context of a modern economy, this form of solar energy is most likely to be converted to electricity so that it can be transported, integrated, and coordinated with other sources of electrical energy.

Direct conversion of solar radiation to electrical energy is also technically feasible. However, like solar-thermal and wind, the resource is dilute and intermittent.

It is the dispersed or dilute and intermittent nature of most of the various solar forms of energy rather than absolute quantities that are the limiting factors in their economic use. Consider biomass, for example. Forest products, agricultural crop residues, and other forms of biomass can be accumulated or concentrated over time on a variety of regeneration cycles. The fossil fuels upon which we now depend are in fact concentrated forms of biomass accumulated over an extremely long regeneration cycle. In addition, some of this biomass was "processed" by nature to form natural oil and gas. When these reserves are exhausted, much of what was done by nature on an extremely long time scale must now be done by man on vastly shorter regeneration cycles, using manmade materials, devices, and energy. From this perspective alone, there appears to be little hope that we can ever produce synthetic fluid fossil fuels from biomass sources on a continual basis in quantity and at costs comparable to the natural fuels.

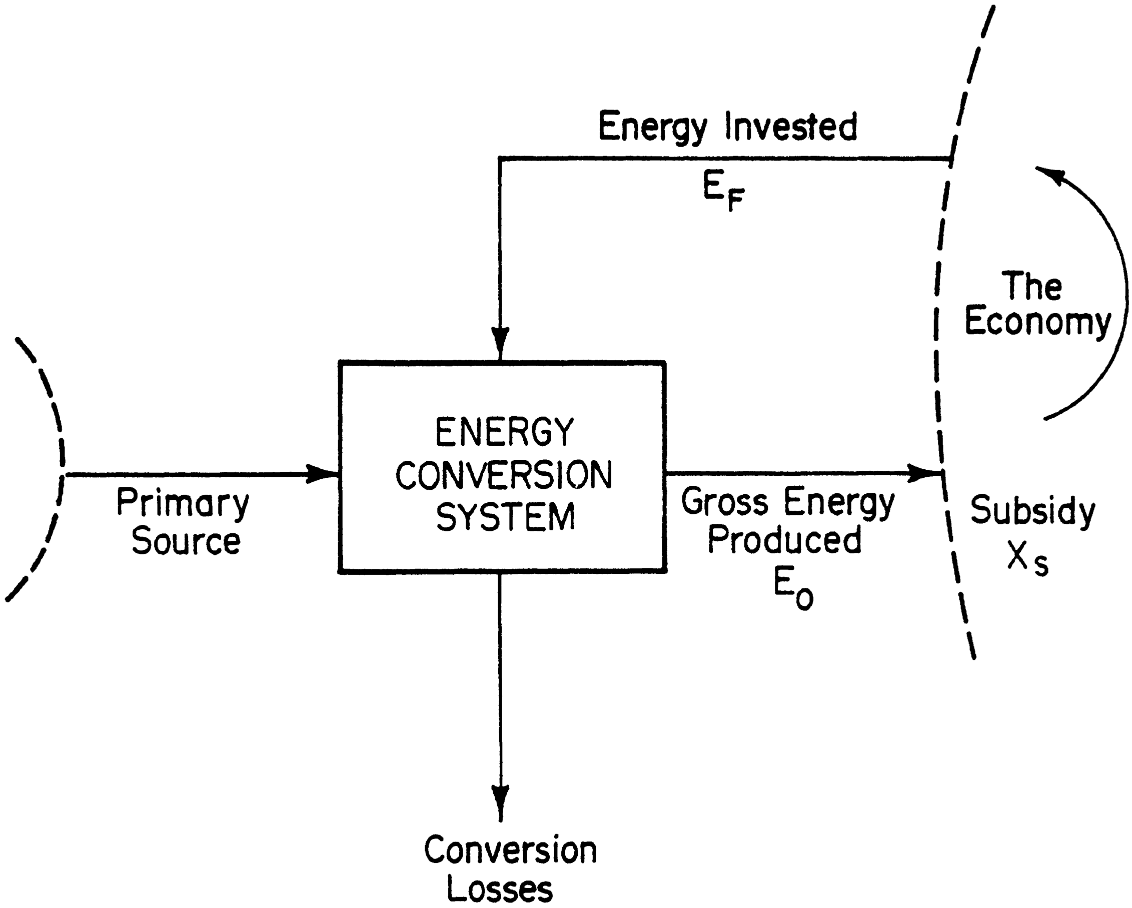
Similarly, hydro energy is an extremely dilute form of work energy resulting from falling rain and snow. It is collected, concentrated, and stored by the network of natural streams and rivers on relatively short and dependable regenration cycles--one or a few years. Unfortunately, most of the large semi-natural "solar-hydro collectors" have already been developed in the U.S., and they provide only a small percentage of our current energy "needs." Many small hydro units that were abandoned in the early part of this century can and are being redeveloped.

Much of the debate and divergence in assessments of the longevity of natural petroleum and gas as well as the potential development rates, costs, and availability of alternative resources (coal, nuclear, and the various solar forms) centers around the distinction that must be made between <u>gross energy</u> production and the accessible or <u>net energy</u> that can be derived from geological reserves or from renewable alternatives. Clearly, a quantity of energy E_f must be fed back from the economy to build and operate any energy conversion system as illustrated in Figure 2. The system, in turn, will over its lifetime deliver a quantity E_0 of energy to the economy. Three related policy questions are of central concern in evaluating the cost and availability of alternatives:

1) What is the ratio of energy produced by the system to the energy invested in it measured over its economic lifetime?

Figure 2

THE ENERGETICS OF ENERGY CONVERSION



Net Energy Returns = Energy Produced − Energy Invested

$$\text{Energy Gain } G = \frac{\text{Energy Produced}}{\text{Energy Invested}}$$

$$\text{Coefficient of Peformance } M = \frac{\text{Net Energy Returns}}{\text{Energy Produced}}$$

$$\text{Coefficient of Cost } C = \frac{1}{M} = \frac{\text{Cost of Energy Produced}}{\text{Pecuniary Costs of Conversion}}$$

2) What is the ratio of the net energy delivered by the system to the gross energy it produces, i.e., what is the net energy return measured as a fraction of the gross output?

3) What is the cost of the energy produced relative to labor and other pecuniary costs of production?

The ratio

$$g = \frac{\text{energy delivered}}{\text{energy invested}} = \frac{E_o}{E_f}$$

is called the energy gain of the system. It is only when the gain is greater than one that development of an alternative energy system ultimately results in a net energy return to the economy.

The second ratio

$$m = \frac{\text{net energy produced}}{\text{gross energy produced}} = (1 - 1/g)$$

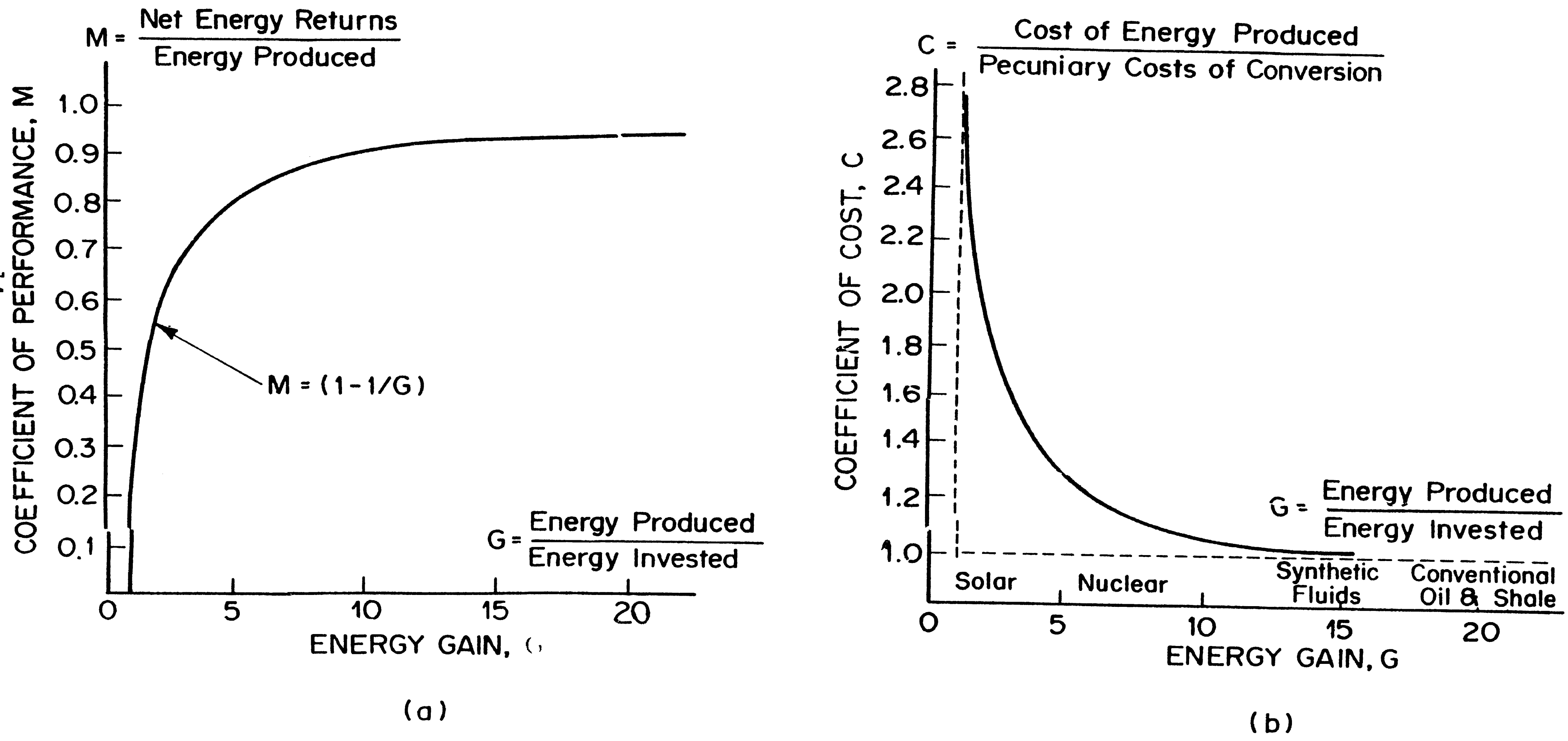
can be regarded as a figure of merit or coefficient of performance, useful in comparing alternative systems.

The relationship between the energy gain g and the coefficient of performance is shown in Figure 3 (a). Estimates of the energy gain for light water reactors, for example, range between g = 5 and g = 15 for an operating life of 40 years. Corresponding estimates of the energy gain for flat plate solar collectors that last 30 years range between g = 2 and g = 3. Referring to Figure 3(a), the coefficients of performance for the two systems are very different: m = 0.7 - 0.9 and m = 0.2 - 0.5, respectively. In contrast to either of the above examples, the energy gains for conventional natural gas and oil systems are well above 25, with coefficients of performance approaching 1. The energy gain for nonconventional sources of natural hydrocarbons such as geopressurized gas, coal seam gas, and oil shale are comparatively much lower, being one or less in many cases. The energy gain for synthetic fluid fuels produced from coal are in the vicinity of 10 and 15, and from agricultural grain somewhere between 1 and 2. If these figures are correct, then (referring to Figure 2) the net energy from the grain is only a very small fraction of the gross production.

The unit cost of the energy produced as a function of the gain g and the unit cost X_f of the energy fed back from the economy as derived

Figure 3

COEFFICIENTS OF PERFORMANCE AND COST



from Figure 2 is

$$X_0 = - \frac{1}{g} X_f - X_c (E_0)$$

where $X_0(E_0)$ represents the non-energy costs of conversion per unit of output -- labor, financials charges, and other pecuniary costs. In general, the non-energy costs are a function of the design capacity E_0 of the conversion units. They typically decrease with increased scale of operation. A positive cost indicates financial expenditure and a negative cost indiciates financial returns per unit of energy flow.

In general, the cost of the energy fed back for the development of the conversion system will differ from the cost of the energy produced by the system. The difference can be considered as a cost subsidy X_s, i.e.,

$$X_f = - (X_0 + X_s)$$

The above equations combine to give the cost X_0 of a unit of the energy as a function of the gain g, the price subsidy X_s, and the pecunicary costs $X_c(E_0)$.

$$X_0 = \frac{-1}{(1 - 1/g)} X_c(E_0) - \frac{1}{g} X_s$$

The conditions under which alternative conversion systems are ultimately competitive with the fossil fuels they supplement occurs when $X_s = 0$, i.e., when

$$X_0 = \frac{1}{(1 - 1/g)} X_c(E_0)$$

The coefficient

$$C = \frac{1}{(1 - 1/g)} = \frac{1}{m}$$

is appropriately called the coefficient of cost. It represents the factor by which the pecuniary costs (non-energy cost of conversion) must be multiplied to obtain the true cost of the energy produced. Stated another way, it represents the ultimate cost of energy relative to labor and other pecuniary costs for alternative systems in relationship to their respective energy gain coefficients g. As Figure 3(b) indicates, this coefficient is very high for low-gain systems and approaches unity for high-gain systems.

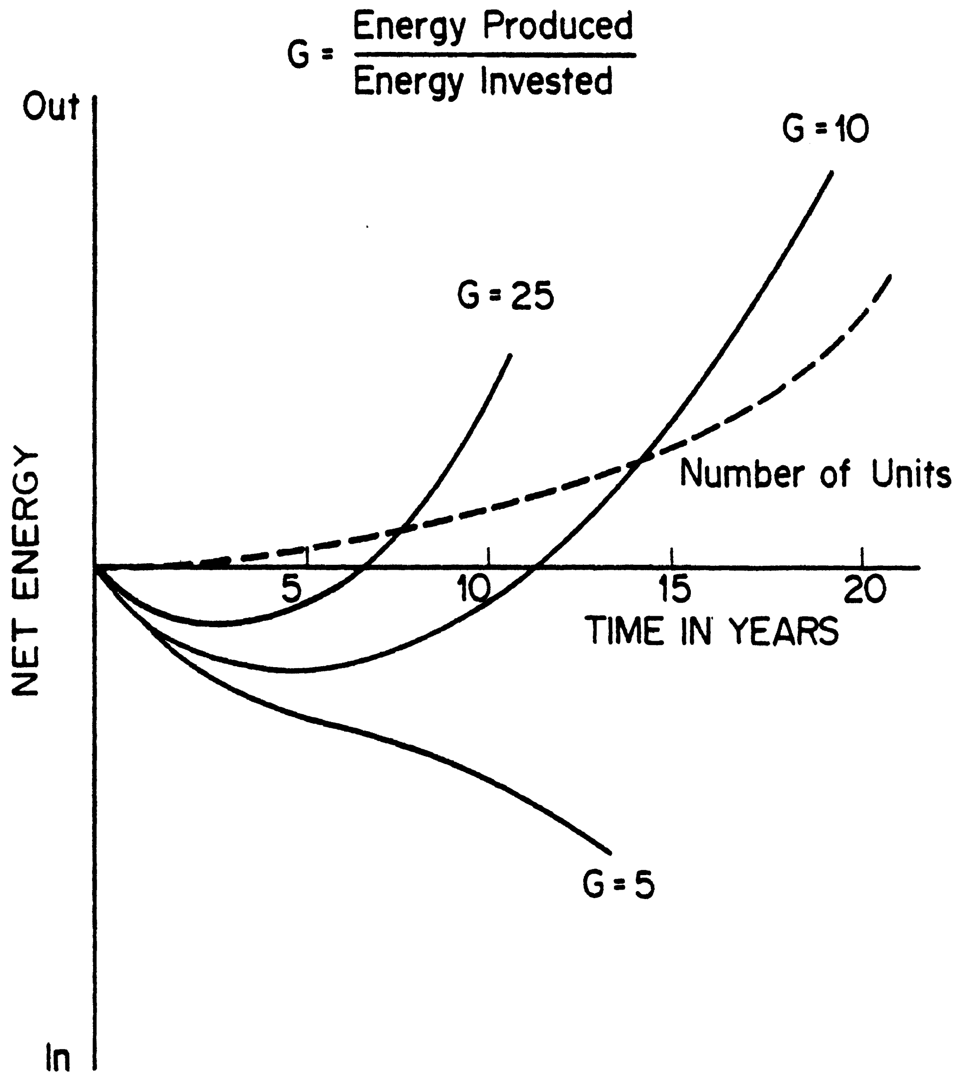
A high coefficient of cost indicates specifically that a large fraction of the energy produced by the system is required for its construction and maintenance. It is an indirect measure of the rate at which the real cost of energy delivered from alternative sources will escalate with the depletion of cheap fossil fuels now used for their construction and maintenance. Energy sources having very high coefficients of cost may never become economically competitive with the fossil fuels they are intended to replace. Except for water heating and passive space heating, solar heating and wind generation of electrical energy currently costs 2-3 times as much as conventional sources. Since the gains of such systems are relatively low, the cost advantage will not improve very rapidly with rising costs of conventional fuels.

To a degree, the energy gain, and hence the coefficient of performance and the coefficient of cost for any given energy system, can be improved through technologies and systems that reduce the energy intensity of the production, distribution, and maintenance processes. In reference to Figure 3(a), small energy savings in construction distribution and maintenance translate into large improvements in the coefficient of performance and coefficient of cost for low-gain systems. On the other hand, the coefficients of performance for high-gain systems are relatively much less sensitive to such savings. Therefore, as the economy shifts to alternative sources having significantly lower energy gains, the overall economic returns from conservation are more than proportionately increased.

The energy gain of a proposed alternative system is also crucial information in assessing how long it will take for a proposed energy industry to pay back the energy that is invested in it; i.e., how long after commercialization begins will it be before the proposed energy industry (solar-thermal, wind energy, nuclear power, coal gasification, etc.) begins to show a net energy return to the economy. The answer depends both on the energy gain and the rate of growth of the industry, as illustrated in Figure 4. The results shown are for an assumed growth

Figure 4

TIME DELAY IN NET ENERGY RETURNS FOR GROWTH RATE OF 14% IN THE NUMBER OF PRODUCTION UNITS



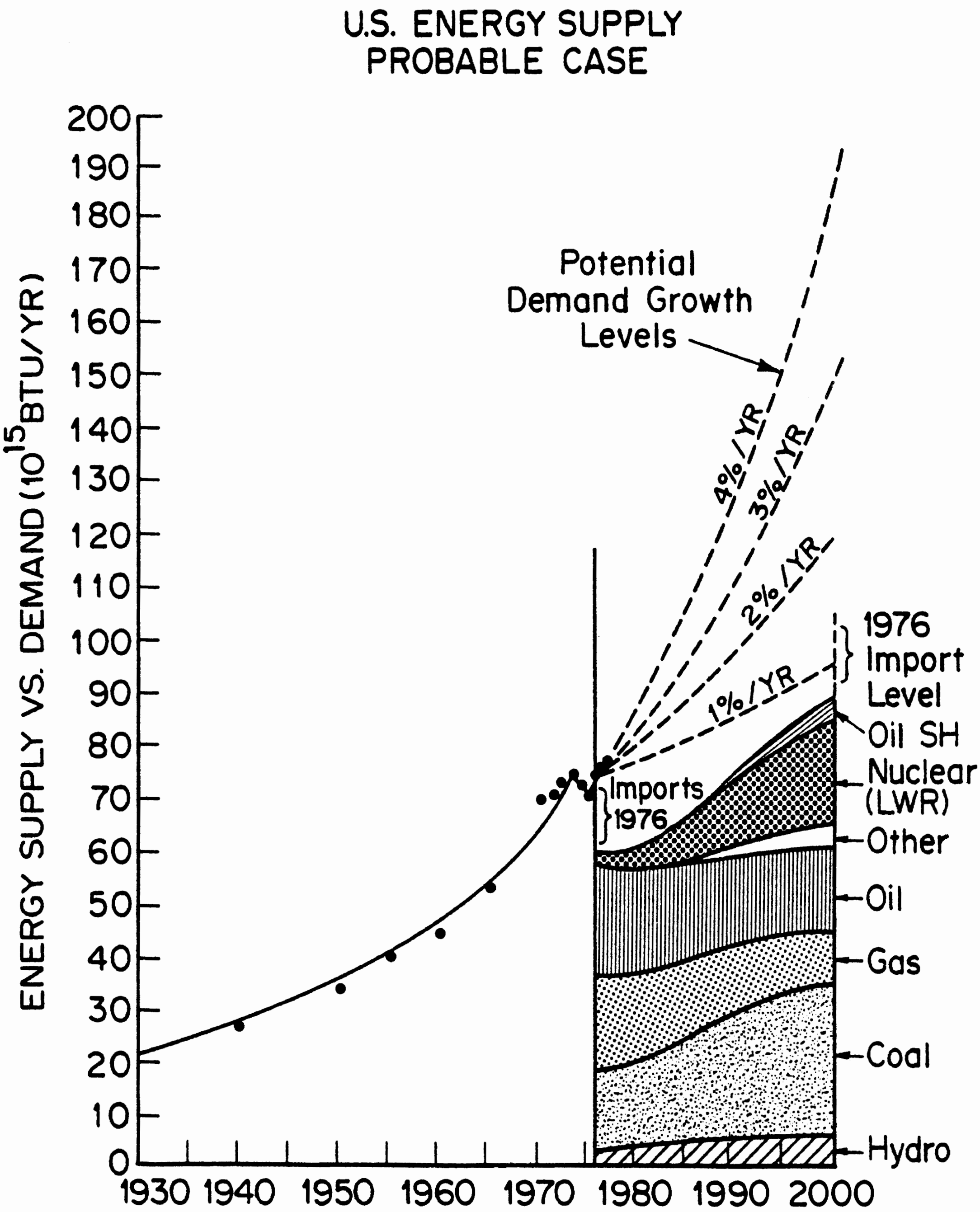
rate of 14% per year in the number of light water reactor units in operation and a range of energy gains between 5 and 25 as indicated. As the assumed growth rate and an energy gain of 10, for example, it takes 12-13 years before the nuclear generating industry begins to "pay off" in energy.

It is the intrinsically long time delays associated with the development of low gain energy sources, illustrated in Figure 4, that may make it impossible (at any cost) to develop alternative sources fast enough to compensate for the decline of the natural fluid fossil fuels. It is for this reason that the time element is so critical. Consider, for example, the assessment of the gross energy that conceivably might be produced from various sources by the year 2000, as given by John W. Duane in Figure 5[11]. The proportion of energy fed back by the economy to develop these alternatives increases with time, because most of the alternatives have a much lower energy gain than the natural fluid fossil fuels they replace. Consequently, the net energy available for transportation and consumer goods production will be a much smaller fraction of the gross in the year 2000 than it is now.

There are some computational and data problems involved in actually assessing the energy gains of alternative systems. The results depend upon how far back into the transportation and processing network one goes in the energy accounting process, and they depend on the technologies of production and modes of transportation used at the various points in the network. For this reason, one may question the specific values of energy gains used in the above analyses, but the basic principles are indisputable. It is also a fact that, in general: (a) the coefficients of performance of many alternative energy systems are significantly lower than the coefficients of performance of traditional oil and gas-based systems; and (b) the coefficients of performance of fossil-based systems decrease as the resource is depleted. Remaining geological deposits, in general, are more difficult to find, recover, and refine than those that have already been depleted.

In the past, assessments of net energy returns and time delays in net energy returns were not essential components of policy planning, because the gains for the energy systems involved are intrinsically

Figure 5


U.S. ENERGY SUPPLY
PROBABLE CASE
ENERGY SUPPLY VS. DEMAND (10^15 BTU/YR)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1930
1940
1950
1960
1970
1980
1990
2000
Potential
Demand Growth
Levels
4% / YR
3% / YR
2% / YR
1% / YR
Imports
1976
1976
Import
Level
Oil SH
Nuclear
(LWR)
Other
Oil
Gas
Coal
Hydro

high -- far above 15 or 20. However, as Figure 3 clearly indicates, when the gain drops to about 10 or below, the decrease in net energy returns expressed as a fraction of the total output decreases disproportionately with corresponding disproportionate increase in cost. For these reasons, assessments of the energy ultimately obtainable from alternative resources and the rate at which they can be developed to replace the natural fluid fuels can be very deceptive and unrealistic unless the physical principles outlined here are taken into consideration. Without a doubt, the subtlety of these principles is a major source of both confusion and complacency about the future availability of energy and its real cost. Much of the petroleum locked in shale deposits or natural gas contained in geopressurized brine, for example, may be simply inaccessible as a primary energy source because it cannot be recovered with a net energy return or the coefficient of performance for the recovery system may be prohibitively low.

III. ENERGY EFFICIENCY IN TRANSPORTATION

The quantity of energy available to industrialized economics has been increasing and its real cost decreasing (relative to labor, land, and other factors of production) from year to year ever since the natural fluid fuels were tapped. The extraordinarily rapid rate of industrial growth in the Western world during the past half century is attributable to the high energy gains (ratio of net to gross) intrinsic to the fluid fossil fuels. The principles developed in the previous section notwithstanding, many are still not prepared to accept the fact that technology probably cannot perpetuate these very recent historical trends indefinitely. But the evidence is overwhelming that even under the most optimistic technological expectations, the real cost of energy will steadily increase in the foreseeable future. The question of availability aside, this fact alone makes conservation in transportation an imperative.

Given that each new unit of energy will cost more than the last, it follows from simple logic that the only way we can retain our standard of living in the developed countries is to use this and other resources more efficiently. Attempts to perpetuate an energy-intensive transportation system indefinitely will only accelerate the rise in the real cost of living and hasten the ultimate decline in our standard of living. Every opportunity must be taken to extend the life of our durable products, reduce the energy intensity of our transportation system, and otherwise improve the overall energy efficiency of the economy.

The U.S. transportation system is or should be a major component of a comprehensive state and national energy conservation program. More than 25% of current annual U.S. energy consumption is used to fuel the transportation system, and more than 15% is required to build and replace the automobiles, trucks, aircraft, ships, and other components of moving stock. Thus, more than 40% of the U.S. energy consumption is associated directly and indirectly with the maintenance and operation of the transportation system. Of particular concern is the fact that the system uses no other fuel than petroleum, accounting for more than 50% of U.S. petroleum consumption. Further, more than 74% of the end-use energy in the transportation system is associated with automobiles and trucks.

Energy conservation in transportation as presented by the U.S. Secretary of Transportation in May, 1978, identifies three basic ways of improving the energy efficiency of our transportation system: (1) improved management of the existing systems and improved technologies, (2) shifting a portion of travel to more energy-efficient modes, and (3) traveling less.[12] These divisions provide as good a framework as any for identifying technical alternatives that should be considered in a comprehensive and coordinated energy/transportation policy package.

Improvements in the Existing System

Technical and managerial improvements within the framework of the existing system as presented by the Department of Transportation (DOT) include:

a) improved auto fuel economy -- from 18 miles per gallon in 1978 to 27.5 miles per gallon in 1985.

b) improved vehicle (car, truck, and bus) maintenance and driving performance -- better vehicle maintenance, improved driver education, radial tire application, etc.

c) traffic operation and maintenance -- enforcement of the 55 mph speed limit, reduction of traffic congestion at freeway entrances and exits, right turns on red, etc.

d) conservation in air travel -- improved engine performance, increased passenger load factor, revised take-off and landing procedures.

e) rail improvements -- freight car management, electrification of highly traveled rail lines, improved locomotive performance.

Most of these adaptations can take place in a relatively short period of time and at relatively low cost, and potentially they can lead to significant savings in the direct energy consumption with the present system.

In addition to the direct savings in end use, it is also possible to effect very significant reductions in the indirect energy required to support the present system. These include but are not limited to the following:

a) technological improvements to increase both the technical and economic life of the automobile.*

b) road management practices which greatly reduce the impact of corrosive chlorides for snow or ice removal -- using less corrosive materials to control hazardous conditions, mandatory fleet rust proofing in the northern "snow belt" states, and other technologies to increase the useful life in the vehicle.

These adaptations are technically feasible and could result in singificant improvements of overall efficiency, since more than 15% of the energy consumed in the U.S. is associated with the production of moving stock. Private industry in Michigan can and to some extent has already begun to take the initiative in increasing the technical and economic life of the automobile through improved product design and manufacture.

But, the subject of life cycle efficiencies is not limited to transportation. The subject pervades the entire durable products sector

---

*There is little evidence that cosmetic styling has any effect upon an automobile's economic life. Although styling has a distinct effect upon interfirm competition for new car sales, automobiles are not scrapped prematurely due to styling which may be obsolete.

of the economy. Our state of well-being in matters of "durable" products such as clothing, automobiles, housing, and household appliances is more appropriately measured by the *standing stock* (states) and not solely by the production rates (flows). Unfortunately, gross national product (GNP), as currently conceived and computed, makes no such distinction.

In retrospect, it would appear that the political and economic systems of much of the industrialized world have placed undue emphasis on labor productivity (material flow rates per man hour) and aggregate leisure in a rather narrow sense without adequately considering the overall energy efficiencies of our system of production and consumption. For example, a labor force A that produces 4 million cars per year with an average economic life of 12 years is more energy efficient and provides more leisure time than labor force B (of the same size) producing 5 million cars per year with an average economic life of 8 years. Yet conventional economic accounting procedures would regard labor force B as more productive than A, since it contributes more to GNP, and creates more jobs.

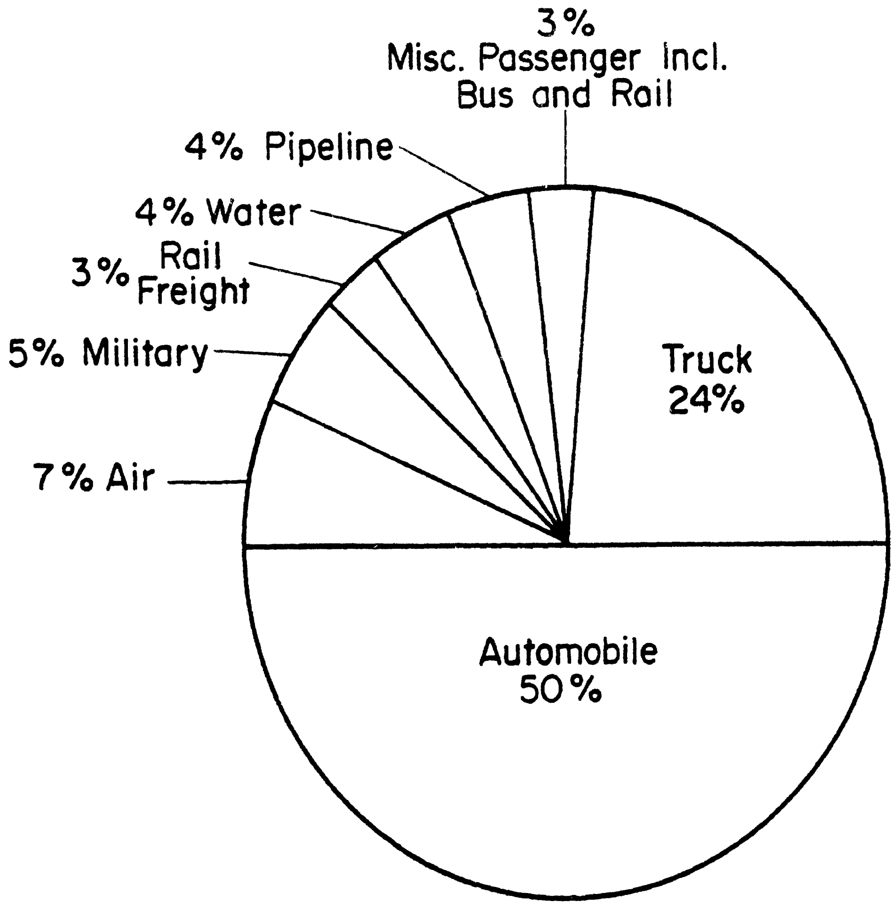
Throughout most of the period of Western industrialization, the ability to economically induce increases in the flow rates of materials and energy in the system in response to varying levels of demand has been a prerequisite to maintaining economic stability. This paradigm of system management promotes product life cycle inefficiencies and has been possible because resource limitations have not been -- until very recently -- a limiting factor in the production process.

More Efficient Modes

The distribution of energy use in the various transportation modes for the United States is shown in Figure 6. The current dominant modes are autos and trucks. Current assessment of energy requirements per ton/mile for freight transported by truck are four to five times higher than by rail or water. Similarly, current assessment of energy requirements per passenger/mile by auto are two to three times more than rail. These assessments, however, do not take into consideration the ridership and freight load factors that currently exist on most systems. Nor do

Figure 6

1976 DISTRIBUTION OF TRANSPORTATION ENERGY



they take into consideration the energy required to build and maintain the capital stock. Direct line passenger and freight hauls must also be supported by indirect distribution services. Studies published by the Office of Technology Assessment and General Motors, for example, indicate that efforts to increase transit ridership to 20 percent of all urban trips, compared to the present level of 6 percent, actually would increase energy use. This would occur due to the increasingly long trip times and higher frequency of trips required to provide improved access to public transit. Other studies suggest that it may take as many as 50 years for the BART system to recover energy savings equal to the energy used in building the system. If this is true, then certainly such systems contribute little if anything to energy conservation; at least not in the short and medium terms. As in the case of alternative energy sources, the net energy saved over the economic life of alternative modes is an important factor to be considered.

To improve load factors of rail freight systems and increase the access and ridership of public passenger transportation, unfortunately, requires basic adaptations in the structure of the transportation system, as well as the community and industrial infrastructure it supports. Adaptation of the structure of the urban community to make light rail a viable option is particularly difficult. Sprawling suburbs as we know them are not compatible with these systems. Many years will be required to make the necessary adaptations in community infrastructure to utilize them effectively. Accordingly, recognition of this situation indicates that high priority should be placed on increasing the efficiency of autos and trucks and on the conservation of energy in transportation. The greatest energy conservation potential in the short and medium terms, apart from increasing fuel economy through fleet average requirements, lies in increasing automobile occupancy through car pooling, van pooling, and shared-ride taxis, and in increasing the load factors and eliminating "dead heading" in trucking.

The conservation potential of public transit is attainable only over a much longer planning horizon and is closely linked with changes in land-use densities. In fact, the relationships between transportation, energy, and land-use are so strong that the conservation potential of public transit cannot be achieved on a piecemeal basis. What is required at both the state and federal levels is comprehensive long-range transportation development and redevelopment consistent with the lead times required to make the requisite structural changes.

The State of Michigan is surrounded by lakes and waterways that potentially might be developed into an energy-efficient transportation network connecting the state to both the heartland of the continent as well as the international seaways. A combined rail/water/highway system capitalizing on these natural resources potentially might give Michigan increased competitive advantage over other states in many of the heavy industries as the cost of energy increases. It may be a critical factor in making the coal from western fields available to our Michigan industries at costs that are competitive to other parts of the country.

Reducing Transportation Demand

The need for travel, and hence the level of passenger and freight transport required to support an economy, is heavily dependent upon land-use allocations and the degree of regional economic diversification and levels of regional economic self-sufficiency. The extraordinarily low cost of transportation in the decades past has made it possible for regions of the country to specialize in a relatively small number of products and capitalize on economies of scale associated with high-volume production. To the extent that the rising cost of energy cannot be counter-balanced by increased energy efficiency in transportation, economic forces will eventually tend to redistribute many of the industries, generate new patterns of human settlement, and make other adjustments in land-use which reduce both passenger and freight transportation requirements. Already there are scattered instances around the country of the reversal in the wave of suburban settlement to a move back to the cities (or at least to the first circle of suburbs) so as to reduce the amount of travel associated with employment and to participate in the cultural and other activities of the cities. These movements apparently are also motivated by a desire to improve the day-to-day self-sufficiency of communities so that transportation needs are lessened.

Changes in land-use allocations, urban form, and levels of regional economic diversification clearly go hand in hand with transportation planning and development. Long lead times are required to design, develop, and modify the transportation system in anticipation of these changes. Further transportation planning can be a positive force in giving direction to land-use allocations and the community structures so as to minimize transportation requirements. It is well established that the structure of the rail system in the United States was a major factor in determining the location of many of our major metropolitan areas. It is also well known that the trolley system, rather than the automobile, gave Los Angeles its initial sprawling structure -- although suburban growth and development around the trolley system was very different from that associated with a ubiquitous grid of highways and streets.

The central point is that an integrated systems approach to regional and urban economic development and redevelopment can and must have a major influence on the level of transportation services required to support <u>routine</u> economic activities. Reducing the routine aspects of transportation is an essential component in allowing the various transportation modes to be used for weekend travel and recreation -- a critical factor in preserving our standard of living in the face of inevitable increases in the cost of energy.

The urban-suburban complex in Southeastern Michigan should receive special attention now. It is perhaps one of the most energy-intensive urban structures in the nation. The state should consider initiating a study of the long-term potential energy savings that are available in the Detroit urban/subruban area through coordinated land-use policies, transportation development, and utilities planning. Of particular interest is the feasibility (technically and socially) of promoting the evolution of the existing structure toward a multi-nucleated city by increasing the intensity and diversity of land-use around existing malls and community centers so as to support both public transportation and district heating systems. Areas in between which are currently dominated by 5-10 acre plots perhaps might remain low density, preserving the option for high-intensity garden farming and recreation at some point in the future. These and other land-use patterns to reduce the need for travel and to accommodate efficient modes (whether small electric or motor cars and/or light rail) need to be considered now so that the evolutionary adaptations can be initiated.

IV. ECONOMIC IMPLICATIONS: A PRELIMINARY ASSESSMENT

Employment and Capital Investment

Unfortunately, most of the components of energy conservation in transportation imply major reductions in employment opportunities in the automotive industry in the medium and long terms. In the long term, conservation measures will prolong the life of the low-cost natural fluid fuels. Also in the long-term, increases in the cost of energy relative to labor will motivate the development of production technologies in all sectors of the economy that are relatively more labor-intensive than they now are.

If the public accepts small cars, it is possible that automotive employment will actually increase in the short-term as the nation changes over to small cars, particularly if gasoline prices increase in line with price in many other countries. To improve the energy efficiency of today's fleet of 120 million automobiles, many of these automobiles must be scrapped.

Preliminary assessments suggest that the major negative and potentially precipitous economic impact is to be found (a) in medium-term employment dislocations in the automotive industry, and (b) in the short-term capital investment demands on the automotive industry required to retool their production facilities for small vehicles.

It is generally agreed by all concerned that automobiles must become more energy-efficient and durable as domestic production of petroleum declines, petroleum imports continue to increase, and fuel prices continue to rise. Since Michigan's economy, in particular, and the nation's economy, in general, is currently dependent upon the economic health of the domestic auto industry, the transition to energy-efficient automobiles should be planned to minimize possible economic hardships. For example, it was very apparent in 1974 that the recession in the auto industry contributed significantly to the recession in the State of Michigan. Unemployment benefits became exhausted, state tax revenues declined drastically and state revenues for welfare and academic institutions were curtailed significantly.

Inequities

Increases in the real cost of energy impact differentially and inequitably on the various income groups within our society -- directly in terms of fuel costs and indirectly in terms of the cost of owning and maintaining an automobile as a prerequisitie to using our highway system. The limited availability of less energy-intensive urban and interurban modes of transportation, and the sprawling laissez-faire structure of metropolitan areas, provide the individual with limited opportunity to mitigate these increased costs.

So far, we in the United States have had no experience with the social inequities imposed by increases in the real cost of energy. Energy prices have, in fact, been held artifically low in an attempt to limit inflation and to mitigate inequities. Increases in fuel costs have not as yet exceeded general inflation levels, but already transportation and utility subsidies for the economically disadvantaged have been initiated by the federal government as well as some states.

To bring about the much-needed structural changes in the economy, energy must ultimately reflect the true cost of production and the social cost of the associated environmental impacts. As the real cost of energy and transportation rises, the inflation and inequity impacts are sure to be of increased concern. Less energy-intensive modes of transportation and more organized community structures are essential to mitigate these impacts. Increases in the fuel efficiency and life-cycle efficiency of the automobile are essential to its continued widespread affordability and use. To this extent, energy conservation in transportation potentially can have a very positive social impact. It most assuredly can have a positive impact on reducing man-induced changes in the composition of the earth's atmosphere and heat balance, thereby reducing the social and economic expenditures for environmental protection measures.

Potential Long-Term Gains

In the long term, as the cost of energy relative to labor increases (as it must), there will be a gradual shift to more labor-intensive technologies, and as previous developments have shown, the labor and capital required to produce a unit of energy will increase as we move from high-gain sources to alternates that, in general, have a substantially lower gain. The problem is not that change is bad or that there are no alternative economic and employment opportunities: change always provides new opportunities. The problem is in recognizing the opportunities and formulating a timely set of goals and policies for capitalizing on them. More specifically, in the medium and long term, capital, labor, and energy savings resulting from the adaptations in the automotive industry are required to develop appropriate transportation systems, develop new integrated community energy systems, and otherwise redevelop or restructure our communities. The potential also exists for increased employment in agriculture, reforestation, forest management, "energy farming," food production, and other aspects of rural resource development, redevelopment, and management. The long-term implied shift in the balance between rural (including small communities) and urban populations potentially could lead to a reduction in the energy intensity of the food chain and improved physical and social environments for many who are now economically and socially disadvantaged.

V. POLICY DIRECTIONS

The problem facing the United States and indeed the entire industrialized world can be simply stated: We are moving from a period of declining real cost of energy and perceived unlimited supplies of natural petroleum and gas to a period of rising real costs of energy and a real decline in the availability (gain) of these resources.

The Michigan economy, dominated as it is by the automotive industry, must expect serious impacts on its employment, income, and tax revenues unless special and unusual cooperation is established between the federal and state governments and the transportation industry in carrying out certain critical transitions in our economy.

A recent study by Harbridge House* presents several conclusions related exclusively to the economic sensitivities of federal regulations on fuel efficiency, environmental standards, and safety.

An abridged statement of these conclusions is as follows:

1. *The regulatory process and pace are accelerating structural changes in the automotive industry, largely by magnifying traditional economies of financial scale. This is likely to lead to an increasing concentration of market share by one or two of the largest companies.*

   Along with their intended benefits to the public in such areas as energy conservation, occupant safety, and emissions control, federal regulatory programs are changing the economics of American automobile manufacture. The unprecedented acceleration of new product development and the scope of effort required to create new generations of passenger cars that both satisfy regulatory standards and meet consumer needs has led the three largest American companies to forecast capital investments of $43.7 billion over the next five years, double the amount invested by them in the previous five-year period... ...The regulatory framework has magnified existing differences between U.S. automakers by applying equally difficult standards to unequal companies. The smaller firms will either have to be unusually skillful or uncommonly lucky to reach 1985 with market shares and a product line breadth similar to those of the past. Without such skill or luck the regulatory framework will contribute to a considerably greater degree of relative industry concentration.

2. *The cost impact of regulatory standards, if passed through in automobile prices along with other cost increases affecting automobile production, is likely to create annual price increases that will exceed rates of inflation or growth in consumer income. If so, this may lead to the postponement of consumer auto purchases or of a "thrifting" of purchase patterns, either or both of which would diminish internal investment flows and thus adversely affect the capacity of the American automakers to generate the investment funds needed for regulatory compliance.*

---

*"Corporate Strategies of the Automotive Manufacturers." VII. Executive Summary of Conclusions Prepared for U.S. Department of Transportation, Interim Report. 1978.

During the past 10 to 15 years American automakers have chosen to keep price increases below the level of increases in the cost of living and personal income. This was done in the expectation that it would help sustain high volumes of demand since purchasing behavior seemed more sensitive to these relationships than any others. A consequence of this policy has been a steady downtrend in their return on sales (ROS) percentage. However, return on shareholders' equity (ROE) has largely been sustained during this same period by a relative decline in new capital investment and by volume growth.

3. *The length of the product planning cycle has been stretched to five or more years by the organic character of change required to meet regulatory requirements. Despite the efforts of the automakers to delay "point of no return" decisions as long as possible in the cycle, they are nonetheless making many basic decisions without the sort of confidence that a closer view of consumer interests and behavior would provide. This increases risks, especially for the smaller American companies that cannot absorb any major product errors.*

   The product planning process typically begins with an effort to identify consumer interests and to integrate these with such business objectives as profitability, volume growth, and improved market share. The cycle, however, has grown progressively longer since each succeeding new product program is technically more complex than its predecessors. The cycle now requires at least 60 months for a new product that does not embody unusual new technology and may stretch to seven years if extensive new technology is required.

4. *In the event of initial consumer resistance to new vehicle configurations, price increases influenced by regulatory costs, or CAFE-related product mix goals of the American manufacturers, the marketing capabilities of the automakers can probably succeed in counteracting some resistance, but efforts to counter major resistance may result in a shrinking of profit margins and, with this, a shrinking of internal investment flows.*

The use of conventional marketing tools, especially consistent advertising in high volume, appears to have been an effective means of inducing the public to accept moderately novel configurations to which there has been some initial resistance, such as the new down-sized General Motors A-body vehicles. Any deep-seated resistance or major obstacles are more unyielding to the marketing tools available to the automakers and require tools that diminish profit margins. These include dealer incentive programs, special accessory "package" promotions aimed at the public, and dealer rebates. In the most extreme situations direct rebates to purchasers have been utilized.

5. *Even a minor recession in the next eight years is likely to destroy the abilities of Chrysler and AMC to maintain their announced investment programs to meet already established regulatory requirements. A major recession, comparable to that of 1974-1975, or a second minor recession prior to 1985 would lead GM and Ford, between them, to raise approximately $5 billion of new capital simultaneously in a capital market of shrunken capacity. As a point of reference, American's largest corporate borrower, AT&T, has never raised more than $1.569 billion at a single time.*

   If a recession of half the relative magnitude of 1974-1975 intervenes (and it is difficult to imagine any continuous eight-year period without at least one moderate recession), General Motors and Ford, although seriously affected, should be able to meet their capital needs through their internal reserves and, perhaps some medium-term borrowing. The impact on Chrysler of even a modest recession might be catastrophic, forcing the company to begin to dispose of marketable assets or to abandon some product lines.

6. *Current trends in the tort litigation system, working on the high expectations likely to be aroused by compulsory passive restraint systems, will cause a considerably higher frequency of product liability suits to be launched against the automakers and, very likely, a higher product liability related cost. The magnitude of this incremental cost remains virtually impossible to forecast.*

7. *Despite the dependence on a single technology (three-way catalytic converters) to meet 1981 emissions standards, despite dependence on the Republic of South Africa as the primary source of the catalytic metals, and despite a mismatch between the natural occurrence of the metals and proportional requirements for them in the converter, it does not appear likely that either the technical or the political problems involved will interfere with the ability of the automakers to meet 1981 standards.*

Although the above conclusions are clearly those of Harbridge House itself and may not coincide entirely with views developed by other research groups, they nevertheless illustrate the scope and the complexity of the consequences of social objectives in safety, environmental stan--ards, and fuel efficiency. Failure to consider the synergetic consequences of policy relating to these three areas could lead to very serious capital expansion, employment, and other economic impacts -- a "cure" that is potentially worse than the "disease."

Finally, the Harbridge House conclusions clearly illustrate the social and economic costs that potentially are associated with rapid adjustments. In addition to the problems of premature obsolescence of production equipment and the problems of new capital formation, rapid transitions can actually result in a reduction in jobs in Michigan by forcing the industry to import production equipment and/or automotive parts from foreign producers -- components and tools which under more favorable time scales could be produced locally by existing firms. The order of magnitude of this impact has been estimated as tens of thousands of jobs potentially lost to the U.S. auto industry. Adequate planning horizons for effecting needed change are absolutely essential; time is one of our most precious non-renewable resources.

Michigan, like every other state, is heavily dependent upon low cost, reliable and versatile transportation to support its industry. Historically, the state has played a pre-eminent role in developing the present system. Our resource base is clearly changing and the evolution of our transportation system must now take on new directions.

The state has fallen heir to the dubious distinction of being called on to provide the wherewithall to downsizing of motor vehicles as the first much-needed major step in improving the energy efficiency of the transportation system. As previous sections have indicated, the cost of this transition to Michigan industry and its citizens in terms of capital requirements and in potential employment dislocations imposes a burden on our economy unlike that experienced by any other state in the nation. State policymakers and industrial executives individually and collectively are faced with a very unusual and difficult task of maintaining economic stability and fiscal solvency in the face of the economic transitions that lie immediately ahead. It is suggested that the following two major policy directions may be helpful in addressing some of the short- and long- term economic implications of energy conservation in transportation.

Improved Government/Industry Cooperation

The relationship between industry and government, particularly at the federal level, can be characterized as adversarial in approach and largely one of mutual distrust and suspicion. This atmosphere must be redirected to one of cooperation and mutual trust built around sober and realistic understandings of the nature of the problems we face and the difficult steps that must be taken to deal with them. Areas of particular concern in this regard include:

a) A more complete understanding on the part of government of the nonhomogeneous nature of the auto firms, their varying ability to respond to the admittedly needed changes, and the social inequities imposed by ignoring these differences; the auto firms on the other hand must understand the urgency of presently imposed standards and the need to adopt a long-term planning horizon in anticipation of changes that are yet to come.

b) The critical role of fuel pricing policy at the federal level in gaining consumer acceptance of smaller, more energy-efficient cars -- virtually a prerequisite to meeting present federally imposed fuel economy standards in the time scale specified.

c) Mutual understanding of the critical role of planning time frames <u>and</u> a reliable and carefully articulated statement of standards on emissions, fuel performance, and safety consistent with these time frames. Many of the adverse relationships that exist center not so much around the ultimate goals and objectives but around the uncertainty, indecisiveness, and inarticulate expression of these goals and objectives and the seeming arbitrariness of the time frames and the mechanisms for achieving them. Quite specifically, some of the auto companies are currently unable to exploit the diesel engine because of the uncertainty surrounding future emission standards. The risks surrounding these uncertainties are too high. Yet without such standards, there are legitimate environmental concerns in some regions of the country.

d) Implementation of the several components of energy conservation referred to in this paper requires accelerated structural changes in the automotive industry. In addition to long-term basic research in the development of more energy-efficent and environmentally benign heat engines, the industry is faced with the opportunity to greatly expand the scope of its involvement. It is in a unique position to take a much more comprehensive and systemic view of transportation (with all of its potential modes and intermodal integration) as a supporting element of future economic growth and development and as a major determinant of the form and structure of our urban communities. If the growth and development of this "new" industry is to be responsive to the needs of the nation and the state, then basic research in the universities and industries must be supported so as to provide sound scientific bases for dealing in a coordinated and holistic manner with the many components of conservation referred to in Section III. Through EPA, national focus and coordination is provided for research and development related to the environment. Through DOE, national focus and coordination is provided for research and development of new energy resources. The nation has yet to develop a corresponding focus for R&D relating to the integrated development in transportation, commerce, community structures, and land-use allocations so that we might use more effectively those resources which we already have and adapt the existing structure of our communities and transportation systems so they can, in fact, utilize the alternative energy sources of the future. We already know these alternatives will be very different in quality and real cost from conventional sources. Transportation is one of the most critical sectors of the economy, not only in terms of employment, but in terms of the critical support it must continue to provide for our industries and the dominant role it plays in determining the structure of our urban communities and life styles.

Interagency Coordination

The several components of conservation in transportation cannot be implemented one at a time according to narrowly defined cost-benefit analysis only or in sequence strictly in terms of their payoff horizon. The potentially negative economic and social impacts of conservation in transportation must be negated insofar as possible by compensating developments in other sectors of the economy. In this important respect, the stability of the state's economy is increasingly dependent upon the level of coordination and cooperation between the departments of commerce, transportation, agriculture, natural resources, and their associated agencies. It is suggested that the interface between these agencies should be significantly strengthened so that collectively they provide a coherent set of policies and programs in the pursuit of carefully evaluated goals in transportation, industry, agriculture, and human settlements which are consistent with our changing resource base. The problems we face require constellations of policies that deal in a balanced and coherent way with the many elements of change that must take place simultaneously in the context of well-calculated time scales.

Pursuant to the conservation principles presented in Section III, it is suggested that the added elements of interagency coordination can best be developed by focusing on specific development objectives. What is required is a mechanism for identifying and carrying out particular programs that are of major concern to the future of Michigan's economy. For example, what are the potential future economic benefits of developing an integrated water/rail/highway system to exploit the water systems that surround the state, or the potential energy savings and social and economic benefits of multinucleation of the sprawling suburbs in Southeastern Michigan so as to accommodate public transportation and district heating?

The feasibility studies and other activities involved in identifying and assessing the potential benefits of particular interagency programs such as these might be carried out under contract to MTRP or other qualified research organizations under the joint support and supervision of the agencies. It is suggested that such a process is a critical first step in facilitating the elements of interagency cooperation and coordination necessary to deal in a practical and productive way with the economic and social impacts of rising costs of transportation.

Recommendations

Pursuant to the above policy considerations, it is recommended that a special task force, consisting of representatives from the Michigan transportation industry, the state departments of government, the universities, and the private sector, be established to:

1) Facilitate improved cooperation between the various agencies of the federal government and the Michigan transportation industry in achieving nationally established goals in energy conservation, environmental standards, and safety in transportation.
2) Define specific areas of research and development where coordinated and integrated developments in commerce, transportation, and human settlements can significantly reduce the short- and long-term impact of rising energy costs on the economy of Michigan and its citizens.

VI. INDUSTRY COMMENTARY

Industry representatives of the MTRP Advisory Committee agree that energy is a critical element in our economic future and recognize the need to improve energy efficiency not only in the transportation sector, but in all sectors as well. Incentives to improve efficiency may be effective in increasing energy availability. There is, however, some difference of opinion regarding the economics and ultimate availability of energy and its development. In addition, as fuel economy standards become more stringent in the future, it is likely that the cost of saving a barrel of oil may become greater than the cost of producing a barrel of oil from alternate sources. Consequently the future welfare of the state and the nation demands increasing attention to the development of alternate energy sources.

The industry representatives feel that a "slowdown" society is not a viable way to deal with the energy problem, since it only postpones the problem and leads to severe economic consequences. They believe that the only realistic alternative is to consciously reinvigorate incentives within the economic system so that the necessary investment will be forthcoming for both energy conservation and supply expansion.

VII. REFERENCES

1. Hubbert, M. King, "The Energy Resources of the Earth," Scientific American, September 1974, pp. 61-70.

2. Michigan Energy and Resource Research Association (MERRA), Toward a Unified Michigan Energy Policy, Detroit, Michigan, 1977.

3. Degloyer and MacNaughton, Twentieth Century Petroleum Statistics, 32nd Edition, Dallas, Texas, 1976.

4. U.S. Department of the Interior, Bureau of Mines, Mineral Industry Surveys: Crude Petroleum, Petroleum Products and Natural Gas Liquids, Washington, D.C., December, 1976.

5. Hubbert, J. King, U.S. Energy Resources: A Review as of 1972, Committee of Interior and Insular Affairs, U.S. Senate Serial No. 93-40 (92-75),July 1974.

6. U.S. Central Intelligence Agency, The International Energy Situation: Outlook to 1985, U.S. Government Printing Office, Report ER77-1028 U, April 1977.

7. Dix, Samuel M., Energy: A Critical Decision for the United States Economy. S.M. Dix & Associates, Inc., Grand Rapids, Michigan, January 1977.

8. Energy Policy Project of the Ford Foundation, A Time To Choose: America's Energy Future, Ballinger Publishing Co., Cambridge, Massachusetts, 1974.

9. As summarized in the Oil and Gas Journal, May 23, 1977.

10. Ibid.

11. Duane, John W., "World and National Oil and Gas Demand and Supply," Consumers Power Company, Jackson, Michigan.

12. U.S. Department of Transportation, "Energy Conservation," programs of the U.S. Department of Transportation, Washington, D.C., May 1978.

13. Ibid.