(continued from the front flap)

Michigan under high, medium, and low levels of energy supply through the year 2000. *Jobs and Energy in Michigan* addresses the trade-offs of increased reliance on conservation, solar energy, and renewable resources versus an all-out push for high energy production.

The authors underscore the risks of uncertainty. Dramatic setbacks may confront us if we plan on having today's amounts of energy in the future—when we may well have less.

The conclusions of this study are important not just to Michigan but to the other states which will be affected both by Michigan's successes or failures and by changing national energy conditions in the years ahead.

Center for Research on Utilization of Scientific Knowledge
Institute for Social Research
The University of Michigan

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Jobs and Energy in Michigan: The Next Twenty Years

Mark R. Berg
Paul H. Ray
Mark A. Boroush

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The authors of this volume argue that jobs in Michigan depend greatly on the amount and stability of national energy supplies. And Michigan may well be a barometer for the nation since its heavy reliance on the automobile industry makes it very sensitive to changes in energy supply.

The current turbulence of world affairs and dwindling resources put future energy supplies in doubt. Shortfalls in energy could send shock-waves through the economy of Michigan and the nation during the next two decades.

This volume carefully examines the implications for jobs and productivity in

(continued on the back flap)

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Preface

This report is the result of a one-year study by the Energy Policy Group (EPG) at the University of Michigan's Institute for Social Research. The EPG was formed in 1978 for the purpose of conducting interdisciplinary energy policy research focusing on the special needs and circumstances of Michigan and the Northern Industrial Region. Principal Investigators for this project were Mark R. Berg and Paul H. Ray. Mark A. Boroush played a major role in the research. A significant contribution was made as well by Mitchell J. Rycus.

The primary goal of this study was to provide a preliminary examination of the potential risks to Michigan jobs resulting from the drastic changes in the price and availability of energy expected during the next two decades. In pursuing this question, the study has limited its focus to those risks which the state might run if energy policies in the public and private sector continued on what might be called a "business-as-usual" path. This was not done because business as usual was felt to be the "best," or even "most likely" policy – indeed, it would be extremely risky. Rather, this approach serves as a baseline analysis and a way of alerting citizens and policy makers to the economic and other risks inherent in the continuation of present energy use practices.

Funding for the Study. The initial funding for this study came from the Michigan Committee for Jobs and Energy. We wish to thank the Committee for this financial support – resources which were given without any preconditions or controls attached to the analytic approach or conclusions of the study. Member organizations of the Committee have reviewed and commented upon an earlier draft of this report (as have other knowledgeable persons in the state). However, the views and conclusions contained in the report, as well as any errors, are the responsibility of the authors.

The authors wish to acknowledge additional financial support provided to the EPG staff by the University of Michigan's Center for the Utilization of Scientific Knowledge (CRUSK) at the Institute for Social Research, the Program in Urban and Regional Planning, and the Office of Energy Research. Their supplementary support allowed completion of a somewhat more detailed and far-reaching study than initially envisioned.

The Structure of this Report. The content and structure of the report are intended to provide government officials, businesses, and citizens in Michigan with information and perspective helpful to them in making informed energy choices in the critical years ahead. The study has examined the prospects for future energy supplies in the United States and in Michigan and the long-run relationship between energy supplies, jobs, and economic growth. Of critical concern, and discussed throughout the report, is the heavy reliance of the state on automobile production. An awareness of this dependence may provide the greatest insight into the vulnerability of Michigan jobs.

Because of the high degree of uncertainty in forecasts of supply and demand for energy, the Energy Policy Group has used a risk analysis approach which places considerable emphasis on the uncertainties to be faced and the risks inherent in those uncertainties. One aspect of this approach is the use of alternative future scenarios which provide a basis for thinking about the nature and implications of high, medium, and low employment and energy supply levels for Michigan in the years ahead. Chapter 1 provides an overview of the approach and a summary of the major conclusions and arguments of the study, with emphasis on the wide range of risks, uncertainties, and energy/employment policy issues which the state will face over the next 20 years.

Chapter 2 begins the detailed analysis by providing background information and comparative perspective about current patterns of energy use, employment, and economic output in Michigan and in the United States as a whole. We examine the amounts and types of energy used by representative sectors of the Michigan economy and the Michigan jobs which currently depend on an uninterrupted and reasonably priced supply of that energy. Chapter 3 focuses on U.S. energy supplies, economic growth scenarios, and the jobs implications of alternative energy/economy interactions. Chapter 4 outlines alternative employment scenarios for Michigan, with special emphasis on manufacturing, construction, and nonmanufacturing jobs. Chapter 5 examines in detail the potential for supply and demand imbalances among the various forms of energy used in the state and relates these to the employment projections of Chapter 4.

1

Overview and Summary

Introduction

The 1973 oil embargo had a massive impact on jobs in Michigan and the overall health of the state's economy. Job losses were over 25 percent in the automobile sector and reached a massive 36 percent in the construction trades. The 1980 recession has had an equally devastating effect on the workers and overall economy of the state. This time, however, many analysts believe the effects will be longer lasting, if not permanent.

The energy crisis, which is a dominant force behind Michigan's economic problems, is a national problem. Its impacts are on a national scale, and many of its solutions must be worked out at the national level as well. National solutions, however, will not necessarily place adequate priority on the long-run interests of Michigan workers. Unfortunately, jobs in Michigan are more vulnerable to energy-based problems than those in almost any other state in the nation. Michigan's heavy dependence on the auto industry and other forms of durables manufacturing has historically meant that problems in the national economy have disproportionate effects on employment in Michigan. The additional burden of energy based problems—within both the state and the nation—will further increase the vulnerability of the state's economy in the years ahead. For example, in 1976 Michigan was seventh highest among the states in its use of energy, yet it imported more than 85 percent of its energy.

An overriding conclusion of this year-long study of jobs and energy in Michigan is that the state's citizens, businesses, and governments will all have to take strong new initiatives if its four million workers are to successfully cope with the problems posed by the new and uncertain era of expensive and supply-limited energy resources which we are entering.

Purpose of this Study

This report by the Energy Policy Group at the University of Michigan's Institute for Social Research is intended to provide government officials, businesses, and citizens with information and perspective helpful to them in making informed energy choices in the critical years ahead. In particular, we have attempted to answer five basic questions:

- How is energy in Michigan used now and how is that energy use currently related to state jobs?
- What is the nature of the relationship between jobs and energy, and how vulnerable are Michigan jobs to the types of energy problems and changes which can be expected over the next 20 years?
- What alternative futures are possible for the U.S. and for Michigan in terms of energy and jobs over the next two decades?
- What types of energy supplies and strategies offer the greatest risks and greatest opportunities for Michigan in the years ahead?
- What are the major energy related risks, uncertainties, and policy issues needing near-term attention by the citizens, businesses, and governments of Michigan?

In exploring these questions, the study has drawn on a wide range of existing data, forecasts, and analyses. Our approach has been to use information available at the national level or from other states and regions and to adapt and interpret it in terms of the specific circumstances and problems of Michigan. For example, a wide-ranging review and synthesis of national energy forcasts and economic forecasts for the year 2000 have provided the basis for development of energy and employment scenarios for the state. These scenarios have in turn provided a basis for drawing the conclusions and identifying the major issues and uncertainties highlighted in the remainder of this summary.

The Link Between Jobs and Energy

The economic disruption resulting from the 1973 oil embargo convinced many observers that a virtual "iron link" existed between jobs and energy. In the short term, at least, it was quite clear that a significant reduction in energy supplies would result in a corresponding reduction in economic output and employment. It would appear now, however, that over the medium and long term, the strong historical correlation between energy use and gross national product (GNP) can be made much looser than previously thought possible. This conclusion is drawn from careful comparisons with the energy and GNP records of other countries, engineering and economic studies of conservation opportunities, and the record of changes since the 1973 oil embargo. All suggest considerable potential for satisfactory growth in jobs and income without correspondingly high levels of growth in energy consumption.

The potential does exist over time to significantly soften the link between jobs and energy. But to do so will require careful energy and economic management focused on changes in lifestyles, business practices, and technologies. While increased energy production will be needed in the years ahead, the future protection of Michigan jobs will depend less on strategies designed to achieve the highest possible energy supplies and more on strategies designed to buffer our energy and economic systems from new shocks, instabilities, and uncertainties in energy supply and demand. This means a strong emphasis on energy conservation which, at the present time, offers the fastest, lowest cost, and most reliable source of energy for the years ahead. Ongoing changes of the past decade have already moved us in this direction, and it is becoming clear that further energy efficient gains—up to 40 percent in some cases—will be economically attractive as the price of energy continues to rise over the next 20 years. Such changes appear possible largely as a result of modest technological improvements and the orderly replacement of older equipment and buildings.

While the potential for such changes exists, this report offers a sobering note with respect to their achievement. We face a very real risk of being overwhelmed, from both an economic and managerial standpoint, by the instabilities and uncertainties of our energy problems. In the short term, the link between jobs and energy will remain quite strong. Perhaps even more important, now and for sometime into the future, we will remain vulnerable to the disruptive effects of events such as new oil embargoes, Middle East war, runaway inflation, or panic and breakdown in financial markets. A series of such disruptions, a wrong choice of strategies, failures in our energy and economic management, or just plain bad luck could leave us without the economic and institutional resources needed to protect jobs and to make a smooth transition to more efficient and secure energy patterns.

How Vulnerable are Michigan Jobs?

The results of this study suggest that, at best, Michigan will face slow growth in employment over the next two decades. In the worst case, wherein the economy is buffeted by energy shocks and instability, we would be faced with virtual economic stagnation in the 1990s and potential decline in some major sectors such as manufacturing and construction. The magnitude of the potential employment problems facing the state are staggering. For example, the difference in employment levels between the most optimistic and pessimistic scenarios for the year 2000 examined by this study is on the order of 30 percent. In contrast to the 1978 Michigan employment level of 3.8 million jobs, employment in the year 2000 could be as high as 5.5 million or as low as 3.9 million jobs. The stakes are extremely large, as are the problems to be faced.

The key problem for Michigan jobs is uncertainty and disruption, not only in energy but also in the national economy. The most critical energy vulnerability for the near-term is in the liquid fuels, such as gasoline, used for transportation. Michigan's auto industry would be more hard hit than most other industries since national demand for cars would be depressed both by oil shortages and by the tendency to reduce new car purchases in times of economic uncertainty. Similar problems would be faced by most of the state's other durables manufacturing industries. Still other jobs are at stake in industries such as tourism, agriculture, and trucking which are dependent on transportation and petroleum products. Commuter lifestyles or even jobs could be seriously affected, especially where no mass transit alternatives are available. There remains considerable room for honest and concerned citizens to differ over the "best" course of action. Few questions remain, however, over the serious risks entailed by a lack of action and failure to make the institutional and individual changes required to cope with our energy problems.

"Business as Usual": A Risky Path to the Future

This study has examined in considerable detail the implications for Michigan of a continuation of "business-as-usual" policies. This is not because we think the lack of institutional changes implied by the term "business as usual" is best or even most likely, but rather because it is important to understand the risks and implications of continuing present practices. We have defined business as usual as a future without drastic changes in values, lifestyles, business practices, or government policies and without major technological breakthroughs. Even within these limitations, substantial changes are assumed to occur, but largely through traditional market forces and subject to the typical delays, uncertainties, and political constraints experienced in the past.

Our analyses of a range of future energy and economic scenarios which could occur for Michigan within the context of business as usual all point to the conclusion that there are extremely large risks of continued high unemployment, coupled with instability, uncertainty, and sporadic crisis in our energy supplies. To reduce these risks and the further risks which would result from decisions made in the midst of crisis situations, or from decisions made to benefit a few special interest groups, the state government must commit itself to a more active energy policy and the development of an enlarged energy analysis and planning capacity. Many positive steps have already been taken on the energy front by both the public and private sectors. For the most part, however, these have been the easy steps. Further progress on the scale needed will require unprecedented levels of capital investment, careful analysis and planning, and timely action. This chapter reviews many of the more important actions which will need to be considered in the near future.

Solving our energy problems and reducing the vulnerability of state jobs is not likely to be accomplished through the crisis-oriented "firefighting" responses which are bound to occur within a business-as-usual context. Nor will it be accomplished by a total reliance on free market solutions. Factors such as imperfect markets, equity issues, massive capital investment requirements, high uncertainty, and long lead times mean that free market signals alone will not be an adequate guide for policy, planning, or action. It falls to the public sector to take a longer-term viewpoint on energy problems in order to aid and encourage consumers and businesses to conserve energy and to substitute away from the most scarce and expensive energy sources.

Energy and Economics in the Year 2000: Alternative Scenarios for the U.S. and Michigan

The basic strategy of this study has been to examine a range of energy and economic futures for the U.S. in the year 2000, and then to "step down" these national level scenarios in terms of their implications for Michigan.

The national energy scenarios are based on a wide ranging review and synthesis by the Energy Policy Group of recent energy supply forecasts and trends. The energy forecasts have been placed in a probabilistic framework to emphasize that the actual supply level in the year 2000 will fall within what is now a fairly wide and uncertain range of values. While it is psychologically comforting to act as if the "most probable," midrange supply level will actually occur, the probabilistic approach makes one face the fact that the actual value may be significantly higher or lower than the medium projection. In order to emphasize this perspective, the study has adopted a risk analysis approach which attempts to address two key questions: What do we risk by acting as if the future will have as much energy as we might like—when it may well not? And what do we risk by acting as if the future will have very little energy—when it may well have more?

The National Scenarios

Tables 1.1 and 1.2 summarize in quantitative terms the high, medium, and low energy projections and economic projections for the U.S. in the year 2000. As argued earlier, the long-term link between total energy supply and economic growth is potentially a loose one. As a result, the projections of high, medium, and low energy supply levels do not automatically yield direct, one-to-one projections of high, medium, and low GNP levels. As suggested in Figure 1.1, the loose link means that under "normal" circum-

TABLE 1.1

EPG Projections of U.S. Primary Energy Supply in 2000
(Quadrillion Btu's of Energy)

Fuel Types	Scenario Low	Scenario Medium	Scenario High	1977
Petroleum Liquids	1	31	41	36
Domestic[a]	8	14	20	
Imported	13	17	21	
Natural Gas	10	19	28	20
Domestic	6	12.5	19	
Conventional	3	4	5	
Nonconventional	1	2.5	4	
Imported	1	2.5	4	
Coal	23-28.5	30-33	32-43	14
Non-Synfuel Users	23-28	30	32-38	
Synfuels[b]	0.1-0.5	.1-3.0	.1-5.0	
Syngas	0-0.5	0-3.0	0-5.0	
Synliquids	0.5-0	3.0-0	5.0-0	
Hydroelectric	2.75	3.5	4.25	2.5
Nuclear	4-8	8	8-12	2.7
Solar/Renewables	3-7	7	7-11	—
Representative Total Supply	71[c]	102[c]	130[c]	75

[a] Includes estimates for shale oil and enhanced recovery.

[b] The values shown here are for primary energy inputs of coal (in quads). Only about 60 percent of the primary energy will be delivered in the form of synthetic gas and oil.

[c] Coal, nuclear, and solar/renewables are all competitive for investment funds; it is unlikely that all would be high or low together. The total supply figures presented here reflect our best guesses as to the outcomes of this competition in overall terms.

stances, a high energy supply would be linked to a high GNP level. However, it could happen that through events such as international turmoil, policy failures, or economic mismanagement, a high energy supply could be linked to a medium growth rate and GNP level or, in the worst case, even to low levels. Similarly, a medium level of energy supply could, with good planning, be turned into a high GNP or, with failures or troubles, it could result in much lower GNP level than otherwise expected under "normal" conditions. It is quite possible that even low energy levels could be turned into medium GNP levels as a result of careful management and good luck.

The three national economic scenarios presented in Table 1.2 are illustrative of the economic and energy circumstances which might be expected under "normal" circumstances. The *high scenario* comes closest to an extension of past trends in terms of relatively high economic growth and employment levels and relatively abundant and stable energy supplies—although at

TABLE 1.2

Scenarios for the U.S. Economy: Year 2000

	High	Medium	Low
GNP (billions of 1972 dollars)	\$2533	\$2296	\$2073
Average Annualized GNP Growth Rate, 1980–2000	3.1%	2.6%	2.0%

considerably higher prices. Economic growth would average 3.1 percent per year between 1980 and 2000, and energy consumption would grow to a year 2000 level of 130 quads (almost double the 75 quads of 1977). Because this type of future would be dependent on the maintenance of high levels of energy supply it is a very risky scenario with a rather low likelihood of occurrence.

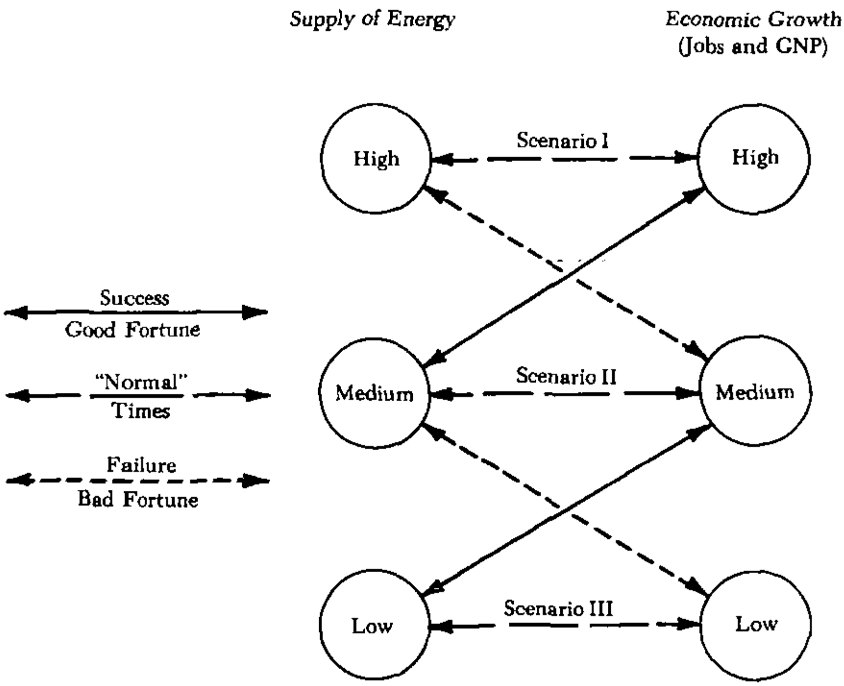
The *low scenario* illustrates a low economic growth condition likely to be associated with a turbulent social and economic environment in which energy supplies would be relatively low and unstable. Year 2000 energy supplies would be at 71 quads and average economic growth for the 1980–2000 period would be 2.0 percent a year (higher in the 1980s and much lower in the 1990s). It is a scenario in which we would lack the energy, economic, and managerial resources needed to solve our energy problems. Unfortunately, it is the scenario which becomes all the more possible given the energy and economic instabilities which are possible in the years ahead.

If we can avoid such turbulence, then the *medium scenario* can be thought of as the "most likely" projection. Economic growth would be at a modest 2.6 percent per year, and the 102-quad energy supply—while considerably more expensive than today—would be generally stable. With careful economic and energy management, that same 102-quad energy supply could potentially be compatible with the 3.1 percent growth rate of the high economic scenario. Looking at the risk, however, poor management or bad luck could mean that the 102-quad energy supply might be required to maintain a less efficient economy with a growth rate closer to the 2.0 percent of the low economic scenario.

These risks are heightened by the fact that economic conditions in the years ahead may not be stable. Rising expectations among third world countries, shrinking resources, political revolutions, unstable Middle East oil supplies, and a host of other kinds of disruptions all point toward continued world turbulence during the next two decades. Many problems that are manageable in stable times become unmanageable in crises. For example, Michigan's auto-based economy suffers excessively during recessions. Re-

FIGURE 1.1

The Energy Supply–Economic Growth Linkage



Depending on the success of our energy/economic management and the effects of uncontrollable circumstances, the relationship between energy supply and economic growth could take a variety of forms.

TABLE 1.3

Total Michigan Employment, 1990 and 2000

	1977	1990	2000	
Scenario I Jobs	3,782,000	4,697,000	5,499,000	
Effective annual growth rate:		1.6%	1.5%	
				Temporary cyclic high 5,520,000
Scenario II Jobs	3,782,000	4,586,000	5,032,000	
Effective annual growth rate:		1.5%	0.9%	Temporary cyclic low 4,936,000
				Temporary cyclic high 4,876,000
Scenario III Jobs	3,782,000	4,419,000	4,625,000	
Effective annual growth rate:		1.2%	0.5%	Temporary cyclic low 3,879,000

peated recessions like those in 1973–75 and 1980–81 could make it much harder for both Michigan and the nation to make necessary adjustments. The kind of social and political unrest which would be likely would lead to disruption of regional, national, and international economies. This would make low growth a more likely outcome. Capital markets would be likely to misbehave leading to tightened credit and skyrocketing interest rates. The overall effect would be reduced long-term investment and fading confidence by business and consumers. If the U.S. were on a major investment program of replacing energy inefficient capital equipment, or developing new (or more) energy production, such economic turbulence would make the transition more difficult.

During the next 20 years, a major source of economic turbulence and low economic growth is likely to be instability and uncertainty in energy supply. In fact, this may be a more serious problem than the absolute amounts of energy available. Energy based instabilities could be possible in any of the scenarios, however, they would be somewhat more likely to come out of the transition to a low energy future because of the greater political, social, and technological adjustments which would be required.

The Michigan Scenarios

The Michigan employment scenarios for the year 2000 which were discussed earlier (and summarized in Table 1.3) were derived from the national economic scenarios using a "shift-share" analysis technique which takes into account changes in both the national economy and the state's share of national economic activity. In addition, several critical assumptions underlie the Michigan employment projections:

- The level of national economic activity is assumed to dominate Michigan's job future.

- Sufficient energy in appropriate forms is assumed to be available to the state to meet the energy requirements generated by the medium and high national economic scenarios.
- Where energy shortages do occur, as in the low national supply scenario, they are assumed to be no worse for Michigan than for the nation as a whole. Their impacts would be passed to Michigan jobs through aggregate U.S. economic conditions.

If these assumptions hold true, then the medium employment projections can be thought of as the most probable outcome. Should they not hold true —for example, should serious local energy shortages occur on a continuing basis—then the dismal employment estimates of the low scenario would become the "more likely" case. Unfortunately, our analysis of supply and demand balances for Michigan in the year 2000 suggests a strong likelihood that the assumption of adequate energy supplies will not hold true. Serious shortages of some fuel types are very possible for the state. In fact, under strict business-as-usual assumptions, supply shortages or constraints would be a virtual certainty for petroleum and natural gas. Even relaxing the business-as-usual assumptions to allow for very extensive (and expensive) conservation and fuel substitution programs does not fully eliminate the vulnerability of Michigan jobs to shortages of petroleum.

The energy supply projections for Michigan in the year 2000 were "stepped down" from the national energy scenarios based on Michigan's historical fraction of U.S. energy and an assessment of other supply related factors such as the building plans of the state's major electrical utilities and the potential for increased use of solar energy. Overall state supply levels for the high, medium, and low projections are 4.8 quads, 3.8 quads, and 2.7 quads, respectively. The 1976 level was approximately 2.9 quads. In order to examine the potential for an imbalance between supply and demand, energy demand projections for the state were developed based on current demand patterns modified to account for future levels of economic activity, population growth, conservation improvements, and fuel substitution.

The Energy Outlook for Michigan

Our comparison of the supply and demand projections on a fuel-by-fuel basis suggests that simply producing as much energy as possible will not be an adequate strategy for reducing our energy risks, nor will a strategy based solely on conservation. A successful energy strategy for Michigan will require a carefully planned and robust mix of conservation, substitution, and new production.

Oil and Gasoline

Michigan is almost certain to suffer serious disruptions and shortages in oil and gasoline supplies before the year 2000, possibly as early as the mid-

1980s. This is exactly the area in which the state's major industries—automobiles, agriculture, and tourism—are most vulnerable. Rising costs and uncertainty of supply are likely to hit these industries, as well as commuters and trucking, extremely hard. Synthetic fuels are likely to have only a limited impact on these problems prior to 2000 due to long lead times and technological, economic, environmental, and political uncertainties.

New petroleum production and conservation efforts are both critically important. However, neither approach, alone or in combination, is likely to provide an adequate buffer against gasoline and oil problems. Substitution to other energy sources will be needed. And we must begin soon, because of the lead times needed for conversions and because shortages could develop quickly if a few negative events should occur together—for example, reduced production by OPEC and cold winters.

Natural Gas

During the 1980s Michigan is likely to remain in a good position with respect to natural gas supplies. It has an extensive capacity for storage and good pipeline connections and contracts.

There is considerable uncertainty at the present time, however, about supplies which will be available nationally in the mid-1990s. Michigan's situation (both supply and demand) needs to be monitored carefully in the years ahead to avoid either an over or under dependence on available supplies. The state will want to be prepared to quickly take advantage of opportunities provided by high supply levels, or to minimize the very serious disruptions caused by low supply levels. This means there is a need for contingency planning and background information about the costs and benefits of alternative options available to the many end-users of natural gas.

Coal

Supplies of coal are likely to be more than adequate to meet the state's needs for both direct burning and electrical generation. If our use of coal is constrained it will result not so much from limitations of supply but from potential problems of air quality, carbon dioxide buildup and waste disposal. The current lack of clarity over the extent to which these problems will constrain our use of coal adds considerable uncertainty to our energy planning problems.

Electricity

Michigan appears to have sufficient electrical generating capacity, in place or currently under construction, to support an early transition period to various alternatives. Even with the higher electrical demand coming from substitutions, it is quite likely that the reserve margins needed for a reliable electrical system through the year 2000 can be maintained with a more modest program of new construction than anticipated just a year or two ago. In the near term it would appear possible for the state to postpone final commitments for new electrical generating capacity until greater clarity is achieved about future demand levels and about the comparative risks and benefits of coal and nuclear-generated electricity.

Solar/Renewables

There appears to be considerably more potential for the use of solar and renewable forms of energy than is currently being tapped in Michigan. For example, substitution toward solar energy within the residential and commercial sectors could provide relatively independent sources of energy for part or all of their space and water heating needs. While the development of solar energy is still faced with many problems (e.g., initial costs, few qualified installers, sun rights, building codes, back-up energy sources, etc.), this approach would for many be a way of reducing vulnerability to rising prices and potential shortages in oil and natural gas. Other renewable energy sources such as wind, fuels from biomass, and hydroelectric may also prove increasingly attractive.

Developing these resources in an economically and energy efficient manner will require planning and incentives which go beyond business as usual. While solar/renewables will not substantially contribute to Michigan's energy needs during the next decade, now is the time to begin laying the groundwork needed for their widespread use during the 1990s and beyond.

Conservation

Energy conservation resulting from increased efficiency and reduced usage offers the fastest and least costly source of energy in the years ahead. In addition, once an investment in conservation has been made, the benefits continue to accrue with little or no additional expense. In contrast, an investment in the production and use of an equivalent amount of new energy is still vulnerable to the continued and rising costs of fuel, plus the risk of potential shortages and supply interruption.

If carried out in a cost-effective manner, conservation could have a positive overall effect on Michigan's economy and jobs. A number of recent studies have concluded that the risk to jobs from potential energy shortages is reduced by conservation efforts. By reducing fuel requirements we reduce the potential for interruptions and shortages and, at the same time, dollars otherwise required for the purchase of energy are made available for other purposes. This serves to increase jobs in the economy at large, since energy production tends to be less labor intensive than most other types of economic activity.

It is important to recognize that conservation means more than cutting back and doing without; it also means more efficiency and greater productivity. This source of "new" energy, more than any other, needs to be pursued aggressively by all of Michigan's citizens, governments and businesses.

Substitution

Electricity, solar and renewable energy technologies, and direct burning of coal are all potential substitutes for oil and gas. However, many of these substitution options will be technically difficult, uncertain, and costly, and they have relatively long lead times for full implementation. For example, both coal and nuclear-generated electricity will be subject to uncertain and potentially serious economic, safety, and environmental delays and constraints. Implementation of solar technologies could occur too slowly or prove too inefficient or unreliable. And neither coal, solar, or electricity would provide adequate near-term solutions for the state's transportation sector. These factors are likely to make the commitment of capital for substitution efforts more difficult to obtain and more risky.

In a period of high inflation, tight money supplies, and high interest rates —such as 1979–80—investors tend to want shorter-term payoffs from their investment decisions than are compatible with the long lead times of major technological systems. As a result, both consumers and producers may wait too long to make the large expenditures required for fuel substitutions. Their private effort to maximize short-term gains and maintain flexibility could make it more difficult for the state as a whole to adjust to worsening energy problems.

In order to increase the thermodynamic efficiency of our energy systems, substitution decisions and all future energy planning will require more care in matching available types of energy to their most efficient end-uses so that, wherever possible, high grade energy goes only to high grade uses while low temperature energy is put to its best use, such as heating buildings. A major policy issue over the next few years will be the extent to which substitution to high grade electricity is possible and desirable. While the economics of electrical conversion vary from case to case, it will be technically possible to convert many energy functions now filled by oil, natural gas, and coal to a reliance on electricity. For example, this could include aggressive substitution to electrical vehicles for transportation, heat pumps for space heating and cooling, resistance heating for industrial boilers and other process needs, and even district heating approaches in which the waste heat from electric power plants provides low-temperature heat for nearby residential, commercial, or industrial needs.

While many of the above changes may prove attractive, the uncertainties and risks of major substitutions to electricity are considerable. For example, plans for district heating could be quickly curtailed by high construction costs or by safety and environmentally based policy decisions requiring new nuclear and coal-fired power plants to be located in rural areas with low population densities and less serious air quality problems. Even more important, a heavy dependence on electric power increases the risks and impacts associated with potential shutdowns of nuclear plants for safety reasons or of coal plants for environmental reasons.

It must also be stressed that, for Michigan, there is only a limited mid-term potential for substituting electricity for oil. Oil accounts for less than 10 percent of electric power generation in Michigan (primarily for peak-load times). This is good in the sense that the oil crisis does not much affect electric generation in the state. On the other hand, while nuclear power can substitute for oil shortages on the East Coast of the U.S., it has little such benefit for Michigan. Michigan's oil shortages will affect transportation, which at present does not rely on electricity. While electric cars may be of major importance around the year 2000, during the next 20 years electricity is not likely to help most commuters, the trucking industry, agriculture, tourism, or the aggregate demand for new cars.

Production

Our emphasis on the importance of conservation should not be taken as an indication that continued extensive production will not be essential in the years ahead. For energy sources such as oil and natural gas, extensive new production efforts will be required just to maintain current supply levels. For other energy forms, such as solar and electricity, the increased demand which could result if extensive substitution occurs would require significant new investment in supply-related equipment.

Given the potential problems and costs of obtaining capital funds, especially should inflation and tight money markets continue for much of the 1980s, the ability of energy producers to expand capacity may be severely limited. There is a practical limit on the share of the nation's capital funds which can go to the energy sector. Politically controversial government intervention is already occurring and can be expected to continue. In the long-run it could become the case that many producers—who would normally gain from increased production—would come to seriously advocate and promote aggressive conservation as they begin to find it too risky or too costly to undertake large and uncertain construction programs.

To rely on the hope that "someone" will produce high energy supplies or to rely on an all-out push for maximum use of coal and nuclear energy are very risky strategies for Michigan. Should the high supplies not arrive on schedule, or should they be too unstable or expensive economically, technologically, or environmentally, the Michigan economy would be extremely vulnerable. We need to begin working toward a stable supply and demand balance at a level of demand at least as low as the medium (or most likely) supply projection. To the degree we can reduce demand even more, we will lower our vulnerability to the economic consequences of the all too likely low energy supply scenario.

Toward a State Energy Policy: Strategies and Issues

Achieving the stable supply and demand balance needed for the long-run protection of Michigan jobs will require the timely resolution of a wide range of energy policy strategies and issues. In resolving these strategies and issues it will be important to consider the total social costs of energy alternatives. Promoting those energy systems whose total social cost is the least means paying attention to not only the dollar outlay for fuels, but also the cost of all capital equipment needed for production and use, the cost of environmental cleanup and health losses, and finally the cost of lost employment and income. Unfortunately, the future social costs and the net benefits of many of our energy alternatives are extremely uncertain. Major uncertainties exist in aspects of all of the following issues:

- Future energy prices and the supplies of different energy sources available at those prices.
- The availability of capital, and the capital equipment costs for energy producers and users.
- The costs and effectiveness of future pollution control equipment for coal.
- The extent of future safety, cost, and political constraints on nuclear power.
- The capacity of solar and renewable technologies in Michigan in the mid and long term.
- The costs, effectiveness, and timing of conservation efforts.
- The ability of the auto industry to improve the fuel efficiency of its products.
- The overall health of the national and international economy.
- The extent and direction of new government policy initiatives affecting energy conservation, production, and substitution and environmental quality.
- The distribution of costs and benefits among different groups of energy producers and users.

In short, there are major uncertainties about the net benefits of *all* energy alternatives, seen in terms of cost, safety, and technical feasibility. If we guess wrong we risk expensive mistakes, not only in terms of investment dollars and health effects, but also in lost jobs and income. These are the risks of failing to deliver energy when needed, as well as the risk of major accidents and environmental impacts. Failures to deliver could result from repeated long-term labor unrest within the coal mining or transport industries, sporadic shutdowns or eventual phaseouts of nuclear power plants, failure of synfuels plants to produce on schedule, failure of solar electric power to be economical, unreliable solar or wind energy equipment from small suppliers, or a host of other contingencies. To be successful our energy strategies will have to go beyond the examination of planned benefits and costs to examine in detail the risks of failure—that is, the likelihood and consequences of not meeting the planned-for goals.

But what can go wrong in our energy strategies? What are the "downside risks" in departing from business as usual? Consider the risks of the following three alternative energy futures:

1. The risk of dithering around on energy problems and having very low production and large energy deficits.
2. The risk of going all out for very high production and not succeeding at it.
3. The risk of going all out for solar/renewables and not succeeding at it.

The risks of a low consensus, low energy production future. Consider what would happen if no real political and economic agreement on energy policy were to emerge in the 1980s among the various interest groups—if nuclear vs. coal vs. solar were not resolved, conservation gains were small, substitutes for oil and natural gas were slow in coming, and no major technological breakthroughs appear to save us. Then the U.S. would be in the worst of all worlds because the economy would still be geared up to use a great deal of energy at low prices, but could only get much smaller amounts at high prices. The balance of payment problems would worsen, and international monetary instability would threaten as the U.S. tried to import oil to cover the energy deficit. The domestic economy would be unstable. The international energy situation would be made even more politically unstable by many groups "snatching and grabbing" for scarce energy resources. In short, it would be a situation ripe for disaster.[1]

The risks of an all-out, high energy production future. Consider what could happen if the U.S. were to go all out for an energy solution dependent upon massive supplies of synfuels, nuclear power, additional coal, and new oil and gas fields. It too could yield economic instability. To achieve this solution, the U.S. would need to double its present energy supplies by the year 2000 and would be making unprecedentedly huge capital investments in all energy industries. This would seriously strain capital markets. Furthermore, the investments would be in new and uncertain technologies, or in new and uncertain high output levels. The energy sector would be pressing hard at the natural and technical limits of supply (not to mention limits of environmental tolerance). A major risk would emerge that one or more of these massive efforts would not deliver large enough amounts of energy on time. All systems would have to deliver, for the economy would be geared up to expect large amounts of energy. In terms of probabilities, we would be dependent on a level of energy output currently having only a 5 percent probability of achievement—a level that most energy forecasters no longer support. The odds are very high that some energy sources would fall short, and the U.S. would turn even more heavily to oil imports to make up the difference. That would be in the 1990s when international oil supplies are likely to be bleak at best and when economic development elsewhere would create more international demand for oil. Economic chaos would be likely, both domestically and internationally, with the same monetary and political disasters being possible as in the "low consensus" future but merely postponed. We would have caused our own downfall. In all such risky outcomes, Michigan's auto-based economy would probably suffer more than the rest of the U.S.

The risks of an all-out, solar and renewable energy future. In this case, the U.S. would seek massive amounts of solar heating for homes and offices, wind power, biomass conversion, geothermal technologies, and energy conservation. In order to get significant results by the 1990s, the U.S. would have to be committed to the technology on a massive scale, without a period of trial and experimentation. A great deal of coal would be burned, but nuclear energy might be phased down. Solar electric power would probably not be practical in time to make a significant contribution. Whole new industries would have to be created where only handicraft and small-scale production now exist. There would be serious quality control problems in terms of what buyers got for their money. Consumers and businessmen would have to be re-educated, then be induced to buy the equipment. The cost-effectiveness of the new technologies would be unclear to customers seeing them in competition with the already subsidized technologies of oil, gas, and electricity. Linkage to existing utilities for "backup" energy could be troublesome and capital investment costs could be very high.

In addition, this strategy would not work without much greater conservation efforts than government has so far been able to induce. Very strong government pressures would be mandatory. This would especially be true of gasoline conservation, since the solar/renewables solutions would have only limited effect on the demand for oil. A major push to smaller, fuel-efficient cars would be required. This could yield a short-term stimulus to Michigan auto production jobs—but with unclear long-term prospects.

In fact, this approach would not work without a mixed strategy of production of *all* fuels *and* conservation to cover the transition period needed for the changeover to solar/renewables. Failing this, slow economic growth would be likely, as would partial failures to come on line soon enough—both with negative effects on Michigan jobs. It would not be a risk of catastrophic failures—failures which might occur would most likely be localized. Rather, the risk is one of stagnation or of moving too quickly and not having time or resources to rectify the error.

A Less Risky Future

In general, none of the "pure strategy" scenarios (e.g., all-out production or all-out substitution to solar/renewables) carry much promise for minimizing risks to jobs in Michigan. This analysis does suggest, however, that while very extensive production and substitution efforts will be required in the years ahead, a strategy which relies heavily upon conservation, in addition to being cheaper and faster, might also hold less risk of failure. There are a number of reasons why this is so. The technology of conservation is, in many cases, relatively simple, inexpensive, and well known. While there may be some uncertainty as to how to best apply the technologies to a particular situation, failures tend to be partial rather than complete and are often easily remedied through modest changes. In the case of increased production and energy substitution, the investment costs and lead times can be considerably greater (as in the cases of synthetic fuels and nuclear power), there is often greater technical and economic uncertainty, and failures may be less graceful and less easily remedied.

One of the major consequences of failure is likely to be a loss of jobs and economic output. Minimizing this risk will require a transition period over the next decade during which all options are explored, new sources of energy are encouraged, and major efforts at conservation are undertaken. The transition should be away from oil and should include the careful monitoring of supply and demand balances for oil, natural gas, coal, electricity, synthetics, and solar/renewables forms of energy. The more conservation and efficiency gains we make, the less we will press on limited and uncertain energy supplies, and the less risky will be the economic and jobs situation. This is especially true for Michigan. The low consensus scenario should be a clear warning as to the dangers of paralysis from a standoff by opposed sides, or from simply postponing action. Overall, in the very long run, 20 to 40 years hence, the solar/renewables path may be less risky, but whether this is so must be actively studied as we gain experience with these technologies.

In the short term, whatever energy strategies we choose will have to be *robust* in their capacity to deal satisfactorily with the wide range of potential events and uncertainties to be faced in the turbulent years ahead. For, as suggested earlier, jobs in Michigan may be tied more to our capacity to maintain a stable and predictable energy supply than they are to the absolute level of supply.

Unfortunately, recognizing a good strategy may be difficult. We will be making hard technological and economic choices, largely in the political arena and based on uncertain knowledge. What will be good for one group in the state may well not be good for others, or for the state as a whole. Yet there will be a clamor of voices, all advocating their own best interests, and claiming to know what is best for society. This means that a successful strategy will have to cope with not just the physical, environmental, economic, and technological limits on energy policy, but also the constraints imposed by social and political factors. A successful energy strategy will require a political consensus on a number of major policy issues which need to be introduced onto the public agenda. Toward this end, many of the specific issues and options which need to be addressed in Michigan are presented below. It is not the goal of this study to resolve these issues. That task must fall to the citizens, businesses, and governments of Michigan in the years ahead.

Major Policy Issues

Policy Issue 1 – Oil and Gasoline: The Impending Shortage

Sixty-five percent of Michigan's use of petroleum products is for transportation. Most critically affected by price rises, shortages, and long-term gasoline deficits would be long-distance commuters, the trucking industry, and tourism. Almost as critical would be the problems of those businesses and industries that have major deliveries by truck and use vehicles a great deal – especially agriculture, wholesale and retail trade, construction and some manufacturing. In most of these cases there would be no near-term substitute for gasoline and diesel oil. Most could make major efficiency gains by using more fuel-efficient vehicles, but few would be able to curtail their level of use in the short run.

A number of options and policy issues need to be examined by both the public and private sector.

For trucking:

- Should additional de-regulation of trucking be encouraged, or at least an end put to the practice of not carrying cargo on return trips?
- Would a different speed limit for trucks be more fuel efficient, and would the gains be worth potential safety and economic tradeoffs?
- To what extent should long-distance hauling by rail be encouraged, e.g., "piggybacking" truck trailers on railroad cars, with trucking limited to short and medium hauls? Recent analyses suggest that deregulation of CONRAIL and other rail freight would substantially aid efficiency and costs (Duke and Williams, 1979). Should this be encouraged? What would be the investment implications for improvements in deteriorated railbeds and new equipment? And what would be the energy implications in terms of the costs of coal transported by rail?

For agriculture and construction:

- These sectors are highly dependent on petroleum but they use only a small share of the state's energy. Should special, high priority allocations be given to these sectors? This would not do great harm to others, but could set undesirable precedents. What changes in agricultural practices would reduce this sector's dependence on petroleum?

For the automobile sector and personal transport:

- It is feasible to produce 40 to 50 mile per gallon cars (like the VW Rabbit diesel) which would increase the fleet rate mileage well beyond the 1985 standards. New cars could go the same mileage on significantly less gasoline. With a massive changeover to such cars, this would postpone the gasoline crunch as much as a decade—giving time to evolve solutions. This would release petroleum from cars for trucking and agriculture. It would keep tourism alive because total driving would not have to be curtailed. Long-distance commuters who cannot ride-share would have more time to adjust.
- In the long term it is essential that Michigan officials and businessmen help pressure car makers to continue to produce even more fuel-efficient cars, not resist mileage standards, even though this will create short-term problems for the auto makers. Policies are needed which limit these problems to manageable proportions. However, many jobs are at stake and the long-term view must be dominant.
- It may be important to aid consumers to get rid of old gas-guzzler cars and buy new fuel-efficient cars. A tax credit to this effect would aid new car sales (and Michigan jobs) and improve overall fleet mileage. The need to stimulate new sales of fuel-efficient cars is real, because in an economic downturn people hold on to older cars instead of buying new ones, slowing the changeover. A tax on fuel-inefficient cars, both old and new, might help.
- If major improvements are made in batteries, electric cars may one day take the burden off gasoline for city driving. However, the effects of such a transition are not likely to be significant until around the year 2000—our problem will be serious much sooner. Too little is presently known about overall system feasibility, consumer acceptance, and the effects of electric cars on the electric utility sector. Research is needed in this area soon if the transition is to be well reasoned and energy efficient.
- Further research is needed on the merits of gasohol production in the state. If it is deemed desirable, the state will need to evaluate a number of options such as regulation and quality control, incentives, subsidies and direct investment.
- In spite of predictable political opposition, a 50¢ per gallon gasoline tax, rebated back to people via the income tax, is probably a good idea and necessary. In this way, consumers would be regularly confronted with the higher price at the pump; the money would stay within the U.S. instead of going to OPEC, and because the extra tax would eventually be rebated

to the consumer, there would be no net income loss. While there would be a short-term regressive effect on lower income groups, the higher prices are probably necessary to reduce demand, and a rebated tax is much less regressive than a non-rebated price increase, for example, via OPEC. This issue is currently being debated at the national level and the state will want to be prepared to deal with its impact.

- Tourism would be aided by fuel efficiency elsewhere. Beyond that, special gasoline allocations to tourist areas may be needed, along with special bus or train trips to tourist areas, and possibly new kinds of facilities providing more concentrated sites. Extensive research is needed here.
- Other long-term prospects are associated with getting people to live closer to work and to relocate back into cities from suburbs, which means making cities more attractive. Rising energy prices, shorter trips, and greater population concentration might eventually—by the year 2000—make mass transit more economically attractive than at present. Research is needed to see what improvements are technically and economically feasible.

For home heating oil and oil-fired electric plants:

- This issue is of less importance for Michigan than for many Eastern states. Nonetheless, homeowners currently heating with fuel oil may need help in converting to other sources such as natural gas, electric heat pumps, and solar/renewables.
- Electricity generation from fuel oil in Michigan is primarily limited to periods of peak demand. Federal law will eventually force most utilities away from oil. Alternative strategies for peak load management need to be seriously considered now so that experimentation and implementation can begin.

Policy Issue 2—Natural Gas: Monitoring the Risks and Opportunities

Natural gas presents a potentially serious long-run problem for Michigan which needs to be carefully monitored over the next decade. The state depends heavily on natural gas and, in the short run, its relatively low price and good supply may not provide market signals which adequately reflect the price and supply conditions to be planned for the next 20 years. There is great uncertainty in this area in terms of the effects of decontrol on new supplies and price levels, the speed and price with which synthetic gas will become available, and the extent to which the U.S. will want to, or be able to, commit itself to natural gas imports.

If the optimists prove correct, then major problems will be avoided or at least postponed for several decades (though prices are likely to be much higher regardless). On the other hand, if discovery rates do not increase significantly over the next decade (as predicted by the industry), if synthetic gas proves to have as long a lead time as the more pessimistic experts think, and if natural gas imports prove as risky and unstable as petroleum imports, then serious supply curtailments could occur in the 1990s.

Could Michigan manage to maintain its present good supply situation, using more than its share of the nation's natural gas while other areas are being hard hit? There is evidence on both sides. Thus far, the federal government has not tampered with supply contracts between distributors and natural gas suppliers. In the face of long-run national deficits, however, federal allocations or, more likely, conservation requirements analogous to those for petroleum are quite possible.

Thus, a primary problem for the state at this time is the uncertainty of natural gas supply rather than its absolute availability. If future supplies were known with more certainty, we would be in a position to plan long-term responses instead of resorting to crash programs as more evidence becomes available. To move aggressively away from natural gas, when supplies could in fact be more abundant than expected, would be inefficient and wasteful of a relatively clean-burning and convenient energy source. To err on the other side and be unprepared for shortages would result in serious hardship and lost jobs. Furthermore, the uncertainty in supplies and price levels contributes to the paradoxical situation in which major industrial users of natural gas may move to reduce their uncertainty by moving early to alternative fuels such as coal or to coal-based cogeneration systems. The subsequent reduction in demand for natural gas, if large enough, could mean that the remaining demand levels could be well below the limits of available supplies and that Michigan could lose a portion of its historical allocation to other states whose demand had increased.

To reduce these uncertainties and plan effectively, a number of steps are needed. Most important, independent and credible sources of information must be developed to evaluate and monitor future supply/demand balances for natural gas. Forecasts by the utility companies do not at this time fill this need, nor is there an adequate program within state government. An effective information and contingency planning program would need to research and resolve the following types of issues:

- Who can reduce consumption of natural gas most easily—either through substitution or conservation? This question needs to be examined in terms of technological options, capital requirements, job impacts, and political constraints. Careful analysis is needed to identify those industries without readily available substitutes for natural gas.
- Which industries are likely to move away from natural gas on their own, and to what extent?
- What sectors or subgroups should be given allocation priority? During temporary shortages in the past, home heating has been given priority over industry. However, some energy analysts have argued that industry

can make more productive use of gas and is in a better position to pay more for it (Ross and Williams, 1979). Furthermore, given 10 to 20 years to change over, homeowners could have a number of options.

- What sectors, if any, should be required, subsidized, or otherwise induced to convert from gas to other energy sources? Analysis is needed to determine the net benefits of such programs to the different sectors and to the state as a whole. Some energy analysts have argued that incentives for residential conservation and substitution, for example, could stimulate the economy while releasing energy needed for protecting industrial jobs.
- What possible substitutes and supplements for natural gas may need promotion in Michigan? Major candidates requiring research in terms of costs and limitations are:
  –low Btu coal gasification
  –methane from organic waste and other biomass fuels
  –use of wood in rural areas, especially in northern Michigan
  –electric heat pumps (for homes and businesses)
  –solar heating (for homes and businesses)
  –gas from Devonian shale

Policy Issue 3—Electricity: How Much Do We Want?

The cost of electricity is relatively high in comparison to other traditional sources of energy on a cost-per-Btu basis. And, as with all forms of energy, the rising costs of building new generating facilities will make electricity more expensive in the future. Fortunately, Michigan appears to have a relatively large electrical generating capacity (in place or under construction) at the present time. Even with increased demand resulting from business-as-usual levels of substitution, utilities in Michigan may need a considerably smaller building program over the next two decades than was anticipated just a few years ago.

- Electricity is both a costly and valuable energy option. As such, there are substantial risks and costs of having either too much or too little generating capacity. What had been a rather steady 7-percent growth in demand for electricity during the 1960s has dropped abruptly over the last few years and remains uncertain for the years ahead due to the effects of conservation and substitution. As in the case of natural gas, there is a critical need for independent and credible supply/demand forecasts and monitoring. Recent forecasts by the utility companies have been severely criticized both by consumer groups and the Michigan Public Service Commission and do not adequately fill this need.
- There is little doubt about the need for continued and perhaps increased reliance on electricity in the short and medium term. At a minimum, it will play a useful role in the long-run transition toward renewable energy sources.

- It is possible that Michigan may wish to rely more heavily on electricity than is implied by the transitional option. Electricity is a very "high grade" of energy which can substitute for many other energy forms and perform a wide range of functions. Its end-use convenience and versatility are clearly pluses. However, the costs and benefits of becoming locked in on an economy which is heavily dependent on electricity need to be carefully assessed against the alternatives which may be available over the next 20 years. For example, the conversion losses in the production of electricity (approximately two-thirds) can make it a relatively expensive and inefficient form of energy for many needs, especially since many major energy uses such as space heating and low temperature process heat do not require high grade energy.
- Based on the current economics and technologies of electric power generation, a strategy of heavy reliance on electricity downplays the downside risks of using coal and nuclear power. On the other hand, many of the alternatives such as synthetic fuels and solar/renewables also have risks—in particular, the downside risks of not being available as quickly or in the quantities desired.

Sources of Electric Power. Over the next 20 years, electric power generation will be dominated by nuclear and coal-fueled plants. Biomass-fueled plants and hydroelectric power will make small contributions and should be encouraged. Solar electric technologies are not expected to contribute significantly during this time period. A major policy issue for the state is the extent to which it should rely on coal versus nuclear power for electrical production.

- Coal and nuclear power both have significant though different benefits and risks. From a utility viewpoint, the cost picture a few years ago favored nuclear power, but the costs are shifting and becoming more unclear, and the extra costs of new plants now appear to differ little between the two. In light of the considerable uncertainties and risks around issues such as shutdowns, waste disposal, pollution, and accidents it would seem unwise for the state to allow the decision to be made on the basis of cost alone.
- The state needs to keep its options open by maintaining feasibility and contingency plans so that both coal and nuclear options will remain available as late as possible in the power plant siting and construction process.

Cogeneration of Electricity. Cogeneration can, under appropriate circumstances, provide substantial efficiency gains for industry (Williams, 1978). High temperature process heat is used twice: once for its original use and again for electrical generation. As the costs of process heat and electricity rise in the years ahead, cogeneration may become increasingly attractive to those large energy intensive industries having an appropriate mix of process heat and electricity requirements along with an opportunity to purchase backup electricity and sell excess electricity at reasonable rates. Given the potential efficiency gains from this approach, it will be to the long-run advantage of Michigan's citizens, utilities, and industries to ensure that cogeneration be given an opportunity to succeed wherever economically and technically feasible.

- Research is needed to identify potential applications for cogeneration and barriers to its implementation. One such barrier is air pollution, since many manufacturers are in heavily polluted areas where no new pollution sources (such as coal-fired boilers) may be added. If current testing and development activities continue to show positive results, the rapidly developing technology known as atmospheric fluidized bed combustion may provide an efficient, low pollution answer to this problem.
- The ability to finance cogeneration will require that rate structures fair to both the cogenerators and the electric utilities be in place for backup power and the purchase of electricity in excess of on-site needs. This is a complex issue involving factors such as equipment ownership, rate base definition, and the costs of alternative generating capacity. To the degree cogeneration proves feasible in practice, it will increase the efficiency of the state's electrical system and reduce the utilities' need to build and finance additional large, centralized power plants.

Policy Issue 4 — Solar/Renewables:
Laying the Groundwork for the Long-Term Transition

The term "solar/renewables" covers a wide range of energy sources, including for Michigan's purposes:

- solar space and water heating (solar electric may be a "don't-hold-your-breath" case, especially for Michigan)
- biomass fuels: wood, farm wastes, and other organic waste
- wind power

There is a problem in having this diverse area treated as a whole for policy purposes. Solutions appropriate to one energy type may not fit another. There is a further problem in lack of standardization and in the need of this type of power source to be applied very differently to various sites. It will be hard to have just one or two big corporations take on the task. Many aspects of solar/renewables will best lend themselves to small firms and local implementation. This is all well and good until we say that Michigan needs a big push to promote these alternative energy sources — decentralized action may be slow and very uneven.

- A technical, management, and policy issue for all of solar/renewables energy, for both public and private sectors, is how to get efficient large-scale use and, at the same time, still have appropriately decentralized use, well-fitted to local conditions. The farm and garden equipment industry or perhaps some parts of the construction industry may provide useful models to learn from.

Solar space and water heating are still at the "infant industry" stage. They may be important after 1990, but for this to be so the groundwork needs to be laid now. Issues that need public policy consideration are:

- Quality control over equipment and installation must be assured.
- "Sun rights" of users (problems with neighbors' shade) need to be legally protected.
- Solar advocates argue that to be competitive, they need to be subsidized like other energy forms. Additional subsidies or other incentives for buyers may need to be instituted to increase market penetration in the face of higher initial capital costs.
- Connection to utilities will be needed for backup systems, at prices which are fair to solar users, non-solar users, and the utility companies.
- Changes may be needed in building codes, zoning regulations, and supportive modifications and tax systems.
- Special aid to infant industries and to manufacturers and installers of solar/renewable equipment may be needed. The job creation issue is potentially important for Michigan given its large pool of skilled workers.
- It will be useful to set up and encourage demonstration projects throughout the state to show people what is and is not possible with solar heating, and to catch potential social, political and environmental problems early in the development and implementation process.

Biomass fuels seem to have three promising areas of application that may require financial and technical aid:

- wood and wood byproducts used for direct burning or production of alcohol
- urban wastes used for direct burning
- agricultural byproducts used for direct burning or for production of alcohol and methane

The list of issues is analogous to that for solar heating.

Wind power has considerable potential in the western part of Michigan especially, although there are technical, environmental, and economic problems which remain. The state may wish to encourage its development, both technically and financially. Applications could be promising both for rural areas and for neighborhood wind generators in small towns and suburbs. The list of issues is analogous to that for solar heating.

In general , while payoffs for the above areas of solar/renewables will be small until the late 1980s, the need and benefits will grow continually. The buildup of such a new industry in Michigan and the availability of enough consumer financing to buy its products should be a focus of public policy debate.

Policy Issue 5—Social Justice: A Necessary Condition for Viable Policy

It is important to see that all our energy options yield a higher cost of energy than we currently have. Michigan's policies must be based on assumptions of much higher energy prices and a recognition that there will be a minimum amount of energy everyone needs to live decently. This means that viable solutions to our energy problems will have to take into account issues of equity and social justice.

- People with fixed incomes or low incomes will be hurt worse than the rest of us and may need income supplements just to live decently.
- Certain industries and certain jobs need fixed amounts of energy and, once they have become efficient, can cut back no more. They will want protection from shortages or guaranteed access to energy.
- Some workers, such as traveling salespersons, construction workers, truckers, etc., must have access to gasoline in larger amounts than the rest of us if their role is to continue.
- Industries such as agriculture, tourism, trucking, and electric and gas utilities are today structured around patterns of cheap and easily available energy. Continued price increases or rapid cutbacks may threaten jobs. In the name of "fairness," they may ask for protection.
- Residents of certain regions with scattered, thinly settled areas such as northern Michigan will use more gasoline per capita merely to get around. They may ask for preference due to inherent need.
- Certain consumer groups, such as suburban commuters, drive very long distances between home and work and, given demands by the groups listed above, may also demand preferential treatment.

Unfortunately, if everyone's special demands were met, no reasonable policy could emerge. The problem is partly political and partly a matter of social justice, or common fairness.

These problems will all be exacerbated over the next decades by the slower growth rates expected for the economy, especially in jobs. This slower growth makes it harder to distribute more to the people who are the worst off (as with compensation for higher energy costs) without taking away from others. Past growth has allowed the U.S. to raise the level of living for poor people by redistributing a bigger pie, without substantially altering the relative standard of living of middle and upper classes.

Higher energy prices coupled with slow growth will leave some persons worse off. Social justice conflicts will intensify. Poor blacks and other minorities risk being excluded from a chance to enter mainstream American life because they haven't the political power to take the income away from the white middle and upper classes. The conflicts of 1967 serve as a reminder of the importance of dealing with this problem in Michigan.

Policy Issue 6 – Conservation and Equity:
Increasing Efficiency vs. Doing Without

In general, equity problems make it very hard to squeeze all households for energy conservation through higher prices. Not everyone can afford to conserve by investing in more energy-efficient appliances, structures, and equipment. Some families and businesses will simply not have the money, or the credit for loans. Poverty level households already spend over 20 percent of their disposable income on energy. In contrast, households with disposable incomes greater than $30,000 spend only 5 percent on energy (Brazzel and Hunter, 1979). Unless these equity issues are dealt with, conservation for the lowest income groups will mean the lifestyle *sacrifices* required for doing with less or going without, rather than the financial *investments* required for increasing efficiency. From an equity standpoint, it makes more sense to squeeze hardest those who can better afford it.

- An example of a bad policy would be one in which government imposed an equal energy cutback on all families: say 500 fewer gallons of gasoline per year, or 10,000 less cubic feet of natural gas. Such a policy would overlook the fact that equal cutbacks do not mean equal sacrifices. The poorest 20 percent of American families use about 15 percent of our energy; their sacrifices would be disproportionately large. The wealthiest 20 percent of families, on the other hand, use 30 to 35 percent of our energy.[8] From an equity standpoint, it would make sense to ask these wealthier families to cut back a larger proportion of their energy use. Poor people are now close to the discomfort/survival margin, and further cutbacks of the small amount they use would put them below the margin. This would be especially true for senior citizens.
- An effective, but unpopular policy alternative would raise energy prices across the board. Then people would perceive the scarcity of energy and cut back the overall amount of energy they use, partially through greater efficiency. The best way to do this may be to have an energy tax, with tax rebates, so that on an annual basis no one has less income. On a daily basis, energy would simply be more costly than other goods, and people would learn to use less of it. While such a program would place a larger burden on the poor prior to receiving their rebates, it would be more equitable than non-rebate plans and could be enhanced, for example, by an energy stamp program analogous to that for food.
- A bad policy from an equity viewpoint would be to let prices be raised without a rebate mechanism, say by energy producers. While price increases will be needed to encourage increased production, the poor would be badly hurt because the impact would be the same as a regressive tax. This was the situation in 1973 and 1974 when the impact of energy price increases was ten times greater for low-income households than for high-income households (King, 1976).

- Strategies to encourage energy conservation at the household-level must be precisely aimed at particular kinds of consumption that are wasteful and inefficient—such as third and fourth cars; big, gas-guzzler cars; poorly insulated homes; energy-wasteful practices, etc.
- Some forms of tax incentives for energy-saving appliances, home repairs,and insulation could turn out to be "welfare for the rich and middle class." The poor and especially the elderly may have no alternative but to continue to live in energy-inefficient homes. This situation could be reinforced by the fact that such tax incentives could reduce public revenues, possibly depressing needed energy welfare programs in the tight budget situation.
- It will probably be more effective and equitable to squeeze businesses and industrial firms for energy conservation harder than households. But just as the poor are at the margin and don't use much energy, neither do the little Mom-and-Pop stores, and the squeeze could hurt them badly. Therefore, it would make sense to push for the biggest conservation gains among the largest industrial and commercial energy users. This would mean careful energy audits for efficiency. It would also mean substituting capital for energy through investment in energy-saving equipment.
- Public policy debates that focus on jobs and energy linkages need to focus on the fact that, at the present time, expenditures for conservation may be a better way to protect Michigan jobs than expenditures for new energy production. This is because spending for energy production is a relatively small stimulator of new jobs, while spending for conservation and for almost anything else is a bigger job stimulator. Furthermore, the dollars spent on conservation are, on average, more likely to remain in the state and, thus, would have a larger multiplier effect on Michigan's economy. This is a social justice matter, since the poor and the minorities are so often the last to be hired and first to be laid off. It is also the case, however, that expenditures for conservation alone would not be an adequate strategy for protecting Michigan's jobs. An investment strategy based on a carefully planned mix of conservation, production, and substitution is required.

Policy Issue 7—Government Action: When and How Much?

Michigan is doing too little in the energy area today. Part of the problem is political; until there is enough voter and consumer sentiment for change, energy issues will remain a low priority for most politicans. Action, however, can be postponed only so long. Extraordinary leadership is called for and, short of this, politically aware citizens must insist that public officials begin resolving these long-term energy issues in which government has a necessary role.

We can certainly begin with conservation efforts as the lowest cost option right now. This would fit with emerging federal government policy as well. There are good reasons not to wait:

- The longer it takes to make conservation gains, the shorter will be the lead time before serious energy problems occur. We need to change over to a more efficient capital equipment pattern for the whole state — among households, commerce, industry, and transportation. Failure to do this will cost jobs.
- There is a paradox here. While it is true that postponing our decisions for a longer time would increase the likelihood of their being correct (because of better information and reduced uncertainty), it is also true that postponing would make it less likely that any decision could be effectively implemented in time, correct or not.
- The bigger the "signal" it takes to rouse the public over energy problems, the longer action will be delayed and the less likely is effective implementation. Indifference to energy issues on the part of Michigan's politicians, businesses, or citizens will cost jobs.
- Major conservation efforts will not interfere with other energy production efforts whether they be in the area of synfuels, coal-fired electric plants, nuclear plants, solar home heating, wind power, or biomass conversion. Some of these alternatives will take time to resolve. Their resolution may be a little less pressing with effective conservation.

How much state action is warranted, given that Michigan is committed to a "free-market" solution to most of its energy problems? In general, the problem of state intervention is that markets are efficient for some problems but not others. For example, market behavior via prices tends to be focused on short-term changes and may not adequately reflect long-term conditions. As a result, the market will not be giving strong enough signals to induce those needed actions which have long lead times. Furthermore, when times are hard and interest rates are high, most businesses and consumers discount the future heavily; their time horizon gets shorter. People need more and better information on their long-term options and, in some cases, incentives for action. A "market-plus" strategy is called for, in which market signals are augmented by the public sector actions which reflect, a longer-term viewpoint on energy problems.

It is important, however, to avoid heavy-handed government controls that may not be very effective. The dilemma is that it may take crises to force action on issues. But, at the same time, crises often call forth strong government controls that lead to inept overcontrol or to waste. The more the state can intelligently anticipate the crises and get ready for them, the better off we will all be. The policy issues listed below, all point to a need for government response. Within the limits suggested above, the state of Michigan needs to consider aiding the market in, at least, the following ways:

- Tax laws can be modified to give greater incentive for investment in energy conservation and certain fuel substitutions in all sectors of the economy. These transitions might also be speeded up by insuring better access to loans, especially for unconventional energy systems such as solar technologies which may be judged as too risky under traditional loan evaluation criteria.
- There must be a bigger push to winterize and insulate all homes. One concept that should be investigated is the Portland Plan, which puts limits on the resale of homes until they have been insulated and winterized up to code. Such a program, as recently proposed for Ann Arbor, for example, is likely to be both effective and controversial.
- Conservation has only a weak and marginal constituency in Lansing compared to other major energy sources such as oil, natural gas, and electricity. The state needs to set up an aggressive energy conservation program within the executive branch, linked to legislative committees with the same focus, and they should be empowered to reach out into the state to build a conservation-oriented constituency.
- By providing better information through an upgraded energy extension service (which both gives out information and collects feedback on successes and failures within Michigan and neighboring states), the risks of investment in new energy systems, such as solar, could be reduced. Consumers and businesses could be helped to find out what equipment to buy to conserve energy, what designs have been most cost effective, and which contractors have not performed according to expected standards.
- The state of Michigan needs to do more to aid local communities to get ready for additional increases in the cost of energy and for unpredictable energy shortages. Serious efforts at local energy planning are needed, yet communities lack all the essentials: money, manpower, and expertise. And in the short run, the state government has its own money problems. It will be essential, although controversial, to put priorities in this area. Federal programs now under consideration in Congress would provide additional funds to state and local units for these purposes. The state would do well to lobby for these programs.
- Economic diversification of the Michigan economy is an old issue in the state. But now the threat to jobs from energy costs and instabilities brings this issue back again. It needs to be seriously addressed because the Michigan economy is too vulnerable to energy-related employment problems—both in the auto industry and other manufacturing. New initiatives are needed to insure that Michigan will be as competitive as other states in attracting jobs by the year 2000. One such initiative would encourage new energy-related industries in the state which would use Michigan's capabilities for mass-production to make equipment such as solar heaters and panels, wind-powered generators, heat pumps, conservation equip-

ment, etc. State action to encourage such development might be worthwhile in terms of both energy and diversification goals.

Policy Issue 8 — Coping with Uncertainty:
Strategies for Reducing the Risks

What makes these long-term energy policy issues especially troublesome for Michigan is their great uncertainty. But, as noted above, we cannot afford to wait for the situation to become clear on its own. Where risks or uncertainties are low we need to act now, and where they are high we need to indicate the research and monitoring programs needed to provide a sounder basis for decision making. The state government should be doing a number of things about uncertainty:

- Avoid being "locked-in" on expensive-but-risky energy paths until some uncertainties are resolved.
- Proceed with the one strategy that yields clear-cut gains, both now and in the future: energy conservation.
- Prepare the groundwork for future decisions by taking action to reduce uncertainties:
  - Get clarification on what the consumers/voters of Michigan want in terms of their values, by (1) researching the acceptability of various energy options, such as heat pumps, solar heating, electric cars, coal vs. nuclear power, etc.; and (2) encouraging serious and well-informed public debate on the benefits, costs, and risks of alternative energy options.
  - Set up demonstration projects (perhaps in cooperation with the private sector or with nearby states) for alternative energy forms, and do careful analysis of the potential and implications for large-scale dissemination.
  - Do more to educate the Michigan population on how to conserve energy, and to think in terms of the long-term energy costs of purchases.
  - Set up policy analyses of alternative energy options as they affect the state, in terms of social and economic impacts on various groups in Michigan due to legal changes, lifestyle and business practice changes, tax issues, financial issues, etc.

Michigan cannot look to Washington to save the state from economic instability or to be sensitive to Michigan's unique needs or goals in policy areas or appropriate technologies. Michigan has to have a well-funded and centralized focus for energy analysis, planning, and information dissemination within the state government structure. The present Energy Administration within the Michigan Department of Commerce may provide a useful base from which to build. However, when measured against the efforts of other major states and the needs of the task, Michigan is seriously inadequate in terms of budget and scope of activity. The state must make the investment required to enable it to do more than just "fire fight" and react to circumstances as they are imposed on the state. Business as usual simply will no longer do. Michigan must take its own new initiatives in the energy area, or risk paying dearly in terms of the personal hardships which will flow from energy instability, lost jobs, and reduced economic growth.

Notes

1. Extremely sobering scenarios of this type have been described fictionally in Paul Erdman's *The Crash of '79* and more analytically in *Business Week's* "The Petro-Crash of the '80's," November 19, 1979.

2. Figures are adapted from national statistics given in a report by the Energy Policy Project of the Ford Foundation, *A Time to Choose*, (Ballinger, 1974, pp. 127–128).

2

Jobs And Energy In Michigan: The Current Picture

How Energy Is Used in Michigan

Michigan, despite being a heavily industrialized state, uses less energy per capita than the national average. In 1976, the 9.1 million citizens of Michigan made up 4.3 percent of the population of the United States and consumed only 3.8 percent of total U.S. energy consumption. This fact is both surprising and somewhat reassuring. Unfortunately, as with so many statistics, it is also somewhat deceptive. The data show that Michigan is both the seventh most populous state and the seventh largest user of energy. In 1976, the state consumed 2.9 quadrillion Btu's of energy, or the equivalent of 1.4 million barrels of oil per day (Gustaferro, Maher, and Wing, 1977). This is roughly the same amount used by the Netherlands and 1.5 times the amount used by Sweden (Darmstadter, Dunkerley, and Alterman, 1977). Clearly, we are an energy dependent state. Not just because we use vast amounts of energy, but, equally important, because we import almost 90 percent of our energy from outside the state.[1]

It can also be deceptive to talk strictly in terms of total energy supply. Of critical importance, and often left out of energy analyses, are the types of energy available and the types of uses for which they are required or most efficient. As argued in Chapter 5, this will be a crucial issue for Michigan in the 1990s. For now, a few examples may help to illustrate the general importance of this point for energy planning.

Some end uses are more easily and efficiently accomplished with one form of energy rather than another. For example, electricity is unsurpassed as a source of energy for lighting, machinery, and thousands of small appliances.

WHAT IS ONE QUAD OF ENERGY?

1Q = 10^{15} (1 quadrillion) Btu's of energy
1Q = 180 million barrels of oil or 42 million tons of coal
1Q = heat for 5 million homes for a year
1Q = 8 billion gallons of gasoline
1Q = power for the cars of 12 million average drivers for one year
1Q = the amount of the U.S. oil shortage which triggered the 1973 oil "crisis"
1Btu = the energy in one match stick

On the other hand, an abundance of electrical capacity is of little value during a short-term gasoline and oil shortage, or if a highly concentrated mobile source of energy is required, as in the case of airplane jet fuel.

Technological change required to convert equipment to alternative energy sources is easier for some forms of energy than for others. For example, oil-fueled furnaces are easily converted to natural gas (or methane), but it is very expensive, if not impossible, to convert them to the burning of coal. This is one reason that the use of coal is well below the levels set in the Federal government's Project Independence Blueprint of 1973–74, and even below the levels set more recently by the Carter administration's National Energy Plan. The failures have not been a lack of supply, as one might expect in an "energy crisis," but rather a lack of demand.

Ultimate supply, stability of supply, and price of alternative fuels can be expected to vary over the years ahead, both nationally and within regions. For different end uses some of these factors will be more important than others. For example, a residential consumer may be willing to pay a higher price for a heating source which can be conveniently and reliably supplied. A small business may be willing to trade a few days of interrupted supply for a lower annual energy bill. And a large, energy intensive industry may have the combination of economic incentive, expertise, and available capita in-

Figure 2.1 shows the different types of primary fuels used in Michigan and in the U.S. during 1976. Although Michigan used more petroleum than any other energy source, the state's energy mix was tipped more toward the use of natural gas and coal when compared to the country as a whole. In the short-run, this is a good position for the state; petroleum is probably the

ENERGY CONTENT OF A GALLON OF GASOLINE

1 gallon of gasoline equals approximately 125,000 Btu's of energy and has the same usable energy content as:

10 pounds of coal
15 pounds of firewood
60 fifths of 100 proof whiskey
72 pounds of sugar
100 pounds of ground beef

1 tub of hot water (approximately 30 gallons), heated from 68°F to 95°F (20°C to 35°C) requires about 6000 Btu's, or 26 tubs to a gallon of gasoline.

1 aluminum beer can requires about 68000 Btu's of total energy or, 3½ six packs to a gallon of gasoline. This is just for the can, the beer itself requires far less.

Adapted from Schipper (1976a).

most vulnerable fuel source in terms of limits and disruptions to supply and potential price rises. In contrast, Michigan has a much better than average storage capacity for natural gas. Similarly, coal is an abundant resource in terms of long-run supply. As noted in detail elsewhere, however, coal is not without its problems with respect to environmental effects, transportation limitations, and conversion costs.

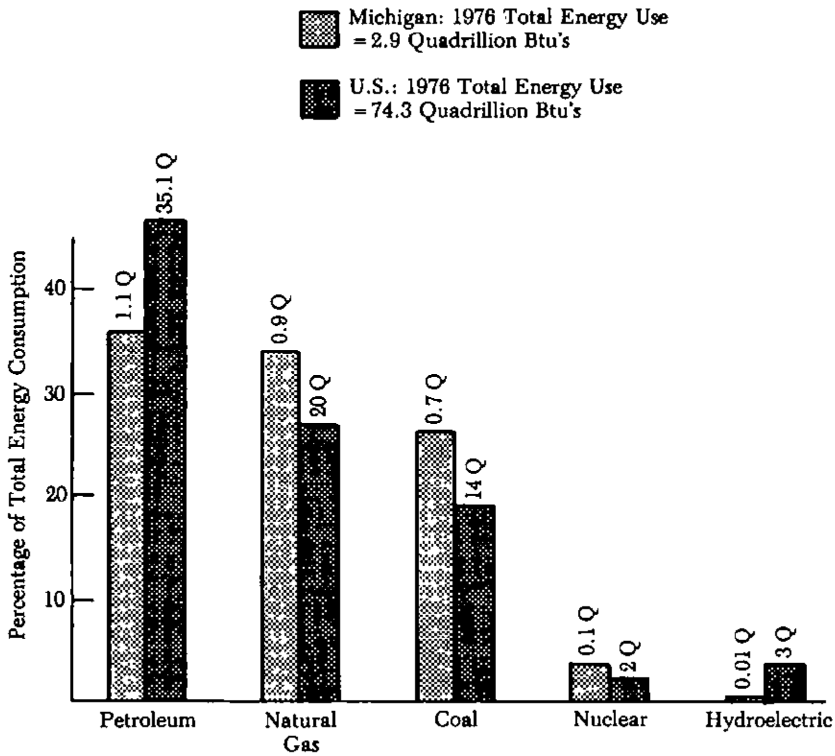
At the present time, over 70 percent of the coal used in Michigan is for the generation of electricity. In 1976, 505 trillion Btu's (over 21 million short tons) of coal were used to generate 167 trillion Btu's (49 billion kilowatt-hours) of electricity.[2]

Electricity is also produced in Michigan from nuclear power, petroleum, natural gas, and hydropower. In contrast to the 70 percent figure for coal, however, only 8 percent of the state's petroleum consumption and 5 percent of its natural gas were devoted to electrical generation in 1976. Figure 2.2 shows the proportion contributed by each fuel to the 250 trillion Btu's of electricity generated in Michigan in 1976 and the equivalent percentage for the U.S. as a whole.

Still another way of providing perspective on the way energy is used in Michigan is the energy flow diagram of Figure 2.3. This is a convenient way of showing patterns of energy consumption, and it is actually somewhat less complex and confusing then it first appears. Starting on the left side of the

FIGURE 2.1

Primary Energy Sources for Michigan and the U.S.

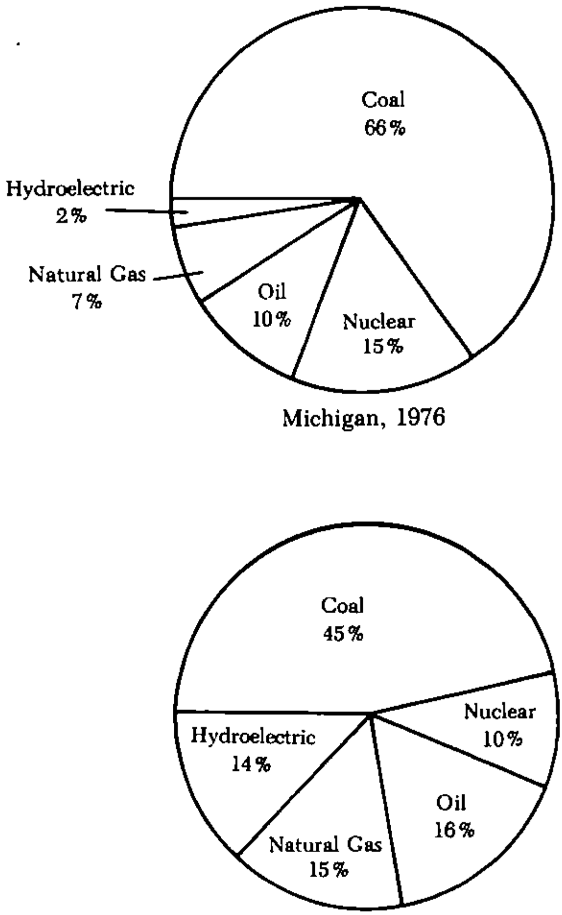


SOURCE: Duane, 1979.

In terms of primary energy sources, Michigan relies more on natural gas and coal and less on petroleum than does the rest of the U.S. In the short run, this is a good position for the state.

FIGURE 2.2

Primary Energy Sources Used for the Production of Electricity in Michigan and the U.S., 1976

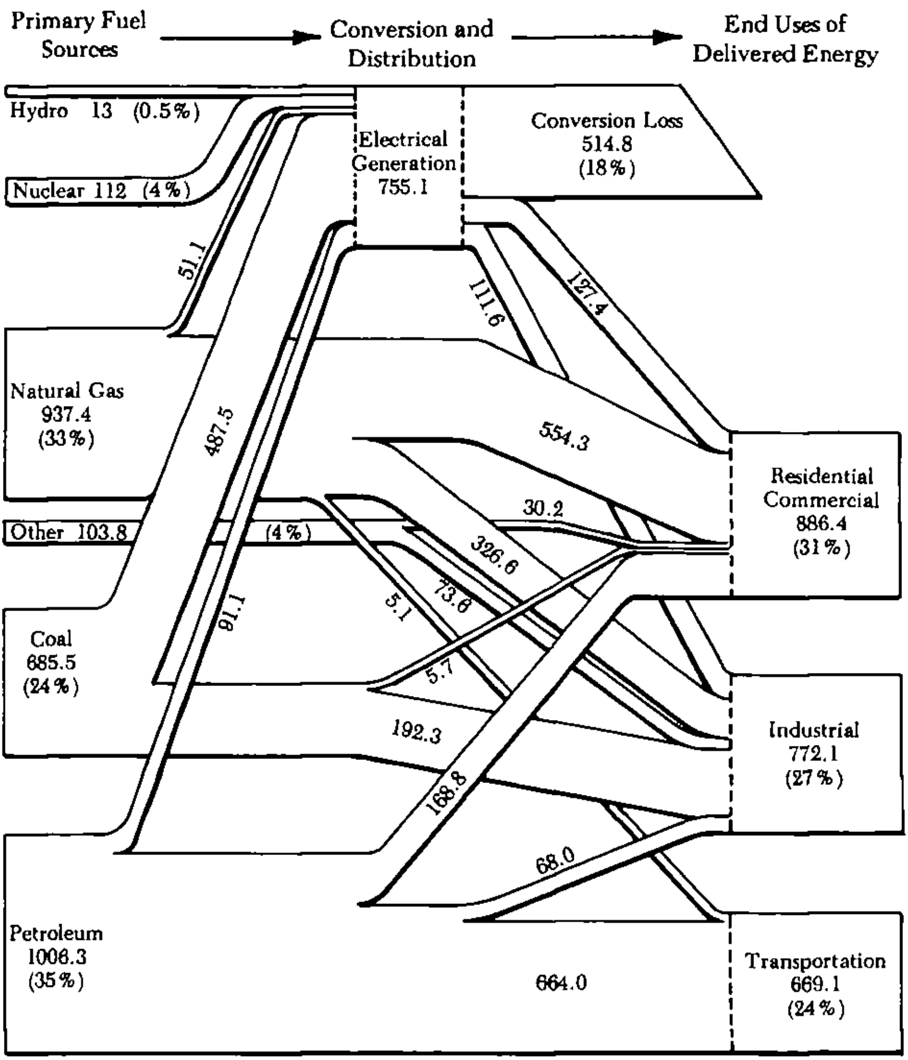


SOURCE: MERRA (1977, p. 67).

In 1976, Michigan used 762 trillion Btu's of primary energy to generate 250 trillion Btu's of electricity.

FIGURE 2.3

Michigan Energy Flows, 1976*
(Units: Trillion, or 10^{12} Btu's)



SOURCE: Michigan Statistical Abstracts (1978).

* A slight imbalance in the figures is due to rounding errors. Some numbers are slightly different from the more recent MEA data used elsewhere.

diagram, energy flows in Michigan begin with the input of primary fuels such as coal, natural gas, and uranium. As noted earlier, a portion of these primary fuels goes for the production of electricity (top center of the diagram). This electricity and the remaining primary fuels are then used by the final energy consumers — the residential/commercial sector (31 percent), the industrial sector (27 percent), and the transportation sector (24 percent), as seen on the far right.[3]

Note from Figure 2.3 that about 18 percent of Michigan's total energy consumption is lost in the conversion of primary fuels such as coal to electrical energy. In general, each Btu of electricity generated requires the input of approximately three Btu's of a primary fuel. This is an efficiency of approximately 33 percent.[4] In most cases, about two-thirds of the primary fuel energy is converted to waste heat and only one-third is converted to electrical energy. The efficiency of this process can be improved through cogeneration, which makes better use of the waste heat, for example, by providing space heating for homes and factories or by providing heat for a variety of production processes. This is currently being done at the Detroit Edison River Rouge Plant and is planned for the Consumers Power Midland Plants and a number of large industrial complexes.

The relative efficiencies of conversion processes and end uses are very important in terms of planning for future energy mixes and conservation strategies. This is illustrated by Table 2.1, which compares overall efficiencies of space heating by conventional gas and oil, synthetic gas and oil, and electricity. The overall efficiency of an end use (e.g., residential space heating) is calculated by multiplying the efficiencies associated with each step in the energy delivery system.

Different forms of energy can have quite different efficiencies for the same function. For example, a natural gas furnace in a typical home has an efficiency of about .6, and the process of getting the gas from the ground to the furnace is relatively efficient (.88), yielding a total efficiency of .52. Electric resistance heating, on the other hand, is very efficient once the electricity arrives in the home, but the overall process of generating the electricity has an efficiency on the order of .28. As a result, the overall efficiency of gas heating is almost twice as great as the electrical resistance heating.

As analyzed in detail in Chapter 5, Michigan's current energy mix can and will change over the years ahead as a result of changes in relative prices, availability, efficiency, and end uses of alternative forms of energy. In some cases, such changes will be easy. In other instances, technical, social, environmental, and economic constraints may require more time and higher cost for the needed transition. In any case, a major factor in determining the long-run vulnerability of Michigan jobs will be the wisdom with which Michigan's government, industries, and citizens plan for changes in the state's energy mix.

TABLE 2.1

Comparison of Space Heating Efficiencies

Energy Source	Primary and Final Processing	Transmission	Electric Distribution	Electric Power Generation	Efficiency as Delivered to User[c]	Home Heating Efficiency[d]	Total
Gas							
Natural	.91	.96	—	—	.87	.6	.52
Synthetic	.55[a]	.96	—	—	.53	.6	.32
Oil							
Conventional	.86	.99	—	—	.85	.46	.39
Synthetic	.60[b]	.99	—	—	.59	.46	.27
Coal	.98	.99	—	—	.97	—	—
Electric	—	.934	.91	.325	.29	1.0[e] .85–3.0[f]	.28 .23–.83

[a] Taken from Schipper (1976b, p. 496) as average for three available gasification processes, then adjusted for final processing efficiency as in MERRA (1977, p. 27).
[b] Calculated in same manner and from same sources as in a.
[c] These figures based on MERRA (1975) compare closely with figures given by Schipper (1976).
[d] End use efficiencies taken from American Physical Society (1975) and MERRA (1977).
[e] Resistance heating.
[f] The coefficient of performance (COP) for a heat pump can be as high as 3 for outdoor temperatures of 45°F. When temperatures drop below 30°F, the COP can drop to below one as the heat pump operates like an electric-resistance heated air furnace.

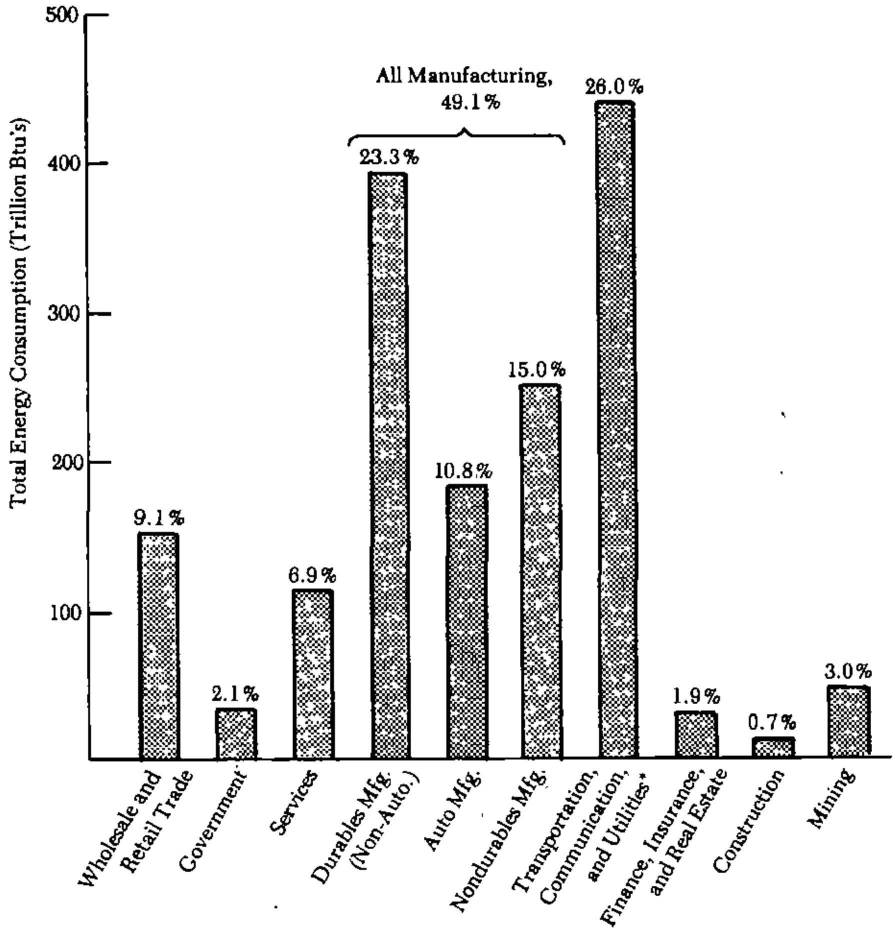
Energy Use by Sector

As discussed earlier, some forms of energy can be used more efficiently and with fewer environmental problems than others. Similarly, there are significant differences with respect to the costs and availability of alternative forms of energy. As a result, Michigan's energy mix—that is, the amount of different energy types used in the economy—becomes important to the vulnerability of Michigan jobs. (This is discussed in detail in later chapters.) Figures 2.4 and 2.5 give a more detailed perspective on Michigan's *current* energy mix in terms of the total amounts and types of energy consumed by ten major sectors of the state's economy.

As Figure 2.4 shows, there are considerable differences in the amounts of energy consumed by each of the sectors. Furthermore, as Figure 2.5 shows, the types of energy used within the various sectors are also quite different. For example, the transportation and agricultural sectors are highly dependent on petroleum products such as gasoline and diesel fuel. Manufacturing sectors, on the other hand, are primarily dependent on coal and natural gas. Almost all sectors are dependent on electricity for certain critical functions,

FIGURE 2.4

Total Nonresidential Energy Consumption in Michigan, 1976



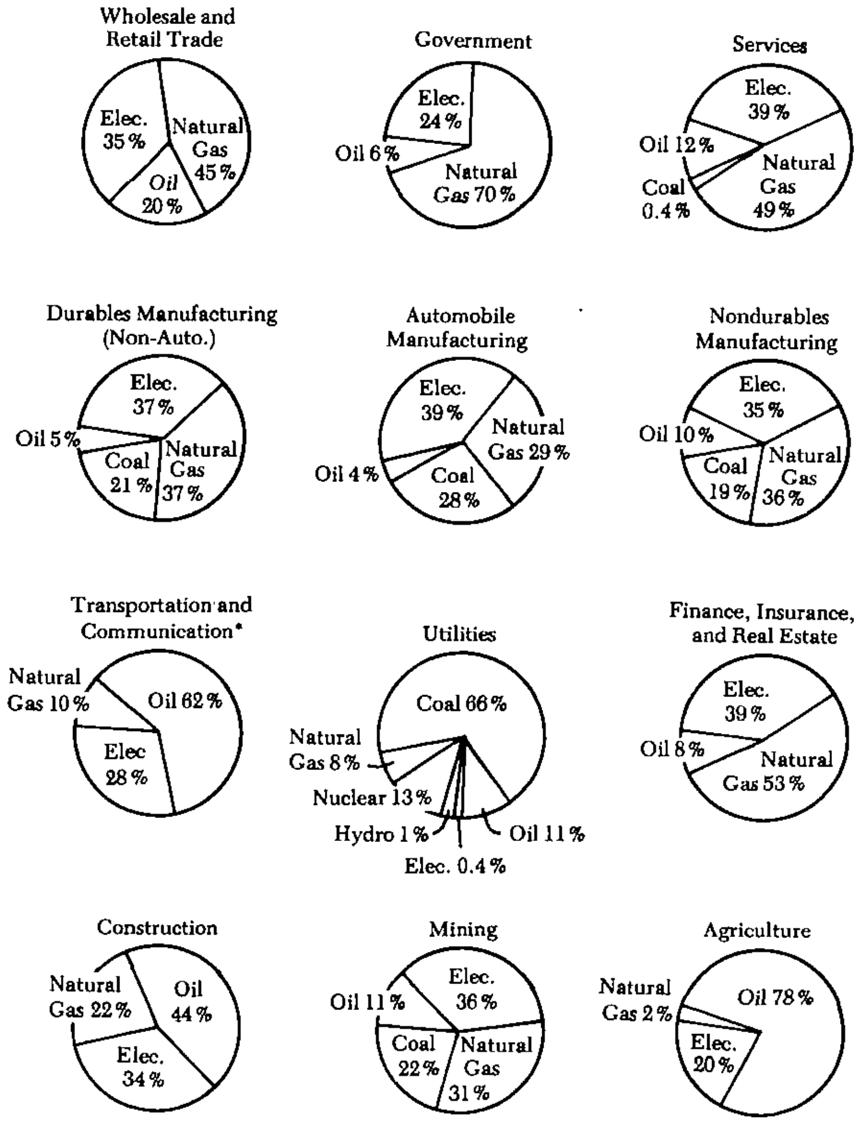
SOURCE: Michigan Energy Administration.

* Includes use of energy by electric utilities for electrical generation. Individual sectors include electrical consumption in terms of primary fuel equivalents.

Major sectors of the Michigan economy use considerably different amounts of energy. While all sectors require energy, some are more dependent than others on delivery of large amounts of dependable energy.

FIGURE 2.5

Fuel Type Use by Sector in Michigan, 1976



SOURCE: Michigan Energy Administration.

* Transportation and communication tend to involve a different mix of fuel types. Unfortunately, current data sources combine these two sectors based on other similarities.

Different sectors of the Michigan economy depend on considerably different energy mixes. As a result, shortages in particular fuel types can have disproportionate impacts in some sectors.

and the electric utilities are highly dependent on coal. As a result, shortages in specific fuel types could have significantly greater impacts in some sectors than in others.

To explore this issue we first examine the relative importance of the different sectors in terms of the contribution they make to the overall output of the Michigan economy and the jobs they provide to Michigan workers. This perspective—on energy, output, and jobs—will then provide a basis for exploring the potential relationships between jobs and energy in Michigan's future.

The Nature of Michigan's Economic Output

Michigan makes a major contribution to the output of our national economy. In fact, Michigan is the leading producer of consumer durables in the nation and is the second largest exporter of goods among the states (California is number one; Kreinen, 1977). In addition, the state's automobile and non-electrical machinery manufacturing industries are heavily involved in foreign trade (Ferris, 1979). Since 1958, Michigan's annual gross state product has been between 4.1 to 4.7 percent of U.S. gross national product (Edens, 1977).

Figure 2.6 shows the state's economic activity categorized into ten principal sectors. Notice that the combined output of the automobile and "other"- durables subsectors comprises the dominant share of total output, amounting to over 65 billion dollars in 1976. While other sectors make substantial contributions to the state's economy, none come close to that of the durables sector. When those businesses directly or indirectly dependent upon the durables sector (e.g., chemical products, textile products, warehousing) are considered, the dominance of the durables sector is even more evident.

All of these features combine to make Michigan's economic sectors particularly interdependent and open—perhaps, more so than for nearly all other states. Michigan's continuing economic health rests in large measure upon the strength of demand for durables goods in U.S. and foreign markets. In addition, much of the economic activity in the state's non-durables sectors depends upon success in durables—either through demands for intermediate goods or through the income generated for its workers. In consequence, the state's economy and jobs are uniquely vulnerable to a wide range of events and policies from the local to international level.

Current Patterns of Employment in Michigan

Jobs as well as economic output in Michigan are heavily tied to the production of automobiles and other durables manufacturing. Figure 2.7 shows the overall job mix of the Michigan economy in terms of the distribution of jobs across ten sectors. Motor vehicles and other durables provided over 25 percent of Michigan's jobs in 1976—a figure which would be substantially enlarged if jobs in "dependent" sectors were added. In 1976, roughly one in every nine jobs in Michigan was in the motor vehicles and equipment sector. For the U.S., that figure was one in 90 (Verway, 1977). This difference in job mix between Michigan and the nation is a key factor in the vulnerability of Michigan jobs to energy-related supply and economic problems.

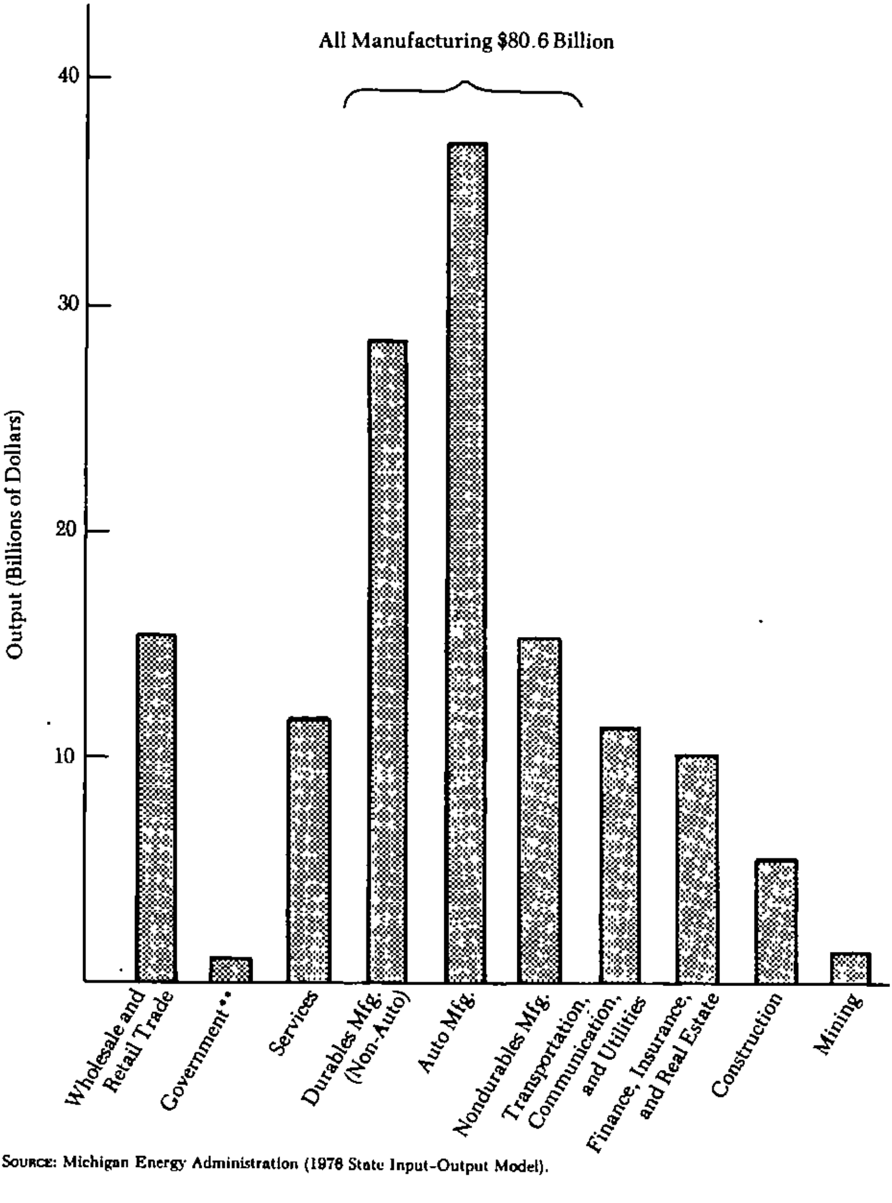
In times of recession, the automobile sector has historically been an unfortunate leader in terms of lost jobs and output. This point is demonstrated vividly in Figure 2.8 which shows employment in key sectors of the state's economy from 1965 through 1977. Employment in durables manufacturing (including automobiles) has been subject to much greater fluctuations than any other type of employment. This hypersensitivity of the durables sector (which is discussed in detail in the next section) results in large part from the postponable nature of expenditures for durable goods (Eden's, 1977).

An additional pattern discernible in Figure 2.8 is that employment in manufacturing (both durables and nondurables) has, on average, remained level during this period. In contrast, employment in government, services, and the private nonmanufacturing sectors has grown almost continuously. All of these trends are generally consistent with patterns in the U.S. economy. However, Michigan has been burdened with a below average rate of economic growth in many of its key industries during the past decade. As shown by Table 2.2, for the period 1970–78, Michigan increased its share of workers (by percentage comparison to the U.S.) in manufacturing and services, while decreasing its share in *all* other sectors. Overall, this led to a decrease in Michigan's share of all U.S. jobs (Verway, 1978a).

Some other employment characteristics of the state are also worth noting. For instance, as shown in Figure 2.9, Michigan can be considered a high wage state. In 1976, the weekly earnings of manufacturing production workers in Michigan were 40 percent higher than the average earnings of their counterparts in the rest of the nation. This is largely the result of the high percentage of union jobs in Michigan as compared to other states. Workers' compensation costs in Michigan are also comparatively high. As a result, Michigan is vulnerable to a loss of jobs to other states (primarily Sun Belt states) which offer businesses lower wage rates and less union activity. For example, some firms which supply the auto industry have chosen not to compete for labor or pay as high wages and instead have located outside Michigan. Furthermore, businesses in Michigan tend to rely more on overtime and less on hiring of additional workers. In this way, they minimize the nonwage costs of labor such as fringe benefits and unemployment insurance (Verway, 1978b). As a result of these factors, Michigan's long-term job openings and labor force are growing more slowly than the U.S. average (see Table 2.2).

FIGURE 2.6

Michigan Economic Output by Sector, 1976*



SOURCE: Michigan Energy Administration (1976 State Input-Output Model).

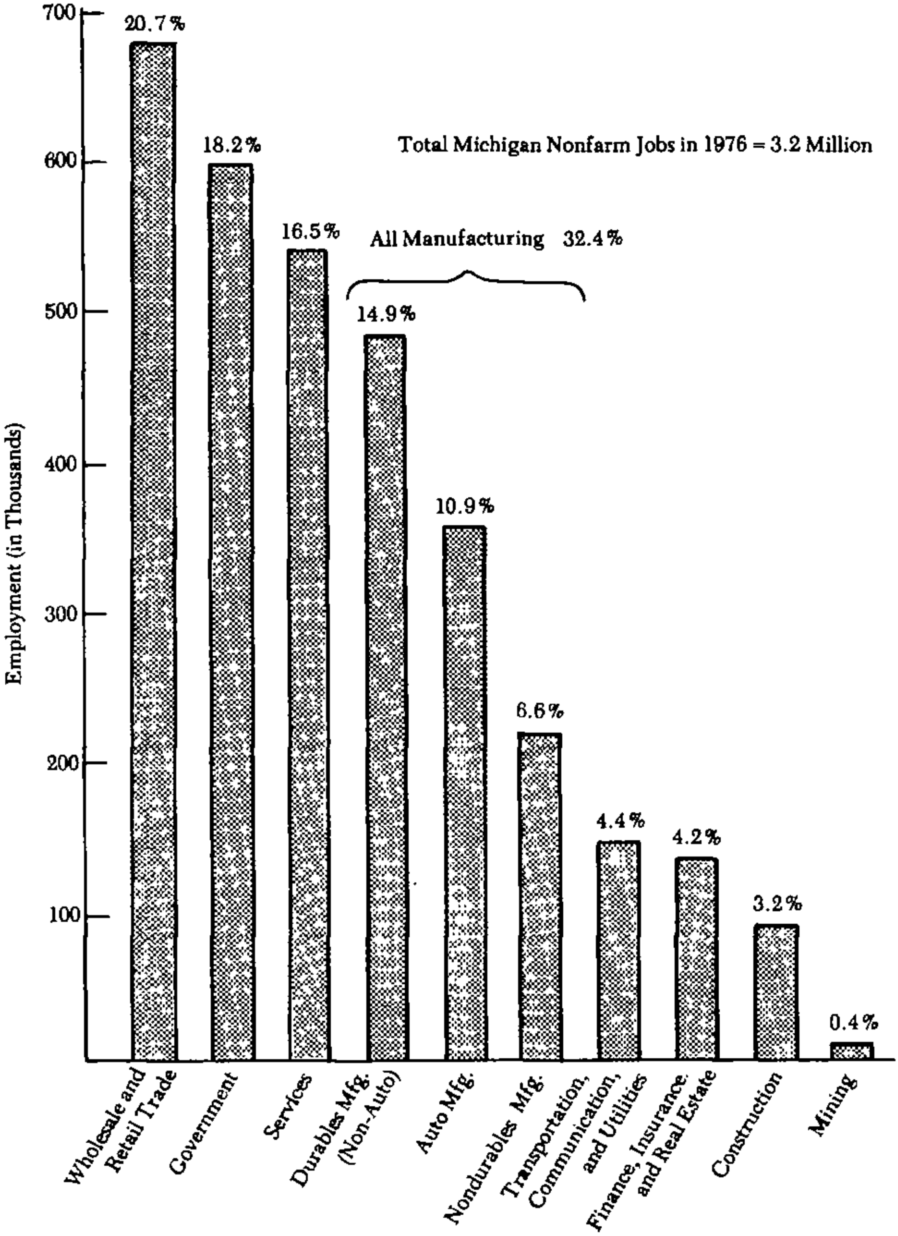
* Output figures for agriculture and tourism are not shown here because corresponding employment figures are not available. Total output for the agricultural sector in 1976 was approximately $2 billion (Wright, 1979) The tourism industry is difficult to estimate accurately in terms of employment and income; however, the Michigan Department of Commerce claims that tourism, recreation, and sports currently represent an $8.3 billion a year industry (*Ann Arbor News,* March 22, 1979).

** Total wages paid to government employees are used here as an estimate of government output. This tends to understate the role of government in the economy.

The output of the Michigan economy is dominated by manufacturing, especially manufacturing of durable goods.

FIGURE 2.7

Michigan Nonfarm Jobs by Sector, 1976

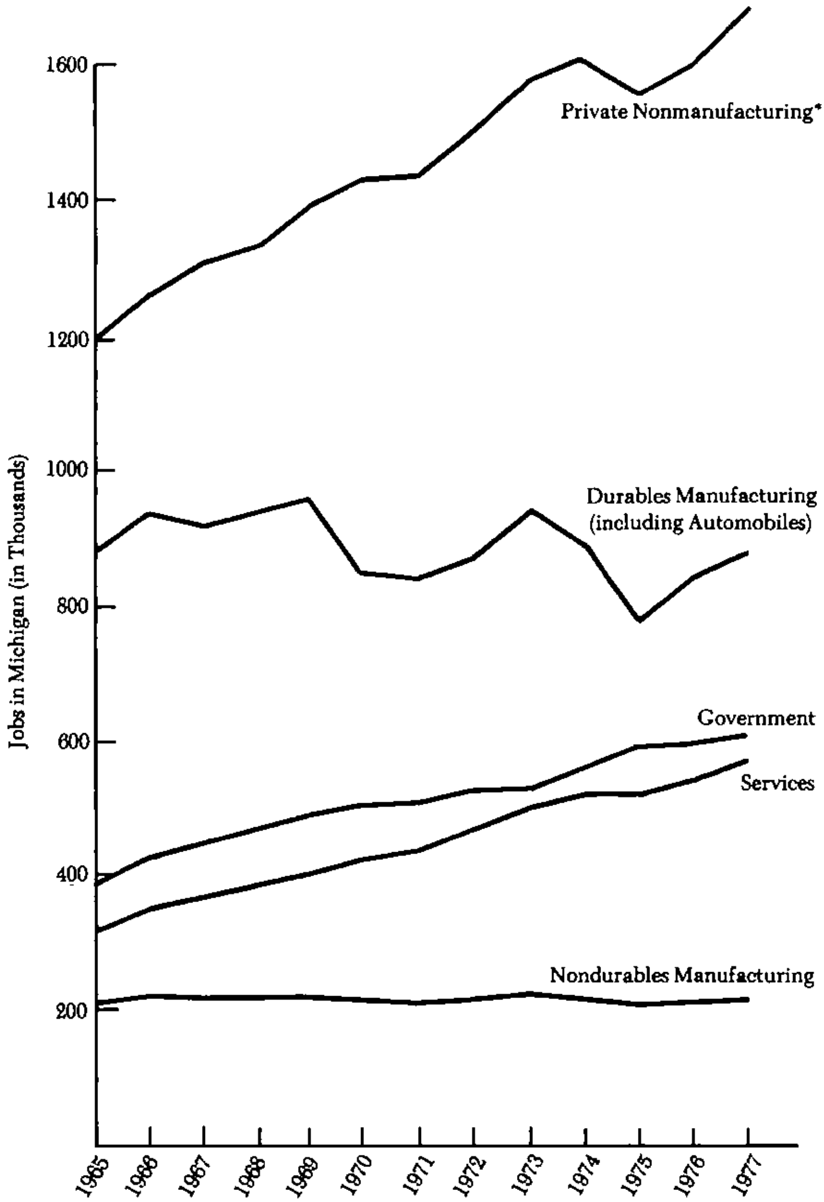


SOURCE: Michigan Employment Security Commission.

One-third of Michigan's jobs are in manufacturing. These jobs, in turn, create and support additional jobs in the nonmanufacturing sectors. As a result, instability in manufacturing employment (especially durables) affects the entire state economy.

FIGURE 2.8

Jobs in Michigan for Selected Industry Groupings, 1965–1977



SOURCE: Michigan Statistical Abstracts (1978).

* "Private nonmanufacturing" is actually an aggregate of a number of sectors: wholesale and retail trade; finance, insurance, and real estate; transportation, communications, and utilities; construction; and mining.

The pattern of employment in the durables manufacturing sector — the sector which dominates the Michigan economy — has been substantially more unstable than that of the other sectors. The magnitude of the instability is actually understated by this data, which is based on yearly average employment rather than highest and lowest employment levels in each year.

TABLE 2.2

Michigan Civilian Labor Force, Employment, Unemployment Rate, and Wage and Salary Jobs as a Percentage of U.S. Total, 1970–1978

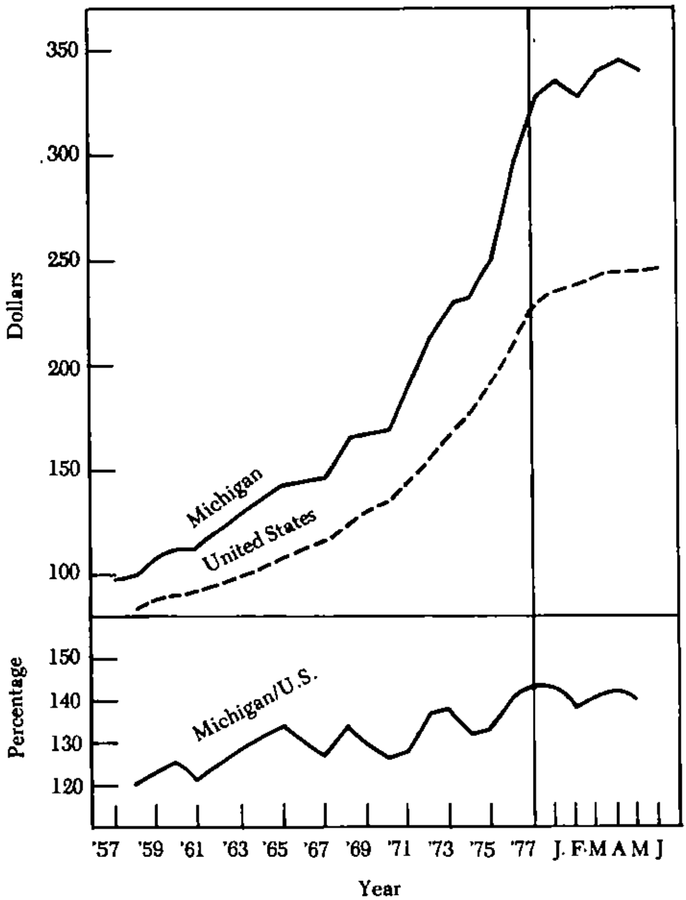
	Civilian Labor Force[a]			*Nonfarm Wage and Salary Jobs*[a]								
Year	*Labor Force*	*Civilian Employment*	*Unemployment Rate*	*Manufacturing*	*Construction*	*Retail Trade*	*Services*	*State and Local Government*[b]	*Wholesale Trade*	*Finance, Insurance, and Real Estate*	*Transportation, Communication, and Public Utilities*	*Total*
1970	4.35	4.27	137	5.58	3.37	4.07	3.58	4.57	3.79	3.24	3.31	4.24
1971	4.25	4.23	129	5.70	3.33	3.98	3.56	4.46	3.78	3.18	3.30	4.21
1972	4.28	4.09	125	5.73	3.36	3.97	3.68	4.42	3.70	3.23	3.25	4.23
1973	4.29	4.25	118	5.87	3.30	4.00	3.76	4.33	3.67	3.18	3.28	4.27
1974	4.27	4.18	132	5.56	3.22	3.99	3.75	4.42	3.64	3.19	3.23	4.18
1975	4.21	4.03	147	5.36	3.03	3.97	3.68	4.40	3.51	3.17	3.19	4.07
1976	4.22	4.14	122	5.57	2.93	3.90	3.68	4.41	3.54	3.17	3.21	4.11
1977	4.25	4.18	117	5.66	3.23	3.86	3.72	4.47	3.71	3.09	3.20	4.15
first 4 months												
1977	4.23	4.18	117	5.66	3.23	3.86	3.71	4.45	3.69	3.11	3.18	4.14
1978	4.22	4.19	111	5.69	3.28	3.78	3.73	4.46	3.75	3.06	3.21	4.16

SOURCE: Verway (June 1978).

[a] Civilian labor force data are developed on the basis of questions asked at a sample of households, whereas the number of nonfarm wage and salary jobs is estimated by querying selected employers. The difference between the two stems largely from nonfarm self-employment (lawyers, dentists, physicians, and other professionals in private practice; domestic workers; "mom and pop" grocery stores, restaurants, and motels, and so forth), agricultural employment (both owners and their employees), workers involved in labor disputes who otherwise would be employed, multiple jobholding on the part of some employed persons, and sampling differences. Also, a worker might be employed in a factory or office in one state, and counted there in the employer survey, but live in another state, and be counted there in the household survey.

FIGURE 2.9

Average Weekly Earnings for Production Workers in Manufacturing for Michigan and the United States, 1957–June 1978



SOURCE: Verway (September 1978).

How Vulnerable Are Michigan Jobs?

Thus far we have emphasized the dominant role of automobile and other durables manufacturing in the state economy. The historical record emphasizes, as well, the volatility of employment in these sectors. Indeed, as shown in Figure 2.10, Michigan's unemployment rate has been 3–4 percent or more above national levels for much of the recent past.

As suggested earlier, these patterns of employment and unemployment are in large measure due to the tendency of durables manufacturing to be significantly more sensitive to economic downturns (and upturns) than other economic sectors. This primarily reflects the tendency of consumers and businesses to postpone large purchases, such as for durables commodities, during times of high interest rates or business cycle downturns (Edens, 1977).

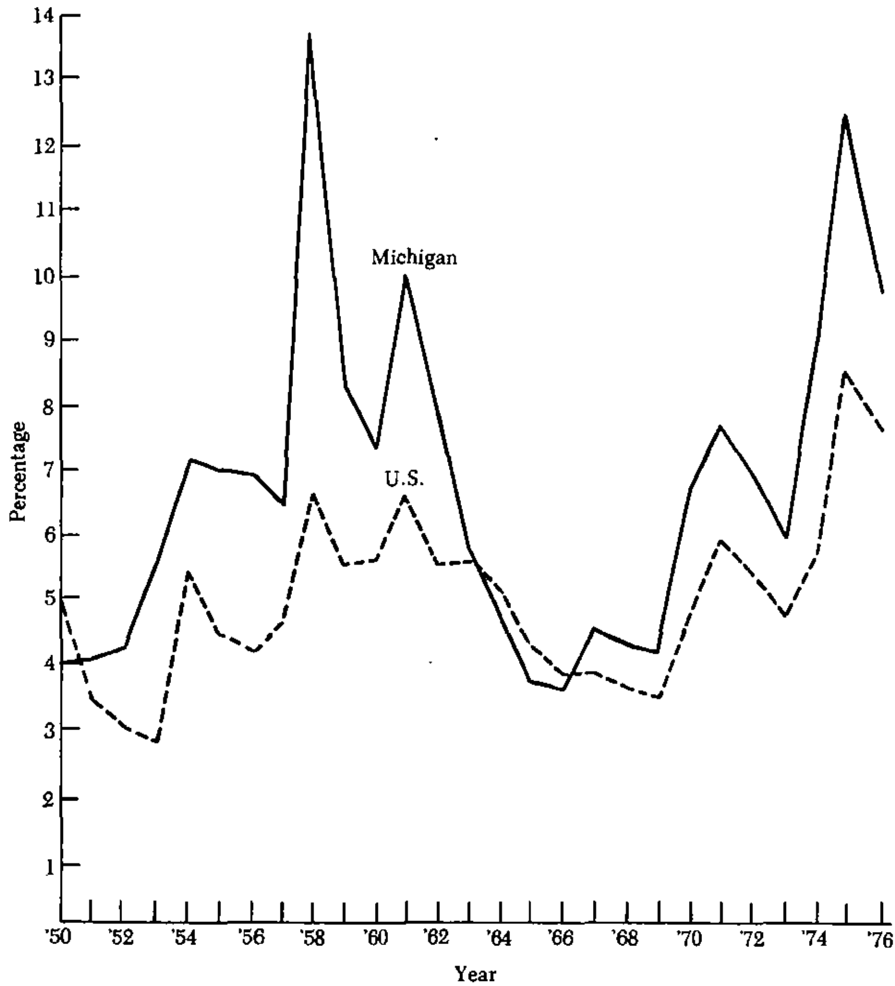
As Figure 2.11 suggests, the above pattern holds true nationally and not just for Michigan's durables sector. It is more important to Michigan, however, because of the dominance of durables manufacturing. As shown in Figure 2.12, business cycle upswings *and* downswings have historically been sharper in Michigan than in the rest of the country. The point is dramatically reflected in quarterly employment data as well. For example, over the past two decades, the size of the Michigan workforce has, on the average, changed by 1.2 percent (up or down) per quarter, compared to the 0.6 percent average rate of change for the total U.S. workforce over the same period.[5] In other words, the average rate of change of employment levels in Michigan has been twice as fast as in the nation as a whole.

Figure 2.13 shows the pattern of employment instability in Michigan on an industry-by-industry sector basis. Industry groups are ranked from highest to lowest in terms of job fluctuations. It is clear that two industry sectors account for nearly all of the instability in employment: (a) the manufacturing sector, and (b) the self-employed workers (professionals such as doctors, lawyers, dentists, and also small proprietors), plus the farm workers sector. Changes in the manufacturing sector result from the sharp swings in durables manufacturing in response to the national economy. Changes in the self-employed plus farm workers sector result more from seasonal employment and the overall health of the Michigan economy (which is, indirectly, dependent upon manufacturing).

The dominance of the automobile sector in the Michigan economy has for many years been seen as a serious threat to the stability of jobs in the state.[6] It has long been clear that in times of recession auto sales and auto-related jobs do not do well. For example, in the 1973–75 recession which followed the 1973 oil embargo, jobs lost in the motor vehicles sector amounted to 27 percent. Losses such as these in income and jobs, and associated increases in uncertainty and pessimism, reverberate throughout the economy with

FIGURE 2.10

Michigan and U.S. Employment Rates, 1950–1976
(as Percentage of Labor Force)

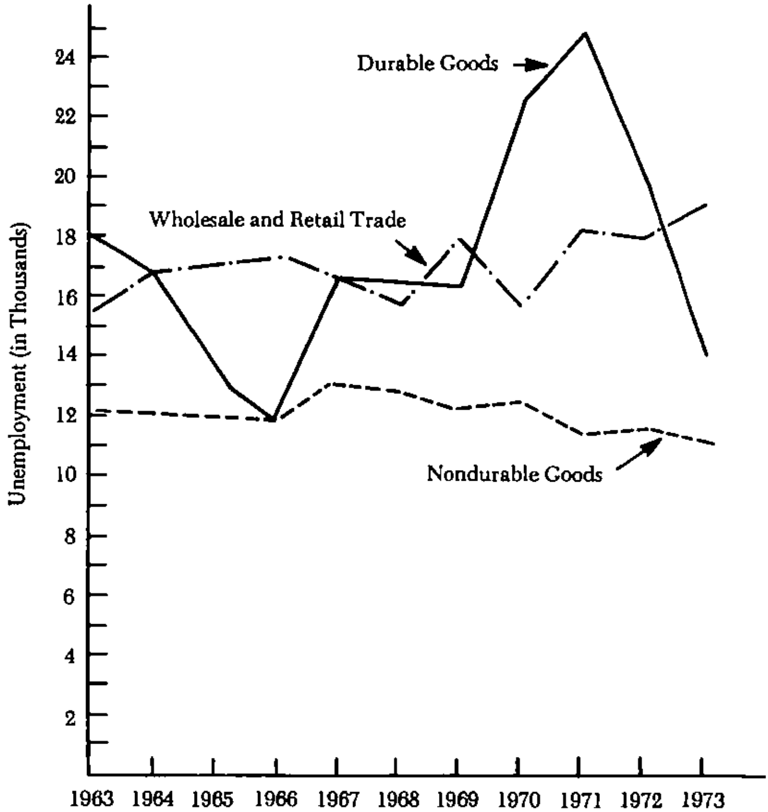


SOURCE: Edens (1977)

Michigan's unemployment rate has been substantially higher than the national average for most of the recent past. This pattern is largely a result of the dominant role of durables manufacturing in the state's economy.

FIGURE 2.11

Long-term Unemployment by Industry for the U.S., 1963–1973
(Annual Averages)

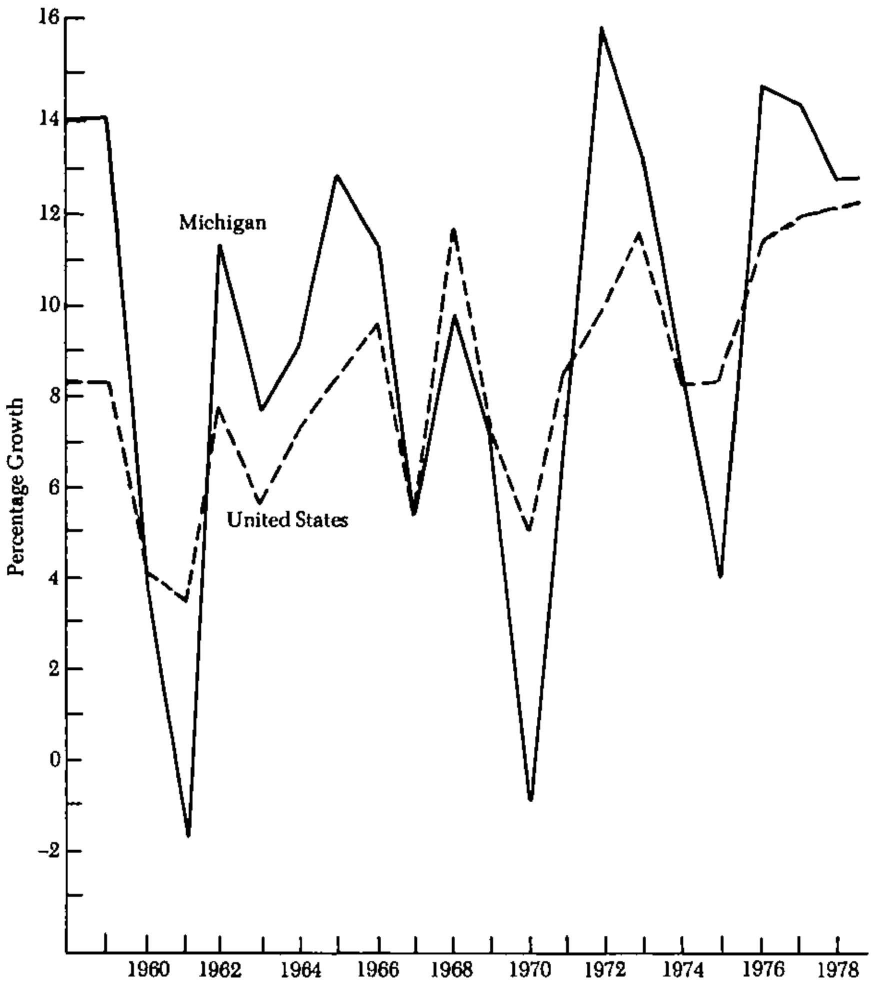


SOURCE: Edens (1977).

Employment in durable goods industries tends to be considerably more sensitive to cyclical fluctuations in the national economy than other industry types. Late 1969 through 1970 was a recessionary period in the U.S.

FIGURE 2.12

An Illustration of Michigan's Hypersensitivity
to National Economic Growth and Contraction
(Annual Change in Gross Product)

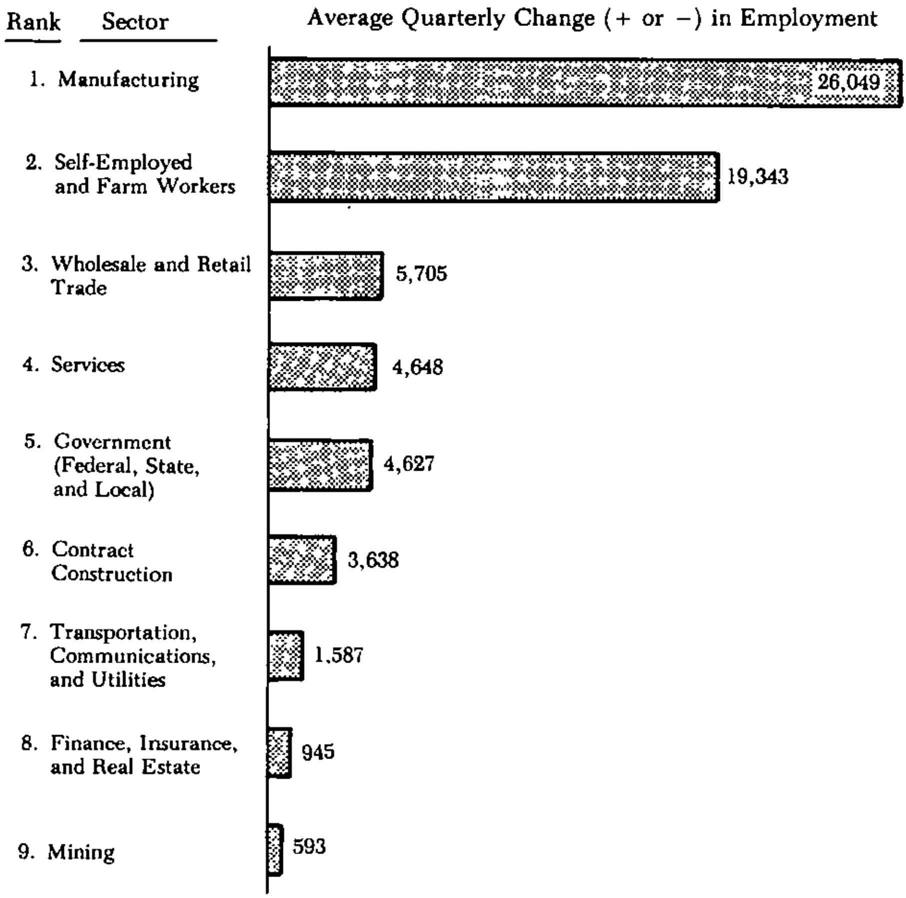


SOURCE: Ferris (1979).

Both upturns and downturns in the economy tend to be sharper for Michigan than for the nation as a whole. The years 1960–61, 1970–71, and 1974–75 were recessionary periods in the national economy.

FIGURE 2.13

Pattern of Job Instability* in Michigan
by Industry Sector, 1956–1978



SOURCE: Michigan Employment Security Commission.

* Computed as the mean of absolute values of quarterly changes in employment by sector.

The sensitivity of durables manufacturing to upturns and downturns in the economy results in high instability in manufacturing employment.

further negative effects. For example, the construction industry, which is typically quite sensitive to economic conditions, although an extremely small user of energy, had a 36 percent loss of jobs in Michigan during the 1973–75 period (Verway, 1977). In other words, reductions in the purchases of durable goods have a multiplier effect in terms of reduced purchases of other durable goods, nondurable goods, and services by both households and business. This is the quantitative evidence behind the familiar phrase, "When the nation gets a cold, the auto industry gets pneumonia" – unfortunately, so do the state's local business revenues, tax revenues, and employment levels.

Without future success in diversifying the state's economy, there are few reasons to foresee any reduction in this pattern of job vulnerability. In fact, several new long-term economic trends are emerging for the state which may further increase job vulnerability. A recent report to the Committee for Great Lake Economic Action has outlined as follows a series of problems expected to confront both Michigan and its neighboring Great Lakes states[7]:

> The Great Lakes states have been the industrial heartland of the United States for more than a century. There is a high degree of economic interdependence in the region. Now this region faces its first severe test as the core of its economic base, heavy manufacturing, is dispersing out of the central cities, and with new manufacturing growth favoring other regions of the country and even other nations. The leadership of the region faces the question of how best to aid the older manufacturing centers in their transition from heavy reliance on manufacturing to more diversified and balanced economic bases.
>
> This transition is made difficult by several factors, which are national, but which especially influence this region's transitional problems:
>
> - Slow employment growth rates in the region, making it difficult to absorb manufacturing workers displaced by modernization as well as increasing numbers of new workers entering the labor force.
> - Slow national economic growth rates which result in lower demands for goods produced in the cyclically highly sensitive Great Lakes economy and which prevent many Great Lakes workers from finding employment in other parts of the nation.
> - Heavy manufacturing, which long undergirded this region's economic dominance, is growing slowly in the United States, still more slowly in the region. Some industrial sectors are sustaining absolute job losses.
> - Nonmanufacturing jobs in the region are not growing fast enough to absorb those displaced by the substitution of capital for labor, absolute losses of employment in some basic industries, natural increase in the size of the labor force, and increased participation in the labor force.
> - The job growth that is occurring, is taking place largely in suburban or nonmetropolitan areas. The older manufacturing centers are facing increasing concentrations of unemployment compounded by the intransigent problems of hardcore joblessness among the poor in the central cities of the larger metropolitan areas.
> - Uncertainty about energy supply, some of the costs of doing business in the region, and selected aspects of transportation, capital availability, water, and other specific problems, represent impediments that must be overcome if new growth in the regional economy is to be stimulated.

> The most serious problems of the Great Lakes Region center on its largest cities and older industrial towns that have formed the backbone of its economy.

In Michigan, unfortunately, those cities which make up the "backbone" of the state's economy tend to be dominated by automobiles and durables manufacturing. Furthermore, from 1960 through 1977, Michigan increased its share of the nation's manufacturing while it suffered a slight loss in its share of non-goods earnings.

Unfortunately, there are significant reasons for concern over the future health of the auto industry. The current problems of Chrysler and Ford bode ill for jobs in Michigan, since nearly all business economics point toward layoffs to make for leaner operations. While General Motors is a somewhat healthier employer, the American auto industry has been the loser in competition with imported cars. The net effect is likely to be a decline or no growth in total automotive employment in Michigan in the next five years, quite apart from the current sales showdown. This is significant because much of Michigan's growth in the 1970s was based on fast auto industry growth which helped to counteract the performance of many other sectors of the economy tending to grow more slowly than the U.S. (Verway, 1978b).

With the onset of the "energy crisis" and prospects for even more serious gasoline shortages, Michigan now faces a second type of long-run vulnerability to job losses in the automobile industry. In addition to job losses from periodic recessions (many of which will be a result of energy-related problems), job losses are quite likely from a long-term leveling off in demand for automobiles. The Congressional Office of Technology Assessment has projected 1985 employment in the auto industry to be virtually the same as or lower than the 1976 levels (Congressional Office of Technology Assessment, 1979). In fact, the negative employment effects which may come from the transition to smaller, more fuel efficient vehicles could be much worse than this. The United Auto Workers have estimated that in the *worst case* the industry's work force could be nearly cut in half by the early 1990s. The labor required to build a subcompact automobile is only about two-thirds of that needed for a standard-size car, and the smaller cars will be built in new and remodelled plants designed to be more labor efficient than the older plants they are replacing. There is concern, as well, that America's Big Three automakers may never be able to fully recover the share of the market they have recently lost to the more fuel efficient foreign-built imports (*Business Week*, March 24, 1980). Michigan's economy will be especially vulnerable to these changes, more so if Chrysler loses its ongoing fight for survival.

Perspective on the implications of such changes is provided by a recent study of the Great Lakes regional economy which examined the impact of a 10 percent decline in national automobile demand. The study concluded that such a decline would result in ". . . over 85,000 job losses in the region's auto industry, but more than 169,000 *other* jobs would be lost through indirect multiplier effects on suppliers and on those whose income is in any way dependent upon auto sales" (Academy for Contemporary Problems, 1977). This would represent a multiplier effect on jobs of approximately three for the region and a loss of $13.4 billion (1975 dollars) in total regional output.[8]

In summary, Michigan has the problems of a heavy industry state: when there is growth in jobs, it tends to be paced by the auto industry, especially since Michigan has had few other fast-growing industries except tourism. At the same time, there is a reliance on cyclically unstable industries. As a result, Michigan's primary job bases are extremely vulnerable. This situation has been bearable in the past as a result of economic growth. However, the state's economy has great sensitivity to problems of gasoline and oil shortages and, therefore, there is a potential for continuing problems of slow growth in the future coupled with the problem of job instability. Unless Michigan significantly diversifies its economy (which will not be easy), the instability (and periods of high unemployment) that have been familiar in the past are likely to be paired with slower growth in the future.

Energy and Jobs: A View to the Future

The discussion thus far has emphasized the historical vulnerability of Michigan jobs to downturns in the national economy, with only limited attention to the role of energy in that vulnerability. This was done, in part, to emphasize that state jobs are vulnerable to a number of critical factors in the national economy beyond the effects of energy. As we move into a new era of higher cost and reduced energy supplies, however, the link between energy, jobs, and economic output will take on increasing importance.

In the short-term, especially, the number of jobs for Michigan citizens and the amount of energy used in Michigan are closely tied to the output of the state's economy. In fact, economists consider both energy and labor (along with capital) to be "factors of production." That is, for given inputs of the factors of production, a certain level of production output is possible. The exact relationship between these factors (known as the production function) can be quite complex. With changes in the productivity of workers, new technologies and production methods, energy conservation efforts, and so forth, the relationship can change over time.

The "factors of production" concept suggests a number of useful generalizations for any short-run period of, say, one to five years.

1. For a given production process, the level of output is directly tied to the input of labor. A higher level of output requires the use of more labor, less output requires less labor.

2. For a given production process, the level of output is also directly tied to the amount of energy used.
3. For a given production process, the ratio of labor to energy is relatively fixed.

These three generalizations have led some earlier observers of the energy/jobs/output interaction to conclude that a reduction in available supplies of energy would automatically lead to a reduction in jobs and output. *In the short-run*, this view may in fact be appropriate, especially in industries where rapid substitutions to alternative fuels or production processes is not possible.

A number of studies have suggested, however, that the relationship between energy, jobs, and output can take other forms, especially over the medium and long-term.[9] According to this argument (which is discussed in more detail in Chapter 3), the ratio of jobs to energy can vary across different production processes and across different products. As a result, it is possible to substitute toward those production processes and products which use less energy per unit of output, i.e., toward those which are less energy intensive. For example, through an investment of capital in new equipment, residual process heat formerly wasted can very often be used to provide space heating or even electrical generation. Similarly, by shifting demand to products which use less energy per unit of output (lower energy intensity) but an equal or greater amount of labor per unit of output (labor intensity), the economy can maintain output and jobs while using less energy. For example, returnable bottles and recycled aluminum cans are less energy intensive than nonreturnables and aluminum containers smelted from raw ore.

From the manufacturers' standpoint, substitutions such as these represent investment decisions which must weigh the cost savings and energy security coming from reduced energy use against the costs of new capital equipment and the risks of energy instability. A rough sense of the potential impacts of such a strategy can be obtained from Table 2.3 and Figure 2.14, which give energy and labor intensities for major personal consumption activities and industrial sectors in the U.S. Notice that the substitution would be away from the more energy intensive goods producing industries, towards the less energy intensive non-goods producing industries. The trend in Michigan over the 1960–77 period was in just the opposite direction. That is, Michigan's share of the nation's goods production increased from 7.2 percent to 8.0 percent, while its share of services decreased from 3.8 percent to 3.7 percent (Verway, 1978b).

Figure 2.14 is especially instructive in understanding the full range of potential relationships among energy, jobs, and output. The plot of Figure 2.14 compares in a somewhat idealized way the energy and labor intensities of a number of representative industries. Actual data, when plotted for these and

TABLE 2.3

Energy and Labor Intensities of the Top 20 (Dollarwise) Personal Consumption Activities in 1971

Personal Consumption Expenditure—Sector Description	Energy Intensity (Btu/$)	Labor Intensity (Jobs/$1000)
Electricity	502,473	0.04363
Gasoline and oil	480,672	0.07296
Cleaning preparations	78,120	0.07332
Kitchen and household appliances	58,724	0.09551
New and used cars	55,603	0.07754
Other durable house furniture	45,493	0.08948
Food purchases	41,100	0.08528
Furniture	36,664	0.09176
Women and children's clothing	33,065	0.10008
Meals and beverages	32,398	0.08756
Men and boys' clothing	31,442	0.09845
Religious and welfare activity	27,791	0.08636
Privately controlled hospitals	26,121	0.17189
Automobile repair and maintenance	23,544	0.04839
Financial interests except insurance co.	21,520	0.07845
Tobacco products	19,818	0.05845
Telephone and telegraph	19,043	0.05493
Tenant occupancy, non-farm dwelling	18,324	0.03258
Physicians	10,271	0.03258
Owner occupancy, non-farm dwelling	8,250	0.01676
Average, including energy purchases	70,000	0.08000
Average, non-energy purchases only	52,000[a]	—

Source: Hannon (1974).

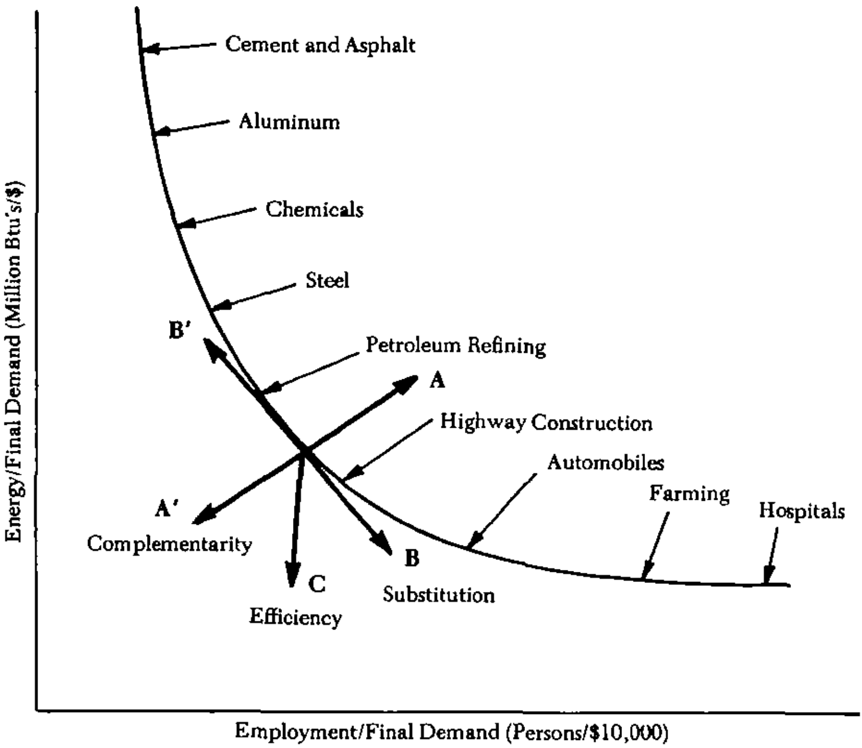
[a] 1967 figure. The corresponding 1967 figure for average including energy was 80,000 Btu/$. Source: Schipper (1976b).

other industries, are not quite as neat but follow the same basic pattern as used here to illustrate the concept. Consider first the short-term relationship discussed earlier in which the ratio of energy and labor is fixed. In this case, energy and labor are *complementary*. Within each industry, any increase in output requires an increase in energy and must follow the path of arrow A. A decrease in output, e.g., a recession or an energy shortage, would result in movement along path A'. This is a path of decreased jobs.

Paths B and B' represent a relationship of substitution between energy and jobs. In theory, two types of substitution can occur. In one case, as suggested earlier, some proportion of output could be shifted from types of production which involve high energy and low labor to types which require less energy and more labor – for example, from production of aluminum to steel. The second type of substitution is, perhaps, more likely and also one which is quite familiar. Over the past several decades, many industries have become more energy intensive and less labor intensive through the use of automation technologies which have substituted cheap energy for expensive labor – path

FIGURE 2.14

Energy and Employment Intensity in the U.S., 1969



SOURCE: Adapted from a graph in Chapman (1977) which is an adaptation from Folk and Hannon.

B' (Energy Policy Project of the Ford Foundation, 1974). In times of scarce, unstable, and expensive energy, however, it could become desirable to substitute in the opposite direction, away from energy toward labor, along path B. In fact, U.S. Labor Department officials believe this tradeoff is already occurring. It is estimated that up to half of the 2 million jobs created in the U.S. during 1979 resulted from the substitution of labor for increasingly expensive energy-driven machinery (*Ann Arbor News*, March 21, 1980).

In the Michigan context, the concern over this type of substitution is with respect to the quality and pay rate of jobs which are saved or created by energy-saving substitutions. For example, to substitute labor and shovels for a backhoe is not likely to be considered progress. On the other hand, as energy costs rise, many of the jobs which could be created would be at least as attractive and well-paying as those which labor organizations have unsuccessfully tried to protect against the encroachments of automation over the past three decades.

The third relationship between jobs and energy is characterized by *increased efficiency* and is shown along path C. As in paths B and B', increased efficiency is largely dependent on changes in equipment and technology. Movement along path C allows the same amount of labor to produce the same amount of output with less energy. For Michigan, this also means the possibility of continued growth in output and jobs without a corresponding increase in demand for energy. Over the past 25 years, the manufacturing sector has achieved significant efficiency improvements, even during periods of low energy prices. Higher energy prices of today can be expected to improve this record (Whiting, 1978; Energy Policy Project, 1974). For example, a recent study by R. W. Barnes of Dow Chemical Company documents that capital investments by industry for a range of new energy conserving technologies (double current efficiencies) have the same labor requirements as do comparable, but nonconserving, new alternative technologies (Bullard, 1977). In short, the energy conserving technologies substitute capital for energy without significantly altering the role of labor. To the degree this finding holds true in the future, wages could be kept up while money saved through conservation could be available for job-creating, nonenergy expenditures.

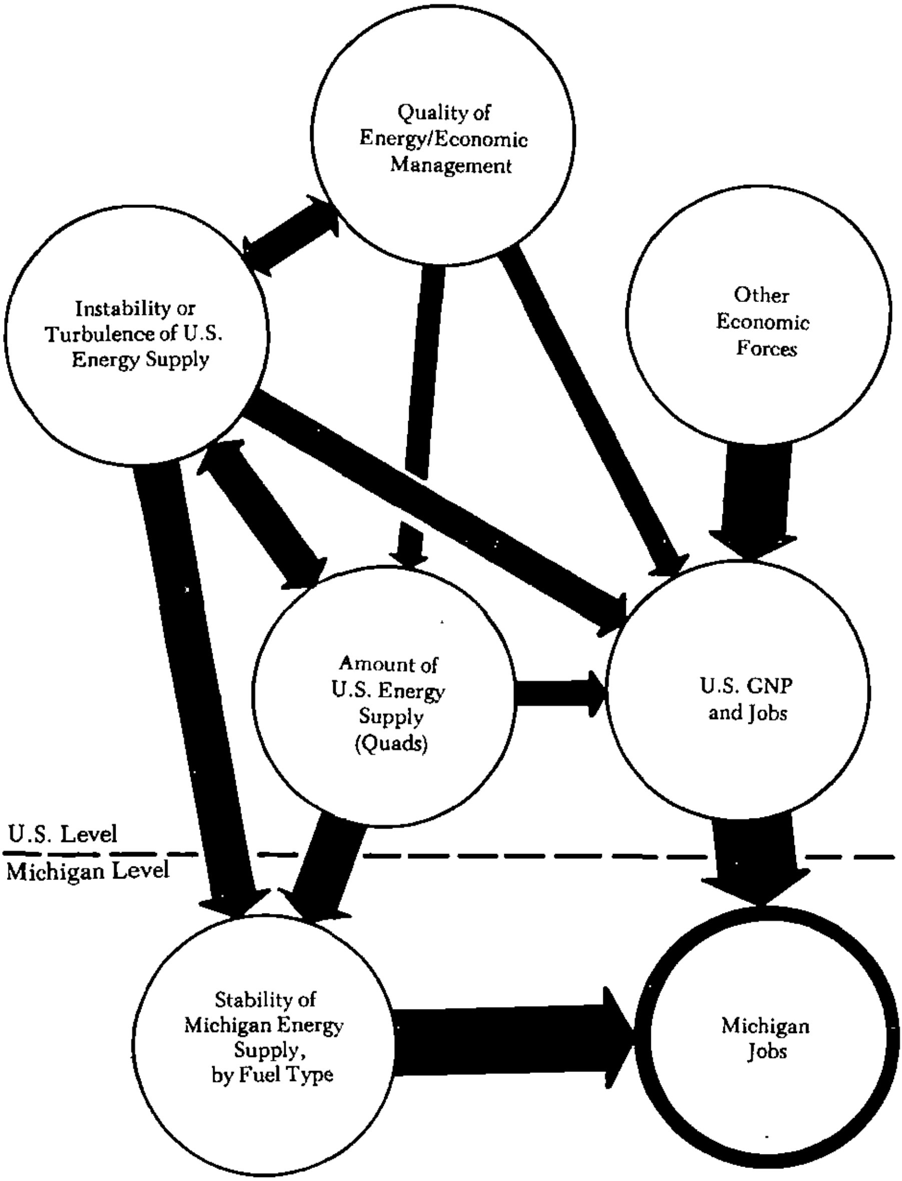
In summary, three alternative relationships are possible among energy, jobs, and output—complementarity, substitution, and increased efficiency. Over the years ahead, there is considerable potential for emphasizing substitution and increased efficiency in the Michigan economy as a major component of strategies for the protection of Michigan jobs. Without such efforts, jobs in Michigan can only become increasingly vulnerable to energy interruptions and to the aggregate effects of rising energy prices.

Jobs and Energy In Michigan: A Conceptual Framework

Clearly, there are many factors which can influence an economy with the size and complexity of the United States'. Figure 2.15 provides an overview of some of these factors and the way they may impinge on the vulnerability of Michigan jobs and energy supplies. The figure is a causal diagram, with arrows showing the dominant direction of causation (A→B, is A causes B), double headed arrows showing mutual influence, and width of arrows giv-

FIGURE 2.15

Relationship of Michigan Jobs to U.S. and Michigan Energy Situation



ing a sense of the relative impact of each of the factors on jobs. The upper portion of the diagram focuses on the U.S. economy. For our purposes, we have isolated three energy-related factors requiring attention: (1) the quality of the public and private management which emerges to deal with future U.S. energy problems; (2) the extent of instability, uncertainty, and turbulence in U.S. energy supplies; and (3) the level of U.S. energy supplies available in the future. The lower portion of Figure 2.15 shows the major forces affecting Michigan jobs.

The diagram also provides a conceptual framework for understanding the overall analysis of the study and a convenient orientation to the structure of this report. In Chapter 3, we examine factors operating at the national level which will eventually impinge on Michigan jobs through the effects of the national economy and national energy supplies. In Chaper 4, we systematically examine the range of employment which Michigan might expect in the year 2000 based on the alternative national economic and energy conditions presented in Chapter 3. Finally, Chapter 5 examines the likelihood that the state may face shortages and uncertainties in specific types of energy which might further hurt state employment prospects beyond the effects flowing from ties to the national economy.

Notes

1. *Ann Arbor News*, "State Ups Oil Sufficiency," March 4, 1979. The overall import figure was 89 percent. In 1978, Michigan imported 81 percent of its oil, 87 percent of its natural gas, and 100 percent of its coal.

2. Data for the energy supply/demand figures given in this chapter came from several sources: "Total Energy Use by Fuel and Economic Sector for Michigan and the United States, 1972 through 1977," Energy Administration, Michigan Department of Commerce, August 1979; "Michigan Energy Prospects to the Year 2000," a report prepared by the Michigan Energy Administration (MEA) and the Michigan Energy Resource Research Association (MERRA), May 1979; and *Michigan Statistical Abstracts*, 13th ed., Graduate School of Business Administration, Michigan State University, 1978.

3. Note that transportation, while a large and therefore interesting sector on its own, can be allocated among its generating sources. That is, a certain portion of transportation is done by private individuals, another portion for industrial purposes, etc. Unfortunately, typical energy accounting systems currently available do not provide the data to routinely and accurately make this important disaggregation.

4. Efficiency, as used here, is simply a ratio of the useful energy out to the total energy in.

5. Calculated from Michigan Employment Security Commission data for the first quarter of 1956 through the second quarter of 1978. Percentages are based on the average of the absolute value of the percentage change per quarter:

$$\frac{E_t - E_{t-1}}{E_{t-1}} \times 100.$$

6. See for example Haber, Spivey, and Warshaw (1965); Haber, McKean, and Taylor (1959); and McCracken (1960).

7. The Committee was appointed by the governors of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. The chairman of the Committee was Richard Helmbrecht, then Director of the Michigan Department of Commerce. The report was prepared by the Academy for Contemporary Problems, December 1977.

8. The employment multiplier is defined as $\left(1 + \frac{\text{local employment}}{\text{nonlocal employment}}\right)$.

9. See Schipper (1976b); National Academy of Sciences/National Research Council (1979); and Council on Environmental Quality (1979).

3

Energy and Economics: National Scenarios for the Year 2000

Introduction

This chapter explores several potential patterns of energy and economics for the United States in the year 2000. Three scenarios, or snapshot portraits, are presented for energy and three for economics. These U.S. scenarios will permit development of the "step-down" scenarios for Michigan's jobs and energy situation in the year 2000, presented in Chapters 4 and 5. The energy scenarios are (1) high and steady energy supplies (fairly unlikely); (2) moderate and fairly steady energy supplies (somewhat more likely); and (3) low and unstable energy supplies (all too likely, though less likely than the medium scenario). Similarly, the economic scenarios reflect high, medium, and low levels of economic growth.

The scenarios assume a business-as-usual kind of future—that is, no drastic changes in values, lifestyles, business practices, or government policies, and no "gee whiz" technological breakthroughs (see Table 3.1 below). This is *not* because the authors think a lack of institutional transformation is "best" or "most likely." Indeed, we think business as usual is rather risky and that changes are needed. It is important, however, to see what is implied by continuing present practices so we can all choose our future more wisely.

Michigan residents in particular may conclude that business as usual is too risky and that major new efforts are needed, such as:

- more energy production—conventional and new sources;
- better energy conservation—not just curtailing what we like, but greater efficiency and productivity.

TABLE 3.1

"Business as Usual" Assumptions

Business as usual means:	Business as usual does not mean:
• Business and government going ahead with presently planned changes in energy production, distribution, R & D, and use of technologies presently on the shelf.	• No changes at all.
• Response by business, consumers, and government to energy price increases by efficiency improvements that don't significantly alter operations or lifestyles.	• "Gee-whiz" technological breakthroughs.
• Government continuing phased decontrol of oil and gas prices, continuing moderate leasing programs for coal and for off-shore oil and gas, building some pipelines for oil and gas from Alaska and Canada, and making moderate changes in nuclear plant siting, licensing, and regulation aimed at greater safety	• Drastic changes in business or government operating procedures, decision criteria, or goals.
• Government attempts to streamline energy development remaining slow and confused, partially due to concerns for safety and environmental quality.	• Massive changes in lifestyles or generally held public values.
• On the societal scale, an extension of many past trends (e.g., population growth rate declining) into the future as modified by easily foreseeable changes in the energy, economic, or international situation.	• Sudden disappearance of uncertainties and conflicts in public opinion over nuclear power, over environmental issues, or over solar/renewables energy sources.
• A requirement for massive capital investment in energy conservation and production, with capital markets being hard-pressed to cope.	• A clear emergence of national consensus on the desirability of nuclear power or the desirability of a mostly solar-powered economy, with massive new accelerated programs designed to implement one or the other.
	• *Large scale* availability at competitive costs before year 2000 of: – synthetic fuels (coal gasification and liquefaction) – nuclear fusion power – nuclear fission breeder reactors – solar electric power
	• Major decline in environmental quality standards.

Before proceeding with the energy and the economic scenarios, we'll explore in further detail the nature of the historical link between energy use and economic growth and the way in which that link may change in the years ahead.

Energy and Economic Growth

This report endorses a key argument, now accepted by a wide range of technical experts, that in the long-run (say, the next 20 years and beyond), the link between energy and economic growth is essentially quite loose. Many combinations of energy use, economic growth rates, and prosperity levels are possible. This is contrary to recent short-run experience. For example, the 1974–75 recession followed the 1973 oil crisis largely because, in the short-run, the U.S. had great difficulty in adjusting to supply shocks and in quickly changing its pattern of energy use. Over the medium and long-term, however, current evidence suggests that there is considerable flexibility and sufficient time for well-planned and efficient changes in energy use patterns and technologies.

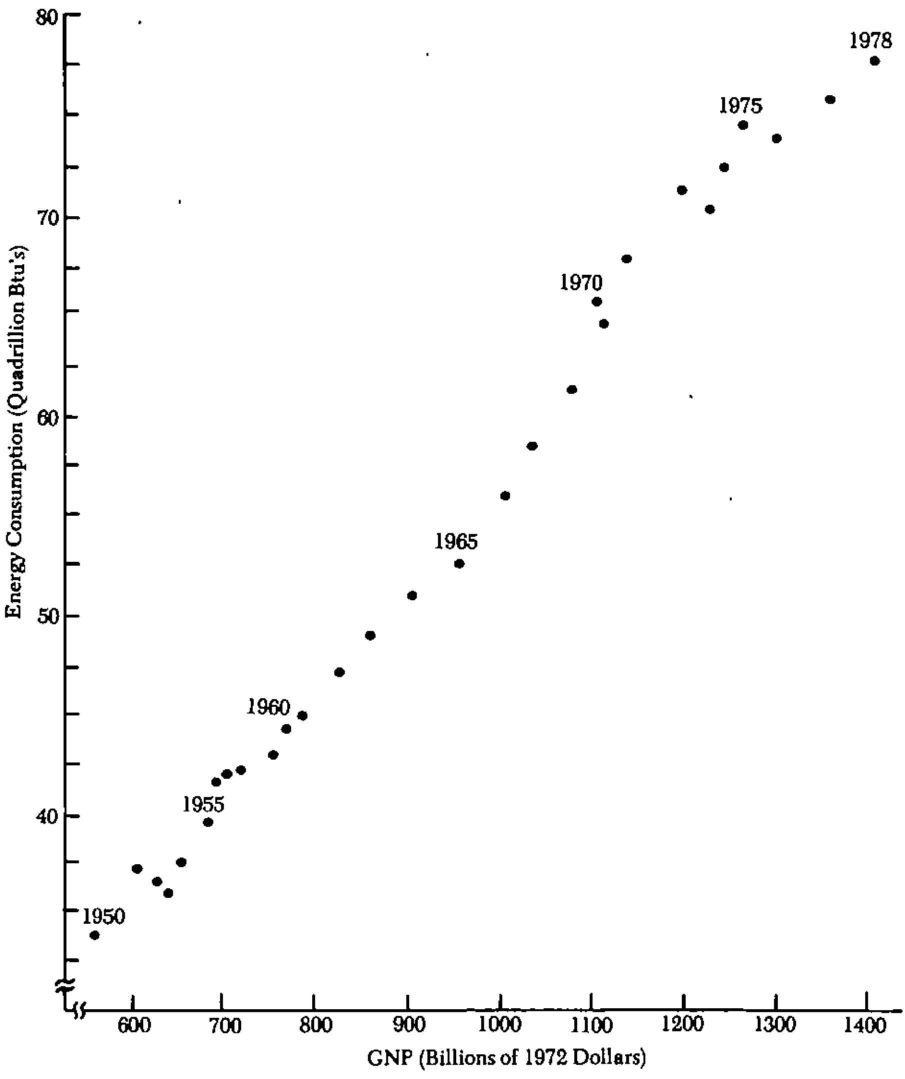
The fairly close correlation apparent in Figures 3.1 and 3.2 between the historical growth in energy consumption and growth in national output has led many concerned observers to conclude that there is a direct, "one-to-one" link between energy consumption and economic prosperity.[1] These historical correlations, along with the energy-based economic problems following the 1973 oil embargo, led many to the false conclusion that the U.S. is inflexible in the long-run and that energy conservation, or efficiency improvements, would cause economic problems. In fact, recent data show that the asserted "iron link" may be much more elastic than expected.

A number of recent engineering/economic studies have concluded that future economic growth will not necessarily require as much energy (per unit of growth) as it has in the past.[2] Indeed, most such studies have concluded quite the opposite, stressing the wide number of options on energy consumption available to the U.S. which would not seriously lower the prospects for economic growth. For example, the conservation panel of the recently completed CONAES study concluded that, from a purely technical standpoint, "very similar conditions of habitat, transportation, and other amenities could be provided in the year 2010 with primary energy consumption ranging from 60 to 135 quads (CONAES, 1978b). (These projections are examined in greater detail in a later section.) Consumption levels at the lower end of this range would require very extensive social, political, and economic changes in addition to technological ones. However, consumption levels at the mid-range — 90 to 110 quads — would probably not require such drastic changes.

The efficiency of industrial energy use has increased markedly in recent

FIGURE 3.1

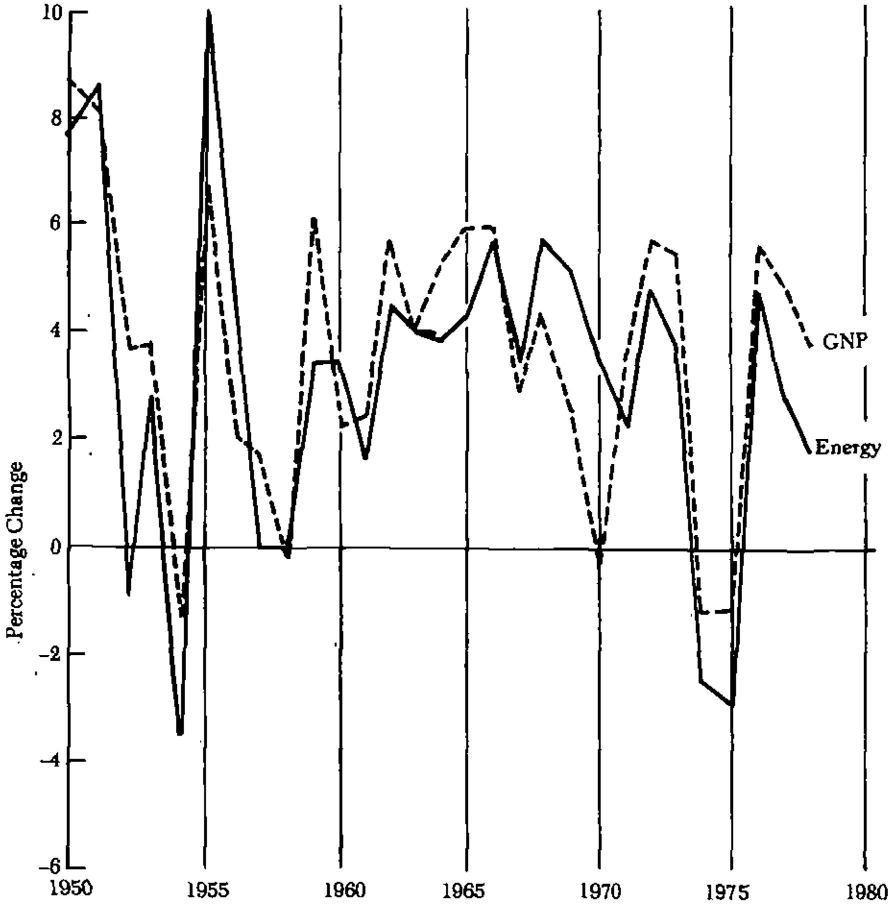
U.S. Primary Energy Consumption and GNP, 1950–1978



SOURCE: Energy Information Agency, U.S. Department of Energy (1979); and U.S. Department of Commerce (December 1979).

FIGURE 3.2

Changes in U.S. Primary Energy Consumption and GNP, 1950–1978



SOURCE: Landsberg, et al. (1979).

TABLE 3.2

Energy/Output Relationships, 1972

Country	GDP per capita (dollars)[a]	Energy consumption per capita (tons oil equiv.)[b]	Energy/GDP ratio (tons oil equiv. per $ million)	Energy/GDP ratio (Indexes. U.S. = 100)
United States	5,643	8.35	1,480	100
Canada	4,728	8.38	1,772	120
France	4,168	3.31	795	54
W. Germany	3,991	4.12	1,031	70
Italy	2,612	2.39	915	62
Netherlands	3,678	4.68	1,272	86
United Kingdom	3,401	3.81	1,121	76
Sweden	5,000	5.31	1,062	72
Japan	3,423	2.90	849	57

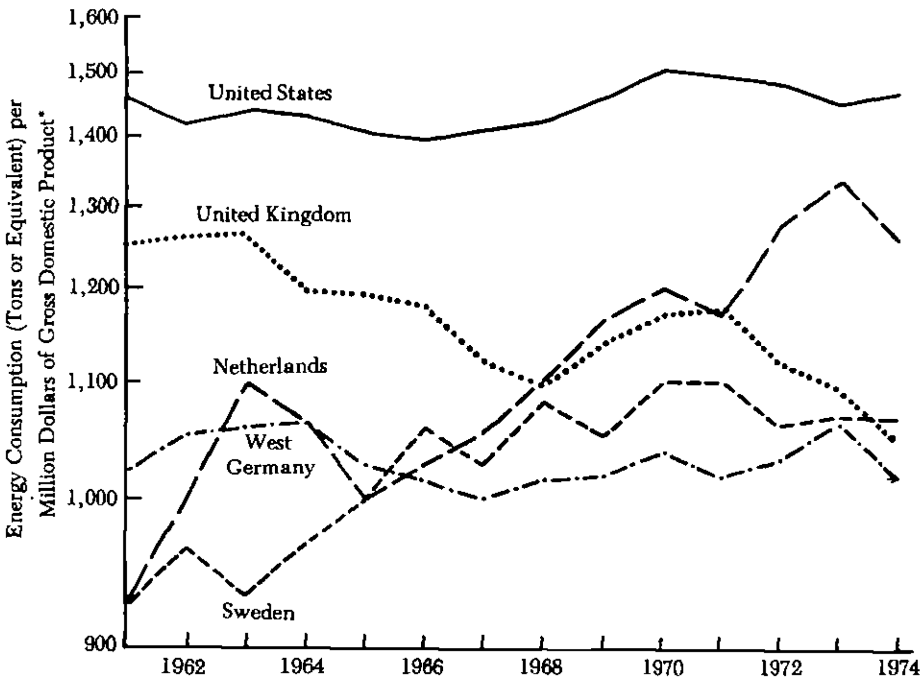
SOURCE: Darmstadter, Dunkerly, and Altermon (1977).
[a] Foreign currencies were converted into dollars using exchange rates which reflect comparable purchasing power.
[b] One million tons equal roughly 20,000 barrels per day.

years. Between 1970 and 1977, the energy required per dollar of industrial output declined by an average of over 2 percent per year (Ross and Williams, 1979). Furthermore, recent studies suggest there is considerable room for major gains in currently energy-intense industries such as glass, paper, chemicals, cement, food, and steel (Whiting, 1978). Major gains are possible from new technologies, replacement of inefficient equipment and buildings, process innovations, and cogeneration of electricity and process heat. Overall estimates of the improvements possible in the industrial sector vary, but 30–40 percent efficiency gains do not currently appear to be unreasonable (Stobaugh and Yergin, 1979). Such gains would constitute "straight forward," profit-maximizing strategies as the price of energy rises.

The same point can be made by comparing the use of energy per unit of economic output in the U.S. (where energy has been relatively cheap) with equivalent data for other industrialized countries (whose energy has been relatively more expensive over the years). Table 3.2 shows that in 1972 the ratio of energy per unit of gross domestic product varied widely among industrial economies. In addition to these intercountry differences, Figure 3.3 shows that energy to output ratios can change, *often dramatically*, over time. The U.S. has consistently used more energy per unit of economic output than all other industrialized countries except Canada, where energy has also been very inexpensive. A 1977 study of these cross-national differences estimated that 40 percent of the differences in energy to output ratios was attributable to differences in the types of economic activities emphasized

FIGURE 3.3

Energy/Output Ratios for Five Selected Countries, 1961–1974



SOURCE: Darmstadter, Dunkerley, and Alterman (1977).

* GDP is constant 1972 dollars converted at purchasing-power-parity exchange rate.

in the different countries. The remaining 60 percent, however, reflected differences in the efficiency of energy use (Darmstadter, Dunkerley, and Alterman, 1977).

If the U.S. moves aggressively to increase its energy efficiency through wide-ranging conservation programs, economic growth can occur without correspondingly high increases in the use of energy.[3] This means that over the long-run – 1980 to 2000 – the American economy has time to adjust. Jobs and income can grow satisfactorily at many different levels of energy inputs, provided that the economy is well-managed and that we make appropriate business and engineering adjustments. There is no "one-to-one" relationship between energy and how we do on jobs and prosperity. In fact, several recent studies have suggested that carefully designed conservation strategies could have the effect of *increasing* the net overall level of employment.[4] New jobs can be created not just in industries which make and install energy conservation materials and equipment, but also in the rest of the economy through the "re-spending" of the consumer dollars which would otherwise have been spent on energy. In general, energy producing industries are considerably less labor intensive than almost all other sectors of the economy.

The key. point is that the U.S. economy has the potential to make an enormous number of changes over the next 20 years:

- Energy prices will provide an incentive to make further energy efficiency improvements. Under standard business economics, it will become cost-effective to invest in more efficient buildings, equipment, and practices.
- Rising energy prices should induce consumers to insulate houses better, drive smaller cars, use more efficient appliances, etc., assuming they have the resources and information needed to change.
- On the negative side, high prices will hurt those on fixed and low incomes. There may also be problems with reduced consumer buying power, thus causing slower economic growth.
- The Federal government is finally moving to stimulate both more production of energy and more conservation. This should eventually have an effect.
- *If* there are stable economic conditions, *then*, in the broad view, many different combinations of business practices, social patterns, and market baskets of goods and services would be compatible with economic progress at varying levels of energy.

The Need to Understand the Risks of the Various Alternatives

So why be alarmed if, indeed, such a range of options is feasible? The answer is fourfold and emphasizes the fact that all of our options entail *considerable risk*. (1) There is much about our energy picture, present and future, which is irreducibly uncertain. (2) Given these high levels of uncer-

WHAT IS ENERGY CONSERVATION?

Conservation is not curtailment, it is more efficiency and greater productivity.

Conservation is properly interpreted as efficiency improvements, so that we are more productive in our use of energy for various purposes. Conservation gives the same amenity with less energy. This usually means replacing energy-wasteful equipment with energy-efficient equipment. At higher energy prices, this pays for itself. In most cases, there is no particular need to cash in existing machinery, cars, buildings, appliances, etc., before their time. It will also pay to change business practices to eliminate waste and to make people energy-cost conscious, both at home and at work. The lifestyle changes required will simply grow out of adjustments to higher energy prices, especially if we develop equitable programs to aid those most affected by rising energy costs. Little sacrifice is required.

It is commonly believed that "*conservation of energy*" means doing without, cutting back on what we want or need to do. The idea was picked up in the 1973–74 crisis, when lines formed at gas stations and people were told to "dial down" the thermostat. This is better described as *curtailment*—which is what happens when there's a short-run shortage of energy (also called a shortfall).

Shortfalls are not the same as deficits. An energy shortfall is a short-run drop in energy supply, as when we cannot get enough gasoline for some months, but then a recovery occurs. An energy deficit is the long-run condition of having our economy geared up to need or demand more energy than we can on average supply. In a long-run deficit condition, by straining ourselves we would get enough energy some years and not enough other years. Prices would rise and output would decline. The long-run solutions to deficits are to be able to produce enough energy from different sources and to become more efficient energy users. Thus, economic output could be maintained without repeated energy shortfalls.

tainty, efforts to change current energy use patterns could easily go in the wrong direction or be started too late. (3) Continued energy-based shocks to the economy could create an economic environment which is not strong enough or stable enough to support the large-scale transition which will be required in the years ahead. (4) Some industries, occupations, and regions may be hurt worse than others given the particular nature of their energy needs. Michigan's economy could well be in the poor group.

Pervasive Uncertainty

There is at present great uncertainty over our energy future. As detailed in the next section, experts disagree sharply as to how much energy, of what kinds, and at what prices, the U.S. can expect over the next 20 years. The highs and lows disagree by as much as 100 percent. The disagreements range from wild optimism about supplies "if only we will pay for it," to deepest gloom and forebodings of disaster "if we don't do X" (the forecaster's favorite panacea).

Because of the pervasiveness of our energy uncertainties, this report emphasizes risks and payoffs in terms of safer and riskier economic situations as a result of the jobs and energy link. One way to think about this is: What do we risk in job terms by acting as if the future will have lots of energy (when it may well not)? And what do we risk in job terms by acting as if the future will have very little energy (when it may well have more)? In general, if the U.S. produces more of its own energy and also conserves through increased efficiencies, then it will be less vulnerable to serious problems from energy shortfalls, economic shocks, and foreign control of energy supplies. If, on the other hand, energy supplies come out at the "low" end of projected levels, then serious disruptions and conflicts are likely. If demand is far greater than supplies, then social and political conflicts will escalate, at home and abroad, as individuals, corporations, and nations fight for as big a share as they can take. The poor, the weak, and the aged will probably be hurt the most.

Lead Time and the Risk of New Technologies

The development of new and untried energy sources, substitution to abundant energy sources such as coal and solar, and increased conservation will all require decades for planning, capitalization, and construction on a society-wide basis. Given high levels of uncertainty, many of our investments may prove to be unproductive, or worse. Yet our greatest threat may come from the inaction of business investors, and from consumers who may not receive consistent market signals which adequately reflect long-run changes until it is too late to act effectively.

The Risks of Economic Instability and Turbulence

There are a number of reasons to suggest that economic conditions may not be stable in the years ahead. Our path to the future may not look like a straight line on a graph, it may look like the jagged sawtooth of boom and bust cycles. We live in a turbulent world with problems such as revolutions, unstable Middle Eastern oil supplies, and many other kinds of disruptions. Many problems easy to manage in stable times become worse in crises. Michigan's auto-based economy, for example, suffers excessively in recessions. Repeated recessions like those of 1973–75 and 1979–80 could make it much harder to make necessary adjustments. For this reason, our analysis does not assume equilibrium (stability) for the years between now and 2000, as do many other studies. Equilibrium approaches tend to assume away and average away the most serious problems, uncertainties, and risks to be confronted. In contrast, the approach of this study *emphasizes* analysis of the uncertainties and risks in our situation.

As noted earlier, if given a smooth transition period, enough advance warning, and good energy-economic management, the U.S. could satisfactorily make a transition to any of several alternative levels of energy supply. This may be true even for surprisingly low levels of supply.[5] However, in the face of shocks, turbulence, shortfalls, and conflict, the U.S. and Michigan economies could be unstable. Businessmen, investors, and consumers would be likely to lose confidence in the economy, thereby worsening each downturn. Thus, a transition could be very rocky indeed. Unfortunately, there may well be some unknown low level of energy, below which the scarcer are energy supplies, the more economic instability could be expected. Unfortunately, economic instability is quite possible in the years ahead from a wide range of additional sources.

Table 3.3 lists 13 major sources of potential turbulence over the next 20 years. Nearly all of the shocks are capable of triggering major consequences (see Table 3.4), or worsening recessions in the U.S. economy or in regional economies such as Michigan's. The reader, no doubt, could add additional problem areas to the list. Realistic consideration shows that it is prudent to expect more of these troubles in the next 20 years than in the past. It is worth noting that it took the U.S. economy four years to recover from the combination of the oil shock of 1973 and the Russian grain deal of 1974. Repeated exposure to such shocks leaves an economy reeling. All it would take is several of these 13 problems, appearing within a few years span to cause a similar, or even worse, recession. This is extremely likely sometime during the next 20 years.

Special Risks to Subsectors of the Economy

Given the size and complexity of the U.S. economy, it is quite likely that, even if the national energy supply and demand picture should look satisfactory in the aggregate, conditions in specific industries, occupations, and regions may be quite different. New England, for example, depends disproportionately on petroleum, whereas Michigan depends disproportionately on coal and natural gas. Or, as noted earlier, even a mild downturn in the

TABLE 3.3

Potential Sources of Turbulence Over the Next Twenty Years

1. Severe weather—several heavy winters or droughts in a row, with heavy impacts on fuel use and food supply.
2. International monetary instability—reduced value of the dollar, banking failure, etc.
3. Natural resource shortages—leading to bottlenecks, inflation, and political/economic blackmail by cartels.
4. Nuclear proliferation—problems with uncontrolled weapons, fallout, low-level radiation, nuclear blackmail, waste disposal accidents, etc.
5. Major labor strikes—coal, railroads, trucking, or other key areas.
6. Middle East turmoil and wars—price shocks, cut-offs, production cutbacks.
7. Oil supply interruptions from other sources—Venezuela, Mexico, Alaska pipeline, etc.
8. Disruptions in U.S. nuclear generating system—moratoriums, major shutdowns for safety problems, etc. Major power system network failures—blackouts and brownouts.
9. Food shortages—regional, national, or international, resulting from poor weather, high cost, or unavailability of fertilizers, etc.
10. Environmental disruptions beyond threshold levels—micro or macro, resulting from phenomena such as major inversions, acid rains, major oil or chemical spills, carbon dioxide buildup, etc.
11. Major water shortages or contaminations—massive impacts on health and production processes.
12. Urban violence—massive disruption and destruction of urban sectors resulting from dissatisfaction in areas such as civil rights, the economy, equity with respect to energy issues, etc.
13. Runaway inflation, disruption in capital markets, and other assorted economic ills.

national economy can have very serious impacts on the automobile and construction industries and on the Michigan economy. In short, local circumstances are important and may provide a very different picture of risks and opportunities than is presented at the national aggregate level.

Studying the Future Through Alternative Scenarios

The magnitude of the energy transition we must go through in the years ahead and the pervasiveness of the uncertainties in that transition are indeed awesome. To deal more effectively with our situation we need realistic and vivid images of alternative future outcomes which can aid current decisions by informing us about the risks and payoffs of pursuing alternative strategies. This study has used alternative future scenarios to provide this kind of imagery in the area of jobs and energy.

Our images of the future are typically based on our images of the past. Future scenarios are no different, except for a systematic attempt to include aspects of the future which may differ from the past. There are several emergent facts about our future, different from our historical experience, that may be surprising and which will affect all of the energy and economic scenarios which follow.[6]

TABLE 3.4

Consequences of Turbulence (Shocks, Shortfalls, etc.)

- Nasty social-class conflicts
  - middle class wanting inflation controlled, at the cost of job losses
  - working class wanting jobs kept up, at the cost of inflation
  - big losers would be people on fixed incomes, and non-union blue collar and marginal white collar
- Inability of capital markets to function properly
  - string of bank failures
  - international currency crisis
  - inability to shift to energy efficiency
- Harm to selected industries or regions
  - auto industry depression
  - economic decline in the industrial Midwest
- Harm to selected consumers and lifestyles from price rises and instability
- Tendency to crisis response patterns in a short-run rationality mode that's harmful in the long run. Politics of "jobs vs. environment" and "energy at any cost" vs. many social/environmental values.
- Irrational or extreme political responses, including authoritarianism or anarchism, either sparked by energy shortages or terrorism.

- Population growth will be slow in Michigan and the U.S. to the year 2000. This will cause an aging population, with fewer children born, a lower percentage of youths, and a lower percentage of workers supporting more old people. One consequence of this is that the "full employment" GNP growth rate does not need to be as fast as the 3.5 percent that has been necessary historically. In the future, 2 percent to 2.5 percent growth may be sufficient to give "full employment." (We assume for all scenarios a year-2000 population of 245 million which corresponds to the Census Bureau Series III projection of U.S. population growth.
- Historically, the U.S. has experienced steadily declining energy prices (in deflated or "real" dollars), compared to other goods and services. Even after the 1973 oil crisis, the higher 1974 prices started edging downward again (in real dollars). When compared to the higher prices of other goods, energy was still a bargain. This will most likely never be true again; prices for most fuels will rise faster than other prices. Hence, the kinds of decisions about energy by businesses and consumers that were seen in the last 20 years are unlikely to be repeated in the next 20 years. Energy will, in all cases, be scarcer and dearer and, in some future scenarios, it could be incredibly more costly. Whatever uses a great deal of energy today is likely to be less common and more costly in the future. The auto industry, for example, is likely to remain under intense pressure to change its product line and, in the long run, may grow more slowly than in the past, or may even decline.

- The past U.S. business pattern of creating and marketing new energy-intensive consumer products (consuming a lot of energy every time they are used) will disappear. Many basic amenities have been made more comfortable or convenient for customers by energy-intensive technology over the last 50 years. However, many of these markets—for example, for transportation, home and office heating/cooling and lighting, and household conveniences—are nearing saturation. The future's new products are more likely to be low-energy users like calculators and home computers.
- The past pattern of rapid growth of wages and salaries for U.S. workers has probably reached a limit. While wages and salaries will still grow somewhat, the growth will be slower for most groups, and many groups may permanently lose ground due to inflation losses. The aging population will have more retirees on relatively low incomes. The past pattern of fast wage growth led employers to substitute energy and capital (such as automation equipment) for workers. As discussed in Chapter 2, energy shortages and higher costs will probably cause marginal substitutions back toward more workers, at wages which will be good but not much higher than now in relative terms. As a result, the past's big increases in consumer buying power are likely to be gone, with only slow increases for the future. These slower growth effects come from a slower growth in labor productivity, a slower growth in the full employment economy, an older population which is not increasing as rapidly, higher direct energy prices, and higher relative prices for other consumer goods which require energy for their production. The higher energy prices will be equivalent to an income-reducing tax on all workers and households.

Forecasting Energy Supplies for the Year 2000

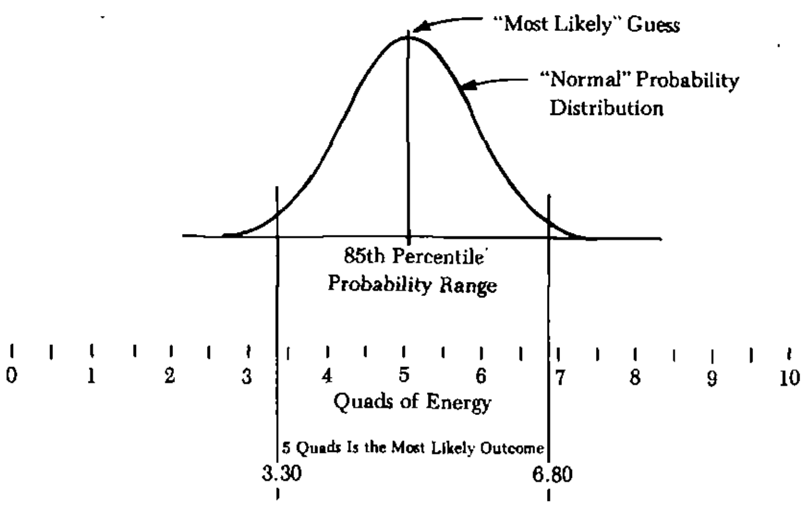
As suggested earlier, we have no data about the future, only about the past. As a result, statements about the future are based on past experience, with assumptions that some things will change very little and that others will change in fairly predictable amounts and directions. Simply extrapolating past trends can be dangerous, however, for what caused the trends may itself be changing. This is especially true for energy. Physical facts and relationships are easier to extrapolate to the future than social, political, and economic ones because the former are simpler, change more slowly, and have greater scientific understanding than the latter. Thus, it is easier to talk about the physical supply of energy than the energy to be supplied by business and nations, or the future energy demand by businesses and households. Moreover, even the physical supply of energy has a risky enough economic component, and enough competing ideologies, organizational interests, and personal biases that these "facts" are also in dispute.

A NOTE ON THE METHODOLOGY FOR FORECASTING ENERGY SUPPLY

The following example may help to illustrate the approach used in developing the energy supply scenario. Figure 3.4 is a probability distribution based on expert forecasts about the future supply of some form of energy. There will be only *one* actual number for this fuel in the year 2000. A "normal" probability curve has been constructed on the assumption that the actual supply level will fall within the 85th percentile confidence band of the energy forecast distribution. In other words, our view is that the odds are 85 percent that the future will match *some* expert's estimate and that the most likely outcomes are in the middle of the range where the hump of the probability curve is highest. For us to act now, our "best bet" is to take the peak of the curve as the most likely value, while giving considerable attention to the range of the forecasts. This will factor in many different aspects of the problem and factor out many biases. It will allow us to think about likely outcomes as they appear now, but it will not tell us what *the* future will be. The steeper the curve, the smaller the range, and the lower the risk in acting as if the most likely estimate is correct.

FIGURE 3.4

A Probability Distribution for Future Energy Supply



However, we *can* take the various forecasts as "social facts" *in themselves*. A quasi-statistical approach can be used to lay out the range of these forecasts for each fuel type and to construct representative energy supply scenarios corresponding to these possible outcomes. Such an approach seeks not simply to derive a single "most likely" forecast, but rather to emphasize the range of possible outcomes explicit in our uncertainties about the future. Some energy forecasts (like for hydroelectric power) have a small range; we are fairly certain how much we will have in the year 2000. Others like coal have a big range; we know there's a lot of coal in the ground, but there are many social, environmental, and economic uncertainties about its use by 2000.

Figures 3.5a and 3.5b show a series of probability curves for each major contribution to U.S. probable total energy supply in 2000: domestic oil and natural gas, imported oil and natural gas, synfuels (liquids and gases), hydroelectric power, nuclear power, and solar/renewable energy.

These probability curves were constructed based on the numbers shown in Table 3.5 in the column labeled "Energy Policy Group 85% Confidence Interval." These estimates were developed by the Energy Policy Group based on an examination of a wide range of expert forecasts, combined with our own judgment of probable supply levels under the business-as-usual assumptions of this study.[7] Table 3.5 also shows several other recent expert forecasts for comparison with the EPG numbers.

Several points are worth noting about the distributions. First, the means and ranges of the probability distributions are consistent with this study's business-as-usual assumptions. That is, extreme energy supply values tend to violate business as usual by requiring extraordinary subsidy or optimism for high supply levels and by requiring great pessimism and/or ineptitude by business and government for low supply levels. It should also be noted that, at present, nearly all energy forecasters are sharply revising previous estimates downward, largely because past forecasting approaches have proven to be over-optimistic on the supply side and over-pessimistic on the demand side. Thus, the more recent forecasts tend to cluster in the low to mid range of the probability distribution.

Under business-as-usual assumptions, it is time for the U.S. (and Michigan) to face realities: we cannot get the energy we want at the prices we are used to. We may not get all we want at any price. As a supplement to the quantitative projections of Table 3.5, the following qualitative discussion of alternative energy supplies reviews some of the major factors which will affect U.S. energy supply over the next two decades.

Petroleum Liquids

Domestic Oil. The expert consensus is now growing that the estimates for oil (and gas) developed 20 years ago by Dr. M.K. Hubbert are turning out to

FIGURE 3.5a

Probability Distributions for Various U.S. Energy Supplies, Year 2000

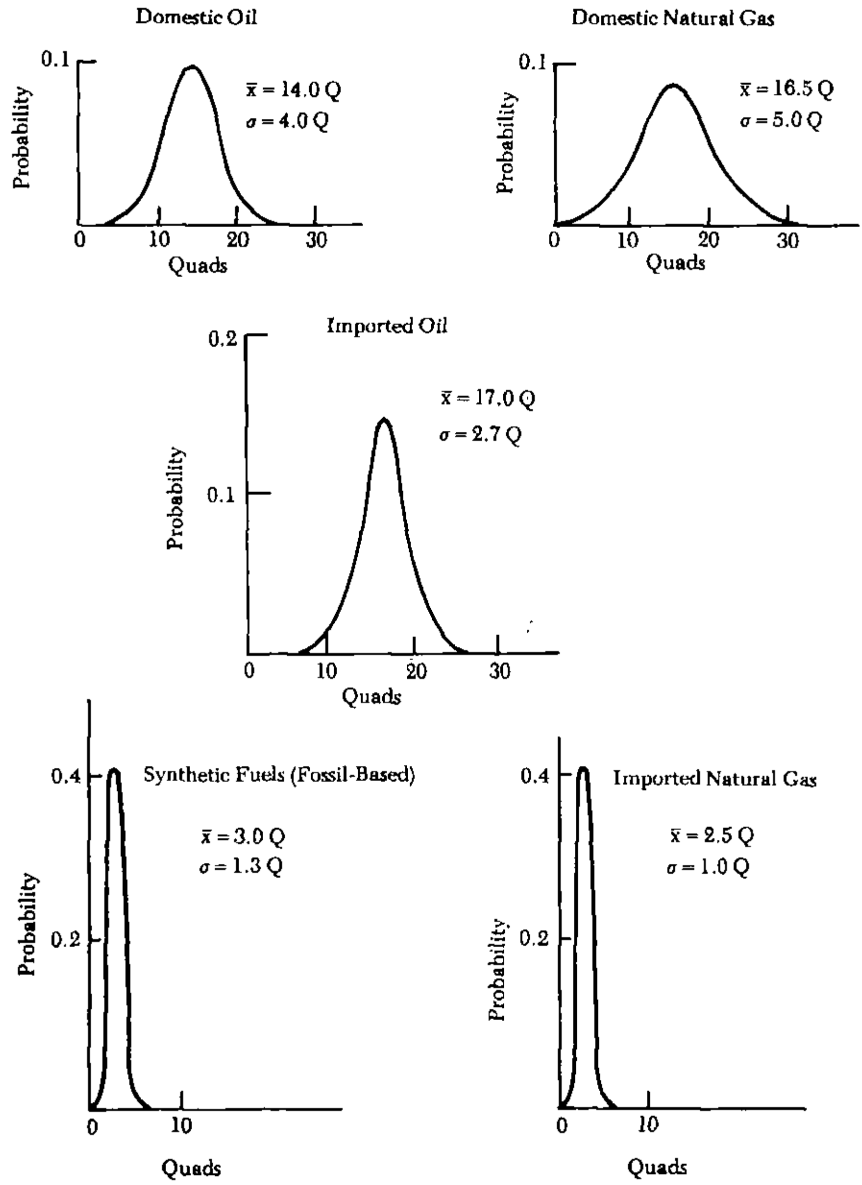


FIGURE 3.5b

Probability Distributions for Various U.S. Energy Supplies, Year 2000

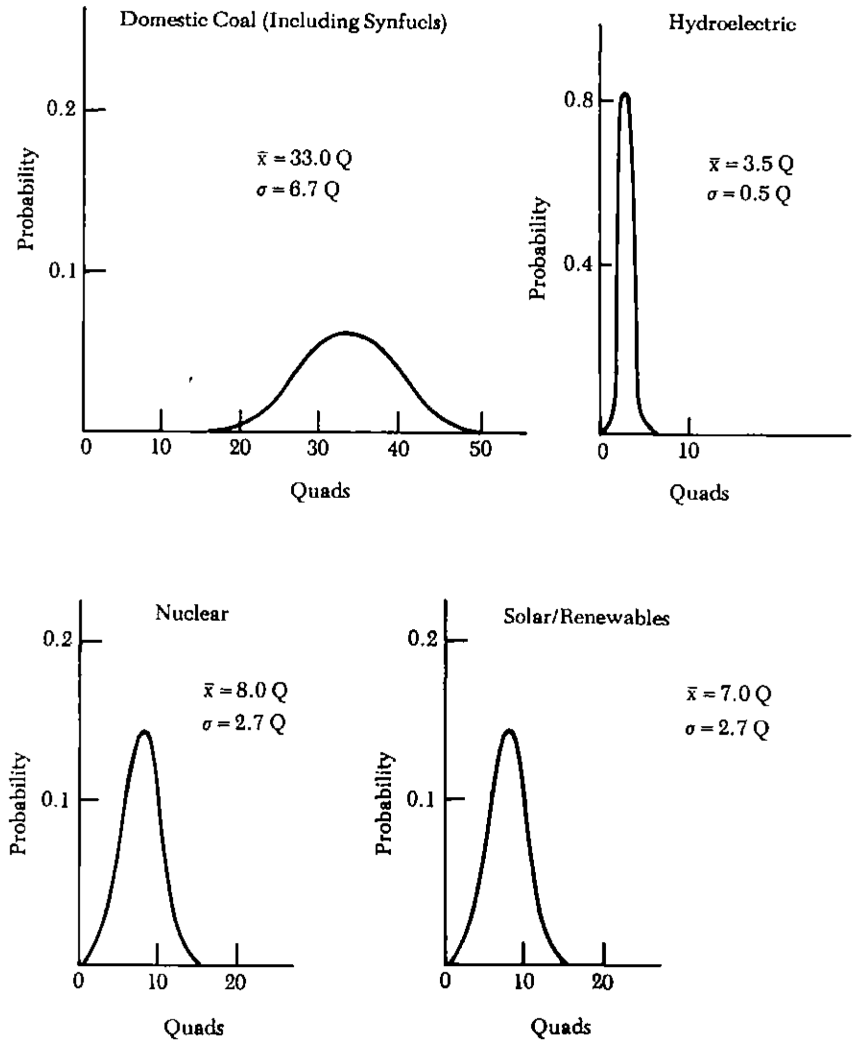


TABLE 3.5

Comparison of EPG Projections and Other Forecasts of U.S. Primary Energy Supply in the Year 2000 (Quadrillion Btu's of Energy)

	Energy Policy Group 85% Confidence Interval[a]			Duane* "Probable"	
Fuel Types	Low	Medium	High	Case	Hayes**
Petroleum Liquids	1	31	41	31	32
Domestic[b]	8	14	20	16	15
Imported	13	17	21	15	17
Natural Gas	10	19	28	14	10
Domestic	6	12.5	19	9	6
Conventional	3	4	5	–	3
Nonconventional	1	2.5	4	5	1
Imported	1	2.5	4	5	1
Coal	23–28.5	30–33	32–43	30	32
Non-Synfuel Users	23–28.0	30	32–38		
Synfuels[c]	0.1–0.5	0.1–3.0	0.1–5.0		
Syngas	0–0.5	0–3.0	0–5.0		
Synliquids	0.5–0	3.0–0	5.0–0		
Hydroelectric (FFE)	2.75	3.5	4.25	5	3.5
Nuclear (FFE)	4–8	8	8–12	10 15 20	11
Solar/Renewables (FFE)	3–7	7	7–11	5[d]	6.5
Representative Total Supply	71[e]	102[e]	130[e]	95 100 105	95

* John Duane, Consumers Power Company, in "Michigan Energy Prospects to the Year 2000," by MERRA and the Michigan Energy Administration, May 1979.

** Earl Hayes, "Energy Resources Available to the United States, 1985–2000," *Science*, 203, January 19, 1979.

[a] See Figure 3.4 for explanation of confidence interval approach.

[b] Includes estimates for shale oil and enhanced recovery.

[c] The values shown here are for primary energy inputs of coal (in quads). Only about 60 percent of the primary energy will be delivered in the form of synthetic gas and oil.

[d] Duane's value is definitionally lower by excluding some categories of solar thermal as "conservation." The EPG and Hayes definitions include: Solar thermal, solar electric, wind electric, biomass, and geothermal.

[e] Coal, nuclear, and solar/renewables are all competitive for investment funds; it is unlikely that all would be high or low together. The total supply figures presented here reflect our best guesses as to the outcomes of this competition in overall terms.

be remarkably accurate. Numerous independent studies using different estimating techniques confirm this conclusion.[8] These studies suggest that the U.S. will be effectively out of economically recoverable conventional domestic oil in the first few decades after 2000. It will be difficult indeed to escape the conclusions of these studies since they already incorporate into their analyses the fact that energy prices will rise dramatically and that more expensive recovery methods and some major new finds (such as Mexican oil) can be expected in the years ahead. That the increased rate and depth of drilling for new oil over the past few years has not added greatly to known reserves, only serves to underscore the probable accuracy of the Hubbert conclusions. EPG has estimated the most probable level of domestic oil production at 14 quads for the year 2000. This figure includes expected contributions from enhanced recovery methods and shale oil.

Imported Oil. While geological limits apply to imported oil as well as domestic, the more immediate and serious constraint has to do with the political and economic problems which flow from heavy dependence on imported oil. Dependence on imports severely hurts balance of payments problems and the value of the dollar. Of equal seriousness is the vulnerability it creates by leaving the country open to the shocks of cutoffs and distortions in foreign policy. Furthermore, it is becoming quite clear that the oil exporting countries are seeing the wisdom (from their perspective) of limiting their exports in an effort to maximize the long-run value of their oil resources and to allow for more manageable short-term growth of their internal economies.

While these political and economic factors could change over the next decade, drastic changes are not probable. The EPG estimate of 17 quads of imported oil is in close agreement with those projected by Duane and Hayes for the year 2000.

Synthetic Oil. There is little doubt that synthetic coal-based oil will make some contribution to domestic oil supplies by the year 2000. However, within this time frame, that contribution is likely to be relatively expensive and small. It now appears that, contrary to President Carter's initial proposal for a large-scale crash program, a substantial period of research, development, and demonstration will occur before massive commitments to numerous large-scale production facilities. This approach, which is probably a necessary one, means that large amounts of synthetic oil will not be available much before the mid to late 1990s (Marshall, 1979; Carter, 1979; and personal communication with Dr. Elton Hall, Battelle Memorial Institute). EPG has estimated a range of .3 to 3 quads of synthetic oil by 2000, based on a primary fuel input of .5 to 5 quads of coal. This is a highly uncertain area, subject to both technological and political choices over the years ahead. It is likely, however, that within the time frame examined by this study, synthetic oil will only provide marginal assistance to the U.S. energy picture. The EPG's mid-range estimate is a maximum of 1.8 quads by 2000.

Natural and Synthetic Gas

Domestic Natural Gas. Estimates of future natural gas supplies are similar to those for petroleum in that geologically based estimates tend to suggest a smaller potential supply than do economically based approaches focusing on price/supply relationships. In the case of natural gas, however, there exists in both approaches less agreement among experts as to ultimate supply levels. Over the past decade, the domestic rate of discovery has been only about half the rate of annual production. What is unclear is the increment in discovery rates which might be expected from deregulation of natural gas prices. It is this factor which will determine whether current rates of natural gas consumption can continue for the next decade or the next century. Unfortunately, as the recent Harvard Business School study points out, "a range of estimates that varies between 15 and a 100 years is hardly a sure guide for policy" (Stobaugh and Yergin, 1979).

EPG's estimate of 19 quads of natural gas supply in 2000 is higher than those of Duane or Hayes due to greater emphasis on the wide upward range of industry analyses of effects of price decontrol. Should decontrol of natural gas prices be stopped, the EPG estimate would have to be adjusted downward toward the Duane and Hayes estimates.

Imported Natural Gas. Pipeline-fed imports of natural gas from Canada and Mexico are not expected to amount to more than about one quad annually over the years ahead. (Stobaugh and Yergin, 1979). Most observers attribute this to a reluctance on the part of these countries to commit large amounts of this precious resource for external use and a reluctance on the part of this country to recreate for gas the same dependency situation which has occurred for oil. The potential for importation of liquified natural gas (LNG) is likely to be limited by these same concerns, as well as by concerns over cost and safety. The EPG estimate, therefore, has been limited to a median level of 2.5 quads, with a range of 1–4 quads in the year 2000.

Synthetic Gas. The synthetic coal-based gas situation is much the same as for synthetic oil. It will make some contribution by the year 2000, but that contribution is likely to be a marginal one at best. EPG has estimated the same range for syngas as for synoil, .3 to 3 quads per year based on a primary fuel input of .5 to 5 quads. As explained in Table 2.3, however, the combined total for these two coal-based synthetic energy sources is not expected to total more than 3 quads of delivered energy (Marshall, 1979; Carter, 1979; Hall, personal communication, Fall 1979). The EPG mid-range estimate is for a maximum level of 1.8 quads. Clearly, if the lower projection levels prove to be accurate, synthetic gas will not provide sufficient new supply to cover the gap between available supply and current levels of consumption.

Coal

The problem with coal is not supplies in the ground — we have enough for centuries. The problems are those of the industry in expanding production by a very large amount. At present, there is too little demand for coal, due to business uncertainties by users. Supplies can expand in the short-run, but, after a moderate expansion, an interlocking series of constraints will take over (Duane, 1979). The more significant constraints are: (1) unclear status of pollution laws, especially sulfur emissions; (2) problems with the condition of the railroads that transport coal; (3) potential labor instability; (4) opposition to environmental and water impacts of strip mining in the West's semi-arid regions; (5) negative impacts on communities near coal mining activities; (6) obsolete company managements and unsafe practices; (7) muddled coal leasing by government; and (8) delays from unclear federal policies. With all of this, coal output can more than double by year 2000, but it is generally agreed that federal officials have been over-optimistic in projecting very much more.

The critical short-term uncertainty for coal is the resolution of conflicts over the setting and enforcement of environmental standards, especially in current "nonattainment" urban areas. Solutions, here, whether through new technologies or relocation of plants to non-urban areas, are likely to be expensive. Over the long-term, considerable uncertainty exists over the potentially serious problem of CO_2 buildup in the atmosphere (Chen, Winter, and Bergman, 1979). The EPG mid-range estimate of 30–33 quads of coal in the year 2000 is in basic agreement with the estimates of Hayes and Duane.

Hydroelectric Power

As Hayes argues, "It has taken more than 50 years of effort to reach a level of 57 gigawatts of installed generating capacity that produces 2.7 quads of energy from hydropower. The better sites have been used, and even an accelerated effort (the current Administration has a deceleration policy) will produce only a modest addition" (Hayes, 1979). Based on analyses made by the Federal Power Commission (1976), the EPG estimates 3.5 quads of hydroelectric power for the year 2000.

Nuclear Power

After the Three Mile Island incident, Duane added a strong caveat to his U.S. and Michigan energy projections, saying of his 20-quad estimate for nuclear power that it could just as easily be 10 quads. He saw the key problems as political. Ten quads would, in fact, be consistent with recent Department of Energy projections of 8 to 12 quads by the year 2000. Since 1972, projections for nuclear capacity have dropped by a factor of four. During this same period, many standing orders for new plants have been cancelled or postponed (Landsberg et al., 1979; *Business Week*, Nov. 19, 1979). As a result, according to a recent Ford Foundation-sponsored study, ". . . a substantial excess in manufacturing capacity now exists in both the United States and Europe." The report from that study went on to summarize the situation this way:

> In these circumstances, speculation about the future of nuclear power is necessarily fraught with great uncertainty—an uncertainty heightened by the Three

> Mile Island accident. The growth of the industry will depend on the regulatory environment (and not only on that affecting nuclear power directly, but also on that affecting its competitors), on local attitudes, on the resolution of such questions as spent fuel storage and waste disposal, on the constraints imposed relating to nonproliferation objectives, and presumably not least on economic consideration. (Landsberg et al., *Energy: The Next Twenty Years,* 1979.)

The Ford Foundation study is one of three major new studies of energy, which as a package represent the most recent thinking of over two dozen leading technical and policy experts.[9] In calling attention to the overall message of these studies, *Newsweek* found them to reflect a "silent optimism" and considerable agreement (*Newsweek,* Sept. 24, 1979). All three studies view the environmental constraints on coal to be very serious and conservation as having a major role in future energy planning. Our report concurs on both points. The three studies also reflect the general trend noted above with respect to a downward shift in expectations about the future role of nuclear power. *Newsweek* made the point this way:

> Even on the highly controversial subject of nuclear power, the three studies reach roughly the same conclusion: because of the thorny issues, both technical and political, that surround it, nuclear fission cannot be counted upon for a major contribution to the American energy mix in this century.

It is possible that over the long term the political, regulatory, and economic environment for nuclear power could turn more supportive, for example, as a result of electrical "brownouts" or curtailments of imported oil. However, the short-term indicators seem to point toward a less supportive environment at least for the foreseeable future. On the *political* horizon, for example, opposition to nuclear construction has become more vocal and gained in coordination over the past year, especially after the Three Mile Island incident. With such highly emotional issues and high stakes, the probability of continued activist opposition, judicial interventions and delays, and even sabotage and terrorism are likely to increase. The same can be said for more traditional forms of political opposition as politicians and bureaucrats respond to real and imagined problems and fears and pressures of constituents.

On the *regulatory* horizon, the Three Mile Island incident can only mean that nuclear power will be subject to an even more stringent regulatory environment in the years ahead. This is clear already just from the recommendations of the President's Commission headed by Dr. John Kemeny (Kemeny, 1979). In addition to this study, however, there are at least six different commissions set up to make recommendations with respect to nuclear power and the Three Mile Island accident (Burnham, 1979a). Such recommendations will have to be sufficient to convince the public, political decision makers, investors, and technical experts that nuclear power can be safely and economically used on a large scale over many years.

On the *economic* horizon, there is also considerable uncertainty. An early and major appeal of nuclear power has been its economic advantages over other types of electricity generation. That advantage is now in doubt as regulatory and licensing requirements mount, as the recovery costs of crippled reactors are considered (Three Mile Island may cost several times more to clean up than it originally cost to build), and as decisions are made as to whether investors or rate payers will pay for construction and clean-up operations (Burnham, 1979b; *Business Week*, July 30, 1979). Similarly, the economics of nuclear insurance could change dramatically in the years ahead. Recent reports indicate that such considerations have led major actors in the investment community to move "cautiously on the question of long-term financial backing for the nuclear industry" (Burnham, 1979b).

Even prior to the Three Mile Island incident, however, the Wall Street financial community and some utility companies had begun to show caution on the nuclear question. Recent studies from within the business community have argued that nuclear technology was oversold by manufacturers (or in the case of waste disposal, not fully developed). What had appeared to be a cheap and reliable means of producing electricity has instead been plagued by continued delays and escalating costs of plant construction. For example, in Michigan, Consumer Power's Midland I and II plants were originally budgeted at $350 million, with completion scheduled for 1975. As of early 1980, however, the costs had escalated to a minimum of 3.1 billion, with completion not before the end of 1984 (*Wall Street Journal*, March 4, 1980). While lead times and costs have also increased for coal-fired plants, the record is worse, on average, for nuclear plants.[10]

The recent Ford Foundation study, which was administered by Resources for the Future, points out a number of additional problems which have befallen the nuclear option over the past five years.

> In adding new electrical generating capacity, the choice between nuclear and fossil fuel plants has been increasingly dominated by uncertainty about future demand for electricity. Projection of future demand has been very uncertain since 1974, and the electrical utility industry has consequently been disposed to delay commitments as long as possible. This uncertainty has weighed heavily against the nuclear choice, because licensing and construction time has been much longer and capital costs larger for nuclear units. It has been entirely rational for utilities to accept the possibility of higher fuel costs if a plant must be built (the extreme case obtaining with gas turbines) in preference to a very early commitment to large capital costs for a nuclear plant for which there might not be adequate demand by the time it becomes operational. The points are made in [Table 3.6] which gives some illustrative estimates, which would have been appropriate for the United States two or three years ago, of construction time, capital costs, and fuel costs for alternative generating options.
>
> The total time for construction and licensing of nuclear plants has probably increased by a couple of years since then and that for fossil fuel plants by even more—perhaps by as much as four years—with the passage of the 1977 amendments to the Clean Air Act and the requirements for "best available control technology" (for sulfur dioxide emissions) and "prevention of significant (air

TABLE 3.6

Estimated Costs of Adding Electrical Generating Plants

	Nuclear Units	Coal with Flue Gas Desulfurization	Oil, Steam Generation	Oil, Combined Cycle	Oil, Gas Turbine
Construction and Licensing Time	10 years	6	5	5	3
Capital Cost per kWe (1976 dollars)	$700	600	450	370	200
Fuel Cost Mils per kWh (1976 dollars)	6	12	21	16	24

SOURCE: *Energy: The Next Twenty Years*, copyright 1979, the Ford Foundation; reprinted with permission from Ballinger Publishing Company.

> quality) deterioration." These considerations, and uncertainty about public acceptance of nuclear power, disposal of nuclear wastes, the future regulatory environment for both nuclear and fossil fuel power plants and future demand for electricity, make the planning of additional generating capacity extremely difficult.
>
> In other countries, additional considerations may militate against a nuclear choice. Among these are foreign exchange problems, the fact that nuclear units tend to be too large for small grids, and uncertainty about access to fuel.
>
> In the light of these considerations, simple comparisons of generating costs are not likely to be controlling in decisions about new generating capacity even where they are made, as in the United States, by utilities. (Landsberg et al., *Energy: The Next Twenty Years*, copyright 1979).

These cautionary notes do not mean that nuclear power has no future. When the risks of continued heavy emphasis on nuclear power are balanced against the risks of coal, may observers will find nuclear to be the more attractive alternative, especially so in light of the very large investment already made. But a realistic appraisal does suggest that the future of nuclear power is likely to be difficult and cloudy. This point has been dramatically demonstrated by Detroit Edison's recent cancellation of construction for two large nuclear plants. While continuing to publicly support nuclear power, Edison officials indicated that changes required in the aftermath of the Three Mile Island incident had made the project's design obsolete, and that the $4 billion plus price tag was more than the company could afford (*Ann Arbor News*, March 25, 1980). The Ford Foundation study concluded that "in attempting to look beyond 1990, we have no good basis for concluding that lower bounds on nuclear generating capacity for the world, or for that matter for the United States, will be higher than our estimates for the late 1980s." This reasoning would place a lower bound on nuclear power in the year 2000 in the range of four to six quads. This would represent a 2.5 to 4-fold increase over the current 1.6 quad U.S. capacity (late 1978;

Landsberg et al., 1979). As a lower bound, this would correspond to a scenario in which the 72 currently operating reactors are joined by the 91 additional U.S. reactors now having construction permits. While many of the more optimistic nuclear observers would view this as a very pessimistic scenario even as a lower bound, a 4-fold increase in nuclear capacity by 1990 in the face of the political, regulatory, and economic uncertainty cited above could end up being a substantial victory for the currently sagging nuclear industry.

In light of the uncertainties and problems cited above, the EPG forecasts a range of 4 to 12 quads, with a most probable level of 8 quads nuclear in the year 2000. This range discounts the more extreme voices (both pro and con) in the ongoing nuclear debate. At the lower end, it foresees the completion of all currently approved nuclear plants. At the mid-range, it foresees growth by a factor of 5 over current levels. And, at the high end, it foresees growth by a factor of 8 during the next 20 years. Overall, this projection suggests nuclear power would be contributing 6–10 percent of the country's primary energy supply in 2000.

Solar/Renewables

Solar/renewables technologies are a mixture of diverse energy sources, no one of which will be enormous, but which taken together can make a significant contribution by the year 2000. Experts disagree sharply, with numbers going from a churlish 1 quad to a utopian 30 quads. There is not even total agreement as to what types of energy technologies should be included under the generic heading of solar/renewables. This "accounting" problem often makes it difficult to compare different projections of future solar energy contributions. Nonetheless, widely respected studies have indicated a larger potential for solar/renewables than had been anticipated even just a few years ago. The recent Ford Foundation report while stopping short of forecasting a particular goal or expected contribution from solar, stated that ". . . we are basically optimistic about the contribution that solar energy can actually make to energy supply within our 20 year period" (Landsberg et al., 1979). This is especially noteworthy since the 19 widely respected authors of this study are not generally considered to be solar advocates. In fact, virtually every recent major study which has examined the solar/renewables option in detail has come to the conclusion that the potential for solar is extensive and increasingly economical as the price of other energy sources rise over the years ahead.[11]

The largest solar contribution will be for home and commercial *space heating and water heating* rather than for electricity. These applications are sometimes counted as conservation rather than energy supply. For example, a home with passive solar heat could, for accounting purposes, be viewed as a very efficient structure. As the price of conventional heat sources rises, solar heating of this type will have enormous potential. In the short-term, however, it has the problems of handicraft-level production and installation and numerous institutional barriers such as housing codes, retrofit problems, property taxes, lender policies, and lack of business and homeowner information. Current trends would suggest that a solar space and water heating industry will develop in the years ahead along with streamlining of barriers by government and the financial community. *Solar electric*, however, will probably remain uneconomical for at least a decade, if not more, except for specialized applications in sunny climates. In some regions *windpower* could become significant, especially as new wind generator technologies become economically viable and commercially available.

Conversion of biomass such as trees, agricultural waste, and garbage can go several ways—to alcohol and methane, direct burning for heat (boiler fuel as well as home heat), and for electricity. The U.S. once used huge amounts of wood and can be expected to return to it. Scandinavian countries use wood for 8 to 15 percent of their energy needs; the U.S. could eventually do far more than at present, up to 5 percent (3 or 4 quads; Stobaugh and Yergin, 1979).

The CONAES Demand and Supply Panel argued that as energy prices rise, different solar and renewables options will become competitive in the 1990s, accelerating rapidly to penetrate various markets, and by 2000 would be at a moderate 7 quads (and by 2010 up to 15–20 quads).[12] EPG adopted this 7 quad estimate as a mid-range value which might be anticipated under business-as-usual assumptions. Many qualified solar analysts (and most solar advocates) would argue that this is too conservative and that at least 12 quads is more realistic. Such views might well be justified in years ahead if problems and cost increases for other energy sources become more severe. However, a solar contribution at that level, while possible and perhaps desirable, would go well beyond business as usual with respect to future investment patterns, building design, and lifestyles.

Growth in Energy Demand

The individual probability distributions for each major fuel source (Figures 3.5a and 3.5b) have been combined in Figure 3.6 to form a probability distribution for the total amount of primary energy supply that the U.S. can expect in the year 2000. Note that the most probable supply level is 102 quads. This is compared with various growth rates on the bars below. The most likely average energy growth rate (corresponding to a supply of 102 quads) is in the vicinity of 1.3 percent per year to year 2000. The absolute upper-limit of what can be expected is 2.5 percent per year. Practically speaking, energy growth will most likely be faster than 2 percent in the near term and slow toward zero growth by the end of the century. This may be seen in Figure 3.7, which compares alternative growth patterns in energy

FIGURE 3.6

Probability Distributions of U.S. Energy Supply (Quads) vs. Demand Levels

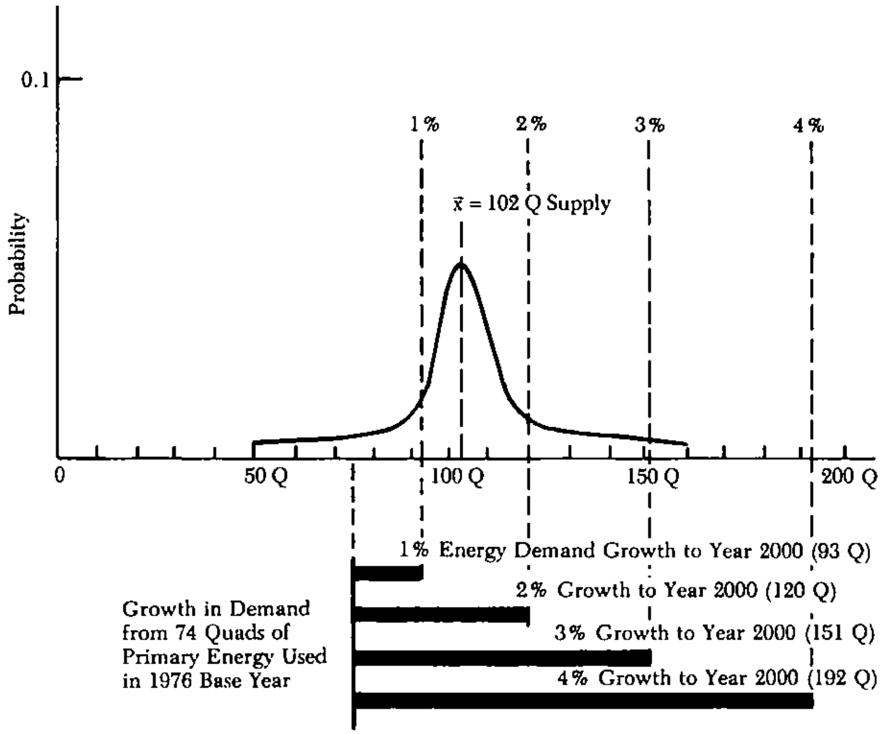
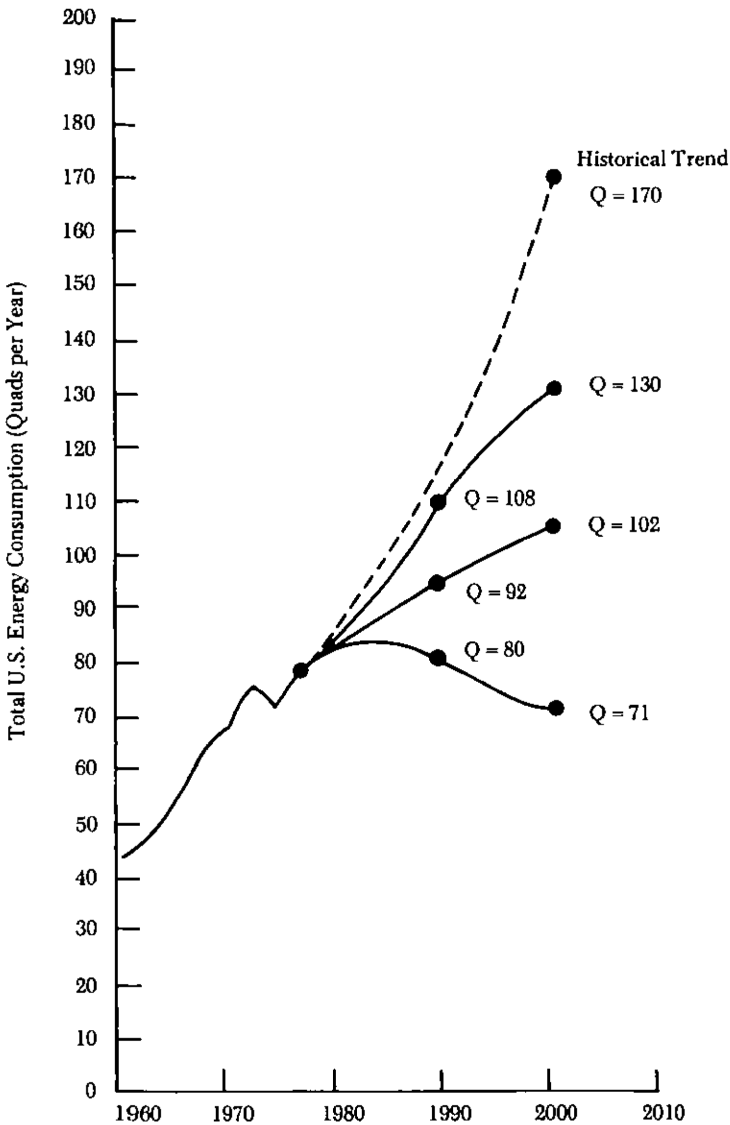


FIGURE 3.7

Possible U.S. Energy Consumption Paths to Year 2000



consumption. Put another way, what the probabilities in Figure 3.6 show is that zero energy growth (no more energy than we have today) is just as likely as 2.5 percent per year energy growth, and neither is as likely as 1.3 percent per year growth. By way of comparison, even the higher rates are well below the 3–4 percent annual energy growth rate experienced prior to the 1973 oil crisis.

But could we meet the energy demands of a healthy economy with energy growth rates so far below historical levels? A qualified yes can be drawn from the work of the Demand and Conservation Panel of the recent CONAES study of the National Academy of Sciences.[13] The CONAES study examined four alternative energy futures for the year 2010. Of greatest relevance here is the 96 quad Scenario III which assumes an average .9 percent per year energy growth and a 2 percent per year GNP growth, a doubling of 1975 energy prices (in real dollars) by year 2010, and a business-as-usual kind of profile for the economy. Greater efficiencies are assumed to occur through well-known technologies only, due primarily to higher prices rather than intervention by government. Anticipated energy savings through efficiency gains are 25–40 percent for buildings and appliances, 25–35 percent in industry, 15 percent in agriculture, with autos at 27 miles per gallon. These seem realistic. Population growth accounts for a significant portion of the energy demand growth to 96 quads. The CONAES Panel, however, used Census Bureau Series II projections (279 million in 2000) which, in light of recent population trends, seem high and therefore conservative. Thus, a smaller U.S. Population (245 million), as assumed by the EPG scenarios using Census Bureau Series III, would mean that the U.S. would have even less difficulty adjusting to a 1.3 percent energy growth rate while maintaining prosperity.

Additional perspective is provided by the CONAES Scenario II projections for 77 quads consumption in the year 2010. This represents consumption at today's levels, after a peak in 1990. In order to have economic growth at 2 percent a year, real energy prices are assumed to quadruple. Vigorous government intervention would be required through incentives, taxes, regulations, standards, considerable research and development, and public education — all pushing toward very high efficiency energy utilization. This departs from the business-as-usual assumptions of this study. While this scenario is technically possible, many institutional changes would be necessary on a massive scale, with tight governmental regulation. The CONAES results do suggest, however, that over the long term, zero energy growth would *not* be inevitable disaster for the national economy, *if* the U.S. could restructure itself in time. This would probably require more of a political consensus than at present, much cleverness, and good luck in the transition period. The results could mean, however, that regional economies and, especially, states such as Michigan, might be badly hurt in such a transition.

TABLE 3.7

Potential Energy Supply–Economic Growth Patterns

	Economic Growth		
Energy Supply	High	Medium	Low
High and Stable	Scenario I "Normal" Good Times	Unfulfilled Expectations	Bad Fortune Management Failures
Medium or Stable	Successes, Good Fortune	Scenario II "Normal" Fair Times	Time of Troubles
Low or Unstable	Total Social Transformation	Successes, Good Fortune	Scenario III "Normal" Hard Times

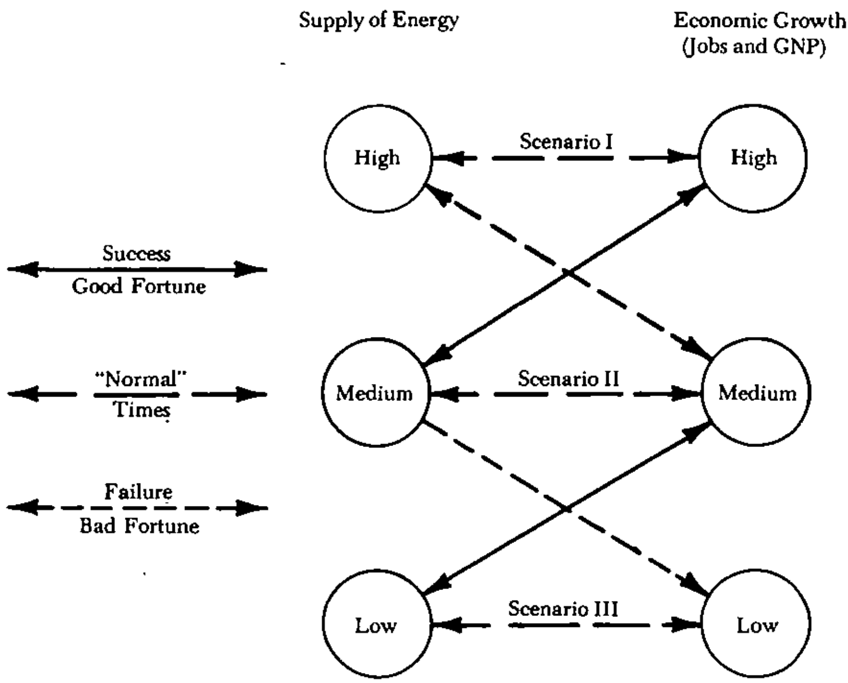
Linking Energy Forecasts to Economic Scenarios

If we can believe that even a 1 percent growth in energy supplies is compatible with 2 percent economic growth, as suggested by CONAES, then a matching of supply and demand for energy at around 102 quads can be taken as the most likely estimate for the year 2000. As argued earlier, however, the link between total energy used and economic growth is a loose one. As a result, the projections of high, medium, and low energy supply levels do not automatically yield direct one-to-one projections of high, medium, and low GNP levels. Rather, the two kinds of projections are more loosely linked as shown in Figure 3.8. Here we see that under normal circumstances, a "high" energy supply would be linked to a "high" GNP level. However, it could happen that through bad luck, such as international turmoil, policy failures, or economic mismanagement, a high energy supply could be linked to a medium growth rate and GNP level. It is conceivable even that problems of one form or another could link high energy and low GNP. A middle level of energy supply could, with success and/or luck, be turned into high GNP or, with failures and/or troubles, be turned into low GNP, instead of the expected medium. Similarly, low energy supplies could, with luck and skill (as in the CONAES's no-energy-growth scenario), be turned into medium GNP levels, instead of low levels. The various contingencies are summarized in Table 3.7.

The three national economic scenarios presented in the next section are illustrative of the economic circumstances likely to be associated with the "normal times" scenarios identified in Table 3.7. Scenario I represents a relatively high GNP growth situation characterized by relatively abundant and stable energy supplies although at considerably higher prices. Scenario II

FIGURE 3.8

Energy–Economic Linkage



Depending on the success of our energy–economic management and the effects of uncontrollable circumstances, the relationship between energy supply and economic growth could take a variety of forms.

represents a more moderate GNP growth situation in which energy supplies are considerably more expensive than today and generally stable, although not as plentiful as in Scenario I. Scenario III illustrates a low economic growth condition likely to be associated with a turbulent social and economic environment in which energy supplies ar relatively low and unstable.

In general, turbulence is likely to be a better predictor of hard times than the amount of energy available. It is assumed that such turbulence could grow out of either medium or low total energy supply levels, or from significant shortages in particular fuel types at any of the overall supply levels. As suggested earlier, numerous potential sources of turbulence are possible and, in fact, are more likely to occur when energy supplies are scarce. Thus, severe economic disruption is somewhat more likely to come out of a low energy scenario.

U.S. Economic Growth Scenarios

The three economic scenarios give high, medium, and low estimates of growth rates and Gross National Product (GNP) levels in the U.S. for the years 1990 and 2000. These scenario values, given in Table 3.8 and Figure 3.9, were developed by combining our analysis of projections by Data Resources, Incorporated (DRI), a highly regarded economic forecasting firm, with the energy-economic interactions analyses done by Hogan and Manne in their well-known energy modeling efforts at Stanford University (Hogan and Manne, 1977).[14]

The GNP forecasts reflect quite different growth rates for the U.S. economy across the three scenarios. What the scenarios have in common, following the DRI reasoning, is a continually slowing rate of growth for the U.S. economy through the 20-year period of 1980–2000. This may be seen, in Table 3.8, by comparing the annualized percent growth rates for 1980–1990 versus 1990–2000 across scenarios.

Scenario I: High Growth

Scenario I, the *high* value, is based on neoclassical economic growth patterns, in DRI's TRENDLONG 0779 model. This model creates trends largely independent of concern for business cycles, tending to assume a relatively strong and well-coordinated economy, while not departing too far from past behavioral trends. Its growth rates are 3.63 percent per year (on average) for the 1980s, and 2.52 percent (on average) for the 1990s, or 3.08 percent per year (on average) for the 1980–2000 period. Essentially, this is the full employment economy without economic troubles. The slowing growth reflects (1) a slowing population growth rate—proportionately fewer consumers and fewer workers in the population—and (2) energy prices doubling by the year

TABLE 3.8

U.S. Gross National Product to 2000
(in billions of 1972 dollars)

Trendlines:	High	Medium	Low
1980	$1382.2[a]	$1382.2[a]	$1382.2[a]
1990	$1975.1[b]	$1883.7[c]	$1737.9[d]
2000	$2533.2[e]	$2296.2[f]	$2072.8[g]
Annualized Percent Growth, 1980–1990	3.63%/yr.	3.14%/yr.	2.30%/yr.
Annualized Percent Growth, 1990–2000	2.52%/yr.	2.00%/yr.	1.78%/yr.
Annualized Percent Growth, 1980–2000	3.08%/yr.	2.57%/yr.	2.05%/yr.

SOURCES:

[a] Data Resources Incorporated (DRI) CYCLELONG 0779 Forecast, July 1979.
[b] DRI TRENDLONG 0779 Forecast, July 1979.
[c] DRI CYCLELONG 0779 Forecast, July 1979.
[d] Use of estimate by Hogan and Manne (1977) of GNP losses when elasticity of energy substitution is − .2, and energy supplies are as given in low scenarios. GNP loss = 40%, or .6 times the expected "high" value, in this case, the TRENDLONG 0779 forecast.
[e] Adjustment of DRI TRENDLONG 2003 forecast for 2000 for results of more recent values in DRI TRENDLONG 0779.
[f] Extrapolation of DRI CYCLELONG 0779 to year 2000, proportional to TRENDLONG forecasts.
[g] Same as note d, for TRENDLONG at year 2000.

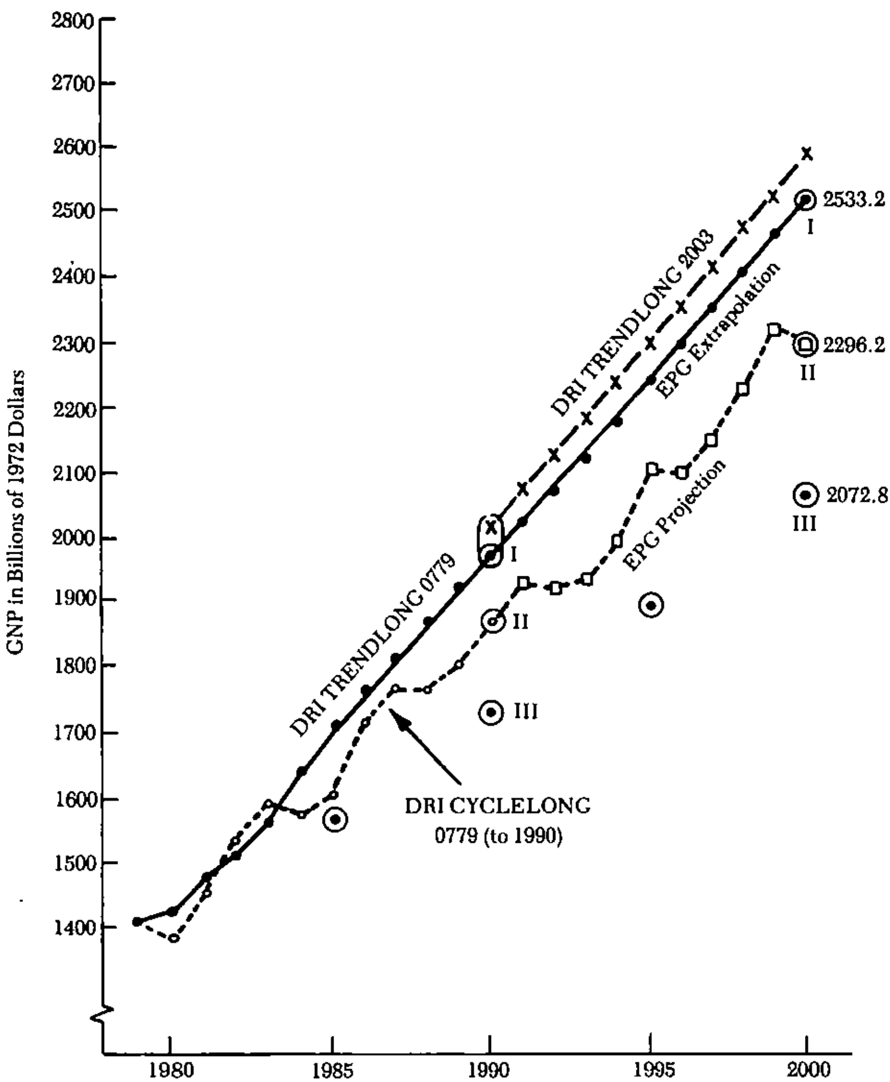
2000. (This implies deregulation of domestic energy prices and continued increases in the costs of imports.) The DRI projections (in constant dollars) assume the Census Bureau Series II population forecasts, which many experts now believe to be too high—Census Series III forecasts an even slower growth rate. This fact would make the DRI growth rates over-optimistic. Should population growth be closer to series III then the U.S. economy would not need to grow that fast to keep per capita incomes up, and, in fact, would not grow so fast.

Scenario II: Medium Growth

Scenario II, the *medium and most likely* value, is based on the use of business cycle models, DRI's CYCLELONG 0779, tied to the long-term trend models. It is inherently the case that growth rates will be lower when cyclical disruptions are taken into account. Other assumptions are similar, except the assumption of optimum behavior by business or government is replaced by "normal" behavior. It is also a business-as-usual forecast for doubling energy prices and slowing population growth (though, as discussed earlier, perhaps not slow enough). Its growth rates are 3.14 percent per year (on average) for the 1980s and 2 percent per year (on average) for the 1990s, and

FIGURE 3.9

Three Alternative Scenarios for U.S. Gross National Product to the Year 2000



2.5 percent for the 1980–2000 period. The model assumes only minor disruptions from abroad, but it does incorporate cyclical fluctuations on a four-year cycle. EPG considers this to be the most probable economic forecast and one compatible with a wide range of energy supply values.

Scenario III: Low Growth

Scenario III, the *low* value, assumes that a time of troubles is upon us and that frequent "shocks" will disturb the U.S. economy, causing serious problems with repeated sharp recessions and severe inflation in recovery periods. Such a pattern would disturb investment and capital formation in the U.S., and interest rates would tend to stay very high. "Stagflation" would become very common—both slow growth and inflation. This would very likely be associated with medium to low energy supplies, *and also* with repeated disruptions of energy supplies, causing shocks to the economy similar to the 1973–74 problems. In a worldwide time of energy troubles, it is argued that everyone will be "snatching and grabbing" at whatever is available and that international conflict will be heating up. Politicians may repeatedly over- or under-react for a variety of reasons—which can easily worsen business conditions with a start-stop stuttering pattern of government efforts to aid and control. In such conditions, needed investment in energy efficiency (conservation) and energy production (of many kinds) would be disrupted by the poor conditions of financial markets. Economists would say that there is a "low elasticity of substitution" away from inefficient energy uses—that is, slow replacement of energy-wasteful capital equipment, both because of slower economic growth and lack of investment capital. Unfortunately, this dismal picture is all too likely, considering the performance of government, international relations, and the economy, since the 1973 oil shock. The result is that the 1980s would see 2.3 percent economic growth per year (on average) because energy problems are not yet *too* bad, but a 1.78 percent growth per year (on average) in the 1990s, with an overall average of 2.05 percent per year 1980–2000. It will also be noted that these averages conceal some very *deep* recessions, in a boom-bust cycle pattern. It is not a pretty picture.

As stated previously, the medium scenario is considered to be the most likely of the these. Between the high and low scenarios, the low projections are, unfortunately, considerably more likely than the high.

Employment Levels in the Three National Scenarios

Employment levels in 1990 and 2000 are much more difficult to forecast than GNP and, thus, there is more uncertainty in our employment estimates for the various scenarios. For each scenario, levels of Total U.S. Employment, U.S. Manufacturing Employment, and U.S. Construction Employ-

A NOTE ON THE USE OF FORECASTING MODELS

It is possible to develop widely varying scenarios for the future by using different models and assumptions. This is so even though the different models may each be internally consistent and "reasonable" in structure. Furthermore, the same model can often produce quite different results due to only small differences in a critical piece of data or assumption. In short, the use of models for long-range forecasting is a rather footless activity with considerable room for variation and error.[15] Furthermore, the very creation of a forecast may mobilize the forces needed to move away from the "predicted" outcome.

It should be stressed, then, that our purpose here in laying out scenarios which rely on the outputs of models is not to "predict" the future. This should be clear just from our use of *alternative* scenarios. Rather, we have chosen to employ the models (despite our recognition of their many faults and problems) as an aid in the creation of scenarios which are reasonably coherent and consistant internally and from one to another. For example, we can (as for the economic scenarios) use the internally coherent structure of the model, i.e., its mathematical equations, to provide a reasonable estimate of employment in the manufacturing sector which is consistent with a given GNP level. Even this use of such models is acceptable only under the business-as-usual assumptions of this study—that is, assuming that the basic structure of the economy which has been modeled will remain the same over the forecast period. The longer the time horizon of the forecast, and the greater the changes that a society is going through (for example, responding to an energy crisis), the farther from reality such an assumption is likely to be.

The final word must be, then, that long-range forecasting models should be seen as tools for learning and for increasing understanding. We should avoid the trap of relying on them as magic boxes which can relieve our uncertainty about, or responsibility for, the future.

ment are discussed in terms of the high and low points in the business cycle as well as the trend at the middle of the cycle.

Total U.S. Employment has become more difficult to project than it used to be for several reasons:

1. The labor force is changing in new ways: more women are entering the labor force; two-worker families are common; families are breaking up more readily with a need for both former partners to work; teenagers are hard to place in the labor force; with a more elderly population, there may be a change in work after "retirement age," and so on.
2. The demand for workers by different kinds of businesses is changing, as well as total demand for workers. For example, automation used to be thought of in terms of blue-collar occupations in manufacturing, but now it is found in offices affecting clerical workers. It is clear that relatively fewer workers will be needed to produce each billion dollars of GNP, but how many fewer is uncertain. To make these projections, past trends of declining numbers of workers per GNP were extended into the future, with a tendency for the decline to slow down. (Both DRI forecasts and University of Michigan econometric data were used.)[16] This argues that some parts of the economy will be slower to replace workers with capital equipment than in the past. These trends in workers per unit of GNP are shown in Figure 3.10.

The above argument applies to manufacturing and construction as well. Both have unemployment rates that change more than the rest of the economy, so that they are of concern and, also, more uncertain. Manufacturing has been sharply declining in terms of workers needed to produce each billion dollars of output, but this downward trend is projected to flatten out. The extent of these changes, however, is uncertain in light of potential changes in the manufacturing workforce. The same argument is also true of construction. Some of the decline of these kinds of jobs relative to GNP also has to do with jobs appearing faster in services. That is, rising affluence in the U.S. results in people spending relatively more disposable income on services (which are labor-intensive) and proportionately less on manufactured products. This part of the trend will almost disappear in the medium to low growth scenarios, simply because the age of rapidly rising disposable income is gone—future gains will be slower, or stop in those scenarios.

Table 3.9 shows *Total U.S. Employment* projections for 1990 and 2000 under the three scenarios. As a reference, 1978 employment level is approximately 94.4 million jobs. The high values of Scenario I give 115.6 million jobs in 1990 and 136.8 million jobs in 2000. There are no cyclic peaks or troughs. In Scenario II, medium values are 113.6 million jobs in 1990 and then are shown to vary according to whether the year 2000 falls on the peak, trough or middle of a business cycle. A cyclic peak would be 137.5 million workers; the trend middle would be 126.3 million workers, and the trough would be 123.8 million workers. In Scenario III, the low values are 109.5 million jobs in 1990, and are shown to vary for 2000 for peak to trough, in

FIGURE 3.10

Derivation of Employment in Relation to GNP

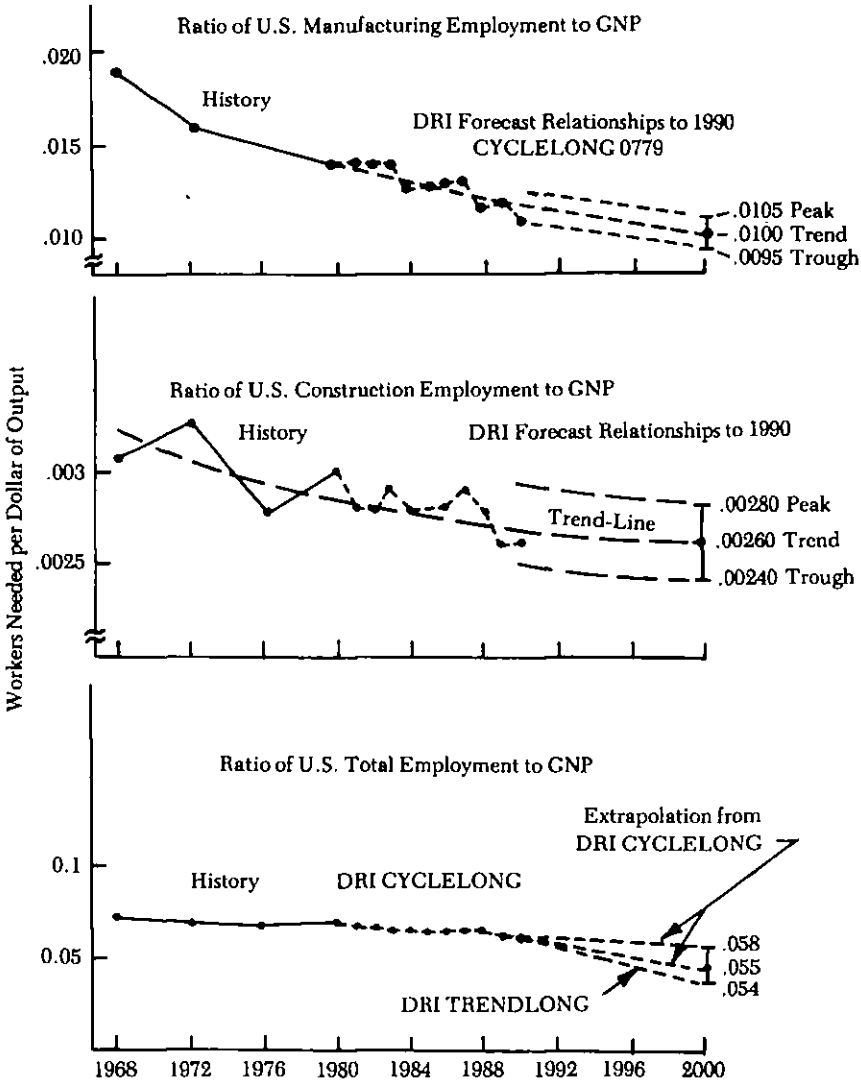


TABLE 3.9

Projection of U.S. Total Employment to 2000
(1978 Employment = 94.4 million)

	1990 Employment (in millions)		2000 Employment (in millions)
Scenario I	115.6		136.8
Scenario II	113.3	Peak	137.5
		Trend	126.3
		Trough	123.7
Scenario III	109.5	Peak	123.8
		Trend	117.1
		Trough	98.3

even more dramatic fashion. The cyclic peak would be 123.8 million jobs, the trend middle would be a grim 117.1 million jobs, and the low could be a near-disastrous 98.3 million jobs. The low-low projection reflects a "down-side" risk of zero growth in GNP from 1990 to 2000, resulting from multiple shocks to the economy, declining per capita income, declining investment, and deep downturns when they happen.

U.S. Manufacturing Employment under the three scenarios is shown in Table 3.10 for 1990 and 2000. The 1978 value is 20.3 jobs. The high values of Scenario I give 22.4 million jobs in 1990 and 25.3 million jobs in 2000. There are no cyclic peaks or troughs. In Scenario II, medium values are 21.5 million jobs in 1990. For 2000, the cyclic peak would be 24.9 million jobs, the trend middle would be 21.8 million jobs, and the cyclic trough would be 21.3 million jobs. It can be seen that adding a business cycle to the projections shows these jobs as fairly unstable. This is still more dramatic in the low projection of Scenario III, which gives 20.8 million jobs in 1990, and for the year 2000, a cyclic peak of 21.3 million jobs, a troublesome trend middle of 19.7 million jobs and a grisly recession value of 16.5 million jobs.

U.S. Construction Employment has a similar pattern to manufacturing (taking into account, however, the counter cyclical nature it often shows) and is seen in Table 3.11 for the three scenarios, 1990 and 2000. The 1978 value is 4.20 million jobs. The high values of Scenario I give 5.2 million jobs in 1990 and 6.6 million jobs in year 2000. The medium values of Scenario II give 4.9 million jobs in 1990, and peak to trough for 2000 are: a cyclic peak of 6.2 million jobs, a trend middle of 6.0 million jobs, and cyclic trough of 5.8 million jobs. The low values of Scenario III give 4.9 million jobs for 1990, and peak to trough for 2000 are: a cyclic peak of 5.8 million jobs, a trend middle of 5.4 million jobs, and trend low of 4.5 million jobs. Thus, while construction would be unstable, its cyclic troughs are not as disastrous as manufacturing.

TABLE 3.10

Projection of U.S. Manufacturing Employment to 2000
(1978 Employment = 20.33 million)

	1990 Employment (in millions)		2000 Employment (in millions)
Scenario I	22.4		25.3
Scenario II	21.5	Peak	24.9
		Trend	21.8
		Trough	21.3
Scenario III	20.8	Peak	21.3
		Trend	19.7
		Trough	16.5

TABLE 3.11

Projection of U.S. Construction Employment to 2000
(1978 Employment = 4.20 million)

	1990 Employment (in millions)		2000 Employment (in millions)
Scenario I	5.2		6.6
Scenario II	4.9	Peak	6.2
		Trend	6.0
		Trough	5.8
Scenario III	4.9	Peak	5.8
		Trend	5.4
		Trough	4.5

Discussion of the U.S. Employment Scenarios

It is clear from the employment scenarios that there could be serious problems in the future. The high and medium growth rates of Scenarios I and II are not surprising, for they are typical of what business forecasts usually show—the DRI forecasts, which provide the base for our analyses, are considered authoritative and reputable. These traditional analyses have a shortcoming that needs to be carefully considered however: External shocks to the U.S. economy are assumed away. These scenarios represent the "surprise-free" world. The real world is considerably riskier, not only for energy concerns, but also because of wars (ours and/or the Middle East's), problems of the dollar in international money markets, and so on. (Recall the long list of potential sources of trouble and instability presented earlier in Table 3.3.)

The point to realize is that forecasting models, such as DRI's, are good only as long as economic trends are strictly caused by economic issues. Once energy, war, environment, international politics, agriculture, and social problems have to be considered, the econometrician's task becomes much more difficult, if not impossible. Yet experience shows that these are often the sources of shocks to the economic system, and unfortunately a steady stream of such troubles is very likely in the years ahead.[17]

When these shocks are translated into economic terms, the low growth scenario presented here is all too plausible. Consider a supply shock, such as a repeat of the 1973 oil crisis. The economy is far from an equilibrium condition, with unemployment high from the short-term effects of a shock, and then the question arises as to what government should do. If no stimulus occurs (as in 1973–74), then unemployment lingers and there is an inflationary perid before economic growth resumes. If there is a *perfect* government stimulus, growth continues and employment rises again, at a cost of a one-time surge in inflation. Too much stimulus generates runaway inflation, and too little gives a lingering slow recovery, also with inflation. While the employment-inflation gyrations go on, other socio-economic fallout, as shown in Tables 3.3 and 3.4, is likely. In particular, capital markets misbehave—the interest rate skyrockets, there may be a credit crunch, investment is dampened, and business and consumer confidence withers. This is not unlike the 1980 recession, except it could easily be worse with bad luck or bad management. The political response to demands to "do something" is not always good economics or even good public policy. Many small firms and some very large, but marginal firms such as Penn Central, Lockheed, or Chrysler go into crisis. Particular economic regions and occupations (e.g., auto and construction workers) are hurt worse than the nation, depending on the type of shock and the direction of its reverberations.

As noted earlier, if the U.S. is on a major investment program of replacing energy inefficient capital equipment, or developing new (or more) energy production, such economic turbulence makes the transition more difficult because of its effects on planning and investment. The ability to adapt to drastically changing conditions declines (the elasticity of energy substitution declines), and the long-term growth rate is depressed. That is how we get to the low values of Scenario III and how we arrive at the key conclusion:

- It may not be the absolute *amount* of energy that affects economic growth, but rather disruption in supply, or any other disruption. Therefore, actions that reduce the riskiness of supply are likely to be the most important actions.

Notes

1. For example, the *Energy Report from Chase* (Manhattan Bank) argued that "There is no sound proven basis for believing a billion dollars of GNP can be generated with less energy in the future" (September 1976 issue). This is directly contradicted by the data.

2. This is a point which has been made repeatedly by a number of recent expert studies: Landsberg et al. (1979); Alterman (1977); CONAES Demand and Conservation Panel (1979); W.W. Rostow (1978).

3. CONAES, National Academy of Science (1979); Ross and Williams (1977); Widmer and Gyftopoulos (1977); and CONAES Modeling Resource Group of the Synthesis Panel (1978a).

4. See particularly: Hannon (1977); Bullard (1977); Council on Economic Priorities (1979).

5. CONAES Demand and Conservation Panel (1978). Essentially, the CONAES scientists and engineers judged that from an *engineering* viewpoint, there are few, if any, constraints on our ability to conserve energy and have a good future.

6. These assumptions follow the reasoning of the widely respected Demand and Conservation Panel of the Committee on Nuclear and Alternative Energy Systems (CONAES). These are summarized in CONAES Demand and Conservation Panel (1978b). For a full reporting see CONAES Demand and Conservation Panel's *Alternative Energy Demand Futures to 2010* (1979).

7. EPG reviewed a wide range of current government, industry, and trade organization forecasts in preparing our projections: Hayes (1979); Duane (1978); Workshop on Alternative Energy Strategies (1977); Committee on Energy and Natural Resources, United States Senate (1978; includes a wide range of independent government, trade organization, and industry forecasts to 1990); Schurr et al. (1979); Landsberg et al. (1979); Stobaugh and Yergin (1979); Exxon Corporation (1977); Energy Information Administration (1978); Elliot (1977); Lawrence (1979—includes review of NED II and American Gas Association forecasts to year 2000); Commoner (1979); Gustaferro et al. (1978).

8. See Hubbert (1969); Committee on Interior and Insular Affairs of U.S. Senate (1974); Elliot (1977). See also MEA and MERRA (1979).

9. The three studies are reported in: Landsberg et al. (1979); Stobaugh and Yergin (1979); Schurr et al. (1979).

10. See analyses in Miller (1976); Stobaugh and Yergin (1979, chapter 5); Bupp and Derian (1978); Mooz (1978).

11. For example, see Stobaugh and Yergin (1979, chapter 7); Stanford Research Institute for the Energy Research and Development Administration (March 1977); Council on Environmental Quality (1978); Office of Technology Assessment (1977).

12. CONAES Consumption, Location, and Occupational Patterns Group Report (1977); original source, CONAES Solar Resource Group.

13. CONAES, Demand and Conservation Panel (1978). The demand scenarios assume a smooth transition from 3 percent GNP growth in the late 1970s to about 1 percent by 2010, with an average over the period of 2 percent. This means that changes from 2000 to 2010 will be small compared to the 1975–2000 period. The assumption of a smooth transition implies a smaller demand in 2000 than in 2010. For these reasons, the analysis of a potentially successful match between supply and demand is conservative.

14. The EPG staff compared many energy-economic interaction models and considered these two sources to be the most insightful for our analysis, though we have numerous disagreements with them over details.

15. For critiques of forecasting models, see Mayer (1977) and Ascher (1978).

16. See Table 3.10 for DRI sources. Source for the University of Michigan econometric data is the Research Seminar in Quantitative Economics, Department of Economics, 1979.

17. For a detailed examination of the compounded effects of the 1973 oil embargo, the 1974 Russian grain deal, and the 1971–1974 wage-price controls, see Dornbusch and Fischer (1978).

4

Michigan's Jobs Future

Overview of the Chapter

In this chapter we step down the national economic projections presented in Chapter 3 to their implications for jobs in Michigan. Employment prospects in the manufacturing, construction, and non-manufacturing sectors are examined according to low, medium, and high economic condition scenarios which each assume adequate overall energy supplies within Michigan. As an aid to readers less interested in the detailed technical presentation, a non-technical overview of the chapter's results is presented first, and is followed by the detailed technical discussion.

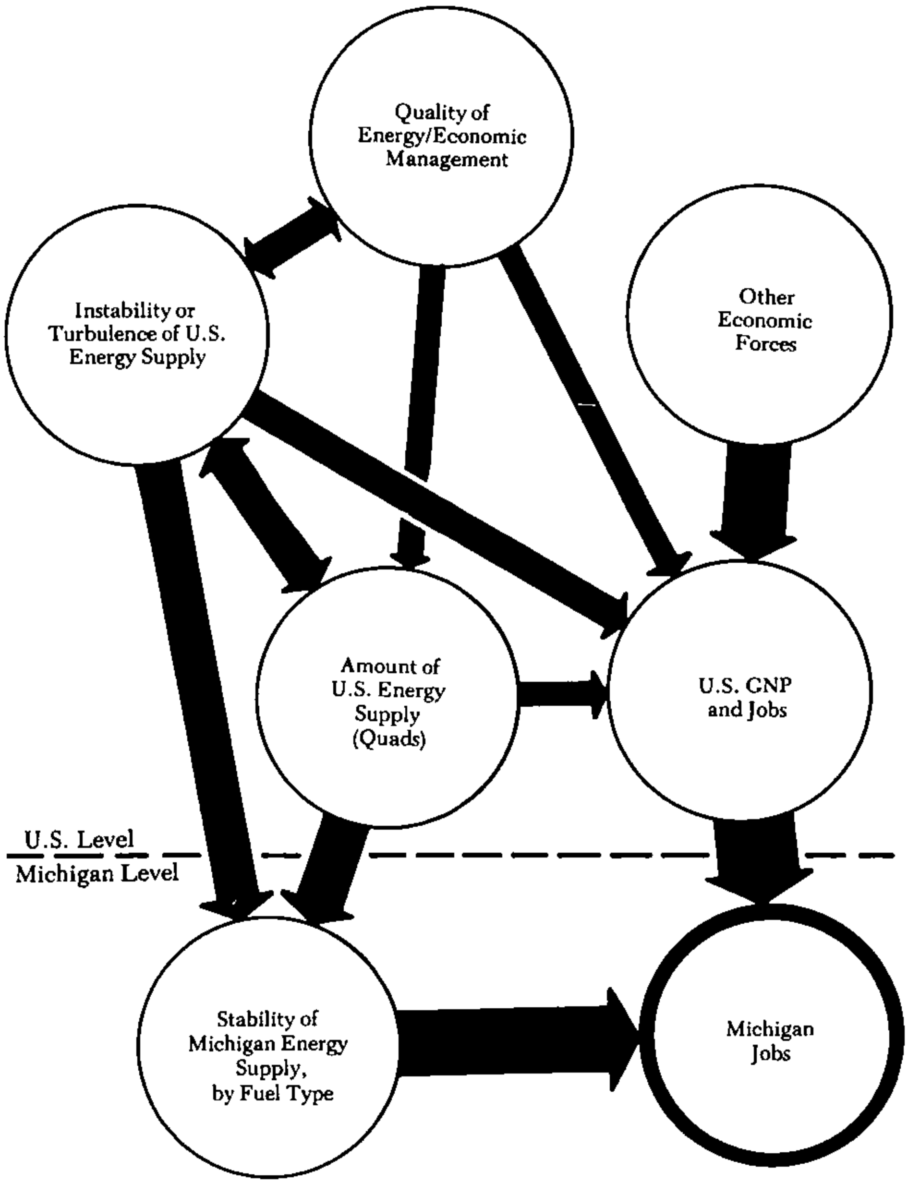
Major Forces Affecting Jobs and Energy in Michigan

As suggested in Chapter 1, there are many factors which influence an economy as large and complex as that of the United States. Recall the representation in Figure 2.15 (repeated here as Figure 4.1) of the three energy-related factors of central importance for the U.S. economy: (1) the quality of energy/economic management, both public and private, in the U.S., (2) the amount of turbulence in U.S. energy supplies, and (3) the amount of U.S. energy supplies. As suggested by the width of the arrows, non-energy related factors are just as important to national GNP and jobs as are the energy-related factors.

In this chapter we examine the effect of these national level factors on Michigan jobs. Assuming that Michigan has supplies of energy at adequate and stable levels to provide for the nationally generated level of state economic activity, then the national activity will dominate Michigan's

FIGURE 4.1

Relationship of Michigan Jobs to U.S. and Michigan Energy Situation



future. It is such a case which is examined in this chapter by means of shift-share analysis[1]. This approach steps down the national energy/economic conditions to Michigan in terms of the level of Michigan jobs resulting from the state's share of overall national economic activity.

This analysis assumes that aggregate U.S. economic conditions pass national economic and energy turbulence to Michigan jobs, particularly the automobile industry, which in turn impacts the rest of the Michigan economy. In the case of Scenario III, the low employment scenario which assumes energy shortages at the national level, shortages in Michigan are assumed to be no worse than for the nation as a whole.

Thus, this portion of the analysis assumes that sufficient energy in appropriate forms will be available to meet Michigan's energy requirements. In this context it is worth noting that a national downturn or economic/energy shock would lessen aggregate U.S. demand for Michigan products and the state would thus need less energy. In some circumstances, this could reduce the potential for local fuel shortages. On the other hand, such downturns or shocks could be large enough to seriously affect the availability of financial resources for investment in conservation, new energy supplies, or fuel substitutions. In such a case, fuel shortages and energy related turbulence could be expected *both* nationally and within the state.

It is quite possible, however, that the state will not have sufficient supplies, or the right mix, of fuels to meet its nationally generated energy requirements. That is, shortages in Michigan could develop of one or more types of needed fuel without a correspondingly serious shortage at the national level. Michigan jobs would thus be constrained by energy factors, rather than by national economic factors, and business closings and layoffs would result. Continued over a period of years, such energy constraint would likely lead to a serious movement of jobs from Michigan to other states not suffering from equally serious energy shortfalls. The uncertainties involved in such disruptions prevent quantitative estimates about this kind of job loss. However, it is safe to conclude that the Michigan jobs picture would be considerably worse than that projected by the scenarios of this chapter, which assume no serious energy shortages for the state.

Unfortunately, Chapter 5, which examines energy supply and demand scenarios for the state, suggests a very high probability that serious shortages among some fuel types (petroleum especially) may occur in Michigan. In fact, under strict business-as-usual assumptions, supply shortages or constraints would be a virtual certainty in the state. Even relaxing business-as-usual assumptions to allow for very extensive (and expensive) conservation and fuel switching programs suggests that Michigan jobs may be highly vulnerable to shortages in particular fuel types between 1990 and 2000. The full extent of this problem is discussed in detail in Chapter 5. We mention it here to emphasize that the Michigan employment scenarios presented in this chapter reflect only national conditions; conditions in the state could be considerably worse than described in this chapter's otherwise "most probable" scenario, the medium-range Scenario II. Should local energy shortages occur, the dismal numbers of Scenario III become the "more likely" projection. In other words, even this chapter's dreary projections may be more optimistic than the grim possibilities shown in Chapter 5.

Summary of Michigan Employment Projections

Michigan faces very great uncertainty in the years ahead. This chapter's analysis shows a wide range of possible growth levels in Michigan employment (Figure 4.2), due largely to the uncertainty of future energy and economic conditions in the U.S. as a whole. As suggested in earlier chapters, Michigan is closely tied to the larger U.S. economy, particularly by the auto industry and other durables manufacturing. As a result, it is not likely that the state will do better than the nation as a whole in the next twenty years. It may, in fact, do worse, and slow Michigan growth rates are very likely.

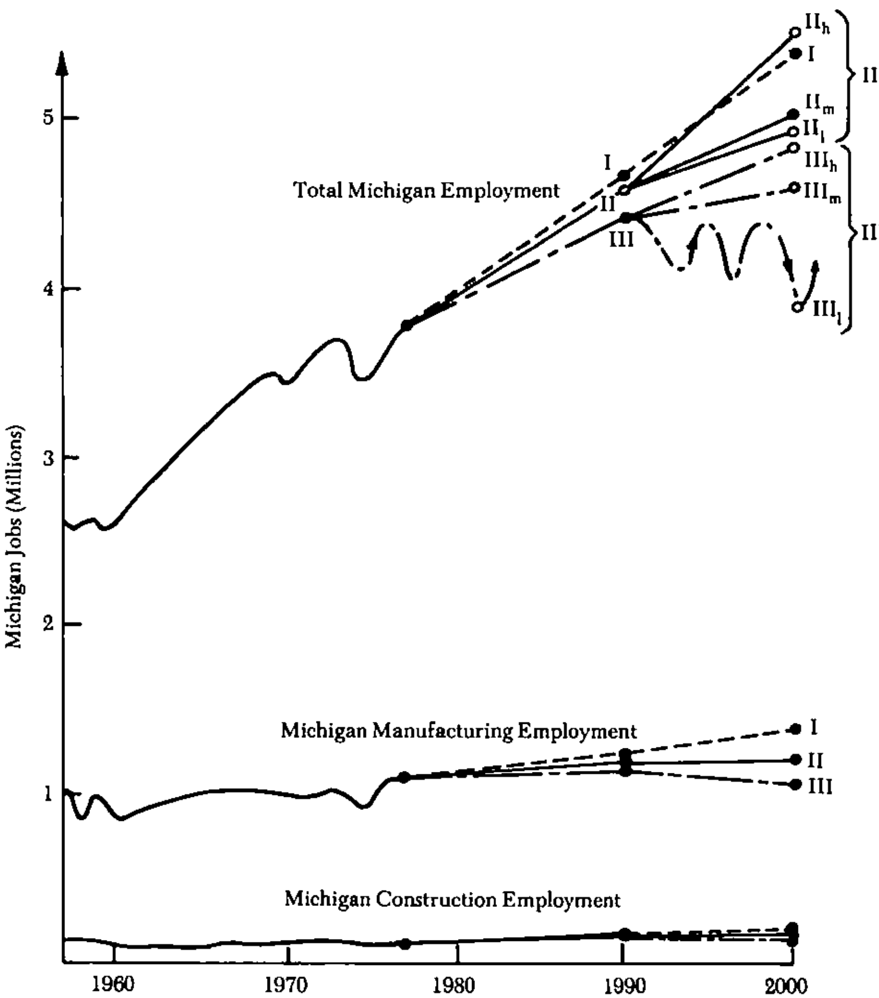
The upper limit of jobs growth in any of the three Michigan job sectors analyzed is 2 percent per year under very favorable circumstances. The lower limit is stagnation and decline under moderate to unfavorable circumstances. Overall, according to the most likely projection, the state can expect job growth at no more than 1.5 percent per year in the 1980s, and no more than 1 percent per year in the 1990s. This is likely to be coupled with equally slow population growth, so average levels of unemployment would not necessarily rise. But in the more unstable scenarios, unemployment would be very high.

Energy prices and problems play a role in slower economic growth in the U.S. in general, and indirectly impact Michigan jobs in all of our scenarios. In addition, local energy shortages (as described in Chapter 5) could produce stagnation-decline results like Scenario III, but with even more serious impacts on state employment. If the state is not severely impacted by energy shortages, then growth rates at 1.5–2 percent as in Scenarios I and II are more likely, with energy issues merely being part of the state's overall economic climate. But any other kinds of instability (such as further problems with Chrysler Corporation) add to the likelihood of low Scenario III projections, with consequent high unemployment.

On a sectoral basis, Michigan's problem is that it is a heavy manufacturing state at a time when, according to national forecasts, all manufacturing in the U.S. is expected to slow in job growth. Durables manufacturing, furthermore, being quite sensitive to fluctuations in the national economy is not stable employment at all times. Furthermore, jobs in all sectors of the state will be affected by the expected slowing of total U.S. job growth. Last, but not least, Michigan is not particularly competitive with other states in at-

FIGURE 4.2

Alternative Employment Scenarios for Michigan



tracting new jobs and income, so that it consistently tends to grow more slowly than the rest of the U.S. All scenarios project this noncompetitiveness to moderate by the year 2000, due both to presumed státe efforts to attract jobs, and to wages and employer costs not rising quite as fast as in other regions. But, nonetheless, this factor is expected to depress growth for most of the 20-year period until 2000, and no unique new competitive advantages are projected for Michigan after this time. Such new factors are simply not visible at present.

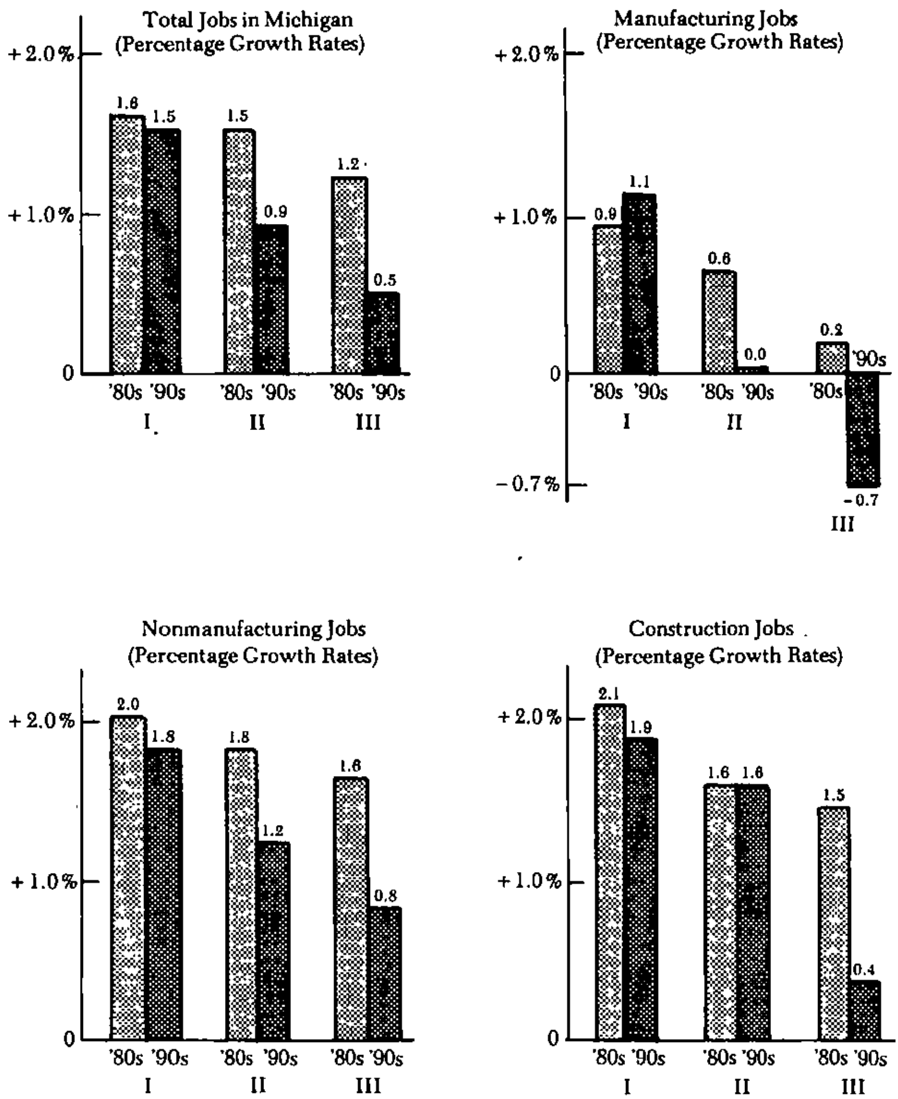
Figure 4.2 shows the trend lines for projected jobs in Michigan divided into the categories of total jobs, manufacturing jobs, and construction jobs. (The number of non-manufacturing jobs is the difference between total jobs and manufacturing jobs.) The three alternative scenarios are represented for each jobs sector by three trend lines. To simplify the presentation, the trend lines "average out" business cycle effects. As can be seen, manufacturing and construction growth is projected to be very slow at best. The potential growth in total jobs is in non-manufacturing jobs other than construction. The wavy boom and bust line around the Scenario III trend line in total jobs is to remind the reader that in hard times the lower limits of 1990 to 2000 projections show wide and unstable convulsions in the economy, not a straight trend line. In all cases, the trend to growth slower than in the past is visible; Michigan shows the signs of a "mature" economy. Michigan also is projected to be less dominated by manufacturing—between 1 million and 1.3 million jobs by the year 2000, in comparison to total jobs between 4.6 million and 5.5 million jobs by the year 2000. For the mid-range projections the percent of jobs in manufacturing drops from 29 percent in 1977 to 22 percent in 2000.

Figure 4.3 compares growth rates for different job categories across the three scenarios. For *Total Jobs in Michigan*, the three scenarios' growth rates do not differ greatly in the 1980s, but they diverge markedly in the 1990s. Even the highest values—of 1.6 percent per year in the 1980s and 1.5 percent in the 1990s—are below Michigan's historic growth rate, because of slowing U.S. economic and population growth, with Michigan growing slightly slower than the rest of the country. The low Scenario III values—1.2 percent per year in the 1980s and 0.5 percent in the 1990s—are close to stagnation. If one assumes that serious energy/economic disruptions will not occur, then Scenario II, the mid-range, with annual growth rates at 1.5 percent in the 1980s and 0.9 percent in the 1990s is most likely. If one assumes Michigan may have energy shortfalls, or that national economic problems may arise, then the stagnation of Scenario III is as likely.

Manufacturing Jobs show a relatively low annual percentage growth rate around 1 percent per year, even in Scenario I. This is because of slow manufacturing growth in the U.S. In Scenario II, manufacturing jobs decline to zero growth by year 2000. In Scenario III, economic instability leads to an

FIGURE 4.3

Comparison of Growth Rates for Three Scenarios



absolute decline in manufacturing in Michigan. For both Scenarios II and III – the more likely of the three – one can expect fairly high unemployment in Michigan manufacturing in the 1990s.

Non-Manufacturing Jobs are what will keep Michigan employment going in the future. Their growth rates are higher than for total jobs in each scenario. In Scenario I, the historic growth rate in Michigan is maintained at close to 2 percent per year. In Scenario II, the growth rate drops to 1.2 percent per year in the 1990s. In Scenario III, due for the most part to economic/energy turbulence, the annual growth rate is halved by the 1990s, dropping from 1.6 percent to 0.8 percent per year.

Construction Jobs are a subset of all non-manufacturing jobs. As may be seen here, under relatively stable conditions they are projected to do better than other non-manufacturing jobs. But in the unstable conditions of the low Scenario III, growth in construction sector jobs could drop to 0.4 percent per year in the 1990s.

In general, the pattern that emerges from detailed analysis is slow growth of jobs in Michigan, with a persistent "downside" risk of high unemployment and stagnation from economic/energy instability if the conditions of the low scenario are created. The midrange scenario would be considered the more probable in normal times, giving growth at around 1.5 percent per year. The prospect of energy shortages in Michigan, as detailed in Chapter 5, however, raises the specter that the low scenario may be almost as probable. Consequently, the most optimistic projections which continue past trends, must be regarded as the least likely future for Michigan.

The complexity of labor markets makes it very difficult to predict the unemployment rates which would be likely to arise in each scenario. However, the difference in total employment between the most optimistic and the most pessimistic scenarios for the year 2000 is on the order of 30 percent. That is, total employment could be as high as 5.5 million or as low as 3.9 million (in 1976 it was 4.2 million). Somewhat more likely is the emergence of circumstances leading to the pessimistic projection of Scenario III, and if this occurs the state will face an economic environment with very serious unemployment implications.

Stepping Down National Job Projections to Michigan

As suggested above, the success of the Michigan economy is closely tied to that of the U.S. economy. The step down analysis described here assumes that the prime determinant of Michigan jobs, projected for 1990 and 2000, is the U.S. economic activity for those dates. Thus, for the purpose of our analysis, the major jobs-to-energy linkage for Michigan comes through national energy impacts on GNP and aggregate demand, rather than through localized energy shortages. The next chapter raises the prospect that future

A BRIEF NOTE ON THE "SHIFT-SHARE" METHODOLOGY USED IN THE ANALYSIS

The three Michigan employment scenarios are derived from the national forecast using a "shift-share analysis" to step down U.S. employment by sector to Michigan employment by sector. This approach takes into account the historical share of employment held by each Michigan job sector along with expected shifts in the historical shares over the forecast period. Special emphasis was given in the analysis to factors affecting the comparative growth rates of Michigan and U.S. employment sectors. In all cases, the Michigan growth rates are seen as limited by, and tied to, slowing U.S. growth rates. We have assumed that Michigan's "industry mix" will not change dramatically, i.e., Michigan employment will still be dominated by manufacturing. Since manufacturing in general across the U.S. will grow very slowly, so will Michigan's. We have also assumed that Michigan's current relatively poor "state competitive position" (i.e. ability to attract growth, compared to other states) will improve toward rough parity with other states by 2000. This is based on assumptions that wages in other states will have risen to a level closer to Michigan's and that increasingly vigorous efforts will be made to attract and hold industry in the state.

growth in Michigan jobs could be even lower than that projected from national conditions due to the impact of localized fuel shortages in the state should they be allowed to occur.

In general, one may expect that forces now in motion will dominate the Michigan economy for the next five to ten years, and no startling departures from past practices or diversification patterns should be expected. But by 1990, new economic forces will be emerging under the steady pressure of rising energy costs. In fact, many current minor trends may become quite large by that date. This pattern is reflected by the three projections of Michigan total employment in Figure 4.2 and Table 4.1. Notice that there is a narrow spread of values for 1990, with growth rates in a range of 1.2 percent to 1.6 percent per year, with a midrange value at 1.5 percent per year. Stated in total jobs, the 3.8 million jobs of 1977 could grow by 1990 to a range of 4.4 million to 4.7 million, with the most likely figure at around 4.6 million jobs.

TABLE 4.1

Total Michigan Employment, 1990 and 2000

	1977		1990		2000	
Scenario I Jobs	3,782,000		4,697,000		5,499,000	
Effective Annual Growth Rate:		1.6%		1.5%		
						Temporary Cyclic High 5,520,000
Scenario II Jobs	3,782,000		4,586,000		5,032,000	
Effective Annual Growth Rate:		1.5%		0.9%		Temporary Cyclic Low 4,936,000
						Temporary Cyclic High 4,876,000
Scenario III Jobs	3,782,000		4,419,000		4,625,000	
Effective Annual Growth Rate:		1.2%		0.5%		Temporary Cyclic Low 3,879,000

By contrast, there is much greater uncertainty for the year 2000, as depicted by the wide band of values in Figure 4.2. Scenario III, which assumes the U.S.'s inability to cope with energy problems, projects low values, giving 4.6 million Michigan jobs, at an annual growth rate of 0.5 percent per year from 1990 to 2000, as the trend. The range shown for Scenario III contrasts the depths of a deep recession (3.9 million jobs), to rather greater Michigan success within a poor U.S. scenario (4.9 million Michigan jobs). This may be contrasted to the high value of Scenario I, which projects considerable U.S. success in coping with energy matters. In such a case, Michigan jobs would grow at 1.5 percent per year from 1990, with employment at 5.4 million in the year 2000. No business cycle extremes are shown for Scenario I.[2]

Scenario II shows a growth rate of 0.9 percent per year from 1990 to 2000, resulting in 5.0 million Michigan jobs. If we consider the peak-to-trough range of business cycle possibilities that might exist in 2000, the jobs picture could be temporarily as low as 4.9 million or as high as 5.5 million, around the basic trend value of 5.0 million jobs. This peak-to-trough range of 12 percent suggests that one should not expect the Michigan economy to be notably more stable in the future than it has been in the past.

All projections for Michigan show a growth rate in employment that seems quite slow by historical standards. This is less alarming than it may seem, however, in that population growth will be slowing, and that the whole U.S. economy will be growing at a slower rate than in the past. The reasons for Michigan's projected slow growth will become more apparent in the next sections where we examine employment projections for the manufacturing construction and non-manufacturing sectors of the Michigan economy.

TABLE 4.2

Michigan *Manufacturing* Employment, 1990 and 2000
Summary of the Three Scenarios

	1977		1990		2000	
Scenario I Jobs	1,105,000		1,238,000		1,382,000	
Effective Annual Growth Rate:		0.9%		1.1%		
						Temporary Cyclic High 1,366,000
Scenario II Jobs	1,105,000		1,192,000		1,196,000	
Effective Annual Growth Rate:		0.6%		0.0%		Temporary Cyclic Low 1,174,000
						Temporary Cyclic High 1,168,000
Scenario III Jobs	1,105,000		1,140,000		1,067,000	
Effective Annual Growth Rate:		0.2%		−0.7%		Temporary Cyclic Low 905,000

Michigan Manufacturing Jobs

The situation of Michigan manufacturing jobs can be described as "stagnant" at best for all scenarios as summarized in Table 4.2. This is the result of national changes in manufacturing employment due to automation, national moves to a more service-dominated economy, and Michigan's relatively weak competitive position, as compared to other states, in attracting and keeping manufacturing jobs.[4] The assumptions of Economic Scenarios I and II are not particularly dominated by energy issues *per se*. Rather, high energy costs are one cluster of causes among many that contribute to slower growth under the business-as-usual assumptions. It is indeed possible that an additional energy factor will emerge in the 1980s and 1990s. That is the possibility that some manufacturers will wish to be in the sun belt where energy supplies may be more stable. Such a possibility would make the medium and low projections all the more likely.

Scenario III, by contrast, shows manufacturing hit hard by cyclic instabilities induced by energy shocks and shortfalls. Michigan would suffer more than most states simply because it has more manufacturing, particularly the auto industry. This is especially troublesome since the Michigan energy projections in the next chapter show the state to be highly vulnerable to shortages in some fuel types.

A summary of the manufacturing shift-share analyses is presented in Tables 4.3, 4.4, and 4.5, beginning with the more likely midrange number II scenario.

TABLE 4.3

Michigan *Manufacturing* Employment Based on Shift-Share Analysis
Scenario II: Mid-Range Projection

	1977	1990	2000	
				Temporary Cyclic High 1,366,000
Total Jobs:	1,105,000	1,192,000	1,196,000	
				Temporary Cyclic Low 1,174,000
Effective Annual Growth Rate:	0.6%	0.0%		

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan manufacturing jobs grew at same rate as U.S. employment:	+ 277,000	+ 137,000
Employment losses from changes in manufacturing practices in the U.S. economy:	– 166,000	– 123,000
Employment losses from changes due to Michigan's competitive position:	– 24,000	– 10,000
Net change:	+ 87,000	+ 4,000

Result: In this scenario, Michigan manufacturing employment would grow at well under 1 percent per year in the 1980s, and cease to grow by the year 2000. This would be partly due to automation—fewer workers per dollar output, both in the U.S. and Michigan. It would also be due to decline in manufacturing employment's share of the U.S. workforce in general, with a continuing shift to other kinds of jobs. A second assumption is that new manufacturing jobs in Michigan would fail to compensate for losses, but the problem would be leveling off by the end of the century. If Michigan held its own with respect to competitive position, there would still be only about a 30,000 job difference (out of 1.2 million workers) over the whole period to 2000. The "problem" would primarily be slow growth in manufacturing employment in general. Overall, Michigan would remain an important manufacturing state because of capital investments in factories, a skilled workforce, and a central position in the Midwest industrial complex. Past cyclic instabilities of manufacturing employment would be likely to continue.

TABLE 4.4

Michigan *Manufacturing* Employment Based on Shift-Share Analysis
Scenario I: High Projection

	1977	1990	2000
Total Jobs:	1,105,000	1,238,000	1,382,000
Effective Annual Growth Rate:		0.9%	1.1%

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan manufacturing jobs grew at same rate as U.S. employment:	+306,000	+277,000
Employment losses from changes in manufacturing practices in the U.S. economy:	−144,000	−67,000
Employment losses from changes due to Michigan's competitive position:	−29,000	−16,000
Net change:	+133,000	+194,000

Result: The projected upper limit for growth in Michigan manufacturing employment is for just under 1 percent per year in the 1980s and just over 1 percent per year in the 1990s. Automation effects—fewer workers per dollar of output—and a general decline of manufacturing's share of the U.S. workforce, would cause slow growth in manufacturing everywhere, despite a healthy national economy. Michigan's competitive position in manufacturing would be poorer than the medium projection because rapid new growth would tend to favor the sunbelt. This projection is substantially better than the medium projection because it envisions faster U.S. employment growth overall, and a tendency of U.S. manufacturing in the 1990s to slow its decline of the 1980s.

TABLE 4.5

Michigan *Manufacturing* Employment Based on Shift-Share Analysis
Scenario III: Low Projection

	1977	1990	2000	
				Temporary Cyclic High 1,168,000
Total Jobs:	1,105,000	1,140,000	1,067,000	
				Temporary Cyclic Low 905,000
Effective Annual Growth Rate:	0.2%		−0.7%	

Shift-Share Analysis	1977–1990	1990–2000
Employment gains if Michigan manufacturing jobs grew at same rate as U.S. employment:	+231,000	+80,000
Employment losses from changes in manufacturing practices in the U.S. economy:	−158,000	−144,000
Employment losses from changes due to Michigan's competitive position:	−38,000	−9,000
Net change:	+35,000	−73,000

Result: The projected lower limit for Michigan manufacturing jobs shifts from virtual stagnation into long-term decline by the year 2000. The principal problem would be the disastrous condition of the U.S. economy under energy shocks and shortfalls as posited by this scenario, especially after 1990. Manufacturing would tend to be hard hit in general, and Michigan would share in those problems. The role of the auto industry is not explicitly shown here, but the overall numbers are proportional to likely effects on Michigan auto production. Michigan's state competitive position would not be so bad in the 1990s as in other scenarios simply because little manufacturing expansion would happen anywhere. In addition, the long-term decline in manufacturing jobs in Michigan would be coupled with great cyclic instability.

TABLE 4.6

Michigan *Construction* Employment, 1990 and 2000
Summary of the Three Scenarios

	1977		1990		2000	
Scenario I Jobs	124,000		162,000		196,000	
Effective Annual Growth Rate:		2.1%		1.9%		
						Temporary Cyclic High 184,000
Scenario II Jobs	124,000		153,000		179,000	
Effective Annual Growth Rate:		1.6%		1.6%		Temporary Cyclic Low 174,000
						Temporary Cyclic High 171,000
Scenario III Jobs	124,000		151,000		157,000	
Effective Annual Growth Rate:		1.5%		0.4%		Temporary Cyclic Low 132,000

Michigan Construction Jobs

Michigan's construction employment, which has for a time been relatively stagnant compared to conditions elsewhere, is projected in these scenarios to do about as well as other types of non-manufacturing employment. As summarized in Table 4.6, the average growth rate from now to 2000 is approximately 1.6 percent in the mid-range scenario. In good times growth rates do slightly better, in bad times slightly worse. The upper limit of growth in construction jobs is posed by national and state overall economic growth trends. Furthermore, the condition of financial markets and of home mortgage markets has a major impact. In general, hard times (Scenario III) would hit construction worse than other non-manufacturing if there were cyclical instability coupled with inflationary uncertainty in the money markets. The more uncertain and unsettled business expectations are in the long-run, the more likely are Scenarios II and III with their slow growth patterns. Energy instability would hurt worse than pinched energy supplies for precisely this reason. On the other hand, energy-related changes in business capital plant and home—for retrofits for greater conservation and efficiency, and for new energy production facilities—could keep construction jobs up even, while manufacturing leveled off or declined. A summary of the construction shift-share analysis is presented in Tables 4.7, 4.8, and 4.9.

TABLE 4.7

Michigan *Construction* Employment Based on Shift-Share Analysis
Scenario II: Mid-Range Projection

	1977		1990		2000	
Total Jobs:	124,000		153,000		179,000	Temporary Cyclic High 184,000 Temporary Cyclic Low 174,000
Effective Annual Growth Rate:		1.6%		1.6%		

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan construction jobs grew at same rate as U.S. employment:	+31,000	+18,000
Employment gains from changes in construction practices in the U.S. economy:	+3,000	+10,000
Employment losses from changes due to Michigan's competitive position:	−5,000	−2,000
Net change:	+29,000	+26,000

Result: The projected mid-range growth pattern for Michigan construction jobs is at about 1.6 percent per year throughout the entire period. Though U.S. job growth would slow in the 1990s, required energy-related efficiency improvement in businesses and homes would create more new construction activity, as would new energy production facilities. Hence, the net effect would be that job growth in construction would not slow down as much as in manufacturing or non-manufacturing sectors. Michigan's weak competitive position in getting and holding jobs would tend to be compensated by the energy "retrofit" phenomenon it would experience being a northern state.

TABLE 4.8

Michigan *Construction* Employment Based on Shift-Share Analysis
Scenario I: High Projection

	1977		1990		2000
Total Jobs:	124,000		162,000		196,000
Effective Annual Growth Rate:		2.1%		1.9%	

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan construction jobs grew at same rate as U.S. employment:	+34,000	+30,000
Employment gains from changes in construction practices in U.S. economy:	+9,000	+7,000
Employment losses from changes due to Michigan's competitive position:	−5,000	−3,000
Net change:	+38,000	+34,000

Result: Michigan's projected upper limit for growth in construction jobs is around 2 percent per year for the period. This reflects faster U.S. growth than the medium-range scenario, but also less energy-related pressure to retrofit businesses and homes. The net effect would be that job growth would not slow down as much in other sectors, but for slightly different reasons than in Scenario II. Overall, stronger U.S. growth would give more capital plant formation and construction jobs, but might also leave Michigan in a weaker competitive position for construction activity.

TABLE 4.9

Michigan *Construction* Employment Based on Shift-Share Analysis
Scenario III: Low Projection

	1977		1990		2000	
Total Jobs:	124,000		151,000		157,000	Temporary Cyclic High 171,000 / Temporary Cyclic Low 132,000
Effective Annual Growth Rate:		1.5%		0.4%		

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan construction jobs grew at same rate as U.S. employment:	+26,000	+11,000
Employment gains/losses from changes in construction practices in U.S. economy:	+7,000	−1,000
Employment losses from changes due to Michigan's competitive position:	−6,000	−4,000
Net change:	+27,000	+6,000

Result: Michigan's projected lower limit for growth in construction jobs is a shift from about 1.5 percent in the 1980s to stagnation in the 1990s. The principal problem would be instability in the U.S. economy, especially in financial markets, brought about by energy shocks and shortfalls, and this would hurt the construction industry. Almost as serious a problem would be slow growth in the U.S. economy due to the same forces. Short-term employment gains due to changes in construction practices in the 1980s would be reversed in the 1990s. Michigan's competitive position would be worsened by the hard-hit position of durables (especially automobile) manufacturing in the state, tending to slow all new construction after a while. Energy-related instability would create a situation much worse for construction jobs than that envisioned in Scenario II.

TABLE 4.10

Michigan *Non-Manufacturing** Employment, 1990 and 2000
Summary of the Three Scenarios

	1977		1990		2000	
Scenario I Jobs	2,677,000		3,459,000		4,117,000	
Effective Annual Growth Rate:		2.0%		1.8%		
						Temporary Cyclic High 4,154,000
Scenario II Jobs	2,677,000		3,395,000		3,836,000	
Effective Annual Growth Rate:		1.8%		1.2%		Temporary Cyclic Low 3,762,000
						Temporary Cyclic High 3,708,000
Scenario III Jobs	2,677,000		3,280,000		3,559,000	
Effective Annual Growth Rate:		1.6%		0.8%		Temporary Cyclic Low 2,974,000

* Non-manufacturing employment *includes* employment in the construction sector. Total Michigan employment is the sum of manufacturing and non-manufacturing employment.

Michigan Non-Manufacturing Jobs

The situation for Michigan non-manufacturing jobs (including construction) can be described as slow but steady growth for all scenarios as summarized in Table 4.10. This would be especially the case if new efforts to diversify the state's economy prove successful by 2000. While Michigan's competitive position would not permit its non-manufacturing jobs to grow as fast as elsewhere, the situation is projected to improve by the year 2000. The situation for non-manufacturing jobs is far better than for manufacturing, and in general, non-manufacturing jobs become more important in Michigan's economy. The growth pattern for non-manufacturing jobs would reflect both the national economy and Michigan's manufacturing. As a result, the non-manufacturing jobs would tend to be more diverse in the cyclical response than those in manufacturing. In Scenarios I and II, energy issues do not dominate, although they are part of the cluster of factors leading to slower growth under business-as-usual assumptions. By contrast, Scenario III projects energy shocks and shortfalls creating problems in the 1990s. Overall, the pattern is of continually slowing growth, with energy problems adding to cyclical instability under some conditions.

Shift-share analyses are shown in Tables 4.11, 4.12, and 4.13, with the mid-range case, Scenario II, shown first.

TABLE 4.11

Michigan *Non-Manufacturing* Employment Based on Shift-Share Analysis
Scenario II: Mid-Range Projection

	1977	1990	2000	
				Temporary Cyclic High 4,154,000
Total Jobs:	2,677,000	3,395,000	3,836,000	
				Temporary Cyclic Low 3,762,000
Effective Annual Growth Rate:	1.8%	1.2%		

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan non-manufacturing jobs grew at same rate as U.S. employment:	+672,000	+390,000
Employment gains from changes in non-manufacturing practices in the U.S. economy:	+110,000	+82,000
Employment losses from changes due to Michigan's competitive position:	−64,000	−31,000
Net change:	+718,000	+441,000

Result: Michigan non-manufacturing employment would most likely grow at just under 2 percent per year in the 1980s and just over 1 per cent per year in the 1990s. Non-manufacturing employment would grow at a faster rate than total U.S. jobs, and its slowing growth would reflect both slowing U.S. jobs growth and slowing economic growth. Michigan's relatively poor state competitive position would improve slightly by the end of the century. The U.S. economy is expected to be more service-oriented, and Michigan would fit that trend. As a result, Michigan jobs would be less dominated by manufacturing (a shift from 29 percent to 24 percent). However, slow growth and cyclic instability in manufacturing create problems for *all* jobs, and Michigan would remain one of the most manufacturing-oriented states, though somewhat more diversified than now.

TABLE 4.12

Michigan *Non-Manufacturing* Employment Based on Shift-Share Analysis
Scenario I: High Projection

	1977		1990		2000
Total Jobs:	2,677,000		3,459,000		4,117,000
Effective Annual Growth Rate:		2.0%		1.8%	

Shift-Share Analysis

	1977-1990	1990-2000
Employment gains if Michigan non-manufacturing jobs grew at same rate as U.S. employment:	+742,000	+633,000
Employment gains from changes in non-manufacturing practices in the U.S. economy:	+94,000	+42,000
Employment losses from changes due to Michigan's competitive position:	−54,000	−17,000
Net change:	+782,000	+658,000

Result: Michigan's projected upper-limit for growth in non-manufacturing employment is 2 percent per year in the 1980s, and only slightly slower in the 1990s. This scenario's projection is higher than the more likely medium projection because it envisions both a stronger U.S. economy in the 1990s, and a substantial improvement in Michigan's relatively poor state competitive position for jobs. In this scenario, the U.S. and Michigan economies would not shift from manufacturing to service jobs quite as markedly as in the medium scenario.

TABLE 4.13

Michigan *Non-Manufacturing* Employment Based on Shift-Share Analysis
Scenario III: Low Projection

	1977	1990	2000	
Total Jobs:	2,677,000	3,280,000	3,559,000	Temporary Cyclic High 3,708,000 / Temporary Cyclic Low 2,974,000
Effective Annual Growth Rate:	1.6%		0.8%	

Shift-Share Analysis

	1977–1990	1990–2000
Employment gains if Michigan non-manufacturing jobs grew at same rate as U.S. employment:	+560,000	+230,000
Employment gains from changes in non-manufacturing practices in the U.S. economy:	+107,000	+95,000
Employment losses from changes due to Michigan's competitive position:	−64,000	−46,000
Net change:	+603,000	+279,000

Result: The projected lower limit for Michigan non-manufacturing jobs is 1.6 percent per year in the 1980s and half that at 0.8 percent per year in the 1990s. The principal problem would be the bad condition of the U.S. economy brought on by energy shocks and shortfalls in the 1990s. In this scenario, both non-manufacturing and manufacturing jobs would be hit hard, as overall slow growth combined with cyclic instability to create a bleak picture for Michigan jobs. Non-manufacturing job growth would be slow in Michigan because of a decline in industrial jobs (less money circulating) and because of slower U.S. growth.

A Brief Review: Economic Growth and Energy Instability

This gloomy assessment of job growth in Michigan results from the fact that turbulence in the form of economic, environmental, political, or energy uncertainties and disruptive events, can take situations with fairly good energy supplies down to medium levels of economic growth, and mediocre energy supplies with turbulence may convert to low economic growth. While it is true that good economic management and good luck can raise our growth rates, absence of turbulence, will not. The kinds of downside risks Michigan faces are associated with the unclear conditions of the auto industry, and with the likelihood (discussed in the next chapter) that by the 1990s Michigan is likely to see serious shortages of gasoline—and, potentially, of natural gas as well. These factors increase the likelihood of the low scenario. The kinds of energy and economic instability the state may face are, to a large degree, unpredictable, as are the exact patterns the impacts would take relative to Michigan jobs. It is clear, however, that the greater the turbulence, the more likely are severe problems. From a strategic perspective, this means that Michigan energy policies should put a premium on those energy and job strategies which are least vulnerable to the risks of an unstable future.

Notes

1. See page 123 for a discussion of the shift-share methodology.
2. This is due to the nature of the DRI TRENDLONG projections.
3. For further details and examples of the shift-share analysis approach see: Ashby (1964 and 1965) and Hirsch (1973).
4. The state's ability to get and hold jobs *may* improve over the long run due to a slower growth of wages in Michigan than elsewhere.

5

Energy Supply/Demand Scenarios for Michigan in the Year 2000

Overview of the Chapter

To what extent should the state be concerned about the amount and kinds of energy that are likely to be available over the years ahead? Are there particular fuels likely to be most vulnerable to supply shortages? This section examines these questions through a series of energy supply and demand projections for the state in the year 2000. These projections, or scenarios, are based on the three national energy supply scenarios presented in Chapter 3, and the state economic scenarios presented in Chapter 4. Through these scenarios we can examine a range of potential energy supply and demand patterns which the state may experience over the next two decades.

The extent to which energy shortages emerge or are avoided in the future will depend upon a number of factors. Some of these will be largely beyond state control, but others will be subject to considerable influence through future decisions of the state's citizens and its public and private sector policymakers. Some of the major factors affecting Michigan's long-term energy supply and demand situation are:

- the future level of Michigan's economic output and the future share that energy intensive industries will contribute to this total;
- the national availability of fuels — natural gas, oil, coal, uranium, and synthetic fuels — for importation by Michigan;
- the extent to which state activities, public and private, are able to increase energy supplies over which Michigan has primary control: electrical generating capacity, active and passive solar, and non-traditional

energy sources such as biomass (wood and fibers), urban waste, and synthetic fuels;

- the outcome of economic and demographic trends affecting the number of energy consumers (businesses and households) in the state, and the nature of their consumption patterns;
- the level of energy conservation which can be induced among energy consumers over the next several decades;
- the extent to which the state maintains its current energy mix (based heavily on petroleum, which can be expected to be in short supply in the future), or shifts to alternative patterns and to increased use of new sources such as solar and renewable energy technologies.

A large number of possible futures for the state emerge from this list. For our purposes in this section we have limited the range of potential outcomes to those which might occur under essentially business-as-usual conditions. Starting with very narrow business-as-usual assumptions, we first examine the supplies and demand for particular fuels which might be expected if the present patterns of state energy consumption expanded proportionately with future state economic growth. We then broaden the analysis by examining a range of energy conservation and substitution responses that might occur under a broader definition of business as usual (i.e., as a result of normal market forces). In all cases, the projections include appropriate adjustments for expected state population growth and for the shifting composition of the state's economic output (as discussed in Chapter 4).

As a preview of the detailed discussion which follows, the major conclusions of the chapter are outlined below:

- The prospects for very serious shortages of oil prior to 2000 are substantial. This is true even granting quite liberal assumptions about the availability of synthetic liquids by the year 2000. Thus, in the context of Figure 4.1, both national economic conditions and local energy supply circumstances can be expected to affect Michigan jobs in the future.
- Energy conservation will be a major part of the future for all energy consumers in the state. But improved conservation practices alone are still likely to leave the state vulnerale to serious shortages of petroleum, and perhaps other fuels as well, if some of the more pessimistic supply forecasts turn out to be correct, or if conservation gains are lower than expected. To reduce our dependence on petroleum (and other energy sources, should problems occur) we will need to develop energy sources which are by their nature more plentiful.
- Supplies of coal and electricity potentially available for the future appear to be satisfactory for any of the levels of demand examined. Indeed, considering resources alone, there is considerable room for the expansion of the use of these energy forms in the state—should the state wish to pursue

such options. The same conclusion could be true for natural gas, if the more optimistic supply projections prove to be correct.

- Overall, the kinds of conservation and fuel substitution strategies which are likely to emerge in the context of business as usual cannot be counted on to effectively eliminate the future energy imbalances which could occur. The future of Michigan jobs will hinge on our ability to plan and implement an energy future which goes well beyond business as usual.

Assessing Michigan's Energy Supplies in the Year 2000

Table 5.1 describes three scenarios for state energy supplies in the year 2000. The scenarios were developed by "stepping down" to the state level the high, medium, and low national energy supply scenarios presented in Chapter 3. Just as in the national scenarios, the medium state supply scenario can be viewed as the most likely outcome. The low and high scenarios represent less likely outcomes at the lower and upper ends of the probability distribution (see Figure 3.6, Chapter 3).

Total energy supply projected for the state (in primary fuel equivalents) is 2.7 quads in the low scenario, 3.8 quads in the medium scenario, and 4.8 quads in the high scenario. By these projections energy supplies for the year 2000 could be 7 percent lower or as much as 66 percent higher than the 2.9 quads used in 1976. The more likely medium case represents an increase of 31 percent in total state energy supply.

As explained in detail in the boxed section below, supply projections for Michigan are based on the assumption that the state will retain its current share of national supplies for each major fuel type. This could, however, be an overly optimistic assumption. A number of factors suggest that the historical pattern of allocation could change, and that the more likely changes would reduce Michigan's fraction, rather than increase it. Shifts in employment, in industrial composition of the economy, and in population could all have impact on the state's share of U.S. energy supply. Similarly, future energy turbulence—higher prices, periodic shortages, and government intervention—could fundamentally alter the economic and political environment in which energy allocation decisions are made.

The fuels most likely to be affected, should there be a change in historical allocations, would be petroleum, natural gas, and coal. Federal petroleum allocation programs are already in place. Natural gas and coal supplies are often based on long-term contracts, which thus far have not been seriously tampered with by the Federal government. Should shortages occur, however, it is conceivable that Federal allocation, or, more likely, conservation requirements analogous to those for gasoline, would be enacted. If allocations to the states were roughly proportional to their respective shares of

TABLE 5.1

Michigan Energy Supplies in the Year 2000;
State "Stepdowns" of the Three National Energy Supply Scenarios

	Low	Medium	High
Petroleum includes synliquids 10^6 bbl	130–135 (0.72–0.75)	175–190 (0.97–1.06)	230–260 (1.28–1.44)
Natural Gas includes syngases 10^{12} cf	.40–.43 (0.41–0.44)	.81–.89 (0.83–0.91)	1.20–1.32 (1.22–1.35)
Coal elect & direct use 10^6 tons	51–62 (1.21–1.48)	66 (1.57)	71–84 (1.69–2.00)
Solar/Renewables Quads, FFE	.08–.20 (.08–.20)	.20 (.20)	.20–.31 (.20–.31)
Electricity 10^9kwhr	75–146 (0.78–1.51)	75–146 (0.78–1.51)	75–146 (0.78–1.51)
Annual Total* Quads	2.7	3.8	4.8

*Based upon the mid-range outcomes for each fuel type listed (see also footnote e, Table 3.5). Total does not directly equal the column sum of all quad equivalents since double counting of fuels used to generate electricity must be removed.

The figures in parentheses are the Quad values (primary fuel terms) of the stock fuel projections directly above.

Interpretive Notes:

- For each scenario, the projections of natural gas, petroleum, and coal assumes that Michigan retains its historical share of each of these fuels. Any shifts away from historical fractions are more likely to be downward than upward.
- The range of values on the petroleum and natural gas estimates reflect uncertainties in the availability of fossil-based synthetic fuels in the year 2000.
- The projections for solar/renewables estimate the outcomes of varying levels of national emphasis, state potential, and rates of growth of the markets for these technologies.
- The projections for electricity are based upon state utility company construction plans to the year 2000 (as reported in *Coordinated Regional Bulk Power Supply Programs*, ECAR, April 1978). Variations on the upper level of supply are possible (see the notes to Figure 5.5).

total U.S. employment in the year 2000 (see Chapter 4), Michigan would experience reductions on the order of 5 percent. That is, under a nationally imposed fuel allocation plan, supplies to the state could be 5 percent lower than the values shown in Table 5.1.

To interpret the state supply figures meaningfully, we need to examine the availability of individual energy forms such as petroleum, natural gas, and electricity in the context of the expected demand for each type of energy. In the remainder of this chapter we compare the potential energy supplies in each of the three scenarios with the energy demands which might be expected under three different sets of assumptions:

HOW THE STATE SUPPLY PROJECTIONS WERE PREPARED

The three EPG national energy scenarios were the starting points for the projections of Michigan's year 2000 energy supplies. National economic and energy supply conditions were treated as the major determinant of the state supply of each energy type except electricity and, to some extent, solar/renewables.

The projections for petroleum, natural gas, coal, and fossil-based synthetic fuels assume that Michigan will retain the share of national supply for each fuel that it has held over the recent past (1972–1977).

The projections for electricity are based upon the major state utility companies' published plans for additions and retirements of generating facilities by the year 2000. The supply estimates are based upon the continuation of current reserve margins and capacity factors. As examined later in this chapter, these key factors could change in the future, resulting in somewhat greater supplies. In addition, a greater level of supply than indicated here is technically feasible should a series of public and private sector decisions (not currently visible) be made to commit substantial additional resources for electricity production.

The projections for solar/renewables are based upon initial estimates of the potential of these technologies in Michigan, and upon the rate of innovation suggested by varying levels of national and state commitment. The paucity of research on the potential of the solar/renewables technologies in Michigan means that only tentative estimates of future supply levels are possible.

1. *Current Trends Continue*. This is a baseline case in which we project no changes in current energy consumption patterns, but do adjust current energy consumption levels to reflect economic and population changes between now and 2000. Efficiency gains and substitution of plentiful or less expensive fuels for scarce or more expensive fuels are specifically excluded from these projections. This obviously unrealistic outcome provides a useful measure of how much change will be necessary to avoid energy shortages.

2. *Increased Conservation*. This series of projections includes assumptions about the amount of conservation likely to occur in each sector of the

HOW THE "CURRENT TRENDS" AND "DEMAND CONSERVATION" PROJECTIONS WERE PREPARED

Projections for Michigan's future demands of energy were prepared through analysis of five broad sectors of the state's economy: manufacturing, non-manufacturing (including government and commercial sectors and non-electric utilities), residential, transportation, and electricity generation. The starting point for the "current trends" series of the projections was the level and pattern of consumption of major fuels and energy carriers (oil, natural gas, coal, electricity, nuclear, hydro, solar/renewables) by each of these five sectors in 1976 (see Chapter 1). Future demands for all energy forms in the manufacturing and non-manufacturing sectors were calculated proportionately from projected future output in each of these sectors (based on employment levels specified in the state economic scenarios of Chapter 4 and average recent values for productivity). Future demands for energy in the residential sector were derived proportionately from expected changes in the state's population (9.1 million in 1976; 10.4 million estimated by the U.S. Census Bureau's Census III projections for 2000). Future energy demands in the transportation sector were projected proportionately from expected

economy under the business-as-usual constraints of this study. The levels of conservation are realistic and quite substantial. These projections are obviously more realistic than the "Current Trends" projections. They provide indication of the extent to which conservation alone will serve to avoid energy shortages without the introduction of large-scale substitutions of plentiful fuels for scarce fuels. Furthermore, the conservation projections, having taken account of the likely effects of conservation, show us which interfuel substitutions may be needed.

3. *Increased Conservation and Fuel Substitution.* This series of projections is the most realistic of the three sets, since under business-as-usual assumptions, both substantial conservation and fuel substitution can be anticipated. There is, however, an extremely wide range of substitution patterns which could occur. We have explored just three of these alternative patterns as a guide to the general range of outcomes which might be pos-

changes in the state's population and the overall level of output of the state's economy. The state's generation of electricity was assumed to respond to demands from the other four sectors. But no fixed assumptions have been made as to the relative shares of coal and nuclear power in the generation of electricity; instead, a range of values is presented.

The "current trends" demand series assumes the continuation of the state's present fuel consumption pattern scaled-up proportionately by the new demands of the major energy consuming sectors of the state economy. The "conservation" series adjusts current trends in light of anticipated business-as-usual patterns of energy conservation in each of the sectors.

The conservation gains incorporated in the scenarios are summarized in Table 5.2. These levels should not be difficult to realize over the next two decades. Energy conservation trends are already rather visible. More importantly, recent engineering and economic analyses argue for these trends to continue and expand, even under business-as-usual assumptions. In addition, saturation in demand for relatively energy-intensive commodities, especially in the residential and commercial sectors (e.g., space and water heating, refrigeration, stoves, air conditioning, etc.), may reduce growth in energy demand over and above the effects of increased efficiency. (CONAES Demand and Conservation Panel, 1978; Ross and Williams, 1979).

sible. No one substitution pattern is treated as more likely than another. To minimize confusion from a proliferating number of scenarios, alternative substitution patterns are explored only for the medium supply/demand scenarios, and not for the low and high cases.

In the sections which follow, we systematically examine the implications of the three sets of demand assumptions for the supply/demand balances in the high, medium, and low year 2000 Michigan energy scenarios. The "high" state energy scenario is based on the "high" national energy scenario and the number I (high) state economic scenario, the "median" state energy scenario is based on the "median" national energy supply scenario and the number II (median) state economic scenario, and the "low" scenario likewise. The specific variations examined are shown in Figure 5.1. As noted above, the pattern shift projections, which include both conservation and substitution of fuels, are examined only for the medium scenario. This

FIGURE 5.1*

Supply/Demand Configurations Examined in Chapter 5.

Supply/Demand Scenarios	Demand Assumption				
	Current Consumption Patterns Continue	Conservation	Substitution and Conservation		
			Pattern Shift A	Pattern Shift B	Pattern Shift C
High Supply and High Economic Growth					
Median Supply and Median Economic Growth					
Low Supply and Low Economic Growth					

* The shaded boxes indicate the supply/demand configurations examined in this chapter. Less likely scenario configurations, such as low supply coupled with high economic growth, or high supply with low economic growth, are not specifically examined. The reader can make such comparisons, however, based on the data provided in Figures 5.2 through 5.8 and Tables 5.2 through 5.9.

scenario can be thought of as a more likely outcome than either of the other two, and is based on the assumption of median supply levels for the state, coupled with median state economic growth.

Year 2000 State Energy Demand:
"Current Trends" and "Conservation" Projections

Tables 5.3–5.5 compare expected year 2000 state energy supplies with the "Current Trends" and "Conservation" demand projections for the medium, high, and low state energy scenarios. Table 5.3 shows that for the most likely, or medium, scenario, the continuation of current trends in consumption of petroleum and natural gas would result in serious imbalances between supply and demand. Furthermore, even the levels of conservation which could be anticipated under business-as-usual assumptions would not be adequate to eliminate the potential imbalances.

In fact, under the continuation of current trends, shortfalls of supplies relative to demands on the order of 8 to 25 percent could be anticipated for even the more optimistic high supply scenario (Table 5.4). With luck, conservation efforts might result in a tenuous supply/demand balance in the high scenario. However, in the low supply scenario, even with conservation demand could be as much as twice the level of supply. By way of comparison, the oil supply problems of the 1973–1974 period left the state some 4 percent short of its desired total energy demand for a relatively short period of time. The potential deficits in the year 2000 scenarios could, should they occur, be significantly more serious because of their long-term nature.

In reality, however, imbalances of these magnitudes would not be likely to occur. Other forces, including the types of fuel substitutions discussed later in this chapter, would intervene to adjust demand downward to match available supply. But this adjustment process could take many forms—some with highly negative implications for the state. The situation in which long-term planning and sustained investments in energy efficient habits and capital stock allow the economy to continue functioning and growing with less energy is obviously quite different from the situation in which the adjustment is forced on a "surprised" society through lowered production, economic instability, and higher unemployment.

Supply and Demand for Specific Energy Types

A fuller understanding of the potential for energy shortages (or their elimination) requires a detailed look at the state's energy future on a fuel-by-fuel basis. These fuel-specific projections will have major implications for the state in regard to both employment and future energy planning. The remainder of the chapter provides a more detailed analysis and clarification of the scenarios on a fuel-by-fuel basis.

TABLE 5.2

Energy Conservation Gains Assumed to be Realized in the "Demand Conservation Scenarios," Present to 2000

	Consuming Sector			
Scenario	Manufacturing	Non-Manufacturing	Transportation	Residential
High[a]	0.7% decline in total sector demand per year Trend toward greater energy efficiency continues—but at slower rate	0.9% decline in total sector consumption per year Better energy efficiency in new products and buildings	0.4% decline per year in total sector demand Some saturation in auto transportation demand No shifts in typical modes of transportation Slow improvements in energy intensiveness of all modes Mass transit doubles	0.9% decline in total sector consumption per year Slow improvement in the energy intensiveness of new products and buildings
Medium[b]	1.0% per year decrease in per unit output demand for energy More efficient use of energy in production process as a result of higher prices	1.4% decline per year for whole sector More efficient uses of space & lighting Saturation of energy intensive products such as air conditioning	Trucks & autos: 0.8% decline of total demand per year Other modes parallel growth in GNP Fuel efficiency of autos & small trucks increases due to mandated standards	0.6% decline in total sector demands per year Growth of less energy intensive multi-family housing Saturation of demand for energy intensive products New purchases are for less energy intensive products
Low[b]	Same as medium	Same as medium	Same as medium	Same as medium

[a] Based upon projection in CONAES Demand and Conservation Panel's (1978) "Scenario IV."

[b] Based upon Ross and William's (1979) "*Business-as-Usual*" *scenario.*

TABLE 5.3

Michigan 2000 Energy Supplies and Demands—
"*Medium*" National Energy Supplies
and "*Medium*" State Economic Scenario (more likely outcome)

Corresponds to a U.S. Energy Total of 102 Quads in the Year 2000

	Michigan 2000 Supply	Michigan 2000 Demand	
Energy Source	Historical Fraction	Current Trends	Demand Conservation*
Petroleum includes syn-liquids (10^6bbl)	175–190	290 (22)	230 (18)
Natural Gas includes syngas (10^{12} cf)	.81–.89	1.35 (.08)	1.13 (.06)
Coal elec. & direct use (10^6 tons)	66	28–50 (14–36)	18–39 (7–29)
Solar/Renewables (Quads, FFE)	.20	.20	.20 .4
Electricity (10^9Kwhr)	75–146	105 Fossil: 49–96 Nuclear: 0–47 Hydro: 9	88 Fossil: 32–79 Nuclear: 0–47 Hydro: 9

*Based upon engineering/economic estimates by Ross and Williams (1979).

Interpretive Notes:

- The range of values on the petroleum and natural gas supply projections reflects a range of estimates of the availability of (fossil-based) synfuels in the year 2000.
- The range in the electricity supply figures reflects published state utility plans for generating capacity additions to the year 2000 (at current capacity factors). Variations on the upper level of supply are possible; see notes to Figure 5.6.
- The number noted in parentheses for the petroleum, natural gas, and coal demand projections identify the respective amounts of these fuels which would be used in meeting the projected electricity demand.
- The range of values expressed in the demand projections for coal (parenthetical figures as well) reflects the amount of coal required in meeting projected levels of electricity demand in light of minimum and maximum levels of nuclear generated electricity.
- The range of values in the expressions for solar/renewables demands reflects uncertainties as to how markets for these energy sources will develop under business-as-usual conditions.

Future Petroleum Problems. The potential for future supply/demand imbalances for petroleum can be seen more clearly in Figure 5.2. Even with the full realization of the conservation measures described in Table 5.2 there are significant risks of petroleum shortages in each of the three scenarios. In the more likely medium scenario, business-as-usual levels of conservation could leave a deficit of 40 million barrels annually. Without conservation, the gap

TABLE 5.4

Michigan 2000 Energy Supplies and Demands—
"High" National Energy Supplies and
"High" State Economic Scenario (less likely outcome)

Corresponds to U.S. Energy Total of 130 Quads in Year 2000

	Michigan 2000 Supply	Michigan 2000 Demand	
Energy Source	Historical Fraction	Current Trends	Demand Conservation*
Petroleum includes syn-liquids (10^6bbl)	230–260	305 (24)	265 (20)
Natural Gas includes syngas (10^{12} cf)	1.20–1.32	1.45 (.08)	1.20 (.07)
Coal elec. & direct use (10^6 tons)	71–84	34–56 (18–40)	24–47 (10–33)
Solar/Renewables (Quads, FFE)	.20–.31	.20–.31	.20–.31
Electricity (10^9Kwhr)	75–146	115 Fossil: 59–106 Nuclear: 0–47 Hydro: 9	95 Fossil: 39–86 Nuclear: 0–47 Hydro: 9

*Based upon engineering/economic estimates by CONAES Demand and Conservation Panel (1978). Interpretive Notes: See Table 5.3.

could be as high as 125 million barrels. This is a range of 17–43 percent of demand. The "low" scenario reflects an even greater magnitude of shortfall. The minimum gap of 5 million barrels annually in the optimistic—but less likely—"high" scenario is probably not troublesome. But note that even there the potential exists for considerable shortfall if petroleum conservation measures are not realized. As a point of reference, the petroleum shortfall to the state of Michigan during the 1973–74 world oil crisis was on the order of 19 million barrels annually. The most optimistic shortfall of oil in the likely scenario is over twice that size! Note, as well, that conditions could be even worse if the state were to receive less than its historical share of national supplies.

As indicated throughout this report, the implications of petroleum shortages in Michigan are extremely serious for the automobile industry, tourism, agriculture, trucking, and commuters. For at least the next decade, petroleum is likely to be our most serious energy problem. It is worth pointing out, again, that the supply scenarios already include estimates for imported oil

TABLE 5.5

Michigan 2000 Energy Supplies and Demands—
"Low" National Energy Supplies and *"Low"* State Economic
Scenario (less likely outcome)

Corresponds to U.S. Energy Total of 71 Quads in Year 2000

	Michigan 2000 Supply	Michigan 2000 Demand	
Energy Source	Historical Fraction	Current Trends	Demand* Conservation
Petroleum includes syn-liquids (10^6 bbl)	130–135	270 (20)	220 (15)
Natural Gas includes syngas (10^{12} cf)	.40–.43	1.25 (.07)	1.06 (.06)
Coal elec. & direct use (10^6 tons)	51–62	25–47 (12–34)	20–43 (11–33)
Solar/Renewables (Quads, FFE)	.08–.20	.08–.20	.08–.20
Electricity (10^9Kwhr)	75–146	100 Fossil: 44–91 Nuclear: 0–41 Hydro: 9	80 Fossil: 24–71 Nuclear: 0–47 Hydro: 9

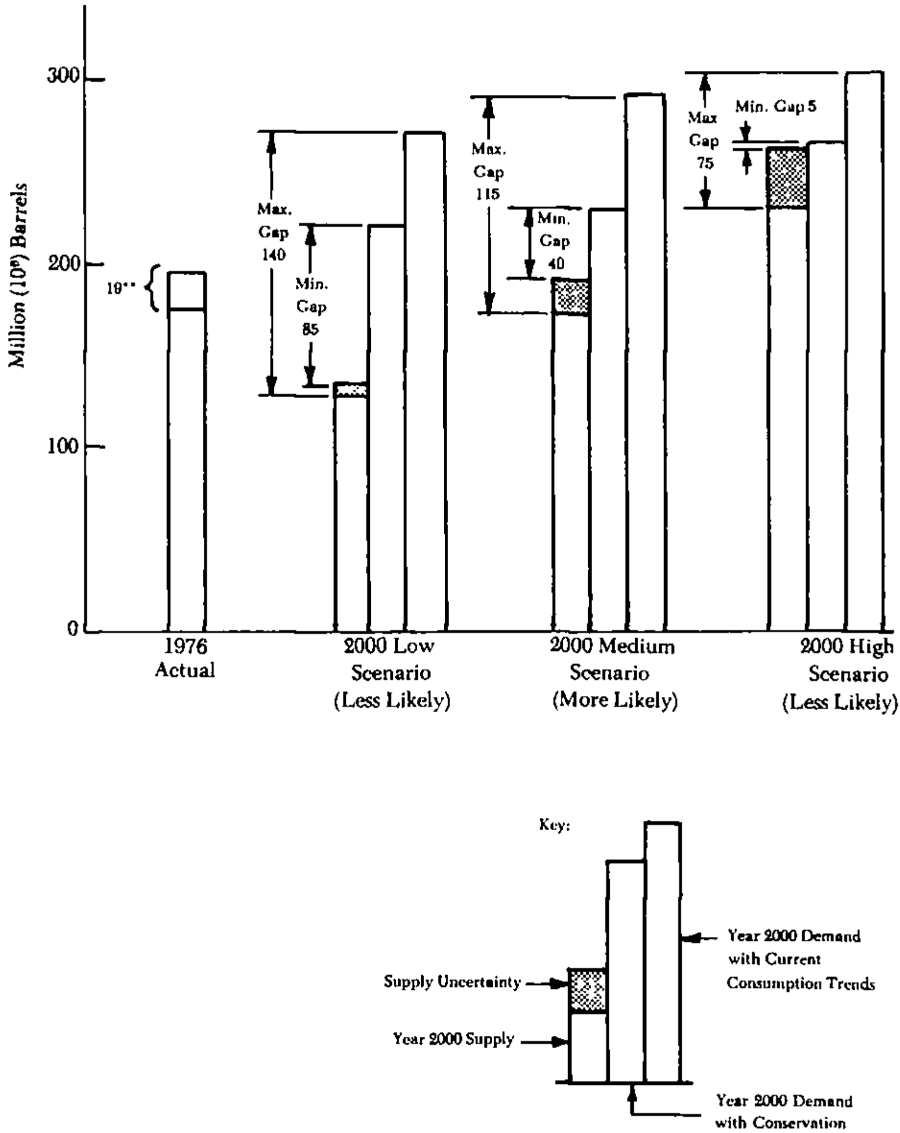
*Based upon engineering/economic estimates by Ross and Williams (1979).
Interpretive Notes: See Table 5.3.

and synthetic fuels. Synthetic fuels—even at optimistic levels—do not basically alter the supply-demand imbalances. As discussed in the latter parts of this chapter, fuel substitutions away from petroleum will be necessary *and* difficult. Even more importantly, we are likely to need petroleum conservation programs which go well beyond the business-as-usual conservation levels examined in this study.

Natural Gas Supplies. The implications of a continuation of "current trends" and of "conservation" on supply/demand balances for natural gas are shown in Figure 5.3. The continuation of current consumption trends would, in the more likely medium scenario, result in a deficit of up to .54 trillion (10^{12}) cubic feet. Business-as-usual levels of conservation could be expected to reduce this deficit to about .24 trillion cubic feet, a difference of approximately 20 percent between supply levels and potential demand. By way of comparison, the major economic dislocations occurring in Ohio in the winter of 1976–77 resulted from a short-term natural gas shortfall on the order of 10 percent (Ohio Department of Energy, 1979).

FIGURE 5.2

Projected Petroleum Supplies and Demands
for Michigan in the Year 2000, by Scenario*



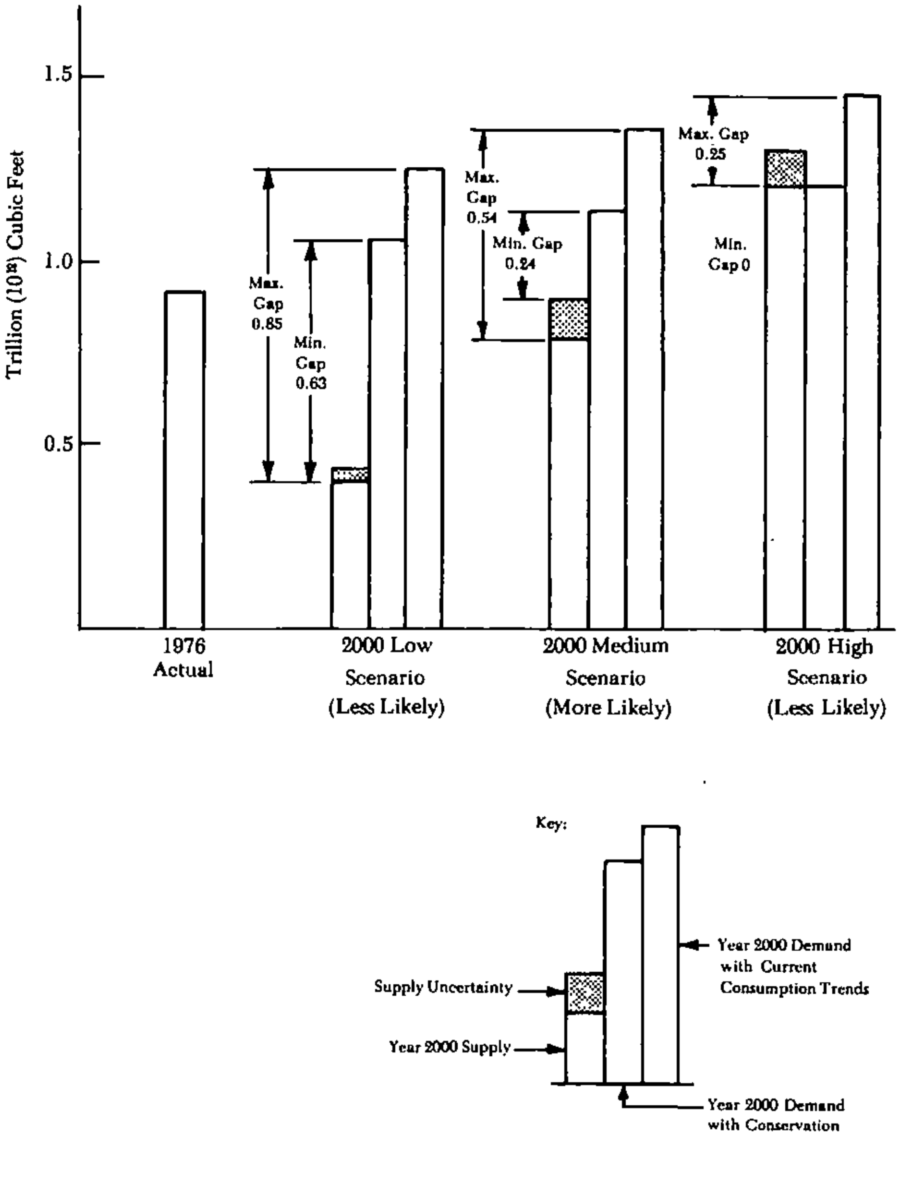
* Includes estimates of synthetic liquids availability by the year 2000; the range in the supply projections reflects uncertainty about the availability of these synthetic liquids. This figure is based upon projections given in Tables 5.3 through 5.5.

** Approximate size of the oil shortfall in Michigan during the 1973–74 Arab oil embargo.

The prospects for significant imbalances in Michigan's long-term future demands and supplies for petroleum are substantial. In the more likely scenario, business-as-usual efforts at conservation alone would still leave a large imbalance. A large success nationally with fossil-based synliquids by the year 2000 would not fully redress Michigan's petroleum problem.

FIGURE 5.3

Projected Natural Gas Supplies and Demands
for Michigan in the Year 2000, by Scenario*



* Includes estimates of synthetic gas availability by the year 2000; the range of values in the supply projections reflects uncertainties in that availability. This figure is based upon projections given in Tables 5.3 through 5.5.

Future imbalances in the supplies and demands for natural gas could be significant. In all but the "high supply" scenario, business-as-usual conservation would not be a sufficient response to remove the problem. In the "low" and "medium supply" scenarios, even a large success nationally with fossil-based syngases would not be sufficient to remove the imbalance.

The relatively large range of uncertainty regarding natural gas supplies is demonstrated by the relatively large differences between the low, medium, and high scenarios. If the pessimistic forecasts of the low scenario prove correct, potential demand could be twice the level of supply, even after adjusting for conservation gains. If current trends were to continue, without conservation or fuel substitutions, deficits as high as .85 trillion cubic feet would be possible. Fortunately, the low scenario is not as likely as the less problematic medium case. Unfortunately, the high scenario, in which conservation efforts could result in a balance of supply and demand, is not very likely either.

There is an important difference between the potential supply problems for petroleum and for natural gas. While in both bases business-as-usual levels of conservation are not likely to be adequate to avoid deficits, there is considerably more opportunity to eliminate natural gas deficits by substituting more plentiful energy sources such as coal, electricity, and solar/renewables. Specific substitution options are discussed in detail at the end of this chapter. Those conclusions are previewed here in order to emphasize the point that natural gas deficits are not likely in Michigan in the year 2000, unless the lower (and less probable) estimates of supply prove correct. There is, however, a need to monitor this situation closely over the next decade, since such shortages, should they occur, would be very serious because of the large role natural gas plays in the industrial, commercial, and residential sectors of the state's economy (see Figure 2.5). On the other hand, to move away from natural gas, when there could be adequate supplies, would be a costly mistake in which the state might lose the right to its historical national share of a relatively inexpensive and clean-burning fuel.

In this regard, it is worth emphasizing again that the real implication of the large potential deficits in petroleum and natural gas, pointed to above, is not so much that supply/demand imbalances will actually occur at this magnitude, but rather that significant changes will occur first. In the best of circumstances, the changes will be well-planned, orderly, and relatively efficient. Most important, they will avoid the economic disruptions associated with serious energy interruptions and turbulence. But in the worst of circumstances we will not react quickly enough. Gas lines will be a way of life; homes and offices will be unacceptably cold; industries will be crippled; and unemployment will be high. The potential for such turbulence is enormous. Gains in conservation and in new production sources could both be slower and more expensive than anticipated. Similarly, diversifying our transportation system will be a long, complex, and expensive process. The path ahead is riddled with uncertainties and could be littered with both short-sighted and honest energy planning mistakes. The cost in both cases will be the health of the state's economy.

Future Coal Supplies. Many knowledgeable people have expressed concern regarding the difficulties the U.S. will face in mobilizing its vast resources of coal (Duane, 1977). Yet the projections in Tables 5.3–5.5 suggest that, despite problems, sufficient coal should be available to meet the state's needs. In fact, the use of coal could be expanded significantly without supply difficulties. This conclusion stands out clearly in the comparisons depicted in Figure 5.4. Indeed, when all the possible outcomes are considered, coal supplies are inadequate to meet demand only in the unlikely case that the state economy is in high gear, no conservation of demand has occurred in the previous two decades, none of the state electricity is provided by nuclear energy, and coal supply is at the "low" level.

It should be stressed, though, that this optimistic conclusion leaves aside the problem of periodic supply disruptions due to labor disputes—a not infrequent occurrence in a labor force with a history of strikes and labor-management conflict. It leaves aside as well the potential limitations on coal combustion imposed by ambient air quality standards. Coal combustion is a major source of pollutants such as nitrogen and sulfur compounds, and particulates—each of which is currently the focus of national and state air quality legislation. It is also the source of a large number of other pollutants which are currently being scrutinized for their health and environmental risks with an eye toward possible controlling legislation. The exact extent to which current and future environmental quality legislation will constrain coal is not clear—it is an important issue which adds considerable uncertainty to energy planning, but one which is beyond the analytical scope of this effort.

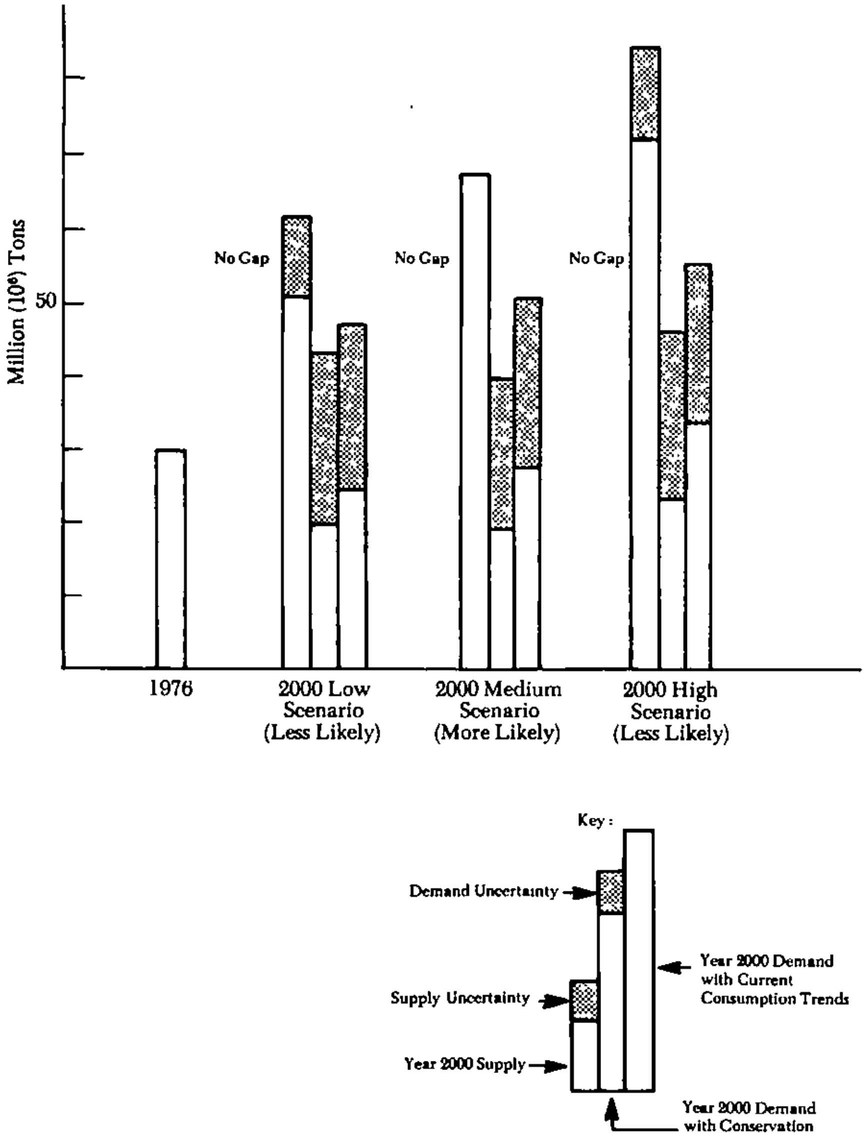
Future Electricity Demands and Supplies. The scenarios suggest that from a technological and fuel standpoint, the state is likely to have sufficient electricity through 2000. These conclusions are based on the state electricity demands in the scenarios, on broad projections of the relative role electricity could play in the state's future total energy supply situation, and on an assessment of published state electrical utility plans for installed generating capacity through 1997. Our analysis does not, however, systematically incorporate the potentially important constraints on electrical supply which might result from financing or construction difficulties, or from restrictions imposed by environmental quality and nuclear safety considerations.[1]

Figure 5.5 summarizes the electricity supply and demand aspects of the scenarios. The scenarios span a range of demands from 80 billion kwhr/year to 115 billion kwhr/year. Like the earlier projections for petroleum, natural gas, and coal, the demand projections for electricity are based upon recent trends in use within major consuming sectors. (Shifted roles for electricity in the state's total energy picture are examined on pages 178–186.)

The supply projections for electricity, however, are different in nature

FIGURE 5.4

Projected Michigan Coal Supplies and Demands
in the Year 2000, by Scenario*

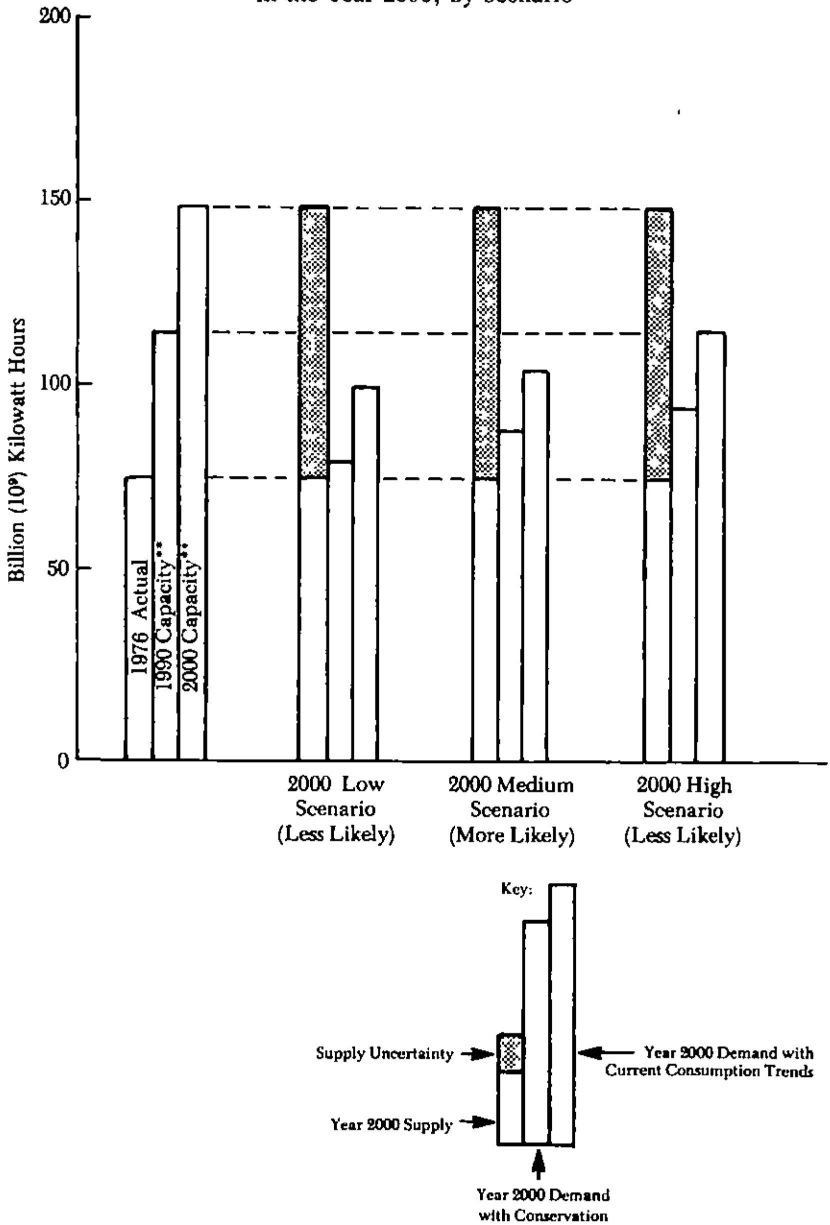


* For direct uses and the generation of electricity only; does not include coal used for synfuel. The range of values presented for supply reflects uncertainties as to how much of an investment is made nationally (within each scenario) to bring coal "on line." The range of values presented for demand reflects a range of roles for coal in delivering electricity. This figure is based on projections given in Tables 5.3 through 5.5.

Michigan's supplies of coal are likely to be sufficient to meet demand in the future. A significantly increased role for coal in the future is not infeasible from the standpoint of resources likely to be available.

FIGURE 5.5

Projected Michigan Electricity Supplies and Demands in the Year 2000, by Scenario*



* The range of values in the supply projections is based upon recent state utility plans for generation capacity additions through the year 2000. The demand projections assume that electricity's relative role in each major consuming sector of the economy remains the same as at present. (Alternative roles for electricity are considered elsewhere in this chapter.) This figure is based upon the projections given in Tables 5.3 through 5.5.

** Annual electricity available if planned additions to the state's capacity are realized (based upon current capacity factors and reserve margins).

The future electricity demands anticipated here for Michigan are well within the capacity of future planned additions to the state's electrical generation capabilities. Higher levels of electrical supply are technically feasible, particularly in the "medium" and "high" scenarios. This would depend, however, upon state and utility decisions to commit additional finances and resources. In this respect, the upper supply level projected here for the "low" scenario is probably a substantial overestimate, due to the precarious and turbulent economics of this scenario.

than those for other energy sources. Utility company plans and state and local regulatory decisions will play a dominant role in determining the future supply of electricity available in the state. To follow the projection procedure used for other energy sources by "stepping down" state supplies from a range of forecasts of future national electricity supplies would not provide a useful indicator of expectations for Michigan. In this case, current state utility plans for capacity additions and retirements through 1997 (as reported by the East Central Reliability Council, 1978) are used as the basis for the supply projections. The highest supply level identified in Figure 5.5 corresponds to the full realization of these plans, assuming the continuation of current capacity factors and reserve margins.[2] Higher levels of supply are technically possible, but to realize them would involve a greater commitment of resources and a larger growth in demand than are currently foreseen.

In view of the importance of Michigan-based initiatives in determining future state electrical capacity, the current mid- and long-range plans of the state's major utility companies are reviewed below in relation to the scenario demand projections.

Electrical Capacity in Michigan: A Brief Review. In 1978 the state's effective electrical generating capacity amounted to some 17,000 megawatts (MW).[3] Throughout the year this capacity was operated on average to yield approximately 51 percent of its potential electrical output ("capacity factor")[4] — the generating capacities of other regions of the U.S. currently operate in the 42 percent–64 percent range (National Electric Reliability Council, 1978). While this may seem like a very poor use of available electric plants, there are a number of reasons for not operating at 100 percent of capacity:

- Demand for electricity is higher during some times of the day or year than in others. The highest demand is known as the "peak." During low demand periods, only "base load" plants are operated. As demand rises, additional "peak loading" plants are brought on line.
- "Excess" capacity is needed so that service can be continued, and system stability preserved, while some plants are "down" for planned or unplanned maintenance.
- Utility companies maintain a "reserve margin" of capacity greater than their expected peak demand in case of forced or planned outages, severe weather, and unanticipated growth in demand. For Michigan the "reserve margin" standard is 20 percent. In 1978, the peak demand and available capacity were such that the actual reserve margin in the state was about 30 percent.

Tables 5.6 and 5.7 summarize recent plans of the state's two major electrical utilities for capacity additions and deratings through 1997. Two utility companies, Detroit Edison and Consumers Power, supply about 90 percent of Michigan's electrical needs. The service area for Edison and Consumers

TABLE 5.6

Total Electrical Generating Capacity for Consumers Power and Detroit Edison (Megawatts)*

	Coal	Oil and Distillates	Natural Gas	Nuclear	Hydro	Pumped Storage Hydro	Total
Current (1978)	8,320 53%	3,877 25%	647 4%	801 5%	134 1%	1,872 12%	15,651 100%
1984 (current construction)	10,452 50%	4,577 22%	647 3%	3,229 15%	135 1%	1,872 9%	20,911 100%
1997	13,000 43%	4,000 13%	600 2%	10,600 35%	0 0	2,000 7%	30,300 100%

SOURCE: East Central Area Reliability Coordination Agreement, 1978.
*Takes into account projected retirements, upratings, deratings. Capacities refer to Design Electrical Rating.

includes about 95 percent of all the state's heavy industry. The remainder of Michigan's electrical supply comes from a number of municipally owned or rural electrical cooperatives as well as two out-of-state power companies (Wisconsin-Michigan Power Company and Indiana and Michigan Power Company). The determination of the total generating capacity available to Michigan is made considerably more complex by the 10 percent of supply contributed by the smaller and out-of-state facilities. For example, the Indiana and Michigan Power Company has about 2000 MW of installed nuclear generating capacity at its Cook facilities in western Michigan, but less than 5 percent of the electrical output of those plants goes to Michigan.

In light of these complexities, and the fact that this analysis is intended merely to lay out the broad boundaries of the state's current and future electrical supply, we have simplified the analysis by considering only the combined electrical generating capacities of Detroit Edison and Consumers Power. Assuming that they will continue to supply about 90 percent of the state electrical supply, we have estimated the state's current and planned future generating capacity by increasing the Edison and Consumers capacity by 10 percent. An interpretive perspective based upon these numbers is presented in Figure 5.6. Figure 5.7 shows how the scenario demand projections and the utility construction plans would unfold over time.

The lower portion of Figure 5.6 shows the electrical output which would be available to the state from (1) its currently installed generating capacity (approximately 17,000 MW), (2) its currently installed, plus currently under construction, capacity (minus those facilities planned for retirement during this period), and (3) capacity currently planned to be available as of 1997.

TABLE 5.7

Future Additions to Current Capacity by Fuel Type in Megawatts

Fuel Type	Year	Company	Location	Capability	Totals		
Oil	1979	Edison	Greenwood 1	780			780
Coal	1980	Consumers	Campbell 3	791			
	1983	Edison	Bell River 1	676			
	1984	Edison	Bell River 2	676	(1984)	2,143	
	*1986	Edison	Unassigned	650			
	1988–97	Consumers	Unassigned	1,600			
	1988–97	Edison	Unassigned	800	(1997)	3,050	5,193
Nuclear	1980	Edison	Fermi 2	1,093			
	1981	Consumers	Midland 2	805			
	1982	Consumers	Midland 1	530	(1984)	2,428	
	*1987	Edison	Unassigned	1,208			
	1988–97	Consumers	Unassigned	2,700			
	1988–97	Edison	Unassigned	3,500	(1997)	7,408	9,836
				TOTAL NEW ADDITIONS:			15,809

SOURCES: ECAR, 1978; and personal communication with John Duane, Consumers Power Company, P-26-303, February 1979.

* As this volume goes to press, Detroit Edison representatives have indicated through personal communication that these plants are no longer being considered. In late March 1980, Detroit Edison publically announced cancellation of plans for two 1,200 megawatt nuclear plants to have been constructed at its Port Huron, Greenwood site in the 1990s.

Available output from each of these levels of generating capacity is evaluated, based on both the current capacity factor of approximately 50 percent and an increase in capacity factor to 70 percent. The 70 percent figure is at the upper range of system capacity which would be possible without downgrading reserve margins (Carlson, Freedman, and Scott, 1979).

The logic of considering alternative capacity factors is as follows. Both a lower reserve margin and reduction in peak demand relative to average demand would allow for increases in capacity factor, i.e., increased utilization of available generating capacity. Within limits, this would allow for an increase in electrical output without a corresponding increase in new (and increasingly expensive) generating capacity. This is a complex issue, however, and maintenance requirements and the increased use of older plants must be carefully taken into account. Many of these older plants are less efficient and more polluting than new facilities and some use fuels likely to be in scarce supply. Over the long run, for example, it would not make sense to significantly increase the use of oil-fired plants. The major point to be made is that there is room for increasing the overall capacity factor of the state's electrical generating system. Determination of the specific level which would provide an optimal balance between cost and reliability for the

FIGURE 5.6

Future Electricity Demand and Planned Capacity in Michigan

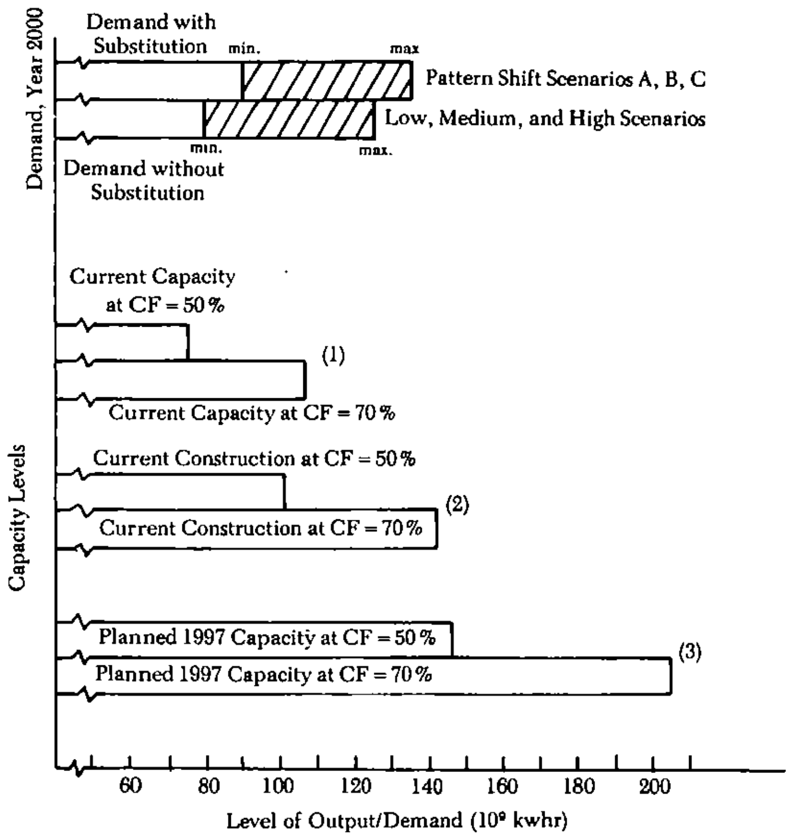
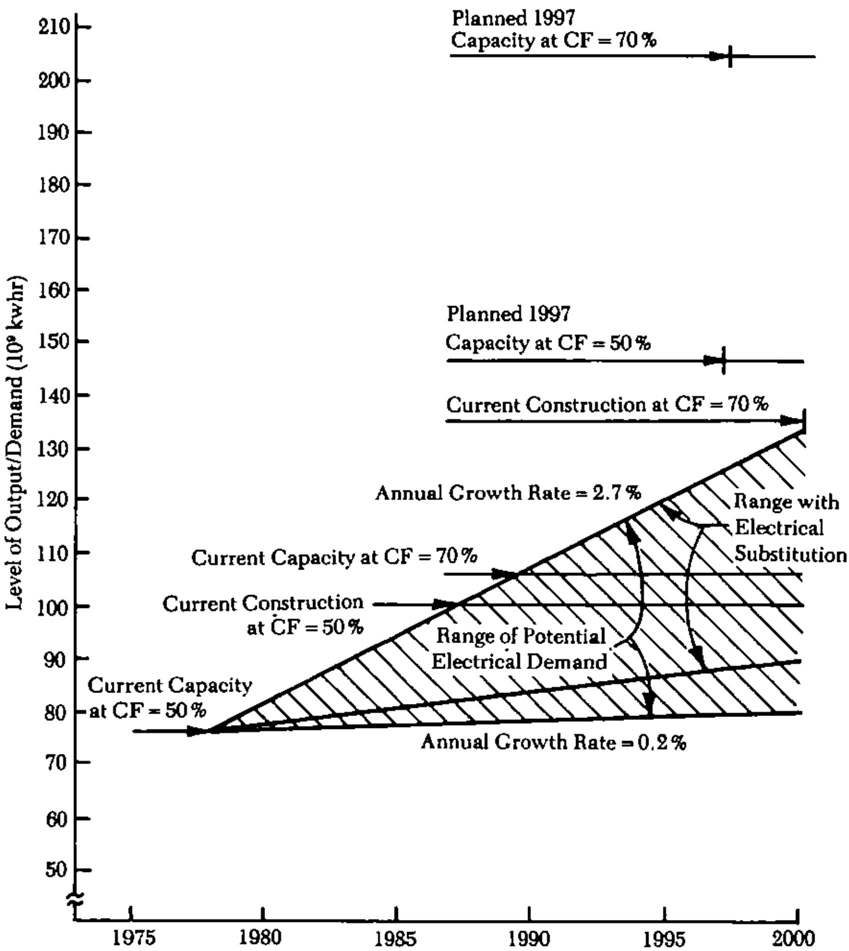


FIGURE 5.7

Time Phasing of Future Michigan Electricity Demands and Supplies



Michigan system would require a plant by plant analysis which is beyond the scope of this study. There is little doubt, however, that over the long term the optimal level is greater than 50 percent and less than 70 percent.

A reserve margin of 20 percent above expected peak demand is generally associated with an expected "loss of load" (inability to meet peak demand) once in ten years (Bolger, 1978). The exact nature of the relationship between reserve margin and LOLP (loss of load probability) is a complex one, currently subject to considerable debate (Bernow, 1979). Recent studies have suggested that the traditional one-day-in-ten-years criterion may be too high and may not provide consumers with the least costly system able to provide reliable service (Wolff, 1979). Part of the difficulty here is that the reliability needs and cost of outages are different for different classes of users (i.e., higher for industrial and commercial users, lower for residential). The optimal reserve margin for an electric supply system is a function of fixed and variable costs, environmental costs, and the costs of supply outages (Electric Power Research Institute, 1978). The most appropriate balance among these costs and the distribution of their burden among different classes of users will be debated in the years ahead, and will in fact be changing as a number of peak demand management strategies continue to be tested and implemented. Strategies involve approaches such as voltage reductions, interruptible service, utility controlled residential appliances, rate surcharges and alternative pricing strategies, demand control devices, and others. There appears to be much that can be learned, for example, from the European utilities, who have for some time been successfully reducing peak local demands through pricing strategies (Mitchell, Manning, and Acton, 1978).

Clearly, the issues involved are very complex. The detailed planning of our future electrical supply system will depend on a number of social, economic, technical, and political factors, and will require data and projections at a higher level of precision than those available here. It is possible, however, to lay out some of the possibilities and limits of current and projected electrical capacity. It is with this more modest purpose in mind that Figures 5.6 and 5.7 explore the levels of electrical demand which, based on current and utility company projected available capacity, could be met in the next twenty years.

The upper portion of Figure 5.6 shows the range for electrical demands projected in the alternative state energy scenarios for the year 2000. The lower range ("demand without substitution") corresponds to the three scenarios presented and discussed earlier in this section. As has already been observed, these scenarios assume that electricity's current role in the state's total energy mix will stay relatively constant over the next 20 years. Future population trends, the level of economic output, and prospects for conservation are the major determinants of the range of values reflected here. The upper range, in contrast, is derived from three additional state energy scenarios which are discussed in more detail in the last sections of the chapter. These scenarios assume that electricity's relative role could increase substantially in the future, as it substitutes for many needs that are currently met by oil and natural gas.

Notice, by comparing the range for electrical demand in the year 2000 with potential output under the alternative capacity and capacity factor assumptions, that Michigan's expected demand can most probably be met either through increasing capacity factors, through a smaller construction program than currently anticipated, or through a combination of the two.

Figure 5.7 yields a similar conclusion. It depicts a slowing growth in demand between now and year 2000, with the wide range of the shaded area showing great uncertainty. It is clear that with just current capacity plus those plants currently under construction operating at, or below, a capacity factor of 70 percent, the state could meet demand up to the year 2000. Since demand may well be below the maximum projected, and since modest new construction could be initiated in the mid to late 1980s if demand grows at the higher levels, capacity factors could remain at well below 70 percent if that were deemed desirable.[5]

The slow growth of Figure 5.7 reflects major conservation and efficiency gains as well as slow economic growth. Consider electric motors, for example. Nationwide they use 64 percent of all electricity. This represents as much energy as is used by U.S. automobiles. Recent innovations (Wanlass windings and semiconductor controls) permit 10 to 38 percent efficiency gains (Arthur D. Little, Inc., 1976; Ben Daniel and David, 1979; U.S. Department of Energy, 1980). Exxon Corporation researchers estimate widespread use of their semiconductor controls by 1990 could save 110 billion kwh per year, an equivalent of 600,000 barrels of oil per day. It is also arguable that by 1990 electric battery improvements will permit widespread use of electric cars, thus increasing total electrical demand. However, this will be efficient off-peak nighttime battery recharging, which will not add significantly to peak-load capacity requirements. Furthermore, the demand decrease due to electric motor improvements is likely to be larger than the demand increase from electric car adoptions in this century. Hence demand could easily be in the lower portion of the shaded area of Figure 5.7 in which capacity would pose few problems.

The Role of Conservation. The energy conservation adjustments (see Table 5.2) incorporated in the "demand conservation" scenarios reflect efforts to use energy more efficiently, as well as several anticipated saturations of demand, particularly in the residential and transportation sectors. As the percentages in Table 5.8 indicate, conservation adjustments would significantly reduce demands for fuels in each scenario.

TABLE 5.8

Percentage Reduction in Demands for Fuels
Resulting from Realization of Conservation Adjustments
(As percentage of "Current Trends" Projections)

	Scenario		
Fuel:	Low	Medium	High
Petroleum	19	11	13
Natural Gas	15	16	17
Coal	9–20	22–36	16–29
Electricity	20	16	17

In nearly every case considered, conservation makes a larger contribution toward reducing potential supply/demand imbalances than do the turn-of-the-century contributions of synfuels, maximum investments in bringing coal on line, or actions to insure that the state continues to receive its historical share of energy. Note, however, that even the full realization of these conservation adjustments would not, by itself, remove the substantial supply and demand imbalances for petroleum and natural gas which are indicated in the scenarios.

As a final note, it should be remembered that the conservation adjustments included in these projections incorporate outcomes assumed to be realized within the business-as-usual features of our scenarios. Recent engineering/economic analyses, however, have pointed to considerable additional prospects for energy conservation which could result from much more aggressive energy conservation policies and investment incentives (CONAES Demand and Conservation Panel, 1978). The implications of such "beyond business-as-usual" conservation alternatives are addressed in a preliminary way as one option among several discussed in the section on "Demand Projections Including Substitution and Conservation," below.

The Potential for Interfuel Substitutions in Major Sectors of the Michigan Economy

The analyses of the previous section serve to demonstrate that very large changes in energy use patterns will have to occur if Michigan is to avoid energy shortfalls and their related economic disruptions. To be sure, shortfalls of the magnitude shown in Figures 5.2–5.5 are not likely to occur. Even in a business-as-usual framework we would expect that conservation and substitution to other fuels or technologies would occur as a result of rising prices and spot shortages of the most seriously affected fuel types. This and the following section explore alternative patterns of energy use which might result from business-as-usual levels of conservation and substitution.

The exact patterns and timing of conservation and substitution which may occur are difficult to forecast in detail due to high levels of uncertainty with respect to future technological developments, government policy, relative availability and prices of alternative fuels, and the comparative risks of alternative energy strategies. It is possible, however, to examine some of the broad patterns of conversion which are possible in terms of current estimates of technical feasibility and relative availability of supply.

Petroleum Substitutions

Petroleum products make up just over one-third of the state's primary energy supplies, and almost two-thirds of that amount is used for transportation in Michigan. For a number of reasons, petroleum, or liquid fuels, may represent the most serious energy problem for the state and the nation. On the supply side we face prospects of decreasing domestic production and increasingly turbulent and uncertain availability of imports. On the demand side, and in the transportation sector especially, options for short and medium term fuel substitutions are minimal. Since all other sectors depend on transportation, the problem is multiplied throughout the economy. And while automobile production is not extremely dependent on petroleum as an input, sales of vehicles, and thus the health of the industry, are intimately tied to the availability of gasoline. Also at risk are tourism, agriculture, construction, and trucking in the state, all of which are closely tied to the availability of stable gasoline supplies.

Unfortunately, heavy dependence on imported oil will keep the nation, the state, and the auto industry highly vulnerable to supply interruptions and price rises. Petroleum-based political and economic difficulties can be expected to continue (or worsen) in the form of increased conflict with third world countries over available supplies and price, energy-related wars, foreign exchange problems, and instability or unfavorable restructuring of the international monetary system (*Business Week*, Nov. 19, 1979).

In Michigan, much will depend on the ability of the auto industry to improve the *actual* mileage of the nation's vehicle fleet.[6] The potential for rapid movement is quite large since about half the U.S. vehicles are replaced every five years. In fact, short-term prospects for auto sales may be enhanced by the desire for more fuel-efficient vehicles. In the longer term, however, a "conservation mentality," improved mass transit, increased telecommunications, and eventual saturation in miles driven per vehicle may serve to level off, if not reduce, new vehicle sales. Michigan faces the additional problem that an increasing proportion of the new fuel-efficient cars which are sold may be built in newer production facilities outside the state.

In terms of substitutions, the transportation sector, with its need for high quality mobile sources of energy, appears to be "locked in" to petroleum until well into the 1990s or beyond. In the short term, substitution of synthetic oil will not be possible on a significant scale. Some relief may be possible from gasohol, if it is produced efficiently and with an emphasis on renewable rather than nonrenewable energy inputs in its production (Chambers, et al., 1979).

For some applications, substitutions towards electric vehicles, mass transit, trains, and vehicles powered by alternative, nontraditional fuels such as methane and hydrogen are possible. However, problems of cost, lead times, consumer acceptance, and capital stock turnover rates are such that significant changes in power systems and/or fuel sources are likely to have little effect prior to the turn of the century.

In the long term, continued efficiency gains for automobiles and trucks will be essential. However, these gains will need to be consolidated by changes in behavioral patterns, geographic location decisions, and substitution of communications for some travel. Without these additional structural and value-based changes, increases in efficiency may merely serve to decrease the conservation incentives created by increased costs of fuels.

In contrast to the transportation sector, there are a number of substitution options available in the residential, commercial, and industrial sectors, although these options as well are limited by lead time, capital requirements, and uncertainties. Rapid increases in the cost of home heating oil, along with the threat of shortages, are already pushing some residential users to heavy conservation (gains of 30–40 percent are possible) and to alternative heat sources such as natural gas, electric heat pumps, solar designs, and wood stoves. Use of coal in the residential sector is not expected on a wide basis due to the costs of conversion and storage, potential air quality problems, and the general inconvenience of use in comparison to available alternatives. In Michigan only about 16 percent of the residential sector currently uses oil for heating. This accounts for ten percent of the state's petroleum usage.

Commercial firms and small industrial concerns can be expected to follow substitution patterns similar to those in the residential sector. Smaller industries with the need for high temperature process heat may be limited in the short term to electricity or natural gas. However, this is an area which could be changed dramatically by advances in the use of high temperature solar, biomass, hydrogen, or clean-burning small and medium-sized coal boilers.

Where air quality standards permit, larger industries can be expected to switch to coal, and in some cases cogeneration of electricity and process steam. It is possible, however, that those industrial concerns currently operating in areas designated as air quality nonattainment zones by the EPA will be forced to convert to electricity or natural gas, or to relocate in areas where the direct use of coal will be permissible.

Many of the substitutions away from non-transportation uses of petroleum will be to electricity. Since many of the nation's utilities (especially in the East) use oil for electrical generation, the utility companies will face a double burden. Michigan is fortunate in this regard in that only about 7.5 percent of its petroleum is used in producing 10 percent of the state's electrical output (1976 figures). Most of this oil is used during peak demand periods, and, as in the case of natural gas, consumption may be further reduced by the substitution of other fuels and load management practices.

Natural Gas Substitutions

As indicated earlier, there is considerable uncertainty regarding availability of natural gas for the year 2000. The 1978 Natural Gas Policy Act has set in motion and otherwise encouraged much of the research and development activity which will be needed over the next decade to resolve the major economic, political, technological, and geological uncertainties which exist.

At a minimum, it can be said that supplies of natural gas, which account for about one-third of the state's primary energy use, appear to be adequate through the 1990s. Prices, however, can be expected to rise significantly during this period, assuming decontrol policies continue. Beyond the early 1990s, supplies will most likely be adequate, although they could be anywhere from seriously low to abundantly high depending on whether actual supplies are closer to the medium, low, or high supply scenario level.

On a comparative basis, Michigan could be expected to remain better off than many other states as a result of long-term contracts and an extensive natural gas storage system. However, if the more pessimistic supply forecasts prove correct, there is some possibility that federal intervention could occur in an effort to balance supplies among the states. For example, it is difficult to imagine Michigan being allowed to provide gas to "nonessential users" while other states are not able to meet the needs of "essential users." Such intervention could take the form of state-by-state conservation requirements analogous to those for gasoline. Additional interventions are possible as a part of overall energy strategies which could alter supply priorities, e.g., by emphasizing industrial over residential use, or the reverse. However, even with government intervention, it is difficult to imagine Michigan being any worse off than the rest of the nation with respect to natural gas supplies.

As suggested by the conservation scenarios detailed earlier (see Figure 5.3), conservation alone may not result in a supply/demand balance even in the medium (or most likely) supply scenario. However, the demand scenarios described in the next section, which include both conservation and substitution of fuels, do suggest the likelihood of a year 2000 supply/demand balance for the medium supply scenario. Two of the three substitution and conservation scenarios incorporate no more than business-as-usual levels of conservation and substitution. In fact, many of the changes envisioned in these scenarios are already underway. In the past few years considerable conservation has occurred as homes and businesses have lowered thermostats, and purchased more efficient equipment. As a result of rising prices, these efforts can be expected to accelerate in the next few years, as will the efforts of a number of large industrial users of natural gas to shift to other fuels.

The industrial sector currently uses about one-third of Michigan's natural gas supply. If, over the next decade, 1990 supply levels appear to be lower or more uncertain than expected, it is this sector which may be most likely to switch to other sources of energy such as coal and electricity. The industrial sector, more than any other, can most adequately handle the capital requirements (which will be substantial) and the technical and planning aspects of a conversion process. It may also have the greatest incentive to switch since, during past shortages such as that in Ohio, industry has been classified as a nonessential user subject to supply curtailment. In fact, a number of industrial users have already begun a substitution toward coal, partly because of its long-run supply availability, and partly because of the uncertainties which have surrounded natural gas supplies (especially prior to passage of the 1978 Natural Gas Policy Act).

From an environmental standpoint, *large* industrial users will be best able to cope with the environmental problems associated with the direct burning of coal, low BTU coal gasification, or the cogeneration of electricity and steam from coal. As discussed elsewhere, however, these problems are substantial, and may create an upper limit on the amount of substitution which would be possible, especially in current air quality nonattainment zones. In fact, as a result of air quality issues, some firms now switching away from high priced and unstable oil supplies are resisting a substitution to coal and are turning to natural gas as, at least, an interim solution (EPA, 1980). This movement to natural gas is possible, in the short term, due to the "gas bubble" phenomenon by which conservation and substitution have created a short-term abundance of natural gas. If supplies remain at relatively high levels, use of natural gas could be a viable option for many firms during the next two decades. Smaller firms especially, overwhelmed by the difficulties of coal conversion as a substitute for oil, could turn to natural gas in addition to electricity and, in some cases, to renewable energy sources. Indeed, if the more optimistic forecasts of natural gas supply prove correct, it could offer a relatively clean and efficient substitute for many end uses otherwise served by oil, coal, and electricity. In fact, some analysts have argued that natural gas will be the cornerstone of our eventual transition to renewable forms of energy.

The state's electrical utilities now use natural gas to provide some electricity during peak demand periods. It is possible that other energy sources and more careful management of peak demand requirements will be able to minimize or eliminate this use of natural gas. However, in Michigan the amounts involved are relatively small and the elimination of natural gas as a primary fuel for the generation of electricity will not play a major role in the state's long-term natural gas supply situation.

In the commercial and residential sectors, the major natural gas alternatives (beyond conservation) involve either electricity or solar forms of energy, or a combination of the two. Heat pumps for electric heating and cooling, or combined solar and wood, or solar and electric, systems may prove attractive. Tough new building standards can facilitate a more rapid and economical transition to conservation, and to the use of solar designs in new construction for space and water heating needs. Retrofits of older homes and buildings, however, will be expensive, and because of the decentralized nature of the task, will require considerable time and large numbers of trained workers. While there is some uncertainty as to the pace with which such changes should proceed, it is clear that programs giving sound information, economic incentives, and access to capital with respect to conservation and retrofits will be important factors in avoiding serious energy disruptions in the residential and commercial sectors.

Exactly when such substitutions should and will occur will be a function of state and federal government natural gas allocation policies, of the effectiveness of conservation and new production efforts, and of price signals from the market. A major danger for Michigan workers and their families is that price signals by themselves may not be adequate, or may be too slow, to encourage substitutions prior to the serious shortages which could occur if the more pessimistic supply estimates prove correct. The time and capital requirements for conversions on the scale required would be immense, whether they occur in the industrial, commercial, or residential sector. This lead time issue is of critical importance if we are to maintain a stable energy future. It requires that natural gas supply and demand levels be closely monitored during the next decade so that informed decisions about substitutions away from, or towards, natural gas can be made as early as possible.

Coal Substitution

Since the direct burning of coal will be one of the major short-term substitutes for oil and natural gas among large industrial users, many of the issues surrounding coal have already been discussed. Coal's abundance makes it an attractive alternative, but that is about all that makes it attractive. The conversion to coal can be very expensive, involving land and equipment for transportation, storage and handling, and pollution control. On the supply side, the expansion of coal production may at some point be seriously constrained by labor disputes, interstate political conflicts, and transport problems. While the health and safety record of the coal industry is improving, the expansion of coal production will certainly result in additional deaths of miners and negative impacts on coal mining communities.

Some of these negative effects can be minimized, but doing so will involve increased costs and may serve to slow the expansion of production.

More coal means more mile-long coal trains and Great Lakes coal barges with potentially negative impacts on rights of ways and the lakes themselves. Coal is a major source of particulates, oxides of sulfur, and oxides of nitrogen. As a result of sulfur emissions, sulfur-based acid rains are already becoming a serious problem in many parts of the eastern U.S. Technologies such as fluidized bed combustion and exhaust stack scrubbers can help to minimize some environment-related problems, but not all of them. Furthermore, the long-term effects of carbon dioxide buildup in the atmosphere as a result of fossil fuel burning may turn out to be the most serious constraint on the use of coal (Chen, Winter, and Bergman, 1979).

In the longer term, synthetic fuels from coal may become a valuable source of liquid and gaseous fuels. However, this approach has its own problems and limitations, in the form of environmental impacts, extensive water requirements, lower net energy efficiency, and, at present, relatively high costs. As the costs of traditional sources of energy continue to escalate, the costs of synthetic fuels *may* level off and make them an increasingly attractive alternative. This is especially so since synthetic fuels would represent a source of stable energy supply not controlled by other countries, and a form of energy more easily used by the residential, commercial, and transportation sectors.

Short-term substitutions towards coal in the residential, commercial, and transportation sector will occur through the use of coal for the generation of electricity, rather than through direct burning or synthetic fuels. In the longer term, synthetic fuels from coal may play a significant role in these sectors.

Electricity Substitution

Electricity is, in many ways, the most controversial form of energy available in Michigan in the years ahead. Virtually every source of electrical generation—nuclear, coal, natural gas, oil, hydro, and solar—is fraught with some type of controversy or uncertainty, whether on grounds of health, safety, environmental impact, cost, efficiency, or availability. Electricity is a very "high grade" form of energy which, in theory, can perform a wide range of functions. It is this view of electricity which leads to the concept of the "all electric economy." Earlier we mentioned many of the potential uses of electricity, for example, electric heat pumps, electric vehicles, and industrial process heat from electricity as possible substitutes for oil and natural gas. On the other hand, as described in Chapter 2, the conversion losses in the production of electricity (approximately two-thirds) can make it a relatively inefficient form of energy for many needs, especially since many major energy uses such as space heating do not require "high grade" energy.

It is this view of electricity which leads critics such as Amory Lovins and followers of the "soft energy path" to suggest that in the long run, only five to eight percent of our total energy is really *needed* as electricity (Lovins, 1976).

At the present time, the cost of electricity is relatively high in comparison to other traditional sources of energy on a cost per Btu basis. And, as with all forms of energy, the rising costs of building new generating facilities will make electricity more expensive in the future. Fortunately, as described earlier, Michigan appears to have a relatively large electrical generating capacity in place (and under construction) at the present time. This means that even with increased electrical demand resulting from substitution, utilities in Michigan may need a smaller building program over the next two decades than will many other states. In addition, the state's heavy dependence on coal and low dependence on oil and natural gas for electrical generation mean that electrical production will be somewhat buffered from critical shortages of oil during the years ahead.

Michigan will not, however, be buffered from the twin dilemmas associated with the future use of either coal or nuclear power for the generation of electricity. Both forms of energy are fraught with controversy and long-term uncertainty with respect to issues of health, safety, environmental effects, and costs of construction and operation. At the present time, Michigan, with only 5 percent of its installed generating capacity as nuclear output, generates less than 15 percent of its electricity from nuclear power. However, assuming plants currently under construction are completed and licensed, both of those percentages will increase rapidly over the next five years. By 1984 we will go from 5 percent to 15 percent installed nuclear generating capacity, with one-third to one-half of all electric output coming from nuclear energy. During this same period, the percentages of installed capacity devoted to coal would remain at a relatively constant 53 percent. In 1976, these coal facilities produced about 66 percent of the state's electrical output.[7] As shown earlier in Table 5.6, Detroit Edison and Consumers Power Company plans for 1997 (as published in 1978) call for increasing to 35 percent the installed capacity devoted to nuclear power, and decreasing to 43 percent the installed capacity devoted to coal (which would still involve an absolute increase in coal generating capacity).

It must be stressed that should the state reduce its commitment to nuclear power, it would be forced to pick up that difference in part through conservation, in part through a heavier reliance on coal, and in part through increased utilization of remaining generating capacity. As noted earlier, the increased use of coal carries its own set of risks and penalties. We can expect that the question of which risks and potential penalties the state wishes to take on vis-a-vis nuclear and coal generated electricity will be a continuing debate over the years ahead.

Fortunately, due to its relatively large current generating capacity, Michigan appears to have more time available to monitor and resolve its electricity issues than it does to deal with the potential shortages in oil. It should be stressed, however, that the time for making such decisions cannot be stretched too far. The lead time for new generating capacity is now on the order of at least nine years for coal, and thirteen years for nuclear once an appropriate location has been identified.[8] Electricity demand has dropped so dramatically during the past decade that the historical record is no longer an adequate guide to future generating capacity needs or policies. There is a critical need to improve monitoring and forecasting methods in order to minimize, to the extent possible, the uncertainties introduced by factors such as rapidly rising costs of electricity generation, modifications in rate structures and load management techniques, government tax incentives for conservation and solar systems, and technological changes—cogeneration, fuel cells, heat pumps, electric vehicles, and semi-conductor a-c electric motor control devices, to name several (Electric Power Research Institute, 1978; Ben Daniel and David, 1979). There is a clear need to avoid under-developing the electricity option. However, this need has to be balanced more carefully than ever against the fact that the slower growth rates in demand anticipated in the years ahead will mean that errors of overcapacity will be more costly and less forgiving than in the days when electricity demand doubled every ten years.

Solar/Renewable Energy Substitutions

As suggested in the more detailed discussion of solar/renewables in Chapter 3, the extent to which solar/renewable forms of energy will substitute for traditional energy sources such as natural gas, oil, and electricity is difficult to estimate. This is largely because, for those things it can do, solar is limited more by policy and uncertain economics than by geology (as in the oil and gas cases). Under business-as-usual assumptions, what solar can do well is primarily in the areas of space and water heating, and of low temperature process heat.[9] A modest amount of electricity and/or higher temperature heat can also be expected from wind power and from the burning of urban waste, wood chips, and other combustibles. In addition, use of some liquid fuels from biomass can be anticipated, especially in the form of gasohol for transportation, and diesel fuel for the agricultural sector.

Things remaining uncertain about these applications of solar/renewables during the next two decades include (1) level of acceptance and demand on the part of consumers, (2) future costs of solar installations and alternative fuels (which will determine the solar payback period), and (3) state and federal government initiatives and incentives over the next decade. To date, there has not been adequate systematic study of the optimal role of solar/renewables in Michigan's future, and of the problems and risks which might be anticipated as part of an increased solar role. More importantly, in light of impending shortages of nonrenewable energy sources, there has not been adequate study of what can be done by both the public and private sector to insure that solar/renewables play as large a role as socially, technically, and economically feasible in the years ahead. The novel nature of solar/renewables is such that without these studies, and without specific programs designed both to reduce uncertainties and barriers in solar/renewables implementation, and to create incentives for its use, the state will be detoured from one important, although only partial, solution to its long-run energy problems.

Demand Projections Including Substitution and Conservation

The most likely response to the kinds of energy supply and demand imbalances which are suggested by the "current trends" and "conservation" projections earlier in this chapter will be deliberate efforts to shift the state's energy mix away from energy sources in short supply to those in which adequate supplies are expected. The discussion above indicates the wide range of substitution alternatives that exist—many with already well-known engineering characteristics. The real future energy issues are not whether these changes can and will occur, but which alternatives ought to be emphasized, and whether innovation can be stimulated sufficiently and soon enough to avoid the kind of possible imbalances which we have already discussed.

This section explores these issues by examining three additional year 2000 energy demand projections based on alternative, plausible patterns of energy substitution. The three projections are based upon recent engineering-economic studies of alternative energy use patterns for the U.S. to the year 2010. We have "stepped down" these projections to Michigan to indicate the changes which might be expected by the year 2000. They are three of many alternatives that could have been considered. They are presented here not as predictions, but rather to indicate in a rough way how different patterns of energy substitutions could affect the supply/demand imbalances discussed earlier.

It is stressed that the substitution projections are "suggestive" only and are intended merely to provide a preliminary indication of issues and outcomes, as well as to provide guidance for further discussion and research. The process of determining long-term energy goals for the state will eventually require considerably more detailed examination of Michigan's particular circumstances and options.

Three Alternative State Demand Patterns

The three demand projections presented in Table 5.9 incorporate both energy conservation and substitutions. To avoid the proliferation of out-

TABLE 5.9

Michigan 2000 Energy Supplies and Demands

	Michigan 2000 Supply	Michigan 2000 Demand				
Energy Source	Historical Fraction	Current Trends[a]	Demand Conservation[a]	Substitution A & Conservation[b]	Substitution B[c]	Substitution C[d]
Petroleum includes syn-liquids (10^6 bbl)	175–190	290 (22)	230 (18)	180 (25)	205 (20)	190 (20)
Natural Gas includes syn-gases (10^{12} cf)	.81–.89	1.35 (.08)	1.13 (.06)	.85 (.10)	.65 (.05)	.60 (.05)
Coal elec. & direct use (10^6 tons)	66	28–50 (14–36)	18–39 (7–29)	40–60 (25–45)	25–45 (5–25)	30–50 (10–30)
Solar/Renewables (Quads, FFE)	.20	.20	.20	.08	.06	.09
Electricity (10^9 kwhr)	75–146	105	88	135	90	90
		Fossil: 49–96	32–79	79–126	34–81	34–81
		Nuclear: 0–47	0–47	0–47	0–47	0–47
		Hydro: 9	9	9	9	9

[a] See Table 5.3
[b] Based upon projections by Ross and Williams (1979).
[c] Based upon projections by CONAES Demand and Conservation Panel (1978): Scenario III.
[d] Based upon projections by CONAES Demand and Conservation Panel (1978): Scenario II.

comes which would occur if substitution was considered in the context of the high, medium, and low state scenarios, only the more likely medium case is examined. The key assumptions which are incorporated in each of the substitution projections are summarized in Table 5.10. In general, the three substitution projections reflect the following:

Substitution Pattern A. Approximately 95 Quads total energy available nationally. Price induced conservation measures in all sectors and some market saturation for energy intensive products, particularly in the residential and non-manufacturing sectors. Policy efforts to reduce dependence upon petroleum and natural gas; major rise in relative share for electricity (2.7 percent average annual growth through 2000). By and large, a business-as-usual outcome by 2000 with some deliberate policy decisions with respect to more electricity. (Based on Ross and Williams, 1979.)

Substitution Pattern B. Approximately 96 Quads total energy available nationally. Conservation efforts similar to Shift A. Less emphasis on shifting to electricity (only 1 percent average annual growth through 2000). Greater emphasis on reducing demands for natural gas. Again, a business-as-usual outcome but with different policy emphasis than Shift A. (Based upon CONAES Demand and Conservation Panel, 1978: Scenario III.)

Substitution Pattern C. National energy demand peaks around 1990 and drops gradually thereafter to present levels by 2010. Major additional efforts at conservation in all sectors. Greater reliance upon electricity and solar technologies especially in the residential and commercial sectors. Public policies provide incentives, taxes, standards and regulations, vigorous R&D and public education to help accelerate society toward highly efficient energy utilization. Beyond business as usual but with technologies that are already available. (Based upon CONAES Demand and Conservation Panel, 1978: Scenario II.)

The comparative implications of these scenarios are summarized for each of the major fuels in Figure 5.8. The previous projections for "current trends" demand, and "demand conservation" in the "medium" economy scenarios, have been added for reference purposes.

Petroleum and Natural Gas

Each of the "shift" patterns makes a substantial contribution toward relieving the year 2000 supply/demand imbalances which would be indicated for petroleum and natural gas under the continuation of "current trends" or with "conservation" alone. In reference to the "current trends" projections, the overall demand for petroleum is reduced by at least 29 percent, and that for natural gas by at least 37 percent. With respect to the "demand conservation" projections, the savings amount to at least 11 percent for petroleum and 25 percent for natural gas.

HOW THE PATTERN SHIFT SCENARIOS WERE PREPARED

The pattern shift scenarios use the state supply projections presented earlier in this chapter. In order to simplify the presentation of this section, only the more likely "medium" comparison situation is considered, that is, "medium" state energy supply and "medium" state economy outcome.

Alternative energy demand scenarios, including both conservation and fuel substitution, were "stepped down" for Michigan from U.S. energy scenarios recently completed by Ross & Williams and CONAES (as referenced above). Multipliers were developed, including the changes in the level and relative share of each fuel specified by these scenarios compared to the 1976 situation. These multipliers were then applied to the "current trends" demand series for the state (as discussed above) to produce the demand projections for the shift scenarios.

The substitution patterns examined in these projections were "stepped down" from national level engineering/economic projections which could be possible, although clearly not optimal for Michigan. Notice in Figure 5.8 that none of the three substitution patterns fully eliminate the potential for shortages in petroleum. In projection B, demand for petroleum is 8 percent above the most optimistic supply level. For projections A and C, petroleum demand is below the supply projection which assumes optimistic levels of synthetic oils, but significantly above available supply under pessimistic assumptions. That both conservation and substitution do not fully insulate Michigan from the prospects of petroleum shortages is a matter of grave concern. Energy initiatives beyond those incorporated in these scenarios will be needed.

Each of the substitution projections is quite aggressive in substituting away from natural gas toward other fuels. Projections B and C may even reduce natural gas consumption below the levels which would be desirable should either the medium or high supply estimates prove to be correct. (Note, however, that should supplies of natural gas turn out to be closer to those indicated in the low scenario [see Figure 5.3], then levels of substitution and conservation well beyond those shown here would be needed.) As suggested in earlier discussions, the potential for excess supplies of natural gas

TABLE 5.10

Key Features of the Substitution and Conservation Projections—Present to Year 2000

Substitution A and Conservation[a]	Substitution B and Conservation[b]	Substitution C and Conservation[c]
• Slow incorporation of measures to increase energy efficiency as prices rise; deliberate policies to foster larger role for electricity and lesser roles for liquid and gaseous fuels. • The real prices of energy rise by 60% over the period. • 1% per year decrease in per unit output demand for energy in industrial sector. • 1.4% per year decline in energy use in non-manufacturing sector—more efficient uses of space and light, saturation of many energy intensive products. • 0.8% decline per year in total energy demand by trucks and autos; other transport modes parallel GNP growth; mandated fuel efficiency standards. • 0.6% decline per year in residential sector demand for energy; growth of less energy intensive multifamily housing; saturation of demands for major energy intensive products; new purchases are for more energy efficient products. • Relative roles of liquid/gas fuels decline: demand for gases and liquids 30% less in	• Slow incorporation of measures to increase energy efficiency; deliberate policies and decisions to begin to shift away from the historical reliance upon liquid and gaseous fuels. • The real prices of energy rise by 60% over the period. • Industrial energy demands per unit output decline by 0.9% annually; industrial cogeneration widely practiced, slower growth in energy intensive industries such as chemicals and aluminum, some industrial shifts reflecting demands by construction and manufacturers for less energy intensive products. • Demand for energy in the non-manufacturing and residential sectors declines by 0.6% per year; major gains in provision of space heat; widespread use of efficient electric heat pumps; solar energy becomes increasingly important around 2000 for air conditioning, space heat, and water heat. • Per capita energy consumption in transportation sector remains the same as current; rail freight expands; mass transit	• Public policies provide incentives, taxes, standards and regulation, vigorous R & D, and public education to help accelerate the U.S. toward high efficiency of energy utilization. • The real prices of energy increase 2.7-fold over the period (in part a policy outcome). • Industrial demands for energy decline the equivalent of 1.2% per year over the period; in addition to the initiatives noted in pattern B, substantial investments are made over the period in retrofit and new process technologies which reduce sector-wide energy demands; adaptive new products find profitable markets: e.g., reuseable packaging, strong lightweight materials for automobiles, chemical foams and fiberglass for insulation. • Demands for energy in the residential and non-manufacturing sectors decline the equivalent of 1.1% per year; new habits in setting thermostats, high efficiency electric and gas heat pumps combined with thermal storage, decen-

TABLE 5.10 (continued)

Substitution A and Conservation[a]	Substitution B and Conservation[b]	Substitution C & Conservation[c]
2000 than current; use of fluid fuels for priority tasks—transportation, food stocks, low temperature heat; significant shifts to coal, electricity and biomassed fuels; some solar—particularly in residential sector. • Relative role of coal increases by 25% over current—primarily in industrial and utility sectors. • Relative role of electricity increases 50% over current; substitutions for variety of needs in manufacturing, non-manufacturing, and residential sectors currently met by liquid/gas fuels.	grows to 2-½ times current; air travel grows to 2% per year; auto and truck mileage increases slightly but major gains in fuel efficiency are realized. • Relative role for petroleum (and syn-liquids) declines 10%; dramatic 50% reductions in relative role of natural gas (and synthetics) are realized. • Coal's role (direct uses) increases significantly: 70% greater than current. • Electricity's relative role increases only marginally: 4% greater than current.	tralized solar applications for space heating, air conditioning, and water heating, improved retrofit and construction practices (e.g., insulation) including designs emphasizing use of passive solar, some underground or earth covered construction; all contribute to the realization of such savings. • Demands for energy in the transportation sector decline the equivalent of 0.6% per capita per year—this despite substantial increases in air travel and time spent in autos; mass transit expands more than 3-fold; new technologies (e.g., Brayton and Stirling engines) and mandated fuel efficiency standards and major forces in efficiency achievements. • The relative role of petroleum (and syn-liquids) declines by 10%; the relative role of natural gas declines by over 40%. • Coal's relative role (direct uses) nearly doubles—more stringent pollution control laws are deliberately put aside to favor this outcome. • Electricity's relative role grows by 10% over current.

[a] Based upon Ross and Williams (1979).
[b] CONAES Demand and Conservation Panel (1978): Scenario III.
[c] CONAES Demand and Conservation Panel (1978): Scenario II.

FIGURE 5.8

Substitution and Conservation Projections for Medium Scenario for Year 2000; Comparison of Supply/Demand for Various Fuels*

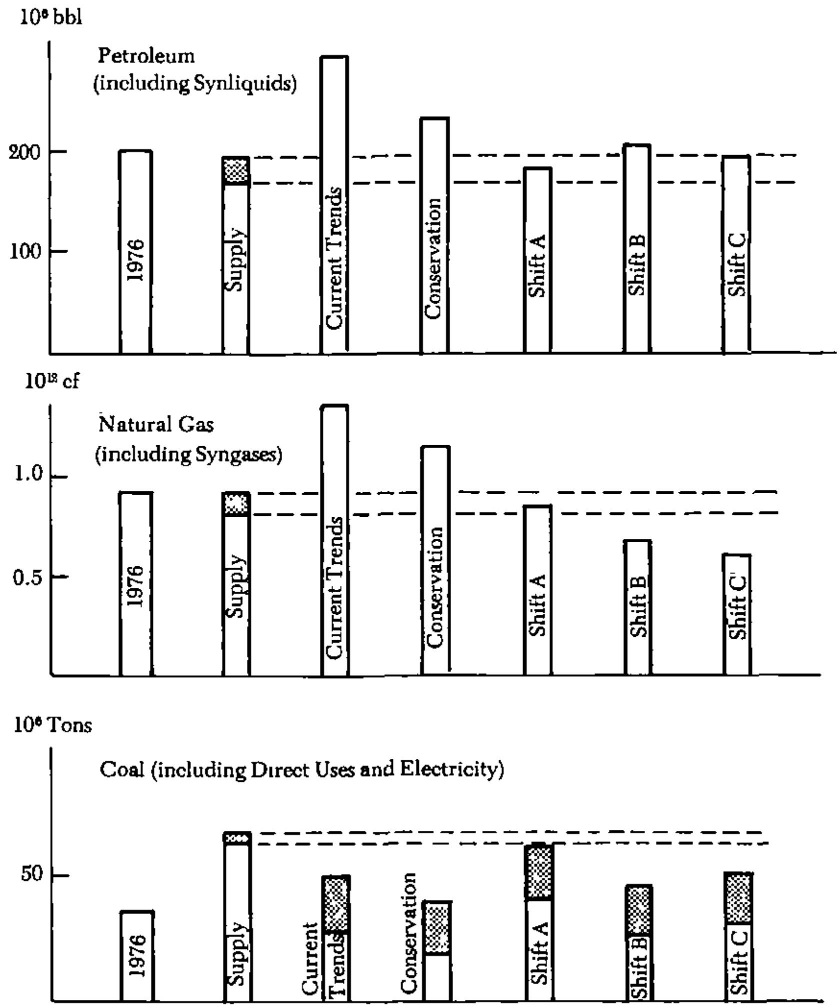
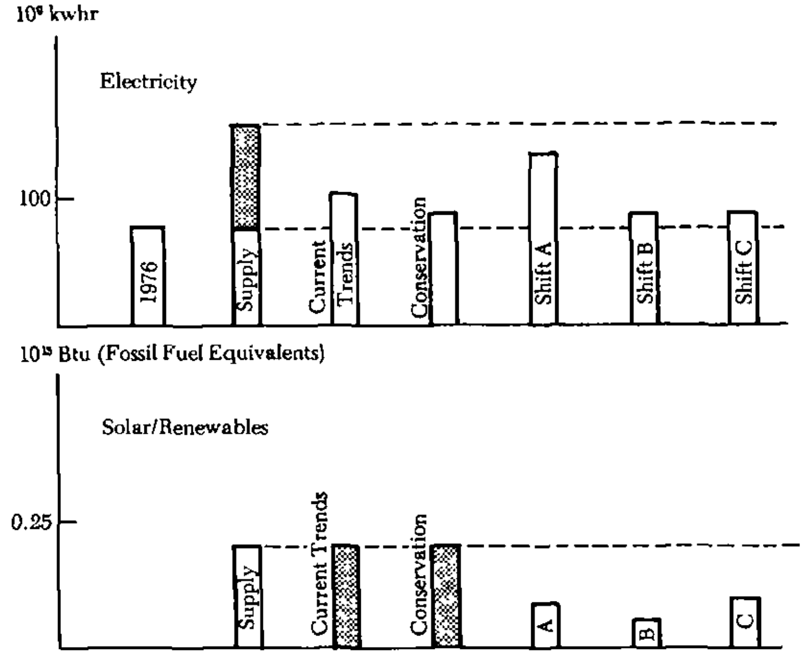


FIGURE 5.8 continued



* The cross-hatched areas reflect levels of uncertainty in the projections. The figures are based on upon the projections in Table 5.9.

The range of values in the supply projections for petroleum and natural gas reflects uncertainties as to the availability of synfuels; those for coal demand reflect uncertainties as to the role of coal in Michigan for electricity generation; that for electricity reflects uncertainty over the extent to which current plans for capacity additions to the year 2000 are realized. The range of values for the solar/renewables projections reflects gross uncertainties over the extent to which these energy technologies will be developed in a business-as-usual orientation.

could represent a valuable opportunity for the state. This provides all the more incentive for monitoring and reducing the uncertainties over natural gas supplies (and demand) as quickly as possible.

Coal and Electricity

All of the substitution projections incorporate greater relative roles for both electricity and coal. The direct use of coal (excluding inputs for synfuels and electricity) increases in the substitution projections by 150–200 percent. The largest fraction of this increase occurs in the manufacturing sector. Substitution projection A represents a substantial upward shift in electricity's role—the equivalent of 2.7 percent average annual growth. The electrical role shifts for the other two scenarios are more modest—the equivalent of 1 percent average annual growth.

Even with the additional growth in demand resulting from substitution, the supplies of both electricity and coal appear to be sufficient to meet potential demands. Even the most pessimistic projections for low supply of and great demand for coal show some excess supply. As discussed earlier, electrical generating capacity currently installed and under construction appears to be sufficient to meet the needs of these scenarios, especially Scenarios B and C. At worst, modest additions to capacity and more effective load management techniques may well be sufficient to assure a sufficient and stable electricity supply.

Solar/Renewables

There is little available information for providing detailed projections regarding future solar/renewable supply and demand. However, one recent analysis conservatively suggests that as much as 0.2 Quads (fossil fuel equivalent) of solar/renewables energy might be technically and economically feasible for the state by the turn of the century (Gustaferro et al., 1978). These projections, even if only approximate, suggest that none of the three substitution scenarios fully utilizes the solar/renewables potentially available to the state. At this time, the actual limits and risks of solar energy in Michigan are highly uncertain and require considerable additional exploration and analysis. Resolving these uncertainties remains a high priority in light of the potential these technologies seem to have for supplying residential and non-manufacturing energy demands currently being met by petroleum and natural gas.

Energy Instability and the Implication for Michigan Jobs

The Michigan employment scenarios of Chapter 4 show slow growth at best for Michigan jobs, even under the assumption of no local energy shortages. When oil and gas shortfalls are factored in, then Scenario III's gloomy

FIGURE 5.9

Energy-Employment Linkage, with Emphasis on the Negative Effects of Unstable Energy Supplies on Employment

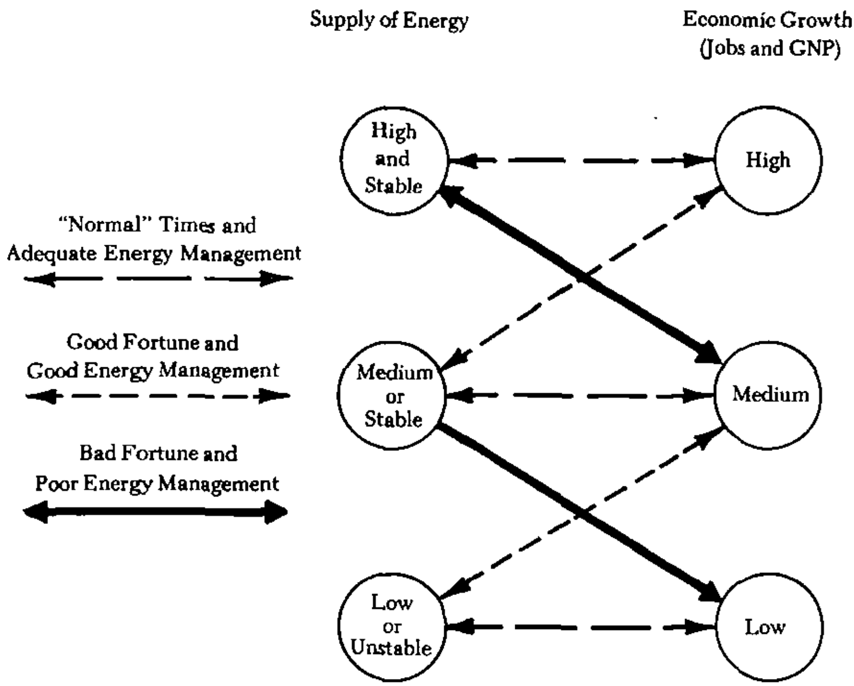


TABLE 5.11

Range of Employment in Michigan for the Year 2000
Assuming Energy Turbulence

Employment Sector	1977	Employment Range for Year 2000	Growth Rate 1977–2000
Overall State Employment	3,782,000	3,879,000–5,520,000	.1%–1.7%
Manufacturing	1,105,000	905,000–1,366,000	(–.9%)– .9%
Construction	124,000	132,000– 184,000	.3%–1.7%
Non-Manufacturing (including Construction)	2,677,000	2,974,000–4,154,000	.5%–1.9%

employment projections appear as likely as Scenario II's medium values. This point is illustrated by Figure 5.9 which emphasizes that good energy management increases the prospects for higher employment, and that energy turbulence erodes employment prospects. Should the types of energy shortages shown to be possible in this chapter actually occur, then the most likely range of employment in Michigan in the year 2000 is that shown in Table 5.11. This corresponds to growth in employment in the range of .1 percent to 1.7 percent for the state as a whole. The sectoral growth rates would be –.9 percent to .9 percent for manufacturing, .3 percent to 1.7 percent for construction, and .5 percent to 1.9 percent for non-manufacturing employment. In the worst cases, this could correspond to depression-level unemployment rates of 20 percent or more.

Michigan can do better than the gloomy outcomes of a business-as-usual future sketched above. As we stressed in Chapter 1, there are available to the state options which go beyond the business-as-usual approaches examined in this study. The point of this analysis, in fact, is not to "predict" that the business-as-usual outcomes will actually occur, but to alert citizens and policy makers to the need for going beyond traditional approaches in seeking solutions to Michigan's problematic energy future. It is our hope that this study will contribute to the state's energy policy process by providing a better understanding of the major uncertainties and policy issues which must be confronted in the years ahead as we move into a new era of scarce and expensive energy.

Notes

1. Recently announced difficulties encountered by both Detroit Edison and Consumers Power Company would suggest that such constraints may play an increasingly important role in determining the state's electrical future.

2. The implications of alternative capacity factors and reserve margins are examined in a preliminary way in the section which follows.

3. This figure refers to the design electrical rating (DER), which is the maximum power production capacity of a plant under optimal conditions minus power consumed in the plant.

4. A capacity factor of 51 percent means that the electric system supplied only 51 percent of the electricity which could have been delivered if all plants had operated at their maximum for 24 hours each day of the year.

5. As this volume goes to press, Detroit Edison Company has indicated a cutback in its long-term construction plans (see Table 5.1). The conclusions of this study are not significantly altered by the changes in the Edison Construction Program. The reverse is more the case: the reduced construction program is in line with the results of our analysis.

6. Recent reports have suggested that fleet mileage improvements under current Environmental Protection Agency test standards may be overestimating actual improvements by as much as 50 percent. See Carter (1979).

7. Percentage output can be higher than percentage installed capacity because nuclear and coal facilities are used more intensively (technically speaking, have a higher capacity factor) than are the oil and natural gas facilities which are used primarily during peak demand periods.

8. Personal communication from Gordon Heins, Consumer Power Company, January 1980.

9. Analysis by the Minnesota Energy Agency suggests that simple flat plate collectors have the potential to meet 50 percent of Minnesota's needs in these areas (Minnesota Energy Agency, 1978).

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