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MINNESOTA'S ENERGY FUTURE

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STATE OF MINNESOTA

AS PRESENTED

TO THE

COMMISSION ON MINNESOTA'S FUTURE

on AUGUST 20, 1976

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THE OBJECTIVES OF THIS REPORT

The objectives of this report are to provoke more thought and discussion about alternatives for Minnesota's energy future, and to encourage conscious choices, decisions and actions by citizens and policymakers to help shape a sound energy future for the state. The report was prepared as part of the work of the Commission on Minnesota's Future.

The report is designed to meet its goals by describing the nature of the present energy situation as we near the end of the fossil fuel age, by presenting three energy scenarios speculating on near-term developments and by proposing actions by Minnesotans to meet short-term and long-term needs.

There will be disagreement with the scenarios and with policy recommendations in the report. But if they contribute to a debate which produces a meaningful energy policy for Minnesota and guidelines for action, they will have served their purpose.

Power Resources

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I. SUMMARY AND COMMENTS

This assignment to produce a report on Minnesota's energy future was undertaken in the belief that the state could be in energy trouble soon. Research and conversations in the preparation of the report have confirmed that concern. Minnesota is in a precarious position with respect to energy supplies.

This is caused in part by the fact that the state has no native supplies of the fossil fuels conventionally used today. Minnesota must import all the natural gas, oil and coal consumed in the state.

But the larger, more central reason for the energy problems facing Minnesota and indeed the rest of the world is that the beginning of the end of the fossil fuel age is at hand for Earth, confronting us with the immediate need to develop new energy sources. We are running out of natural gas and oil now. Coal and other fossil fuels will not be long for this world either. Coal reserves and oil shale are said to be sufficient for 250-300 years - but at today's coal and petroleum consumption rates.

It is vitally important to understand, however, that exponential growth such as doubled fuel consumption every ten years can telescope today's 300-year supply to a 40 or 50-year supply.

The table below illustrates what happens to a fuel supply when consumption of that fuel doubles every ten years.

Period	Cumulative Consumption At End of Period
1976-1985	15 times 1976 usage
1976-1995	45 times 1976 usage
1976-2005	105 times 1976 usage
1976-2015	225 times 1976 usage
1976-2025	465 times 1976 usage

Measuring the energy future in terms of today's consumption is dangerous. We must either adjust our thinking or energy growth rates, or both.

The United States and Minnesota are beginning to feel the stress of fossil fuel depletion. The signals include the rising prices for fossil fuel heating and for gasoline, natural gas curtailments, increasing importation of foreign oil at a cost of

billions of dollars annually, formation of new government agencies to deal with energy problems, some energy legislation, emerging interest in energy conservation, and acceleration of research into alternative energy sources.

But most Minnesotans, like their fellow citizens in the rest of the nation, don't seem to accept in 1976 that there are real energy problems ahead. "We got through that oil shortage business at the end of 1973 okay, didn't we, and besides that it was a put up job by the oil companies." The 55 mph speed limit is observed by a handful of law-abiding squares and only rarely enforced. The federal government has yet to develop a meaningful energy policy.

Yes, there are pockets of activity and concern about the energy future, but for the most part Americans who have lived in energy affluence all their lives will be slow to change their attitudes or their ways - until crisis strikes. We can't count on overnight technological miracles or the sudden arrival of major new energy sources to save the day.

There have been objections to the three energy scenarios in this report, which are based on the hypothetical postulation that Minnesota will do little in the period immediately ahead to avert or soften a coming energy crisis. "We won't let that happen," say some. "We'll plan. We'll take leadership. Minnesota will take action."

Let's hope so - that Minnesotans as individuals and through their state and local governments will consciously determine to do all within their power to manage their energy future. If they don't, other people and events will call the whole tune for them. An aggressive program by Minnesotans to shape and manage their energy future must include unilateral actions by the state and its citizens in matters under their control, coupled with determined efforts to influence federal policy and actions. The most difficult task immediately ahead will be adjusting to the diminishing supplies of natural gas and oil. This will be disruptive and expensive for many people and businesses. The sooner we begin making the adjustments to compensate for the depletion of natural gas and oil, the easier our path will be. A small adjustment today can prevent a major upheaval ten years from now.

Energy conservation is the most significant means available right now to help ease the pain. It must become a way of life and business in Minnesota. Coal will help fill the gap, too, serving as the growth fuel in the years immediately ahead. But it, too, will go the way of other fossil fuels. An era of new energy

sources must emerge as fossil fuels phase out. Major effort must be directed now to developing the energies of the future.

Solar energy and some form of nuclear energy appear to be the best candidates based on today's technological development. Perhaps some new energy source as yet unforeseen will emerge to make a major contribution. Minnesota must consciously keep all of its energy options open and should approach the task of finding workable solutions among them with a willingness to experiment and to pioneer new approaches. To buy time for this exploration on the energy frontiers, we must extend the "life" of fossil fuels just as long as possible through conservation and other means.

Man is an adaptable animal who can cope with change. He made the transition from wood as a primary energy source to highly sophisticated systems for obtaining and using fossil fuels. The size and complexity of the systems for extracting, distributing and consuming natural gas, which have essentially been developed over the last 30-40 years, should give us hope for the future development and use of new energy sources.

As a final note, Minnesota has a major resource to draw upon in its energy future: A large group of knowledgeable, dedicated people with vision. A number of them have given time and counsel to this project. Thank you.

Gene Felton

August 1976

II. RECOMMENDATIONS

Minnesota should consciously develop a state energy policy consisting of:

Actions that individuals, local governments and state government can take unilaterally, independent of the federal government or others outside Minnesota . . .

Coupled with directions in which state government, Minnesota Congressmen, Senators, business people and voters try to influence federal policy and action

Recommended energy steps for unilateral action by Minnesota include:

Implementing a strong energy conservation program

Enacting a mandatory energy allocation program for energy use

Investigating establishment of a state-financed or state-subsidized insulation program

Studying the relationship between cost and availability of energy and population growth and distribution

Studying the possible effects of energy price manipulation on customer use and the Minnesota economy

Developing a state water use policy relating to energy conversion

Encouraging solar energy installations in the state

Encouraging use of other energy alternatives by Minnesotans

Developing a state position regarding future nuclear power plants in Minnesota

Encouraging a peat gasification demonstration project in the state

Investigating the potential for coal gasification plants in Minnesota

Investigating district heating concepts employing a power plant on an urban site both as a source of electricity and of warm water for heating

Encouraging construction of new pipeline capacity from the Gulf Coast to supply either petroleum products or crude oil to Minnesota

Studying possibilities for reducing the siting and licensing time for new energy facilities in Minnesota, along with study of the potential impacts of acceleration

Encouraging separation of train and vehicle crossings at critical points along the western rail routes to minimize traffic tieups caused by coal trains

Expanding energy data for the state and co-ordinating energy forecasting assumptions and techniques among the state's energy suppliers

Expanding energy education and publicity

Minnesota should attempt to influence federal energy policy and activity in the following areas of interest to the state:

Urging deregulation of new natural gas prices and oil prices

Urging the federal government to do all it reasonably can to encourage the Canadian government to extend the time in which Canadian crude oil will be available to the U.S., including Minnesota-area refineries

Evaluating and encouraging adoption of the best oil pipeline route from the Pacific Coast to supply Alaskan and foreign oil to Minnesota and the Upper Midwest

Encouraging adequate funding for an accelerated, major solar energy research and development program

by the federal Energy Research and Development Administration (ERDA)

Encouraging more ERDA research into other energy alternatives

Supporting breeder reactor and fusion research and development

Obtaining Alaskan natural gas for Minnesota

General Recommendations:

State government should not allow Minnesota to become locked into one dominant energy source, because the state becomes so vulnerable to events affecting that source.

Minnesota should strive for maximum flexibility for its energy future by developing a range of alternatives and then keeping them open as long as possible. The risks of concentrating on one or two seemingly obtainable energy alternatives, to the exclusion of others, are too great in this period of uncertainty, rapid change and newly-developing technology.

State government should move carefully in any consideration of energy price manipulation or regulation of certain energy uses because of the complex inter-relationships among energy forms and the state's economy.

III. THE PRESENT - AND NEAR-TERM FUTURE

Minnesota in 1976 is seeing early signs of major changes in its energy resources. Curtailment of natural gas to Minnesota consumers has begun. Canada also has started curtailing exports of its oil to Minnesota and other northern tier states. Natural gas and oil together account for about three-quarters of Minnesota's total energy supply and Canadian oil alone represents 25 percent of the total state energy supply. The curtailment problem is serious for Minnesota, but similar conditions also exist in other parts of the nation.

The fundamental cause of the curtailments is that the end of the fossil fuel age is in sight for this world. Natural gas and oil, the two fossil fuels used most heavily in the United States today, are beginning to run out. The United States has proven reserves of about 11 years' supply of natural gas and six years' supply of oil, based on current consumption. World-wide reserves of both fuels extend further but not enough to give us much comfort. Reserves may be extended somewhat by new discoveries, but with today's presently high rate of consumption for both oil and natural gas those new reserves are not expected to make a significant difference in how much longer the two fuels will last.

Reserves of other fossil fuels, such as coal, oil shale and peat are significantly larger. But growth in use of these fuels as they are substituted for oil and natural gas will number their days also.

Thus, it is imporant to look at the over-all picture - one of diminishing fossil fuels - in analyzing Minnesota's energy picture.

A second important factor to recognize is that Minnesota does not have any native supplies of the fossil fuels conventionally used today. If the state did, it might be able to hang onto them for its own uses somewhat longer, although that is debatable. Minnesota does have peat reserves which may be used to either produce synthetic gas as a replacement for natural gas, or as fuel for electric power plants. Minnesota consumers also will be able to utilize solar energy in the future. But much work and development need to be undertaken in Minnesota before either peat or solar energy resources make any real contribution to the big energy picture.

So, Minnesota, the United States and the rest of the world are

in a transition period from the conventional fossil fuels used over the last 100 years to new forms of energy and new energy sources. The transition period is traumatic. It causes disruptions and dislocations, higher prices, charges and countercharges, confusion, politicking, and regional and international tensions. This will continue until new energy sources begin to make major contributions.

A Closer Look at Natural Gas and Oil

In 1975 petroleum accounted for about 44 percent of Minnesota's total energy supply and natural gas represented about 30 percent. More than 90 percent of the natural gas came from a single pipeline supplier from fields in Texas, New Mexico, Oklahoma, Kansas and Montana.

More than half of the petroleum used in the state comes from Canada, principally from oil wells in the province of Alberta.

The state's largest natural gas supplier has indicated that it expects supplies will be reduced by 2-3 percent per year. Natural gas already is nearly phased out as a fuel for electric power plants in the state. Large volume industrial customers who have used natural gas on an interruptible basis in the past will be increasingly curtailed. In addition the taconite industry, which presently uses about 10 percent of Minnesota's natural gas supply, is expected to lose most of its natural gas supply in the future.

Natural gas prices in the interstate market are presently regulated and restricted by the federal government, whereas prices of natural gas produced and sold in the same state are not regulated. As a result, an increasing percentage of natural gas is being sold in the intrastate market because of the higher prices it commands there. It is possible that prices of natural gas from new wells will be deregulated by the federal government within the next several years. This presumably would result in some increase in natural gas reserves because there would be more of a price incentive for producers to develop new wells. However the impact of deregulation on natural gas supplies is extremely hard to predict. In fact, the whole question of fuel prices and their effect on development of new supplies and on usage by consumers is a cloudy one. Energy prices in the United States have traditionally been low over the last 30-40 years, so there is little experience to draw upon in forecasting what the effect of pricing may be on consumption.

Canada, as a matter of national energy policy, has stated that it

will phase out its deliveries of crude oil to the United States by the early 1980's. Minnesota area refineries are attempting to obtain replacement supplies. One proposal is that a deep water port be developed near Prince Rupert, British Columbia, that could receive Alaskan oil brought in by tanker or oil from other world sources. An 800-mile pipeline would be built from there eastward to connect with a present pipeline near Edmonton, Alberta. This is the pipeline that presently delivers the Canadian crude to Minnesota. Another possibility is construction of a new pipeline from Seattle eastward across the northern tier of states to supply Alaskan and foreign oil to those states, including Minnesota. Another oil option would be constructing new pipeline capacity to bring petroleum crude or oil products to Minnesota from the Gulf Coast. (Petroleum products from the southwest presently come into Minnesota via a major pipeline between Tulsa, Oklahoma, and St Paul.)

Coal - The Near-Term Growth Fuel

Coal is expected to be the major growth fuel for Minnesota in the near-term future. Present natural gas users who will be curtailed, such as the taconite industry, may turn to direct use of coal. Electricity that is substituted for natural gas and oil will be largely produced by burning coal, at least over the next ten to fifteen years. Most of the coal will be delivered to Minnesota by train from mines in Montana and Wyoming. The Minnesota Energy Agency forecasts that the amount of coal used in Minnesota will triple by 1985, increasing from about 9,000,000 tons annually to 28,000,000 tons.

A concern about the use of coal - or any other fuel - in today's electric power plants is that about two-thirds of the energy in the fuel is lost as waste heat. Technology now being developed to make more efficient use of fuel should be utilized as fully and as quickly as possible. However, efficiency improvements will be limited by the laws of thermodynamics.

Solar Energy

The use of solar energy in Minnesota and the nation could be substantial, depending on economics and technological development.

Solar energy equipment is available for heating and cooling homes and buildings and for water heating, but equipment costs are presently high. Accelerated research and development of solar heating and cooling technology is needed at the federal level,

coupled with a program in Minnesota to encourage solar installations. Tax incentives or state subsidies for solar installations should be explored.

Research and development are under way on installations that would convert the radiant energy from the sun into electricity, either directly or through production of steam to drive turbo-generators. Any full scale application of those concepts is considerably in the future.

Peat

Peat, Minnesota's only native fossil fuel, may well be an energy source of the future. The peat would be burned as a fuel for production of electricity in conventional power plants, as is done in European countries, or it could be converted into a synthetic gas to replace natural gas. An investigation into the latter possibility is under way in the state. Minnesota has about half of the total peatland acres existing in the contiguous United States. Most of Minnesota's peat is located in the northern part of the state.

Other Alternatives

Other energy sources also hold potential for making a contribution to the energy future. They include:

- Wind power
- Burning of agricultural and forest residues
- Burning refuse
- Converting animal manures to gas
- Utilizing waste heat from power plants

It does not seem likely that these presently unconventional energy sources will make a major contribution to Minnesota's total energy supplies in the future. They will be important, however, in that they make use of resources that are presently wasted, and their use also would conserve other resources.

The foregoing discussion of alternative energy sources boils down to the fact that there will be no short-term panaceas or technological miracles to save us during the next 20-30 years as we struggle with natural gas and oil shortages. From 40 to 60 years has been required historically to fully develop and utilize a new energy technology on any broad scale.

IV. THREE SHORT-TERM ENERGY SCENARIOS FOR MINNESOTA

Three energy "scenarios" have been developed by the author as tools for considering Minnesota's energy future to the year 2000. The scenarios should be thought of as stories, not as projections, predictions, or forecasts. However, an attempt has been made in developing them not to stray too far from what seems credible or logical.

The scenarios are all based on the assumption that Minnesota will let energy events take their course - up to the crisis point. The scenarios assume that until crisis occurs, we will blow with the wind, at the mercy of fate, chance and actions of others. This is an extreme position, of course, for Minnesota already has done some things to prepare for the energy future and will surely do more. However, scenarios based on inertia and inaction, up to the point of a real energy crunch, appear to be more realistic than would scenarios portraying a strong base of citizen support for aggressive legislation and regulation or concerted voluntary action by Minnesotans to avert or soften future crises.

The three scenarios basically depict different amounts of petroleum supplies for the state of Minnesota. Petroleum was chosen as the "swing" fuel because there is considerable uncertainty about supplies and sources in the future. Minnesota's natural gas future seems to be pretty well mapped out at the present time. Oil also is the state's largest primary fuel now, so changes in oil supplies will have major impact on the state and its people.

ADEQUATE SUPPLY SCENARIO
(Business as Usual)

This scenario is essentially a projection of Minnesota's present energy affluence over the next 25 years, perhaps moderated somewhat by rising energy prices. Over-all supplies are adequate through the end of the century to support us in the style to which we have become accustomed, although prices do rise faster than inflation because of the competition for energy supplies. Because energy supplies are adequate, Minnesota postpones any meaningful actions to prepare for the day oil runs out or foreign oil sources establish embargoes. Development of alternative energy sources occurs basically because of economic incentives, not because of a desire to find replacment forms or to conserve conventional resources against the day that oil runs out. The ongoing growth in Minnesota's energy use continues the state's

heavy dependence on petroleum imports. This growth also greatly increases the state's use of coal, with attendant transportation and air pollution problems.

Through the end of the century, Minnesota is no worse off or no better off, on balance, than the rest of the nation with respect to over-all energy costs and supplies:

- Minnesota has a favorable cost and supply position for western coal

- Minnesota also has a good supply situation for Alaskan oil and gas but transportation costs from Alaska boost prices

- The supply situation for oil products coming up from the south is not as secure as for the Alaskan oil, because Minnesota is at the end of the line, and prices also are high because of transportation costs

However, price differentials in oil, gas or coal are not large enough to attract industry to or from Minnesota in any significent numbers.

Over-all, Minnesota gets all the energy it wants. The only significant change in energy use patterns is caused by the curtailment of natural gas to large interruptible customers but other forms of energy are available to make up for the loss of natural gas. The large interruptible gas customers make the switch from natural gas to oil, coal or electricity without serious disruption to them or to the state's economy.

Minnesota increases its use of petroleum by about 40 percent between 1975 and 1985 and a similar increase occurs in the decade following. Minnesota continues to receive Candian crude oil into the early 1980's and also receives Alaskan oil. The remainder of the state's petroleum supply comes from domestic sources plus U.S. imports of foreign oil (other than Canadian crude). The U.S. continues to import large quantities of foreign oil to meet such needs in Minnesota as well as in other states.

While natural gas is entirely discontinued for the large interruptible customers by 1981, natural gas service continues to residential and small commercial customers without restriction. Congress removes interstate price regulations on new natural gas discovered beginning in 1978. All price controls on crude oil

and petroleum products are removed effective in 1978 as another incentive to oil exploration. Consumer costs for both natural gas and petroleum move up faster than inflation, initially as the result of deregulation and then later as the result of competitive pressures on the two fuels. Natural gas prices for residential and small commercial customers increase 12 to 15 percent annually in the first few years after deregulation. (That means prices double every five to six years.) Price increases for oil average around ten percent annually, a doubling time of about seven years.

Coal use in the state increases from about 9,000,000 tons in 1975 to about 28,000,000 tons by 1985 with further increases occuring after that. Coal prices go up about ten percent per year. The increased coal use is caused primarily by the construction of new coal-fueled power plants and by the conversion of the taconite industry from natural gas to direct combustion of coal. The coal tonnage accounts for 14 western coal trains each with 100 cars, crossing the state every day in the year by 1985 (seven full, seven empty). Additional coal trains cross the state on their way east and southeast. The coal train traffic presents difficult problems for the local citizenry at crossings in towns and cities along the western rail routes.

The amount of power plant capacity for producing electricity in the state triples by the year 2000, going from about 7,500 megawatts in 1975 to about 23,000 megawatts. The state's electric utilities, state agencies and citizens groups spend a great deal of time locating and discussing various sites for the new plants as well as resolving pollution problems associated with the plants. Large investments are required by both utilities and by the industrial firms using coal directly to minimize air pollution. Electricity prices go up about 10 percent per year to pay for the new power plants and to meet general inflation.

The rising energy costs by themselves are not enough to cause significant shifts in population distribution. Rising gasoline prices, however, encourage increasing production and sales of gasoline-efficient cars.

Times become more difficult for low income energy users, who are squeezed hardest by the price increases. They seek special, low utility rates.

By the mid-1980's, the over-all energy growth rate starts to moderate slightly because of the rising prices. Consumers begin practicing more voluntary energy conservation. However, there is

no particular new effort toward mandatory energy conservation measures or toward reducing growth in energy usage because energy supplies are adequate. There is some work toward improving solar energy technology and reducing costs of solar energy installations in the homes and businesses. Likewise, peat gasification, wind energy and energy from agricultural residues and urban wastes get some attention. However, these energy alternatives do not get a strong push before 1985, because other energy supplies are sufficient. In the late 1980's interest and action toward energy alternatives picks up because rising prices of conventional energy sources improves the economics of alternatives.

Construction of coal gasification plants begins in the state between 1980 and 1985 under the impetus of curtailments and rising prices for natural gas. The purpose of the coal gasification plants, located along Lake Superior, is to assure future supplies of gas for residential and small commercial customers.

Thus, by the end of the century Minnesota's energy scene is not markedly different from what it was 25 years before. Yes, initial steps have been taken toward developing some alternative energy sources and toward increasing energy conservation. But those arise more out of economic interests than they do out of concern for what Minnesota does the day that oil and natural gas run out.

STATIC PETROLEUM SUPPLY SCENARIO

This scenario projects an "energy crisis" of medium proportions in Minnesota reaching its full impact in the early to mid-1980's. The situation occurs because of the state's inability to increase its petroleum supplies above 1975 levels. This spurs greater use of coal and accelerated development of solar energy installations, coal gasification and peat gasification projects as well as a strong conservation push.

Minnesota doesn't get as much Alaskan oil as it had hoped to replace the Canadian crude phased out in the early 1980's. Even with federal deregulation of prices for oil and new natural gas, domestic supplies of both do not increase fast enough to supply new growth projections. However, purchases of domestic oil and imports to the U.S. from other than Canada enable Minnesota to at least keep its petroleum supplies up to 1975 levels.

The high demands for petroleum in the face of Canadian crude curtailments and inadequate domestic oil production force the U.S. to continue heavy reliance on foreign oil imports. Thus, the nation continues to be exposed to multi-billion dollar annual payments for foreign oil, price manipulation, economic blackmail and oil embargoes.

Minnesota experiences higher prices for petroleum products and shorter supplies than the rest of the nation during the period that Canadian crude oil supplies to the region's refineries are being wound down to zero and during the subsequent period of adjustment to other petroleum supplies. Gasoline and heating oil prices jump sharply by as much as 50 percent in some locations. There are long lines at gas stations, and tourist travel wanes in Minnesota because of the gasoline prices and lines.

Plans go forward to build a new pipeline into Minnesota from the south to bring oil up from the Gulf Coast. Eventually federal allocations and the national marketplace provide more oil for Minnesota so it can come back up to mid-1970 levels. Petroleum price increases then drop to about 10 percent per year.

The curtailment of natural gas on top of the oil situation presents a very difficult situation. Large interruptible gas customers can't switch from gas to oil. Because of the waning supplies, natural gas curtailment begins for firm industrial and large commercial customers. Price increases range from 12 to 15 percent each year for natural gas.

This puts pressure on electricity.

Heavier substitution of electricity occurs than planned. The supply is strained. It's nip and tuck for the electric utilities to serve their customers but they do it with a few scattered blackouts. Electric utilities propose both coal-fueled and nuclear-fueled power plants to meet needs, contending that putting too many eggs in the coal basket is not sound policy. Plans are made to bring Minnesota's electric generating capacity to nearly 30,000,000 kilowatts by 2000, quadruple the state capacity in 1975. The Minnesota Public Service Commission orders state-wide interruptible electric rates for large industrial and commercial customers as well as rates encouraging use of electricity at non-peak times. The Public Service Commission also raises all electricity rates significantly (except those for low-income users) to dampen use. Electricity price increases go from an average of 10 percent per year to 15 per-

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cent annually during this two to three-year PSC pricing/ conservation program. The legislature places a heavy tax on utility profits thus generated. The excess profit taxes go toward financing energy research and development and insulation improvements in Minnesota.

Industrial conversions from oil and natural gas to direct use of coal occur at a rapid place. As a result 25 trains a day are moving back and forth across Minnesota by 1985 to supply industrial plants and power plants in the state, with even more traffic on the horizon. Cities along the railroad lines protest loudly, and strong pressure builds for separated grade crossings for vehicles to eliminate traffic tieups caused by the coal trains. Pressure also mounts for development of a coal slurry pipeline from the west. Accelerating coal use requires huge investments for air pollution control.

Not only is there a strong push in 1980-82 for additional electric power plants, but there is also an urgent need to have alternative energy sources such as solar installations, peat gasification and coal gasification. However, two to five years is required before the latter alternatives can be placed in service and even with streamlining of the state regulatory and permit processes for new electric power plants, they still take six to eight years to design, license and construct. Thus, Minnesota faces an energy drought in the early 1980's. Work proceeds on the alternative sources and new power plants while Minnesota tightens its energy belt.

The legislature initiates strong new conservation programs, among them a state-financed home insulation program. Research and development funds are allocated by the state for further investigation into wind power, agricultural residues, and urban and animal wastes as energy alternatives.

Minnesota returns to the 55 mph speed limit (which was changed from 55 to 60 mph in 1978). The Governor mandates strict enforcement of the new limit.

Sporadic layoffs occur over the state in the mid-1980's because of energy shortages. Some businesses move out of the state and others do not move in because of the supply and price situation. The high cost of home heating in Minnesota becomes a larger factor for businesses considering the state as a location. Demand for gas efficient cars exceeds availability in the state. Electric cars make their entry into the market.

The times are very difficult for low-income energy users. And middle-income consumers begin to feel the energy cost squeeze, too. High gasoline prices reduce the mobility of both low and middle-income people.

By 1990-95, Minnesota has come through the worst of the energy crunch. The state's economy has been somewhat depressed and Minnesotans have had to adjust to new energy use and price patterns, but the wounds are not deep or lasting. Minnesotans have developed a strong conservation ethic supported by state law and a state insulation program. Solar energy installations for homes and buildings are increasing as the result of improved technology and equipment cost reductions. Several peat gasification plants manufacturing gas for direct use by residential and commercial customers or for use in combined-cycle electric power plants are making significant energy contributions. The state is moving from total reliance on energy sources from outside its borders to a position where conservation, emerging development of peat, and greater use of solar energy make Minnesota less vulnerable to others.

PETROLEUM REDUCTION SCENARIO

This scenario depicts a major energy crisis developing fast in Minnesota in the late 1970's. The crisis is a wrenching experience for Minnesotans, shaking the state's economy, its government and its people in their daily lives.

As in the previous two scenarios, Canada steps down exports of crude oil to Minnesota, phasing them out completely by the early 1980's. However, Minnesota is unable to fill the gap with domestic oil or other imports because of national petroleum shortages and foreign embargoes and pricing policies. Natural gas is eliminated for large interruptible customers by 1981, as in the other scenarios and eventually is curtailed to large firm industrial and commercial customers.

Thus, Minnesota gets into a tight energy bind in the late 1970's and it really begins to hurt in the early 1980's. The state has particular problems because of its reliance on Canadian crude oil. There is insufficient planning and preparation for its elimination from the state energy mix. While the federal energy administrators and allocators are wrestling with "the Minnesota problem," gasoline and heating oil prices double in the state almost overnight, if you're lucky enough to buy either. The state steps in

with an emergency rationing (allocation) program for both gasoline and heating oil. Tourism in the state comes to a virtual halt.

Finally, federal allocations bring more oil into Minnesota, improving the state's situation somewhat. Still, the state does not have the oil and natural gas supplies to satisfy its appetite, so the painful dieting begins.

Spot energy shortages necessitate numerous temporary layoffs. Some industries and small businesses close up permanently. Others move out because of high energy prices and uncertainty of supplies. Energy intensive industries such as taconite processing and pulp and paper manufacturing are particularly hard hit. Farmers suffer temporary gasoline shortages but they receive first priority in the state's gasoline rationing program because of agriculture's importance to the state's economy.

There is a great rush to convert to electricity, which overburdens the capacity of Minnesota's utilities to produce it. Sporadic curtailment of electricity occurs. New power plants are required urgently and new state legislation is passed speeding up the state licensing for power plants. It still takes six to eight years to complete a new plant, however. One solution would be to build gas turbine-type power plants which take only two or three years for construction but, alas, they burn oil for fuel. Minnesota's electric utilities lay plans for a major expansion of both coal-fueled and nuclear-fueled plants. Some 38,000,000 kilowatts of total electric generating capacity are projected to the year 2000, approximately five times the total generating capacity in the state in 1975. Electricity prices rise 12-15 percent annually to pay for the new plants. Utilities must pay premium prices for borrowing because of the competition in the money market.

Rapid action occurs on a number of energy fronts in the state:

- Stringent conservation measures are mandated by the state legislature
- State-financed insulation program is set up
- The Minnesota Energy Agency is given direct control of certain energy uses, and penalties are established for "exorbitant" use of electricity
- Selection of sites for new power plants goes forward quickly, but water supplies for them looms as a restraint.

- Evening and Sunday closing of stores is enforced
- Low mpg cars are banned in the state
- State subsidies are offered for installation of solar energy systems in homes and buildings
- A consortium of oil and coal companies announces plans for immediate development of two major coal gasification plants on Lake Superior
- Construction begins on a peat gasification demonstration unit by a major natural gas supplier

After Minnesota begins receiving oil under the federal allocation program, oil prices rise 12-15 percent annually and natural gas prices 15-18 percent annually.

Low income users demand and get special energy rates from utilities plus subsidies for gasoline purchases.

Mass transit (by bus) expands rapidly in the state. Direct conversions to coal occur even more rapidly than in Static Petroleum Supply Scenario, creating even bigger traffic problems along the rail lines as well as air pollution problems.

The worst is over for Minnesota by 1990. New electric plants are coming on line. Energy alternatives are making an increasingly bigger contribution and energy conservation is a way of life in the state. Minnesota has gained a reputation for energy shortages and poor planning. The need to move decisively and swiftly in the face of a state-wide energy emergency has left scars on the people and the environment in the state that will be a long time healing.

WHICH SCENARIO FOR MINNESOTA?

The Static Petroleum Supply Scenario seems to present the most realistic supply future for the state of Minnesota - an energy supply problem reaching its peak in the early to mid-1980's because the state cannot get all of the petroleum that it wants. The increasing curtailment of Canadian crude for Minnesota, waning domestic supplies of oil and the uncertainties associated with continuing heavy dependence on foreign oil imports all add up to a very shaky situation for oil supplies in Minnesota. A lot of things have to happen just right in order for the state of Min-

nesota to increase its supply of oil in future years. It does not seem realistic to assume that all of these things will fall into place neatly.

The Adequate Supply Scenario probably represents the expectations and desires of most Minnesotans in that it is a future not markedly different from our energy affluent past. However, that scenario is too optimistic based on an objective appraisal of Minnesota's energy supply prospects.

V. THE LONG-TERM FUTURE, AFTER THE SHIFT FROM FOSSIL FUELS

New energy sources will be needed to replace fossil fuels. The two leading candidates, based on present knowledge and technology, are solar energy and some form of nuclear energy.

Reducing the cost of solar systems for heating and cooling in homes and commercial buildings will expand the use of such solar applications. Central solar stations for large-scale generation of electricity may make a contribution, but much work remains to be done to overcome economic and environmental obstacles for such facilities.

As for nuclear energy, breeder reactors are being built today for large-scale commercial production of electricity. This type of nuclear reactor produces more fuel than it consumes so it does not have the fuel supply constraints associated with the light water fission-type reactors. Environmental and health concerns about the plutonium fuel cycle associated with the breeder reactor are slowing breeder development in the United States, however. Fusion power may make a contribution to the energy picture after the year 2000. Fusion promises a limitless supply of energy but the question of whether man can harness fusion in any sustained way to produce large amounts of electricity remains to be answered.

Concurrent with the national debate about the breeder reactor, Minnesota should examine its position and its concerns regarding future construction and operation of nuclear power plants, including breeders, in the state. With the likelihood that Minnesota may need large amounts of nuclear-generated energy in the future, a citizen-legislative task force should be set up to examine the nuclear power option in the state, and to report to the legislature for possible enactment of legislation. The task force should determine if new nuclear power plants will be acceptable to citizens and state government, and if so, under what conditions. The study should cover potential needs for nuclear power generation, plant siting, and environmental restrictions. It is far better to hammer out such state policy now then to have it developed piecemeal later under stress and perhaps emergency conditions.

VI. MINNESOTA'S OPTIONS - WHAT SHOULD WE DO?

The citizens and government of the state of Minnesota have a number of options available to them as we move into the energy future. They divide into four primary options:

1. Do nothing until crisis confronts us (the scenarios are based on this option)

2. Monitor trends and develop alternative plans

3. Influence federal policy

4. Adopt and implement a state energy policy

What do the three short-term scenarios and the longer-term prospects say to us about the options that are best for Minnesota?

1. The period between now and 1985 appears to be the most critical for Minnesota. The long lead times required to design and construct new energy facilities make it difficult to increase supplies significantly before 1985 beyond those facilities already being designed or built.

2. Minnesota faces difficult energy times in the near term because of the curtailment of natural gas and the phasing out of Canadian crude oil. Consumers must make some major adjustments in their use patterns, including transition to other sources of energy and serious conservation.

3. Public lethargy, inertia and general disbelief that there is any energy problem coming could impede or prevent necessary steps to soften or avert future crises.

4. A major conservation effort throughout the state by all residential consumers and by business and industry is absolutely necessary to help protect the state's energy security. Conservation can make significant contributions faster than any other effort.

5. Minnesota will need to be able to take advantage

of every available energy option open to it in the future. Ruling out certain forms of energy for whatever reasons will put an impossible burden on other sources.

6. New electric power plants and other energy facilities may be needed much faster than is possible under present state siting and permit processess.

7. Prices of oil products, including oil-fueled space heating and gasoline, and electricity prices may double every seven years or so. Natural gas prices may double every five to six years between now and the mid-1980's. This will put a tremendous strain on low and middle-income consumers and could result in open rebellion by consumers. The energy price squeeze will be a dominant factor affecting public policy dealing with energy issues.

8. The federal government will have major influence over energy policy and energy supplies. The federal government will control oil and natural gas prices, fuel allocations to states and to refineries, foreign policy that may effect our ability to import petroleum, legislation affecting strip mining and use of nuclear fuels, and the principal funds for research and development of solar, breeder reactor, fusion and other alternative energy sources.

9. Experimentation and pioneering regarding alternative energy sources and energy pricing will be extremely valuable for Minnesota. The sooner they begin the better the chances of finding good, workable solutions and discarding unacceptable options.

10. Minnesota's water will be a major resource, perhaps as important as the southwest's oil or Montana's coal. Future electric power plant development, peat gasification and coal gasification plants will rely on adequate water.

11. Minnesotans need education and information to gain an understanding of their energy situation and the

options available to them.

12. Accurate and credible data is essential to develop the public understanding and to make sound decisions in energy matters.

The above observations all point to the conclusion that Minnesota should move aggressively in shaping and managing its energy future. Of the four primary options listed, adopting and implementing a state energy policy and influencing federal policy are the two that should be followed.

State energy policy will consist of what the state of Minnesota can do unilaterally, independent of the federal government or others, coupled with the directions in which Minnesota government people, Congressmen, Senators, business people and voters try to influence federal policy and action. The next two sections look at what actions can be taken by the state unilaterally and at directions in which federal policy or action might be influenced.

The objectives of a state energy policy are to:

1. Procure and preserve a fair share of energy for Minnesota

2. Minimize vulnerability to shortages and unexpected events

3. Avoid unnecessary cost increases

Looking at the complex, interwoven networks over the world that influence our energy situation today, it's clear that no state can be an energy island. Minnesota's energy fortunes are interrelated with those of other states in the region and affected by federal policies and actions. But there are areas where Minnesotans can take unilateral action or can take the lead. Both government and the private sector will have key roles, but those roles are not clear yet in this time of energy change. Should state government primarily be a co-ordinator, providing guidelines, information and analysis to help the private sector? Or, should state government exercise firm direction and control? Minnesotans who shape the state's energy future should be conscious of these basic considerations.

VII. ENERGY ACTIONS THAT CAN BE TAKEN UNILATERALLY BY MINNESOTA

1. Implement a strong conservation program - Minnesota state government through its energy agency should take the lead in designing and implementing an effective energy conservation program. As one option, Minnesota could take a moderate approach to energy conservation or slowing energy growth, which would include appeals for voluntary cooperation or establishment of economic incentives such as off-peak energy discounts, use of tax policy or payment of direct subsidies. Or state government could take a hard line approach, instituting legislation or regulations controlling energy supply, certain users, certain uses or building codes stringently. The sooner the conservation effort really begins before crisis time, the more moderate it can be. If voluntary conservation or economic incentives fail to produce good results, then the Minnesota legislature should mandate conservation measures.

   A state financed or state-subsidized insulation program for both new and existing residences should be investigated. At the very least, tax credits could be given for insulation expenditures. Selective price manipulation could be utilized to reduce usage in certain key areas. Careful attention should be paid to the effect of conservation on utility operations and loads. Electric utilities, for example, are most interested in reducing their peak demands or the growth in demands so that they can then reduce the amount of expensive new electric generating capacity that must be installed. Ideally, the electric utilities would like to reduce usage at peak times and have that usage shift to the non-peak times - in other words, "fill the valleys." Conservation may simply reduce the amount of electricity sold at non-peak times without reducing the peak demand growth. This results in revenue losses for the electric utilities as well as poor efficiency caused by an over-all reduction in the use of electric generating equipment.

2. Strengthen emergency energy allocation program - The state legislature should approve a plan, developed by the Minnesota Energy Agency, under which fuels and energy forms would be allocated to users on a mandatory and priority basis in the event of emergency energy shortages. This would be a stronger program than the energy agency's present plan incorporating voluntary action in the event of an emergency.

3. Study energy's relationship to population growth and distribution - A task force from the State Planning Agency and the Minnesota Energy Agency, utilizing the help of other experts in the state, should study the relationship between the cost and availability of energy and population growth and distribution. Such information would be extremely valuable in energy pricing considerations and in any effort to manage or influence future population distribution patterns in the state.

4. Study the effects of energy price manipulation - The Minnesota Public Service Commission and the Minnesota Energy Agency, in concert with Minnesota's energy suppliers, should study the effects of energy price manipulation. The goals of this study would be to develop an understanding of how energy pricing affects customer use, how peak demands for utilities would be affected, and the impact on Minnesota's economy of various energy pricing approaches. An interesting demonstration project would be to select a test community where energy prices would be manipulated and results evaluated. Another test community could be selected for a demonstration of the effect of a total energy conservation effort in the community.

5. Determine priorities for Minnesota's future - The Minnesota legislature should carry forward the work begun by the Commission on Minnesota's Future to define what the state should be like in the future. Minnesota's future "character" will have a major bearing on energy uses just as energy supplies and consumption will have a bearing on the state's future economy and settlement patterns. Questions about population size, kinds of state industry, and Minnesota's economic mix should be addressed. Do we want to discourage energy intensive industry from locating in Minnesota in the future? Will we want to establish high priorities for energy supplies for farming and other agri-business sectors?

6. Develop a state water use policy relating to energy conversion - As mentioned earlier in the report, Minnesota's water supplies may become a sought-after resource for converting energy into other forms. A major constraint on locating electric power plants and coal gasification plants in North Dakota, Montana and Wyoming where the coal is located is the supply of water available. Minnesota is likely to become a prime location for electric power plants and coal gasification plants if state policy allows it. Therefore, the Minnesota Department of Natural Resources should establish a task force to make recom-

mendations about the future use of Minnesota's waters for energy conversion.

7. Encourage solar installations - The Minnesota Energy Agency working with ERDA should seek to establish as many solar energy installations in the state as possible. These will contribute to the developing solar technology and will also help to develop a distribution and marketing system in the state for solar equipment. Tax incentives or state subsidies for solar installations should be explored.

8. Encourage use of other energy alternatives - Minnesota energy users should be encouraged via technical assistance programs, tax incentives or subsidies to experiment with and utilize other energy alternatives such as warm water, animal wastes, refuse, wind energy and biomass. It is important that building codes and regulations at all levels of government be amended when necessary to remove provisions that might deter use of energy alternatives or conservation.

9. Develop a nuclear power policy - As discussed earlier, Minnesota should attempt to develop a state policy with respect to future nuclear power plants, including breeder reactors, being located in the state. A citizen-legislative task force should study the options and make recommendations to the appropriate bodies for policy development and implementation.

10. Encourage peat gasification demonstration project - Minnesota state government should continue its active interest in investigating the uses of peat in the state, including encouragement and technical assistance for a peat gasification demonstration plant.

11. Investigate coal gasification potential - The Minnesota Energy Agency and the Minnesota Department of Natural Resources jointly should immediately begin investigating the potential for coal gasification plants in the state. Investigation should include potential sites, environmental impact, water needs, economic comparisons and implementation strategies.

12. Investigate district heating concept - The Minnesota Energy Agency along with an electric utility or a group of electric utilities should investigate the feasibility and economics

of locating a small or medium-sized electric generating plant in an urban area so that warm water from the plant's condenser cooling could be used for space heating in the area surrounding the plant. The possibility of such a plant burning refuse as its primary fuel should be part of the investigation.

13. Encourage new pipeline capacity from the Gulf Coast - Minnesota state government should actively encourage construction of additional pipeline capacity from the Gulf Coast to Minnesota to supply either more petroleum products or to bring crude oil into the state for refineries here.

14. Study shorter siting/licensing time for new energy facilities - The Minnesota Environmental Quality Council and state utilities should study possibilities for reducing the time presently required for the state regulatory process in siting and issuing permits for new power plants and other energy facilities. The study should include careful consideration of the impacts of acceleration. Any recommended changes should be forwarded to the appropriate state bodies for their consideration. Power plants, for example, presently require eight to 10 years from inception to being placed into operation with about half of the time consumed by the state regulatory process. Future energy needs may require faster action on proposed new facilities.

15. Encourage separated rail crossings in the state - The Minnesota Environmental Quality Council, working with railroads and with cities along rail routes from the west, should investigate the separation of train and vehicle crossings at key points along the lines in view of the steadily increasing coal traffic. One method of financing the construction of such crossings might be a state tax on coal moved through Minnesota.

16. Expand energy data for the state - The Minnesota Energy Agency should continue to expand its data regarding energy uses in the state, energy supplies and forecasts. Statewide data is needed regarding end uses of energy. Utilities and other energy suppliers should use the same forecasting techniques and assumptions, coordinated through the Minnesota Energy Agency. For example, electric utility assumptions about how much electric usage will increase because of natural gas curtailment should be matched against the oil industry's expectations of how much more oil will be required as a

result of natural gas cutbacks. Differences and gaps can can then be addressed.

17. Expand energy education and publicity - Minnesota elected officials and state agencies with any energy involvement should publicize three principal points as often and as widely as possible.

    a. Minnesota's energy problems relating to natural gas and oil supplies

    b. The great need for serious conservation of energy

    c. The need for bold, aggressive action by Minnesota state officials and policy-makers supported by their constituents, to procure and secure energy supplies and experiment with and develop energy alternatives.

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VIII. WHERE MINNESOTA SHOULD ATTEMPT TO INFLUENCE FEDERAL POLICY AND ACTION

Minnesota has several things going for it which suggest that the state can carry weight in influencing federal policy and actions. Minnesota is seen as a forward looking, aggressive state that warrants listening to. The state has considerable political clout in Washington. The state also carries increasingly important weight in the nation and the world as a center for agricultural production and agri-business, parts of which are energy intensive. Minnesota should be able to use its political clout and its agri-business leverage to influence federal energy policy.

The following are areas where Minnesota should become involved in influencing federal policy and activity:

1. Deregulation of natural gas prices - Minnesota should push hard for deregulation of new natural gas prices so that both prices and availability of gas equalize over the nation. Natural gas price deregulation will increase costs for consumers in this state, of course, but if deregulation also spurs new exploration and discovery of more natural gas, as is hoped, then natural gas supplies will be extended.

2. Deregulation of oil prices - Similarly, Minnesota should encourage deregulation of oil prices as an incentive to domestic oil exploration.

3. Extend Canadian crude oil supplies - The federal government should be strongly urged to do all reasonably within its power to encourage the Canadian government and its National Energy Board to extend the time in which Canadian crude will be made available to Minnesota area refineries.

4. Support best oil pipeline route from the Pacific Coast - Minnesota should evaluate and encourage adoption of the best oil pipeline route from the Pacific Coast to supply Alaskan oil and foreign oil to Minnesota and the Upper Midwest, as a replacement for Canadian crude.

5. Obtain Alaskan gas for Minnesota - Minnesota Congressmen and Senators should strive to obtain some share of the natural gas that will be available from Alaska for Minnesota, working in concert with other northern tier states.

6. Encourage more solar energy research funding - Minnesota Congressmen and Senators should support adequate funding for

ERDA for an accelerated, major solar energy research and development program.

7. Encourage more research into other energy alternatives - Minnesotans also should urge increased ERDA research funding for other energy alternatives such as coal gasification, synthetic oil from coal, warm water utilization, animal wastes, refuse, wind energy and biomass.

8. Support fast breeder and fusion research and development - Research and development of commercial breeder reactors, coupled with resolution of environmental concerns, should be pressed with all speed. Fusion power research also should be a high priority item.

IX. WHAT SHOULD MINNESOTA NOT DO?

1. The state should not impose energy pricing as an attempted means of constraining use without careful investigation of possible results followed by experimentation. Energy interrelationships are extremely complex and changes in one may create unforeseen waves in other areas.

2. State government should not allow Minnesota to become locked into one dominant energy source such as coal, nuclear fuel, or oil. We are now having to contend with potential problems caused by our heavy dependence on oil in Minnesota.

3. Consumers and state agencies should not expect electricity to completely fill the gap caused by shortages of other energy sources. There are time and financial constraints on the construction of new electric generating facilities.

4. Minnesota must not rush blindly in various directions to solve energy problems and meet future needs. The state must develop and follow a unified, sound energy policy.

X. WHERE ARE THE DANGER SPOTS? WHERE MIGHT MINNESOTA BLOW IT?

1. Inertia among consumers, and disbelief that any energy problems might exist are perhaps the biggest potential trouble spots for Minnesota in the energy future. People who don't care or who don't believe aren't going to act or sacrifice.

2. It will be easy, and highly risky, to focus most of our time and energy on one or two seemingly obtainable energy alternatives, while letting others slide. For example, it would be easy for Minnesota to rely on a Prince Rupert to Edmonton connection to get Alaskan and foreign oil to Minnesota while not pursuing construction of additional pipeline capacity from the Gulf Coast. We must keep all of our energy options open just as long as we possibly can.

3. Minnesota could distort its entire energy picture and cause severe harm to the state's economy by severe price manipulation that is not carefully thought out and tested. The federal regulation of interstate natural gas prices is a fine example of how government can mess up the normal operation of the marketplace.

4. Minnesota state government could cause serious problems by regulating certain energy uses without thorough investigation of the ramifications of that regulation. For example, giving tourists a high priority on gasoline in a time of gas shortage could cut too deeply into supplies for the agricultural sector and commuters. Alternatives and their likely outcomes should be investigated before energy action is taken.

XI. ENERGY TECHNOLOGIES

Electric power plants fueled by coal, natural gas or oil - The fuel is burned to produce steam which in turn drives a turbine - generator to produce electricity. About 60 percent of the electricity produced in Minnesota in 1975 was generated by those three fuels.

Hydro-electric (water) power - Electricity is produced by falling water which turns a turbine-generator. Hydro-electric power plants produced about three percent of Minnesota's total electricity in 1975. Expansion of hydro-electric capacity is limited by sites available in Minnesota and the U.S. and the environmental impact of such installations.

Nuclear fission - Controlled nuclear fission, the splitting of atoms, creates heat in a nuclear reactor, turning water into steam which drives a conventional turbine-generator to produce electricity. In 1975 the three nuclear-fueled generating units in Minnesota produced about 37 percent of the state's total electricity. Nuclear fission power plants in use throughout the world today use uranium fuel. Known reserves of uranium are estimated to be sufficient to support existing nuclear fission plants and those that are planned for construction in the next 30 years over their operating lifetimes.

Breeder reactor - Breeder reactor plants also use nuclear fuels to generate electricity but in the process they produce more fissionable material than they consume. This greatly extends the nuclear fuel supply. Commercial breeder reactors for electric power generation are in operation in European countries and a 350,000-kilowatt demonstration breeder plant is planned in the U.S. The objective of the federal Energy Research and Development Administration (ERDA) is, "to develop and demonstrate a safe, reliable, and economically viable breeder reactor for installation into utility systems to make possible an initial contribution beginning before 2000 and a very major contribution in the post 2000 period."

Development of the breeder reactor in the U.S. and greater utilization of nuclear fission plants have been slowed for a variety of reasons, including concerns about health and safety, environmental protection and security of nuclear materials, as well as high capital costs. These matters must be resolved before the future of nuclear power in the U.S. can be forecast with any reasonable accuracy.

Oil and gas - enhanced recovery - Additional technological development is expected to increase the extraction and recovery of oil or natural gas from existing wells beyond amounts extracted using current methods. ERDA's goal is for new enhanced recovery techniques to make major contributions to oil and gas supplies by the year 2000. This would extend supplies of those fuels while energy alternatives are being developed. Such new recovery techniques are more expensive, however.

Oil shale - Oil shales are a large and special type of energy resource available in the western United States. Research and development is designed to extract hydrocarbon products from the shale and to convert the products to liquid or gaseous fuels or other chemical commodities. Successful development of this resource depends on economics, adequate water supplies and minimizing surface disruption. ERDA's objective is to bring oil shale technology to the point where it can make a moderate contribution to the nation's energy mix by the year 2000.

Solar energy - Systems are now available for utilizing solar energy in heating and cooling homes and buildings. The equipment is presently expensive, ranging between $5,000-$7,000 to provide about 50 percent of the annual heating requirements for a 1,000 sq. ft. home. (A conventional backup heating system is required to provide the remaining energy when solar energy is not available.) However it is hoped that technological advances, coupled with increasing prices of conventional energy sources, will make direct solar applications competitively attractive. Research is also being carried on to transform the radiant energy of sunlight into electrical power, either by producing steam for operating a conventional turbine-generator or by direct conversion to electricity. ERDA estimates that up to seven percent of the nation's total energy needs may be supplied by solar energy by the year 2000.

Gaseous and liquid fuels from coal - Coal gasification and liquefaction are other approaches toward replacing oil and natural gas fuel. The production of either liquid or gas fuel from coal is not a new art, but improved technology is required to meet modern large volume requirements as well as environmental requirements. Research and development is aimed at processes for producing clean gases of high energy content as a natural gas replacement, clean gases of lower energy content for use as boiler fuel, and production of oils and other clean liquid fuels or solid fuels which have higher heat content, less ash and fewer impurities than natural coal. ERDA sees the possibility that coal gasification and liquefaction can make a major contribution to energy supplies in the nation by the year 2000.

Peat - This fossil fuel resource is partially decayed vegetative matter. It is Minnesota's only native fossil fuel and holds promise for future use in the state. Peat can be burned directly in power plants or it could be converted into a synthetic gas to replace natural gas.

Coal - direct utilization by industries - Efforts are under way to develop environmentally acceptable technologies for expanded direct use of coal by industries which will not have natural gas or oil available to them. The research and development work includes investigation into new combustion methods, more efficient boilers, cleaning the coal before combustion and use of additives during combustion.

Waste utilization - The Minnesota Energy Agency estimates that if the energy from refuse from all communities in the state could be harnessed, urban waste could provide nearly three percent of the total state energy requirement annually.

Warm water from power plant condensers is an energy source. It is used in some European countries where a small to moderately-sized electric power plant is located right in the urban area and the warm water from it piped to consumers in the area for heating. Warm water from a power plant in central Minnesota is being used in a test project for growing plants and vegetables in a greenhouse.

Animal wastes are a potential source of energy. The commercial feasibility of producing methane gas from cattle manure has been demonstrated. A major hurdle is developing a system for recovering and collecting the waste for use in a central conversion plant.

Geothermal - This involves extracting the heat energy contained in geological formations and converting it to electric power or other uses such as direct heating. It includes such geothermal resources such as hot rocks, dry or wet steam and hot brine. In the United States today, natural steam from the Geysers area in north central California is used to generate electricity. This resource appears to be limited to the areas of the United States where geothermal sources are relatively close to the earth's surface.

Fuels from biomass - Agricultural field residues, forest litter, and wood plantations are seen as possible energy resources. Biological materials can be burned directly or can be used to produce alcohol, methane or other fuels.

Fusion - Nuclear fusion, in which the nuclei of hydrogen are fused to form helium with the resulting liberated energy harnessed to produce electric power, is a possible "inexhaustible" source of energy. Tremendously high temperatures must be produced to sustain a fusion reaction sufficient to produce large amounts of energy. While fusion research is being carried on in several countries, the scientific or technical feasibility of fusion power has not been proven yet. In any event it is anticipated that if fusion power is workable, its commercial application as a major energy source is still 40-60 years away.

Wind energy - Conversion of wind energy into electric power is a proven technology. Minnesota's high average wind velocity offers potential for use of this resource in the state. According to the Minnesota Energy Agency, the state might reasonably have 1000-1500 megawatts of large-scale wind capability that could be fed into a power system.