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1984 Energy Policy
and Conservation Biennial Report

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and Economic Development
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Foreword

In July 1984, the Energy Division of the Minnesota Department of Energy and Economic Development published the Draft 1984 Energy Policy and Conservation Biennial Report. Following distribution of the report to the legislature and interested parties, the Division held four public meetings in Duluth, Mankato, Moorhead, and St. Paul to answer questions and solicit comments.

This final biennial report incorporates many of the suggestions presented during the comment period, and responds to several questions and concerns that were raised. Most of these responses have been incorporated directly into the text. Some comments, however, required a separate response. These are presented in the Public Comments section.

The report includes six major sections:

Executive Summary

Highlights the major events of the past 10 years and the major issues Minnesota faces in the coming decade

Recommendations

Presents the Energy Division's recommendations for action to maximize the state's ability to meet and deal with energy issues in a positive and beneficial way

Ten Years After the Oil Crises: Lessons for the Coming Decade

Presents an in-depth analysis of the past decade, forecasts of energy prices and consumption to the year 2000, and a discussion of the issues Minnesota will face in the coming decade

Public Comments

Discusses and responds to issues raised during the public comment period that required a separate response

Abstracts

Summarizes various reports and public hearing testimony prepared by the Division during the past two years (for those interested in reading the complete document, copies can be obtained by contacting the Division)

Master Tables

Provides historic and projected energy consumption and price data

In addition to this report, the Division has published a companion Energy Data Book. The data book is a compilation of over 100 tables and graphs of the data produced by the Energy Division for use in energy forecasting and policy analysis by both the public and private sector.

To receive a copy, call the Energy Information Center at 296-5175 in the Twin Cities, or Minnesota toll free 1-800-652-9747 outside the Twin Cities area and ask for "Energy."

Throughout this report, reference is made to "the Energy Division." This term is used to indicate the unit of state government that has been responsible for energy issues in Minnesota since 1974. Originally, it was called the Minnesota Energy Agency. In 1982, it became the Energy Division of the Department of Energy, Planning and Development, and in 1983, the Energy, Policy Analysis, and Energy Finance Divisions of the Department of Energy and Economic Development.

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Executive Summary

1984. Ten years have passed since the Arab Oil Embargo confronted us with a new set of energy realities. This report focuses on the lessons to be learned from e experience of the last decade and attempts to draw on that experience in formulating a plan for future actions.

In reviewing the past decade, three major lessons stand out. First, the condition that enabled the Organization of Petroleum Exporting Countries (OPEC) to increase real oil prices fivefold was the increasing worldwide demand for petroleum, which exceeded the production capacity of non-OPEC suppliers. More specifically, when market demand rises sufficiently in relation to available supply, OPEC, as the marginal producer, has been able to enforce real price increases. It appears that the trigger point for initiating these price increases is when OPEC production reaches 80 percent of capacity. When production approaches 100 percent of capacity, prices increase exponentially.

The second lesson to be learned from the past 10 years is that energy and the economy are linked. Rising real energy prices in the seventies contributed to a condition where inflation and economic stagnation occurred simultaneously. In the decade preceding the Arab oil embargo, inflation averaged 3.8 percent annually; in the following decade it averaged 8.4 percent annually. For the same periods, Gross National Product dropped from an average of 4.2 percent real annual growth to only 1.7 percent. While improvements in energy efficiency have reduced the economy's energy dependence, energy expenditures in Minnesota still represent 13 percent of the state's Gross State Product.

Rising energy prices hurt all sectors of the economy. However, the hardships associated with these price increases have fallen disproportionately on Minnesota's poor. Between 1973 and 1981, energy costs as a proportion of income rose from 7 percent to 13 percent for households living at the poverty level—an 86 percent increase. Low income households were also hurt indirectly by rising energy prices. In the rental sector, many landlords reduced maintenance budgets and increased rents to cope with higher prices, which resulted in lower quality housing at higher cost for many low income renters. Also, most local governments found it necessary to increase regressive taxes and reuce services, in part to offset rising energy bills and maintain balanced budgets. These actions further eroded the standard of living for low income households. Increases in government subsidies and income maintenance programs offset only an estimated 16 percent of the total loss experienced by the poor.

The third lesson of the past decade is that conservation and alternative energy are successful tools for weakening OPEC's price setting ability and improving the economy. Since 1973, each Minnesota household has reduced its energy consumption an average of 26 percent; commercial businesses have reduced consumption an average of 24 percent; the industrial sector has improved efficiency 27 percent; and the transportation and agricultural sectors have improved efficiency by 18 percent and 17 percent, respectively. This improvement in energy efficiency, coupled with the shift to alternative fuels, has been a chief contributor to the decline in world demand for petroleum specifically, and for energy in general.

Currently declining oil prices and stable natural gas prices are due in large part to this decrease in world petroleum demand. Lower energy prices have contributed to recent economic improvements by lowering business operating costs and household energy expenditures, improving our balance of trade, and stemming inflation.

Are the lessons of the past decade, then, merely of historic interest? Do stable and declining energy prices signal the end of our energy problems? As outlined below, there are several reasons for continuing our commitment to Minnesota's energy future.

- First, there is much cost effective conservation and alternative energy investment still to be accomplished. For example, while the average home has reduced its energy consumption by 26 percent, the Division estimates that an average household could cost effectively reduce its consumption by 40 percent.
- Second, while many of us have benefited from stable prices and an improved economy, the poor are still facing a true energy crisis, making daily tradeoffs between heat, food and shelter. Recent cuts in federal energy assistance programs have only increased the immediacy of their needs.
- Third, as a result of population and economic growth, worldwide demand for petroleum will begin increasing this decade and continue growing throughout the century. These forecasts suggest that OPEC could again be in a position to raise real energy prices in the late 1980's.
- Fourth, the pollution caused by traditional fuel use is imposing real costs on our society by degrading our environment and damaging our health. Among the most serious environmental issues related to traditional fuel use are acid rain pollution, the greenhouse effect, and lead poisoning from leaded gasoline use.

In order to achieve all of the potential economic benefits from cost effective investment of conservation and alternative energy technologies, to avoid environmental pollution and to reduce our dependence on unstable energy sources, Minnesotans must work together to address several key barriers.

In the residential sector, research will be needed to address the secondary effects of conservation such as reduced ventilation, increased moisture levels and product durability. Much more attention must be given to the rental sector and to the effectiveness of conservation technologies. Defining the role of the utilities in the design and delivery of conservation programs will also be a key issue. Even more pressing will be the need to address the severe impact that rising energy costs have had on the poor.

Conservation efforts must also continue in the commercial/institutional and industrial sectors. Incorporating the value of efficiency improvements into the value of commercial and industrial buildings and rents will contribute substantially to continuing conservation improvements over the next decade. Efforts must be made to evaluate the decade of innovation that has taken place in commercial building design, and to transfer those techniques that work to new building designs. Delivery of energy audits and technical information will also be important in meeting the needs of a more informed business sector. Institutionalizing the link between building operation and energy cost control through such techniques as energy accounting must also be accomplished in the decade ahead.

Overall, energy demand in the commercial/institutional and industrial sectors is projected to increase far faster than in any other sector in the years ahead. For this reason, long range policy and programming should especially target these sectors for technical and financial conservation assistance.

Although conservation is still Minnesota's most effective energy tool, development of the state's native fuels will become increasingly important as a means of diversifying supply sources, providing lower cost fuels, and developing new areas for economic growth. There are many barriers to alternative energy development and they are often specific to a particular energy source. The overriding barrier, however, is the price disparity between traditional and alternative energy sources. This disparity exists because government has subsidized traditional fuels for decades and producers have not had to bear the significant external costs to society resulting from environmental impacts such as acid rain. The need for countervailing subsidies to bring about price parity will be a critical issue to the rate of growth of this industry.

Use of coal and electricity in the commercial/institutional and industrial sectors is projected to grow sharply in coming years, offering the greatest opportunity of alternative energy substitution. The state should specifically examine targeting development of alternative energy sources as substitutes for these fuels.

The following section presents the recommendations developed by the Energy Division to address these issues in the decade ahead. Although the recommendations focus on the efforts of state government, it will take the commitment of all Minnesotans to embrace the lessons of the past decade and move to a more secure energy future.

Recommendations

The following recommendations relate specifically to Energy Division programs and to legislative initiatives that policy makers should consider in the years ahead. However, the solution to the problems that impede full investment in cost effective conservation measures and the development of an indigenous energy industry will require the commitment of the entire range of energy decisionmakers — state government, business, industry, utilities, the financial community, local governments, and individuals. Because we will all reap the benefits of a more energy efficient and self sufficient Minnesota, we all share the responsiblity for making it a reality.

Residential

Strategies for residential energy conservation must promote continued investment in cost effective conservation and alternative energy technologies by:
- providing and responding to clear and correct energy price signals and investment incentives
- developing an accurate understanding of the performance of conservation technologies
- assisting those unable to afford efficiency improvements to reduce their energy consumption

The most important actors in the residential sector will be individual homeowners. Education about and investment in conservation measures and alternatives to reduce home energy expenses must begin with them. However, the financial community must also recognize that energy costs are an integral part of a renter's or homeowner's total housing costs, usually greater than taxes and insurance combined. Until residential energy expenses are reflected in the value of a home, homeowners will not be fully rewarded for investing in conservation technologies. Private sector initiatives such as a low interest loan program to assist moderate income households who would not otherwise be able to afford conservation improvements would be a significant spur to continued efficiency improvements in this sector.

State and local governments can also play an important role in improving residential energy efficiency. An especially important area is the transfer of information and programs to communities for local delivery. Regulation may also work to correct inappropriate price signals and promote consumer protection.

Specific recommendations for state action

1. Solar and Energy Conservation Bank
The Bank (see Recommendation 32) should expand the availability of alternative financing for those unable to obtain or afford conventional financing for energy improvements.

2. Rental Housing Efficiency Standards Certification
The legislature should enact a program requiring that owners of rental housing certify that their property meets state rental housing energy efficiency standards.

3. Residential Energy Audits
The Energy Division should undertake a comprehensive review of the residential energy audit program, in cooperation with the Joint Legislative Energy Commission and other interested parties, in order to determine how it can be made more effective and efficient.

4. Home Energy Rating System
A pilot program should be implemented that would test the effectiveness and other factors of a home energy rating system, and involve lenders, realtors, appraisers, builders, home buyers and others.

5. Builders Education and Assistance
Efforts to keep builders, code officials and others up to date on the rapidly changing energy technologies involved in housing should be significantly expanded. In particular, the following should be developed: a manual and course on accepted construction practices in meeting the new energy code, an owner/operator manual for high energy efficient homes, and technical training and materials in moisture control, ventilation, air quality control, foundation insulation, and cost efficient techniques.

6. High Efficiency Housing Standards and Tax Incentives
The legislature should adopt a high efficiency housing tax incentive with eligibility standards based on the Home Energy Rating System and other appropriate criteria. The proposal should be tied to builder education programs enabling builders to become knowledgeable about accepted construction techniques.

7. Low Income Weatherization
The legislature should expand state funding of low income weatherization programs to include investment up to the optimal level identified in the weatherization study.

Building research

8. Indoor Air Quality
The state should design and implement a multi-year program to identify indoor air quality problems in Minnesota and develop strategies and techniques to correct the problems.

9. Optimal Weatherization
A carefully designed study should be undertaken to determine optimal expenditure levels and techniques for weatherizing low income housing.

Utility Conservation Investment

10. Analysis of Level of Investment
A thorough study should be undertaken to determine the appropriate level of investment for utilities to make in energy conservation and renewable energy development.

11. Inverted Rates
The Public Utilities Commission should act to implement the intent of the legislative mandate requiring major utilities to institute pilot programs for an inverted rate structure for residential users of natural gas to determine the potential for conservation and effects on utility bills.

Commercial/Institutional and Industrial

Strategies to improve efficiency in commercial/institutional and industrial energy use must promote continued investment in cost effective conservation and alternative energy technologies by:
- providing and responding to clear and correct energy price signals and investment incentives
- developing accurate information about consumption behavior and technology performance

The key actors in the commercial/institutional and industrial sectors must be business owners and operators. Efforts to reduce energy costs will provide direct benefits to Minnesota businesses and, as a result, should be initiated by them. Business owners are especially essential in making building operators accountable for building energy costs, a problem discussed extensively in this report.

Local and state governments, as owners of schools, hospitals and other buildings, must fully invest in conservation measures in order to minimize the cost to taxpayers of operating these buildings. Furthermore, such investments can set an example for all citizens by demonstrating the commitment of government.

Specific recommendations for state action

12. Financing for Energy Improvements
Existing programs that provide financing for energy improvements for businesses

and municipalities should be continued and expanded.

13. Venture and Working Capital Financing
The legislature should consider enacting a program that would provide venture and working capital loans and/or grants for energy business development.

14. Total Energy Management (TEM) for Commercial and Industrial
A program (modeled after TEM for Schools) should be developed that provides comprehensive information and education services to the commercial and industrial sectors, and linked to available energy audits and financing.

15. State Building Operator Training
The legislature should continue this program, which was funded in FY84.

16. State Building Steam Trap Operation and Maintenance
A follow-up to the state steam trap program should be developed that creates a preventative maintenance program, makes available equipment for repair and replacement of faulty traps, and provides staff to implement the program.

17. Ice Air Conditioning
A study should be conducted of the potential impact on electricity demand that could result from large scale conversion from absorption (natural gas) air conditioning to electric air conditioning. A demonstration project should be implemented using ice storage or other load management techniques to minimize increased electricity demand.

Energy Code

18. Code Upgrade
The Energy Division should identify specific code issues and seek appropriate funds to adequately research these issues, and adopt rules to upgrade the Energy Code.

Alternatives

Strategies to expand the use of alternative fuels must encourage development of an alternative energy industry by:
- providing adequate investment capital
- improving and demonstrating the new technologies
- providing accurate information about the potential and performance of these technologies

The commitment of investors and the financial community will be essential in order for the alternative energy industry to move out of its infancy and into commercial viability. Without significant investment capital, alternative energy development will not occur.

Local governments play an especially important leadership role in the development of alternatives. An example of the importance of this role was shown by St. Paul in developing the city's district heating system. Another area that is particularly dependent on the commitment of local government is the development of waste-to-energy systems. For this technology to reach its full potential, local units of government must discontinue the practice of buying farmland for landfills.

State government also will play an important role in promoting alternative energy. Research, demonstration, and transfer of technological adaptations, as well as providing financial incentives that reduce the risk of investing in these young industries, are critical roles of government.

Specific recommendations for state action

19. Buy-back Rates
The legislature should establish clear and easily administered guidelines for utility purchases of electricity from small power producers and co-generators between 40 kW and 80 MW capacity. Consideration should be given to legislation requiring all electric utilities to establish and publish buy-back rates in a standard contract offer for facilities between 40 kW and 80 MW capacity.

20. Alternative Energy Investment Incentives
The legislature should adopt incentives (such as investment tax credits) to stimulate investment in alternative energy development.

21. Residential Renewable Energy Tax Credit
The legislature should extend the residential renewable energy tax credit, which expires at the end of 1985.

22. Information, Education, Technical Assistance
Efforts should be expanded at the state and local levels to promote the transfer and use of alternative energy technologies and native energy resources.

23. Strategic Development Plan
The state, in partnership with the private sector, should develop a comprehensive development plan for our native energy resources including identifying development opportunities, setting development goals, establishing a plan for action, and instituting a systematic data collection and monitoring system to evaluate progress.

24. Financial Assistance
The state, through the Energy and Economic Development Authority, the Iron Range Resource and Rehabilitation Board other agencies, and the private sector should expand the availability of financial assistance for energy development, particularly in the areas of venture and working capital.

25. State Facilities
A comprehensive program for using state facilities to demonstrate the use of native Minnesota energy resources in a cost effective manner should be developed. The program should involve all relevant agencies, and be based on a systematic identification of potential opportunities and the rigorous evaluation and dissemination of results.

Fiber Fuels

26. Standardized Fuel Specification
The state should continue to assist the industry in developing standardized fuel specifications.

27. Market Development Program
The state should assist the industry in developing the market for its products through the identification of potential users, the provision of technical assistance in assessing the feasibility of conversion the development of information and education programs, and the creation of a producers cooperative to help assure reliability of supply.

28. Survey of Existing Installations
A statewide survey and evaluation should be made of a representative sample of existing conversions to fiber fuel use to gather information on their cost effectiveness, and to help identify areas where conversions and operations can be improved. This information should then be disseminated to help encourage the use of fiber fuels.

Solid Waste

29. Comprehensive Waste-to-Energy Program
The state should develop a comprehensive program to facilitate the installation of energy recovery and recycling of solid waste. Objectives of the program should include: improving the conditions of existing government programs, conducting a statewide analysis of solid waste, identifying potential projects, providing on-site technical and financial assistance to assess economic feasibility, and providing long term financing to local governments or businesses for project design and construction.

30. Review of Flow Control Statutes
A review of flow control statutes should be undertaken to ensure that they do not ›ose an unreasonable barrier to the de-.elopment of waste-to-energy projects.

31. Certificate of Need for Landfills
The legislature should adopt a Certificate of Need process for landfills in which all cost effective alternatives are exhausted before permission is granted to develop new sites.

Solar

32. Solar and Energy Conservation Bank
The state should develop a Solar and Energy Conservation Bank to complement the federal program. Funding should be directed toward financing low energy, low cost housing applications, as well as energy retrofit needs not met by existing programs.

33. Solar Industrial Process Heat
A program should be developed to identify potential applications of solar heating to industrial processes, and to demonstrate its technical and economic feasibility in Minnesota.

Wind

34. Demonstration Wind Farm
ne legislature should provide incentives for investment in a demonstration wind farm over 1 MW to be developed in Minnesota. This, along with buy-back rates recommended previously, would encourage investment of Minnesota dollars in this renewable technology.

Ten Years After the Oil Crisis: Lessons For the Coming Decade

Analysis of the cause and effects of the oil price explosion

In 1905, George Santayana wrote, "Those who cannot remember the past are condemned to repeat it." Today, as the world economy begins to recover from the stagflation[1] that has battered it since the oil price shocks of the seventies, it is important to remember and learn from the lessons of the past decade.

The experience of the past 10 years has taught us that as a cartel, the Organization of Petroleum Exporting Countries (OPEC) can set either price or production, but not both simultaneously. Over the past decade, OPEC has been able to institute real oil price increases only when world demand is so great that the cartel is operating at or near its full production capacity. When that condition was present, as in 1973-74 and 1979-80, real prices rose; when that condition did not exist, OPEC did not raise prices.

This relationship is of more than historical interest. In the coming decade, as growth in population and economic activity lead to increased world petroleum demand, increased OPEC production will be necessary to meet that need. This increase will again put OPEC production at a level exceeding the capacity threshold at which price increases can be instituted and maintained. Thus, the conditions necessary for a reassertion of OPEC's pricing power are likely to return.

Despite the increase in energy efficiency that importing nations have realized in the last decade, another round of price hikes will severely affect them. In particular, the impact on developing countries, already burdened by $600 billion in outstanding debts, could trigger a serious worldwide economic crisis.

Santayana's warning may be as much a reflection of the difficulty of stimulating innovation on the part of the large centralized organizations that characterize industrial society as it is a result of their inability to perceive the lessons of history. Past shifts in energy systems — from wood to coal, coal to oil, oil to gas — have taken an average of 40 to 50 years to complete. While governments may realize that they do not have the luxury of a half-century's wait if they are to avoid the negative consequences of remaining tied to fossil fuels, the past offers meager guidance in how best to hasten such a massive transition of one of society's most important physical support systems.

The Energy Division has worked since its creation in 1974 to facilitate this transition from an economy and culture that was accustomed to operating on cheap energy to one faced with fuels that have become unexpectedly expensive. Over the past 10 years, the Division's efforts have focused on developing and disseminating a base of information about the most cost effective ways to save energy, and about the indigenous resources that have the greatest potential for replacing traditional fuels in Minnesota.

This 1984 biennial report to the legislature reviews the responses of consumers and businesses to the energy crisis and the Division's efforts to promote appropriate responses. Although the recession and past conservation efforts have created a "lull," the energy crisis is not over, and many sectors remain extremely inefficient and vulnerable to future price shocks. As a result, the report also discusses the key energy issues remaining to be addressed in the 1980's and suggests specific steps that Minnesota can take to address those issues.

When operating above 80 percent of production capacity, OPEC raised real oil prices

It has been a decade since OPEC confronted the world with a new set of energy realities. On October 17, 1973, six members of OPEC agreed to increase the price of their crude oil by 70 percent. On the same day, nine Arab oil producers imposed an embargo on the United States and the Netherlands in response to their support of Israel in the 1973 Yom Kippur War.

These two actions created upheavals in international energy, economic, and political arenas that have lasted for a decade and are not yet settled. OPEC was capable of such influence because of changes in world demand for, and production of, crude oil that had occurred throughout the preceding two decades, largely without notice.

During the fifties and sixties, the industrialized world in general, and the United States in particular, became dependent on cheap sources of traditional fuel. Between 1950 and 1970, demand for petroleum among developed nations grew by 340 percent. However, petroleum production among developed nations increased by only 95 percent. As a result, imports of petroleum to developed nations swelled nearly 10-fold over the 20-year postwar period, from 572 million barrels per year in 1950 to 5.3 billion barrels per year in 1973.[2]

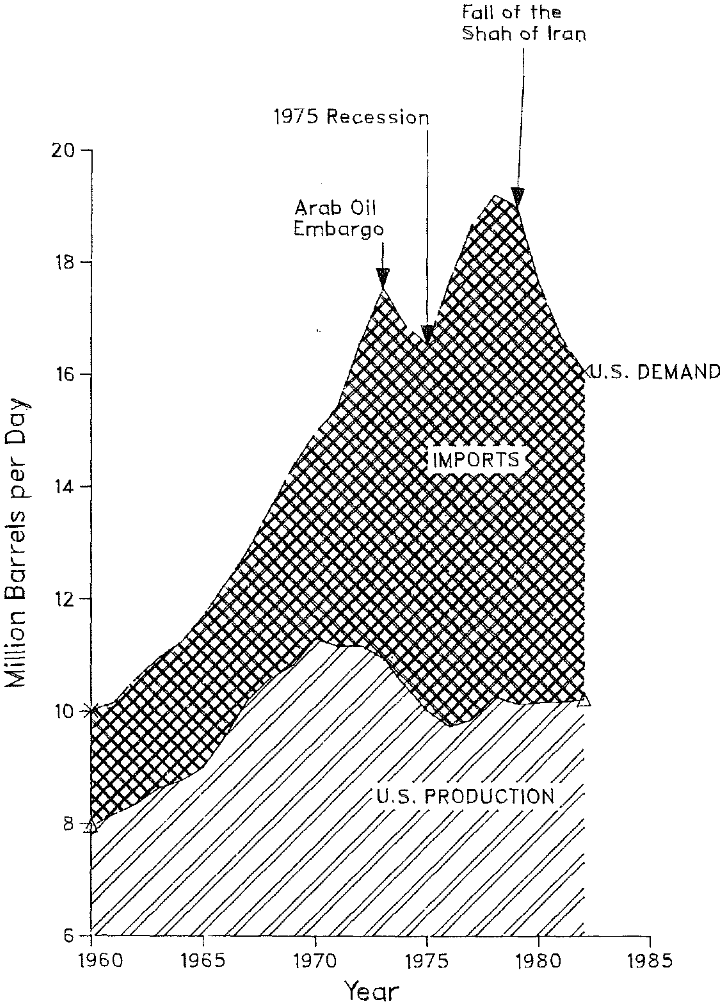
The United States, as the largest single consumer of petroleum in the world, experienced similar trends. Although the U.S. possessed and produced large quantities of petroleum, growth in domestic demand began to outstrip growth in crude production. By 1970, when U.S. crude production peaked at 3.52 billion barrels per year, the U.S. was importing 23 percent of its petroleum supplies. In the next three years, U.S. production declined 9 percent, while continued growth in demand resulted in imports accounting for 36 percent of supplies in 1973.[3] (See Figure 1.)

1 Stagflation is a term used to indicate a rather unusual condition in which inflation and slow or negative economic growth occur at the same time.

2 *World Energy Supplies 1950-1974*, Series J. No. 19 of Statistical Papers, United Nations, New York (1976), pp. 3 and 193.

3 *1982 Annual Energy Review*, Energy Information Administration, Department of Energy, Washington, D.C. (April 1983) p. 51.

Figure 1
U.S. Petroleum Production and Imports, 1960-1982



However, dependence on imports—even of an essential resource such as energy—is not necessarily problematic. As long as no single producer, or unified group of producers, controls enough of the resource to influence prices or production significantly, importing can simply be an economically efficient and rational action. It was, then, the formation of OPEC and its control over the incremental petroleum production necessary to meet growing world demand that made U.S. and world dependence on imports a critical vulnerability.

Although OPEC was formed in 1960, its first decade was marked by weakness both because organization members were unwilling to act in concert and because there existed a worldwide surplus in crude oil production capacity. However, by 1970, growth in world demand had eroded excess capacity, and OPEC, operating at nearly 100 percent of its capacity, was producing 52 percent of the non-communist world's crude supplies. In 1970, Libya was able to force a price increase on the major oil companies operating in that country, providing a larger share of oil revenues to the government. Early in 1971, OPEC, following Libya's lead, negotiated price increases with the oil companies. By the early seventies, OPEC member governments assumed nearly full ownership and management of crude operations in their countries from the multi-national oil companies, ending the concession system tied to colonial rule that had been established after World War I.

Thus, in October of 1973, OPEC both better appreciated its power and, continuing to produce at nearly full capacity, was in a better position to use it.[4] Within four months of announcing its first unilateral price increase, OPEC was able to quadruple its price. This price shock contributed to inflation and a worldwide recession. Largely as a result of the recession, U.S. petroleum consumption dropped by 6 percent to 16.54 million barrels per day in 1975. Overall, demand for OPEC oil dropped from 30.99 million barrels per day in 1973 to 27.16 million barr per day in 1975, a decline of 12 percen

A similar worldwide decline in demand resulted in four years of relatively stable oil prices. The price of Saudi Arabian oil grew only 5 percent in real terms between 1975 and 1978. Even the price of crude from Algeria, a price hawk, rose by only 9 percent over the same four year period.[6] The U.S. and the world were apparently lulled into complacency by these events, and petroleum consumption began growing again in 1976. By 1978, U.S. consumption peaked at 19.22 million barrels per day, of which 43 percent was imported.

In 1979, OPEC output rose to 30.8 million barrels per day, again nearly 100 percent of its estimated operating capacity. As a result, when Iranian exports were completely cut off in December of 1978 due to the revolution, spot market prices reacted quickly. Although Iranian exports resumed within a few months, prices in the spot market skyrocketed to $40 per barrel, nearly double that of most official OPEC prices. In 1980, official prices rose to meet spot market prices and by January 1, 1981, the Saudi price (which is the OPEC benchmark price) reached its all-ti high of $36 per barrel. (See Figure 2.)

It should be noted that in both "oil crises," the actual reduction in crude supplies was small. In 1974, the Arab producers implemented a 5 percent cut in production, which was offset in part by increased production by some non-Arab OPEC members. Thus, total OPEC production was 30.7 million barrels per day in 1974, down less than 1 percent from 1973. In 1979, the "crisis" was even less apparent in terms of production. As stated, Iranian production resumed by mid-1979. In addition, the Saudis increased production by 1 million barrels per day to stabilize markets. These actions, coupled with increases from other non-OPEC countries, resulted in actual first quarter production that was marginally higher (.8 million barrels per day) in 1979 than in 1978. What, then, was the source of the "crisis"?

The fear that world oil markets were operating at nearly 100 percent capacity and could not replace lost production caused panic in both the oil industry and governments. As a result, major oil

4 Aperjis, D., *The Oil Market in the 1980s*, Chapter 1 "Creation and Rise to Power of OPEC," Ballinger Publishing Co., Cambridge, Mass. (1982).
5 op. cit., *1982 Annual Energy Review*, p. 79.
6 Ibid., p. 89.

companies attempted to build stocks and reduce supplies to third parties. This brought pressure on independent oil companies, forcing them to rely more on higher priced, less certain spot market crude oil. Government officials worsened the problem by proclaiming "a shortage" without implementing significant strategies to address the problem.[7] OPEC capitalized on the panic by instituting permanent price increases.

Thus, rather than supply disruptions, high demand for OPEC production is the source of OPEC's power and is the factor that is ultimately responsible for the rising prices of the 1970's. This fact is further evidenced by the supply disruption resulting from the outbreak of the Iran/Iraq War in late 1980. In that war, Iran and Iraq lost 4 million barrels per day in production capacity. But because there was more than 5 million barrels per day excess capacity even after this lost production, markets remained calm and prices actually began falling in early 1981.

The key lesson of the seventies is that, as demand forces OPEC production toward full capacity, it is increasingly likely that OPEC will institute sharp price increases. This relationship reflects the dynamics of supply and demand in the marketplace. When demand for OPEC oil is high, OPEC members generate more revenues than are necessary to cover their import requirements. This surplus enables them to implement the production cuts necessary to sustain a price increase. Conversely, when demand for oil is too low to cover revenue requirements, OPEC members must lower prices in order to increase demand for their product and enhance revenues. The U.S. Department of Energy (DOE) has measured this relationship between the proportion of OPEC's production capacity that is utilized and its ability to raise oil prices. (See Figure 3.) When operating above 80 percent of production capacity, OPEC has raised real oil prices. As production approaches 100 percent of capacity, prices have grown exponentially. It is this relationship and its continued relevance that foretells OPEC's future power and Minnesota's continued vulnerability.

Rising energy prices contributed to condition of inflation coupled with economic stagnation for world, national and state economies

By 1981, real oil prices were five times higher than in 1973. The prices of substitutes for oil, such as natural gas, were

Figure 2
Petroleum Prices, 1970-1982

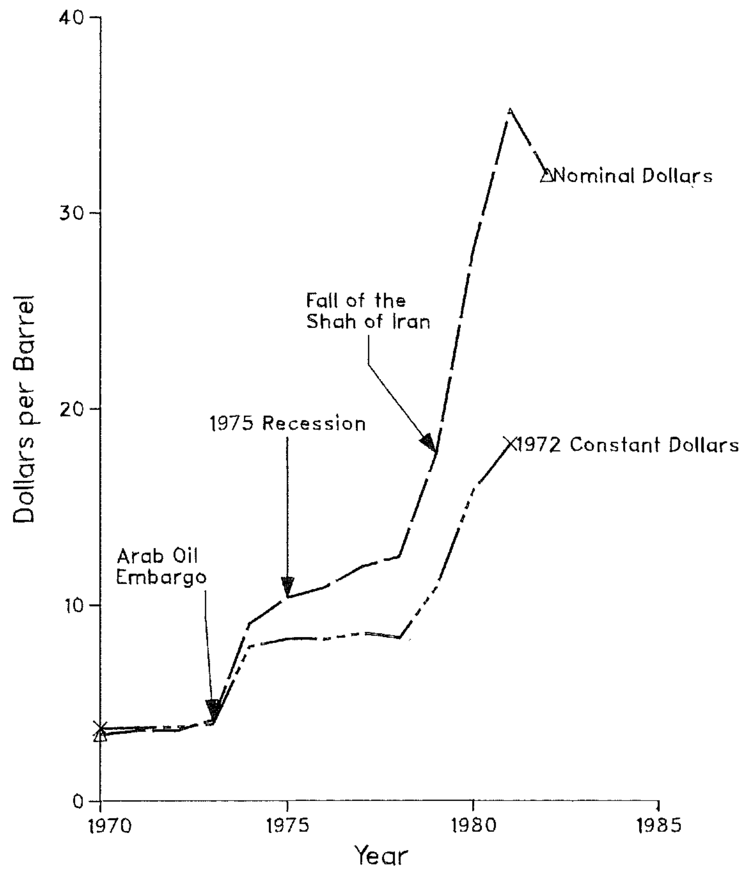
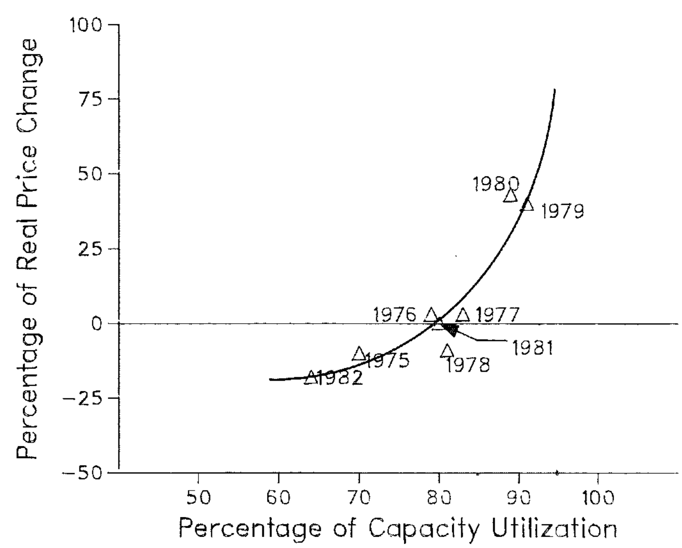


Figure 3
OPEC Pricing Behavior (percentage real price change from previous year vs. percent of capacity utilized



Note: Production capacity is defined as the maximum production rate that can be sustained for several months. The curve was fitted to historical data using least squares regression.

7 op. cit., Aperjis, D.

escalating simultaneously. While many factors contributed to the economic ills of the 1970's, this energy price explosion must be considered a key contributor to the inflation and economic stagnation that were the hallmarks of the period.

Increases in relative energy prices caused increases in individuals' and businesses' costs for heating, processing and transportation fuels, and for petroleum-based products. Rising energy prices contributed to general inflation by inducing an increase in nominal prices and wages in order to maintain the existing structure of relative prices and wages. This effort to maintain the relative price structure failed. As a result, real price increases for energy contributed to a worldwide decline in economic activity, which is very dependent on the cost and availability of energy. In 1980, inflation in the United States reached a 25-year peak of 13.5 percent annual growth. (See Figure 4.) In the decade preceding the Arab oil embargo, inflation had averaged 3.8 percent per year; in the decade following, inflation averaged 8.4 percent per year.[8]

The decline in the availability of cheap energy and the institution of monetary and fiscal policies to control inflation contributed to recession. Real economic growth in the U.S., as measured by Gross National Product (GNP), averaged 4.2 percent per year between 1963 and 1973. In the last decade, real GNP has grown at only 1.7 percent per year.[9] (See Figure 5.) Furthermore, growth in productivity also dropped. Postwar output per man-hour grew, on average, at a rate of 3.3 percent per year prior to 1973; and at less than 1 percent per year in the decade following 1973.[10]

Thus, the energy price explosion contributed to both inflation and recession. It also contributed to another serious worldwide economic problem, the dimensions of which may not yet be fully appreciated. As oil revenues in OPEC countries grew, creating significant surpluses, OPEC recirculated dollars to financial markets through investment in western economies. In turn, industrialized countries financed economic expansion in non-oil producing developing countries, encouraging Third World countries to increase their debt by readily providing loans. The growing cost of imported oil necessary to fuel the ex-

Figure 4
Relationship of Oil Prices and Inflation, 1970-1982

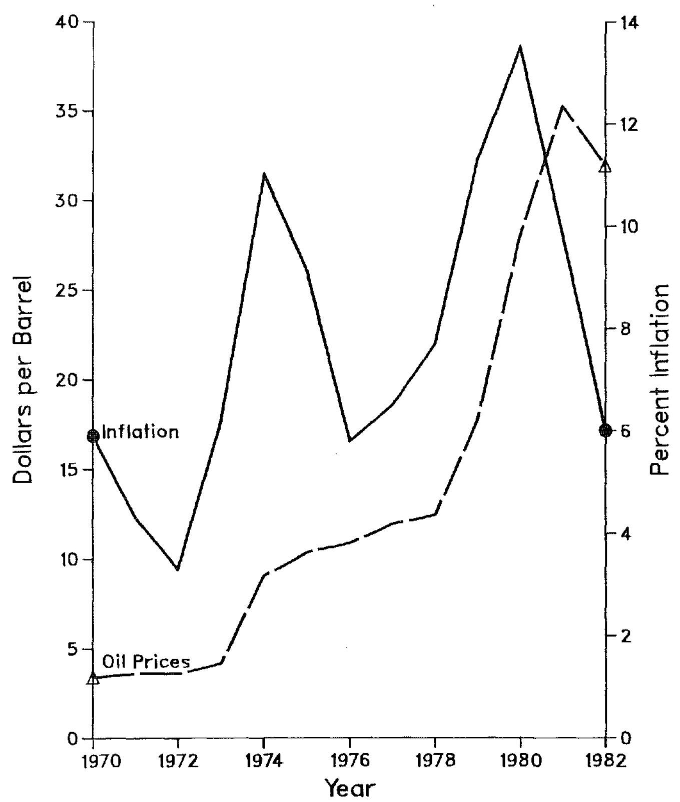
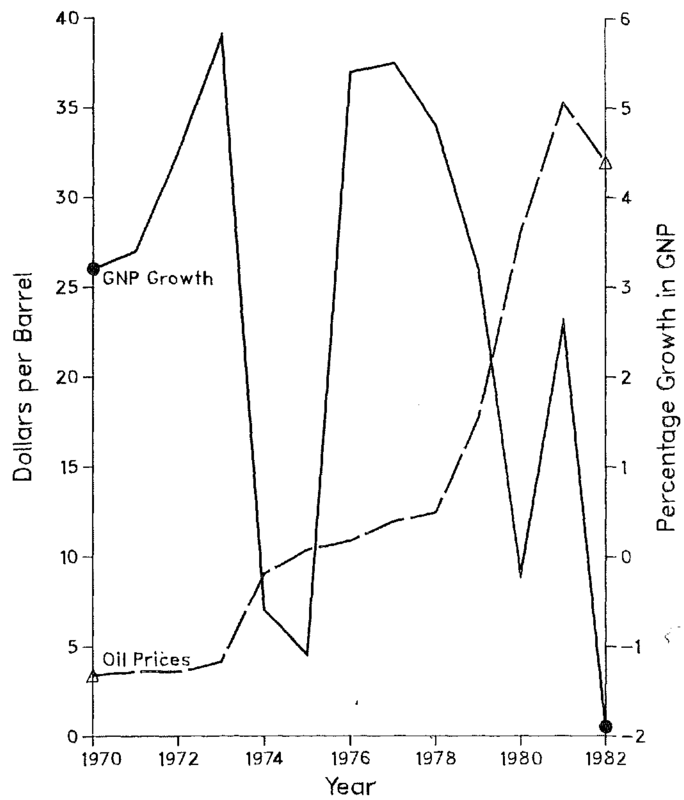


Figure 5
Relationship of Oil Prices and Growth in Gross National Product, 1970-1982



8 *Statistical Abstract of the U.S.—1981*, Bureau of the Census, Department of Commerce, (1981), p. 459 and *Survey of Current Business*, U.S. Bureau of Economic Analysis, February 1984.
9 Ibid., p. 421.
10 Silk, L., "The Painful Shift to Costly Oil," *The New York Times*, Wednesday, September 28, 1983.

pansion also exacerbated Third World countries' financing requirements.

Other important factors contributing to rising Third World debt included the world recession of 1979-1983, which reduced exports from less developed countries to industrialized countries, and worldwide inflation, which caused rising interest rates. These factors led to an explosion of Third World debt, which rose to $664 billion in 1983.[11] At least five nations stood on the verge of default by 1983, including Mexico, Brazil, Venezuela, Chile, and Argentina. The result of the Third World's potential inability to service its debt is likely to have long term implications for worldwide economic growth. International bankers are less willing to finance future Third World expansion, slowing growth in demand for imports from western economies. With slower growth in markets for their goods, growth in developed nations' economies is also slowed. Thus, the consequences of the energy price explosion on the world's economies are likely to continue to be felt well into the coming decade.

For Minnesota, slowed economic growth was compounded by loss of competitive advantage to energy producing states

As part of the national economy, Minnesota's economy also suffered. The rising price of energy directly affected individuals and businesses by increasing the cost of fuel for heating, processing and transportation. Between 1973 and 1982, average household energy expenditures (including gasoline) rose from $757 per year to $2,315 per year. This increase represents an annual loss in discretionary income of over $500 (in real terms).

Similarly, costs rose for Minnesota's businesses and industries. In the manufacturing sector, energy costs as a proportion of value added[12] rose from 1.12 percent in 1972 to 3.5 percent in 1980. In the mining and taconite industries, energy costs as a percent of value added rose to 16 percent in this period, a 23 percent increase from 1972. Finally, energy costs in the agricultural sector rose to 9.6 percent of total value added, up 26 percent from 1972. The total state energy bill increased from $2.02 billion in 1973 to $6.82 billion in 1982. Although state economic output was rising, these energy expenses rose even faster. Minnesota's energy bill rose from 8 percent of Gross State Product (GSP) in 1973 to 13 percent of GSP in 1982.

Minnesota's slowed economic growth was caused directly as wages and prices failed to increase as fast as energy prices, resulting in a decline in purchasing power for wage earners and in net income for businesses. However, the relative level of economic activity is also affected by how stimulative the purchase of a good or service is on the local economy, as measured by its economic multipliers. Although multipliers vary by type of energy, the overall net economic multiplier for energy is estimated to be .90. In contrast, the economic multiplier for all other goods and services in Minnesota is estimated to be 2.62. This means that $1 spent on traditional fuels stimulates 90 cents of economic activity, while $1 spent on other goods stimulates $2.62 of economic activity. Thus, the increase in Minnesota's energy expenses also slowed economic growth indirectly as Minnesota purchases shifted away from goods and services that are more stimulative of the economy to energy expenditures that produce relatively lower levels of economic activity.

Due to both these direct and indirect effects, Minnesota's economic reaction to this price shock mirrored the nation's inflation coupled with economic stagnation. Minnesota's GSP rose by 4.1 percent (real) per year in the decade preceding the Arab oil embargo, but at a rate of 3.0 percent in the decade following. Similarly, the rate of growth in employment slowed from 2.4 percent per year between 1963 and 1973 to 2.0 percent per year between 1974 and 1982, a 17 percent drop.[13]

Energy Division analysis indicates that in the absence of the 1979-80 energy price escalation, GSP would have been $58 billion in 1982. In comparison, actual GSP was $55 billion, indicating a loss of up to $3 billion in potential economic activity due to higher energy prices. Employment in Minnesota was approximately 2 million jobs in 1982, but would have been an estimated 2.1 million if the 1979-80 price hikes had not occurred. Thus, the state lost an estimated 100,000 potential jobs as a result of these price increases alone. (See the 1982 biennial report for a detailed discussion of the effects of rising energy prices.)

Although Minnesota's experience generally reflected national trends, it fared much worse than states with indigenous traditional fuel industries, such as Texas. The energy price shock reduced consumer and business purchasing power in energy producing states as it did in Minnesota. However, this income loss was more than offset by rising incomes of oil and gas production, drilling, service and sales companies. Data from the *Survey of Current Business* show increases in after tax profits for oil and gas extraction companies of 357 percent and for petroleum refining companies of 700 percent between 1973 and 1981. In contrast, corporate profits after taxes nationwide rose only 95 percent from 1973 to 1981. As a result, the economies of many energy producing states boomed during the 1970's. For example, between 1973 and 1982, average per capita income rose 151 percent in Texas, compared with only 117 percent in Minnesota and 120 percent nationwide. (See Figure 6.)

In addition, the economies of energy producing states were, and continue to be, benefited by the inflow of revenues from energy severance taxes. In 1970, only one state (Louisiana) received 20 percent or more of its income from severance taxes. But by 1980, seven energy producing states relied that heavily on severance taxes. Minnesotans paid $50 million in oil and gas severance taxes to Texas alone, between 1980 and 1982. Thus, while Minnesota has been forced to raise taxes over the past decade in order to maintain the state's educational system, roads, and general infrastructure, the energy producers have been able to rely on revenue sources that have not increased the cost of living and doing business in their states.

These states also have used this revenue to enhance their competitive position in new industries. For example, through investment of severance tax income in the University of Texas at Austin, Texas has become a national leader in the area of high technology and one of Minnesota's chief competitors for high technology industries.

The energy price explosion of the seventies resulted in loss of real income for both Minnesota consumers and industry. However, rising prices had even broader consequences for the Minnesota economy, resulting in slowed economic growth and a loss of competitive advantage.

11 Ibid.

12 Value added is the cost or value of the product excluding the cost of the materials used to make the product.

13 Minnesota Gross State Product, 1960-1969 Council of Economic Advisors, Minnesota State Planning Agency; 1970-1977 Research Division, Minnesota Department of Economic Development; 1978-1982 Data Systems Unit, Minnesota Department of Energy and Economic Development. Original data in nominal dollars adjusted to constant 1972 dollars using GNP implicit price deflator.

Minnesota's poor bore brunt of state's hardship; government programs did not offset impact

Rising energy prices affected every Minnesota household. Energy expenditures (including gasoline) rose from 6 to 9 percent of a median income household's budget between 1973 and 1981, which represents a 50 percent increase in the portion of a household's income commited to energy expenses. However, certain segments of the population have suffered more from rising energy prices than others.

Low income households have been particularly hurt by escalating fuel bills because they must contribute an even higher portion of their income to energy payments than other households. For example, in 1973 an average Minnesota household living at the poverty level paid approximately $310, or 7 percent of its income, for home heating, cooking and other residential energy costs (excluding gasoline).[14] By 1981, that same household paid nearly $1200, or 13 percent of its annual income, to meet its basic energy needs. In contrast, an average median income household paid approximately 4 percent of its income in 1973 and 5 percent in 1981 for residential energy expenses. (See Figure 7.)

Increased government subsidies and income maintenance programs have not offset the impact of rising energy expenses for the poor. A recent analysis by the Consumer Energy Council of America (CECA) found that, while increases in government benefits to low income families increased by a total of $12 billion between 1973 and 1981, the aggregate loss of purchasing power by low income households exceeded $75 billion. Government programs offset only an estimated 16 percent of rising energy bills.[15]

Not only have their incomes not kept up with rising energy prices, but low income families are also less able to reduce energy costs by investing in cost effective conservation measures. Low income households are less likely either to have cash available for such investments or to be eligible for loans from private financial institutions. As a result, low income households were unable to reduce their consumption (corrected for weather variations) between the 1979/80 and 1980/81 heating seasons, even in the face of a 39

Figure 6
Comparison of Per Capita Income Growth, 1973-1982

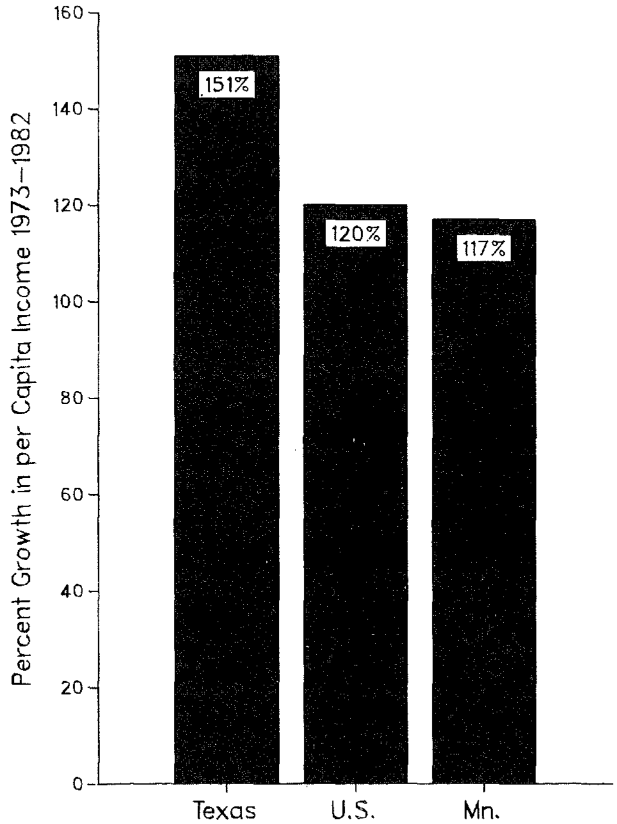
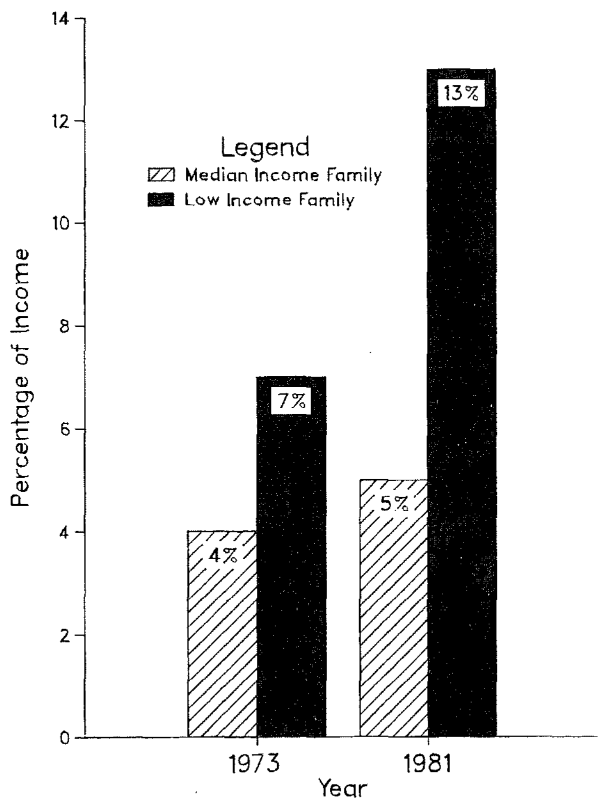


Figure 7
Comparison of Percent of Income Paid for Energy by Low vs. Median Income Minnesota Household, 1973 and 1981



14 Using federal poverty level for a family of four: $4,460-1973; $9,300-1981.

15 Cooper, M., et.al., *Equity and Energy*, Chapter 6 "The Loss of Purchasing Power," Westview Press, Boulder, Colorado (1983), pp. 101-114.

percent increase in home heating costs.[16]

In addition, the CECA research found that the living standards of low income households have been indirectly eroded rising energy costs through deterioration in the rental housing market and a decline in public services, coupled with a shift toward regressive taxes. Deterioration in rental properties occurred as energy costs rose from 14 percent to 30 percent of net rental unit operating costs. As operating costs rose, landlords both reduced maintenance budgets and increased rents. This phenomenon was especially evident in low income rental properties. Thus, low income families, who are much more dependent on rental housing, paid a higher fraction of their income for poorer living conditions.[17]

A similar phenomenon arose with services provided by local governments. Faced with rising energy prices, local governments both increased taxes and decreased services. The CECA analysis indicates that because low income households are more dependent on government services, cuts affect them disproportionately. Furthermore, the weakest constituency was found to be most likely to bear the heaviest burden of not only service cuts but also tax increases. The study found that local governments are more likely to increase regressive taxes rather than progressive taxes such as the income tax.[18]

In sum, the deterioration in the standard of living of low income households resulting from energy price increases of the 1970's was much more severe than for moderate and upper income households. To date, government programs have not been adequate to correct this situation.

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16 McKenzie, A., *The Cost-Effectiveness of the Minnesota Weatherization Assistance Program*, Minnesota Department of Energy and Economic Development, St. Paul, Minnesota (July 1983), p. 9.

17 op. cit., Cooper, M., et. al., p. 7.

18 Ibid., p. 9.

Historic Minnesota consumption trends

The events of the 1973-1980 period slowed growth in world, national and state economies, moving us from an era of relatively rapid growth and expansion to a decade of retrenchment and low growth. Individuals and businesses have responded to higher prices by significantly reducing their consumption of fossil fuels, both by improving the efficiency of their energy use and by substituting alternative sources of energy.

Since its peak in 1978, U.S. oil consumption has dropped by 20 percent. Moreover, total U.S. energy consumption declined 10 percent since its peak in 1979. In Minnesota, overall energy consumption has declined 12 percent since its 1979 all time high. (See Figure 8.) By 1982, use of petroleum products had declined by 21 percent to 3.4 billion gallons.

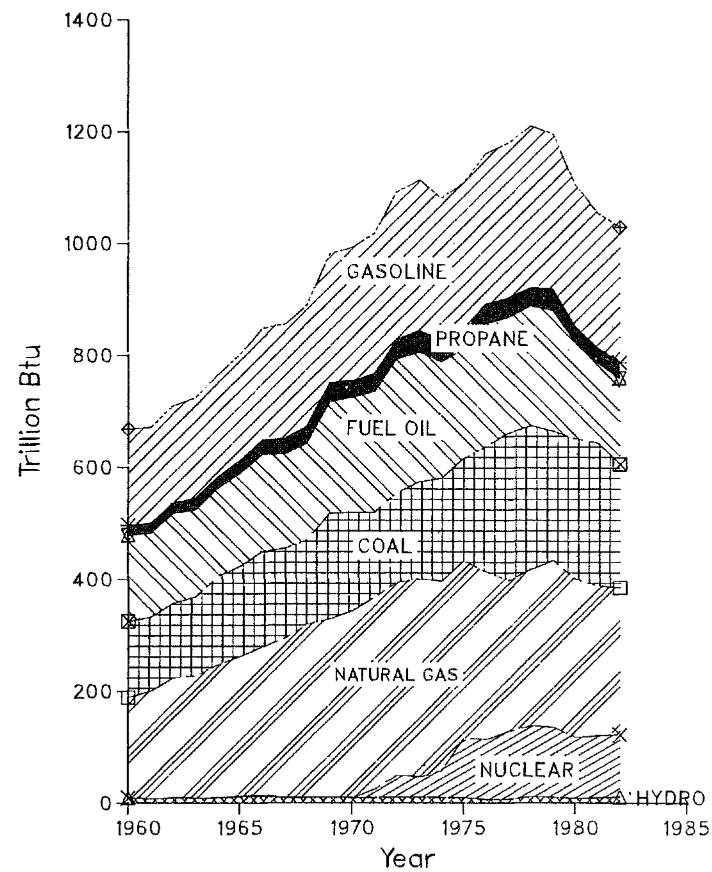
Natural gas prices and consumption were also affected by the increase in oil prices. Natural gas is a substitute for oil in residential, commercial, and industrial heating and processing. As a result, when the phasing out of natural gas price controls was initiated in 1978, natural gas prices quickly began to rise to the Btu equivalent level of petroleum product prices. Nationally, wellhead natural gas prices rose by 165 percent between 1978 and 1982. In Minnesota, residential natural gas prices rose more than 100 percent. The natural gas price escalation had a direct impact on demand for natural gas. In Minnesota, natural gas demand declined by 12 percent between 1979 and 1982.

The oil price shocks of 1974 and 1980 also indirectly affected electricity prices and consumption because oil is used to generate some electric power and because slowed economic activity dampened electric demand. Before the 1973-74 OPEC oil embargo, the real residential electric price in Minnesota was actually decreasing at an average rate of 4.3 percent per year for the period 1960-1973. For the period 1973-1982, the real residential electric price for Minnesota reversed its trend, growing at an average rate of approximately 2.0 percent per year.

As a result of slower economic growth and higher prices, growth in demand for electricity slowed markedly in the decade following the Arab oil embargo, as compared to the preceding decade. Historically, for the period 1960-1973, total electric energy (kWh) sales in the U.S. were growing at an average compound rate of 7.3 percent per year. For Minnesota, this growth rate was 7.6 percent per year for the same period. However, since the embargo, this rapid growth has been transformed into a slow growth in electric sales for both the U.S. and Minnesota. For the period 1973-1982, the average growth rates are 2.3 percent per year and 2.4 percent per year for the U.S. and Minnesota, respectively.

This sudden drop in the growth of electricity demand caught the electric utility industry off-guard, leading to overestimates of future need for new capacity. In 1977, for example, utilities serving Minnesota collectively projected that electricity demand in 1992 would reach

Figure 8
Minnesota Energy Consumption by Fuel Type, 1960-1982



20,788 megawatts. By 1981, their projection had decreased to 13,195 megawatts. The difference between the two forecasts—7,593 megawatts—is significant because, to meet this difference, more than nine new power plants the size of Sherco III would have been required. Building these additional plants would have resulted in higher rates for Minnesota customers, increased environmental problems, and excess capacity.

The Energy Division, through the Certificate of Need process, played an important role in guiding the state to a more realistic assessment of future demand for electricity. As one of the first to use econometric forecasting methodologies, the Division presented testimony at Certificate of Need hearings showing projected demand levels that were more reasonable and accurate than those forecasted by the utilities. (See Figure 9.) As a result, utilities began revamping their own forecasting methodologies, delayed the in-service dates of new generating plants, and cancelled plans to build unneeded power plants.

For example, NSP dropped its plan for Sherco 4 and delayed the initial in-service date of Sherco 3 from 1983 to 1988. These actions were beneficial to Minnesota in that they delayed and/or avoided the negative environmental impacts of coal-fired electric production, such as acid rain, and reduced the addition of new capital costs to the rate base.

The following sections will discuss how, over the past decade, Minnesota has improved energy efficiency in the residential, commercial/institutional, industrial, agricultural, and transportation sectors, and the effects of these efficiency improvements on energy demand. In addition, developments in the use of alternative energy resources in Minnesota over the past 10 years are presented. Also, the role of the Energy Division in facilitating efficiency improvements and alternative energy developments is highlighted.

Average Minnesota household reduced energy consumption by 26 percent

The residential sector is comprised of a large number of small energy consuming units, each with its own distinct characteristics. These units are occupied by individuals, each with widely varying energy using habits. In 1982, Minnesota had 1.5 million occupied housing units, compared with 1.2 million in 1973. Single unit dwellings represent 70 percent of the housing stock; mobile homes and multi-unit apartment and condominium buildings represent nearly 30 percent.

Given the great diversity of the housing market, the decline in consumption that has occurred in this sector is remarkable. Fuel oil consumption declined 41 percent between 1973 and 1982 as individuals switched to less costly fuels (often wood) and insulated their houses. Natural gas consumption also declined, by 5 percent since 1979. (See Figure 11.) In 1973, the average Minnesota household's total annual energy consumption was 160.3 million Btu, or 18,696 Btu per degree day. By 1982, consumption per household was 132.1 million Btu, or 13,814 Btu per degree day. When consumption is normalized taking into account the difference in degree days, average energy use in Minnesota households has dropped 26 percent since 1973. (See Figure 12.)

Overall, approximately 70 percent of the energy savings in the residential sector has come from lifestyle changes. The remaining 30 percent has been achieved primarily by improving the thermal characteristics of houses—reducing air infiltration and adding attic and wall insulation. Yet the greatest potential for energy savings will actually come from more energy efficient housing designs and appliances (including furnaces). Thus, in many respects, improving the energy efficiency of Minnesota's housing stock is just beginning.

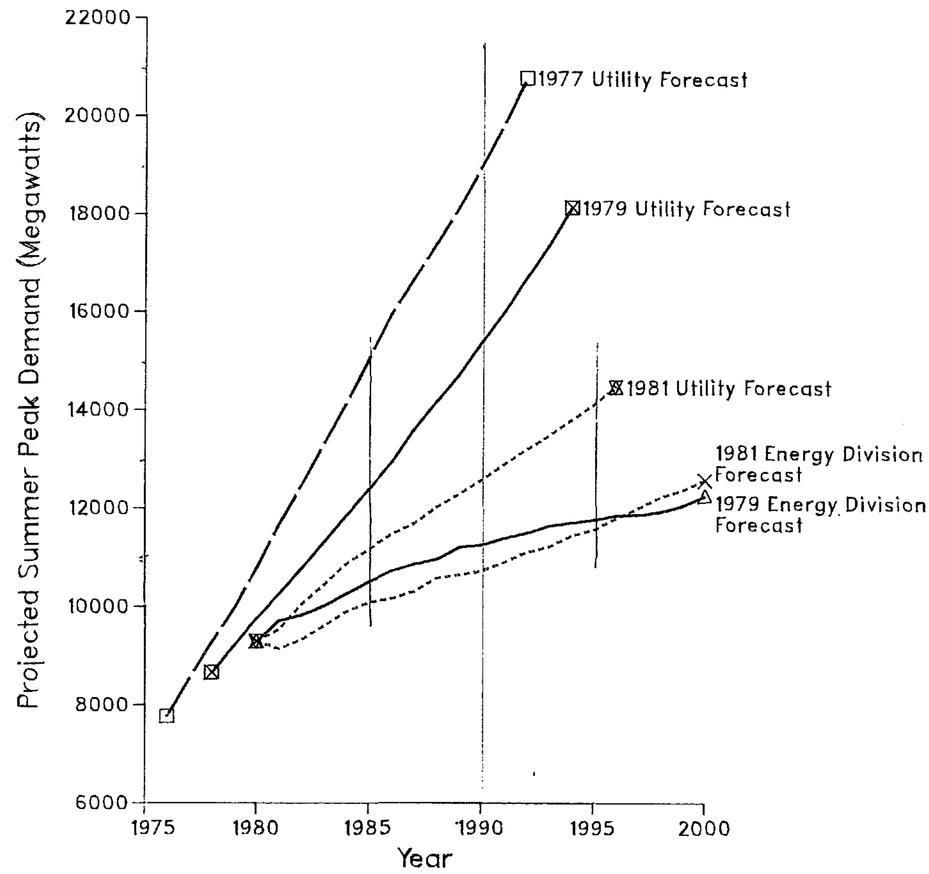
Lifestyle changes, primarily lowered thermostat settings, responsible for 70 percent of savings

Initially, higher energy prices induced low cost lifestyle responses, primarily lowered thermostat settings. On a national level, 85 percent of households set their thermostats during the day at 70°F or higher in 1973; only 45 percent did so in 1981. At night, 51 percent of households had thermostat settings above 70°F in 1973, whereas only 22 percent did in 1981. (See Figure 13.)

This national trend toward lower thermostat settings has also occurred in Minnesota. A survey of 1,000 Minnesota households indicates that at least 57 percent have reduced their thermostat settings in the last two years.[19] Much of the state and national populaton appears to have permanently adopted lower winter indoor temperatures and somewhat higher sum-

19 Hirst, E., Goeltz, R., Thornsjo, M., Sundin, D., *Evaluation in Minnesota: the Northern States Power Experience.*

Figure 9
Summer Peak Demand Forecasted by Utilities and by the Energy Division



mer indoor temperatures. The average winter daytime thermostat setting in Minnesota is now estimated to be 67°F.

Reducing air infiltration and adding attic and wall insulation account for approximately 30 percent of savings

Improving the thermal qualities of existing houses is more difficult and more costly than designing new energy efficient houses. Since the interior and exterior surfaces are finished, addition of more insulation is difficult. However, over the past 10 years, homeowners have increased insulation levels in attics, above grade walls, and along foundation walls of existing houses. While 12 inches of attic insulation has been common in new houses for some time, older homes frequently have no insulation or at most 3 inches. During the past 10 years, it has become common for homeowners to increase attic insulation levels to 12-14 inches (R-38 to R-42). Many homeowners have also had loose, short fiber insulation blown into the uninsulated wall cavities of their houses and, more recently, some are adding exterior foundation insulation.

Reduction of infiltration in existing houses is less difficult and costly than insulating. As a result, caulking and weatherstripping has been more widely employed in the residential sector than adding insulation. Caulking and weatherstripping are most effective when done on the interior so as to help prevent moisture from entering wall and attic cavities. Also, there are fewer joints and cracks to seal on the interior, and the work can be done year round. Recently, new testing methods have been developed to locate leaks. Sealing these leaks further reduces infiltration.

Today, approximately 75 percent of the nation's housing stock has full attic insulation and 65 percent has wall insulation.[20] However, less than 5 percent of the housing stock has foundation insulation or high efficiency furnaces. In addition, much of the retrofit work that has been done is primarily in owner-occupied housing as there are few direct incentives for either the renter or the landlord to improve the efficiency of rental housing. However, rental property represents 28 percent of the housing stock, or more than 400,000 units.

Overall, less than 1 percent of the state's housing incorporates all available cost effective conservation improvements. Thus, although extraordinary advances have been made in improving the energy efficiency of Minnesota's housing stock, the majority of it remains to be improved.

As energy losses have been reduced, other problems have been created. The addition of insulation has meant increased potential for the condensation of moisture within the structure. This has necessitated better ventilation and vapor control techniques. Tightening houses has reduced fresh air exchange, creating the potential for indoor moisture and air quality concerns. These, in turn, have re-

20 *Residential Energy Consumption Survey: Housing Characteristics 1981*, Energy Information Administration Office of Energy Markets and End Use, U.S. Department of Energy, DOE/EIA-0314(81) (August 1983), pp. 80, 81.

Figure 10
Residential Energy Consumption as a Portion of Total Minnesota Demand, 1982

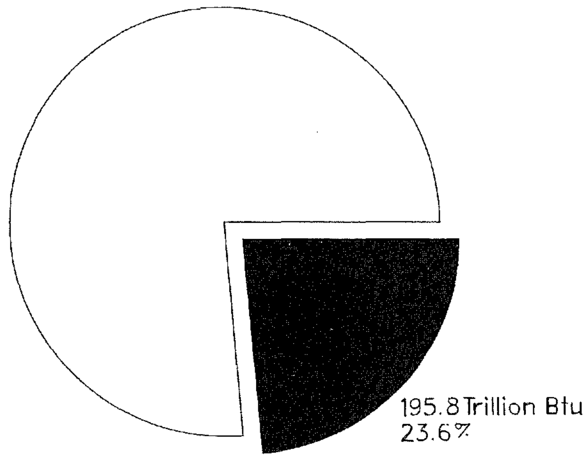
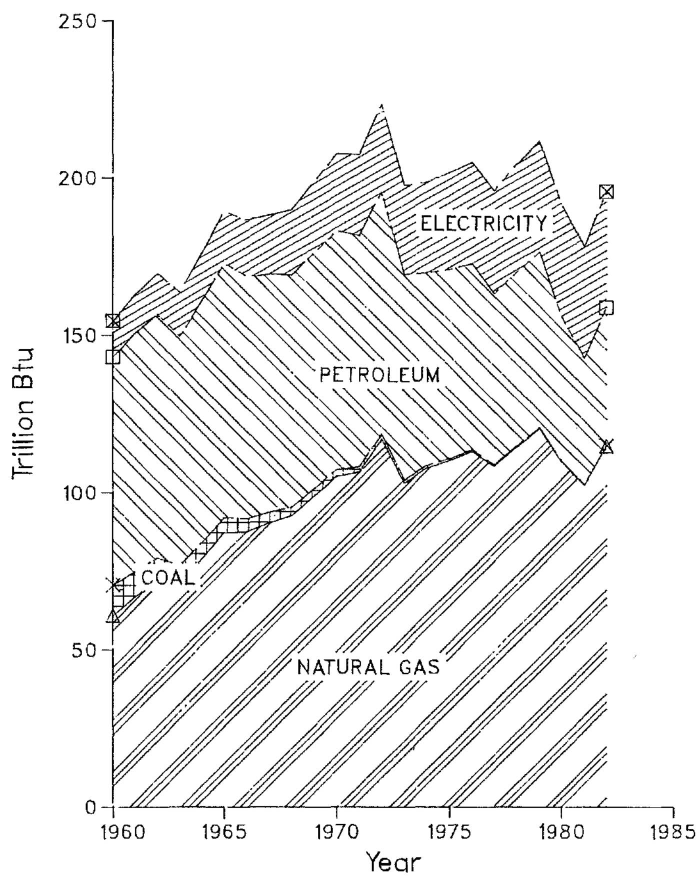


Figure 11
Residential Energy Consumption by Fuel Type, 1960-1982



quired increased attention to ventilation techniques. It is clear that substantial research and education efforts must continue to take place if the state is to improve its housing stock safely and effectively.

New energy efficient housing designs and appliances begin to appear on market—offer greatest potential for future savings

As easily implemented lifestyle and retrofit changes began to reach their limits, consumers turned to the marketplace in search of more efficient housing and appliances, only to find a lack of comparative information on energy efficiency and a lack of efficient products. The failure of the private sector to respond quickly to either of these two needs resulted in the federal government imposing mandatory appliance labeling and efficiency standards. The Minnesota Legislature enacted a number of energy efficiency regulations including a state energy code for buildings, air conditioner efficiency standards, and a ban on pilot lights for ovens, ranges and dryers.

By the late seventies, information about the energy costs of operating basic consumer goods began emerging and a fundamental change took place in purchase decisions. Consumers began to shift from a "first cost" to a "life cycle cost" basis for making purchase decisions. The payback period became important, and there was increased emphasis on product quality and durability. This trend led to what may be the greatest amount of experimentation and innovation in housing in our nation's history. The goal of reducing energy costs to a minimum has led to an explosion of design options with energy concerns often overshadowing aesthetic considerations. At first, strong advocacy groups emerged around specific technological approaches including earth-sheltered construction, passive solar design and, somewhat later, superinsulated construction. As experience was gained with each technology, however, the best aspects of each design strategy began to merge into more aesthetically pleasing and cost effective hybrids.

Despite this decade of experimentation, little rigorous research has been done on the comparative cost effectiveness of these alternative approaches. The transfer of technology has relied primarily on case studies and word-of-mouth exchange of information among the highly dispersed residential building community. In addition, the significant design constraints posed by the new technologies has slowed the entry of these alternative approaches into the marketplace.

Figure 12
Residential Energy Consumption per Household Unit per Degree Day

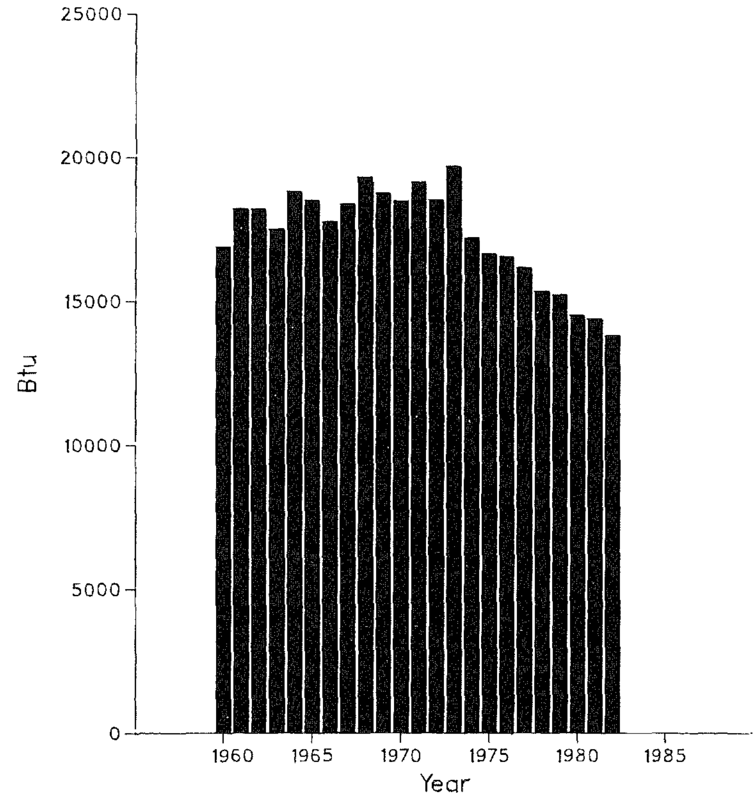
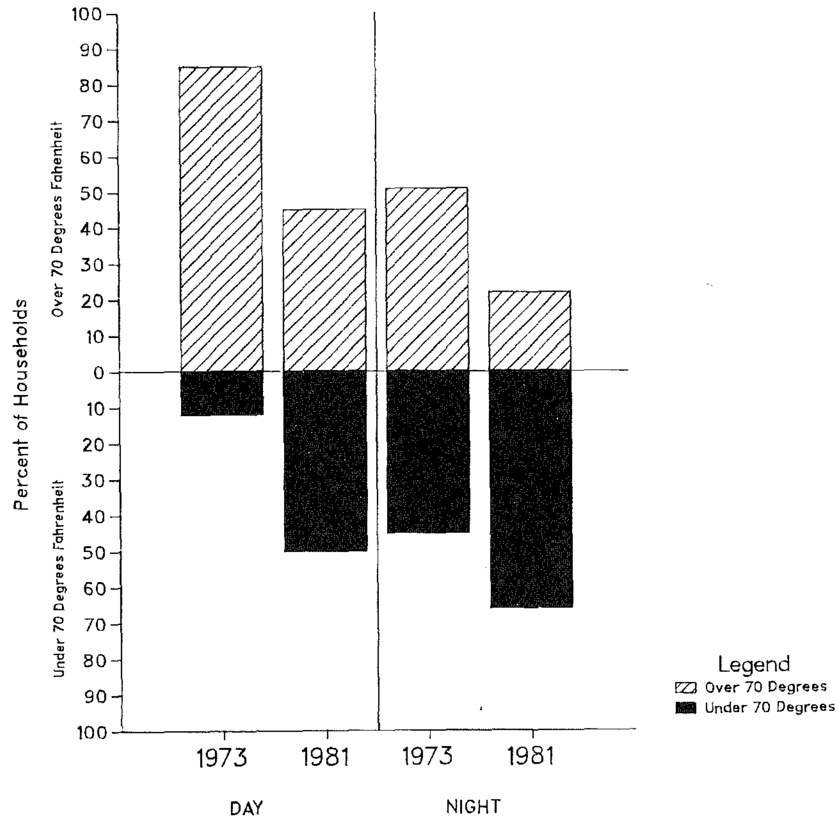


Figure 13
Distribution of Households in the U.S. by Thermostat Setting



The result has been that the dominant energy technology in new housing is simply the use of increased insulation ˀd reduced infiltration, usually with some ɔnsideration to passive solar gain. This approach has permitted the preservation of traditional architectural styles while significantly reducing energy use.

The key areas of continued technological development involve moisture control, maintenance of indoor air quality, and heating/ventilating system designs. It has proven relatively easy for builders to improve building envelope performance through increased insulation and decreased infiltration. However, this has necessitated greater use of controlled ventilation such as exhaust fans in kitchens and bathrooms, or air-to-air heat exchangers. Further improvements in reducing air leaks in housing will be dependent on improvements in home ventilation systems. Based on work in Sweden, however, where infiltration standards were enacted in 1978, it appears that high efficiency, airtight construction will actually result in improved indoor air quality over conventional construction because of the greater control over ventilation. Honeywell, for example, is developing home ventilation systems that sense indoor air pollutants and automatically bring in fresh air when levels get too high.

High efficiency housing can achieve energy reductions as great as 90 percent over conventional housing. The remarkable realization to emerge from the past decade is that home heating can actually be a relatively minor expense—even in Minnesota! As heating costs are reduced, however, energy for appliances becomes a larger portion of the utility bill. In a superinsulated house, water heating can be 55 percent of total energy costs. Thus, it is likely that improvements in appliance efficiency will receive increasing attention in the future.

Since 1972, significant efficiency gains and energy reductions have been made by the appliance industry. (See Figure 14.) However, there is still much room for improvement, especially in room air conditioners. The lack of efficiency improvements in room air conditioners is of special concern because residential air conditioning comprises 25 percent of NSP's summer peak electricity demand. Despite past gains in most appliances, there is still much room for improvement. Heat pump water heaters use one-half the amount of energy used by conventional electric water heaters. Solar water heating is also cost effective as a replacement for electric water heaters in Minnesota, and is now in widespread use. (A detailed discussion of solar applications is presented in the section on alternatives.) Integrated appliances are being developed where the heat from the refrigerator is used to heat water.

Perhaps the most important appliance in terms of energy use is the furnace. Dramatic improvements in furnace efficiency have been made over the past few years, bringing the annual fuel use efficiency (AFUE) up from 65-75 percent to as high as 96 percent. These new furnaces utilize pulsed combustion of fuel, recuperative condensation of flue gases, pilotless ignition, and flue dampers to increase both the steady state and the seasonal efficiency of the furnace or boiler.

Methods to improve efficiencies in existing heating systems through cleaning, adjustment, repair of leaks, and derating of oversized heating systems were also developed during the seventies. Other improvements include installation of flame retention burners in oil furnaces, intermittent ignition systems and, in some

.igure 14
Trends in the Efficiency of New Products

	Efficiency Parameter	1972	1978	Efficiency[a] 1980	1981	1982	1983
Gas furnace	Percent seasonal efficiency[b]	63.2[e]	63.6	63.3[f]	—	—	69.6
Gas water heater	Percent overall efficiency[b]	47.4	48.2	47.9[f]	—	—	—
Electric water heater	Percent overall efficiency[b]	79.8	80.7	78.3[f]	—	—	—
Central air conditioner	SEER[c]	6.66	6.99	7.60	7.83	8.31	8.43
Room air conditioner	EER[c]	6.22	6.75	7.02	7.06	7.14	7.29
Refrigerator/freezer	Energy factor[d]	3.84	4.96	5.59	6.09	6.12	6.39
Freezer	Energy factor[d]	7.29	9.92	10.85	11.27	11.28	11.36

[a] Average efficiencies are weighted by manufacturers' shipments. Data provided by the industry associations AHAM, GAMA and ARI. Also, see "Consumer Products Efficiency Standards Economic Analysis Document," DOE/CE-0029, U.S. Department of Energy, March 1982, p. 31.

[b] The seasonal efficiency for gas furnaces is the AFUE value and the overall efficiency for water heaters is the service efficiency as specified by the US DOE test procedures.

[c] EER is the energy efficiency ratio in terms of Btu/hr of cooling output divided by watts of electrical power input. The SEER for central air conditioners is a seasonal energy efficiency ratio as specified by the US DOE test procedure (see "Federal Register," Vol. 44 p. 76700, Dec. 27, 1979).

[d] Energy factor is the corrected volume divided by daily electricity consumption where corrected volume is the refrigerated space plus 1.63 times the ·eezer space for refrigerator/freezers and 1.73 times the freezer space for freezers.

[e] 1975 rather than 1972.

[f] These values are estimates made by manufacturers in 1979.

Source: Howard Geller, "Efficient Residential Appliances and Space Conditioning Equipment: Current Savings Potential, Cost Effectiveness and Research Needs," ACEEE, Santa Cruz, California, August 1984.

cases, vent dampers. Also, insulating boiler hot water pipes has been used to help prevent heat loss to unused basement areas.

Energy Division efforts focus on conservation programs, information/technical assistance, research

Since its creation 10 years ago, the Energy Division has developed and coordinated conservation programs that have increased the level of conservation activity and reduced residential energy consumption in the state. The Division's efforts to influence residential energy consumption have focused on developing and administering conservation programs directed at specific audiences, providing information and technical assistance to a wide variety of individuals and groups, and participating in research projects to determine the effectiveness of conservation measures.

Conservation programs

The largest energy conservation program that has evolved during the Division's history is the Minnesota Energy Conservation Service (MECS), begun by the Division in 1981. Under this federally mandated program, major utilities have conducted over 30,000 Class A energy audits each year for their residential customers. In addition, there are over 500 suppliers and contractors of weatherization products and services that participate in MECS and nearly that same number of trained residential energy auditors. The impact of this program goes far beyond the 75,000 audits conducted to date. This is evidenced by the fact that other organizations such as the Minnesota Housing Finance Agency, Farmers Home Administration, Department of Housing and Urban Development, and local community action agencies all rely to some extent on the MECS auditor certification regulations or the audit itself in implementing their own energy related programs.

A complement to MECS in the rental sector is the Residential Rental Retrofit Program through which minimum energy efficiency standards for rental housing were mandated by the legislature in 1977. These standards were developed by the Division and phased in between 1980 and 1983 to allow landlords time to make any necessary improvements. The Energy Division has amended administrative rules in order to strengthen the standards and to provide more flexibility for landlords to comply with the standards.

For new single family residential structures, the Energy Division's work has focused on three areas. The first is the Minnesota Energy Code. The first code was conceived and developed in 1976 by the Building Codes Division in cooperation with the Energy Division. In the last two years, the Division has developed a revised code, which became effective January 1, 1984, and includes significant new requirements including increased envelope standards, residential foundation wall insulation, and vapor barriers. Energy consumption in a house built according to the revised code will be up to 35 percent less than in a house built according to the old energy code. In addition, these standards include maximum sizing limits on furnaces and air conditioners, and higher efficiency standards for HVAC and water heating equipment. The Energy Code is the primary force driving energy efficiency in new house construction.

The second effort is the superinsulation (SI) housing demonstration program, which began in 1981. This project has produced impressive results including construction of 19 new SI homes, remodeling of 5 houses to SI standards, development of a workbook that was used by over 170 instructors throughout the state to teach SI housing design and construction techniques, and the development and marketing of 4 SI houseplan designs (to date, 566 houseplans have been sold). In addition, the project has produced a number of very favorable spin-offs: thousands of Minnesotans have toured the SI open houses; scores of SI workshops have been held throughout the state with hundreds of participants; accredited SI courses for real estate professionals are being offered; two international SI conferences have been held in Rochester; home builders across the state are now building SI homes; and manufacturers of products for SI homes are being attracted to the state.

The third effort has been the development of a house efficiency information system. The first Division effort, the Home Energy Disclosure Program, was rescinded by the legislature in 1983. Currently, the Division is focusing on alternatives to this effort, such as a home energy rating system, which would summarize the energy efficiency of new homes (similar to the "miles per gallon" rating for cars) and allow consumers to compare the predicted energy consumption for a variety of new and existing homes.

Information and technical assistance

Energy Division efforts in the area of information and technical assistance are carried out by four units: Community Services, the Energy Information Center, Energy Communications, and the Library.

Community Services provides technical energy assistance to communities and local units of government. This effort wa initiated in 1977 to provide assistance to communities in developing energy awareness committees, and directly reached 200 cities. Since then, Community Services work has evolved to assisting communities in developing energy profiles and plans for local efforts to reduce community energy costs. In 1983, the Division began the Governor's Community Energy Program, which is designed to assist cities throughout Minnesota in establishing community energy councils to deliver local energy programs.

The Energy Information Center maintains a toll free energy information hotline that answers approximately 20,000 telephone information requests annually. In addition, over 200,000 energy related brochures, fact sheets and technical publications are distributed each year to hotline callers and at energy fairs and workshops.

All activities within the Division are supported by the Energy Communications unit, which plans and develops a variety of marketing, advertising and public information programs, and handles press relations. Over the past 10 years, Energ Communications has produced numerous publications, feature articles, public service announcements, and TV, radio, and newspaper ads to provide information to the public about energy conservation, alternatives and financing. It has also planned and coordinated two solar open house tours and several media campaigns to inform the public about new technologies and programs. In addition, WCCO Radio has generously provided a two-minute slot to the Energy Division every Friday morning since the Arab oil embargo, which has allowed the Division to bring timely energy information to thousands of Minnesotans.

The Energy Division Library is the single most complete source of energy information in the state, and one of the largest in the U.S. In addition to providing support to all Division activities, the Library is also open to the public, thus providing an important service to all Minnesotans.

Research

The Energy Division's research efforts have aimed at providing a better understanding of how best to conserve energ Early in the energy crisis, the Divisio emerged as a nationally significant researcher and source of information. In the mid-seventies, the Energy Division conducted critical studies on moisture accumulation in wall insulation, air infiltration around windows, and energy savings from eliminating pilot lights. In 1979, the Division established one of the first conservation program evaluation efforts with the help of a scientist on loan from Oak Ridge National Laboratories. The Division's program evaluations have often been used in Congressional hearings to support the continuation of federal funding for conservation. Research was also conducted in 1979 concerning the economic justification for utilities to invest in conservation, laying the theoretical foundation for the state's current efforts.

In 1982, the Division began a cooperative research effort with the Minnesota Housing Finance Agency on 144 high efficiency homes. The results showed that these houses used about one-third the amount of energy of a conventional house.[21] These findings, presented at a major national conference in 1982, led to the U.S. Department of Energy providing the Division with $100,000 to continue its investigation of which components were working most effectively and to expand the study to include indoor air quality. This "laboratory" of houses is perhaps the best documented in the U.S.

A second group of houses that the Energy Division analyzed was a sample of 30 houses weatherized under the Weatherization Assistance Program. Weatherization of these houses was limited to improvements in the building envelope and domestic hot water system such as added insulation, caulking and weatherstripping, insulation of hot water storage tanks and the addition of clock thermostats. The average reduction in total gas usage in these homes was found to be 14.5 percent. At an average cost of approximately $1,000, these projects will achieve payback periods of 6.4 years.

A third study was an analysis of 3,245 Minnesota houses that were eligible for the MECS or PUCIP programs, which were developed by the Division.[22] Energy savings of households that had audits (under the MECS program) or had audits and took out loans (under the PUCIP program) were compared with those that did not have audits. Households that did not have audits saved an average of 6.4 percent of their natural gas usage. Households that had audits under the MECS program saved 9.5 percent. These savings are averages of all audited households regardless of whether conservation actions were taken. Households that had audits and took out loans under the PUCIP program saved 19.5 percent. Analysis of a subset of 346 of the MECS audited houses demonstrates an average of 11 percent savings in audited households that installed at least some of the recommended measures.[23]

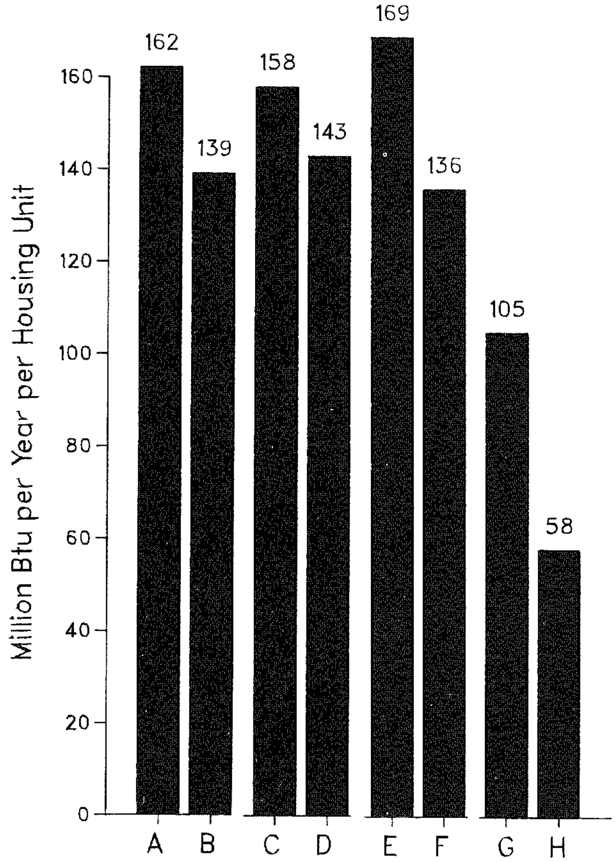
These studies demonstrate the direct energy savings that have been achieved through four Minnesota programs. (See Figures 15 and 16.) Together with other information and research efforts conducted over the past 10 years, they have provided a base of knowledge about how Minnesotans can best improve the efficiency of their housing. The availability of this information has encouraged count-

21 Hutchinson, M., Nelson, G., Fagerson, M., *Measured Thermal Performance and Cost of Conservation for a Group of Energy Efficient Minnesota Houses*, presented at American Council for Energy Efficient Economy Summer Study at Santa Cruz, California (August 1982), p. 11; and Fagerson, M, Lancaster, R., *A Statistical Analysis of Passive Solar Superinsulated Homes in Minnesota*, presented at the American Solar Energy Society Conference, Minneapolis, Minnesota (June 1983).

22 op. cit., Hirst, E., Goeltz, R., Thornsjo, M., Sundin, D.

23 Hirst, E., Goeltz, R., Comparison of Actual and Predicted Energy Savings in Minnesota Gas-Heated Single Family Homes, Oak Ridge National Laboratory, ORNL/CON-147 (December 1983), p. v.

Figure 15
Residential Energy Consumption by Conservation Program



Key

Low Income Weatherization
A Average natural gas use before weatherization
B Average natural gas use after weatherization

Minnesota Energy Conservation Service (MECS)
C Average natural gas use before MECS audit (1980-81)
D Average natural gas use after installing measures recommended by MECS audit (1982-83)

PUCIP
E Average natural gas use before audit (1980-81)
F Average natural gas use after audit, loan, and installation of conservation measures (1982-83)

Energy Efficient Housing Demonstration Program (EEHDP)
G Estimated average total energy use in new Minnesota houses (1981-82)
H Average total energy use in EEHDP houses (1981-82)

less Minnesota citizens to invest in conservation. These efforts, combined with the Division's work to mandate efficiency improvements through regulatory approaches, have significantly contributed to the 26 percent saving in household energy use that occurred between 1973 and 1982.

Commercial/institutional and industrial sectors decreased use of natural gas, coal, and petroleum products; increased use of electricity

The combined commercial/institutional sector includes facilities such as schools, hospitals, public care institutions, government buildings, commercial offices, retail stores, shopping centers, warehouses, hotels, motels, and restaurants, as well as street and highway lighting. Over 90 percent of the energy consumed by this sector is for space heating, air conditioning, water heating, and lighting.

In contrast, the industrial sector, which includes manufacturing, mining, and other non-agricultural operations, uses energy primarily in the production of outputs such as chemicals, paper, food, textiles, metals, glass, transportation equipment, and machinery.

In the commercial/institutional sector, use of natural gas, coal, and petroleum products declined from 106.2 trillion Btu in 1973 to 90.5 trillion Btu in 1982. However, use of electricity increased from 29.9 trillion Btu in 1973 to 41.5 trillion Btu in 1982. Overall, total energy consumption by the commercial/institutional sector decreased from 136.1 trillion Btu in 1973 to 132 trillion Btu in 1982. (See Figure 18.)

There is no firm information regarding statewide trends in efficiency over the same period in commercial and institutional activities measured in terms of existing and new building floorspace. However, national and regional studies show that commercial and institutional floorspace increased between 2 to 3 percent per year since 1971. Assuming the same historical trend for Minnesota, th drop in consumption implies a decline energy use per unit of floorspace. In other words, the energy efficiency of commercial and institutional buildings in the state can be estimated to have improved by at least 24 percent during the period from 1973 to 1982.

The same historical pattern applies to the industrial sector. Use of natural gas, coal, and petroleum products decreased from 220.4 trillion Btu in 1973 to 108.0 trillion Btu in 1982. Use of electricity increased from 25.2 trillion Btu in 1973 to 34.0 trillion Btu in 1978, but then decreased slightly to 30.5 trillion Btu in 1982. When combined, total energy consumption by the industrial sector decreased from 245.6 trillion Btu in 1973 to 138.5 trillion Btu in 1982. (See Figure 20.)

Figure 16
Estimated Total Annual Energy Savings Attributable to Conservation Programs and Undocumented Actions Compared to Estimated Maximum Annual Savings

	Number of Houses x	Annual Savings (10^6 Btu) =	Total Annual Savings (10^{12} Btu)
Weatherization	83,000[a]	23.3[g]	1.934
MECS	72,400[b]	15 [h]	1.086
PUCIP	4,700[c]	33 [h]	.155
EEHDP	144[d]	47 [i]	.007
			3.182
Undocumented actions	1,371,800[e]	9	12.346
Total explainable savings			15.528
Approximate total actual savings	1,532,044[f]	50.4[j]	77.215
Estimated maximum possible savings	1,532,044	101 [k]	154.736

Data Sources:

[a]Weatherization Program
[b]Minnesota Department of Energy and Economic Development
[c]Minnegasco, Energy Resource Center, Duluth Water & Gas
[d]Minnesota Housing Finance Agency
[e]Total estimated number of 1983 households minus the total number of households
[f]1980 Census + 6% = estimated number of households in 1983
[g]Wheeler, Herzog
[h]Hirst, Goeltz, Thornsjob, Sundin
[i]Hutchinson & Nelson
[j]Based on "Residential Energy Conservation: How Far Have We Progressed?" actual energy use
[k]Based on report listed in "j" above, estimate of energy use in retrofitted or designed with all cost-effective conservation strategies

Industrial energy intensity is determined by computing the energy use per dollar of value added. In 1974, energy intensity was 11.2 thousand Btu per dollar of value added (in 1981 dollars). By 1981, energy intensity was reduced to 8.2 thousand Btu. Thus, industrial energy efficiency has improved by 27 percent.

The trend toward increased use of electricity over the past two decades is due to a number of factors, particularly in the commercial/institutional sector. Increased air conditioning, excessive lighting of work and shopping areas, less energy efficient building design (specifically the increased use of glass), increased use of electrical labor saving devices, and some substitution of electricity for other fuels for heating have all contributed to this trend.

In addition, the real price per million Btu of electricity has been decreasing while the real price per million Btu of primary energy sources has increased. (See Figure 21.) Thus, although the price of electricity is still higher than that of primary fuels, the gap has narrowed considerably, and there has been some shifting to electricity. As this trend in real energy prices is expected to continue in the coming decade, it is likely that the use of electricity will increase in both the commercial/institutional and industrial sectors.

Floorspace in institutional and commercial buildings in Minnesota is projected to increase by 49.5 percent, from 715.8 million square feet in 1980 to 1069.8 million square feet in the year 2000, which represents approximately a 2 percent annual increase over the 20-year period. Minnesota industrial value added is also projected to increase, from 14.6 billion dollars in 1980 to 25.2 billion dollars in 2000, or an increase of 73 percent. This translates into an annual rate of increase of 3.7 percent. In view of these projected increases in commercial/institutional and industrial activities, it will be necessary to continually improve energy efficiencies in these sectors in order to sustain the historical decline in energy use. The following discussion highlights the key areas in which the energy efficiency improvements of the past decade occurred.

Commercial/institutional conservation aims at reducing space heating, cooling, water heating, and lighting demands

Although commercial and institutional facilities vary widely in size, function and type of construction, their energy use patterns are similar. Four basic functions—space heating, cooling, water heating and lighting—account for over 90 percent of the energy used in these facilities. Thus, significant energy savings are achieved by efficiency measures directed toward these end uses.

Energy conservation measures are considered cost effective if the annualized investment cost per unit of energy saved is less than the unit price of the same amount of energy if it were consumed

Figure 17
Commercial/Institutional Energy Consumption as a Portion of Total Minnesota Demand, 1982

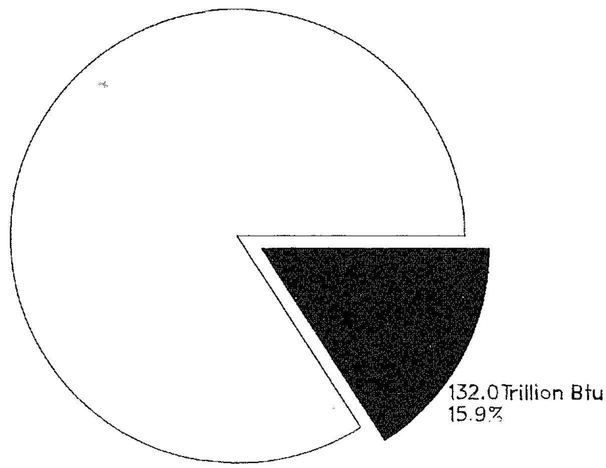
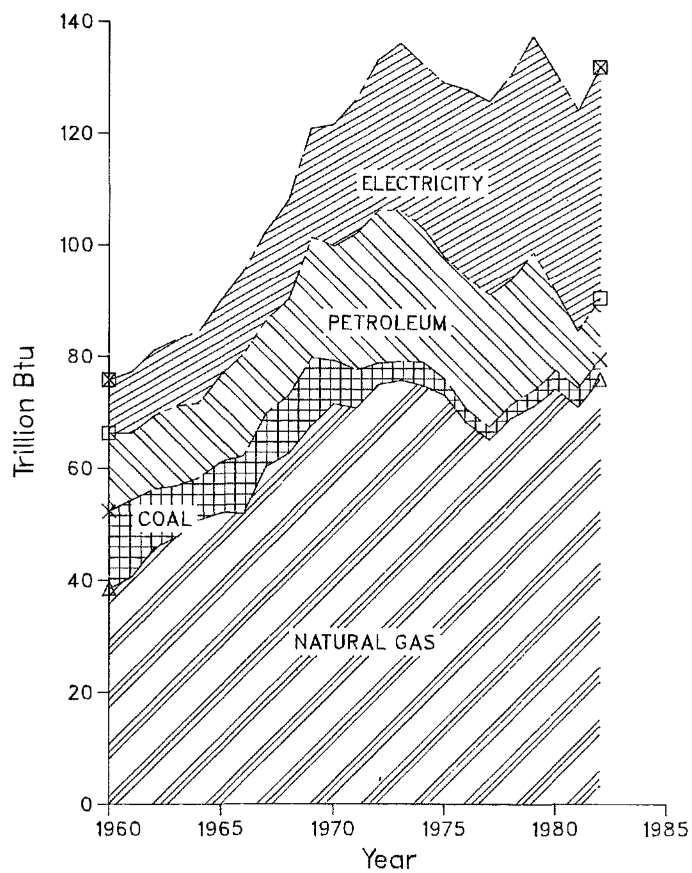


Figure 18
Commercial/Institutional Energy Consumption by Fuel Type, 1960-1982



instead. Figure 22 lists some of the cost effective measures from an optimal conservation investment study based on audits of 200 schools. The first column shows the per unit cost of consuming energy that would be saved by the measure based on 1982 energy prices. In contrast, the second column shows, in 1982 dollars, the annualized investment cost per unit of energy saved due to the same measure.

Changes in operating and maintenance procedures in buildings usually require little or no investment and can result in immediate energy savings of 5 to 10 percent or more. As a result, these improvements have been instituted first. Changes in operations can affect lighting, ventilation, temperature control, and many other areas of a building. For example, in retail establishments temperatures can be reduced during operating hours from 72°F to 68°F or 65°F. When the stores are closed, temperatures can be further reduced to 55°F or 45°F. These measures alone have reduced heating costs as much as 19 percent. Similar temperature changes can be made in the summer for savings in air conditioning.

Temperature setback, replacing leaky faucets, regular appliance and furnace tune-ups, turning out lights in unused areas, and shutting down ventilation at night are all effective low cost energy conservation measures that have payback periods of less than one year.

Building owners have reduced lighting costs by replacing less efficient lighting with energy conserving systems, and by instituting regular lighting maintenance procedures.

In Minnesota, all existing public buildings of over 5,000 square feet must meet the illumination standards specified in the state building code, wherever compliance with these standards is economically feasible.

Control systems can affect every aspect of the heating, ventilating and air conditioning operations in a building. Investment in automatic control devices and adjustment of existing controls have resulted in savings of up to 20 percent of the energy used in buildings.

Control modifications can vary widely depending on the size and complexity of the HVAC system. One of the simplest control devices in many buildings is a night setback system. For retail stores, the average cost of an automatic night setback thermostat and accompanying equipment is $500. Such an investment pays for itself within a year.

Ventilation requirements can be reduced in most buildings with minimal loss in air quality. Reduction in the use of outside air in both summer and winter, rebalancing the system, reducing fan horsepower, installation of low leakage dampers, and other ventilation modifications can add up to as much as a 30 percent savings in many buildings. While these measures require some investment in new equipment, payback periods are generally short.

Substantial energy savings can result from modifications in the envelopes of most buildings. These modifications include insulation, weatherstripping and caulking, and the addition of storm win-

Figure 19
Industrial Energy Consumption as a Portion of Total Minnesota Demand, 1982

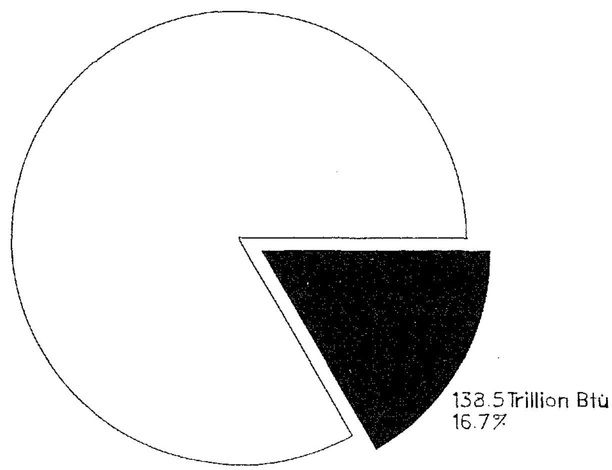
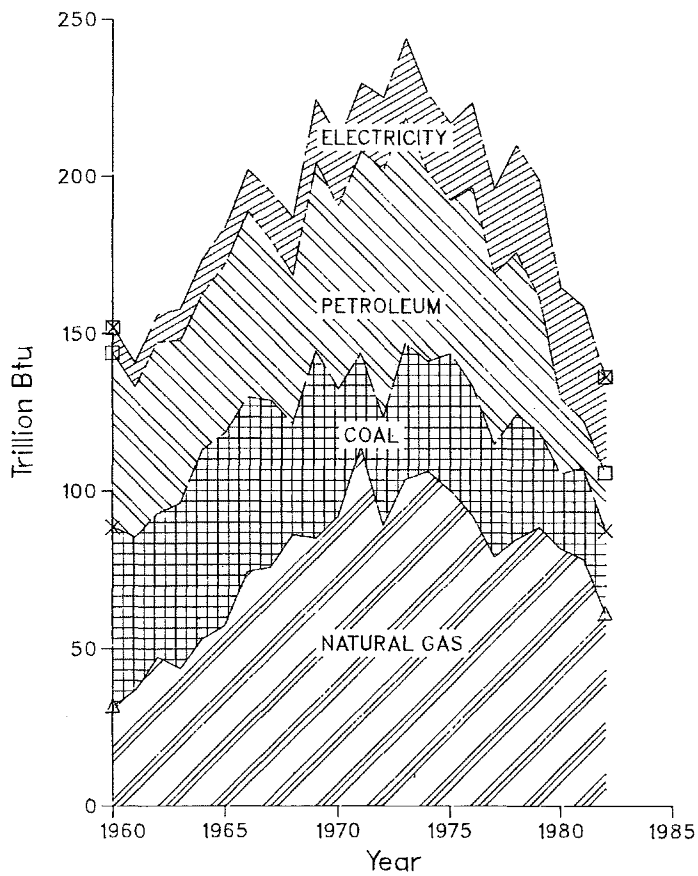


Figure 20
Industrial Energy Consumption by Fuel Type, 1960-1982



dows and/or shutters. In large buildings, these modifications can be both difficult and costly. However, energy savings can be very high. Building surveys or audits are essential for determining which modifications will result in the greatest savings.

New technologies have arisen over the past decade that can reduce energy costs in buildings through the use of high efficiency HVAC systems and heat recovery devices. As with building envelope modifications, the initial investment in such equipment may be very high and a careful study should be made to determine the most efficient system. With rising energy prices, heat recovery systems and replacement of outmoded HVAC equipment can be wise investments in many commercial buildings.

Industrial conservation more complex— must be tailored to each specific industry

Industry is the most complex of all the sectors. Conservation strategies in the commercial/institutional sector are relatively simple to describe since over 90 percent of total energy consumption is for end uses such as space heating, cooling, water heating, and lighting. In contrast, over 50 percent of energy consumption in the industrial sector is for direct process heat, process steam, machine drive, vehicle/equipment operation, electric generation, coke processes and electrolytic processes. Thus, conservation strategies must be specifically designed for each industry.

A company can expect sustained and substantial savings in energy costs by establishing a comprehensive energy management program. The exact nature of the program will vary with the size and characteristics of the firm, but successful efforts generally include the following activities:

- a manager or energy committee is given responsibility for reducing energy consumption in the company
- energy use is monitored to determine the potential savings of conservation opportunities and to evaluate the effectiveness of actions that are implemented; an energy accounting system can be developed that separates consumption into energy components associated with specific industrial processes and the building itself
- an energy audit of the facility, usually performed by company staff, will identify potential conservation opportunities; more costly investments may require an engineering study
- companies can implement employee awareness, training, and involvement programs to realize savings from low or no cost conservation opportunities; involving employees in the effort to conserve energy can change ingrained energy consuming habits and procedures

A 1981 survey of industrial plants in Minnesota and Wisconsin, prepared by Anderson, Birdie and Associates, found that 75 percent of all plants with more than 100 employees had implemented a system for monitoring energy use on a regular basis. Sixty-nine percent have held meetings with employees to encourage conservation through housekeeping practices.

While most larger companies have implemented some aspects of an overall energy management program, small industrial plants present a difficult challenge to private or public conservation actions or programs. Smaller firms generally have not implemented energy management practices to the same extent as large sophisticated firms.

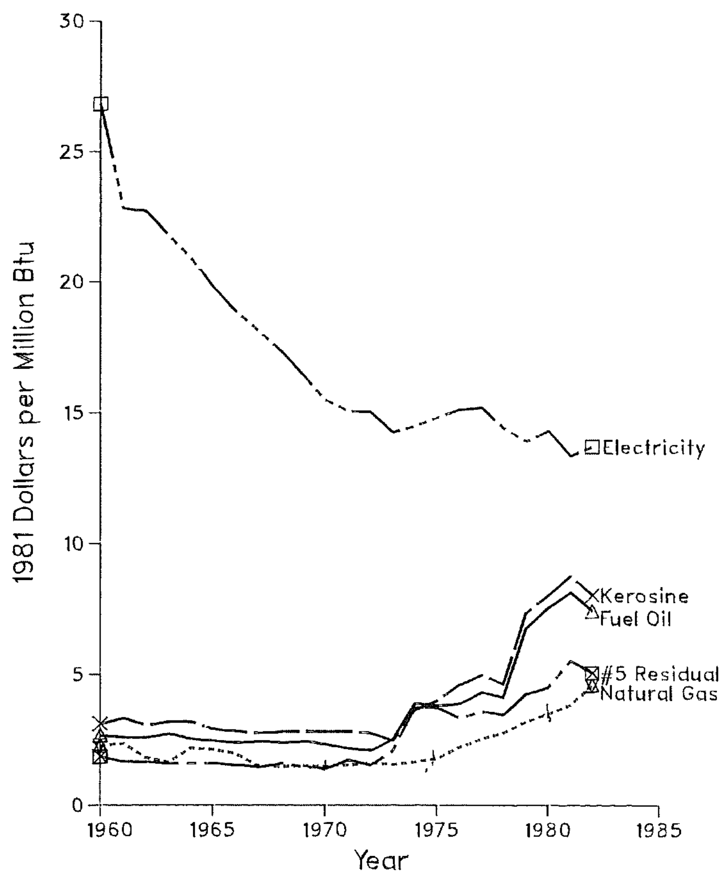
Industrial firms can adopt many low and no cost measures to conserve energy. For example, regularly scheduled maintenance programs can control major energy losses caused by inefficient equipment. Maintenance includes cleaning and adjusting the combustion efficiency of furnaces and boilers, checking for defective steam traps in boiler systems, and keeping equipment in good repair.

Furthermore, energy consuming procedures can often be changed without reducing productivity; e.g., immediately turning off equipment whenever it is not being used. Waste heat from furnaces and boilers can often be economically captured and used. The savings are especially great for processes requiring high temperatures.

Conservation investments to improve the efficiency of existing equipment can recover costs very quickly. Although this obvious technique is often ignored, insulation can reduce heat loss from buildings, steam pipes, furnaces, process tanks, and other containers from which heat is otherwise lost.

Recent innovations in electronics make it possible to monitor and adjust energy consuming systems to automatically reduce energy use. Automatic controls can maintain combustion efficiency in boilers and furnaces and help heating, ventilating and air conditioning systems maintain temperature and ventilation more effici-

Figure 21
Real Energy Prices, 1960-1982



ently. Load shedding systems can level out an industrial facility's electric use, cutting the surcharge for peak electric demand. These systems automatically cut power to nonessential uses of electricity during periods of peak demand.

Electric motors and some other uses of electricity reduce the effective power of electric lines by interfering with the phase of the alternating current maintained by the utility. Installing capacitors can correct this reduction in power factor and reduce the penalty that utilities charge industrial plants with electric motors.

Although more costly than the measure previously mentioned, investments in new facilities and equipment can provide long term reductions in energy costs. For many types of equipment, such as boilers and electric motors, the more efficient models on the market are well worth the extra cost. As old equipment needs replacement and repair, companies should carefully consider these alternatives.

Investments in new industrial plants provide an opportunity to design for greater energy efficiency and to use more

Figure 22
Cost Effective Conservation
Measures in Secondary Schools

	Avoided Cost of Energy Saved[a] (Dollars/Million Btu)	Investment Cost of Energy Saved[b] (Dollars/Million Btu)
Replace electric motors with high efficiency units	$ 7.52	$2.07
Install additional roof insulation	6.05	2.41
Install storm windows or thermopane glass	6.04	2.14
Reduce window area with insulated wall/panel	5.73	2.13
Caulk and weatherstrip exterior cracks	5.48	1.68
Install time clocks or night set-back on HVAC equipment	6.14	0.44
Install or modify HVAC controls	7.18	0.75
Reduce the amount of cold outside ventilation air	6.09	0.71
Add multiple light switches	15.07	1.39
Replace incandescent lighting with fluorescent fixtures	10.35	2.19
Install energy efficient lamps and ballasts	14.68	6.04
Install separate domestic hot water heater so boiler can be shut off in summer	5.26	0.98
Install flow restrictors in faucets and shower heads	6.79	0.31
Replace oil boiler burner with efficient unit	6.31	1.71

[a]This is the same as the price that would be paid in dollars per million Btu for the energy saved by the measure if this same energy were consumed instead. In effect, this is the cost avoided by implementation of the measure.

[b]This is obtained by apportioning the total investment cost of a measure into (constant) annual equivalents over the life of the same measure and dividing the annual equivalent by the estimated annual energy savings. This measures the investment cost of avoiding energy consumption.

Source: Optimal Energy Conservation Investments for Elementary and Secondary Schools from a Cost-Effectiveness Analysis of Energy Conservation Measures in Minnesota IBGP Maxi-Audits, Department of Energy and Economic Development, November 1983, Tables 7 and 8, pp. 28-31.

efficient technologies. One example is a new paper forming process that uses less water, so less energy is required for drying operations.

Electric power plants lose about two-thirds of the fuel they consume in the form of waste heat. A more efficient approach is for industrial facilities to generate electricity and use the waste heat in their own process heating needs. Industrial cogeneration raises numerous practical problems, but potential energy savings are very great. District heating, where utilities sell both electricity and hot water or steam to customers, is another alternative that is discussed later in this report.

Energy Division efforts focus on institutional energy management programs

A variety of programs are currently available to institutions to assist them in implementing cost effective energy management programs. These programs can help administrators of school districts, managers of institutional buildings, and local units of government reduce the impacts of rising energy costs and the resulting tax burden borne by the clients they serve.

Institutional Building Grants Program (IBGP)

IBGP is built on three major energy conservation grant programs enacted by the U.S. Congress and the Minnesota State Legislature:

- Federal Schools and Hospitals Grant Program
- Federal Units of Local Government and Public Care Institutions Grant Program
- Minnesota Schools and Units of Local Government Grant Program

IBGP, now entering its sixth funding cycle, has provided almost $24 million in state and federal funds to public and private nonprofit institutions for energy audits and installation of energy conservation measures.

Over the past five years, this program has funded over 7,000 building audits for schools, hospitals, and local government and public care institutions in Minnesota. Over 1,000 institutional buildings have received funding for installation of energy conservation measures. Total savings from funded projects were estimated to be $30 million at the end of 1981, and it is projected that over 10 years, savings will amount to $602 million (based on November 1981 price projections by the Energy Division). This amount represents 20 times the original state and federal investment in the program.

Recently, a study was conducted of 110 previously audited school, hospital, and local government buildings to determine the actual savings attributable to implementation of audit recommendations. Actual annual energy consumption before and after implementation of the recommendations was collected and analyzed for each building. The portion of energy consumption used for space heating was then adjusted for the effects of weather. The study shows that building energy consumption was reduced by an average of 8 percent, primarily through implementation of recommended modifications in operations and maintenance procedures such as those listed in Figure 23. These procedures are the most commonly recommended in school audits but they are also appropriate for other types of buildings in the commercial and institutional sectors.

Many schools have begun significant programs of capital investment to conserve energy in their buildings. A recent study has shown that Minnesota school districts invested $23,300 per building between the school year 1978-79 and July 1982 to conserve energy or convert to renewable fuels. This investment has resulted in average savings of $14,500 in fuel costs per building in the 1981-82 school year alone. These savings represented a decrease of 10.8 percent in the amount of energy used, from 107.7 to 96.1 thousand Btu per square foot per year (normalized for weather differences).

Energy accounting

An Energy Accounting Procedures Manual for Local Government and School Districts has been developed to help institutional administrators and operators track energy costs and consumption. The manual provides a framework for developing accurate energy budgets, measuring results of existing conservation programs, identifying cost effective conservation opportunities, and managing daily operations.

A software package has also been developed based on the Energy Accounting Procedures Manual. The software package is designed to be used on a standard Apple II computer. This computerized version of energy accounting can perform all of the procedures outlined in the manual in addition to assisting institutions in preparing state and federal energy reports. The software package includes a simple step by step procedures manual to assist institutions in implementing the system.

Building Energy Management Training Program

This program was developed to train building managers, supervisors and operators in energy management techniques. It is a joint project of the Energy Division, Area Vocational Technical Institutes (AVTI), and the Minnesota Department of Education. The training is offered through AVTIs throughout the state, and is often taught on site at the participant's building. It is task oriented so that each skill can be practiced as it is learned. The course has been available throughout the state since fall 1983.

Conference of Local Energy Officials (CLEO)

This organization was founded to provide an information exchange network for local government officials interested in energy conservation and management programs that are sponsored by the League of Minnesota Cities in cooperation with the Energy Division. CLEO is now a private, nonprofit corporation.

Membership in CLEO is open to all elected and appointed officials of city, county and state government who wish to exchange energy management ideas and receive updated information on energy technology, financing strategies, and resources available in Minnesota for carrying out local conservation programs.

Since August 1981, CLEO has provided its members with information and technical materials on energy accounting, energy efficient procurement procedures, efficient building operations, training courses, seminars, and workshops co-sponsored by various organizations.

Special Purpose Capital Expenditure Levy Law

This law allows school districts to build a local energy improvement fund to help pay for cost saving measures.

The levy is equal to $25 per pupil unit or 2 mills, whichever is less. Proceeds from the special levy go into a district's capital expenditure fund and are allowed to accumulate over several years. This money can help pay for major energy conservation improvements requiring large capital investments.

Conservation programs for commercial and industrial sectors sponsored by Energy Division and many other organizations

State legislation and federal grants for conservation programs have concentrated on the residential and institutional sectors. However, some educational projects and energy saving competition programs have been directed toward industrial and commercial businesses. In addition, many other organizations offer information and training programs.

Training/education programs

A number of training and education programs have been provided to persons who design, own, and operate commercial buildings in the state. These programs have been offered by many different organizations including the Energy Division, the Minnesota Department of Education, Area Vocational Technical Institutes, technical and professional societies, utilities, and private educational institutions. Several series of well-attended workshops have been conducted throughout the state.

Workshops conducted by the Energy Division and the Minnesota Department of Education include:

- Boilers, Operations and Maintenance
- Tracking Energy, Energy Recordkeeping and Energy Systems
- Steam Trap and Steam Systems
- Pneumatic Temperature Control
- Thermal Insulation
- Waste Heat Recovery
- Preventive Maintenance
- Light Systems

Attendance at these workshops has totaled 6,000 since 1980. The pneumatic temperature workshop series alone had completed 131 two-day sessions in Minnesota by June 30, 1984. These are attended by plant engineers, building operators, building supervisors, maintenance personnel, temperature control sales persons, manufacturing engineers, and energy managers.

Display Lighting Standards
In 1979, the Energy Division promulgated rules for display lighting standards, which specified permissible hours of operation of outdoor display lighting. These standards are still in effect.

Emergency Building Temperature Reduction Program
The U.S. Department of Energy enacted this program in 1979. It required all non-

Figure 23
Low Cost Conservation Measures
Most Commonly Recommended in
School Audits

Clean and adjust controls of electrical distribution system.

Align/lubricate motors and adjust belt tension.

Adjust door closers; keep exterior and vestibule doors closed.

Encourage staff to use window drapes to maximize solar gain.

Caulk exterior cracks; weatherstrip doors and windows.

Repair broken/cracked windows and closing latches.

Adjust/calibrate HVAC controls.

Reduce space temperature during occupied periods to 65-68 degrees.

Reduce the fresh air ventilation rate during occupied periods to minimum code or comfort requirements.

Reduce space temperature to 50-55 degrees during unoccupied periods manually or through use of night set-back controls.

Turn off ventilation systems during unoccupied periods through use of manual switches or timeclocks.

Maintain HVAC components; filters, steam traps, dampers, etc.

Turn off classroom lights when not in use.

Replace existing lamps with high efficiency/reduced wattage lamps.

Remove or disconnect lights in overlit areas.

Begin a preventive maintenance program and schedule.

Schedule the use of the building to reduce energy use.

Adjust/maintain controls of kitchen and laundry equipment (dishwashers, exhaust hoods, etc.) and turn off when not in use.

Reduce the temperature of domestic hot water.

Install flow restrictors in faucets and shower heads.

Test and adjust boiler for maximum combustion efficiency.

residential building owners and managers to reduce their thermostat settings to 65°F during the heating season and to raise them to 78°F during the cooling season. Furthermore, water for personal hygiene and general cleaning could be heated no higher than 105°F. The Energy Division administered this program in Minnesota. Follow up studies indicated that this was one of the most cost effective programs carried out by the federal government. However, it was eliminated in February 1981.

Minnesota Energy Savers Award of Excellence
This annual competition for the institutional, commercial and industrial sectors has been held for eight years. It offers each sector an opportunity to describe its successful energy management programs. The award winning programs are published each year in a summary manual. Figure 24 lists examples of award-winning conservation programs from the eighth annual competition in 1984. Sixty-two organizations have been recognized for their accomplishments during the past eight years.

Minnesota Energy Conference
The two-day Minnesota Energy Conference provides an opportunity for building designers, owners, and operators to learn new ideas in energy efficient building design and operation. The tenth annual conference was held in February 1984 and was co-sponsored by a host of organizations including the Energy Division, utilities, and private businesses.

Figure 24
Examples of Award Winning Conservation Programs from the 8th Annual Award of Excellence Competition

Clarissa Public Schools

Implemented several low cost measures including closing exhaust systems, replacing three sets of vestibule doors, and insulating the previously uninsulated attic of the school building.

Converted an oil fired boiler to burn wood pellets. Conversion cost: $44,000; first year savings: $17,500. In addition to the savings, this action stimulated the local economy by using a locally produced product.

Rosemount School District

Ongoing comprehensive energy conservation program including improvements in lighting, retrofit, energy recovery, transportation, water management, and preventive maintenance.

Installed an energy management system to control the district's 15 schools and administrative buildings. Main features include demand control, duty cycling, night temperature setback, and optimum start-stop time scheduling.

Saved $557,000 in electricity bills alone from 1979 through 1982.

St. Joseph's Hospital in Park Rapids

Initiated a three-step energy program. Step 1: started an energy accounting system. Step 2: implemented low cost measures such as an energy awareness program for employees, weatherstripping, and steam trap maintenance. Step 3: implemented more expensive measures such as installing two small gas water heaters so the main boiler could be shut down during the summer, reclaiming air-water heat from the boiler, and installing an energy management system.

Reduced fuel oil consumption by 50 percent and electricity use by 31 percent.

Saved $96,000 in energy bills in four years (total investment was $30,000).

Southern Minnesota Sugar Cooperative

Installed capacitors on all motors; power factor increased significantly from .72 to .88.

Revised the vapor heating system to use exhaust heat, and to store condensates for irrigation during summer months.

Tennant Company

Implemented numerous energy conservation projects that included adding roof insulation, upgrading boiler controls, and improving ventilation systems.

Implemented a comprehensive preventive maintenance program to monitor the operation of their energy efficient improvements.

Reduced fuel bills by more than 50 percent.

Wells Municipal Power Plant

Installed radiator drain tanks on the standby and emergency service generating units so boiler water does not have to be circulated to the radiators when units are not in operation.

Reduced fuel bills by more than 50 percent.

Attendance at this annual event has increased from 114 in 1974 to 1,250 in 1984. Almost 100 exhibits and 20 speakers and workshops provide participants an opportunity to explore current institutional, commercial, and industrial energy equipment and technologies.

Industrial outreach activities
The Energy Division's efforts to improve employer awareness and understanding of energy conservation opportunities have included:

- publication of manuals and bibliographies on specific aspects of industrial and commercial energy conservation, which are distributed through the Energy Information Center and at workshops, conferences, and other outreach activities
- development of a pilot program to provide direct technical assistance to Minnesota industries in establishing energy management programs
- distribution of current energy price forecasts to 1,800 businesses, institutions, and individuals who are involved in making energy conservation decisions

Industrial Energy Efficiency Reporting Program
This program was established by the U.S. Department of Energy to encourage industrial conservation. The program works with industry to set conservation goals, monitor improvements in energy efficiency, and encourage the implementation of company energy management programs. The program has documented substantial improvements in energy efficiency in each of the 10 most energy consuming industrial sectors.

Development and demonstration programs
Because conservation technologies historically have received little private research support, the U.S. Department of Energy has provided extensive support for development and demonstration programs. In 1980 over 100 projects were being implemented. Current and emerging technologies may be able to improve industrial energy efficiencies by 30 to 50 percent.

However, because energy costs are only a small percentage of industrial output, new conservation technologies may not receive sufficient research and development for many of these improvements to take place. The situation is aggravated by the fact that federal funding for both development and demonstration programs, and also for the reporting program, was eliminated in 1983.

Energy Division bibliographies
In order to fill the need of commercial building designers and managers for information on energy conservation technology and economics, the Energy Division has compiled and published for distribution a number of bibliographies. These cover topics such as energy efficient commercial building design, waste heat recovery, power factor correction, steam trap maintenance, and lighting.

MSAIA Energy Sourcebook
Through a grant from the Energy Division, the Minnesota Society of the American Institute of Architects has published an energy sourcebook. This is a comprehensive collection representing the state-of-the-art in energy conscious design. Supplements to the sourcebook are provided quarterly with an annual subscription through the Minneapolis office of MSAIA.

Agricultural energy consumption per acre farmed dropped 17 percent

Agriculture is a major component of Minnesota's economy that employs about one-third of the state's wage earners in food and fiber production, marketing, processing, and distribution. Food production from Minnesota's 105,000 farms generated 7.3 percent of Minnesota's 1982 Gross State Product and placed the state fifth nationally in total cash farm income.

The fuel used to produce these crops and livestock amounted to 6.6 percent of Minnesota's total primary energy consumption. Higher energy prices have reduced agriculture's total energy demand by 14 percent since 1979. Petroleum demand alone has declined 16 percent. (See Figure 26.) When examining improvements in energy efficiency, reductions in agricultural energy demand are even more remarkable. Demand for energy per acre in production dropped from 2.8 million Btu to 2.4 million Btu, a 17 percent improvement in efficiency. However, there are significant opportunities for further conservation through the use of reduced tillage and crop drying methods, and by improving the energy efficiency of farm buildings.

Mulch-till, ridge-till and no-till operations are all reduced tillage methods that have gradually begun to replace conventional tillage operations. These conservation tillage operations conserve soil and fuel, reduce labor and machinery costs, and retain topsoil moisture. Mulch tillage practices replace typical moldboard plows and other heavy tillage equipment with a chisel plow to reduce fuel consumption for planting operations by 30 percent. Ridge-till and no-till practices eliminate all tillage operations and typically reduce consumption by 60 percent.

In 1982, these reduced tillage operations were used on 16 percent of the state's corn and soybean acreage, and 25 percent of the small grain acreage. It is expected that by the year 2000, conservation tillage will be used on 80 percent of all acreage and will save 40 percent of tillage fuel requirements. Although conservation tillage offers numerous advantages, these practices require high-level management and the increased use of fertilizers in some crop situations.

Crop drying represents another major agricultural energy use. Corn is the primary crop that requires drying, and energy demand is particularly weather sensitive. During normal years, farmers consume an estimated 45 to 65 million gallons of propane for on-farm drying, but demand can exceed 90 million gallons in years of extremely late, wet harvests.

Energy used for crop drying can be saved by avoiding overdrying (below 15.5 percent moisture) and by shifting to more energy efficient drying methods. Figure 27 compares energy needs for different types of drying and illustrates that savings of up to 47 percent are possible.

Demonstrations using corn stalks or corn cobs to replace propane as fuel for drying have recently been conducted. Corn cobs are particularly attractive because they can be crushed and mixed with the corn to eliminate a separate collection operation. Further, they are clean burning, and there is very little nutrient loss to the soil.

Nonresidential farm buildings utilize energy primarily for space heating, ventilation, lighting, water heating, and cooling. Frequently, these buildings are drafty and poorly insulated. Increased levels of insulation, and weatherstripping and caulking yielded sizable energy reductions in this sector during the seventies. Further energy savings can be achieved through efficient ventilation. Ventilation removes moisture, odors, and bacteria by exhausting warm, stale air directly outside. Unfortunately, during winter months over half of the heat loss in animal confinement buildings may be lost through ventilation. These losses can be minimized by either reducing the level of ventilation or by installing a heat exchanger. Careful maintenance and operation of space and water heating equipment also contributed to the reduction in energy consumption in the last decade. Finally, construction designs that maximize southern exposure and utilize earth sheltered construction techniques have been demonstrated to be effective in saving energy.

During the past decade, the agricultural sector also faced an indirect effect of rising energy prices—higher prices for fertilizers and chemicals. Fertilizer and chemical production are very energy intensive. For example, 36.5 thousand cubic feet of natural gas are required to produce one ton of anhydrous ammonia, a major source of nitrogen for corn. As the price of natural gas and petroleum increased in the past decade, corresponding increases in fertilizer and chemical prices occurred. Thus, during the 1970's, crop research in nitrogen fixation to utilize atmospheric nitrogen and genetic engineering to produce new higher yielding crop strains were initiated. Scientific developments in these areas can reduce fertilizer requirements and enhance yields, but commercial application does not appear imminent.

Miles traveled per gallon by all vehicles in Minnesota increased by 18 percent between 1973 and 1982

Energy consumption in the transportation sector is dominated by the automobile. However, this sector includes other forms of passenger and freight transportation such as truck, air, rail, pipeline, and waterway. Transportation is the largest of Minnesota's energy consuming sectors, involving such fuels as gasoline, diesel, jet fuel, and residual oil.

Fuel consumption in Minnesota's transportation sector increased steadily from 1973 through 1979 with the exception of a brief decline in 1974. Total energy consumption in this sector rose by 12 percent over this period. Between 1973 and 1978, gasoline consumption in this sector rose 8 percent, from 1.99 billion gallons to 2.14 billion gallons. Diesel fuel showed an even more dramatic growth—up 55 percent, or 146 million gallons per year between 1973 and 1979. (See Figure 29.)

Despite increasing consumption during this period, fuel efficiency in the transportation sector was making steady improvements. After declining 8 percent between 1960 and 1973, miles traveled per gallon of gasoline (mpg) began rising after the Arab oil embargo. The U.S. fleet average mpg rose from 13.10 mpg in 1973 to 14.06 mpg in 1978. (See Figure 30.) The increase in consumption was primarily due to growth in the number of vehicles operated in Minnesota and miles driven per vehicle. Car registrations rose from 1.9 million in 1973 to a peak of 2.4 million in 1979. Similarly, truck registrations grew from 527,000 in 1973 to a peak of 971,000 in 1979. Average miles traveled per passenger car rose to 10,046 miles per year between 1973 and 1978, an 11 percent increase.

However, beginning with the price increases resulting from the fall of the Shah of Iran in 1979, the upward trend in transportation fuel consumption reversed. Transportation fuel consumption has declined 13 percent in Minnesota since that time. Gasoline consumption has shown a particularly steep decline, dropping by 17 percent since 1978 to 1.931 billion gallons per year in 1982.

Fuel efficiency, miles traveled per vehicle and number of vehicle registrations

Figure 25
Agricultural Energy Consumption as a Portion of Total Minnesota Demand, 1982

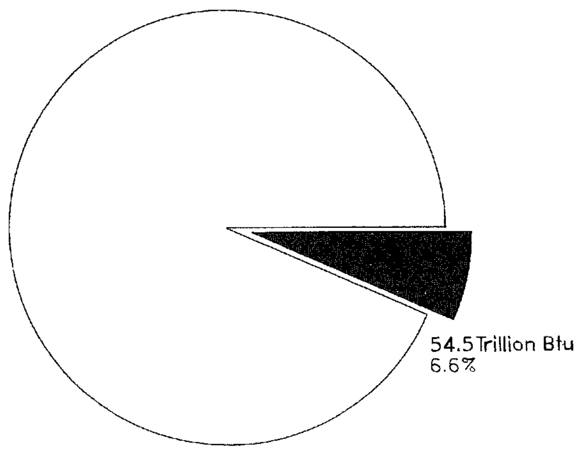
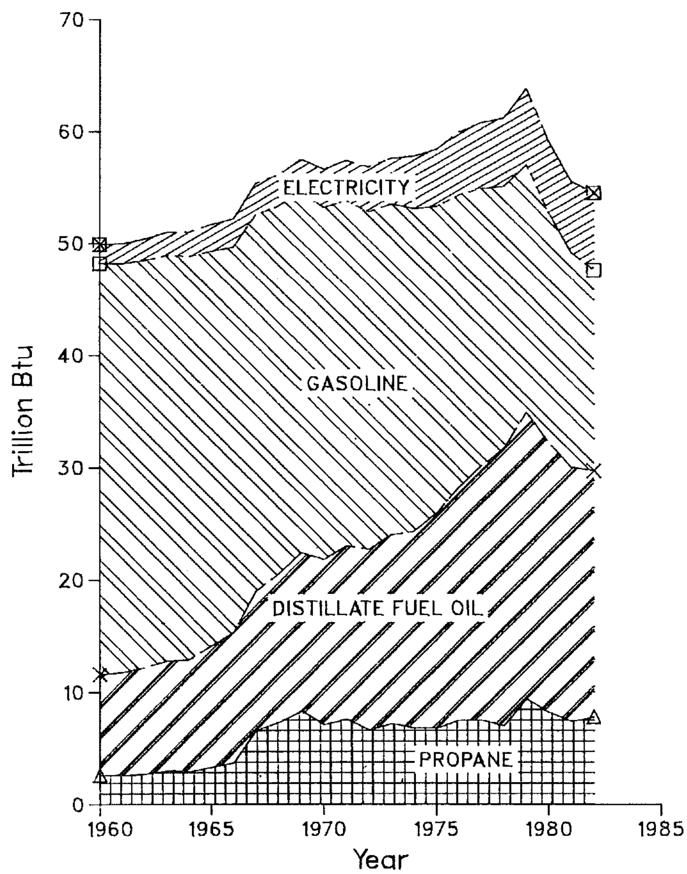


Figure 26
Agricultural Energy Consumption by Fuel Type, 1960-1982



all contributed to the decline in demand. For example, miles traveled per passenger vehicle per year declined by 10 percent since 1978. This may be evidence that private auto users are planning and combining trips more carefully in order to reduce energy costs. At the same time, Minnesota had fewer trucks and cars on the road. The number of registered autos declined by 70,000 and the number of trucks by 50,000 between 1979 and 1982.

Finally, and most importantly, improvements in fuel efficiency began to grow rapidly. From 14.06 mpg in 1978, the U.S. automobile fleet average rose to 16.33 mpg by 1982. In Minnesota, miles traveled per gallon of gasoline consumption for all vehicles (autos, buses, trucks and motorcycles) rose from 11.93 in 1973 to 14.04 in 1982, an 18 percent increase in fuel efficiency. Fleet efficiency was primarily improved by the introduction of new, smaller, more fuel efficient cars. The slower driving speeds required by federal regulation also contributed to the efficiency improvements.

The transportation sector alone represents 35 percent of our total energy consumption and 60 percent of our petroleum consumption. Thus, improvements in efficiency in the transportation sector have been essential in order for Minnesota and the nation to reduce its energy dependence. Although the Energy Division has not been significantly involved with transportation programs, federal and state government actions have been instrumental in achieving these gains. The federal mandatory fuel efficiency standards have been the primary force behind the increase in new car efficiency.

At the state level, the Department of Transportation's rideshare program has been a landmark effort, and enforcement of the 55 mph speed limit by the Department of Public Safety has been instrumental in reducing fuel consumption. Another recent state initiative has been the passage of incentives to develop alternative transportation fuels. In 1983, the Minnesota Legislature passed a 2 cent per gallon tax credit for gasohol that uses agriculturally-derived ethanol. In 1984, a state loan program for alcohol production facilities was also passed.

Continued effort to reduce consumption of traditional fuels in the transportation sector by improving efficiency and developing alternative fuels will be a critical challenge of the 1980's.

Use of alternative sources of energy increased 31 percent in two years

The price increases and supply disruptions of the last decade demonstrated the need to develop indigenous alternative energy sources. Solar, wind, biomass, district heating, hydro, and peat have emerged over the past 10 years as important potential sources for Minnesota's energy needs.

In 1980, the first year of available data on alternative energy use, Minnesotans consumed 35 trillion Btu of alternative fuels, of which 21 trillion Btu was from wood. By 1982, total alternative energy consumption was 46 trillion Btu, an increase of 31 percent. (See Figure 31.) Wood was still the primary alternative fuel used, representing 63 percent of total alternative energy use. Although this growth in alternative energy use is promising, Minnesota's alternative energy industry is still in its infancy. In 1982, alternative energy provided only 4 percent of the state's total fuel use, and non-wood alternatives represented less than 2 percent of total energy use. The 1970's saw the emergence of alternatives as exciting new technologies and industries. However, progress out of its infant stage to full

Figure 27
Estimated Energy Requirements to Dry 25.5 Percent Moisture Corn to 15.5 Percent[a]

	Propane per 100 Bushels of Corn (Gallons)	Electric Energy per 100 Bushels of Corn (kWh)	Total Energy Use[b] (Million Btu)	Bushels Dried per Million Btu[b]	Percent Reduction to Energy Use Compared to High-Speed Drying
High speed dryer with in-dryer cooling[c]	20	10	1.87	53	
Dryeration[d]	14.5	7	1.32	76	29%
In-storage cooling[e]	17.5	8	1.63	61	13%
Combination drying[f]	8	70	1.0	100	47%

[a] There are wide variations in energy use from one system to another. This table compares alternatives.

[b] One gallon of propane equals 92,000 Btu; 1 kWh of electricity equals 3,412 Btu.

[c] This system would include batch and continuous-flow dryers which rapidly reduce the moisture level in less than 24 hours.

[d] This system dries corn to 16.5-18% moisture, and transfers the grain to a bin where it is allowed to "temper" or "steep" for 6-12 hours and then cooled. This allows transfer to storage at 14-15.5% moisture.

[e] This system transfers dried grain to a storage bin where it is then cooled.

[f] This system dries grain down to 22% with heated air. The grain is then transferred to storage where it is dried down to 14-16% using unheated or "natural" air.

Source: Morey, R. Vance and Cloud, Harold, "Energy Conservation in Grain Drying: Final report," Table 1.

commercial viability is a challenge that must be met in coming years.

Solar energy provided 212 billion Btu of energy in 1982

The use of direct solar energy in Minnesota increased dramatically over the last 10 years. From less than 10 dealers and about 500 installations in 1974, it has grown to over 200 dealers and an estimated 7,000 installations. Solar domestic hot water systems make up a large proportion of this market, along with solar room heaters and active and passive space heating systems. It is estimated that between 1980 and 1982, the total amount of energy provided by active solar installations increased from 151 to 212 billion Btu. This represents approximately .02 percent of Minnesota's total energy use.

The Energy Division played a vital role in this development. Since its inception, the Division has provided solar information by planning and sponsoring two open house tours, and by producing and distributing numerous slide-tape presentations, public service announcements, and factsheets and booklets about solar energy. The Energy Information Center has acted as a major source of solar information for the state over the past seven years. The Division has also conducted monitoring programs to determine performance of solar water heaters and passive solar homes.

Recognizing the value of encouraging alternative energy, the federal and state governments established tax credits in 1979. Residential solar installations receive a 40 percent federal and a 20 percent state tax credit for the first $10,000 spent. Commercial solar installations receive a 15 percent energy investment tax credit. All of these tax credits continue through 1985.

The Energy Division has recently developed a solar collector certification program that will become effective in July 1984. This program will provide a strong consumer protection mechanism by requiring all manufactured and most custom built solar collectors to be certified by the State of Minnesota in order to be eligible for the Minnesota Renewable Energy Tax Credit.

143 windmills provided .01 percent of state's electricity needs

Windmills are an ancient technology and wind electric installations were common 70 years ago. However, by 1974 rural electrification had reduced the need to the point that there were less than 10 operating wind electric systems remaining in Minnesota. Since that time, the reported number of windmills in the state has grown to 143. Today, wind energy provides .01 percent of Minnesota's electricity needs.

The Energy Division assisted this development by providing extensive information to the public on wind. Several publications, including wind siting and zoning manuals, are distributed through the Energy Information Center. The Division has also conducted wind monitor-

Figure 28
Transportation Energy Consumption as a Portion of Total Minnesota Demand, 1982

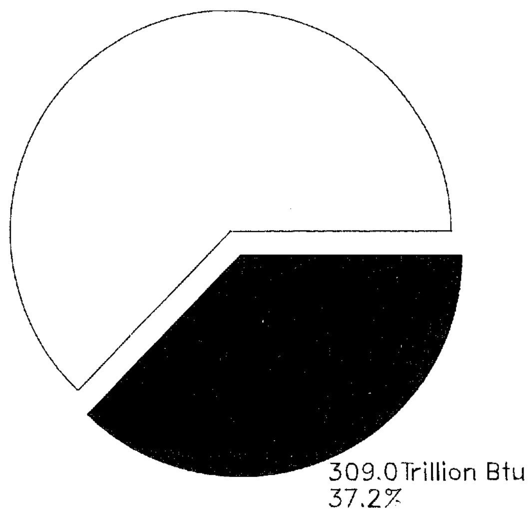
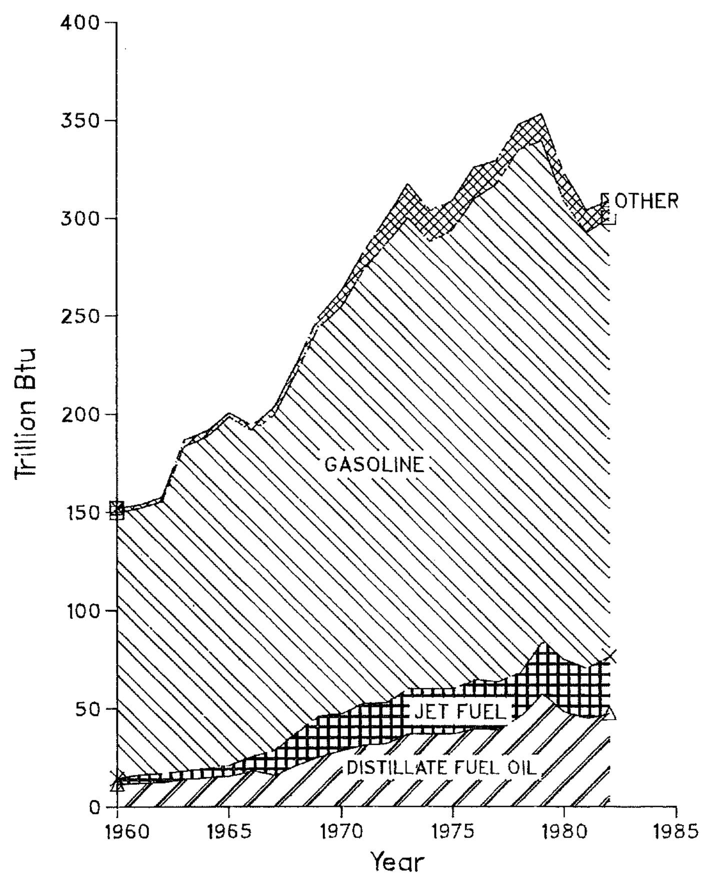


Figure 29
Transportation Energy Consumption by Fuel Type, 1960-1982



ing programs to determine the availability of the resource around the state. In addition, the Division promoted the 40 percent federal and 20 percent state tax credit for the first $10,000 spent for residential wind systems, and the 15 percent energy tax credit for commercial wind systems.

The Public Utilities Regulatory Policies Act (PURPA) of 1978 was a significant stimulus to wind energy development. It required utilities to interconnect with wind systems and pay "full avoided costs" for power produced. Under the Minnesota laws implementing PURPA, small power producers of 40 kilowatts capacity or less may choose "net energy billing," which in effect pays them residential retail rates for any excess power they produce.

In states where the right environment for investment in wind power exists, growth has been phenomenal. The American Wind Energy Association estimates that 8000 wind systems have been installed in the U.S. during the past 10 years for a total capacity of 295 megawatts. On wind farms alone, 3600 wind machines now have a combined capacity of 239 megawatts.

Energy consumption from fiber fuels totaled 29 trillion Btu

Fiber fuels are Minnesota's largest source of alternative energy. This resource includes peat and renewable biomass (agricultural crop residues, farm animal residues, wood and wood residues, special energy crops). In the last 10 years, the use of fiber fuels as a source of energy has increased substantially. From less than 50,000 wood stove users in 1974, there are now over 220,000 residences that use wood for heating or to supplement traditional fuel consumption, and there are over 70 commercial, industrial and institutional wood burners in Minnesota. There are five operating ethyl alcohol plants in the state, three facilities that burn municipal solid waste and three commercial bogs producing peat fuel. There are also 26 firms that manufacture or distribute densified fiber fuels (pellets or briquets) from wood residues, agricultural crop residues and peat. Energy use from fiber fuels increased from 21 trillion Btu in 1980 to 29 trillion Btu in 1982, which represents nearly 3 percent of the state's primary energy use.

The Energy Division has taken a lead role in promoting fiber fuels in Minnesota by sponsoring studies of resource availability, market potential and economic feasibility. The Division also serves as an information source regarding all forms of fiber fuels energy.

Figure 30
U.S. Fleet Average Miles per Gallon, 1960-1981

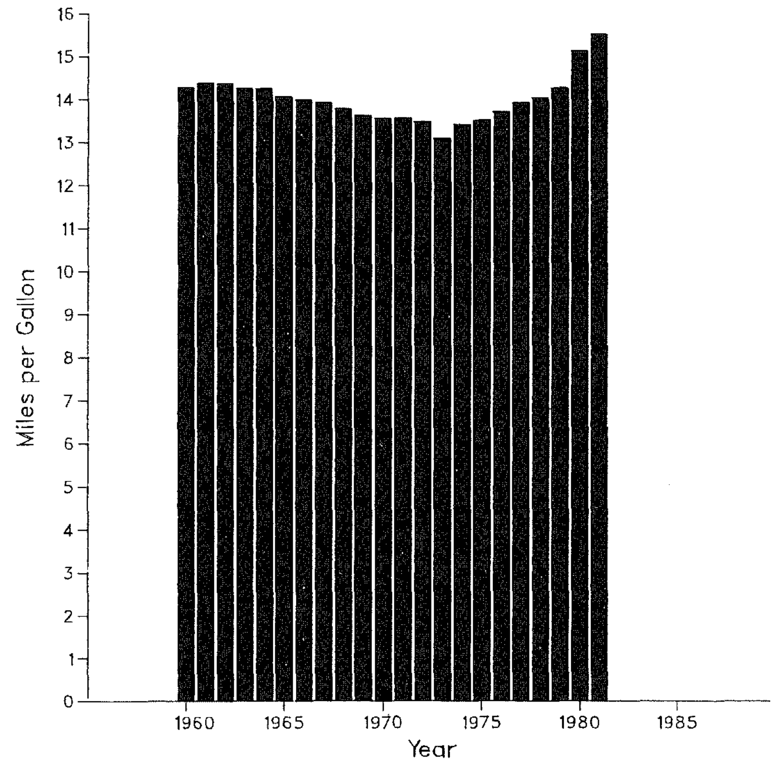
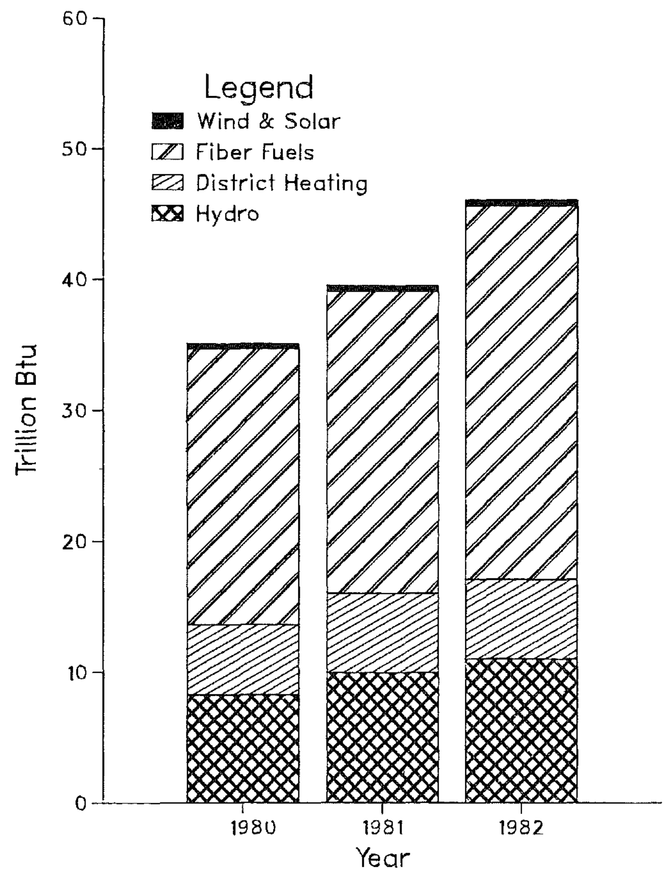


Figure 31
Minnesota Alternative Energy Consumption, 1980-1982



The federal government provided a 10 percent energy tax credit for commercial purchase of fiber fuels equipment. There '- a federal subsidy of 50 cents per gallon .1 biomass-derived alcohol fuel. In 1983, Minnesota added a 20 cent subsidy that will increase to 40 cents in 1985. Finally, in 1980, Minnesota established a tax credit of 20 percent of the first $10,000 spent for the purchase of alcohol or methane production equipment.

Hydropower provided nearly 4 percent of state's electricity needs

Minnesota hydro-electric development long precedes the oil crises of the 1970's. One of the first hydro installations in the United States was at St. Anthony Falls on the Mississippi River. Minnesota hydro-electric facilities peaked in the 1940's with 50 installations. In the 1950's and 1960's, a combination of low electric prices and the need for dam repairs led to the closing of 19 sites. With the changing energy situation in the 1970's, many of these sites are being considered for renovation. One of them, the Rapidan Dam located south of Mankato, was put back into service in 1983. Through developments such as these, hydropower provided nearly 4 percent of Minnesota's electricity needs in 1982, or more than 1 billion kilowatt .irs. This represents nearly 1 percent of Minnesota's primary energy consumption.

The Energy Division worked with the University of Minnesota's St. Anthony Falls Hydraulics Laboratory (SAFHL) and the Hydropower Redevelopment Task Force to identify potential sites and help bring about hydro-electric renovation. There are 34 sites identified around the state that show potential. Of these, SAFHL has performed detailed feasibility studies on several.

As with the other alternative energy technologies, the Federal government provides a 10 percent energy tax credit for purchasing hydropower equipment.

District heating provided more than 6 trillion Btu of end use energy for heating

At one time, Minnesota had 52 municipal steam district heating systems. These were usually connected to small electric generating plants. As large central electric plants were built, and oil and natural gas heat achieved high market penetration rates, these small district heating systems b ıme less competitive. As a result, y of these systems have been abandoned, and several are in the process of closing down.

During the last seven years, the Energy Division, in cooperation with the federal government, has conducted numerous feasiblity studies to determine the potential for district heating development and the technology best suited for Minnesota conditions. As a result of this effort, a new hot water district heating system in the St. Paul central business district has been constructed, and the city of Willmar has converted a major portion of an old steam district heating system to a new modern hot water system. These two successful developments have provided the technical and economic information needed to encourage other communities to seriously consider district heating. In 1982, district heating provided more than 6 trillion Btu of end use heat in Minnesota, which represented nearly .6 percent of the state's primary fuel needs. Presently, there are about 15 communities in Minnesota that are in various stages of district heating feasibility assessment.

The state has provided financial assistance through the Energy Division to communities that are considering district heating development. This assistance is in the form of grants for project design and planning, as well as loans for engineering design and construction.

Energy from solid waste produced by three facilities

During the last decade, solid waste disposal has become an increasingly serious problem. At this time, 35 of Minnesota's 87 counties have landfill capacity of less than 5 years. Significant potential exists to reduce the demand for landfill sites by burning the solid waste and recovering the energy. Presently, there are three waste-to-energy systems in operation: a facility in Red Wing that produces steam and sells it to a nearby industry, one at St. John's University at Collegeville that produces steam for its own use, and Richard's Asphalt Refining in Savage.

Both Hennepin and Ramsey counties, which produce about one-half of the state's 10,000 tons per day of municipal solid waste, have extensive studies underway for waste-to-energy systems. About 16 communities outside the metro area are in the early stages of considering waste-to-energy systems. If all the waste-to-energy facilities presently in the planning stage were built, the total capacity would be about 3,000 tons per day.

In sum, Minnesota's energy picture has changed from one of being at the "end of the pipeline" and, therefore, vulnerable to supply disruptions and price fluctuations, to one of having a rich and renewable diversity of indigenous energy resources and great conservation potential.

Extensive application of conservation techniques has already significantly improved the state's energy efficiency, yet more can be done. In the near term, conservation will be the primary tool to reduce traditional fuel consumption. In contrast, alternative energy development is still in its infancy and alternatives provide only 4 percent of Minnesota's energy needs. Yet previous biennial reports showed that it is technically feasible for these resources to provide 100 percent of the state's energy demand. Overall, much remains to be accomplished.

Energy forecasts

The economic downturn, penetration of alternative energy sources, and improvements in energy efficiency discussed earlier have led to a significant reduction in demand for oil and other traditional fuels in Minnesota, and in the nation and world. Because OPEC oil supplies are both less stable and slightly more costly than those from other sources, OPEC has become the supplier of "last resort." Oil production from non-OPEC countries has risen in the last few years, and these countries now are operating at more than 90 percent of capacity. Thus, OPEC has disproportionately borne the reduction in world demand for crude oil. From its peak production of 30 million barrels per day in 1979, demand for oil from OPEC members dropped to about 17 million barrels per day in 1983. OPEC's share of world production decreased from 51.9 percent to 32.7 percent during these years.

OPEC's ability to control prices has been substantially eroded by this decline in demand. Several member countries are not producing enough oil to cover their import expenses. Furthermore, the Iran/Iraq war has put pressure on those two countries to increase their oil revenues. Thus, many of OPEC's members have had a strong incentive to undercut official OPEC prices in order to increase production.

In 1982 and 1983, OPEC production ranged from 55 percent to 60 percent of capacity utilization. Following its historical practice, OPEC reduced the price of its crude by $4 per barrel. World prices adjusted quickly to this change. By April 1983, the U.S. average refiner acquisition cost of crude oil dropped to $28.33 per barrel, almost $10 below its peak of more than $37 per barrel in early 1981. Natural gas prices also stabilized during this period, due to both declining demand and more competitive oil prices.

Do these recent events herald the demise of OPEC and the end of the energy crisis? The Energy Division believes that the lessons of the past decade remain critical to Minnesota's future. First, there are still many cost effective conservation and alternative energy investments yet to be made at today's prices. For example, between 1973 and 1982, the average household reduced its energy consumption by 26 percent. Yet, the Division estimates that an average household could cost effectively reduce its consumption by 40 percent. Similarly, while commercial buildings have improved efficiency by an estimated 24 percent, Division estimates indicate that an improvement of at least 32 percent is cost effectively possible.

As we learned from the experience of the past decade, cost effective reduction in energy consumption is beneficial both to the individual investor and to the larger economy. The investor benefits by reducing building or home operating costs. These savings then create increased economic activity because expenditures on products other than energy have much higher economic multipliers than do energy expenditures (see page 17 for a more detailed discussion of this effect).

Energy also remains important because the poor are facing an immediate crisis, making tradeoffs between food, shelter and heat. Government programs can do much to meet their needs by improving the efficiency of their housing.

Environmental problems from traditional fuel use will also be a major concern of the eighties. Two of the many environmental concerns relating to traditional fuel use are acid rain and carbon dioxide.

Acid rain is the presence of sulfuric acid and nitric acid in both wet and dry deposition. It is estimated that 30 percent of the acid deposition in the state is produced from sources within Minnesota. Acid rain is of concern to Minnesota because, as a result of the glacial and geologic history of the state, much of northern and eastern Minnesota is sensitive to acid deposition. It is estimated that about 3.5 million acres of forest soils are sensitive or potentially sensitive to acid deposition. This represents about 19 percent of the forested land in Minnesota. Lakes in this region are generally low in buffering capacity; i.e., capacity to neutralize acid. Between 1,500 and 2,500 lakes are sensitive to acid deposition in varying degrees. Acid degradation of forests, lakes and watersheds would be extremely costly to the nation, and to Minnesota in particular.[24]

Another potentially serious problem is the increase in atmospheric carbon dioxide (CO_2) due to increased fossil fuel combustion, which is thought to cause a global warming of the earth's climate due to the "greenhouse effect." According to this theory, the CO_2 layer in the atmosphere acts as a one-way mirror, allowing visible light to pass through but preventing infrared heat from escaping the earth's atmosphere.

Although estimates of the CO_2 effect on climate are highly uncertain, the global impact of such a warming trend would cause worldwide changes in rainfall, river flow and sea level. Since tourism and agriculture are extremely important in Minnesota, the possible impact of CO_2 accumulation could be serious. A recent simulation of the effect of weather on the yield of spring wheat in the Red River Valley (which includes western Minnesota) showed that a 1°C increase in temperature and a 10 percent decrease in precipitation could cause an average decrease of 7 percent in yield.

Another possible effect would be increased demand for electricity during the summertime, due to additional air condi-

24 "Acid Precipitation in Minnesota," *Report to the Legislative Commission on Minnesota Resources*, Minnesota Pollution Control Agency and Minnesota Department of Natural Resources (January 26, 1982).

tioning use. This increased summer peak demand could result in more fossil fuel combustion and, thus, more CO_2 emissions, which could further accelerate and intensify the potential problems of the CO_2 effect.

The costs of these and other environmental effects may significantly increase the costs to society of electricity, petroleum and natural gas consumption in the future. Thus, the price of these fuels may be even higher than projected and our ability to continue relying on them may be severely limited by the end of the century. These factors add further urgency to the need to reduce our traditional fuel consumption by conserving and developing renewable energy sources.

Finally, it is possible that as early as the late 1980's OPEC will again achieve the power to control production and institute real price increases. A careful examination of world trends in supply and demand of oil demonstrates this possibility.

Industry and government forecasts project increasing petroleum demand throughout the century

The drop in oil prices and the worldwide economic recovery have apparently halted the nearly four-year decline in demand for petroleum products. Forty to fifty percent of the 1979-1982 decline in petroleum demand is estimated to be related to the concurrent worldwide recession. In the past, a 1 percent growth in economic activity resulted in a 1 percent growth in energy consumption. Although improving energy efficiency has broken this one-to-one relationship, economic growth still results in increased consumption of energy, including petroleum. It is currently estimated that a 1 percent growth in Gross National Product (GNP) will result in a .6 to .65 percent increase in petroleum demand.[25]

As a result of the economic recovery, U.S. petroleum demand actually exceeded the previous year's level during the last half of 1983. U.S. demand for gasoline was up by 3 percent and demand for distillate products was up 5 percent in the last months of 1983, compared with the same period in 1982. Both industry and government forecasts are projecting that petroleum demand will continue to grow. By 1990, DOE projects that U.S. petroleum demand will be up 9 percent from 1982 levels.

As the economic recovery spreads to other countries, worldwide demand for petroleum is also projected to grow. DOE forecasts world petroleum demand to grow by 11 percent by 1990, from 1982 levels.[26] Industry estimates, though slightly lower, reflect similar forecasts of world petroleum demand: up 9 percent by 1990 and up 20 percent by 2000, from 1982 levels.[27] (See Figure 32.)

Who will meet the growing demand for petroleum products in the U.S. and the world? As discussed earlier, non-OPEC oil production is very close to full capacity. In the short term, no more than 3 million barrels per day can be provided for export from non-OPEC oil producing countries.

In the long run, oil production in the U.S. (still the free world's single largest producer of oil) is projected by both industry and government sources to remain stable or decline slightly through 1990. Other industrialized nations including Canada, Britain and Norway are projected to increase production only slightly during the 1980's, with peak production well below previous estimates. Oil production from other non-OPEC countries is projected to grow by 1 million barrels per day by 1990, while oil exports from communist countries are projected to decline by .8 million barrels per day by 1990.

In total, production from non-OPEC sources is predicted to remain at approximately 1983 levels through 1990. Thus, OPEC production must rise by 4.5 million barrels per day in order to meet predicted world demand in 1988.

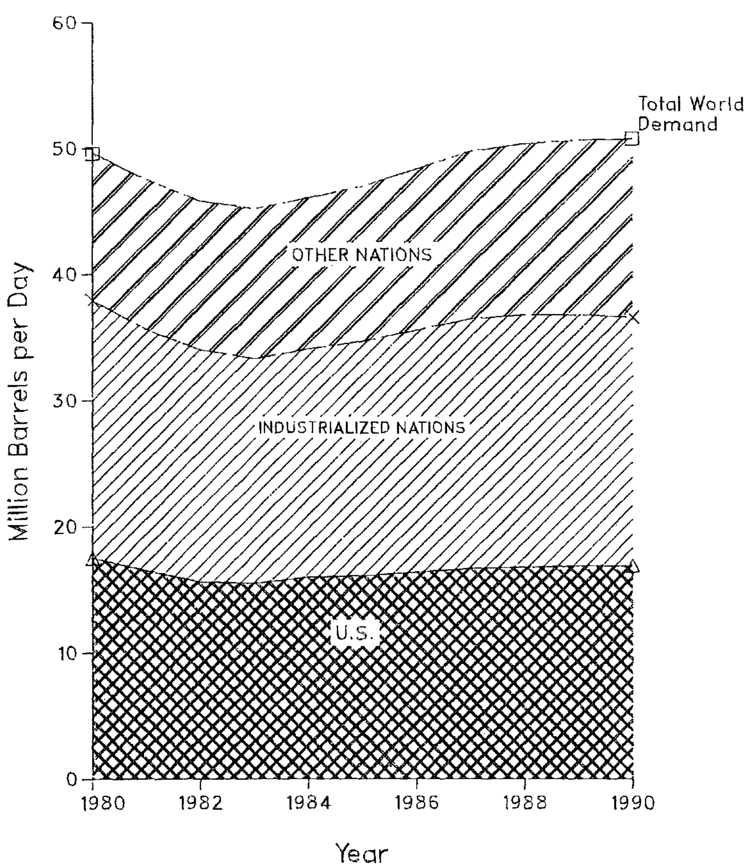
However, production is not the sole measure of OPEC's market influence. A more important indicator is the amount of "exportable" crude production; that is, OPEC's proportion of world trade in oil. Thus, in 1980, OPEC countries produced only 43 percent of world oil supplies, but their share of world trade was 86 percent. Non-OPEC countries outside the communist bloc accounted for 33 percent of world production in 1979, but their share of the oil trade was only 7 percent. As

25 Beck, Robert, "OGJ Forecast/Review," *Oil and Gas Journal*, PennWell Publishing Company, Tulsa, Oklahoma (January 30, 1984), p. 102.

26 *1983 Annual Energy Review*, Energy Information Administration, Department of Energy, Washington, D.C. (May 1984), p. 20.

27 *Worldwide Energy Outlook Through 2000*, Conoco, Stamford, Connecticut, (April 1983), p. 5.

Figure 32
Projected Worldwide Demand for Petroleum, 1980-1990 (excluding communist countries)



indicated above, these net export situations are unlikely to change by 1990.[28]

Oil reserves are the underlying factor 'ving these production forecasts. OPEC ..olds 75 percent of the non-communist world's proven reserves. At current rates of production, proven OPEC reserves would last 75 years. In comparison, U.S. reserves would last only 8 years. Furthermore, while OPEC reserves are largely undeveloped, U.S. reserves have been thoroughly explored. Even with 80 percent of all wells drilled between 1970 and 1983 located in the U.S., proven domestic reserves have declined by 17 percent since 1977. In 1982 alone, U.S. oil reserves declined 5.3 percent, a drop unprecedented in this decade. In comparison to OPEC's 75 percent of proven reserves, Western Europe holds less than 4 percent of the world's proven reserves. Furthermore, like the United States, these reserves have declined by 10 percent since their peak in 1978.[29]

OPEC likely to regain control of prices this decade as conditions of the seventies recur

OPEC's continued dominance over world reserves and, ultimately, production is a ..logical fact. Based on these facts, it is ..ly that demand for OPEC oil will reach 80 percent of capacity by the end of the decade. As discussed earlier, it is at this level of capacity utilization that OPEC historically has been in a position to raise the real price of its crude. As learned in the seventies, it is at this point that the perception of supply vulnerability exists and the oil industry and governments become more likely to panic should political events cause a supply disruption. Thus, as the eighties progress, it is increasingly likely that OPEC will again begin to institute real price increases, or that a supply disruption will cause a crisis. Most analysts project that the real price of oil will begin to rise in the late eighties. (See Figures 33 and 34 for Minnesota nominal price forecasts; Tables 13 and 14 in the Master Tables section provide forecasts of real energy prices.)

Emerging changes in OPEC export strategies also are likely to reinforce OPEC's position. The most important of these is the increase in direct government-to-government sales between exporting and

Figure 33
Projected Energy Prices, 1981-2000

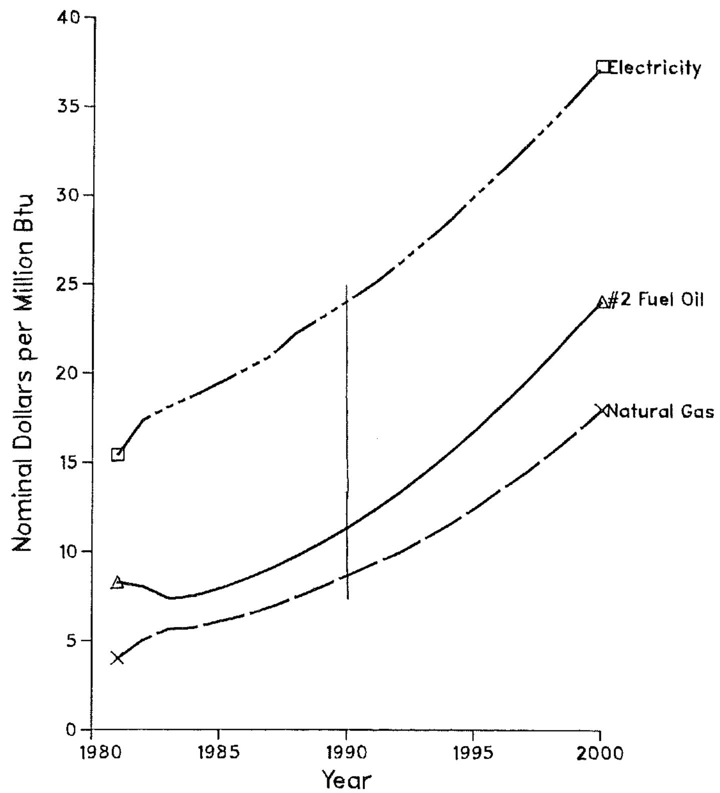
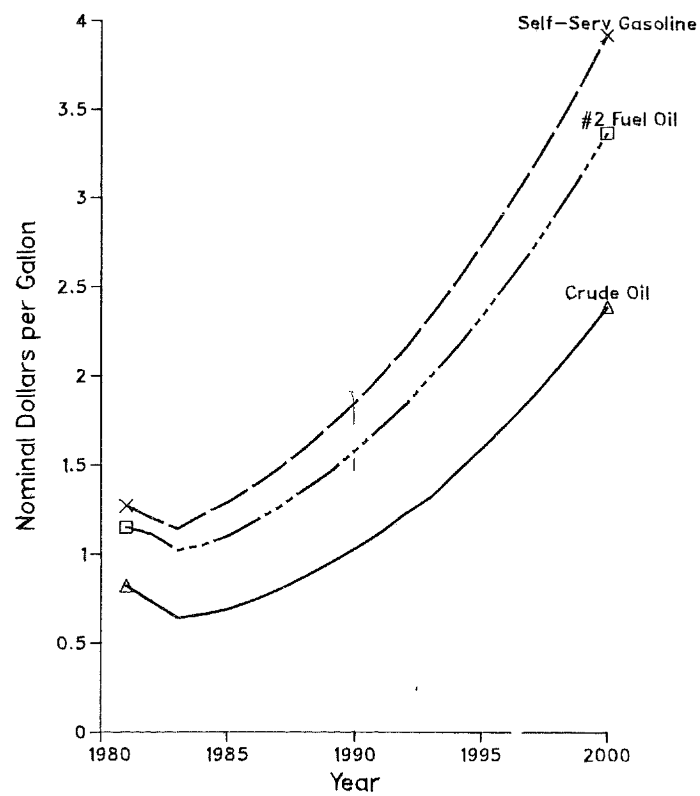


Figure 34
Projected Petroleum Prices, 1981-2000



sharaki and Isaak, *OPEC, the Suez, and the World Petroleum Market*, Westview Press, Boulder, Colorado (1983), p. 29.

29 *Basic Petroleum Data Book Volume III, Number 3*, American Petroleum Institute, Washington, D.C., Section II tables 1 and 4, Section III tables 11 and 12.

importing countries. These have increased from 1.5 million barrels per day in 1973 to 7.6 million barrels per day in 1980. Correspondingly, sales to major oil companies and to third parties who have acted as middlemen in the past will continue to decline. By 1990, OPEC nations may well be handling over 75 percent of their exports directly. Third-party sales are likely to be eliminated altogether and the majors themselves will become oil deficit companies. Third-party purchasers can no longer depend on the majors and will have to make their own arrangements with OPEC nations.[30]

The trend toward more destination-specific transactions reduces the flexibility that multinational oil companies once had to move supplies geographically so that the effects of a disruption could be spread more equally throughout the world. Thus, the impact of any supply curtailment is magnified, thereby increasing the influence of the oil exporters.

Like other countries, in order to meet growing demand and compensate for declining domestic production, the U.S. will become increasingly dependent on OPEC oil in the eighties. Because of this increasing dependence on OPEC supplies, the U.S. (as well as other industrialized nations) is susceptible to political and military pressure from these countries. Thus, our need for OPEC oil is not only an economic concern, but will continue to be a national security concern as well.

Natural gas prices will follow rising oil prices

The recession, relatively warm winters, and conservation resulting from high prices caused demand to fall for natural gas as well as for oil. U.S. natural gas consumption has declined from 20.24 trillion cubic feet in 1979 to 16.97 trillion cubic feet in 1983. As a result, a natural gas deliverability surplus, or "gas bubble," has developed. Estimated by the American Gas Association at between 1.9 and 2.7 trillion cubic feet in 1982, the bubble grew to 2.5 to 2.7 trillion cubic feet in 1983, excluding nearly 1 trillion cubic feet of Canadian gas under contract but not purchased. A survey by the *Oil and Gas Journal* in late 1983 yielded responses from 63 producers who collectively reported shutting in over 48 percent of their productive capacity. This decline in demand coupled with softening petroleum prices has resulted in the cessation of the natural gas price increases experienced over the past few years. However, reports of the imminent deflation of the gas bubble have been issued regularly in recent years. Although some analysts project the bubble to remain as long as six years, the industry currently estimates reaching a supply/demand balance in the latter half of 1986. As a result, it should not be concluded that the current surplus means there are no supply problems associated with domestic natural gas. The surplus is more a result of a temporarily lower demand than of increased supply. Although 4,300 more gas wells were drilled in 1982 than in 1979 (a 29 percent rise), the amount of gas in these wells did not increase. Each successful foot drilled in 1979 added 190 million cubic feet to gas reserves. By 1982, this figure had dropped to 135 million cubic feet.

When analysis is restricted to new exploratory wells, which contain the highest probability of finding new reserves, this pattern is repeated. A 28 percent jump in the number of exploratory gas wells drilled between 1979 and 1982 contrasted with a 7 percent decline in the amount of reserves found in those fields. Only 16 of the new fields were estimated to hold more than 6 billion cubic feet or more in reserves, compared with 28 such fields in 1979 and 61 in 1978.

These figures indicate that, despite the drilling records set each year from 1973 through 1982, drilling productivity is declining. More wells must be drilled than in the past just to find the same amount of gas. The more than doubling of wellhead prices that has occurred under the Natural Gas Policy Act has not led to commensurate increases in gas supplies. Furthermore, the indefinite delay of the Alaskan National Gas Pipeline has significantly reduced expected available future gas supplies.

As a result, we cannot expect natu gas to replace significant amounts of o crude oil in the long run. Also, as the supply surplus is eroded, we can only expect natural gas prices to rise along with crude oil price increases, as they did in the 1970's.

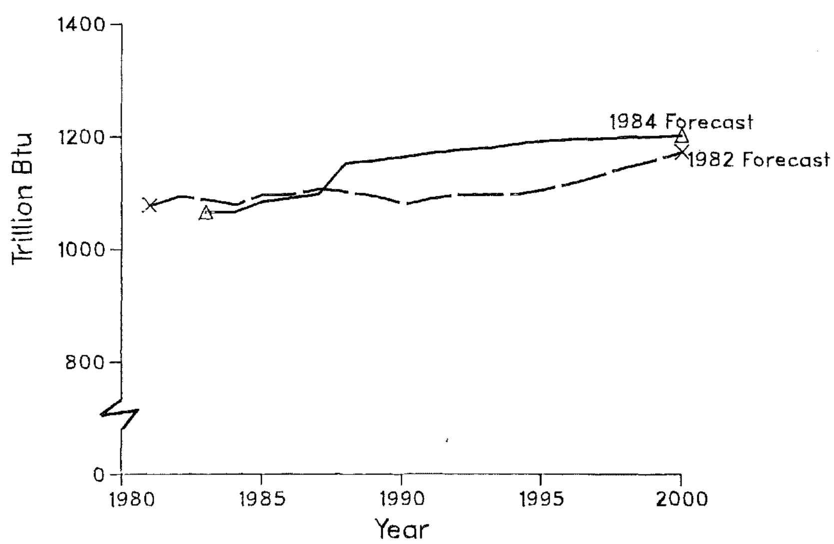
Minnesota traditional fuel demand projected to grow by 16 percent; alternatives expected to supply 4 percent of state's energy needs in 2000

How vulnerable will Minnesota be to the energy price increases, potential supply disruptions and environmental problems that are expected in the 1980's? Between 1980 and 1982, Minnesota energy demand declined more than had been predicted, due to both the unexpectedly poor economy and significant conservation efforts. As a result, demand for traditional fuels in Minnesota is lower in 1983 than was predicted in previous biennial reports. However, current projections for growth in traditional fuel demand between 1983 and 2000 are higher than the projections in the 1982 biennial report.[31] Thus, the past and current projections for traditional demand in the year 2000 are virtually the same. (See Figure 35.) Under current

30 op. cit., Fesharaki and Isaak, pp. 31-51.

31 *1982 Energy Policy and Conservation Biennial Report*, "Rapid Transition Scenario," Minnesota Department of Energy, Planning and Development, pp. 28-35.

Figure 35
Comparison of Energy Division's 1982 and 1984 Traditional Fuel Forecasts



projections, Minnesota demand for traditional fuels is expected to grow by 16 percent over the 17-year forecast period; the 1982 biennial report projected growth only 8 percent. Furthermore, in the 1982 report, alternatives (excluding fiber fuels) were expected to supply approximately 10 percent of our total energy needs by 2000, but current forecasts project that solar, wind, district heating and methanol will supply only 4 percent of Minnesota's total energy needs by 2000. (See Figure 36.)

The single most important factor contributing to this higher projected rate of growth in Minnesota demand for traditional fuels and lower growth in alternative energy supplies is the decline in oil prices (as discussed earlier) that has occurred over the past two years. The drop in oil prices has not only led to lower prices for petroleum products like gasoline and fuel oil, but also has acted to cap the growth in prices for natural gas.

This stabilization, or decline, of energy prices will slow investment in conservation and alternatives, relative to past forecasts. The first signs of the impact of lower prices have already been evident. In the last few months of 1983, demand for gasoline and fuel oil in Minnesota was higher than in the previous year, reversing a three-year decline in demand for petroleum products.

Thus, while the improvements in efficiency and alternative energy use described earlier have vastly improved Minnesota's energy picture, these improvements are not predicted to continue as rapidly as previously estimated. The specific fuel and sector forecasts are described in detail below. The forecasts incorporate "expected" saturation of conservation improvements and penetration of alternative energy technologies. The expected rate of penetration is that which occurred in the past with other new energy technologies, specifically in the shift from oil to natural gas.

Petroleum products remain Minnesota's most important energy source, providing an estimated 37 percent of the state's primary energy in 1983. Use of gasoline is projected to decline steadily, after rising slightly in 1984. By the end of the century, gasoline demand is projected to have declined by nearly 15 percent, from 2.01 billion gallons per year in 1983 to 1.71 billion gallons per year in 2000. This trend is primarily due to continued penetration of more fuel efficient cars and substitution of alternative fuels.

In contrast, both fuel oil and LPG use are projected to grow steadily over the 17-year forecast period. After declining sharply during the past decade, Minnesota demand for fuel oil is projected to grow by 30 percent over the next 17 years. In 2000, demand for fuel oil, including both residual and middle distillate fuels, is expected to total 1.48 billion gallons. LPG use is projected to increase by 8 percent from 1983 use, to 382 million gallons per year by 2000. For both LPG and fuel oil, economic expansion in the state is a primary factor contributing to the projected growth in demand.

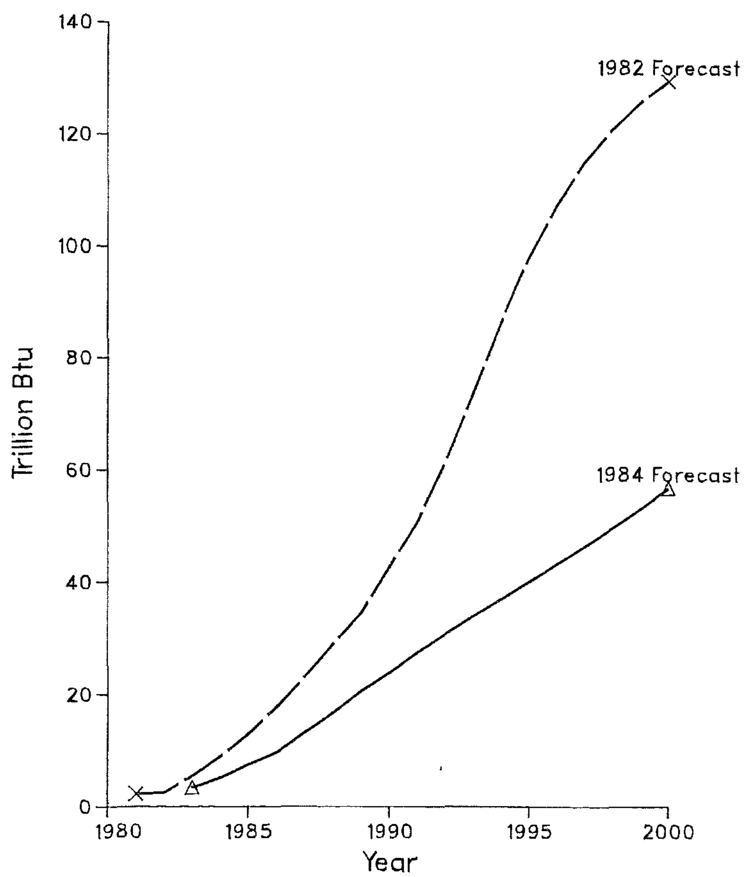
Based on these projections, Minnesota's dependence on crude oil, our most vulnerable energy source, will be much greater than previously expected. In fact, by 1990 current forecasts indicate that Minnesota will consume 17 percent more petroleum than had been projected in the 1982 biennial report. (See Figure 37.)

Natural gas demand is projected to rise through the mid-1980's and then decline slowly over the rest of the forecast period, reaching a level of 248 billion cubic feet in 2000, which is identical to 1983 consumption. Supplies to fuel this short term rise are available as a result of lowered sales in the early 1980's caused by the recession. The increase itself, particularly in the industrial sector, is a consequence of the economic recovery. The slow decrease in consumption through 2000 reflects continued conservation, the cancellation of the Alaskan natural gas pipeline project, the assumption that unconventional gas technologies will not prove to be economically feasible, and lower supplies from conventional sources.

Electricity demand is projected to climb by a remarkable 42 percent, the highest growth rate for any fuel. This increase in demand will be met primarily with coal-generated electricity. Based on these projections, environmental side effects of coal use, as discussed earlier, can only be expected to increase over the coming years. The growth in electricity use can be largely attributed to growth in population and economic activity coupled with stable real prices.

Alternative energy use is predicted to grow substantially over the 17-year forecast period. (See Figure 38.) However, it is lower than had been projected in the 1982 biennial report, due to lower prices for traditional fuels and continuing bar-

Figure 36
Comparison of Energy Division's 1982 and 1984 Alternative Energy Forecasts (excluding fiber fuels)



riers to development. By the year 2000, solar energy is projected to grow 19-fold, to 4.8 trillion Btu per year. Wind energy is projected to grow even more rapidly, from 25 billion Btu per year to 8.2 trillion Btu per year in 2000. Energy provided by district heating systems is projected to nearly double by 2000, to 11.5 trillion Btu per year. In total, however, these alternatives will continue to provide only a small part of Minnesota's energy needs; approximately 2 percent by 2000.

As in the 1982 biennial report, fiber fuels are projected to provide the largest share of Minnesota's alternative energy demand. Ethanol produced from biomass is projected to grow from 39 billion Btu per year in 1983 to 21.7 trillion Btu per year in 2000. Biogas is projected to begin commercial penetration in the late 1980's and grow to 16 trillion Btu per year in 2000. Fiber fuels used in solid form (such as wood and peat), will continue to be Minnesota's single largest source of alternative fuel. By 2000, use of solid fiber fuels is projected to double to more than 46 trillion Btu per year. Yet fiber fuels will still represent only 4 percent of Minnesota's total energy needs in 2000.

Residential demand climbs by 6 percent in 1990, then declines by 3 percent in 2000

Demand for energy in the residential sector is expected to climb steadily through 1990, and then gradually begin to decline. (See Figure 39.) This trend reflects increasing efficiency in new and existing houses along with a projected decrease in additions to the housing stock after 1990.

Use of fuel oil and LPG for home heating is projected to continue its 10-year decline. Residential fuel oil use in Minnesota is projected to decline by an additional 54 percent over the next 17 years. This will occur largely as home owners shift to less expensive substitute fuels such as natural gas. Reflecting this, natural gas demand in Minnesota's residential sector is expected to grow by 6 percent from 1983 to its projected peak in 1989. After 1990, efficiency improvements and slowed population growth will lead to a projected decline of 9 percent in natural gas use between 1990 and 2000.

Electricity demand in the residential sector is projected to grow steadily throughout the forecast period from 44.2 trillion Btu in 1983 to 57.9 trillion Btu in 2000; a 31 percent increase. This will occur largely because electricity prices are projected to be stable in real terms through the end of the century. Thus, the price of electricity is declining relative to other fuels.

Figure 37
Projected Minnesota Energy Consumption by Fuel Type, 1983-2000

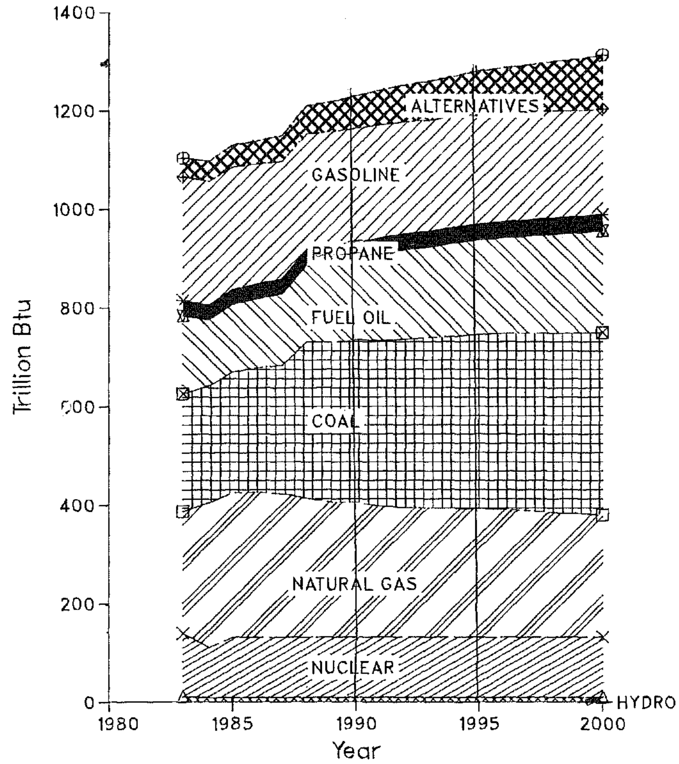
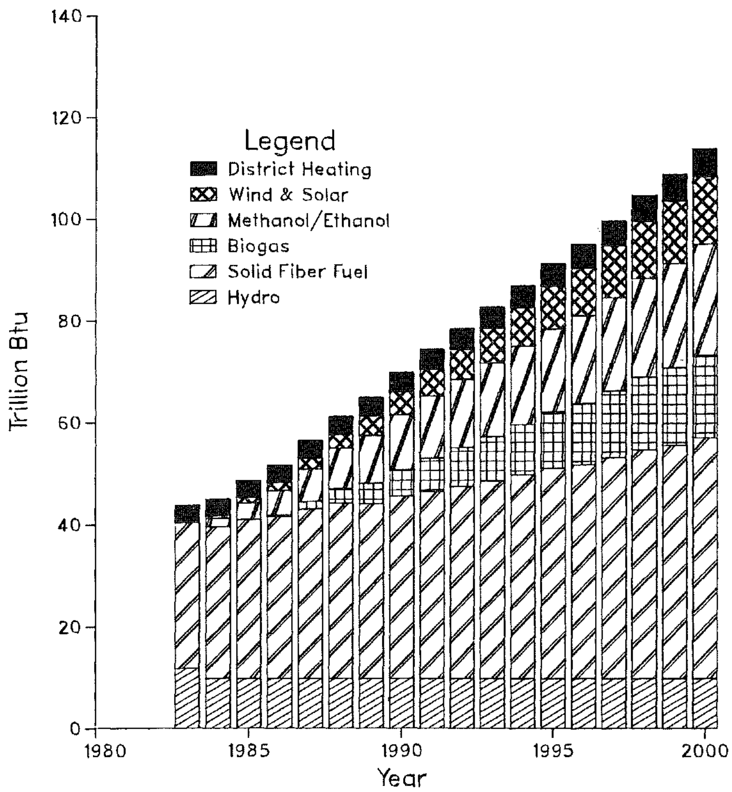


Figure 38
Projected Alternative Energy Consumption by Source, 1983-2000



Commercial/institutional demand rises by 59 percent

Energy demand by the commercial/institutional sector is projected to rise steeply through the end of the century. Total commercial/institutional demand is forecasted to grow by 59 percent between 1983 and 2000. (See Figure 40.) The current forecast for commercial/institutional energy demand is 13 percent higher in 1990 than was projected in the 1982 biennial report. By 2000, the current demand forecast for this sector is 23 percent higher than was projected in the previous report. This projected trend is due to both lower energy prices and higher growth in economic activity than was previously forecasted.

This growth in energy demand will be met primarily by growth in fuel oil use. Fuel oil demand is projected to grow to 317 million gallons by 2000, up more than 72 percent from 1983. Coal also is projected to display steep growth, up nearly 400 percent to 2.2 million tons per year by 2000.

Natural gas use, after increasing in the mid-1980's, is projected to decline to its 1983 level by 2000. As in the residential sector, electricity demand in Minnesota's commercial/institutional sector is projected to rise steadily throughout the forecast period, to a peak of 55.8 trillion Btu in 2000.

Industrial demand increases by 49 percent

Energy use in the industrial sector is also projected to rise steeply through the end of the century. Total energy demand in this sector is forecasted to grow by 49 percent by 2000. (See Figure 41.) As with commercial/institutional demand, these new forecasts for industrial energy demand are significantly higher than forecasted in the 1982 biennial report. By 2000, the current forecast for industrial demand is 24 percent higher than projected in the previous report.

The industrial sector's demand for electricity, fuel oil and coal are all projected to rise significantly over the next 17 years. As in other sectors, stable real electricity prices coupled with continued economic growth are projected to stimulate a 51 percent increase in electricity demand by the end of the century. Fuel oil and coal demand are projected to rise even more steeply; 100 percent and 74 percent, respectively, by 2000. These sharp increases result from both continued economic growth and a shift away from natural gas use in this sector. Although gas consumption rises during this period, its share of total industrial use falls from about one-half to one-third.

Figure 39
Projected Residential Energy Consumption by Fuel Type, 1983-2000

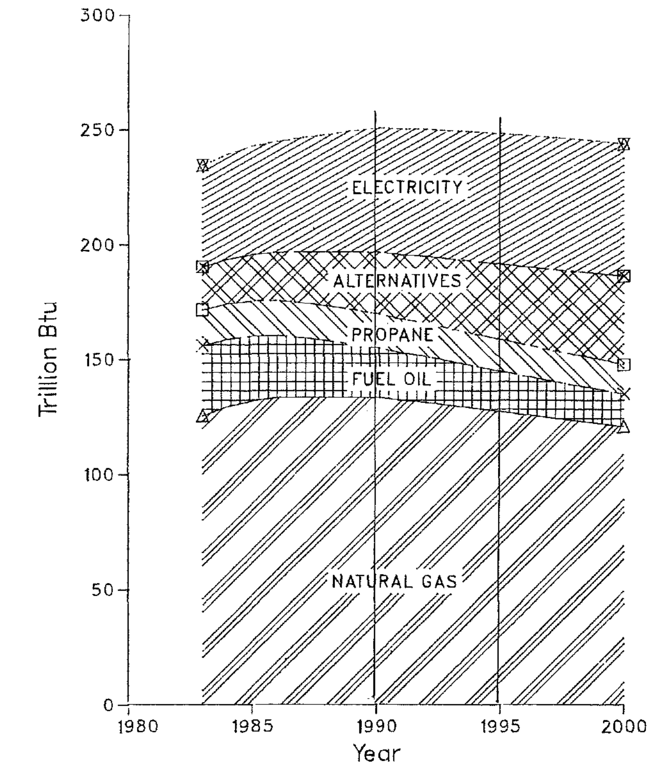
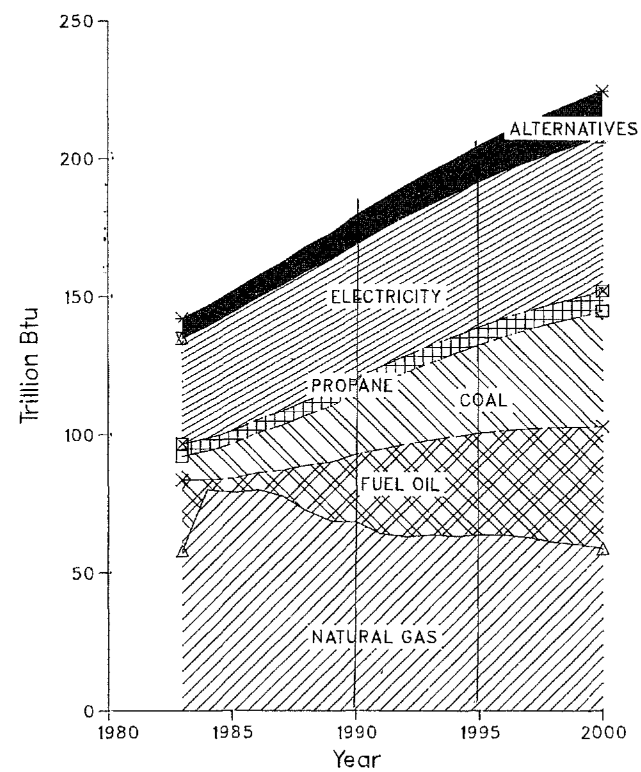


Figure 40
Projected Commercial/Institutional Energy Consumption by Fuel Type, 1983-2000



Agricultural demand declines by 20 percent

Energy demand in the agricultural sector is projected to decline steadily throughout the century. Continued efficiency improvements and a decline in the number of acres farmed are expected to result in a 20 percent drop in agricultural fuel use by 2000. (See Figure 42.) However, these forecasts are still 5 percent higher in the year 2000 than had been forecasted previously.

A decline in gasoline use accounts for the drop in agricultural demand. From 144 million gallons in 1983, gasoline demand is expected to decline to less than 50 million gallons by 2000. Continuing the trend of recent years, the shift from gasoline to diesel fuel will result in a steady demand for fuel oil of approximately 160 million gallons per year throughout the remainder of the century. Similarly, demand for LPG is projected to remain constant at approximately 90 million gallons per year.

Transportation demand increases by 10 percent

Energy use in Minnesota's transportation sector is projected to increase by 10 percent between 1983 and 2000. (See Figure 43.) Projections for transportation demand in this biennial report are more than 22 percent higher by 2000 than had been forecasted in the 1982 report, again reflecting the impact of the drop in world oil prices that occurred over the past two years.

The projected increase in transportation demand over the coming years is primarily accounted for by an increase in demand for diesel fuel and use of alternative fuels such as methanol for fuel additives. Diesel fuel demand is projected to grow by 47 percent by the end of the century to more than 740 million gallons per year. Use of alternative energy fuels is projected to increase to over 300 million gallons by 2000. In contrast, use of gasoline is projected to decline significantly. From 1.87 billion gallons per year in 1983, gasoline demand is projected to drop to 1.66 billion gallons per year in 2000.

Clearly, the effects of the current short term decline in energy prices are likely to have profound long term effects on Minnesota's energy use. Current forecasts for energy use in Minnesota show that the state will remain extremely dependent on unstable, environmentally hazardous fuels throughout the century. In the commercial/institutional, industrial, and transportation sectors particularly, traditional fuel demand forecasts are significantly higher than projected in the 1982 biennial

Figure 41
Projected Industrial Energy Consumption by Fuel Type, 1983-2000

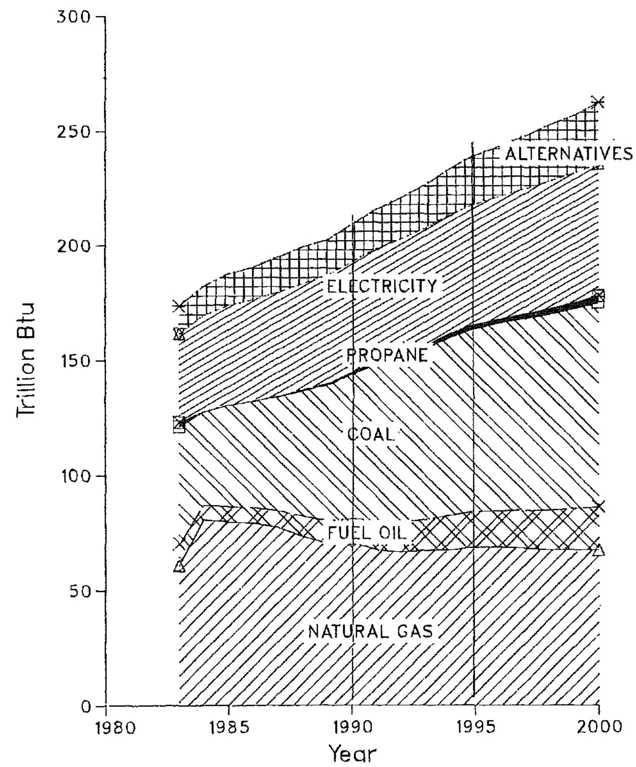
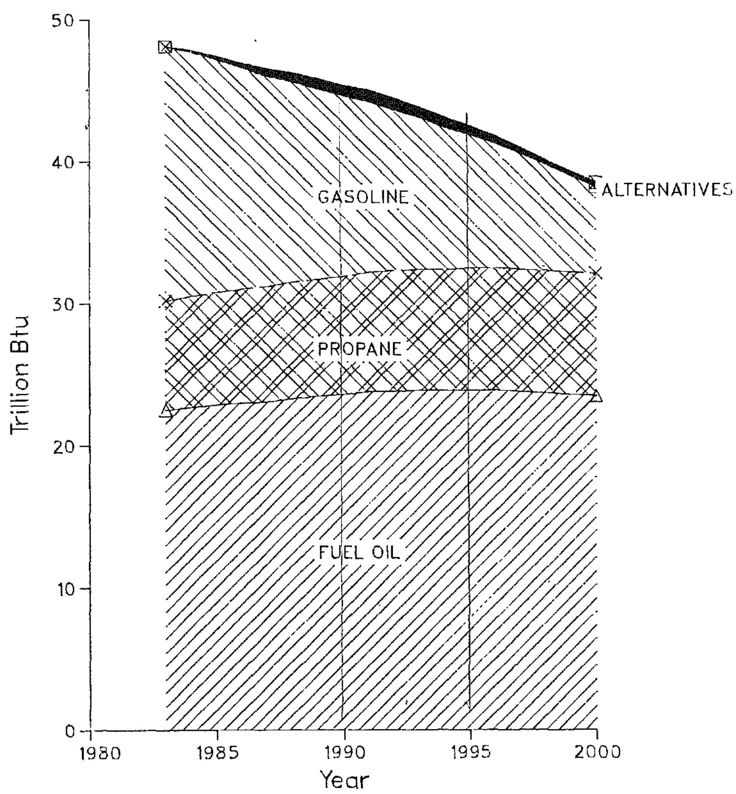
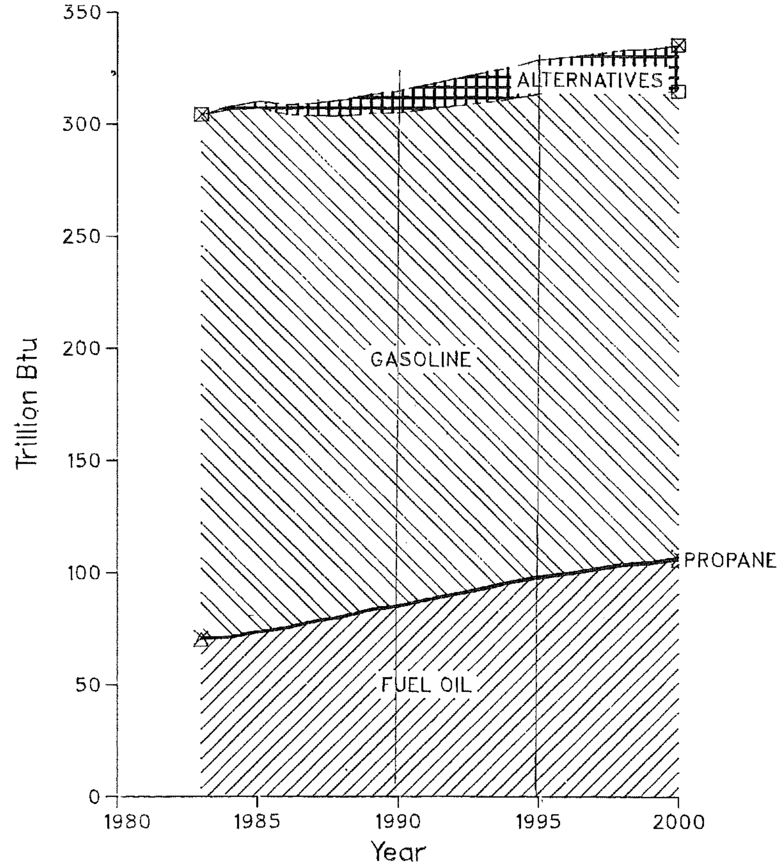


Figure 42
Projected Agricultural Energy Consumption by Fuel Type, 1983-2000



report. In addition, use of alternative fuels is projected to be significantly lower than previously expected.

Figure 43
Projected Transportation Energy Consumption by Fuel Type, 1983-2000



Issues of the coming decade

As Santayana warned, unless we are to relive our experience of the seventies—including a stagnant economy, spiraling inflation and energy supply disruptions—Minnesota must address and solve the problems impeding full investment in cost effective conservation and alternative energy technologies. By moving away from dependence on higher cost traditional fuels, Minnesota can:

- minimize the effects of potential future price shocks and supply disruptions
- reduce the burden on low income households
- foster economic growth and security by reducing energy expenditures and promoting development of alternative energy and conservation industries within Minnesota
- protect the environment by reducing pollution from traditional fuel combustion

The following sections identify the key issues that must be addressed in the coming decade in order to continue to progress toward these goals, and presents the most important actions that must be taken by Minnesota government to ensure and facilitate that progress.

Residential sector needs answers, rating system, continued low income assistance, efficiency standards for rental housing

Perhaps more than any other sector in the Minnesota economy, the residential sector has been the major focus of efforts to improve energy efficiency. The federal and state governments have spent over $100 million in grants to weatherize the houses of low income homeowners. The Minnesota Housing Finance Agency has provided well over $100 million in rehabilition loans, a significant portion being spent to add insulation and to purchase such items as new furnaces and storm windows. Conventional lenders have provided even greater sums in the form of loans to homeowners for energy efficiency improvements.

The challenge of the coming decade will be to continue the level of investment that has occurred in recent years. This section will discuss and identify the issues that must be addressed in order for residential energy use to show continued improvement.

Retrofit does not always achieve predicted savings— why?

As discussed earlier, the tremendous surge of conservation activities in the 1970's and early 1980's has resulted in significant reductions in consumption. However, we are just beginning to realize that conservation actions have side effects that were never anticipated. These side effects, both technical and structural in nature, are critical to the future of conservation and there must be efforts to better understand them if we are to continue to improve the efficient use of energy in Minnesota's homes.

One major issue that confronts policy makers (and homeowners as well) is the uncertainty about how much energy is actually saved by the installation of different conservation measures like foundation insulation or new, more efficient furnaces. While calculation procedures to predict energy savings do exist (generally in the form of energy audits), these measurements are estimates and are not based on actual empirical evidence of the performance of the conservation improvements. Preliminary research indicates significant discrepancies between the predicted and actual level of energy savings.

There are several possible causes for these discrepancies. One possibility is known as "behavior backlash." For example, a homeowner may add wall and foundation insulation to reduce the amount of heat lost through these areas of the house. These actions will increase the home's comfort level and will significantly reduce energy consumption and save money. As a result of these savings, however, the homeowner may conclude that it is now affordable to keep the house warmer, and turn up the thermostat to a higher setting. Unfortunately, this action will decrease the dollar savings gained by the conservation actions and the homeowner may improperly conclude that the insulation work was not worth the investment. Sufficient research has not been done to evaluate the extent to which residents change their behavior after improving the energy efficiency of their homes, which may have a detrimental impact on their energy savings.

A second factor that may cause the predicted energy savings to be significantly different from the actual savings is the quality of the installation work. If the homeowner or contractor improperly installs the energy conservation measures, they will not save as much as they should. Studies around the country, for example, have shown that contractors frequently do not completely fill all of the cavities of walls with insulation. If there are sufficient numbers of voids, the energy savings will not be as great as predicted. However, the homeowner rarely has the information necessary to determine if the work was done properly, and instead assumes that the energy saving predictions were inflated. Research is needed to determine if this is a problem in Minnesota, and if it is, state standards for conservation contractors may be necessary.

A third factor leading to differences between predicted energy savings and actual savings may be the calculation procedures themselves. Because there is a scarcity of baseline data and carefully controlled installation experiments, it is difficult to be entirely sure that the calculation procedures that have been adopted are entirely accurate. Again, more research is needed.

Finally, current retrofit technology may need further development to achieve predicted energy savings. In the last few years it was discovered that a previously ignored phenomena known as air bypasses, have a significant impact on energy savings. Bypasses are direct air passages that occur around penetrations into attics and walls that permit the passage of heated air directly from the interior to the outside, completely "bypassing" the recently installed insulation. Unless these gaps around pipes, electrical wires and boxes, and chimneys are plugged, the effectiveness of the insulation is minimized. Careful engineering assessments are needed to locate common bypasses and determine the impact they have.

These factors—changes in behavior, quality of the insulation work, accuracy of the calculation procedures, and changes in technology—all affect the energy savings homeowners realize when they improve the efficiency of their homes. Because these variables are not taken into account, savings may be significantly different from what was expected. Residents are rightfully upset when their investments fail to generate the expected savings, which may lead to a lesser propensity to make other energy conservation improvements. Research is needed to enable these factors to be taken into account.

Tightening the house yet avoiding indoor air quality and moisture problems—how?

Another major issue confronting residents is the impact that increased insulation levels and decreased infiltration (through caulking and weatherstripping) have on indoor air quality and moisture levels. Many homeowners and tenants who have weatherstripped their windows and doors frequently discover that during cold weather they have moisture condensing on their windows, with water running down onto sashes and other woodwork. In severe cases, moisture condenses on some areas of the walls, especially in corners, and occasionally mold and mildew results.

This relatively recent phenomenon is the direct result of sealing the residence to limit cold drafts and to reduce heat loss. However, because humidity levels are higher indoors than out, better sealing of the home limits the exchange of cold dry air with the warm moist air inside. Moisture levels build up and eventually may condense on colder exterior walls. These effects may cause significant damage to the home, causing deterioration of walls and woodwork.

A second consequence of reducing infiltration is the potential build up of pollutants inside the residence. With fewer exchanges of air due to better sealing of the building envelope, higher levels of carbon monoxide and carbon dioxide may result. Other pollutants such as formaldehyde, nitrogen dioxide and radon also may accumulate without proper ventilation.

The increase of moisture levels and other indoor air pollutants is a problem that must be resolved in the coming decade as we make homes more and more energy efficient. While air exchange rates in older homes may be as much as six changes per hour, and three per hour in new homes, exchange rates in superinsulated homes are less than one or even one-half change per hour. Builders of superinsulated homes are cognizant of the need for mechanical ventilation (often heat recovery) to alleviate moisture and air quality problems. However, this need is not so clearly recognized for newer homes or for tightly sealed retrofits of existing homes. Changes in technology must lead to changes in construction practices to avoid creating air quality problems.

More engineering evaluation is needed to determine rates of mechanical ventilation that are needed to maintain safe indoor air quality levels. In addition, different ways of providing ventilation need to be evaluated for effectiveness and cost. As energy costs continue to rise, people will want to make their homes more energy efficient by reducing heat loss through the building envelope and by reducing air infiltration. Research to develop minimum air exchange rates and control methods for healthful living is critical.

Conservation services—who should provide? who should fund?

Conservation services are now funded and delivered by a multiplicity of groups. (See Figure 44.) As most of these groups have been operating for a number of years, it is now appropriate to evaluate their performance and ask several basic

Figure 44
Public Sector Providers of Conservation Programs (1983 estimates)

	Dept. of Economic Security	Minnesota Housing Finance	Community Action Agencies	Neighborhood Groups	Municipalities	Utilities
Low Income Weatherization Grants			$13,000,000[a]			
Fuel Assistance	$75,000,000					
Low Interest Loans		$8,700,000			$3,900,000	$800,000
Energy Audits				(10,000 Audits)		(27,000 Audits[b])
Furnace Retrofits			$ 500,000[a] (950 installations)			

[a]The money for this program is passed through the Minnesota Department of Economic Security.
[b]Some of this money is used to fund energy audits done by neighborhood groups.

policy questions regarding the funding and delivery of conservation services. These questions include:
- who should deliver which services?
- who should fund which services?
- how effective have various programs been?

To date, federal law has placed the primary responsibility for funding and delivering energy audits on the large gas and electric utilities. The federal law requiring utilities to offer audits to their residential customers expires at the end of this year. However, a new law gives them responsibility for commercial and apartment energy audits beginning this year. A basic question facing the state is whether the utilities are the most effective and appropriate group to provide these audit services. There are several reasons to question the utilities' role:

- Utilities have an apparent conflict of interest in promoting conservation because it can directly reduce their revenues. This disincentive to promote conservation may result in less effective delivery of energy audit programs.
- Utilities nationwide and in Minnesota are increasing efforts to market their product. There is considerable potential for abuse of conservation programs by using them to promote energy consumption rather than energy conservation. It may be an unwise public policy to have the same institution promoting saving energy that may also be promoting its use.
- In the past seven years since Congress placed conservation responsibilities on the utilities, other public and private sector entities have emerged to deliver conservation services. The ability of utilities to offer subsidized audits, particularly to commercial and industrial customers, may actually harm small businesses that have emerged to meet this need. Community based organizations that provide energy services are also undermined by utility audit programs in their neighborhoods.
- Utility delivery of conservation services may be economically inefficient. A comparison of audit costs and effectiveness suggests that community based organizations can deliver audit services more cheaply and with greater effectiveness than utilities. It is likely that private engineering firms would also deliver audit services more efficiently than utilities to commercial and industrial customers.

In summary, the state faces what might be termed an "issue of governance" with regard to audit services and for conservation services in general. The utilities have been empowered, and indeed required, to offer audit services. But it must be assessed whether this is the appropriate institution to provide audit services; i.e., whether the state should pursue a community and private sector based strategy or a utility based strategy.

Funding for conservation comes from a variety of sources through a variety of programs. The sheer number of these programs, each with its own rules, greatly complicates delivery of services and introduces inefficiencies. Different sectors of society often have significantly different access to services, particularly financing. For example, income guidelines for fuel assistance do not coincide with those for weatherization grants. Thus, a household may be receiving fuel assistance but cannot afford to weatherize, and yet is not eligible to receive a grant for weatherization. Renters have historically been at a serious disadvantage in obtaining weatherization financing.

The state must undertake a comprehensive review of the delivery and financing of conservation to determine gaps and inequities, and to identify opportunities to improve the efficiency of delivery. Options such as the use of consistent auditing techniques need to be considered. Organizational options, such as the consolidation of all state residential conservation financing and delivery programs, should be considered. Again, a clear delineation needs to be made regarding the role of the utilities.

On this latter issue, state law now requires larger regulated utilities to make significant investments in conservation. The law is based on the premise that it is in ratepayers' interest to improve energy efficiency in order to avoid expensive new power plants or natural gas. Cost effective utility conservation investments represent sound energy policy. Care must be taken to maximize cost effective utility conservation investments without expending ratepayers' money beyond the point where it is economically efficient.

Finally, it may be necessary to distinguish between the utilities as a funding source for conservation and a delivery source. Where economics dictate that the utilities should spend ratepayers' money to save energy, other policy considerations mentioned earlier may suggest that non-utility groups should deliver conservation services in order to avoid conflict of interest and anti-competitive effects, and to maximize cost effectiveness.

Home energy efficiency rating system needed

During the 10 years since the 1973 oil embargo, real energy prices increased an average of 150 percent. With such dramatic increases in a relatively short time, it would be expected that consumers would consider energy costs in their purchase of products that consume energy.

In many areas, that has been the case. Perhaps the best example is the sticker on each new car showing the estimated miles per gallon that the owner can expect. When oil prices were low, gasoline consumption efficiency was simply not a major variable in the purchase decision. Similarly, major appliances like refrigerators, freezers and water heaters now have labels telling purchasers of expected annual electricity or gas costs. Consumers can then make better decisions when they purchase these goods.

Unfortunately, similar information is not available to buyers of the largest single commodity they will purchase in their lifetime—their house. Energy costs to heat a home, to provide hot water, and to operate appliances are now a major component of a monthly budget. However, these costs are rarely taken into account when comparing different homes or when calculating affordability.

In contrast to the early 1970's, energy costs to operate a home are now a significant burden. When lenders review the monthly financial obligation of purchasing a home they generally consider the principal, interest, taxes and insurance (PITI). However, energy costs to operate the residence frequently exceed taxes and insurance. Thus, lenders may be overlooking a major factor as they evaluate whether a buyer of a home can actually afford it.

Many home buyers look at the fuel bills of any house they are considering buying, as well as asking the realtor about insulation levels and the age of the furnace. Such information is helpful in gaining a rough gauge about the efficiency of the home. However, knowing the fuel bills for a year does not indicate how efficiently the heating system used that fuel, how well insulated the house was to keep the heat inside, how warm the house was kept, or how mild or severe the winter was. Any one of those factors can have a dramatic effect on the final bill.

For example, research has found that different families living in virtually identical houses can experience fuel bills that differ by up to 50 percent. Basic lifestyle and behavior patterns can have a significant impact on consumption that cannot be accounted for by reviewing fuel bills.

To help homebuyers cope with this major variable in their home purchase decision, a rating system similar to the "miles per gallon" rating for cars is needed.

Such a rating should provide an unbiased and accurate estimate of what a homeowner can expect to pay for energy.

Minnesota experimented with a program to provide unbiased information about the energy use characteristics to potential homebuyers. Under the Home Energy Disclosure program, home sellers were required to obtain an energy audit disclosing how efficient their homes were, and to provide that information to the buyers. Unfortunately, the program was not well publicized or supported by the major groups involved in the real estate transaction process, and it was rescinded by the legislature in 1983.

The experience provided several lessons that are essential if a labeling system is to be workable. In order for a home energy efficiency rating to work, the following components are needed:

- The label must be universal. That is, it must be available for each home in the market to enable comparisons.
- The label must be simple and understandable. Preferably, one single number should be used to summarize all of the factors that affect consumption.
- The label information must be able to be integrated into the procedures used by financial institutions to calculate affordability.

In addition to providing potential homebuyers with better information with which to make their decisions, a labeling system also permits lenders to include that information in the loan underwriting process. A more energy efficient home may cost somewhat more than a conventional one, which results in a higher monthly mortgage cost. But the more efficient home will also have lower energy bills, allowing the buyer to be able to spend more on the monthly mortgage payments. A labeling system will provide the energy factor (E) that can be added to the PITI + E calculation to evaluate the tradeoff of a more expensive but energy efficient home against a less efficient home that has higher utility bills.

It is critical that Minnesota develop and adopt a labeling system that permits buyers to make better decisions about the homes they purchase. Just as important, a labeling system is essential to enable more energy efficient homes to be credited for their lower fuel bills in the financial underwriting process.

Low income households must have assistance; existing programs can do better job of targeting

While the rapidly rising energy prices since 1973 have fundamentally changed all of our lives, they have had the greatest impact on the poor. In 1973, low income households spent approximately 7 percent of their income for energy needs, but by 1981, almost 13 percent of their income was required to meet those same needs; nearly an 86 percent increase. In comparison, median income households spent approximately 4 percent of their income in 1973 and 5 percent in 1981 for energy.

Because low income households have less discretionary income, they have been less able to withstand the shocks of higher utility bills. Many of these households frequently have to make critical choices between heating and other needs such as food or clothing. Without the federal fuel assistance program, which provides grants to low income households to help pay fuel bills, the situation of many Minnesotans would be desperate.

Unfortunately, the federal assistance program is in a precarious state. First, funding levels for the nation have to be set each year by Congress. Delays in taking action and changes in allocation formulas have made the fuel assistance program a very difficult one for states, including Minnesota, to implement. Second, funding for that program is derived from the Windfall Profits Tax on Oil Companies, which is slated to end in 1990. Because energy costs are so high, there are large numbers of households that are very dependent on this form of assistance. If the program were to end in 1990, one consequence might be that many thousands of households would be cut off by the utilities for non-payment of bills.

Finally, while it is essential that the public sector provide assistance to households in meeting their energy needs, fuel assistance is not a permanent solution. Unless consumption of energy is reduced to a level where low income households can afford to pay their own bills, long term reliance on assistance results. Minnesota (and other states) needs to take action to improve the energy efficiency of these residences to limit future reliance on the fuel assistance program. While weatherization programs provide permanent relief by making improvements to reduce demand for energy, fuel assistance essentially sends money up the chimney. Each dollar spent on weatherization reduces future need for fuel assistance.

There are numerous programs that currently exist to assist low income residents. The Federal Weatherization Program, Minnesota Housing Finance Agency Deferred Loan Programs, Federal Community Development Block Grant Funds, and others all exist to help low income families improve and increase the energy efficiency of their homes. However, because the programs are provided by different agencies with widely varying eligibility rules, coordination of programs is difficult best. Frequently, a homeowner will ceive assistance that results in only a part of the total weatherization work being completed. Either funding for individual projects or programs is too limited, or rules regulating the program are so narrow that all necessary repairs cannot be made. If Minnesota is committed to reducing its reliance on precarious federally funded fuel assistance, it must review its existing programs and work to improve both coordination and funding levels.

In addition to programs specifically designed to assist low income families, there are several others that could do a better job of targeting assistance to this sector. For example, major gas and electric utilities are required to provide energy audits and related services to their residential customers. However, studies have found that the majority of participants in this informational program are moderate to high income households. Although such audits indicate savings from installing a range of energy conservation measures (many of which may be unaffordable by low income households) they also include a large number of low cost and cost recommendations to reduce ene use. If properly marketed, the energy audit program could be a great benefit for low income homeowners.

One utility, Northern States Power, is currently implementing a pilot program to more aggressively attract low income households to the program. Efforts include waiving the $10 fee that is normally charged; offering the audit through other programs in which low income families participate; providing incentives such as shower flow restrictors, water heater blankets, and small weatherization kits; and emphasizing low cost/no cost improvements. This effort should be adopted by other regulated utilities, as well as municipal utilities and rural electric cooperatives.

Utilities have also been increasingly involved in other conservation programs, including financing. Under the Pilot Utility Conservation Investment Program, for example, NSP offered deferred loans to a randomly selected sample of their residential customers. Because deferred loans are an ideal mechanism for financing improvements for low income homeow (there are no monthly payments on loan; instead, it is repaid when the home is sold) the program should have been targeted to them. However, the pilot program was generally unsuccessful in reaching this group, partially because it was not properly marketed. These kinds of programs should be continued, but directed at those who need financing the most.

It is clear that rapidly rising energy prices have had a detrimental impact on those who can least afford it. While a number of programs exist to assist them, there is a lack of coordination, insufficient funding, and a lack of marketing to the appropriate client groups. Minnesota needs to review these programs in the broadest context to develop a cohesive and integrated system to help low income residents in the coming decade.

Energy efficiency standards for rental residences needed

Most conservation programs in the 1970's were designed to help homeowners cope with rapidly rising energy prices. Energy audit programs, information/education campaigns, and the majority of the loan and grant programs have been directed to owner-occupants.

For a number of reasons, rental housing has been virtually ignored. To begin with, dealing with the tremendous barriers that face owners and tenants of rental housing is an almost impossible task. For example, in rental units where the tenant is directly responsible for paying the energy bills, the property owner realizes no direct financial benefit from improving the energy efficiency of the building. In rental units where the owner is responsible for paying for utilities, the costs are deductible as operating expenses for income tax purposes. To a great extent, landlords are shielded from facing the true energy costs of operating their buildings.

Other barriers to improving the energy efficiency of rental buildings include:

- lack of tax incentives for making improvements (although they are available for homeowners)
- concern that if energy conservation improvements are made the property will be reassessed, which will result in higher property taxes
- lack of accurate, reliable, and unbiased information for landlords about the most cost effective retrofits available
- lack of financing from conventional lending institutions to install energy conservation measures
- traditional distrust between landlords and tenants that must be overcome, since conserving energy frequently requires cooperative actions

These barriers are so formidable that it is not surprising that little has been done to improve the efficiency of multi-family housing. Unfortunately, to the extent that we ignore rental housing, we also ignore the needs of low and moderate income households. Minnesota's (and most other states') focus on homeowners has unintentionally ignored the needs of some of those least able to afford the tremendous increases in fuel costs over the last 10 years.

Unlike other states, however, Minnesota has attempted to deal with multifamily housing. In 1977, the legislature established authority for the adoption of minimum mandatory energy efficiency standards for existing rental housing units. These standards, the first of their kind in the country, require that approximately 400,000 units meet minimum standards regarding caulking; weatherstripping; attic, wall, rim joist, and foundation insulation; and storm windows and doors.

Unfortunately, the program has suffered from rather fundamental flaws. First, a loophole was discovered in the insulation standards that permitted owners of rental property to get around the requirements for attic and wall insulation. Second, the Energy Division has never been provided with the resources to adequately publicize the standards. Third, the Division has never had staff to implement compliance activities against owners who do not comply with the standards. Fourth, the enforcement process is so cumbersome and the legal mechanism so protracted that it is virtually impossible to effectively enforce the standards against recalcitrant owners.

Finally, it is difficult for a standards program to exist in a vacuum. To be successful, a standards program has to be integrated with information and energy audit programs so that owners can be aware of which standards apply to them. In addition, there has to be a generally available source of financing for owners who need loans to make the required improvements.

A standards program is essential to improving the general efficiency of rental housing. While audit programs and financing can certainly exist independent of standards, they will not necessarily change the status quo. Aggressive and knowledgeable landlords will seek out information and locate financing because they are aware of the benefits of conservation. However, for the remaining owners, a set of minimum standards with an effective compliance program is needed to entice them to take action.

However, major issues need to be resolved to make the standards effective. The loopholes in the standards need to be closed, more extensive publicity efforts need to be undertaken to inform property owners of both the existence of the standards and the availability of information and financing programs, and an effective enforcement mechanism needs to be devised and adopted to encourage the highest rate of compliance possible.

Commercial/institutional and industrial sectors need incentives to make efficiency improvements in buildings and operations

Efficiency has significantly improved in Minnesota's commercial/institutional sector; however, much remains to be done. Although there is insufficient research on energy use and conservation in commercial buildings, detailed engineering audits of 270 buildings at 41 state institutions do give some indication of the conservation potential of Minnesota's commercial buildings. The buildings that were audited—hospitals, office buildings, transportation facilities, and college buildings—are similar in a number of respects to commercial buildings.

Implementing all of the individual energy conservation recommendations identified in the audits would cut energy use by 71,000 Btu per square foot annually, which is equivalent to 32 percent of the baseline energy use of these buildings. The cost of implementing all these measures is roughly $1.90 per square foot with an average payback of less than 8 years using 1978 fuel prices.

Among the 270 buildings audited, 7 were office buildings. These seven buildings have an average energy intensity well below the U.S. average, yet they can be retrofitted for about $1 per square foot. Their fossil fuel use can be reduced by an estimated 50 percent and electric use by 27 percent. The conservation cost of $1.22 per million Btu of conserved energy is well below 1981 commercial energy prices: $4 per million Btu for natural gas, $8.19 per million Btu for fuel oil, and $13.93 per million Btu for electricity. This large gap between the conservation cost and the price paid for energy indicates a sizeable savings potential from retrofit investments in commercial buildings.

In schools and other publicly supported institutions, there also remains a large potential for additional cost effective investments to further reduce energy expenditures. A cost benefit analysis of audit data from 200 elementary and secondary schools was recently completed to determine optimal levels of energy conservation investments in these schools. This study found an optimum cost effective investment of $70,000 per elementary school building and $176,600 per secondary school building. The annual energy cost savings resulting from these levels of investments would be approximately $10,000 and $32,000 per building, respectively. These represent reductions in annual energy use by 33.5 percent for elementary schools and by 35.2 percent for secondary schools. Equivalently, these translate into an annual energy cost savings of 29.6 percent and 31.1 percent for elementary and secondary schools, respectively.

In both the commercial and industrial sectors, the greatest potential for savings in electrical use is in the area of improvements in lighting and motor efficiency. Of NSP's electric deliveries (41,263,455 MWh) to these sectors, 81.6 percent is used for lighting, process motors and HVAC motors. Engineers estimate that efficiency improvements in lighting and motors could easily achieve 10 percent annual savings. These savings would result in 1,735,000 MWh less electricity, which is comparable to 38.1 percent of Sherco III annual production.

As discussed earlier, the Energy Division has made only modest efforts in the past to promote cost effective energy conservation efforts in the commercial sector during the past seven years. Because business has a clear profit motive and better access to information than do homeowners, the Division's work has focused on the residential sector, leaving business decisions to business decisionmakers. However, it has become increasingly evident that many of the impediments to energy efficiency in the residential sector also exist in the commercial and industrial sectors. For example, many commercial users are also renters and, as such, face all the disincentives to conservation investments that residential renters face. Issues that must be addressed to improve efficiency in this sector over the coming decade are discussed in detail below.

Information, efficiency standards, and financing incentives needed to overcome distorted market signals

Commercial and industrial energy use and conservation investments are distorted by at least three factors that mute the effect of price and cost signals in the building market and, thereby, inhibit full incorporation of efficiency into the marketplace.

First, many industrial and commercial businesses rent their property. Thus, as in the residential sector, the building owner realizes no direct financial benefit from improving the energy efficiency of the building if the renter is directly responsible for paying the energy bills. In the case where the owner is responsible for paying the utilities, energy costs are deductible as operating expenses for income tax purposes, thus shielding the building owner from the full costs of energy consumption. As a result, there is no incentive for either the renter or the owner to reduce energy expenses through capital improvements. Furthermore, renters have only limited ability to incorporate energy costs into their rent cost calculations. An examination of previous energy bills offers only extremely rough guidance, because energy use is sensitive to variations in both the weather and the way in which the previous occupants used the building. In order to achieve the full potential for cost effective improvements in the commercial sector, this market distortion must be addressed.

In addition, high real interest rates have also discouraged capital intensive energy conservation investments. High real interest rates act to reduce the present value of future cost savings from reduced energy bills, thereby reducing the net benefits of the investment.

Another problem may result from the fact that developers frequently design and construct new buildings that are sold to business owners. This requires the building buyer to calculate the value of the conservation investment and incorporate it into the price of the building. Although high energy prices certainly have increased buyers' awareness that energy bills are a concern, their ability to accurately value the energy savings from a specific conservation investment may be limited. This limitation prevents conservation from being fully capitalized into the value of the buildings and, in turn, discourages developers from making these investments.

In the coming decade, these impediments to full implementation of cost effective conservation technologies will continue to inhibit the energy efficiency of the commercial and industrial sectors unless remedies are actively pursued. Approaches to these problems include delivery of information to commercial building buyers and renters, or development of an institutionalized information system so they can accurately assess the value of building energy efficiency. A regulatory approach to these problems, which establishes higher efficiency standards for new building construction, may also be needed. Finally, financing incentives that act to reduce the real interest rate would also stimulate more investment in conservation, thereby moving the sector to an improved level of efficiency.

Energy efficient building operations could be encouraged through training and education, technological advances, energy accounting systems, shared savings

Once a builder or owner has decided to install energy efficient conservation measures in a commercial or industrial building, it is sometimes difficult to achieve the expected savings. There are two primary reasons. First, there are natural tradeoffs between the energy efficiency and operational functioning of a building. For example, the less outside air vented into the building, the less energy will be required. However, reduced outside air intake also reduces inside air quality. It is difficult to achieve an optimal tradeoff between energy cost and human resource performance. Other similar tradeoffs include all-over lighting vs. task lighting, and constant room temperature vs. band temperature control.

In part, these problems result whenever people are expected to change their traditional standards for the office environment. Education and demonstration may be the most effective way to overcome these biases. However, technological advances are also needed, particularly in the area of indoor air quality. For example, a technology to clean indoor air so that air quality may be maintained without intaking outdoor air has yet to be developed. Government development of uniform standards for air quality, lighting and heating may also resolve some of these problems.

Building operators generally make the decisions about how to resolve the tradeoff between efficiency and comfort and, as a result, are key to this issue. Building operators receive complaints from occupants about such issues as building temperature and air quality, yet they are not generally held responsible for building energy costs. As a result, there is an institutionalized incentive for operators to respond more to comfort than to efficiency concerns. In addition, operators may know very little about how to operate the equipment installed so that it performs most efficiently.

Training and education can address the latter issue. However, it may be difficult to convince upper management of the need for training and of the cost effectiveness of conservation. One possible approach to this problem is to institute energy accounting, with operators receiving monthly energy cost reports. A shared savings approach, using third party contracts for energy use control, can also provide incentives for more efficient operations.

Progress toward providing more clear and direct price incentives for investment in conservation measures and implementing building operation techniques that achieve full efficiency is essential for continued improvement in these sectors' energy use. Regardless of the approaches selected, resolution of these issues is a critical challenge of the decade ahead.

Alternative energy development will require information, government assistance, financing, and technical assistance

The past decade has taught us that we must make a transition from non-renewable energy supplies (oil, gas and coal) to renewable energy sources. For states with no traditional energy resources, such as Minnesota, beginning this transition immediately has many advantages:

- stemming dollar losses due to importing fuels
- creating new businesses and jobs
- establishing Minnesota as a leader in what will be a major worldwide growth industry in the coming decades
- helping stabilize the state economy by buffering the state from price and supply fluctuations
- reducing environmental damage, thereby aiding the tourism industry, and reducing crop loss and damage to human health

Minnesota has the opportunity to become one of the leading states in the nation in alternative energy technologies, and possibly a worldwide exporter. Capturing this opportunity, however, will take commitment and investment, and this investment is not without risk. One of the major barriers to development is simply the level of subsidies traditional fuels have received and continue to receive. A recent study by the Northeast-Midwest Institute estimates that between 1950 and 1977, traditional fuels received $202 billion in incentives to stimulate development. The federal government does not seem willing to make the same level of investment to develop alternative energy resources. If Minnesota is to develop its own resources, offsetting incentives will have to be provided to achieve market parity with traditional fuels.

Traditional fuels also receive many hidden subsidies which have yet to appear on anyone's cost accounting sheet. These subsidies include the unpaid (even unestimated) costs of damage from acid rain and the rising CO_2 levels that cause damage to human health, and plant and animal life. These damages are paid for through our medical system or in higher food prices. The benefit to society from reducing these negative externalities is one of the major economic advantages resulting from using renewable energy resources. Yet our current pricing system incorporates few, if any, of these into renewable energy prices, and virtually no effort is being made to do so. With the large direct and indirect subsidies that traditional fuels receive, it is understandable why alternative energy technologies are often found to be "not cost effective."

Several other general issues confront alternative energy development. One is the lack of consistent, accurate data. Data are currently collected on some indigenous energy uses such as wood, hydro, electricity and ethanol, but it is collected by different agencies in different formats. This information is critical if decision-makers, both public and private, are to understand the effects of various policies and programs or to identify unmet needs. Information is particularly needed in the early stages of development of this industry because a quick response to changing circumstances may be needed and progress toward growth must be closely monitored.

Another general need facing alternative energy development is that of monitoring and evaluating alternative energy systems that are now being installed throughout the state. These systems include boiler conversion to wood and fiber fuels, fiber fuel gasification plants, wind conversion systems, methanol production systems, and other similar resource conversion or use systems. For example, a recent survey on wood use in the state, conducted by the Department of Natural Resources, reports that 50 schools and 23 public institutions have converted or are converting their facilities to use wood. However, there has been no systematic evaluation of the cost effectiveness of such conversions, or of other factors that influence their effectiveness. Such an evaluation might show when conversions should and should not be recommended, and what types of problems are being encountered that could be remedied. It might also provide a basis for more accurately projecting the ultimate market potential for such wood use. Other alternative energy applications also remain unexamined, leaving policy makers with little information as to whether current developments are beneficial or not. Residential solar water heating is the only application that has been evaluated sufficiently to know that it is a technology that works in Minnesota and ought to be promoted. If alternative energy is to become a significant portion of the state's energy supply, there must be on-going evaluation of the effectiveness of technology applications so that the industry can continually improve itself.

Product development, technology development and market development are all areas that will need continuing efforts. A key issue will be the degree to which government assists in these activities. For example, state government could promote resource development by converting state facilities to use alternatives. Increased funds could be appropriated for research, development and demonstrations. Efforts could be made to increase marketing, information dissemination and education. Issues involved in all of these efforts are the level of public expenditure that is necessary or appropriate for development of this industry, the need for a comprehensive investment and development plan and the coordination of state government activities. No overall development plan exists, nor is there much hard information on the commercialization paths or potential barriers to development, although the Energy Division is studying the latter area.

There is also considerable fragmentation of responsibility among state agencies. The Department of Agriculture is largely responsible for alcohol fuels development; the Department of Natural Resources is primarily responsible for peat, wood and hydro development; the Energy Division is responsible for district heating, solar, wind, fiber fuels and small power production; and the Public Utilities Commission and Pollution Control Agency both have regulatory oversight in a number of critical areas that influence the development of alternative energy resources. Most financial assistance programs for alternative energy are administered by the Minnesota Energy and Economic Development Authority, although the Minnesota Housing Finance Agency funds passive solar homes and the Department of Economic Security has provided substantial funds in the past for alternative energy business development.

Financing alternative energy development is another important issue. No comprehensive assessment has been done to identify the types of financing needs the various segments of the alternative energy business community have. For example, many of these businesses will be start-ups, and may require venture capital. However, the Minnesota Energy and Economic Development Authority (MEEDA) has no venture capital fund.

Furthermore, although MEEDA has the power to make working capital loans, it has not developed a working capital program, which often is needed in the early years of a business.

Although the Energy Division is currently developing information to permit decisionmakers to establish investment priorities for alternative energy, no framework exists in which to make these decisions. A long range, strategic development plan is needed.

Finally, a general need exists for on-site technical assistance, information, and training to accelerate development issues that need to be sorted out, including the proper role of government in providing such technical assistance. If government has a role, it should be one that enhances the opportunities for technical service providers such as engineering firms. Less clear is the role of the utilities in providing information and technical assistance when many of the recipients will be direct competitors in providing energy.

The following discusses the key issues that relate to specific energy sources.

Fiber fuels (peat and renewable biomass) issues include fuel variability, supply uncertainty, information/data needs, environmental questions

Fiber fuels (peat and renewable biomass) are the largest potential source of indigenous energy in the state. Energy from renewable biomass sources alone could ultimately exceed current total state energy consumption. Yet there are only 26 fiber fuel producers and distributors in the state, and production capacity greatly exceeds demand.

As with all the alternative energy sources, a variety of obstacles stand in the way of industry growth. One such obstacle is the absence of standardized fuel specifications. Potential fuel purchasers are faced with fuels that may vary in terms of moisture, heating value, ash content, durability, and other important factors. Equipment designers also have difficulty designing equipment for varying fuel types. The Fiber Fuels Institute is working to address this problem in conjunction with several state agencies.

A second, less tractable concern is the perception by many potential purchasers of the uncertainty of supply. In this young industry, all companies that start up may not succeed, leaving users who have spent substantial amounts converting their facilities to fiber fuels with no supply. The Energy Division recently received a grant from the Great Lakes Regional Biomass Center to explore the possibility of creating a producers' cooperative to guarantee supplies.

The development of a stronger market also remains an urgent need for this industry. Fuel variability and supply uncertainty combine with other factors such as the capital cost of conversion, lack of readily available information on operation and maintenance of fiber fuel furnaces, and a general lack of awareness of project economies, to create a significant marketing problem. One issue is the role of the state in aiding in the marketing of fiber fuels. This issue is complicated by the conflict it may create vis-a-vis other fuels or efficiency improvements; i.e., how does the state allocate its resources in promoting competing energy sources or investments?

A further barrier to market growth has been the lack of detailed, objective data on the installations that have been made. Some information exists on local successes, but no serious evaluation has been done of the cost/benefit of conversion to fiber fuels; operations, maintenance or design problems; and similar information necessary to improve the technology and accelerate information transfer. Some specific technological improvements are known (such as the potential for suspension burners), but demonstrations of this technology and efforts to promote its u need to be made.

Some environmental questions also need to be addressed. It is not known whether substantial use of fiber fuels will add significantly to air pollution (particularly suspended particulates) as it has in several other states. If so, what sort of pollution abatement strategies will be the most effective? In the area of peat development, considerable information exists on the potential consequences of development. It is now necessary to obtain empirical data from actual development in Minnesota.

Special attention should be given to programs and policies that would aid penetration of fiber fuels used in the commercial/institutional and industrial sectors. As noted earlier in this report, these two sectors are expected to experience dramatic growth in energy demand; 59 percent and 49 percent, respectively. In the commercial/institutional sector, fuel oil use is expected to increase 72 percent and coal use, 400 percent. In the industrial sector, fuel oil use is forecasted to increase 100 percent and coal use, 74 percent. Aggressive efforts now cou shift these projected increases of impo ed, non-renewable fuels to indigenous, renewable bioenergy.

Figure 45 illustrates that almost all biomass fuels, as priced near the supply areas, have positive dollar advantages over the traditional fuels. By the end of this decade, however, the opportunity to prevent this significant increase in fossil fuel use will largely be lost because new plants and equipment using traditional fuels will have been purchased and installed.

Figure 45
1984 Commercial Fuel Price Differentials per Delivered Million Btu at Different Unit Prices of Biomass Fuels

	Fuel Oil	Kerosene	#5 Residual	Natural Gas	Electricity
Wood ($60/cord)	2.36	2.73	−0.76	.17	9.32
Chips ($16/ton)	6.56	6.93	3.44	4.37	13.52
Pellets ($55/ton)	4.66	5.02	1.54	2.47	11.62
Wood ($129/cord)	−5.48	−5.11	−8.60	−7.67	1.48
Chips ($37.50/ton)	3.04	3.41	− .08	.85	10.00
Pellets ($128/ton)	−1.34	− .97	−4.46	−3.53	5.62

Source: Minnesota Department of Energy and Economic Development.

Wind energy development faces issue of buy-back rates; accurate data and market development also needed

Wind is a particularly important source of alternative energy in Minnesota. Like solar energy, it is pollution free and renewable. Because wind energy can be easily converted to electricity, it has substantial potential to reduce acid rain and other pollution from coal fired electric generating plants. These plants burned 87.3 percent of all coal used in Minnesota last year.

Wind energy is also important because it presents Minnesota with the potential for becoming a worldwide equipment producer. Minnesota already has seven wind energy conversion equipment manufacturers, second only to California. This situation is not likely to continue, however, unless Minnesota acts quickly to encourage wind development in the state. Manufacturers may easily move to California or some other state to make a significant commitment to wind development.

At issue is the type and level of incentives the state could make to encourage wind development. Considerable work has been done in the last three years to establish rules (issued by the Public Utilities Commission) for interconnecting with the utility grid and to establish buy-back rates for small power producers. The rules, however, still leave buy-back rates too low to make large scale wind development commercially feasible. Key issues in determining these rates are the proper accounting of social, environmental and economic benefits the state as a whole receives in using wind energy; the type of power displaced (i.e., base, intermediate or peak load); and the specific facility that is displaced (e.g., a future "representative plant" or a plant currently under construction). These issues need to be resolved if wind and other power production from indigenous sources is to occur.

Even if true "full avoided costs" are set for the small power producer, investment is not likely to take place without additional incentives. California, for example, offers a 25 percent investment tax credit for wind development in combination with the 25 percent federal credit. If Minnesota is to encourage both wind installations and the location of equipment manufacturers in the state, it will have to compete directly with other states in terms of incentives. This opportunity will exist for one to three years before major locational decisions have been made.

Another barrier to significant wind development in the state is the lack of accurate data regarding the wind resource. Present knowledge of Minnesota's wind resource is largely based on research done for DOE by Battelle-Pacific Northwest Laboratory in 1980-81. Battelle's preliminary assessment indicates that the western and southern parts of the state have particularly good potential, with average annual wind speeds of between 5.6 and 6.0 meters per second, or 12.6-13.4 mph. However, the Battelle research was of low to intermediate accuracy for 56 percent of the land area in Minnesota. For the entire state, Battelle only had five data points with long term data. Also, anemometer height varied from 4 to 20 meters, which is too low to be very useful for current siting needs.

The Energy Division is undertaking a wind resource assessment program to attempt to fill this gap. Initially, it involves the placement of 15 anemometers loaned to the Division by the Western Area Power Administration. Without additional funding, the program will not be able to cover the whole state.

One of the first major users of wind is likely to be the farmer. A 5 percent penetration of this market would result in the installation of approximately 2,200 wind turbines for a total investment of almost $70 million. If this market opportunity is to be realized, a significant outreach and promotional effort will have to be made.

Hydropower development constrained by competing use and aesthetic concerns

Electricity can also be produced by energy from falling water or generated in conjunction with the production of heat in industrial processes. Recent studies funded by the LCMR indicate that approximately 800 MW of electricity generation could be displaced using industrial cogeneration and 163 MW produced from hydro power by refurbishing existing dams. The same barriers slowing wind development also affect these technologies. In addition, individual businesses face other factors regarding their physical plant and potential for cogeneration.

Hydropower development faces a variety of issues and constraints largely revolving around the use of the water for competing activities. Most hydro development is constrained to "run of river" conditions where holding back the water and releasing it during peak electric times, when prices are high, is prohibited. A significant recent issue is the aesthetics of the flowing water itself, as in the proposed development of the Upper St. Anthony Falls Dam in Minneapolis. Additional barriers are caused by antiquated and complex federal rules, confusing jurisdictions and competing interests.

Solid waste issues focus on need for market development, supply assurances, financing

The desirability of recovering energy from municipal waste has been recognized in Minnesota for some time. However, until now the landfill problem has not been severe enough to provide the needed stimulus for development. In 35 of Minnesota's 87 counties, present landfill capacity will be adequate for less than 5 years. New landfills must be sited or existing sites expanded. New environmental protection standards require clay liners and leachate collection systems on all expanded or new landfill sites. This will mean that fees charged to refuse haulers will double or triple. Higher landfill costs are likely to significantly improve the economic feasibility of proposed waste-to-energy facilities in the eighties.

The total municipal solid waste produced in the state is about 10,000 tons per day. About one-half of this comes from Hennepin and Ramsey counties. Extensive efforts to plan waste-to-energy systems are currently underway in both counties. About 16 communities outside the metro area are in the early stages of considering waste-to-energy systems, and most have already completed waste management assessments. If all of the waste-to-energy facilities presently in the planning stage were built, the total capacity would be about 3,000 tons per day.

Reliable technologies are necessary to minimize investment risk by reducing potential revenue loss from equipment downtime. Given the track record of solid waste systems in Minnesota, more demonstration and research is needed in the eighties to increase the reliability of this technology.

Technical and economic feasibility studies for proposed waste-to-energy systems indicate that revenues from both energy production and dumping fees are needed. Normally, the steam produced is priced near its market value and committed to a single customer. The fee charged for refuse is adjusted to meet the costs needed for economic operation. This requires fees about double that of present landfills. Most of the facilities that have been considered are in the 50 to 100 tons per day size range.

There are two major requirements in designing an economically feasible solid waste-to-energy project: finding a market for a large fraction of the steam that will be produced and obtaining firm commitments for a supply of solid waste. In most cases, it has been difficult to locate an industrial customer that can use all the steam that can be produced. Food processing industries such as dairy or cheese plants are considered good candidates. Steam district heating systems with a base load demand that might be large enough to accommodate a waste-to-energy plant are also a potential market. Several feasibility studies have considered a large space heating load as the market for steam sales.

Development of markets for solid waste heat will be a major challenge in order for this technology to reach its potential. Locating industries near planned waste-to-energy facilities could be an improved method of meeting this challenge. Including electric generation in the project to reduce some of the fluctuations in steam demand (thereby increasing potential profitability) could also be used as a method of expanding markets. Both these options need to be explored and their viability assessed in the coming decade.

For a project to be economically viable, a waste stream must be assured for at least the term of the debt financing. Without an assured supply of waste, no guarantee can be provided to customers for delivery of steam or electricity produced by the facility. One method of waste supply control is to set prices and contractual fees at the facility below the market cost of other alternatives, thus attracting sufficient suppliers to assure a supply. However, the current economics of most projects indicate that fees higher than the market cost of landfills will be required. As discussed earlier, increased need for landfills in the coming decade may force landfill fees above those necessary to make solid waste-to-energy projects profitable.

Long term contracts may be established with waste haulers. Where governmental authorities haul and dispose of solid waste, these negotiations are simplified. In cases where several small private haulers will be involved, long term contracts may not be feasible, thus significantly slowing penetration of this technology.

Another area involved in supply assurance is the state's flow control ordinances. These statutes have proven complex and difficult to comply with. A reexamination of the statutes may be warranted in light of recent attempts to comply with them in order to assure waste stream supplies.

Project financing has also proven to be a constraint on development. Federal and state financing programs tend to be categorical in nature, capable of funding only specific aspects of a project. A developer is faced with developing multiple proposals; i.e., trying to tailor the project to the funding constraints, rather than the funding to the project needs. The availability of financing for multi-faceted waste-to-energy projects should be reviewed to assure that projects are not unduly constrained by financing criteria. Modification of the state's district heating loan program statutes by the 1984 Legislature to allow a much broader range of projects should help alleviate some of these constraints.

Alcohol fuels face investment risk and market development issues

While there are many types of alcohol, two are most often considered for fuel use. Ethanol, or ethyl alcohol, is made by a biological fermentation process from sugars or starches. It can also be made from cellulose through a more complicated process not yet commercialized. Methanol, or methyl alcohol, is made through a thermochemical process from coal, peat, any type of biomass or, as is currently most common, natural gas. Most fuel ethanol is currently made in large wet milling corn processing plants centered in Illinois. There are five small commercial ethanol plants in Minnesota using dry milled corn and cheese whey. Most fuel methanol is now made in large chemical plants from natural gas. There is one operating coal methanol plant in Tennessee and a peat methanol plant under development in North Carolina. No methanol is currently produced in Minnesota.

Fuel ethanol and methanol are most commonly used as gasoline octane boosters. Both may be used straight in modified spark ignition engines. Future uses may include fuel cells for electricity.

Two significant problems are now inhibiting development of an extensive alcohol fuels industry in Minnesota. First, although the technology for producing methanol and grain ethanol is well developed, it is very capital intensive. Income streams from this resource are also uncertain because the price of oil, its primary competing fuel, has fluctuated widely in the recent past and is likely to do so again in the future. Thus, the risk of investment in methanol and non-grain ethanol plants is very high.

Furthermore, the use of grain for ethanol competes directly with the use of grain for food. Total grain stocks are small when compared to the nation's demand for liquid fuel. Thus, the cost of grain for feedstock would be driven up if significant production of ethanol developed, thereby increasing the uncertainty of cost estimates. This situation makes grain ethanol production an even greater risk than methanol production.

The other major barrier for development of an alcohol fuels industry is the current lack of a market for the product. Methanol and ethanol are currently us as additives for gasoline. However, cars may be run on straight ethanol or methanol with certain modifications. Specifically, cars that operate on methanol must have stainless steel or plastic tanks and must have carburetors adjusted for the new fuel. Currently, auto makers are not designing cars with these modifications, thereby limiting the market for these fuels.

In the coming decade the issues of investment risk and market development for alcohol fuels must be addressed in order for significant progress to be made. Risk may be reduced by offering price or financing incentives, or by conducting demonstration projects to refine technologies. Development of markets may also be facilitated by demonstrating adaptations of the technology and communicating the advantages of the fuels to potential users.

Solar energy specifics still unfamiliar to most— information needed

Though all renewable energy sources derive their energy from the sun, "solar energy" refers to the conversion of sunlight directly into a more useable form of energy. The two common technologies are solar thermal energy conversion for heating applications, and solar electric energy conversion for generating electricity.

Solar thermal development is one of the most mature of the alternative energy industries in the state. Approximately 200 businesses in the state do all or part of their business in solar energy. Yet despite its prevalence, the commercialization of solar thermal applications still faces a number of problems.

First, the use of solar energy is still unfamiliar to most people, particularly regarding specific applications. Consumers are not familiar with initial costs, operation and maintenance requirements, expected performance, and dollar savings. Information received from solar dealers and others is often contradictory. There continues to be a need for accurate, objective information regarding solar, specific on-site evaluations for potential applications, and marketing similar to that needed for other alternative energy technologies.

The need for customer assurance on quality of equipment and installation also continues to restrain development. This is being addressed by the implementation of a state solar certification program, which requires that solar collectors must be certified by the State of Minnesota in order to be eligible for the 20 percent state tax credit. In addition, the Minnesota Solar Guild (the industry association) is developing an installer training and certification program that will enable consumers to hire industry approved installers.

Most solar applications in Minnesota have been in residential buildings, with some commercial applications. However, a significant potential exists for industrial process applications where high heat loads exist; e.g., paper and food processing. Demonstration and promotion of these applications will most likely be needed to stimulate industry awareness of this solar use.

An emerging solar application with enormous future potential is the direct conversion of sunlight into electricity using photovoltaic cells. The cost of photovoltaic equipment has dropped dramatically in recent years, from $35 per peak watt to a current cost range of $5 to $7 per peak watt. Lower costs are projected in the near future.

Although photovoltaic applications in Minnesota may be limited for some years because of costs, this high-tech growth industry would be an attractive candidate for development in Minnesota. Like wind electric conversion equipment, photovoltaic equipment has a worldwide market. Despite its cost, decentralized photovoltaic conversion may be attractive to developing countries that have areas where no electricity generation or distribution infrastructure exists. The issue for Minnesota will be if, how, and to what extent it wishes to encourage the development of a photovoltaic industry here.

Conclusion

Obviously, the state must address many issues in the coming decade to ensure the development of alternatives and continuing energy efficiency in the residential, commercial/institutional and industrial sectors. To recap,

- we must foster and protect our infant alternative energy industries in order to offset 20 years of subsidies to traditional fuels and to gain the economic benefits of developing comparative advantage in these industries;
- we must ensure clear and direct price incentives for conservation investments in the commercial/institutional and industrial sectors by incorporating the value of conservation improvements into the value of buildings and rents; and
- we must ensure the performance of conservation investments and improve rental property efficiency in the residential sector by developing and expanding research, information and regulatory efforts.

It is not yet clear if we have learned from the experience of the Arab oil embargo and following decade of consequences, or if the temporary glut of oil and gas has lured us into complacency. If we confront the impediments to full investment in conservation and alternative energy technologies, the future can hold significant opportunity for energy cost savings, growth in employment, and economic development. If we ignore the problems, we are left to face an uncertain future fraught with the dangers of energy disruptions, environmental pollution, and price escalation.

No one institution can make the decision to embrace or reject the lessons of the past decade. Rather, it will be made through the actions of literally millions of groups and individuals. The Energy Division urges all Minnesotans to review, discuss, debate, and—most importantly—to act on the data, analysis and recommendations presented in this report.

Public Comments

Comment

The biennial report should include a discussion of the transportation and agricultural sectors in the Recommendations section, and in the Issues of the coming decade chapter of the section, Ten Years After the Oil Crises: Lessons for the Coming Decade.

Response

The Energy Division agrees with commentors that these sectors are vitally important to Minnesota's current and future energy use, as noted in the discussion of these sectors in the chapter, Historic Minnesota consumption trends. Reflecting this policy, the Department provided more than $400,000 in oil overcharge funds to programs targeted toward these sectors in 1984.

Historically, the Department of Transportation and the Department of Agriculture (the two state agencies with substantive responsibility for these sectors) have maintained information about and delivered programs promoting energy efficiency in these sectors.

These two Departments, in conjunction with the Federal Department of Transportation and the Agricultural Extension Service of the University of Minnesota, have conducted the following major programs and initiatives to promote energy efficiency in the transportation and agricultural sectors:

- mandatory automobile fuel efficiency standards
- the 55 mph speed limit
- Minnesota Rideshare program
- promotion of conservation tillage

The Energy Division has supported these efforts in the past and will continue to support such programs in the future.

Question

What is the Division's position on the use of compressed natural gas (CNG) as a substitute for petroleum products in the transportation sector?

Answer

The Division does not oppose the use of CNG as a substitute for gasoline or diesel fuels for fleet vehicles. CNG appears to be a cost effective substitute for gasoline in some fleet applications. The Division finds that if all Minnesota fleet vehicles were to convert immediately to CNG, they would consume an additional 22.2 billion cubic feet per year, increasing the state's 1983 gas consumption by 9.3 percent. (It is unlikely that all fleets would be appropriate for conversion. Since there are few pumps outside the metro area, fleets traveling beyond the Twin Cities on a regular basis would have to rely on gasoline or diesel fuel, thus reducing the cost effectiveness of the conversion.) Since the utilities expect a market penetration of only 5 percent per year, the consumption increases would be negligible. In the short-to-medium run, with both utilities and Northern Natural operating well below capacity, increased throughput will reduce the fixed cost-per-unit to all customers.

However, the Division does not believe there is need for government to actively promote these conversions. Ultimately, natural gas is a depletable natural resource. Proven reserves of natural gas would last only 11 years at current rates of production. This is very similar to the level of crude oil reserves, which would be depleted in 9 years at current rates of production. Furthermore, as discussed on page 46, domestic natural gas reserves are declining. Increased natural gas demand simply depletes those reserves more quickly, leading to more dependence on expensive and uncertain foreign imports of either natural gas or petroleum products.

While CNG conversions may be cost effective for individual fleets, they do little to stimulate the overall economy because natural gas, like petroleum, is imported into Minnesota. As a result, government support of such conversions cannot be justified for economic development purposes.

Thus, use of natural gas as a substitute transportation fuel does not markedly improve the security of Minnesota's energy supply or meet the state's larger economic development goals. Therefore, it is the position of the Division that decisions to convert to CNG as a transportation fuel should be left to the marketplace.

Question

Are fiber fuels being measured with the same environmental yardstick as traditional fuels?

Answer

Yes. Current regulations governing emissions are the same regardless of fuel type. Environmental issues associated with large-size facilities (i.e., air quality impacts, collection and disposal of ash, and pollution control equipment) can be adequately addressed through the existing permit review process and in some cases, the environmental review process. However, in many cases fiber fuels will be utilized in smaller facilities that are not large enough to require a permit.

The Energy Division has initiated studies to determine whether emissions from these smaller facilities might become an environmental concern. Work in this area includes a project to test emissions from medium sized boilers in schools, a peat burn test at Virginia, and a project to establish fiber fuels standards, incuding ash and sulphur content analysis.

If the test results indicate a possible need for emission abatement, the Division will work with the industry and appropriate state agencies to assure that the use of fiber fuels is consistent with the state's standards for environmental quality.

Question

How much has the federal government subsidized development of traditional fuels and why?

Answer

Government has been deeply involved in stimulating the development of new energy sources since early in this century. For the period 1918 to 1977, the federal government expended $217.4 billion through a variety of incentives to encourage energy development. (See Figure 46.) Oil has received the largest share of subsidies; almost half of all those provided. Electricity ranks second, with roughly one-fourth of all subsidies.

There were two primary reasons for the subsidies:

- First, to enhance reliability of supply. This occurred particularly with regard to oil where subsidies were viewed as necessary to maintain a domestic production capacity in case of supply disruptions.
- Second, to serve as an economic development tool. Heavy subsidies to hydropower and the distribution of electricity to rural areas were instituted primarily to stimulate economic development.

These subsidies have not been distributed evenly throughout the nation. States in the Northeast and Midwest have not received a proportionate share. Federal taxes from these states go in part to subsidize energy development of traditional fuels, which in turn are given a severance tax when they leave the producing state that the energy "have not" states must pay again.

Energy conservation and renewable energy sources must often compete without subsidy against traditional fuels. This is viewed as the "free market" condition. New energy sources, however, are placed at a severe economic disadvantage because of the massive subsidies to traditional fuels. A free market does not cur-

Figure 46
An Estimate of the Cost of Incentives
Used to Stimulate Energy Production

	Nuclear	Hydro	Coal	Oil	Gas	Electricity	Total	Percent of Total Incentives
Taxation		1.80	4.03	50.4	16.04	31.37	103.64	47.7%
Disbursements				1.1			1.10	0.5%
Requirements	1.1	.03	.67	41.9	.06		43.76	20.1%
Traditional services			2.31	6.0		.48	8.79	4.0%
Nontraditional services	15.1		2.68	1.5	.30		19.58	9.0%
Market activity	1.8	13.50[a]	.02	.4	.10	24.73[a]	40.55	18.7%
Totals	18.0	15.33	9.71	101.3	16.50	56.58	217.42	100.0%
Percent of total incentives	8.3%	7.0%	4.5%	46.6%	7.6%	26.0%	100%	

[a]This value based on incentive definition 1 (Federal money outstanding).

Source: An Analysis of Federal Incentives Used to Stimulate Energy Production, Executive Summary, U.S. Department of Energy, December 1978.

rently exist with respect to energy, to the extent that true costs are not being reflected in the market. Unless this situation is corrected, traditional resources will be used inefficiently, and conservation and renewable sources of energy will remain underdeveloped.

Abstracts

Analysis of the Future of Canadian Natural Gas Exports *(Comments submitted to the Economic Regulatory Commission, August 1980)*

Canadian exports of natural gas will be a secure source of supply for American pipelines in the future. The reason is that such exports are in the best interests of the Government of Canada and the Canadian energy industry.

First, export sales provide both the government and the industry with revenues needed for a number of energy related tasks. Since domestic oil production will be declining, oil imports will rise and revenues will be needed to pay for them. Export revenues have also been an important source of funds for drilling programs. Finally, revenues will be needed to finance Canada's future energy "megaprojects," including gas delivery projects from Canada's arctic areas and synthetic fuel plants.

Regarding future supplies, Canada's gas reserves are large and growing; the country's reserve/production ratio is about four times that of the United States. Additional supplies present in frontier areas in Canada's arctic region will be added to reserves as new pipelines are built.

Canadian forecasts of future domestic demand have been lowered in recent years. In particular, the government's forecasts of demand from areas in eastern Canada, where natural gas pipelines have not yet been extended, are too high. Heavy fuel oil will retard penetration of gas in the industrial sector. The eastern provinces do not have the financial strength to subsidize gas prices as Alberta did in order to stimulate demand. The transition to gas is likely to be more gradual than projected by the government, thereby increasing potential supplies for export.

Assessment of Industrial Cogeneration Potential in Minnesota

The goal of this study was to estimate the potential for electric cogeneration by Minnesota industry. The study consisted of two phases. In Phase I, cogeneration potential was estimated for possible technologies with and without regard for economic factors. In Phase II, a detailed survey of the best 31 sites in Minnesota was conducted.

Estimates of industrial cogeneration potential were made by determining the amount of electricity that could be produced by each of several technologies, given the amount and characteristics of thermal energy used by Minnesota industrial plants. Standard Industrial Classifications and Minnesota Development Regions were used to estimate the potential electricity that could be generated by cogenerators and the number of possible cogeneration sites. In addition, incremental industrial fuel use, net fuel savings, and capital costs were estimated for several cogeneration scenarios.

In Phase II of the study, 31 industrial sites in Minnesota were surveyed for current and potential electric cogeneration potential. The plants surveyed were separated into the following categories: food, paper, and all other industries. This allowed boiler size, age, electric requirements, anticipated energy use, and financial decision criteria to be compared. The sites were evaluated using a heat balance model for a steam turbine cogenerator system. Capital and fuel costs were estimated, and with the aid of a computer model, investment potential was analyzed for each facility.

An in-depth preliminary feasibility study of a refined gas turbine cogeneration cycle was conducted as an example of new technology that could be applied to Minnesota industry. The site selected for the analysis was the Duluth campus of the University of Minnesota.

The major conclusions drawn from the findings are:

- Existing cogeneration facilities represent the largest source of additional cogenerated electricity in Minnesota. During the survey year, an additional 706,832 megawatt hours of electricity could have been produced with existing turbine capacity, representing approximately 2 percent of electricity sales in Minnesota.
- The potential for electrical generation from steam turbine cogeneration systems by currently non-cogenerating sites was estimated to be 263,800 megawatt hours annually, which represents less than 1 percent of sales of electricity in Minnesota.
- The development of low cost sources of financing will make cogeneration more attractive at undeveloped sites.

Bioenergy in Minnesota: Fiber Fuel Development and Fuel Resource Survey *(December 1982)*

This report examines the production and use of fiber fuels as a source of energy in the Taconite Relief Area of northeastern Minnesota.

A market profile examines three variables associated with a building's heating or energy system: the type and cost of fuel currently used, the annual fuel consumption, and the age of the fuel user's existing heating system. From this examination, an indication of the fuel user's potential interest to utilize fiber fuels can be determined. Segments of the market from which this information was collected include schools, municipally owned buildings and commercial/industrial establishments. The data is presented for 85 percent of the schools in the Taconite Relief Area. A total of 20 of these schools have been chosen to be considered for conversion to a fiber fuel. Data collected from municipal buildings and commercial/industrial establishments was incomplete. A more comprehensive survey is needed from these sectors to determine their impact on the fiber fuel market.

The production profile of this report shows that wood and peat have potential for providing the area with a low cost fiber fuel. The annual supply of wood for fuel use is estimated to be an amount equivalent to 145 million gallons of distillate fuel oil per year. This wood is available from the residues generated from forest lands and from the wood processing industry. The development and utilization of peat is in the early stages of development. The available resource will depend on the mining technologies used and on additional environmental, economical and sociological considerations. Fiber fuels are densified in order to obtain a fuel that is compatible with conventional combustion equipment. The final product is a uniformly sized fuel containing about 10 percent moisture. Currently, two densification plants in the Taconite Relief Area are together capable of producing 100,000 tons of fiber fuel annually. Selling price for this fuel is $41 to $52 per ton.

The fiber fuel user is usually faced with higher capital investment costs and operating costs when compared to a natural gas or fuel oil user. Therefore, the fiber fuel must be made available at a low cost per unit of energy compared to the other two fuels so that the higher investment and operating costs can be economically justified. At this time, the capital investment required for an installed fiber fuel system designed for an average size school can range from $40,000 to over $300,000. The lower cost is possible when existing combustion equipment is retrofitted to burn fiber fuels. The higher investment would be typical of a system designed to burn a non-uniform fiber fuel that contains over 50 percent moisture. Densified fiber fuels can be substituted for coal in existing coal fired boilers with a minimum of equipment modifications and cost.

Other factors that influence the decision to use fiber fuels are the requirements for handling, storage and transportation of the fuel, space limitations and the minimum acceptable return on investments.

Bioenergy in Minnesota: The Peat Special Energy Project (*Final Report to the LCMR, June 1983*)

This report summarizes the development of the Bioenergy Research Project and the status of the Virginia Peat Test Burn Project. In 1981 the Legislative Commission on Minnesota Resources (LCMR) allocated $56,300 to the Energy Division to revise a proposal for research relating to the use of peatlands and other wetlands for energy production. Some of these monies, $10,000, were eventually used to partially fund the Virginia Peat Test Burn Project.

Development of the Bioenergy Research Project began in July 1981 with a revision of the original proposal. The proposal was subjected to a series of reviews by the Interagency Peat Task Force (IPTF), which resulted in the final proposal that was presented to the LCMR in June 1982. Other activities included in the development efforts were a media campaign to promote the bioenergy awareness in northern Minnesota, a public awareness survey, a series of public input meetings, and a project to map available peatlands (conducted by the Department of Natural Resources). Major project objectives include: continuing research on production of emergent aquatic and woody biomass, development of a cattail harvester, and the economic evaluation of production systems. The final proposal was funded for $300,000 by the LCMR. The work outlined will occur over the next biennium (1983-1985).

The Virginia Peat Test Burn Project was initiated in late 1981. Field testing began in late 1982 and will be completed in late 1983. The major objective of this project is to evaluate the performance of peat relative to coal when used as a boiler fuel. This objective will be achieved through determination of 1) maximum steaming capacity, 2) boiler efficiency, 3) furnace emissions (gases and particulates), and 4) other operational characteristics, such as those relating to fuel and ash handling, storage, etc. Preliminary results indicate that particulate emissions are similar for both coal and peat. Efficiencies for both fuel types are comparable, although coal does achieve higher steaming capacities.

Cold Climate Solar Design

In 1978, the Energy Division sponsored a housing design competition and offered awards totaling $85,000. The purpose of the competition was to encourage the design and construction of energy efficient homes. The entrants were challenged to develop a system that achieved a balance between the dwelling and the environment to produce a model of energy efficiency. The goals for each residence were to use a minimum amount of energy, rely on natural and renewable sources for this energy, and use all energy as efficiently as possible. Entrants were to illustrate innovative energy conserving ideas that synthesized the natural energy available in the environment (such as heat from the sun and the cooling effects of the earth) with the energy needs and fuel using systems in the dwelling.

This book is a compilation of the 25 first-phase winning designs. It shows floorplans and energy calculations, and explains the analytical approach taken by the entrants to develop their energy efficient systems. The book also provides a historical look at the evolution of energy efficient housing design that appeared in the late 1970's.

The Cost Effectiveness of the Minnesota Weatherization Assistance Program

This study uses data collected by the engineering firm of Bakke, Kopp, Ballon and McFarlin, Inc. on 306 houses weatherized by the Minnesota Weatherization Assistance Program (WAP). All 306 houses were heated by natural gas to assure accurate measurement of energy consumption.

The study found that post-weatherization consumption was 14.5 percent lower than pre-weatherization consumption. The cost of materials for the average house was $371 and total cost was $1,060. Using these cost and savings estimates, the total sample yielded an internal rate of return (IRR) of 13.8 percent and a net present value (NPV) of $920 per unit weatherized. (Savings for the total sample was estimated using the weighted average price of fuels for all WAP assisted homes.)

Weatherization of multi-family dwellings yielded the highest return per dollar invested of the three housing types, achieving an NPV of $1,706 per unit and an IRR of 24.1 percent. In contrast, mobile homes had an NPV of only $215 per unit and an IRR of 6.3 percent. With the weatherization techniques used at the time of the study, investment in mobile homes was not as cost effective as other weatherization investments. Cost effectiveness for various levels of investment in materials was also calculated. Higher levels of investment yielded lower rates of return, declining from an IRR of 19.5 percent for weatherization with materials costs of less than $200 to only 4.9 percent for weatherization with materials costs of greater than $600.

In general, the cost effectiveness indicators for natural gas heated homes was lower, because natural gas is less expensive than other home heating fuels. This group had an IRR for weatherization of 8.4 percent and an NPV of $432 per unit. The IRR for mobile homes was less than 3 percent and the NPV was negative. This indicates that weatherizing mobile homes heated with natural gas is not cost effective. The IRR and NPV for material costs of more than $600 indicate that such levels of investment in natural gas heated homes were also not cost effective.

Development of a Wind Resource Assessment Program

This report presents results of wind speed monitoring to date in Minnesota, outlines a Wind Resource Assessment Program (WRAP), and discusses the potential market for wind generators in the agricultural sector.

Average wind speed is reported by month for 1982 and early 1983 from ten sites, nine of which are in southeastern Minnesota. The best site was the Rochester airport, which had monthly averages as high as 17.8 mph and an annual average of 14.0 mph. Eight Anemometer Loan Program sites were marginal, with monthly averages ranging from 5.3 to 10.0 mph at a height of 30 feet. These averages are better when the power law is used to extrapolate up to a height of 80 feet; however, reliability of the power law is questionable. The tenth anemometer was 60 feet above a tailings pile at Calumet. Monthly wind speed averages there ranged from 8.0 to 11.1 with a 13 month mean of 9.9 mph.

The proposed Minnesota WRAP would be a cooperative effort involving Western Area Power Administration, Western's customer utilities, and the Energy Division. In order to avoid using questionable height extrapolation techniques, anemometers in this program would be mounted at the 100 foot level on utility owned microwave towers. Fifteen-minute wind speed averages would be recorded on tapes that are changed and "read" on a monthly basis. This proposal includes using information from UPA and NSP wind programs as well as WRAP to build a Minnesota Wind Data Base.

The agricultural market penetration scenario looks briefly at economic impacts in terms of wind industry sales, resultant economic output, and representative energy revenue for 5, 10, 25, 40, and 60 percent penetration. A 10 percent market penetration could mean $134,490,000 in sales to the wind industry, a resultant ·onomic output of $313,360,000, and .1,655,800 in representative energy revenue from annual wind produced electric energy.

An Economic Short-run Equilibrium Model of Investments in Energy Conservation

This report studies the economic value of making investments to conserve energy. The report presents an economic model to provide theoretical support to the assertion that: An investment in an improvement in energy efficiency is cost effective if the total money saved in energy costs during the life of the improvement exceeds the total investment cost. The model assumes a perfectly competitive, short-run equilibrium for an item that uses energy as an input. The model also assumes a change in the efficiency level of the energy input. A comparative static analysis of the market equilibrium of the energy using item is then conducted to determine the derived demand for energy and to assess the impact of the improvement in energy efficiency on energy use.

The report reveals that, all other factors ·maining the same, an increase in energy .ficiency reduces the price of an energy using item. In this case, the percentage increase in the quantity demanded of the item should be less than the percentage decrease in its price in order for an increase in energy efficiency to reduce the demand for energy. However, the only guarantee realized from meeting this requirement is that the improvement in energy efficiency will result in savings in energy and energy costs. Therefore, the requirement that the percentage increase in the quantity demanded for an energy using item should be less than the percentage decrease in its price is a necessary but insufficient condition on which to base investments in improvements in energy efficiency.

An economic formula is derived to calculate energy savings from improvements in energy efficiency. This formula takes into account the variability of demand for the energy using item. This formula also provides a basis to use to adjust engineering estimates of energy savings, given that those estimates implicitly assume that the demand variability is zero. Finally, ·e analysis provides formulas to deter-..ine alternative cost effectiveness indicators such as real and nominal internal rates of return, true and simple paybacks, benefit/cost ratios, and the annualized investment cost per unit of energy saved. These indicators may be used to ascertain whether a specific energy conservation measure will yield an energy cost savings that, over its life, exceeds its investment cost.

The Economics of Alternative Energy Resources and Technologies in Minnesota

A series of five reports (discussed below) were written for the Legislative Commission on Minnesota Resources as separate reports, but have been published as a single package. The macro-economic impacts report, presented first, represents the culmination of the series and the statement of broad, economy-wide impacts. The incentives report is presented next as a review of possible programs that state government could implement to realize the beneficial impacts of alternative energy development. The incentives report includes an evaluation of the effectiveness of some alternative energy incentives. The final three reports presented are the residential, commercial/industrial, and utilities reports. These reports provide background information for the macro-economic impacts paper, as well as reference information on alternative energy resources and technologies in Minnesota.

1. Economic Impact of Alternative Energy Development in Minnesota

This report describes, for a set of three scenarios, the potential economic impact of alternative energy development on the Minnesota economy. In the most optimistic scenario, alternative energy development could result in an additional $4.5 billion in gross state product, $3.7 billion in personal income, $200 million in state tax revenues, and 151,000 jobs in the year 2000. All monetary amounts are in 1983 dollars. To realize all or part of this potential, the substantial barriers to alternative energy development would have to be reduced or eliminated.

2. The Effectiveness of Government Incentives to Alternative Energy Development

This report presents a rationale for government incentives to alternative energy development and relates that rationale to five types of incentives available to government: targeted incentives, direct regulation, incentives based on energy saved, non-targeted incentives, and conventional fuel taxes. The effectiveness of the major incentives now in use by state governments is tested by using active solar residential hot water installations data that is available from Minnesota and other states. The results suggest that state income tax credits, sales tax exemptions, and grant or loan programs are effective. Increases in conventional fuel (i.e., natural gas) prices through taxation or other means also appear to be effective incentives.

3. Costs and Benefits of Residential Alternative Energy Conversion

This report describes the costs and benefits of residential alternative energy resources and technologies. Residences that use fuel oil or electricity as heating fuels are more likely to find alternative energy technologies that are cost effective than are customers with natural gas heating. Generally, the most cost effective alternative energy technologies are passive solar/superinsulation, direct burning of free wood or biomass, and manure digestion on large feedlots. These are followed by active solar, direct burning of wood or biomass pellets that cost $2 to $4 per million Btu, and wind energy in some parts of the state. Liquefaction to ethanol does not appear to be cost effective, but may be feasible for individuals who can take advantage of tax benefits and subsidies.

4. Costs and Benefits of Commercial/Industrial Alternative Energy Conversion

This report identifies several cost effective alternative energy technologies for commercial and industrial applications. Conversion of solar energy for commercial/industrial applications appears to be cost effective compared with kerosene, #2 fuel oil, LPG (propane) and electricity. Conversion of wind energy to electricity can be cost effective compared with conventionally available electricity. Direct burning of biomass can be cost effective compared with all conventional fuels except coal. On-site gasification of biomass for businesses and industries already owning gas or oil burning equipment is cost effective compared with natural gas, LPG, #2 fuel oil and residual oil. Biomass liquefaction to methanol can be cost effective compared with gasoline, and with #2 fuel oil and kerosene. Liquefaction to ethanol does not appear to be cost effective at this time.

5. Costs and Benefits of Alternative Energy Conversion by Electric and Natural Gas Utilities

This report assesses the costs and benefits of alternative energy conversion by electric and natural gas utilities in Minnesota. Hydropower at specific existing dams and wood residue combustion at existing coal-fired electric power plants are identified as cost effective based on direct costs alone. A major economic disadvantage of utilities relative to other businesses involved in alternative energy conversion is that utilities are not eligible for energy investment tax credits. In addition, utilities compare the cost of alternative energy with the production cost of conventional energy, while utility customers compare alternative energy costs with end-use conventional energy costs, which are greater. A comparison of this report with other reports in this series reveals many more alternative energy options for utility customers than for utilities themselves.

Electric Capacity Situation in Minnesota

This paper addresses concerns about excess generating capacity and the faltering taconite industry in Minnesota. The Mid-Continent Area Power Pool (MAPP) region currently (as of the date of the report) has over 40 percent reserves, compared to a 15 percent minimum reserves required by the electric utility industry.

The present analysis leads to three main conclusions. First, reasonable future performance levels of the taconite industry will not affect the statewide electric capacity situation nearly as much as the uncertainty in future levels of demand. Uncertainty about future economic growth, conservation improvements, and substitution effects will affect future load growth to a much greater magnitude. Since Minnesota Power and Light Company provides electric service to the taconite industry, the utility will experience excess capacity in the 1980's. This excess capacity situation could be intensified further when Sherco 3 comes on line in the late 1980's and by lower growth in electric requirements by the electric cooperatives.

The second conclusion is that Minnesota will not experience excessive reliance on expensive oil and gas fired generating capacity in this century, thus benefiting the state's electric consumers. The present ample capacity situation, low growth rates in demand, and anticipated capacity additions all contribute to avoid undesirable reliance on oil.

In order to address the question of whether present or planned capacity levels are costly to consumers, the state's generation mix must be considered. Increasing reserve margins may be appropriate if the addition of generating capacity benefits electric customers (and society) through displacement of expensive generating capacity or through decreases in environmental degradation.

The third conclusion is that Minnesota will continue to have sufficient electric capacity up to the late 1990s. It is probable that electric imports from Canada will continue beyond 1993 and that additional hydro capacity in Canada would be made available to serve Minnesota and neighboring states.

Electric Utility Forecasts 1977-1981: A Report on the Effects of Reduced Forecasts of Demand on Minnesota's Need for New Power Plants

This report documents electric utilities' annual peak demand and sales forecasts and shows how these forecasts have been substantially reduced. It correlates the reduction in peak demand forecasts to a large decrease in anticipated need for new power plants and compares the utilities' forecasts with those of the Energy Division.

Since 1977, electric utilities serving Minnesota have made 14 one-year forecasts for summer and winter peak of electrical demand. During the five years studied, the most significant characteristic of the utilities' projections has been a consistent year-to-year reduction in forecasted demand. Minnesota utilities projected a need for 6,472 megawatts less capacity in 1981 than projected in 1977.

Energy Code Comparison Paper—The 1984 Minnesota Energy Code Compared to the 1978 Code

This paper is a point-by-point comparison of the new 1984 Energy Code with the now outdated code that was in place since 1978. The paper has been written in language more "readable" than the code rules. All parties who order copies of the Minnesota Energy Code from the State Documents Center will also receive a copy of this comparison paper.

The Energy Efficient Buildings Program Needs Assessment

The Energy Division conducted this needs assessment in 1981 to provide a better understanding of the decisions that determine the energy efficiency of new buildings and of how those decisions may be influenced. People from 11 target groups were questioned to determine:

- present practices in new building design and construction to achieve energy efficiency
- the barriers that prevent increased use of energy efficient design and construction techniques
- the types of information needed to advance the use of energy efficient techniques
- the most effective delivery mechanism that could be used to provide that information to the different audience groups

The 11 target groups surveyed were: architects, HVAC engineers, insulation contractors, lumberyard estimators, general contractors, residential developers, commercial developers of property for sale lease, commercial developers of prope for self-occupancy, residential owners of new homes, commercial lighting designers, and building code officials.

Evaluation of the Minnesota Mini-audit Program

This study was prepared by Lynn B. Olsson, P.E., and Tom Schubbe, in May 1982. It is a study of institutions that had mini-audits performed to determine the quality of the original audit, the level of implementation on the part of the institution and the result of that audit, and perceptions and attitudes of the institutional staff regarding the original audit.

A mini-audit is a brief walk-through energy survey by a certified auditor and maintenance staff of the facility to identify low and no cost changes in the operation and maintenance procedures at the building to save energy.

The researchers analyzed 110 previously audited buildings, each randomly chosen from Energy Division files. The sample consisted of 39 school, 30 hospital, and 41 local government buildings—all audited during the fiscal year July 1979 to Ju 1980. Energy use at each was examined for the fiscal year before and after the audit to confirm the savings due to implementing energy conservation measures. As a part of the study, each building was reaudited by a mechanical engineer using standard engineering procedures and calculations to establish an optimal or benchmark audit. This was used to evaluate the original audit and to verify the implementation of action recommended in the original audit. The engineer also administered a brief survey to a staff member at each site to assess attitudes toward the original audit process.

The table below shows the percentage of measures in the benchmark audit that the mini-auditor recommended in the original audit—a measure of the quality of the original draft. The table also shows the percent to which institutional staff implemented measures recommended in the original audit.

Building Type	Audit Quality	Level of Implementatic
Schools	59.1%	50.0%
Hospitals	63.3%	45.9%
Local Governments	52.4%	38.5%

The results of the questionnaire showed 80 percent of the respondents were satisfied with the original audit, 42 percent indicated energy conservation actions moderately increased as a result of the audit, and 15 percent said the audit resulted in significant increases. Lastly, the study showed that these actions resulted in measurable reductions in the energy consumption at the facilities.

The following table shows the annual energy consumption (adjusted for the effects of weather) before the audit and the average reduction in energy use as a result of conservation actions in the buildings.

particular, deregulating "old gas" (gas from wells drilled before April 1977) could add hundreds of millions of dollars to Minnesota's gas bill with no appreciable offsetting gain.

The Energy Division's own analysis of the effects of accelerated decontrol show a significant redistribution of income from labor and non-gas-related capital sectors to gas-related capital. In addition, both inflation and unemployment would be higher than under the NGPA scenario. Gas supplies, after increasing for the first three years after accelerated decontrol, would be lower than under the NGPA for the next twelve years.

Building Type	Energy Consumption Before Audit (1978-79) MBtu per ft^2	Energy Consumption After Audit (1980-81) MBtu per ft^2	Percent Reduction
Schools	116.0	104.4	9.9%
Hospitals	298.4	273.6	8.3%
Local Governments	141.7	131.4	7.2%

In reaction to these problems, the Federal Energy Regulatory Commission (FERC), the agency charged with regulating gas markets, has abdicated its statutory responsibility to protect natural gas consumers from unreasonably high gas prices. In particular, FERC's interpretation of the "fraud and abuse" standard of the Natural Gas Policy Act is so narrow as to virtually assure pipelines that all gas purchase costs will be passed through to consumers.

The FERC has the statutory authority to deal with these questions. One way of curbing gas purchase abuses would be to make the pipelines' rate of return dependent on its avoidance of load loss (due to the purchase of expensive gas which makes its average supply cost uncompetitive). Such a market based mechanism would give pipelines a strong incentive to reduce their gas costs while permitting them flexibility to determine exactly how this can be accomplished.

Field Study of Thirty-five Houses in the Minnesota Weatherization Program

A field study was conducted of 35 weatherized houses in which energy use before and after retrofit had previously been analyzed. The study included blower door testing, infrared scans, and occupant questionnaires. Results of the study indicate that: 1) attic bypasses are a frequent problem, 2) although the quality of insulation in houses weatherized under the Weatherization Program was not always perfect, fewer voids were found than in houses insulated by private contractors, and 3) the infiltration rate of a house may be a factor in the temperature at which the occupants set their thermostat. Analysis of the apparent high and low energy savers indicates that these cases are frequently a result of factors other than weatherization, such as extended periods away from the home or changes in appliances.

Impact of the Natural Gas Policy Act on Current and Projected Natural Gas Markets (*Comments submitted to the Federal Energy Regulatory Commission, August 1982*)

Accelerating the decontrol of gas prices at the wellhead in advance of the January 1, 1985, date set by the Natural Gas Policy Act (NGPA) will have a severe negative impact on Minnesota and the nation. In

Accelerated decontrol is not needed to avoid a large price "spike" in 1985. Gas prices have risen faster under the NGPA than had been anticipated. Conversely, oil prices (the deregulated gas price is assumed to be about 70 percent of the cost of crude oil) have fallen drastically. There is very little "gap" to be closed.

Finally, proponents of accelerated decontrol cite the possibility that, with old gas prices remaining under controls, pipelines with large amounts of old gas, and hence lower average costs, will bid higher prices for decontrolled gas, thereby denying those supplies to pipelines with a smaller old gas "cushion." Evidence based on current purchases of deregulated gas, however, do not bear out this theory. Less deregulated gas has been purchased, and at a lower price, by pipelines with large old gas cushions.

Inquiry into Purchasing Practices of Interstate Pipelines (*Comments submitted to the Federal Energy Regulatory Commmission, June 1983*)

Natural gas markets are in obvious disequilibrium. There is a glut of gas supplies and demand has dropped, yet prices have not fallen. Pipeline companies are trying to modify the terms of past contracts, unilaterally or through negotiations with producers, because they cannot sell the gas at contracted prices.

Measured Thermal Performance and the Cost of Conservation for a Group of Energy Efficient Minnesota Homes

In 1980, the Minnesota Housing Finance Agency (MHFA) implemented a major housing program to demonstrate to the building community and to the public that energy efficient housing was within the reach of available technology. Under the program, 144 housing units were constructed by 23 builders throughout Minnesota. The designs for these were selected on the basis of their predicted energy performance, simplicity of operation, integration of solar domestic hot water system, aesthetic qualities, apparent cost effectiveness, and marketability.

This paper reports the preliminary results of energy use, blower door tests, cost analysis, and construction problem information. The findings include:

- The average Thermal Integrity Factor (TIF) of all houses measured so far is 2.66 Btu per square foot per degree day (Btu/ft^2/DD), which is below the program goal of 3.0 Btu/ft^2/DD. A typical new Minnesota house would have a TIF of between 6 and 8.
- The builders that spent more than $7,000 used 20 percent more energy than the builders that spent less than $7,000.
- It appears that for an extra cost of about $5.00/$ft^2$, a house can be built that will save about 5 Btu/ft^2/DD compared to conventional construction, or about 40,000 Btu/ft^2 per year. If we assume a space heating cost of $10.00 per million Btu and a present worth factor of 18, the energy saved by the $5.00/$ft^2$ investment has a

present worth of $7.20. The simple payback for this investment would be 12.5 years.

- In attempting to apply construction techniques that would reduce the air change rate, builders found their greatest problem was training the work crews to properly handle and install air vapor barriers.
- The problems that arose during the program were caused by 1) lack of development in building techniques, building material, and equipment; and 2) insufficient knowledge and experience with the design and construction of energy efficient housing.

Minnesota Energy Code Rule-making: Statement of Need and Reasonableness

This serves as the principal proof of the need and reasonableness of adopting the 1984 Minnesota Energy Code. It provides information on the authority for the rule-making activity, compliance with the State's legal rule-making procedures, and the need and reasonableness of each element of the proposed rules. The process by which outside opinion was obtained to formulate the rules is explained. Justification is also given for specific building requirements such as foundation wall insulation and vapor barriers.

Minnesota's Position on Current Acid Rain Legislation

The Energy Division believes that enough is known about the relationship between sulfur dioxide (SO_2) emissions and acid rain to justify implementation of emissions reduction technologies. The Division favors the development of a "superfund" through which capital investments for SO_2 emissions would be subsidized. Such a fund would remove a major obstacle—financing problems—to the retrofit of aging power plants. However, the Division believes that these funds should be raised from a tax on SO_2 emissions rather than a tax on generation.

An emissions tax would be more equitable than a generation tax (as proposed in the Sikorski bill) because it would take into account past investments on SO_2 emissions reduction technology. In addition, the cost to polluters would be commensurate to their share of SO_2 emissions. An emissions tax would also provide a tax incentive to reduce SO_2 emissions.

The Energy Division favors the straightforward proportion method contained in the Mitchell bill rather than the formula contained in the Sikorski bill. The Mitchell bill gives better recognition of past investments in SO_2 emissions control.

A straight emissions tax may be politically unfeasible due to the high costs that would be borne by the central industrial states that have high levels of SO_2 emissions. Therefore, it may be necessary to compromise on the funding sources for the superfund. Such a compromise could involve raising half the amount of a superfund from a generation tax and the other half from an emissions tax.

Optimal Energy Conservation Investments for Elementary and Secondary Schools from a Cost-effectiveness Analysis of Energy Conservation Measures in Minnesota IBGP Maxi-audits

This is a cost/benefit analysis of maxi-audit data from 200 elementary and secondary schools in Minnesota to determine optimal levels of energy conservation investments in schools eligible for funding under the Institutional Building Grants Program (IBGP). The analytical framework is based on *An Economic Short-run Equilibrium Model of Investments in Energy Conservation,* which is described in a separate abstract. For the purposes of the study, an investment in a specific measure to improve energy efficiency is cost effective if the present value of energy cost savings realized during the life of the improvement exceeds the investment cost. In turn, the optimal level of investment is the sum of the individual costs of all cost effective energy conservation measures.

This study found average optimum levels of cost effective investments of $70,000 per building (or $1.60 per square foot) for elementary schools and $176,000 per building ($1.38 per square foot) for secondary schools. The annual energy cost savings resulting from these levels of investments would be approximately $10,000 per building ($0.23 per square foot) and $32,000 per building ($0.25 per square foot) for elementary and secondary schools, respectively, using 1982 energy prices. On the average, these figures represent reductions in annual energy use by 33.5 percent for elementary schools and by 35.2 percent for secondary schools. These translate into average annual energy cost savings by 29.6 percent and 31.1 percent for elementary and secondary schools, respectively. Notice that the difference between the percentage annual energy use reduction and percentage annual energy cost savings reflects the savings of different energy types, which differ in price, that would result from the investments to improve energy efficiency.

For all cost effective measures, the study found that, on the average, energy conservation investments have a payback period of seven years for elementary schools and six years for secondary schools. Finally, for every dollar of energy conservation investment, the present value of energy cost savings realized over the life of an investment is $3.60 for elementary schools and $3.80 for secondary schools.

Phase II Analysis of Energy Conservation Investments in Minnesota Public Schools

This research project analyzed the Technical Assistance (maxi-audit) and Energy Conservation grants awarded under Phase II of the Federal Institutional Conservation Program. Data were collected on over 300 public school buildings from more than 200 public school districts. The data collected include 1978-79 energy use and cost, 1981-82 energy use and cost, types of energy projects implemented, costs of energy projects implemented, amount of grants money awarded, district attitudes about energy conservation, and the needs of the public school sector. Preliminary analysis has been completed. Final analysis and publication is scheduled for fall of 1984.

Planning and Zoning for Solar Access: A Guide for Minnesota Communities

The purpose of this guide is to provide information on solar access to planning and zoning staff and to elected officials to enable them to: remove barriers to solar energy use, facilitate good solar access in new areas of development by modifying zoning and subdivision regulations, and provide firmer guarantees of solar access such as solar access permits.

The guidebook includes background information on solar energy systems and solar geometry. Basic solar access policy issues are discussed and sample goal and policy statements are provided. The chapter on removing barriers to solar energy use considers definitions, use designation, and zoning revisions such as exempting solar systems from height and setback requirements.

The discussion of solar access protection techniques is divided into two chapters. One chapter focuses on protection techniques suitable in areas of existing development such as easements and solar access permits. The other chapter covers techniques to facilitate area-wide solar access for currently undeveloped areas. Model language is provided in both apters.

Vegetation and solar access concerns are discussed and model language is provided. Applying solar access protection techniques in commercial and industrial zoning districts is briefly considered.

Appendices include discussions of assessing solar access potential in both existing neighborhoods and undeveloped areas.

***Proposal for Inverted Natural Gas Rates** (Testimony before the Minnesota Public Utilities Commission, 1980-1983)*

Natural gas is presently priced on an average cost basis. That is, more expensive, recently discovered gas is averaged in with cheaper gas contracts signed many years ago. However, as consumption rises, it is the newer gas costs that must be incurred. Conversely, as conservation investments reduce the need for additional gas purchases, it is these more expensive gas costs that are avoided. A flat pricing structure based on average costs thus gives consumers inaccurate price signals because it does not present them with e actual replacement costs (or avoided sts) of the fuel they are consuming (or conserving).

An inverted rate structure is designed to mirror the actual structure of gas costs by charging a below average rate for consumption below a certain amount and a rate closer to the replacement cost of gas for units of consumption above a given level. By constructing the rate so that consumers will have some portion of their consumption in the higher priced "tailblock," we can insure that most consumers will be making consumption/conservation decisions based on the higher "tailblock price." This mechanism increases the incentive to conserve by raising the dollars saved by consumers who make conservation investments.

Inverted rates do not result in higher gas bills for all consumers. By manipulating the "height" and "width" of the two consumption blocks, any number of rate structures can be produced. In the past, the Energy Division has advocated a rate that would result in yearly gas bills identical to those produced under a flat rate. However, the increased incentive to nserve would still be present.

Inverted rates would operate only during winter months, when the bulk of gas is consumed for heating purposes. Flat rates would be instituted during nonwinter months.

***Redevelopment of Minnesota's Hydropower Resources** (June 1983)*

This report summarizes the efforts that have occurred during the last two years to redevelop hydroelectric facilities.

According to the Energy Division's 1982 biennial report, Minnesota realizes approximately half of its hydropower potential. Using presently available technology, it may be possible to develop the remaining half if favorable financing terms and power prices are attainable. As technological advancements are made, additional sites may become feasible.

With funding from the Legislative Commission on Minnesota Resources, the Energy Division established a Hydropower Redevelopment Program. This program has been a cooperative effort between the Energy Division, the Minnesota Department of Natural Resources (DNR), the St. Anthony Falls Hydraulic Laboratory and the Hydropower Redevelopment Task Force. The Task Force was formed in January 1981 and consists of several groups, including communities interested in redeveloping hydro sites, electric utilities and cooperatives, the St. Anthony Falls Hydraulic Lab, and various state agencies with an interest in water resources and hydropower development. The Task Force has become a useful mechanism for providing information to communities and for resolving common problems. The Energy Division's work has been to provide assistance to communities and coordinate local, state and federal government agencies on hydropower projects.

The Water Division of the Department of Natural Resources played a major supportive role in the hydropower redevelopment project. Legislation passed during the 1980 Legislative Session allowed communities to apply for funds for hydro feasibility studies using DNR/Dam Safety funds. During dam safety inspections, DNR/Dam Safety staff talked to dam owners about incorporating future hydro development plans into their dam repair projects. Staff from DNR's Dam Safety unit played an active role at task force meetings by providing status report updates on feasibility studies and also in explaining state regulatory requirements.

The St. Anthony Falls Hydraulic Laboratory that is attached to the University of Minnesota has been instrumental in the state's program to redevelop hydropower. It has conducted two major survey studies that have identified 65 sites that merit consideration for development. The laboratory has also conducted seven feasibility studies for communities and one for Northern States Power Company. Positive recommendations were made for several of the sites. Many of these communities are pursuing redevelopment with the assistance of the Energy Division staff. The laboratory is also installing a turbine testing facility as a part of its program to become a nationwide center for hydropower research.

Residential Energy Audits in Minnesota: A Process Evaluation

An evaluation of Minnesota's Residential Conservation Service (RCS) program was conducted after six months of operation. It found that recently audited customers were significantly more likely to plan conservation actions than non-audited customers, despite similar prior conservation behavior. The indicators of program effectiveness that were examined were participation rates, customer satisfaction, and conservation actions intended and taken. The evaluators found that:

- The two reasons cited most often for not requesting an audit were the perception that one's home was already energy efficient and a lack of awareness of the audit's availablity.
- Some demographic differences exist between participants and non-participants; however, they are smaller than the differences that exist between eligible customers and the entire residential sector.
- Audited customers were generally satisfied with the service; they also seemed more satisfied with the auditor than with the written materials they received.
- The audit had a positive influence in stimulating overall conservation behavior; it was more effective in stimulating low cost, quick payback conservation improvements.

Solar Performance Monitoring—Solar Domestic Hot Water Systems and Passive Solar Homes

This volume contains two reports (discussed below) that outline the results of two solar performance monitoring projects, which were funded by and written for the Legislative Commission on Minnesota Resources. The first report presents the results from a field monitoring study of 14 solar domestic hot water systems in Minnesota. In the second report, the results of a monitoring study of four passive solar, energy efficient houses are presented. Indications of the effectiveness of solar energy performance in Minnesota are provided in both reports.

1. Field Monitoring of Solar Domestic Hot Water Systems in Minnesota

Fourteen Solar Domestic Hot Water (SDHW) systems in Minnesota were monitored in Phase I of this program. This report compares predicted solar fractions to actual solar fractions, predicted performance per square foot of collector to actual performance, and examines auxiliary fuel consumption, hot water usage, solar pump energy required, and other variables. The period of monitoring ranges from 5 months to 2 years on these 14 commercially available systems.

The results of this program demonstrate that SDHW systems can perform effectively in Minnesota. Four of the eight systems with complete data had monitored performances that were within 5 percent of F-chart predictions. Ten of the fourteen showed favorable economic performance when compared to electric water heating.

Phase II of the monitoring program provided field data on eight batch type and other innovative water heating systems. The case studies provide a database on the performance of these types of systems. Observations indicate that both the manufactured and the site built systems can be cost effective.

2. Performance Monitoring of Four Energy Efficient Residences in Minnesota

Four passive solar, energy efficient houses in Minnesota were monitored during the 1982-83 heating season as part of the Solar Energy Research Institute's National Passive Performance Evaluation Program. Site selection, the 24 channel data acquisition system, real-time data reduction methods, one-time tests and monthly data are presented.

Passive solar contribution ranged from 34 percent at Northfield to 11 percent at Esko. Brainerd, with an average solar contribution of 15 percent, depended on two trombe walls that appear to have limited effectiveness, given Minnesota's latitude and cloudy winters. Thermal Integrity Factors (TIF) ranged from .56 to 2.47 Btu per square foot per degree day.

A Statistical Analysis of Emergency Funds Provided by the Low Income Energy Assistance Program and the Incidence of Heating Equipment Fires

Due to the petroleum price shocks experienced in the 1970's, many Minnesota homes returned to wood burning as a means of reducing fuel costs. As the number of homes heating with wood has increased, wood burning equipment has become the leading cause of fires in one and two family dwellings in Minnesota. This problem is many times magnified when systems used to burn wood or other heating fuels are damaged, malfunction, or are "home-made." The problem of substandard or malfunctioning equipment is prevalent among Minnesota's low income households. This problem has been addressed by the staff of Minnesota's Low Income Energy Assistance Program (LIEAP). What resulted was the Conservation/Repair Program, through which LIEAP provides funds to eligible households to repair heating equipment when funds are not available for those repairs from other programs.

In 1982, as part of the Conservation/Repair Program, the Energy Analysis Unit of the Energy Division was asked to initiate an ongoing correlation/regression study to determine whether money provided by this program was an agent in reducing residential fires. So far the study has provided inconclusive results in terms of correlating repair funds to a reduction in residential home fires. This may be due to the relatively small amount of repair funds provided during the first two years of the program. However, the study has shown that Minnesota homes that burn wood as a major source of heat experience a statistically significant high incidence of fire. The analysis is performed each year as data from the State Fire Marshal's Office becomes available. Final results are available in October of each year.

A Statistical Analysis of Passive Solar Superinsulated Houses in Minnesota

This study used multiple regression analysis to analyze the space heat performance of 46 passive solar superinsulated homes whose construction was financed by the Minnesota Housing Finance Agency (MHFA). The results suggest that houses with more south facing glass relative to floor area may not perform as predicted. In the houses with less south facing glass, the passive solar components appeared to perform as predicted.

Superinsulated Housing Demonstration Project Construction Reports

In 1981, the Minnesota Legislature provided funding for a Superinsulated Housing Demonstration Project. A major part of this project was the construction throughout the state of superinsulated homes, including new and remodeled houses. Twenty new and six remodeled home projects were completed in 1982 and 1983.

This report reviews the construction problems and costs reported in written and oral communication with the project leaders, and highlights the solutions and suggestions project leaders had regarding superinsulation construction techniques.

Virginia, Minnesota Peat Test Burn Project: Final Report *(June 1984)*

This report presents the results of a series of eight boiler tests conducted at the municipal power plant in Virginia, Minnesota. The purpose of these tests was to document the relative performance of the boiler using various blends of peat, coal and wood for fuel. In addition to general operating characteristics, items of specific interest were the determination of boiler capacity, efficiency and emissions. The test boiler was a 60,000 pound per hour (pph) unit using a spreader stoker feeding onto a traveling grate. Tests were conducted during the 1982-83 and 1983-84 heating seasons, using the standard methodologies of the ASME and EPA.

Results of the testing indicate no significant technical problems to the use of peat as a fuel in this particular furnace. Maximum steaming capacity, when burning an eastern bituminous coal, is in excess of 60,000 pph. Blends of peat and western subbituminous coal cause capacity to steadily decrease; a maximum of 33,000 pph was realized using 75 percent peat and 25 percent western subbituminous coal. Boiler efficiencies varied between 69 and 82 percent, with most values in the upper 70 percent range. There was no strong correlation between efficiency and fuel type. Particulate emissions varied substantially, but again there was no correlation between particulate levels and fuel type. There was a weak correlation between increasing sulfur content and increasing SO_2 levels. However, the low sulfur in the fuels used brought all levels below EPA standards. There was a strong correlation between increasing nitrogen content and increasing NO_x emissions. Although there are presently no limits for NO_x on the test boiler, this is of concern because peat is a higher nitrogen fuel than coal. There were no other operational problems noted. Therefore, it appears that the use of peat is primarily an economic question rather than a technical question.

Zoning for Earth Sheltered Construction: A Guide for Minnesota Communities

Local zoning ordinances may contain provisions that inhibit or prohibit earth sheltered buildings. These provisions are typically not intentional barriers, but indicate zoning language that was written before earth sheltering became a viable construction option. The purpose of this guide is to provide information on earth sheltered buildings and related zoning issues to enable planning and zoning staff and elected officials to remove barriers to this construction technique.

The guide provides background information that explains what earth sheltering is and why zoning can be a barrier to this construction technique. Model zoning language to eliminate prohibitions and barriers to earth sheltering are included and fully discussed. Model regulations to ensure that earth sheltered buildings are safe and as compatible as possible with adjacent structures are also considered. Model planning goals and policies concerning earth sheltered buildings are provided. Model subdivision regulations to facilitate earth sheltered buildings in areas of new development are also included.

Zoning for Wind Machines: A Guide for Minnesota Communities

Local zoning ordinances typically do not contain any specific references to wind energy conversion systems. Trying to apply existing zoning provisions, like height regulations, to wind machines can be difficult and may represent an unreasonable restriction to wind machine installations in areas under zoning jurisdiction. The purpose of this guidebook is to provide information on wind machines and related zoning issues to enable planning and zoning staff and elected officials to make informed decisions on how small wind machines can be addressed in community plans and zoning. Commercial wind farms and large wind machines (greater than 50-foot rotor diameter) are not considered in the guide.

The guide provides background information on wind machines. Zoning and elected officials need some basic knowledge about wind machines to develop reasonable regulations. Model zoning language with full discussions explaining the model provisions comprise the bulk of the guide. Zoning concerns addressed include definitions, use designation, size regulations, safety of installation and design, siting regulations, noise, and communications interference. Model planning goals and policies on use designation and wind access are provided. Model subdivision regulations on facilitating siting of wind machines in areas of new development are also included.

Master Tables

Table 1
U.S. Economic and Demographic Data, 1960-1982 and Projections through 2000

	Gross National Product (1981 Billion Dollars)	Personal Income (1981 Billion Dollars)	Employment (Millions)	Population (Millions)
1960	1438.9	1143.2	65.8	180.7
1961	1476.5	1175.9	65.7	183.7
1962	1561.6	1226.1	66.7	186.5
1963	1624.6	1269.3	67.8	189.2
1964	1710.1	1338.7	69.3	191.9
1965	1813.2	1418.5	71.1	194.3
1966	1921.7	1494.9	72.9	196.5
1967	1973.3	1554.8	74.4	198.7
1968	2064.8	1632.6	75.9	200.7
1969	2122.3	1696.5	77.9	202.7
1970	2118.4	1730.9	78.7	205.1
1971	2190.4	1765.2	79.4	207.6
1972	2314.4	1856.8	82.1	209.9
1973	2449.0	1967.0	85.1	211.9
1974	2431.7	1981.4	86.8	213.9
1975	2403.0	1962.2	85.8	216.0
1976	2533.9	2052.1	88.8	218.1
1977	2671.7	2145.5	92.0	220.3
1978	2807.6	2248.2	96.0	222.6
1979	2887.3	2321.5	98.8	225.1
1980	2879.3	2361.8	99.3	227.6
1981	2954.1	2426.9	100.4	229.8
1982	2898.5	2425.6	99.5	232.0
Projected				
1983	2988.1	2481.6	100.7	234.2
1984	3132.7	2592.2	103.8	236.4
1985	3244.5	2688.2	106.2	238.7
1986	3344.2	2771.4	108.4	240.9
1987	3455.7	2846.6	110.6	243.2
1988	3562.0	2905.9	112.7	245.4
1989	3668.3	2975.7	114.4	247.6
1990	3783.3	3050.8	116.0	249.7
1991	3895.6	3126.1	117.4	251.8
1992	4001.5	3200.8	118.7	253.9
1993	4102.0	3273.4	119.9	255.9
1994	4206.2	3348.6	121.1	257.8
1995	4312.8	3555.5	122.3	259.6
1996	4506.6	3592.1	123.6	261.4
1997	4633.4	3687.5	124.7	263.1
1998	4762.0	3784.7	125.7	264.8
1999	4895.3	3885.1	126.7	266.4
2000	5031.3	3985.6	127.9	268.0

Source: Data Resources Inc., U.S. Long Term Review, Summer 1983 and Spring 1983 (Trendlong 0683 and Trendlong 2008A), Lexington, Mass.

Table 2
Minnesota Economic and Demographic Data, 1960-1982

	Gross State Product (1981 Million Dollars)	Personal Income (1981 Million Dollars)	Employment (Thousands)	Population (Thousands)
1960	26293	20365	1282	3414
1961	26955	21107	1286	3470
1962	27872	21850	1304	3513
1963	28897	22837	1309	3531
1964	29670	23382	1323	3558
1965	32094	25356	1358	3592
1966	33983	26673	1401	3617
1967	35222	27786	1433	3659
1968	36721	29246	1464	3703
1969	38276	30720	1513	3758
1970	38431	31692	1556	3806
1971	39331	31988	1591	3860
1972	40915	33461	1629	3877
1973	45934	37613	1685	3890
1974	44425	36576	1690	3904
1975	44168	35793	1683	3921
1976	46268	36893	1739	3954
1977	50090	39780	1809	3980
1978	53345	41407	1903	4024
1979	54642	42912	1953	4060
1980	54009	43275	1984	4076
1981	54868	43938	2034	4101
1982	52888	43562	1997	4133
Projected				
1983	53634	42244	1997	4164
1984	55774	44174	2038	4193
1985	57454	45561	2071	4222
1986	59016	46828	2102	4252
1987	60912	48382	2140	4282
1988	62932	50027	2182	4312
1989	64979	51688	2223	4341
1990	67245	53538	2269	4371
1991	69456	55409	2316	4397
1992	71774	57216	2359	4423
1993	73982	59013	2402	4450
1994	76215	60834	2444	4476
1995	78545	62742	2487	4502
1996	80762	64549	2528	4522
1997	82847	66245	2564	4541
1998	84986	67989	2600	4561
1999	87215	69811	2638	4581
2000	89571	71741	2677	4600

Sources:

Historic Data:

Gross State Product: Minnesota Department of Economic Development, "Minnesota Statistical Profile," 1981, St. Paul. Minnesota Department of ergy and Economic Development, "Gross State Product by Sector 1949-1982," St. Paul, Sept. 29, 1983.

ersonal Income: U.S. Department of Commerce, "Survey of Current Business" (April issues), Washington, D.C.

Employment: Minnesota Department of Economic Security Minnesota Work Force Data, Jan. 1960-Dec. 1975, St. Paul. "Review of Labor and Economic Conditions" (Quarterly), St. Paul.

Projections:

GSP, Personal Income: Minnesota Department of Energy and Economic Development "MINTOM Energy-Economic Forecasts" (Computer printout of Model Forecasts, April 13, 1984) St. Paul.

Population: Minnesota Office of the State Demographer.

Table 3
Minnesota Energy Consumption, 1960-1982 (Trillion Btu[a])

	Natural Gas	Coal	Nuclear Power	Total Fuel Oil[b]	Propane	Gasoline	Total Petroleum Products	Hydro Power
1960	180.0	135.8	0	153.9	17.4	171.9	343.2	9.3
1961	193.0	132.5	0	149.2	17.2	171.9	338.3	7.7
1962	214.0	133.5	0	160.0	17.9	174.8	352.6	10.1
1963	219.0	141.6	.01	155.2	19.8	180.4	355.4	8.8
1964	237.0	157.6	.6	157.5	19.2	183.2	359.9	9.9
1965	249.3	160.9	1.6	166.5	22.2	190.2	379.0	11.5
1966	266.0	170.3	1.4	173.6	24.9	200.0	398.5	12.4
1967	284.2	161.0	1.5	168.3	26.8	204.3	399.4	9.1
1968	308.9	150.3	.2	173.7	29.6	215.7	419.0	10.6
1969	319.4	187.7	0	199.7	33.7	229.8	463.2	10.5
1970	334.6	176.0	0	205.4	28.9	238.4	472.7	9.2
1971	242.8	151.7	15.2	215.4	31.0	251.0	497.4	10.1
1972	345.2	158.8	38.8	239.9	34.3	263.7	538.0	10.8
1973	353.8	174.2	35.7	231.6	37.7	269.4	538.7	10.9
1974	339.5	183.9	47.6	208.1	35.6	256.5	500.2	9.4
1975	316.6	183.6	106.4	195.6	35.3	261.2	492.1	9.4
1976	299.5	223.3	108.1	219.4	33.7	271.6	524.8	6.0
1977	268.9	263.9	121.8	205.8	33.9	278.5	518.2	6.9
1978	279.5	256.2	126.5	214.9	31.6	290.4	536.9	11.7
1979	298.4	230.2	125.5	216.3	37.2	277.7	531.2	9.9
1980	282.6	250.5	109.4	173.4	27.2	254.3	454.9	8.3
1981	266.7	255.4	111.1	143.8	25.8	241.2	410.8	10.0
1982	262.9	220.3	111.2	154.0	27.6	241.4	423.0	11.0

[a]Btu figures based on unrounded physical unit numbers.

[b]Total fuel oil represents the sum of distillate, jet fuel and residual fuel oils.

[c]Net import or export of electricity is the difference between the amount of energy in electricity sold within a state (including associated losses) and the energy input at the electric utilities within the state. A positive number indicates that more electricity came into the state than went out of the state during the year; conversely, a negative number indicates that more electricity went out of the state than came in. A net import of electricity is represented by a positive number, while a net export is represented by a negative number. The Btu value represents the primary energy used in the generation of the net import or export of electricity.

[d]Electric consumption in Minnesota is generated from the earlier listed primary energy sources (or is imported). It is separately listed here in the last column and is not included in determining total energy use in Minnesota. The Btu value represents the heating value of the kWh delivery to the ultimate consumer.

Note:
Due to independent rounding, individual fuel sums may not add to total.

Sources:

All Fuels
1960-64: State Energy Data Report, July 1982, U.S. DOE/EIA, Washington, D.C.

Natural Gas, Electricity
1965-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Residual
1965-81: State Energy Data Report, July 1982, U.S. DOE/EIA, Washington, D.C

1982: Petroleum Supply Annual 1982, Volume 1, June 1983, U.S. DOE/EIA, Washington, D.C.

Propane
1965-75: State Energy Data Report, July 1982, U.S. DOE/EIA, Washington, D.C.
1976-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Jet Fuel, Distillate, Gasoline
1965-82: Minnesota Department of Revenue (Petroleum Division) "Product Receipts, Collections, Refunds & Distribution," (Monthly), St. Paul, Minnesota.

Coal
1965-75: State Energy Data Report, June 1982, U.S. DOE/EIA, Washington D.C.
1976-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Nuclear, Hydro
1965-75: State Energy Data Report, July 1982, U.S. DOE/EIA, Washington, D.C.
1976-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Total Primary Energy Consumed	Net Import/ Export of Electricity[c]	Total Energy Consumed	Purchased Electricity[d]
668.3	- 6.5	661.9	30.4
671.5	- 4.9	666.6	32.7
710.3	- 8.3	702.0	35.3
724.9	-10.2	714.7	38.1
765.1	-10.3	754.8	41.1
802.2	- 1.2	801.0	44.1
848.8	- .03	848.7	48.6
855.2	17.5	872.7	52.9
888.9	21.0	909.9	59.4
980.8	26.2	1007.0	65.4
992.5	41.8	1034.3	71.1
1017.2	70.4	1087.6	75.2
1091.5	46.1	1137.6	81.9
1113.2	52.9	1166.0	87.4
1080.7	56.8	1137.5	88.0
1108.1	31.1	1139.2	91.7
1161.7	18.2	1179.9	98.4
1179.7	-25.9	1153.8	100.4
1210.7	15.6	1226.3	111.4
1195.3	56.6	1251.9	117.9
1105.7	47.3	1153.0	116.5
1054.0	47.6	1101.6	117.6
1028.4	76.4	1104.8	115.9

Table 4
Minnesota Energy Consumption by Sector, 1982 (trillion Btu)

	Natural Gas	Coal	Nuclear Power	Total Fuel Oil	Propane	Gasoline	Total Petroleum Products	Hydro Power
Residential	114.8	.2	0	33.1	10.8	0	43.9	0
Commercial	75.9	3.6	0	6.3	4.6	0	10.9	0
Industrial	61.4	26.1	0	15.0	3.4	0	18.4	2.1
Agricultural	0	0	0	21.9	7.8	17.9	47.6	0
Transportation	7.4	0	0	77.1	1.0	223.6	301.7	0
Total End Use	259.5	29.9	0	153.5	27.6	241.4	422.5	2.1
Elec Utility	3.4	190.3	111.2	.5	0	0	.5	8.9
Total Primary Energy Use	262.9	220.3	111.2	154.0	27.6	241.4	423.0	11.0

[a]Does not include industrial self-generation of electricity.

[b]This represents total energy use. The difference between total end use consumption and total energy use represents the amount of energy lost in the process of electric generation and transmission. Sector totals under the total energy use column include the associated electric losses attributable to that category's electric energy consumption.

Note:
- Btu values are based on unrounded physical units.
- Due to independent rounding, individual categorical detail may not add to total.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 5
Projected Minnesota Energy Consumption, 1983-2000 (trillion Btu)

	Hydro Power	Nuclear	Natural Gas	Fuel Oil	Propane	Gas	Coal	Alternative Energy[a]
1983	11.8	128.2	247.4	158.6	30.2	251.2	238.6	38.0
1984	9.8	101.7	293.3	133.8	28.6	252.1	236.8	41.1
1985	9.8	121.8	293.5	137.0	28.9	249.3	245.5	45.0
1986	9.8	121.8	295.0	139.4	29.1	243.8	252.5	47.9
1987	9.8	121.8	290.8	145.3	29.4	239.4	260.8	52.7
1988	9.8	122.2	281.3	154.7	29.8	236.6	318.5	57.5
1989	9.8	121.8	274.1	163.0	30.3	233.9	324.3	61.3
1990	9.8	121.8	273.9	166.9	30.5	231.8	329.5	66.1
1991	9.8	121.8	265.3	176.5	31.1	229.9	336.9	70.8
1992	9.8	122.2	262.2	181.7	31.2	228.3	342.0	74.8
1993	9.8	121.8	262.4	183.2	31.2	226.7	345.8	79.2
1994	9.8	121.8	260.5	189.0	31.5	224.8	350.2	83.2
1995	9.8	121.8	261.0	191.4	31.6	224.3	353.8	87.7
1996	9.8	122.2	259.3	193.9	31.7	222.3	357.5	91.4
1997	9.8	121.8	256.5	197.2	31.8	220.1	360.7	95.9
1998	9.8	121.8	252.9	201.6	32.1	218.0	364.0	101.0
1999	9.8	121.8	250.9	203.2	32.3	215.8	367.0	105.1
2000	9.8	121.8	248.0	206.7	32.7	213.9	370.4	110.3

[a]Includes wind, solar, district heating and all biomass fuels.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Total Primary Energy	Purchased Electricity[a]	Total End Use Energy	Net Losses	Total Energy Use
158.9	36.9	195.8	87.6	283.5
90.5	41.5	132.0	98.6	230.6
108.0	30.5	138.5	72.4	210.9
47.6	6.9	54.5	16.3	70.8
309.0	0	309.0	0	309.0
714.0	115.9	829.8	275.0	1104.8[b]
314.5				
1028.4				

Total	Purchased Electricity
1104.0	120.9
1097.2	128.0
1130.8	133.3
1139.3	136.8
1150.0	140.7
1210.4	144.3
1218.5	147.6
1230.3	150.9
1242.1	153.2
1252.2	155.7
1260.1	157.9
1270.8	160.2
1281.4	162.3
1288.1	164.5
1293.8	166.3
1301.2	168.1
1305.9	169.8
1313.6	171.4

Table 6
Projected Minnesota Residential Energy Consumption, 1983-2000 (trillion Btu)

	Natural Gas	Fuel Oil	Propane	Biomass Alter-natives[a]	Other Alter-natives[b]	Total	Electricity
1983	125.6	30.4	15.5	18.7	.2	190.4	44.2
1984	129.6	29.2	15.5	19.2	.3	193.8	45.7
1985	132.0	28.1	15.5	19.8	.4	195.8	47.2
1986	133.4	27.0	15.4	20.4	.4	196.6	48.5
1987	133.5	25.8	15.3	21.7	.5	196.8	49.9
1988	133.5	24.5	15.1	23.1	.6	196.8	51.2
1989	133.5	23.1	15.0	24.6	.8	197.0	52.6
1990	133.4	21.5	14.8	26.1	.9	196.7	54.1
1991	132.1	20.6	14.6	27.2	1.0	195.5	54.7
1992	131.1	20.0	14.4	28.2	1.1	194.8	55.4
1993	129.8	19.1	14.2	29.3	1.2	193.6	55.9
1994	128.6	18.3	14.0	30.3	1.4	192.6	56.5
1995	127.2	17.6	13.8	31.4	1.5	191.5	56.8
1996	125.9	16.8	13.6	32.4	1.6	190.3	57.3
1997	124.6	16.1	13.4	33.4	1.8	189.3	57.5
1998	123.3	15.4	13.2	34.4	2.0	188.3	57.7
1999	122.1	14.8	13.1	35.3	2.1	187.4	57.7
2000	120.8	14.1	12.8	36.3	2.3	186.3	57.6

[a]Includes solid fuels and fuels derived from biomass.
[b]Includes wind and solar technologies.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 7
Projected Minnesota Commercial/Institutional Energy Consumption, 1983-2000 (trillion Btu)

	Natural Gas	Fuel Oil	Coal	Propane	Biomass Alter-natives[a]	Other Alter-natives[b]	Total	Electricity
1983	58.0	25.7	8.6	4.4	.2	6.9	103.8	38.2
1984	80.2	3.7	10.4	4.5	.3	6.9	106.0	40.4
1985	79.2	5.0	12.4	4.7	.4	7.0	108.7	42.8
1986	80.1	6.1	14.3	4.8	.5	7.1	112.9	44.1
1987	77.8	9.4	16.2	5.0	.9	7.1	116.4	45.6
1988	72.4	16.6	18.1	5.2	1.4	7.3	121.0	47.0
1989	68.6	21.5	20.1	5.4	1.8	7.4	124.8	47.8
1990	68.2	24.7	22.1	5.6	2.3	7.4	130.3	48.7
1991	64.0	30.7	24.0	5.8	2.7	7.7	134.9	49.4
1992	63.0	33.4	26.0	6.0	3.2	7.8	139.4	50.3
1993	63.8	34.1	27.9	6.2	3.7	8.0	143.7	51.0
1994	63.1	36.2	29.9	6.3	4.0	8.1	147.6	51.7
1995	63.8	36.6	31.9	6.5	4.6	8.3	151.7	52.6
1996	63.5	37.9	33.9	6.7	5.1	8.5	155.6	53.3
1997	62.6	39.5	35.9	6.8	5.5	8.8	159.1	53.9
1998	61.0	41.5	37.9	6.9	6.0	9.1	162.4	54.5
1999	60.1	42.5	39.9	7.1	6.5	9.4	165.5	55.2
2000	58.6	44.2	41.8	7.2	7.0	9.7	168.5	55.8

[a]Includes solid fuels and fuels derived from biomass.
[b]Includes solar and district heating technologies.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development

Table 8
Projected Minnesota Industrial Energy Consumption, 1983-2000 (trillion Btu)

	Natural Gas	Fuel Oil	Coal	Propane	Biomass Alter-natives[a]	Other Alter-natives[b]	Total	Electricity
1983	60.9	9.4	50.9	1.8	9.7	2.3	135.0	38.5
1984	80.7	6.2	40.6	.1	10.3	2.5	140.4	41.9
1985	79.7	6.6	44.0	.1	11.1	2.8	144.3	43.3
1986	79.1	6.8	46.1	.1	11.3	2.9	146.5	44.2
1987	77.2	7.4	49.4	.2	12.2	3.1	150.1	45.2
1988	73.3	8.8	54.5	.5	12.9	3.2	153.2	46.1
1989	70.1	10.1	58.7	.7	12.1	3.4	155.1	47.2
1990	70.5	10.7	62.4	.8	12.9	3.6	160.9	48.1
1991	67.4	12.3	68.3	1.3	13.7	3.7	166.7	49.1
1992	66.5	12.9	72.0	1.3	14.3	3.9	170.9	50.0
1993	67.3	13.4	74.3	1.3	15.1	4.1	175.5	51.0
1994	67.5	15.0	77.2	1.6	16.0	4.2	181.5	52.0
1995	68.7	15.5	79.3	1.6	17.0	4.3	186.4	52.9
1996	68.6	15.9	81.4	1.6	17.2	4.6	189.3	53.9
1997	68.1	16.5	83.2	1.8	18.2	4.8	192.6	54.9
1998	67.4	17.3	85.0	2.2	19.5	5.0	196.4	55.9
1999	67.6	17.8	86.7	2.4	20.0	5.1	199.7	56.9
2000	67.4	18.7	88.7	2.9	21.2	5.3	204.2	58.0

[a]Includes solid fuels and fuels derived from biomass
[b]Includes solar and district heating technologies.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development

Table 9
Projected Minnesota Agricultural Energy Consumption, 1983-2000 (trillion Btu)

	Fuel Oil	Propane	Gasoline	Alternative Energy[a]	Total
1983	22.5	7.7	18.0	0	48.2
1984	22.7	7.8	17.2	.1	47.8
1985	22.9	7.9	16.4	.2	47.4
1986	23.0	8.0	15.6	.3	46.9
1987	23.1	8.1	14.8	.5	46.5
1988	23.3	8.2	14.1	.6	46.2
1989	23.5	8.2	13.3	.7	45.7
1990	23.6	8.3	12.6	.7	45.2
1991	23.8	8.4	12.0	.8	45.0
1992	23.8	8.5	11.3	.8	44.4
1993	23.9	8.5	10.6	.7	43.7
1994	23.9	8.5	10.0	.7	43.1
1995	23.9	8.6	9.4	.6	42.5
1996	23.9	8.6	8.8	.5	41.8
1997	23.8	8.6	8.2	.4	41.0
1998	23.7	8.6	7.5	.3	40.1
1999	23.6	8.6	6.8	.3	39.3
2000	23.5	8.6	6.1	.3	38.5

[a]Includes fuels derived from biomass.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 10
Projected Minnesota Transportation Energy Consumption, 1983-2000 (trillion Btu)

	Fuel Oil	Propane	Gasoline	Alternative Energy[a]	Total
1983	70.2	.8	233.2	0	304.2
1984	70.8	.8	234.9	1.5	308.0
1985	73.1	.8	232.9	3.0	309.8
1986	74.9	.9	228.2	4.4	308.4
1987	77.8	.9	224.6	5.8	309.1
1988	79.7	.9	222.6	7.2	310.4
1989	83.1	.9	220.6	8.5	313.1
1990	84.7	1.0	219.2	9.8	314.7
1991	87.4	1.0	217.9	11.1	317.4
1992	89.9	1.0	217.0	12.2	320.1
1993	92.3	1.1	216.0	13.3	322.7
1994	95.2	1.1	214.8	14.2	325.3
1995	97.4	1.1	214.9	15.2	328.6
1996	99.1	1.1	213.5	16.2	329.9
1997	101.0	1.2	212.0	17.2	331.4
1998	103.3	1.2	210.5	18.4	333.4
1999	104.0	1.2	209.0	19.5	333.7
2000	105.7	1.2	207.8	20.7	335.4

[a]Includes fuels derived from biomass.

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 11
Projected Energy Consumption for Electricity Generated within Minnesota, 1983-2000 (trillion Btu)

	Natural Gas	Fuel Oil	Coal	Hydro Power	Nuclear	Alternative Energy	Total
1983	2.9	.4	179.1	11.8	128.2	0	322.4
1984	2.8	1.2	185.9	9.8	101.7	0	301.4
1985	2.6	1.3	189.0	9.8	121.8	.3	324.8
1986	2.4	1.5	192.1	9.8	121.8	.6	328.2
1987	2.3	1.7	195.3	9.8	121.8	.9	331.8
1988	2.1	1.7	245.9	9.8	122.2	1.2	382.9
1989	2.0	1.7	245.4	9.8	121.8	2.0	382.7
1990	1.9	1.7	245.0	9.8	121.8	2.4	382.6
1991	1.7	1.7	244.5	9.8	121.8	2.9	382.4
1992	1.6	1.7	244.1	9.8	122.2	3.3	382.7
1993	1.5	.4	243.6	9.8	121.8	3.8	380.9
1994	1.4	.4	243.1	9.8	121.8	4.3	380.8
1995	1.3	.4	242.6	9.8	121.8	4.8	380.7
1996	1.3	.4	242.1	9.8	122.2	5.3	381.1
1997	1.2	.4	241.5	9.8	121.8	5.8	380.5
1998	1.2	.4	241.0	9.8	121.8	6.3	380.5
1999	1.2	.4	240.4	9.8	121.8	6.9	380.5
2000	1.2	.4	239.8	9.8	121.8	7.5	380.5

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 12
Energy Prices by Sector, 1960-1982 (1981 dollars)

esidential

	Natural Gas ($/Mcf)	Distillate ($/Gal)	Kerosene ($/Gal)	Propane ($/Gal)	Electricity (¢/kWh)	Coal ($/Ton)
1960	3.28	.40	.45	.28	8.14	43.97
1961	3.22	.42	.48	.28	7.98	43.72
1962	3.03	.41	.47	.25	7.54	43.24
1963	3.01	.41	.46	.24	7.37	42.95
1964	2.88	.37	.45	.27	6.99	41.98
1965	2.77	.37	.42	.24	6.53	41.05
1966	2.63	.38	.43	.25	6.20	40.06
1967	2.53	.37	.42	.25	5.87	38.83
1968	2.42	.38	.42	.21	5.60	37.36
1969	2.39	.36	.43	.18	5.35	33.99
1970	2.34	.36	.42	.23	5.03	33.85
1971	2.39	.36	.42	.22	4.92	37.63
1972	2.39	.35	.41	.21	4.95	35.23
1973	2.39	.37	.37	.26	4.69	39.36
1974	2.38	.57	.52	.34	4.70	101.28
1975	2.43	.56	.57	.34	4.78	77.89
1976	2.57	.57	.65	.57	4.91	81.98
1977	2.96	.63	.69	.58	5.15	76.75
1978	2.86	.58	.65	.53	5.27	92.94
1979	3.25	.95	1.01	.61	5.36	75.79
1980	3.54	1.05	1.11	.71	5.24	70.54
1981	4.02	1.15	1.20	.71	5.57	72.20
1982	4.78	1.05	1.11	.69	5.61	73.30

Commercial

	Natural Gas ($/Mcf)	Distillate ($/Gal)	Residual ($/Gal)	Kerosene ($/Gal)	Electricity (¢/kWh)	Propane ($/Gal)	Coal ($/Ton)
1960	2.29	.37	.28	.42	9.16	.25	18.21
1961	2.38	.36	.25	.45	7.79	.25	18.21
1962	1.82	.36	.25	.41	7.76	.22	18.19
1963	1.65	.38	.24	.43	7.45	.22	18.27
1964	2.19	.35	.24	.43	7.15	.21	17.66
1965	2.14	.34	.24	.39	6.76	.21	17.23
1966	1.87	.33	.23	.38	6.45	.23	16.74
1967	1.50	.34	.22	.37	6.19	.22	16.42
1968	1.48	.33	.24	.38	5.93	.19	15.92
1969	1.50	.34	.22	.38	5.62	.16	13.56
1970	1.49	.32	.21	.38	5.29	.21	14.56
1971	1.54	.30	.26	.38	5.14	.20	18.60
1972	1.61	.29	.23	.37	5.13	.19	13.14
1973	1.56	.35	.31	.33	4.87	.24	12.59
1974	1.66	.54	.56	.49	4.95	.32	16.91
1975	1.79	.53	.56	.54	5.06	.32	18.54
1976	2.22	.54	.50	.62	5.17	.54	22.93
1977	2.54	.60	.54	.67	5.19	.56	23.88
1978	2.76	.57	.52	.62	4.92	.50	25.49
1979	3.19	.94	.64	.99	4.75	.58	19.45
1980	3.50	1.05	.68	1.08	4.89	.69	22.85
1981	3.83	1.13	.83	1.18	4.56	.65	23.39
982	4.59	1.03	.76	1.09	4.68	.63	23.85

Agricultural

	Distillate ($/Gal)	Residual ($/Gal)	Propane ($/Gal)	Motor Gasoline ($/Gal)	Electricity (¢/kWh)
1960	.37	.28	.25	.70	9.16
1961	.36	.25	.25	.70	7.79
1962	.36	.25	.22	.66	7.76
1963	.38	.24	.22	.65	7.45
1964	.35	.24	.21	.58	7.15
1965	.34	.24	.21	.62	6.76
1966	.33	.23	.23	.65	6.45
1967	.34	.22	.22	.71	6.19
1968	.33	.24	.19	.66	5.93
1969	.34	.22	.16	.65	5.62
1970	.32	.21	.21	.63	5.29
1971	.30	.26	.20	.60	5.14
1972	.29	.23	.19	.58	5.13
1973	.35	.31	.24	.58	4.87
1974	.54	.56	.32	.76	4.95
1975	.53	.56	.32	.77	5.06
1976	.54	.50	.54	.69	5.17
1977	.60	.54	.56	.71	5.19
1978	.57	.52	.50	.67	4.92
1979	.94	.64	.58	.93	4.75
1980	1.05	.68	.69	1.19	4.89
1981	1.13	.83	.65	1.19	4.56
1982	1.03	.76	.63	1.07	4.68

Industrial

	Natural Gas ($/Mcf)	Distillate ($/Gal)	Residual ($/Gal)	Kerosene ($/Gal)	Propane ($/Gal)	Electricity (¢/kWh)	Coal ($/Ton)
1960	1.10	.37	.28	.42	.25	4.33	18.21
1961	1.01	.36	.25	.45	.25	4.40	18.21
1962	.99	.36	.25	.41	.22	4.32	18.19
1963	.98	.38	.24	.43	.22	4.04	18.27
1964	1.12	.35	.24	.40	.21	3.84	17.66
1965	1.10	.34	.24	.39	.21	3.68	17.23
1966	1.04	.33	.23	.38	.23	3.49	16.74
1967	.96	.34	.22	.37	.22	3.29	16.42
1968	.87	.33	.24	.38	.19	3.08	15.92
1969	.90	.31	.22	.38	.16	2.93	13.56
1970	.89	.32	.21	.38	.21	2.82	14.56
1971	.91	.30	.26	.38	.20	2.83	18.60
1972	.93	.29	.23	.37	.19	2.85	13.14
1973	.99	.33	.31	.33	.24	2.74	12.59
1974	1.08	.54	.56	.49	.32	2.94	16.91
1975	1.30	.53	.54	.54	.32	3.29	18.54
1976	1.66	.50	.38	.69	.54	3.31	22.93
1977	1.56	.56	.42	.67	.56	4.11	23.88
1978	1.60	.52	.38	.65	.50	3.79	25.49
1979	1.84	.88	.50	.99	.58	3.48	19.45
1980	2.61	.98	.54	1.08	.69	4.01	22.85
1981	3.22	1.06	.64	1.18	.65	3.92	23.39
1982	3.98	.96	.59	1.09	.63	4.37	23.85

Transportation

	Distillate ($/Gal)	Jet Fuel ($/Gal)	Residual ($/Gal)	Propane ($/Gal)	Motor Gasoline ($/Gal)	Coal ($/Ton)
1960	.37	.42	.28	.25	.85	18.21
1961	.36	.45	.25	.25	.84	18.21
1962	.36	.41	.25	.22	.80	18.19
1963	.38	.43	.24	.22	.79	18.27
1964	.35	.43	.24	.21	.75	17.66
1965	.34	.39	.24	.21	.78	17.23
1966	.33	.38	.23	.23	.81	16.74
1967	.34	.37	.22	.22	.86	16.42
1968	.33	.38	.24	.19	.82	15.92
1969	.34	.38	.22	.16	.81	13.56
1970	.32	.38	.21	.21	.79	14.56
1971	.30	.38	.26	.20	.75	18.60
1972	.29	.37	.23	.19	.72	13.14
1973	.35	.33	.31	.24	.72	12.59
1974	.54	.49	.56	.32	.88	16.91
1975	.53	.54	.56	.32	.90	18.54
1976	.54	.62	.50	.54	.82	22.93
1977	.60	.67	.54	.56	.83	23.88
1978	.57	.62	.56	.50	.79	25.49
1979	.94	.99	.64	.58	1.04	19.45
1980	1.05	1.08	.68	.69	1.30	22.85
1981	1.13	1.18	.83	.65	1.32	23.39
1982	1.03	1.09	.76	.63	1.20	23.85

Electric Generation

	Natural Gas ($/Mcf)	Fuel Oil ($/Gal)	Coal ($/Ton)
1960	.68	.28	18.21
1961	.67	.28	18.21
1962	.66	.19	18.19
1963	.73	.22	18.27
1964	.64	.21	17.66
1965	.63	.21	17.23
1966	.63	.20	16.74
1967	.64	.22	16.42
1968	.56	.21	15.92
1969	.56	.18	13.56
1970	.53	.17	14.50
1971	.59	.24	14.55
1972	.62	.21	14.74
1973	.70	.22	13.87
1974	.79	.35	14.91
1975	.88	.43	16.49
1976	1.16	.40	17.98
1977	1.50	.43	17.24
1978	1.75	.41	18.33
1979	2.04	.50	21.35
1980	2.17	.82	20.26
1981	2.82	.82	20.75
1982	3.60	.75	21.09

Sources:

GNP implicit price deflators were used for calculating 1981 real prices. See end of source listing.

Residential

Natural Gas
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-78: U.S. DOE/EIA, "Energy Data Reports, Natural Gas Annual Natural Gas Production and Consumption," Table 7, Revenues Divided by Sales, Washington, D.C.
1979-82: "State Register, Average Residential Energy Prices in Minnesota." Average of 1978-79 and 1979-80, and 1979-80 and 1980-81, and the 1981-82 and the 1982-83 state heating season prices.

Distillate Fuel Oil
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-78: U.S. DOE/EIA, "Heating Oil Prices and Margins, Energy Data Reports" (Monthly), Washington, D.C.
1979-82: "State Register, Average Residential Energy Prices in Minnesota." Average of 1978-79 and 1979-80, and 1979-80 and 1980-81, and the 1980-81 and the 1981-82, and the 1981-82 and the 1982-83 state heating season prices.

Kerosene
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-82: "Petroleum Market Data" (Weekly), St Paul, Minnesota, price differential between #2 and #1 are applied to 1976-82 #2 fuel oil prices.

Propane
1960-75: U.S. DOE/EIA/FEA Consumpton Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-78: "Butane Propane News" (Weekly). Average for each year obtained by using last week wholesale price of each month. Dealer Profit and Transportation Margin were added (recommended by Dean Nolte of the National LP Gas Association).
1979-82: "State Register, Average Residential Energy Prices in Minnesota." Average of 1978-79 and 1979-80, and 1979-80 and 1980-81, and the 1980-81 and 1981-82, and the 1981-82 and the 1982-83 state heating season prices.

Electricity
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-79: Edison Electric Institute, "Statistical Yearbook of the Electric Industry," Tables 22S-36S, New York.
1979-80: "State Register, Average Residential Energy Prices in Minnesota." Average of 1978-79 and 1979-80, and 1979-80 and 1980-81 state heating season prices.
1980-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Coal
1960-70: The 1970 state residential coal price was annually adjusted back to 1960 using the rate of change occuring in the price of coal used in the electric utility sector in Minnesota.
1970-80: The historic difference between the national residential coal price from the U.S. DOE/EIA "Energy Price and Expenditures Data Report, 1970-80" and the state residential coal price is assumed to be equivalent to the difference between the price of coal for electric generation nationally and for the State of Minnesota. This difference in percentage form is applied against the national residential price of coal to estimate the Minnesota residential price.
1981-82: The 1980 state residential coal price was adjusted up using the annual rate of change occuring in the price of coal for electric generation in Minnesota.

Commercial

Natural Gas
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-79: U.S. DOE/EIA, "Energy Data Reports, Natural Gas Annual, Natural Gas.Production and Consumption," Table 7, Revenues Divided by Sales, Washington, D.C.
1980-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Distillate Fuel Oil
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-1982: Residential prices less historic difference of 1.5 cents.

Residual
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C. 1977.
1976-79: U.S. Department of Commerce, Bureau of the Census, "Annual Survey of Manufacturers: Fuels & Electric Energy Consumed." Ross Burke, "Petroleum Product Price," December 11, 1979. Assumed historic trend in price differentialbetween industrial and electric generation residual.
1980-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Kerosene
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-82: Estimated commercial based on historic price differential between residential and commercial kerosene and #2 vs. #1 fuel oil (residential).

Propane
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-82: "Butane Propane News" (Weekly). Average for year obtained by using last week wholesale price of each month.

Electricity
1960-75: US. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-78: Edison Electric Institute, "Statistical Yearbook of the Electric Industry," Tables 22S, 36S, Revenues Divided by Sales, New York.
1979: NSP Company, Rate Department estimate for commercial buildings.
1980-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Coal
1960-82: Used industrial coal prices.

Industrial

Natural Gas
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-79: U.S. DOE/EIA, "Energy Data Reports, Natural Gas Annual, Natural Gas Production and Consumption," Washington, D.C.
`30-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

_ .stillate Fuel Oil
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-82: Based on historical trend differences between commercial and industrial.

Residual
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-80: Based on historical trend differences between commercial and industrial.
1980-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Kerosene
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1796-82: Based on historical trend differences between commercial and industrial.

Propane
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-82: "Butane Propane News" (Weekly".) Average for year obtained by using last week wholesale price of each month.

Electricity
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-79: Edison Electric Institute, "Statistical Yearbook of the Electric Industry," Tables 22S, 36S, Revenues Divided by Sales, New York.
1980-82: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Coal
1960-70: The 1970 state industrial coal price was adjusted back to 1960 using the rate of change occurring in the price of coal in the electric utility sector in Minnesota.
1970-80: The historic differences between national industrial coal price from the U.S. DOE/EIA "Energy Price and Expenditures Data Report, 1970-80" and the state industrial price is assumed to be equivalent to the difference between the price of coal for electric generation nationally and for the State of Minnesota. This difference in percentage form is applied against the national industrial price of coal to estimate the Minnesota Price.
1981-82: The 1980 state industrial price of coal was adjusted up using the rate of change occurring in the price of coal for electric generation in Minnesota.

Agricultural

Used commercial sector prices for all fuels except motor gasoline. Motor gasoline data represents transportation sector motor gasoline prices less highway gasoline tax from which agricultural use is exempt.

‾ransportation

.sed commercial sector prices for all fuels except motor gasoline.

Motor Gasoline
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-82: "Petroleum Market Data" (Weekly), St. Paul, Minnesota, yearly average of Twin Cities average regular gasoline price.

Electric Utility

Natural Gas
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-77: Bureau of Power, FPC, "Annual Summary of Cost & Quality of Electric Utility Plant Fuels" (Yearly).

1978-82: U.S. DOE/EIA "Energy Data Report Cost and Quality of Fuels for Electric Utility Plants" (Yearly), Washington, D.C.

Fuel Oil
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-77: Bureau of Power, FPC, "Annual Summary of Cost & Quality of Electric Utility Plant Fuels" (Yearly).
1978-82: U.S. DOE/EIA "Energy Data Report, Cost and Quality of Fuels for Electric Utility Plants" (Yearly), Washington, D.C.

Coal
1960-75: U.S. DOE/EIA/FEA Consumption Studies Division/Federal Energy Administration, "Energy Price Data Base," Washington, D.C., 1977.
1976-77: Bureau of Power, FPC, "Annual Summary of Cost & Quality of Electric Utility Plant Fuels" (Yearly).
1978-82: U.S. DOE/EIA "Energy Data Report, Cost and Quality of Fuels for Electric Utility Plants" (Yearly), Washington, D.C.

GNP implicit price deflators used for calculating 1981 real prices (1981 = 100):

1960	35.59	1972	51.77
1961	35.91	1973	54.72
1962	36.56	1974	59.48
1963	37.11	1975	64.72
1964	37.66	1976	68.08
1965	38.49	1977	72.03
1966	39.72	1978	77.29
1967	40.92	1979	83.86
'968	42.72	1980	91.41
ɘ69	44.90	1981	100.00
1970	47.32	1982	105.90
1971	49.69		

Sources: Economic Indicators, June 1982, United States Printing Office, Washington, D.C., 1982. DRI, U.S. Long-Term Review, Lexington, Massachusetts,Summer 1983 (Trendlong 0683). DRI, Lexington, Massachusetts, Spring 1983 (Trendlong 2008A).

Table 13
Projected Energy Prices per Unit by Sector, 1981-2000 (1981 dollars)

Residential

	Full Service Gas ($/Gal)	Self Service Gas ($/Gal)	#2 Fuel Oil ($/Gal)	Kerosene #1 FO ($/Gal)	Propane ($/Gal)	Natural Gas ($/Mcf)	Electricity (¢/kWh)
1981	1.42	1.27	1.15	1.20	.73	4.02	5.79
1982	1.37	1.13	1.05	1.10	.71	4.78	5.61
1983	1.33	1.04	.93	1.05	.74	5.13	5.44
1984	1.29	.99	.91	1.03	.78	5.02	5.35
1985	1.24	.95	.87	.99	.75	4.90	5.28
1986	1.24	.95	.86	.98	.73	4.77	5.18
1987	1.24	.96	.86	.98	.74	4.74	5.15
1988	1.26	.97	.88	1.00	.75	4.78	5.03
1989	1.28	.99	.89	1.01	.77	4.86	4.93
1990	1.29	1.01	.91	1.03	.79	4.95	4.83
1991	1.31	1.03	.92	1.04	.81	5.03	4.74
1992	1.33	1.05	.94	1.06	.82	5.11	4.66
1993	1.35	1.07	.96	1.08	.84	5.20	4.58
1994	1.37	1.09	.98	1.10	.86	5.28	4.51
1995	1.39	1.11	1.00	1.12	.89	5.36	4.46
1996	1.41	1.13	1.01	1.13	.91	5.44	4.42
1997	1.44	1.15	1.03	1.15	.93	5.53	4.37
1998	1.46	1.17	1.05	1.17	.95	5.63	4.34
1999	1.48	1.19	1.07	1.19	.97	5.73	4.29
2000	1.50	1.22	1.09	1.21	1.00	5.84	4.24

Commercial

	Fuel Oil ($/Gal)	Kerosene ($/Gal)	#5 Residual ($/Gal)	Natural Gas ($/Mcf)	Electricity (¢/kWh)
1981	1.13	1.18	.83	3.83	4.56
1982	1.03	1.09	.76	4.59	4.91
1983	.91	1.03	.64	4.94	4.74
1984	.89	1.01	.64	4.84	4.65
1985	.85	.97	.61	4.72	4.57
1986	.84	.96	.60	4.59	4.48
1987	.84	.96	.61	4.56	4.40
1988	.86	.98	.62	4.61	4.38
1989	.87	.99	.63	4.69	4.29
1990	.89	1.01	.65	4.78	4.22
1991	.90	1.02	.66	4.86	4.17
1992	.92	1.04	.68	4.95	4.11
1993	.94	1.06	.69	5.04	4.05
1994	.96	1.08	.71	5.12	3.99
1995	.98	1.10	.73	5.20	3.94
1996	.99	1.11	.74	5.28	3.90
1997	1.01	1.13	.76	5.38	3.86
1998	1.03	1.15	.78	5.47	3.82
1999	1.05	1.17	.80	5.58	3.79
2000	1.07	1.19	.82	5.69	3.76

Industrial

	Fuel Oil ($/Gal)	Kerosene ($/Gal)	#6 Residual ($/Gal)	Propane ($/Gal)	Natural Gas ($/Gal)	Coal ($/Ton)	Electricity (¢/kWh)
1981	1.06	1.18	.64	.68	3.22	32.42	3.92
1982	.96	1.09	.59	.66	3.98	32.91	4.39
1983	.84	1.03	.58	.68	4.33	31.74	4.02
1984	.82	1.01	.58	.73	4.22	31.25	3.97
1985	.78	.97	.56	.69	4.10	31.55	3.92
1986	.77	.96	.55	.68	3.97	32.00	3.88
1987	.77	.96	.55	.68	3.94	32.24	3.83
1988	.78	.98	.56	.70	3.98	32.55	3.83
1989	.80	.99	.58	.71	4.06	32.95	3.78
1990	.82	1.01	.59	.73	4.15	33.54	3.75
1991	.83	1.02	.61	.75	4.23	33.98	3.73
1992	.85	1.04	.62	.77	4.31	34.55	3.70
1993	.87	1.06	.64	.79	4.41	35.40	3.67
1994	.89	1.08	.66	.81	4.48	36.00	3.64
1995	.90	1.10	.68	.83	4.56	36.41	3.62
1996	.92	1.11	.69	.85	4.64	36.96	3.60
1997	.94	1.13	.71	.87	4.73	37.37	3.58
1998	.96	1.15	.73	.90	4.83	37.55	3.57
1999	.98	1.17	.75	.92	4.93	37.90	3.55
2000	1.00	1.19	.77	.94	5.04	38.08	3.54

Electric Generation

	#2 Oil ($/Gal)	#6 Residual ($/Gal)	Natural Gas ($/Mcf)	Phase 1 Natural Gas ($/Mcf)	Coal ($/Ton)
1981	1.00	.64	2.82	3.78	20.75
1982	.90	.59	3.60	3.86	21.06
1983	.79	.58	3.97	3.97	20.32
1984	.76	.58	3.88	3.88	20.00
1985	.73	.56	3.77	3.77	20.19
1986	.72	.55	3.65	3.65	20.48
1987	.73	.55	3.64	3.64	20.63
1988	.74	.56	3.70	3.70	20.83
1989	.76	.58	3.80	3.80	21.09
1990	.78	.59	3.90	3.90	21.46
1991	.80	.61	3.99	3.99	21.75
1992	.82	.62	4.09	4.09	22.11
1993	.84	.64	4.20	4.20	22.66
1994	.86	.66	4.28	4.28	23.04
1995	.88	.68	4.37	4.37	23.30
1996	.90	.69	4.46	4.46	23.65
1997	.92	.71	4.57	4.57	23.92
1998	.94	.73	4.68	4.68	24.03
1999	.96	.75	4.79	4.79	24.26
2000	.98	.77	4.90	4.90	24.37

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 14
Projected Energy Prices per Million Btu by Sector, 1981-2000 (1981 dollars)

Residential

	Full Service Gas	Self Service Gas	#2 Fuel Oil	Kerosene #1 FO	Propane	Natural Gas	Electricity
1981	11.40	10.15	8.28	8.92	7.99	4.02	16.97
1982	10.92	9.02	7.57	8.18	7.77	4.78	16.44
1983	10.63	8.33	6.72	7.80	8.04	5.13	15.94
1984	10.29	7.90	6.65	7.62	8.54	5.02	15.68
1985	9.93	7.63	6.25	7.31	8.17	4.90	15.47
1986	9.88	7.60	6.19	7.25	8.02	4.77	15.18
1987	9.95	7.66	6.23	7.29	8.07	4.74	15.09
1988	10.06	7.78	6.31	7.38	8.21	4.78	14.74
1989	10.21	7.92	6.42	7.49	8.41	4.86	14.45
1990	10.35	8.07	6.53	7.61	8.60	4.95	14.16
1991	10.51	8.22	6.66	7.74	8.80	5.03	13.89
1992	10.66	8.38	6.78	7.86	9.01	5.11	13.66
1993	10.82	8.54	6.91	8.00	9.23	5.20	13.42
1994	10.99	8.70	7.04	8.13	9.45	5.28	13.22
1995	11.15	8.87	7.17	8.27	9.68	5.36	13.07
1996	11.32	9.03	7.30	8.40	9.91	5.44	12.95
1997	11.49	9.21	7.44	8.54	10.15	5.53	12.81
1998	11.66	9.38	7.57	8.68	10.39	5.63	12.72
1999	11.84	9.55	7.71	8.82	10.64	5.73	12.57
2000	12.02	9.74	7.86	8.97	10.91	5.84	12.43

Commercial

	Fuel Oil	Kerosene	#5 Residual	Natural Gas	Electricity
1981	8.14	8.77	5.52	3.83	13.36
1982	7.43	8.04	5.06	4.59	14.39
1983	6.58	7.65	4.27	4.94	13.89
1984	6.40	7.47	4.28	4.84	13.63
1985	6.10	7.17	4.07	4.72	13.39
1986	6.04	7.11	4.00	4.59	13.13
1987	6.08	7.15	4.02	4.56	12.90
1988	6.17	7.23	4.10	4.61	12.84
1989	6.28	7.35	4.19	4.69	12.57
1990	6.39	7.46	4.29	4.78	12.37
1991	6.51	7.59	4.39	4.86	12.22
1992	6.64	7.72	4.50	4.95	12.05
1993	6.77	7.85	4.61	5.04	11.87
1994	6.90	7.98	4.72	5.12	11.69
1995	7.03	8.12	4.83	5.20	11.55
1996	7.16	8.25	4.95	5.28	11.43
1997	7.30	8.39	5.07	5.38	11.31
1998	7.43	8.53	5.19	5.47	11.20
1999	7.57	8.68	5.31	5.58	11.11
2000	7.72	8.83	5.44	5.69	11.02

Industrial

	Fuel Oil	Kerosene	#6 Residual	Propane	Natural Gas	Coal	Electricity
1981	7.62	8.77	4.17	7.39	3.22	1.53	11.49
1982	6.91	8.04	3.86	7.17	3.98	1.55	12.87
1983	6.06	7.65	3.79	7.44	4.33	1.50	11.78
1984	5.88	7.47	3.80	7.94	4.22	1.47	11.64
1985	5.59	7.17	3.67	7.57	4.10	1.49	11.49
1986	5.53	7.11	3.61	7.43	3.97	1.51	11.37
1987	5.57	7.15	3.63	7.47	3.94	1.52	11.23
1988	5.65	7.23	3.70	7.62	3.98	1.53	11.23
1989	5.76	7.35	3.80	7.81	4.06	1.55	11.08
1990	5.88	7.46	3.90	8.00	4.15	1.58	10.99
1991	6.00	7.59	4.00	8.21	4.23	1.60	10.93
1992	6.12	7.72	4.10	8.42	4.31	1.63	10.84
1993	6.25	7.85	4.21	8.63	4.41	1.67	10.76
1994	6.38	7.98	4.32	8.86	4.48	1.70	10.67
1995	6.51	8.12	4.43	9.09	4.56	1.71	10.61
1996	6.64	8.25	4.55	9.31	4.64	1.74	10.55
1997	6.78	8.39	4.66	9.55	4.73	1.76	10.49
1998	6.92	8.53	4.78	9.79	4.83	1.77	10.46
1999	7.06	8.68	4.91	10.05	4.93	1.79	10.40
2000	7.20	8.83	5.04	10.31	5.04	1.79	10.38

Electric Generation

	#2 Oil	#6 Residual	Natural Gas	Phase 1 Gas	Coal
1981	7.19	4.17	2.82	3.78	1.12
1982	6.50	3.86	3.60	3.86	1.14
1983	5.67	3.79	3.97	3.97	1.10
1984	5.51	3.80	3.88	3.88	1.08
1985	5.23	3.67	3.77	3.77	1.09
1986	5.19	3.61	3.65	3.65	1.11
1987	5.25	3.63	3.64	3.64	1.12
1988	5.35	3.70	3.70	3.70	1.13
1989	5.47	3.80	3.80	3.80	1.14
1990	5.61	3.90	3.90	3.90	1.16
1991	5.74	4.00	3.99	3.99	1.18
1992	5.88	4.10	4.09	4.09	1.20
1993	6.03	4.21	4.20	4.20	1.22
1994	6.17	4.32	4.28	4.28	1.25
1995	6.31	4.43	4.37	4.37	1.26
1996	6.45	4.55	4.46	4.46	1.28
1997	6.60	4.66	4.57	4.57	1.29
1998	6.75	4.78	4.68	4.68	1.30
1999	6.90	4.91	4.79	4.79	1.31
2000	7.05	5.04	4.90	4.90	1.32

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development

Table 15
Conservation Potential under Current Fuel Price Projections and Consumption Trends, 1983-2000 (trillion Btu)

	Residential	Commercial/ Institutional	Industrial	Agricultural	Transportation	Total
1983	14.1	3.3	5.0	3.5	.3	26.2
1985	16.6	10.1	3.5	6.1	1.8	45.0
1990	27.5	12.4	17.6	12.9	11.8	82.2
1995	33.8	19.5	23.4	20.4	33.6	130.7
2000	38.4	31.1	30.1	27.9	55.0	182.5

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 16
Alternative Energy Consumption, 1983-2000 (trillion Btu)

	Residential	Commercial/ Institutional	Industrial	Agricultural	Transportation	Electric Utility	Total
1983	18.9	7.1	12.0	0	0	0	38.0
1984	19.5	7.2	12.8	.1	1.5	0	41.1
1985	20.2	7.4	13.9	.2	3.0	.3	45.0
1986	20.8	7.6	14.2	.3	4.4	.6	47.9
1987	22.2	8.0	15.3	.5	5.8	.9	52.7
1988	23.7	8.7	16.1	.6	7.2	1.2	56.5
1989	25.4	9.2	15.5	.7	8.5	2.0	61.3
1990	27.0	9.7	16.5	.7	9.8	2.4	66.1
1991	28.2	10.4	17.4	.8	11.1	2.9	70.8
1992	29.3	11.0	18.0	.8	12.2	3.3	74.8
1993	30.5	11.7	19.0	.7	13.3	3.8	79.2
1994	31.7	12.1	20.0	.7	14.2	4.3	83.2
1995	32.9	12.9	21.3	.6	15.2	4.8	87.7
1996	34.0	13.6	21.8	.5	16.2	5.3	91.4
1997	35.2	14.3	23.0	.4	17.2	5.8	95.9
1998	36.4	15.1	24.5	.3	18.4	6.3	101.0
1999	37.4	15.9	25.1	.3	19.5	6.9	105.1
2000	38.6	16.7	26.5	.3	20.7	7.5	110.3

Source: Policy Analysis Division, Minnesota Department of Energy and Economic Development.

Table 17
Alternative Energy Consumption by Technology, 1983-2000 (trillion Btu)

	Solid Biomass			Biomass Gas (biogas)			Biomass Liquid (methanol/ethanol)				
	Residential	Commercial/ Institutional	Industrial	Residential	Commercial/ Institutional	Industrial	Residential	Commercial Institutional	Industrial	Agricultural	Transportation
1983	18664	248	9696	0	0	0	0	0	0	0	41
1984	19226	328	10296	0	0	0	0	0	4	121	1513
1985	19823	405	11062	0	0	0	0	0	7	238	2961
1986	20407	481	10956	0	0	290	0	30	8	348	4381
1987	21031	558	11610	685	329	548	29	61	13	457	5804
1988	21702	635	12094	1385	663	782	57	92	16	560	7197
1989	22431	712	11207	2090	1000	918	82	122	16	655	8489
1990	23241	790	11860	2763	1342	1019	105	153	17	733	9787
1991	23599	868	12285	3451	1687	1370	126	184	20	785	11097
1992	23975	946	12795	4112	2036	1475	144	214	22	786	12232
1993	24345	1025	13439	4761	2388	1616	159	245	25	743	13250
1994	24753	1103	14158	5404	2744	1764	175	276	27	658	14210
1995	25158	1181	15037	6027	3102	1908	191	307	30	567	15168
1996	25577	1260	15174	6647	3463	1977	208	337	33	469	16176
1997	25984	1338	16099	7227	3826	2076	222	368	36	398	17241
1998	26397	1415	17192	7781	4191	2267	235	399	39	331	18362
1999	26791	1493	17590	8297	4557	2397	247	429	42	274	19511
2000	27203	1570	18583	8821	4924	2568	257	459	45	268	20720

	Solar			District Heating		Wind Electrical Conversion (WEC)		
	Residential	Commercial/ Institutional	Industrial	Commercial/ Institutional	Industrial	Residential	Commercial/ Institutional	Industrial
1983	232	4	0	6795	2358	25	0	0
1984	266	12	191	6846	2389	36	0	0
1985	312	28	381	6898	2428	55	0	283
1986	362	47	543	6953	2445	80	0	584
1987	432	74	649	7007	2474	112	0	905
1988	493	108	733	7079	2494	151	0	1247
1989	573	150	960	7147	2526	196	0	1996
1990	662	199	1043	7211	2556	246	0	2430
1991	721	266	1154	7332	2614	283	0	2878
1992	786	338	1275	7415	2660	323	0	3338
1993	857	415	1390	7492	2702	369	0	3811
1994	934	510	1461	7563	2761	418	0	4299
1995	1016	626	1551	7651	2808	472	0	4799
1996	1105	754	1719	7686	2900	529	0	5314
1997	1199	898	1840	7851	2978	592	0	5844
1998	1298	1056	1981	7960	3051	659	0	6388
1999	1403	1234	2056	8072	3131	732	0	6948
2000	1516	1428	2148	8186	3219	809	0	7523

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