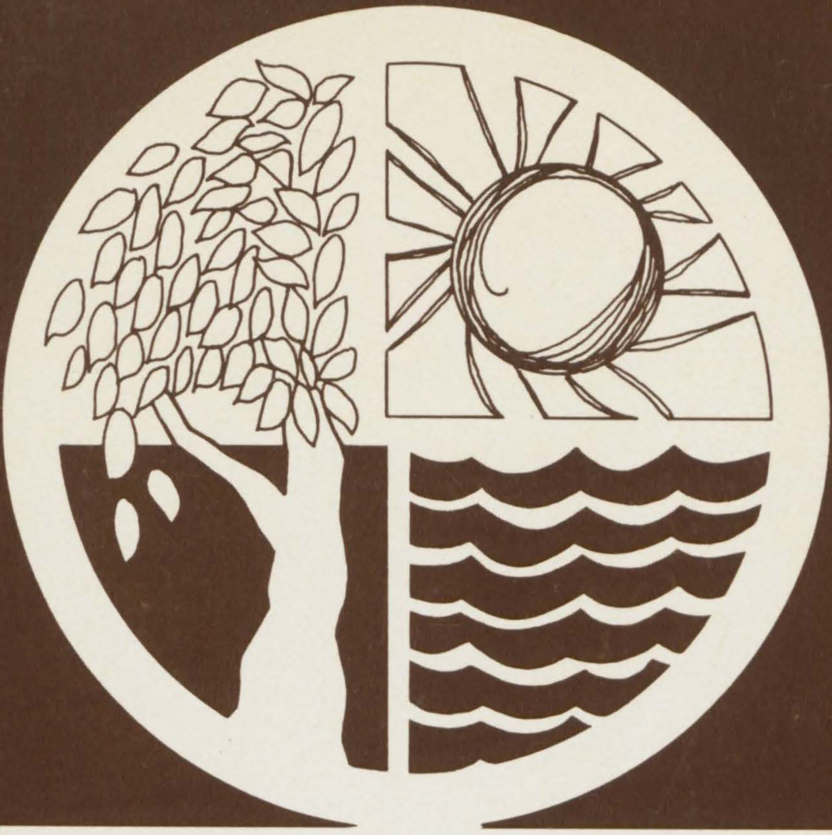


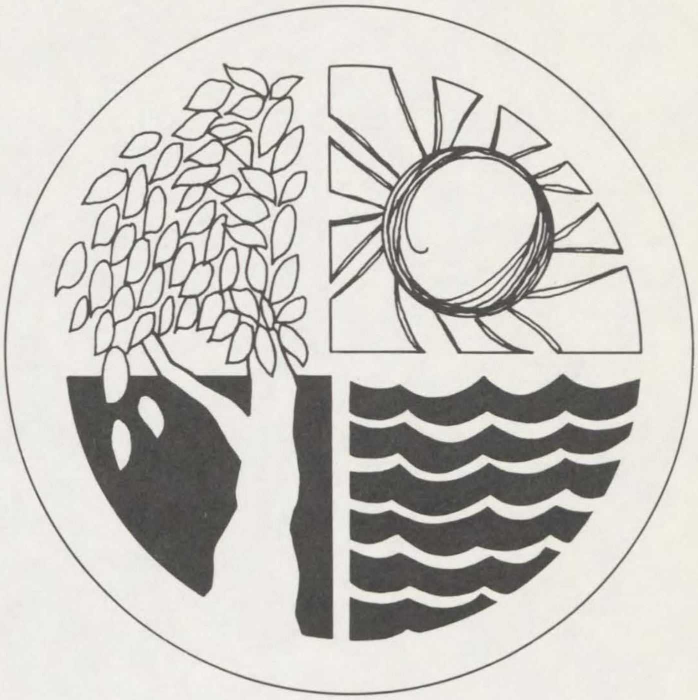
Conference Summary-
Update on

Alternative Energy Sources

Technology and Applications for Minnesota

April 27-28, 1976

Bloomington, Minn.



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Dear Reader:

The Minnesota Energy Agency is pleased to provide you with this summary of the proceedings of the first annual Update on Alternative Energy Sources Conference, held in Bloomington, Minnesota, April 27, and 28, 1976.

This conference has set the stage for the further investigation, development and demonstration of alternative energy sources in Minnesota.

We have limited choices for decisions on our future energy system. The time for those decisions is approaching rapidly. It is our hope that the information presented at this conference will aid the reader in understanding these choices.

I would like to take this opportunity to express my personal gratitude to the many people who made this event and this document possible. A very special thanks and recognition is due the speakers who prepared the excellent presentations for the conference which are summarized in this publication. Without their voluntary participation and their dedication in reviewing these abstracts, neither the conference nor this publication would have become reality.

A special thanks to Dr. Richard C. Jordon, Conference Chairman and the father of solar energy research in Minnesota; to Dr. Perry Blackshear, conference co-chairman and the inspiration for biomass research in Minnesota; to all of our conference sponsors who provided finances, publicity and mailings for this conference; to Ray Fleener of Ellerbe, Inc. for the brochure and cover design; to the Bloomington Chamber of Commerce for their help and loan of their typewriters; to Joe Ball for his advice and assistance in preparing for this conference; to Debbie Pariseau, who pulled this conference together and Marion Winston for her devotion to this task; to the Center for Urban and Regional Affairs (CURA) for providing for the publication of this conference summary, and especially to Mary Moreira, whose cheerful and untiring efforts before, during and after the conference made both the conference and this document possible.

I would further like to express my gratitude to Representative Willard Munger who has ceaselessly worked for the development of alternative energy supplies in the State of Minnesota, and to Senator Winston Borden for his dedicated efforts in making solar energy a viable energy option in the state.

To the Solar Energy Task Force of the State of Minnesota, I offer my congratulations and thanks for a conference well received and a document I am sure they are proud of. Chairman Max Oftedahl, John Weidt, and members Russell Brackett, Edward Aoerb, Dr. James Johnson, and Al Wendt have shown all of us that the efforts of dedicated and concerned scientists, engineers, and architects can provide our state with options for our energy future.

Dr. James E. Carter
Director, Research Division
Minnesota Energy Agency

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*Presentation not available for publication. Richard Jordan, Ph.D., P.E., is Professor and Head, School of Engineering and Aerospace Engineering and Head, Department of Mechanical Engineering, University of Minnesota

OPENING REMARKS

MINNESOTA'S ENERGY FUTURE, John P. Millhone*

Minnesota depends on Canada for half of its petroleum, a supply which is presently in jeopardy. It depends on Northern Natural Gas for natural gas, but this supply will soon be reduced. These reductions mean that alternative sources will need to supply 10 to 20 percent of the state's energy by the year 1985.

The state's current energy budget is 10^{15} BTU per year or 33 x 10^6 kW, at the mean demand rate. At the present rate of use, urban wastes could contribute 2 to 3 percent of this energy; windmills, 4 to 18 percent; manure, 3 percent; forest residues, 23 percent; and field residues from agricultural land, 43 percent.

Solar energy could be used for residential heating as well as power generation. The 25 percent of the state's energy consumption that now goes for comfort heating could be halved by the use of solar energy; with a total capital investment of $14 x 10^9 at present collector costs. In addition, the use of spoiled grain, currently prohibited as feed, fermented to ethyl alcohol and added to unleaded gasoline in the ratio of one part alcohol to ten parts gasoline, has proven to be an effective fuel expander in Nebraska and shows promise for Minnesota.

Minnegasco proposed building a 250 x 10^6 cubic feet per day gas plant utilizing Minnesota's peat. Twelve million tons of peat per year would be required to produce 4.7 x 10^6 kW in total energy, 3 x 10^6 kW of which would be in pipeline quality gas and the balance in energy-rich residues. About 300,000 acres of peatland planted in fast-growing cattails or 1.3 million acres of land planted in tree farms could permit the continued operation of the gasification plant as the peat becomes exhausted.

The immediate and long-term needs are for convenience fuels for transportation and comfort heating. For long-term considerations, tree farming one-third of the forest area (5.3 x 10^6 acres) or double cropping the present agricultural land by sowing winter rye after the fall harvest could supply 100

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*Director, Minnesota Energy Agency

percent of the state's energy needs without diminishing food production. In the long run, the renewable resources of solar power, wind, and biomass will inevitably be deployed. In the short run, the use of coal will increase. The technological and political uncertainties of breeder or fusion reactors are adequate reasons for not developing plans that rely on these long-term energy sources.

By far the most promising alternative energy resource appears to be our ability to conserve without impairing productivity. We are capable of saving up to 50 percent of what we presently consume--and this can be accomplished in a short time with little capital.

SOLAR AND WIND ENERGY

CLIMATOLOGY OF SOLAR RADIATION AND WIND, Donald G. Baker, Ph.D.*

The sun is the ultimate source of the energy of fossil fuels and our weather systems. We should use the sun's energy immediately rather than waiting for it to be stored in wood, coal, gas, or oil. It seems wasteful not to try to harness the wind's energy, too.

The amount of energy intercepted by the earth is approximately 3.7×10^{21} calories per day--over 100 times the energy used worldwide in 1950. But several conditions restrict the amount of energy available. First, the earth's rotation on its axis causes day and night and makes the sun's energy discontinuous. Second, the earth travels around the sun at an angle, causing two effects: the seasonal change in the angle of the sun's radiation and the change in the length of the days. Third, particles in the earth's atmosphere cause scattering and absorption of solar radiation. Finally, the unpredictable cloud cover diminishes and diffuses solar radiation on the surface. Only 57 percent of the time is Minnesota free of cloud cover.

There has not been adequate measurement of solar radiation in the past. On the average, it is much higher in the southwest than in the northeast. Minnesota receives about 64 percent of what El Paso receives, but gets as much as New Orleans and quite a bit more than Seattle. Minnesota has few overcast days from late June through August, but more from late October through December. In January, there is a marked drop in the number of overcast days. Because there are cloudy periods when solar radiation is critically low, a reserve system would be needed with a solar energy system.

There are two areas in Minnesota where wind energy might be used: northwestern Minnesota and along Lake Superior. There are seasonal variations in average wind speed: a marked increase in April and May and a smaller peak in November. July and August have low winds. There are only three or four months out of the year during which wind could be an acceptable power source in Minneapolis. Wind movement increases during the daylight hours. The height required to obtain adequate wind speeds varies with the type of

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*Professor, Department of Soil Science, University of Minnesota

terrain.

Minnesota has more potential for solar energy than the industrial northeast, but marginal potential for wind energy.

FLAT PLATE SOLAR COLLECTORS, James W. Ramsey, Ph.D.*

The efficiencies of several solar flat plate collectors were studied. Aluminum was used in the first absorber panels because it was available, but because there were substantial problems with corrosion, steel is now used for panels. Tests were run utilizing a simulator consisting of a series of lamps and lenses. The power level could be adjusted to change the flux level.

Efficiency is the amount of energy delivered to the working fluid compared to the energy incident upon the collector aperture. At 80^{o} F, the basic collector had an efficiency of over 40 percent. For comparison, tests were made on a collector identical except that its absorber was painted black. This produced a slightly higher absorption level at low temperatures, but the performance dropped off more rapidly as the temperature increased. Both collectors were tested outside as well as with the simulator.

In the next experiment, the collector had a steel absorber panel with a black chrome selective surface. This was more durable and just as efficient. A collector with only one glass cover performed better at low temperatures due to the lower reflected radiation loss, but there was a penalty at high temperatures. The question then was how to reduce reflection losses, which are normally around one or two percent. Acid etching of the glass panels cut reflection losses sufficiently at a reasonable cost. This means that in a typical 1500 square foot house 38 percent of the heating and cooling energy could be supplied by a 750 square foot collector. With a selective coating instead of the simple black coating, the collector could supply around 50 percent of the energy, and with etched glass panels and the selective coating it could supply about 57 percent.

Does it pay off? With limited mass production, the manufacturer's cost would be about $4.71 per square foot. The important measurement is the change in cost effectiveness due to changes in the collector components. With the selective surface and etched glass, energy costs are about ten percent lower.

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*Assistant Professor, Department of Mechanical Engineering, University of Minnesota.

SOLAR HEATING, SPACE HEATING, PROCESS HEATING, AND THE POWER TOWER,
Roger Schmidt*

There are over 200 solar heated and cooled buildings that have received a great deal of public notice and there are many built by private individuals which do not receive much notice.

One of the finest large systems is in the Twin Cities: North View Junior High School. This school has 5000 square feet of collectors. Its system heats water in the collectors and runs the hot water through a storage tank and then through heat exchangers in the air duct system. It can also heat water for showers and other uses. The orginal heating and air handling system is undisturbed except for the addition of the heat exchangers and a two-stage thermostat. When the temperature drops, the first stage of the thermostat calls for solar heat. If the temperature continues to drop, the second stage turns on the conventional heating system. Over the year, this system provides heat equivalent to 10,000 gallons of fuel oil. The sun melts even a heavy snow within fifteen minutes so that it slides off the collectors.

A solar system for a residential home could employ a storage tank from which water is pumped through the solar collector. A total back-up system would be necessary for use when adequate solar radiation is not available. Honeywell has arranged to provide home solar collectors in conjunction with Lennox Industries. The collectors will use copper tubes with a steel plate for the absorber surface. The copper tubes were selected primarily for sales purposes since many people in this country are accustomed to copper for water circulation.

Air circulation systems using solar heat and rock heat storage have a great deal of promise. They have no problems with corrosion, freezing, or leakage, but they suffer from poorer heat transfer in the collector and generally cannot be used for air conditioning.

The difference in cost between solar power and alternative fuels is important. Electric resistance heating costs about $10 per million BTU; natural gas costs only about $1.50 per million BTU. It would take 13 years for a solar energy system to break even with electric resistance heat. This

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*Technical Manager, Solar Pilot Plant, Honeywell, Inc.

is not an attractive investment. The cost of a solar system for one house is projected to be between $5,000 and $10,000.

Additional research is necessary to improve and reduce the cost of solar energy systems and components. A number of concentrating systems are now available. Many groups are working on different collector ideas and they need more federal funding. The commercialization of solar systems is only beginning, but Honeywell envisions a multimillion dollar market by the 1980's.

Solar electric power is receiving much attention. Several companies are working on the design of the first large solar power plant, to be built in the southwest. This system uses tracking mirrors which focus the sun's rays on a receiver at the top of a power tower. The receiver converts water to steam to run a conventional steam turbine. Extra heat from the high sun hours is put in thermal storage and later retrieved for use during cloudy periods. The cost of the solar power tower is nearly competitive; it should produce electricity at about 40 mils per kilowatt-hour.

Another area which holds promise is using solar energy to make fuels instead of electricity. The power tower, for example, could be used to obtain hydrogen from water. The major energy problem in the U.S. is the dwindling supply of liquid and gaseous fuels, not electricity.

USE OF WIND ENERGY CONVERSION SYSTEMS FOR UTILITIES IN MINNESOTA,
O. H. Lindquist*

The federal Energy Research and Development Administration (ERDA) is predicting that wind power will supply the United States with one gigawatt of energy by 1985 and twenty gigawatts by 2000.

This presentation will (1) consider the potential of wind energy in Minnesota for utility companies and (2) present some preliminary results of a Honeywell study on the financial feasibility of wind power. Conservatively, Minnesota has the potential to use wind power to produce the equivalent of three coal-fired generating plants of about 500 megawatts each. With more intensive use of wind power, Minnesota could obtain around 6000 megawatts, the equivalent of five Prairie Island nuclear plants.

In a study for ERDA, Honeywell is using current wind technology data and the existing structure of a utility, Minnesota Power and Light (MP&L), to evaluate the financial feasibility of a wind energy system. Because of the taconite industry, MP&L had a power factor of 0.83 in one year, the highest in the U.S. This means that whenever a windmill produced power, the utility would be able to use that power.

Although the primary ERDA mill is designed for high wind regimes and is not suitable for Minnesota, the Boeing 1000 kilowatt mill and the G.E. 500 kilowatt mill are competitive in terms of unit cost. Based on wind data from Fargo, St. Cloud, Duluth, International Falls, and Minneapolis, the cost for MP&L would be from $0.039 to 0.062 per kilowatt hour, using the Boeing mill. In contrast, MP&L's Hibbard plant generates electricity for $0.028/kWh and the Boswell coal plant provides power for only $0.006/kWh.

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*Senior Staff Engineer, Honeywell, Inc.

EXTENT AND POSSIBLE USE OF MINNESOTA PEATLANDS, Rouse S. Farnham, Ph.D.*

There are over seven million acres of peat in Minnesota, which is 15.6 percent of the total area of the state. Of this, 75.8 percent is over five feet deep. The northern counties have more peatland, but it is not well utilized due to the characteristics of the peat in this area and its inaccessibility. The southern counties contain smaller peatlands which are used to a greater extent for crops.

Currently, 2.7 percent of the state's peatland is cropland, 10.7 percent is used for pasture and forage crops, 60.4 percent is forested, and 26.2 percent is open land. Peat bogs have produced stunted black spruce forests which can be used for Christmas trees and pulpwood. White cedar, common in northern Minnesota, is one of the best bog conifers and will grow to a sufficient size for fence posts. Crops such as cabbage, cauliflower, broccoli, radishes, potatoes, and forage crops, particularly grasses, do well on peatlands. Cattle can graze on the drained lands.

In addition to these current uses, Minnesota's peatland could potentially be used for producing energy, for treating wastes, for producing chemical feedstocks in place of petrochemicals, for biomass production, and for the protection of certain plants and wildlife.

Commercial peat production has a very small potential use. At the present growth rate of 10 to 12 percent per year, only 3 percent of the total peat acreage would be needed by the year 2000. Economically, however, this could be very important to the state. Peat slowly renews itself each year, at the rate of one to two tons per acre.

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*Professor, Department of Soil Science, University of Minnesota.

RESEARCH NECESSARY TO DEVELOP PEAT ENERGY IN MINNESOTA, A. M. Rader*

If peat is to become an energy source, it must be converted to a gaseous or liquid fuel or burned directly to generate electricity. The Minneapolis Gas Company (Minnegasco) feels that it would best be converted to a gaseous fuel since this is more efficient than generating electricity. Conversion to electricity is only about 30 to 35 percent efficient, while conversion to a gaseous fuel is 70 percent efficient.

To make peat competitive with other fuels, we need research in converting peat to a useful energy, in methods of mining peat in an economic and environmentally acceptable manner, and in the environmental effects of producing energy from peat.

Minnegasco's initial evaluation indicates that peat gasification would be economically feasible. Minnegasco is working on a program to prove that the existing technology for converting coal and lignite to gas can be adapted to peat. The present HyGas plant at the Institute of Gas Technology, now producing gas from lignite, could probably be adapted to peat.

When this plant has provided the necessary data, the company plans to build a prototype peat gasification plant that would produce 80 million cubic feet of natural gas per day using 18,000 tons of air-dried peat per day. This plant would use oxygen instead of air in the combustion process and would be self-sustaining, producing its own steam-generated electricity from peat. If this prototype plant were successful, Minnegasco might build a plant that could produce 250 million cubic feet per day--more energy than the total electrical energy used in Minnesota in 1975.

Research might also be conducted in converting peat to liquid fuels, low BTU gas, or chemicals such as ammonia, or in producing electricity by direct combustion of peat.

Peat mining research is necessary. Present mining methods require clearing, draining, and leveling substantial areas. Even the small prototype plant would necessitate opening up over 100,000 acres of peat. In Europe, peat is mined by first leveling off the bog and draining it, so that heavy equipment can be used. The peat is harrowed about 3/4 of an inch deep and allowed to

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*Assistant Vice President, Research Division, Minnesota Gas Company.

dry for 12 to 72 hours. Then, a vaccum harvester gathers the peat, producing large amounts of dust. Another mining method is sod cutting, using a machine which extrudes a brick that takes about three months to dry. This method produces less energy per area than other methods. Methods can probably be devised to harvest peat the whole depth of the bog. If this were done, the mined land could be rehabilitated and used for crops, forests, or recreation. New methods of mining must be developed.

Environmental effects on air and water quality and wildlife and fish habitats must be considered with any large peat development plan. If we can solve these technological and environmental problems, Minnesota could change from a state which imports virtually all its energy to one which is nearly self-sufficient.

MINNESOTA'S PEATLAND--AN ENERGY POTENTIAL, Robert L. Herbst*

Minnesota, Wisconsin, and Michigan have extensive undeveloped peatlands. Estimates are that these three states contain up to six million hectares of peat, roughly 79 percent of the peat found in the contiguous 48 states. Minnesota alone contains about three million hectares with several large deposits occurring in the northern part of the state. It is estimated that more than 90 percent of Minnesota's peatlands are state owned and managed by the Department of Natural Resources (DNR). To manage this resource wisely, the DNR must inventory it, map it, and study it, plus develop staff expertise.

Traditionally, peatlands in the United States have been used mainly for specialized vegetable crops, forage crops, and black spruce. Recently, there has been more demand to use Minnesota's shallow peatlands for wild rice. A few thousand acres of the state's peatlands are presently leased to private operators for the production of horticultural peats.

All peatland development in Minnesota to date has been on small acreages dispersed through several areas. As a result, development problems have been small. However, the ramifications of energy development will increase as a result of the demand for large tracts of bog. Peatland development for energy production is appropriate because the northern lakes states depend entirely on imported fuels. The feasibility of utilizing peat as a source of synthetic natural gas, fuel for generating plants, or other uses should be seriously considered.

State policy transforms academic and technical data into reality. It must be based on sound information, guided by the legislature, and implemented by the management and regulatory agencies.

Large-scale peatland development for fuel could include at least tens of thousands of acres. This could have considerable economic impact in areas which have little employment outside of iron ore and taconite mining. Peat development could provide summer and fall employment. Research into new peat harvesting and drying techniques may make harvest operations less dependent on the weather and thus provide more constant employment. The greatest economic benefit of a gasification facility may be that it would keep existing

*Commissioner, Department of Natural Resources, State of Minnesota.

industry and homes supplied with fuel, replacing the imported fuels which are rapidly becoming scarce.

The development of peatlands on a large scale is not without environmental effects. The DNR should make a careful environmental assessment before development is allowed. It should consider the effect of drainage on the flooding of streams, on local and regional water tables, on water quality and fish in receiving waters, and on vegetation and wildlife. It should also consider air and water pollution from fuel or industrial plants, the destruction of unique bog plants, and the land-use implications. This environmental assessment should be submitted to all local, state, and regional authorities. The results of all environmental, technical, and economic studies should be made available to the public.

Minnesota's vast peat resources has the potential to ease the energy problems we face. Discussion, research, and experimentation in energy production are all appropriate courses of action, but the economic and environmental ramifications should not be ignored.

PEAT AS AN ALTERNATIVE ENERGY SOURCE IN MINNESOTA, Roy Larson*

Although peat accounts for only 0.4 percent of the world's fossil fuel use, it is significant in those countries where it is used. About 17 percent of Leningrad's power and about one-fourth of Ireland's power are generated by peat.

The Soviet Union uses over 90 percent of the fuel peat consumed in the world. Ireland is the next largest user. The United States uses virtually no fuel peat, although it will become a substantial consumer. One of the reasons for the Soviet emphasis on peat is that Russia has over 60 percent of the world's peat reserves--about 200 billion tons. The United States and Canada both have large reserves: In Alaska, there are an estimated 100 million acres of peatland containing about 100 billion tons of peat.

The energy potential of peat is substantial. Worldwide, there is about 60 percent more energy in peat reserves than in known oil reserves. In addition, peat has a low sulfur content which makes it valuable for gasification. Alaskan peat could provide fuel for gasification plants which could utilize the proposed gas pipeline after the natural gas supplies are depleted. In the United States, peat is a significant energy resource, especially in comparison with gas and oil.

Russia, Finland, and Ireland have used peat, especially milled peat, in electric generating plants for years. According to a recent cost-benefit study, Ireland's decision to develop peat rather than continue to use imported fossil fuels has resulted in a more stable fuel supply, increased employment, and a more favorable balance of payments. This peat policy would pay off even if peat were twice as expensive as oil.

The Midwest Research Institute is doing a study on the feasibility of converting the municipal boiler in Virginia, Minnesota, to peat. It would be financially feasible to transport peat twenty miles from a large nearby bog. Peat can be competitive with some other fossil fuels and, as oil prices rise, its competitive position will improve. Already, it is cheaper than coal in many cases.

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*Manager, Engineering and Analysis, North Star Division, Midwest Research Institute.

ANIMAL WASTES AND AGRICULTURAL RESIDUES, A RENEWABLE ENERGY SOURCE

USE OF AGRICULTURAL WASTES IN MINNESOTA, James A. Moore, Ph.D.*

Livestock manure is approximately 80 percent water and 20 percent dry matter. A portion of this dry matter is volatile and thus important as an energy source. Volatile dry matter can be subdivided into biodegradable and nonbiodegradable components; the biodegradable component is of interest as an energy source, a fertilizer and soil amendment, and a potential pollution hazard.

Most of the animal agriculture in Minnesota is concentrated in the southwestern half of the state; corn and oats acreage is concentrated in the same area. Because of this distribution, animal manures can readily be used as fertilizers and soil amendments. Manure is most often used as a fertilizer because of its high organic content and nutrient composition. The land receives applications of manure before or after the growing of a crop. This requires that manure be stockpiled and applied in the spring or fall. For improved sanitation, some operators, such as dairy farmers, may haul and spread manure daily. Hay land or idle land can receive the manure.

Alternate uses of manure might be thermal combustion, thermal conversion, and biological conversion. Oven-dried manure can produce up to 7800 BTU's per pound, but manure's high initial moisture reduces its potential value. In areas with long periods of low rainfall, solar energy can be used to drive the moisture from the manure and make it useful for thermal combustion.

Thermal conversion, another alternative, requires a large plant, high capital investment, and a concentrated supply of manure. In Minnesota, where the animals are spread over wide areas, this would require a large expenditure for transporting the manure.

A third alternative, biological conversion, requires a feedstock which has no toxic substances and is uniform, consistent, and well balanced. Such a feedstock yields manure which is an ideal feed for the closed digestor. It is energy rich and produced daily. It comes from a well-balanced ration and,

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*Professor, Department of Agricultural Engineering, University of Minnesota

in most cases, contains no toxic materials. The disadvantages of this system are the requirements for a constantly elevated temperature and the increased rate of nitrogen loss once the slurry is discharged from the closed digestor. In fresh waste, 25 to 30 percent of the nitrogen is in the form of ammonia; after digestion, from 50 to 60 percent is in this form. The technical requirements for optimizing the digestion process and the production of methane gas require an uncommon understanding and skill. At the present time, the capital investment and operating costs could not be recovered from such an operation.

The other important consideration in evaluating conversion techniques is the location and type of livestock housing. Ninety-six percent of Minnesota's beef cattle are finished in open lots which are usually cleaned once or twice a year. However, some operations in Minnesota are installing closed systems to increase production and provide convenience and comfort in inclement weather. Some of these have automatic daily waste removal and could incorporate a digestor in the normal pattern of waste handling.

POTENTIAL BIOMASS PRODUCTION IN MINNESOTA, Dale N. Moss, Ph.D.*

There are many factors to evaluate in considering the use of crop residues for energy. Nevertheless, the energy of crop residues is great and should not be ignored. The total crop residue in Minnesota has an energy value of approximately 50×10^{13} BTU's, which is about 40 percent of the total annual energy consumption in the state.

Plant growth may vary substantially if sun, water, mineral nutrients, and temperature are insufficient or if toxic substances are present. These factors may vary greatly from one area to another and from year to year. Because of the world need for food, it doesn't seem feasible to use agricultural land for energy production, but there are a number of possible methods for producing both food and energy on agricultural lands.

Removing crop residues could deplete the soil. When we harvest corn, we remove mineral elements which must be replaced through fertilization if the productivity of the soil is to be maintained. If we remove the stalks or the roots, additional fertilizer is necessary.

An additional crop grown in sequence with corn could be a source of biomass for energy. In an experiment, the University planted winter rye in the fall. It was harvested at the end of May and produced 3.8 tons of dry matter per acre. Next, a type of corn that would not ordinarily mature in Minnesota was planted about four times more densely than normal. This corn produced nine tons of biomass per acre for a total production of about 13 tons per acre. Normal corn residue yields only about 2.5 tons per acre.

There is substantial land in the state which is not suitable for agriculture, but which could be used for energy crops such as trees or cattails. Managed stands of cattails have produced approximately 35 tons of dry matter per acre, with an energy content of about 7500 BTU per pound. Cattails are ideally suited to the wet peat deposits of Minnesota, lands which are now essentially useless. Biomass production for energy may be a possible use for these wasted lands.

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*Professor, Department of Agronomy and Plant Genetics, University of Minnesota

BIOMASS ORGANIC RESIDUES, A RENEWABLE ENERGY SOURCE, Walter J. Maier, Ph.D.*

In organic wastes, the energy which was received from the sun is stored as chemical bond energy. It should be possible to capture this energy and put it to use.

Each type of organic waste, when used as a source of energy, has its own problems and advantages. Agricultural crop residues contain about 10.8 x 10^{16} calories, approximately 40 percent of the state's energy consumption. It would be possible to capture half of this energy. Animal wastes do not have a large potential. They could provide about 2.8 x 10^{16} calories per year, about 8 percent of the state's consumption, if it were feasible to collect all the wastes. On a chicken farm, for instance, where the supply is relatively concentrated, animal wastes could not only improve the energy situation, but also resolve the waste problem.

Forest residues could supply about 4.2 x 10^{16} calories per year, about 14 percent of Minnesota's consumption, if a 25-year cutting period were used. But forests are located away from population centers, so transportation would be expensive. Urban solid waste has a small potential for providing energy. In total, only about .29 x 10^{16} calories could be produced each year, about one to two percent of the state's energy use. There is a value, though, in resolving the disposal and pollution problems of solid waste. Sewage sludge also has a small energy potential. Because it is a nuisance, a number of suggestions have been made to burn it for energy. If it could be combined with other materials, it could be burned, but since its water content is over 90 percent, the process would probably use more energy than it could produce.

There are three processes which can be used to produce energy from organic wastes: combustion, pyrolysis, and fermentation. Combustion requires a high temperature and the presence of air; it can cause air pollution. Pyrolysis, another kind of combustion, uses only enough oxygen to raise the temperature sufficiently to cause materials to produce fuel gas or liquid fuels. This process has substantial problems with product purification.

Fermentation can use wastes with a high water content. It requires no air, causes no air pollution, and produces a clean fuel with little sulfur. It lends itself to small scale operations and does not destroy the fertilizer

*Professor, Department of Civil Engineering, University of Minnesota

value of the wastes. The amount of methane produced through fermentation depends on the kind of organic wastes used. This process uses large quantities of materials.

A small scale operation provides the best over-all economics. For a 400-acre farm using a 60-day retention schedule, the digestor alone would cost at least $250,000, a prohibitive investment for most farmers. It is necessary to find ways to speed up the reaction and thus decrease the storage requirements. In experiments, it has been possible to use a 15- or 7-day retention schedule. At present methane prices, the farmer could have an income of between $6,000 and $12,000 per year from fermentation on a 7-day schedule. The pay-back period on the investment would be between 2 1/2 and 10 years.

Presently, the research focus is on decreasing the retention time. Experimenters are attempting to increase bacterial concentrations; to use multiple stage reactors; to increase temperatures; to use immobilized enzymes; to develop pure and modified cultures; and to pre-treat the biomass chemically.

ENERGY AND DOLLAR FEASIBILITY OF COLLECTING AND FIRING CROP RESIDUES,
Patrick J. Starr, Ph.D.*

The energy content of Minnesota's crop residue could supply an estimated 40 percent of the state's energy needs. Our work examined the costs and energy feasibility of a realistic means of utilizing this resource: direct firing it in existing utility boilers to produce electricity. It was assumed that 15 percent of the available residue could be safely removed from the soil and that crop residue could replace 20 percent of the thermal energy in coal-fired boilers. All the residues were assumed to have a heating value of 16×10^6 BTU per dry ton and contain 15 percent moisture by weight.

Information was obtained on the 1974 acreage of corn and six small grain crops. Information on the 1974 BTU consumption of 29 coal-fired boilers that produce steam to generate electric power was also obtained.

The term "strategy" was used to describe a selection of equipment which could perform the sequence of operations involved in removing residue from the field and inserting it into a utility boiler. Ten different stages of operations were identified and these, in turn, were grouped into three major categories: On-Farm, Shipping, and Power Plant. Obviously, there are numerous possible strategies.

Boiler modifications could run from virtually nil in a cyclone boiler to cutting into the side, sealing some water pipes, and setting up controls in another. This was the only cost that could not be determined.

Of the 29 plants considered, those with a yearly energy consumption below 2.5×10^{12} BTU located in farming areas can be supplied with 20 percent of their fuel from an area within a 13 mile radius of the plant. All their fuel can be supplied within a 29 mile radius.

Fifteen different corn strategies and 24 different small grain strategies were examined. The strategies encompassed small bales, roll bales, and stacks. The average supply radius was under ten miles. Roll bale systems resulted in the lowest costs, while small bale systems gave the highest costs. A roll baling system for large or small grain would look promising if coal cost over \$2.00 per 10^6 BTU. Stack systems were more efficient with the higher

*Assistant Professor, Department of Mechanical Engineering,
University of Minnesota

density corn residue.

The cost of fuel from residue could compete with the cost of coal. If coal cost \$1.50 per 10^6 BTU and a typical fuel from corn residue cost half that, then \$10.20 per ton over and above the labor, fuel, ownership, and maintenance costs would be available for boiler modification or profit. Such a system pays for itself. Realistically, even when coal costs are below \$1.00 per 10^6 BTU, an operation could break even. And it could have non-economic benefits, such as off-season employment, opportunities for local cooperative management, and a reduced dependence on the outside energy market. In addition, such systems are efficient energy users.

FUELS AND CHEMICALS BY THERMAL CONVERSION OF BIOMASS, David P. Kittelson, Ph.D.*

There are four main processes for the thermal conversion of biomass.

Direct Firing. Electrical generating plants are already operating on a fuel mixture of 20 percent solid waste and 80 percent coal. In the future, they may be operated solely on a fuel of wood and wood wastes.

Mechanical Processing. It is possible that either solid waste or residue could be finely ground into a fuel that is more easily burned in present systems.

Both direct firing and mechanical processing can be done on a small scale. However, since both processes, even on the farm level, produce excess energy, central plants would probably be more advantageous.

Enzymatic Digestion. When biomass is ground very finely, its cellulose becomes accessible to enzyme action. Enzymatic digestion of cellulose produces glucose, which can be fermented to produce ethanol and then converted to ethylene--a chemical feedstock. Since this feedstock is much less bulky than the original biomass and can be easily transported, small-scale, on-site processing might be attractive.

Hydrolysis, Gasification, Liquefaction. During hydrolysis, at a moderately high temperature and pressure in an acid solution, the cellulose in the biomass is converted into glucose. This process can produce ethanol, but it will not be economically competitive until the price of crude oil reaches $20 per barrel.

During gasification and liquefaction, the biomass is heated in a reactor like the ones used for coal gasification, in an atmosphere deficient in oxygen. Three different temperature regimes are used: high (above 1400° F), medium (around 900° F), and low (around 750° F). In high temperature pyrolysis, cellulose breaks down into a mixture of carbon monoxide and hydrogen, a medium BTU gas. This can be further processed to produce hydrogen alone, methanol, methane, or ammonia. Such high temperature pyrolysis requires large, centralized plants.

With medium and low temperature pyrolysis, smaller plants and possibly even mobile units become feasible. The product of medium temperature

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*Assistant Professor, Department of Mechanical Engineering, University of Minnesota

pyrolysis is a tarry, oxygenated material with the consistency of #6 fuel oil. Since this fuel is less bulky than the original biomass, it can be produced on a farm scale without significant transportation costs. The char which is left over can be recycled into the land as a soil condition. The major product of low temperature pyrolysis is charcoal, with small amounts of gas, tars, and oils.

The economics of thermal conversion are not well established, but some estimates can be made using figures for coal gasification. It is cheaper to use Alaskan oil as long as it is available, but biomass would be cheaper than oil shale. At present, OPEC oil costs around $12.50 per barrel; the same amount of energy produced from biomass would cost from $13 to $19. The costs of alternative energy sources are becoming competitive.

ENERGY FROM AGRICULTURAL PRODUCTS: NEBRASKA GASOHOL PROGRAM, William A. Scheller, Ph.D.*

In an effort to provide a new domestic source of energy and stimulate the agricultural economy of the state, the Nebraska Legislature established a program to develop a grain alcohol industry through the introduction of an automotive fuel consisting of 10 percent agriculturally derived ethyl alcohol and 90 percent unleaded gasoline. This fuel is called gasohol.

In order to encourage the use of gasohol, the legislature reduced the state gasoline tax on this fuel by three cents per gallon. With this tax reduction, the price of gasohol became competitive with that of unleaded gasoline. In the past, grain alcohol was rejected as an additive for gasoline because it cost more than gasoline, but this cost relationship has changed drastically in the last three years. Gasohol costs 62.9 cents per gallon and, because of improved mileage, it is slightly cheaper to use than no-lead gasoline.

A "Two Million Mile Gasohol Road Test" has been designed to develop quantitative data on fuel consumption, cylinder wear, and exhaust gas composition. To date, over one million miles of driving experience have been recorded and all the results are encouraging. No unusual problems have been found. Mileage with gasohol appears to be about five percent better than with unleaded gasoline. Also, since grain alcohol has a very high octane, its addition to gasoline increases the octane of the fuel by about three points.

The cost of facilities to produce about 20 million gallons of alcohol per year from 21.5 thousand bushels of milo per day would be about $21 million. The estimated income would be $29 million per year and the estimated net profit would be $1,310,000 per year.

First quality grains are not needed in a grain alcohol plant. Furthermore, the by-product, distiller's dried grains plus solubles (DDGS), is suitable for cattle feed because toxins which might be present in the grain are destroyed in the normal fermentation and purification processes. Thus, grain which would not normally be used can now enter the human food chain as

*Professor and Chairman, Department of Chemical Engineering,
University of Nebraska-Lincoln

beef protein. In one test that used DDGS in place of corn in cattle feed, there was a 12.9 percent increase in the amount of beef produced. DDGS can also replace soybean meal in cattle feed.

In Nebraska, there is enough distressed grain each year to supply a 20 million gallon per year grain alcohol plant. Grains below sample grade could yield another 60 to 70 million gallons per year. In short, gasohol not only can add needed automotive fuel to the economy, but can increase the production of beef protein.

COSTS OF PRODUCING ENERGY FROM MINNESOTA'S FOREST LANDS, Dietmar Rose, Ph.D.*

The production of energy in intensive, managed fuel plantations of woody species is an alternative to help meet our increasing energy needs. Energy production costs could be competitive with fossil fuels in some parts of Minnesota. The productive potential of woody plants at high densities and comparable cultural levels is as high as that of annual crops. Aspens and poplars offer the best prospects due to their rapid growth, adaptability, and suckering habits.

Methods of producing wood for energy range from traditional, extensive, long-rotation management to highly intensive, short-rotation alternatives. The extensive options utilize natural aspen and involve little management expenditure. The only major activity is the harvesting, since the forest resprouts itself from the stumps. The intensive options require substantially more activity: clearing, site preparation, planting, irrigation, periodic fertilization, and weeding during the first years. The intensive options utilize hybrid poplars which produce five to six times as much dry matter as natural aspen; estimated yields are as high as 10.03 tons per acre per year.

Production cost estimates were derived from a cautious interpretation of available information and from short-run average cost curves. For the intensive cultures, it was necessary to consider the scale of the operations, site conditions, power availability, timing, performance, and economics of scale. All alternatives were analyzed at two discount rates, 10 percent and 6.975 percent.

The wood fiber produced under any management scheme has essentially two uses--as a source of wood pulp for paper making or for energy generation. The two intensive culture alternatives studied could produce wood fiber or energy at a cost less than the current price of $30 per ton or $1.76 per million BTU.

The land requirements to sustain a 150 megawatt generating plant operating at 60 percent average load were calculated to assess the possibilities

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*Assistant Professor, Department of Forestry Services, University of Minnesota

for fuel forests. An intensive culture with a 15 year rotation would require the smallest land area and the smallest annual harvest acreage to sustain the operation of such a plant. The land requirements under intensive management are smaller than for modern pulp and paper mills. One such fuel plantation could supply the electrical energy needs of almost 100,000 persons (based on an average per capita consumption of 7,950 per kWh). Considering that some communities are paying over $2.00 per million BTU for coal and that vast acreages of forests are not producing at their potential, the energy forest is a promising way to provide sufficient and cheap energy.

Important factors other than directly measurable costs must enter any objective comparison of energy production alternatives. Among these are energy input-output ratios, capital and land requirements, environmental effects, and socio-economic consequences.

POTENTIAL SUPPLY OF TIMBER FOR ENERGY USE, Rodney W. Sando*

Wood may provide an alternative source of energy for Minnesota. Minnesota has about 16 million acres of forest land that is capable of producing 20 cubic feet or more of wood per year, most of it in the north and eastern parts of the state. The state produces about 7 million tons of wood each year. Since wood that has traditionally been viewed as waste (limbs, tops, and bark) could be used for energy production, the amount of usable wood per acre could nearly double. Consequently, Minnesota's forest area has the potential of producing 225 x 10^{12} BTU's, assuming no intensification in management. Intensive management could result in much greater yields.

The total demand for wood in Minnesota exceeds 2.3 million cords per year. Minnesota's forest industry has been expanding at about six percent per year and is consuming more low quality material, particularly aspen. It needs less than half of the wood grown and there is a large supply of low quality hardwood available for energy production.

Aspen and birch cost about $17 per cord. At this price, energy would cost about $1 per million BTU. Production costs could be reduced through advances in harvesting technology. An accelerated demand for wood could increase prices, but the large surplus would help keep prices stable.

The use of wood for energy is not free of problems. The technology of converting wood to energy must be improved. Environmental protection must be considered. The large land areas required may cause problems with competing land users. Industry may be competing for the available wood. The wood must be transported long distances.

Still, the advantages of wood as an energy source are substantial. Wood does not contain large quantities of pollutants such as sulphur. Sustained supplies of wood can be produced as long as they are needed. No major changes in law or policy are needed to implement wood harvesting. Considerable forest land is available. And, at present prices, wood is competitive with some energy sources.

Using wood for energy could solve some of Minnesota's problems. Adverse environmental and economic effects are occurring because the trees are growing old without being utilized.

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*Instructor, College of Forestry, University of Minnesota

SOLID WASTE AS AN ENERGY RESOURCE IN MINNESOTA, Luther D. Nelson, P.E.*

The seven county metropolitan area generates approximately 1.9 million tons of solid waste per year, not including construction or demolition materials. The state as a whole generates approximately 3.6 million tons per year, which has the potential energy of two million tons of Western coal or 260 million gallons of fuel oil. Changes in packaging, both quantity and materials, changes in consumer habits, shortages of raw materials, changes in the energy required for production, and new legislation could affect these figures.

The density of solid waste generation is important for estimating transportation costs. By 1995, both Minneapolis and St. Paul and the first ring of suburbs will be generating over 50 tons per square mile per week and a large area around them will be generating between 25 and 50 tons. At present, this solid waste is deposited in sanitary landfills in the outlying areas, thus incurring substantial transportation costs. Many of the landfills will be filled by the early 1980's and, therefore, adequate solid waste disposal systems must be insured. Any disposal system will include some sanitary landfill capacity for residues and non-processable wastes. Proposals for using solid waste as energy, however, would provide for burning in the central city, thus drastically cutting expenses.

Some of the potential markets for solid waste in the metropolitan area are the Northern States Power generating plants. There is also a potential market for steam or for pyrolysis gas in four Twin Cities locations and in some other areas.

Studies have recommended that a 13,000 ton per week solid waste processing facility and energy plant be built in the Industry Square area of Minneapolis. The proposed system would have two shredding processes, would remove ferrous metals, would separate the heavy and light fractions through air classification, and retrieve the aluminum from the heavy fraction. The remaining portion would be burned for energy in two 250,000 pound per hour boilers.

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*Chief, Environmental Division, Hennepin County

This would replace approximately 50 million gallons of fuel oil per year. The system would cost 56.6 million dollars and would be self-supporting. This type of system has proven successful in Nashville, St. Louis, and East Hamilton, Ontario.

SYSTEMS FOR USING SOLID WASTE AS AN ENERGY RESOURCE, Irving M. Stern*

Solid waste disposal is a growing problem. In the United States, over 130 million tons of municipal refuse is collected every year, yet refuse is a relatively untapped resource. The United States could save 73,000 gallons of fuel oil per day by burning only 1200 tons of garbage per day in a refuse-energy steam plant. The collected municipal refuse could generate about six percent of America's power.

The major reasons for this country's lack of interest in solid waste as an energy resource are that other fuels have been cheap and that landfills have been economical.

In addition, there are a number of myths which tend to obscure the benefits of converting refuse to energy. "Gold-in-garbage" publicity has given the impression that a community can eliminate disposal costs by establishing a resource recovery plant; this is not true. Another myth is that resource recovery will solve all of a community's solid waste disposal problems; in fact, waste disposal will continue to require attention. Still another myth is that resource recovery systems are at odds with source reduction programs; actually, the BTU content of waste is increased when cans and bottles are removed.

There is a myth that federal grant monies will produce technological breakthroughs capable of providing more efficient disposal and recovering more valuable products. But instead of hastening the adoption of resource recovery programs, research may actually retard their growth since commercial development could take twelve years or more. There is also a myth that adequate financing at acceptable interest levels is lacking. However, one project in Massachusetts has received more than $40 million in debt and equity financing.

Another possible source of energy from waste is the methane gas that is now allowed to dissipate into the air through pipes stuck into the ground. Now that natural gas is becoming scarce, it is economically feasible to mine the methane.

In Switzerland, solid waste is burned to produce electricity, using movable grates to enable the refuse to burn completely on all sides. After

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*Phoenix Industries

the burning, the metals are recovered and sold, and the sterile sludge which remains is used as a base material for road construction. Air pollution from the burning is minimized with electrostatic precipitators.

In other areas, the heat from the burning waste is used to warm a municipal swimming pool, to heat apartment buildings, or to dry the sewage sludge.

This solution to the refuse problem has been accepted worldwide--in Japan, Germany, Italy, France, and most other western European countries. It is being considered in the United States, where each family throws away enough garbage to light its own home.

CONSERVATION OF ENERGY

CONSERVATION AS AN ENERGY SOURCE, Samuel J. Stewart, P.E.*

Energy conservation is the safest, most reliable, most economical, and least environmentally destructive energy source available. One-half of all the energy used today could be saved through energy conservation.

The Energy Policy and Conservation Act of 1975, the most important energy bill enacted by Congress, contains economy standards for new cars, mandatory energy labeling of major home appliances, authorization of energy efficiency standards for major home appliances, and block grants for states to develop and administer energy conservation programs. In order to obtain funding, a state energy conservation program must be active within five years. It must set mandatory lighting efficiency standards for public buildings, increase the use of car pools and public transportation, develop mandatory efficiency standards for state procurement, develop mandatory standards for thermal efficiency in buildings, and enact laws to allow the right turn on red lights.

Minnesota is one of the leading states in developing such a program. As part of the state program, the Minnesota Energy Agency has gathered data on energy demand and has developed a computer program that can show which kinds of energy conservation efforts have the greatest impact. The Energy Agency has programs in five areas: residential, commercial, industrial, agricultural, and transportation. In each of these areas, the agency has worked with trade associations and utilities and has tried to educate the public about energy conservation methods.

Minnesota has a statewide energy code to regulate energy conservation in new buildings. The Energy Agency is now developing standards for existing buildings and compiling a list of energy conservation consultants.

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*Minnesota Energy Agency

ENERGY CONSERVATION BY BUILDING UNDERGROUND, Thomas P. Bligh, Ph.D.*

The potential for saving energy by designing better buildings is great. Space heating and cooling account for almost 25 percent of the total United States consumption and about 70 percent of all residential energy consumption. This energy use could be reduced if heat transmission and air infiltration could be reduced.

The air infiltration losses are greatly reduced or eliminated by underground construction, since most walls are surrounded by earth. The heat transmission losses are also reduced. They depend on the thermal transmission coefficient U (which measures how easily heat is conducted through the wall) and the difference between the inside and outside temperatures. The U-factor for an underground wall with no insulation is equal to or better than that of an aboveground wall with the best insulation. In addition, underground construction reduces the differences between inside and outside temperatures, by smoothing out the daily and seasonal fluctuations to a more even temperature. In no way can improved insulation on an aboveground building begin to compete with subsurface structures in conserving energy.

Subsurface construction can save energy in other ways, too. It uses soil as an insulator--which requires no manufacturing energy. It avoids direct sun radiation which, in summer, contributes to the cooling load. It avoids wind which, in winter, adds to the heating load.

Subsurface construction is well suited to cold storage facilities because the surrounding earth retains cold, permitting smaller refrigeration plants. It is also well suited to manufacturers of precision instruments, since underground facilities eliminate the vibrations caused by surface ground waves. Underground construction requires less maintenance, provides almost unlimited floor loads for heavy machinery, gives protection from structural shear stress during earthquakes, and reduces noise.

Earth covered housing would share some of these advantages and be designed to have horizontal access to sunlight through windows facing a sunken courtyard. Such housing could be mass produced without causing unsightly visual repetition, since less than one fourth the normal aboveground volumn of

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*Assistant Professor, Department of Civil Engineering,
University of Minnesota

a house would be visible. The area, uncluttered with buildings, would have a feeling of greater outdoor space. A small solar collector system could supply the hot water and heating needs, and an ice air conditioner, and cooling and dehumidification needs. The ice air conditioner is a device to store the winter's cold in a large underground tank of ice. By such means, the house's outside energy needs could be reduced by 84 percent.

At present, lending institutions are reluctant to finance underground buildings because of the lack of experience and fear of public rejection.

USING WASTE HEAT

WARM WATER UTILIZATION FOR GREENHOUSES, Gary Ashley*

In the generation of electricity, three units of input energy yield one unit of electrical energy and about two units of reject heat. Since the efficiency of this process cannot be improved much, Northern States Power (NSP) has tried to put reject heat to some beneficial use.

NSP has researched the use of warm (85° F) water to heat greenhouses. There is sufficient waste heat from the Sherburne County units 1 and 2 to heat about 1000 acres of greenhouse, which is nearly the total greenhouse area in Pennsylvania and Ohio together.

In a 1974 experiment, a greenhouse utilized warm water to heat air which was circulated in ducts. In 1680 consecutive hours, the inside temperature never went below 56° F, although the outside temperature went down to -25° F. The conclusion was that the warm water was sufficient to heat the greenhouse.

The next step was to use this type of heating system in a commercially-sized greenhouse. The greenhouse was a series of fourteen joined, quonset-hut bays, each 96 feet long and 17 feet wide. The bays were covered with two layers of plastic separated by a small air space. NSP, the University of Minnesota Agricultural Experiment Station, and the United States Environmental Protection Agency are involved in this project, trying to demonstrate the technical and economic feasibility of using power plant cooling water to heat greenhouses. The project will also determine whether it is economically feasible to operate greenhouses year-round at power plant sites in northern climates.

The air handlers in this project use a coiled heat exchanger and, in each of the bays, a 3 hp motor which circulates the air through a 30 inch duct. At regular intervals in the duct are large holes so that there is good air distribution. The cooled air is sucked back into the air handler in a free return system.

In addition to the air heating system in this project, warm water is run through a series of underground pipes to heat the soil. This was not

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*Research Engineer, Northern States Power Company expected to heat the greenhouse; it was an experiment to see if the heated soil affected plant growth. The water handling system uses a 4 or 5 hp pump.

The primary purpose of this project is to grow food using what would otherwise be wasted energy.

ALTERNATIVE USES OF REJECT HEAT FROM ELECTRIC POWER PLANTS,
James E. Carter, Ph.D.*

One of the major unused sources of heat energy in Minnesota is the waste heat produced by power plants. For every unit of electrical energy produced there are two units of wasted heat energy that could be partially recovered.

Under present conditions, fossil fuel and nuclear power plants operate at approximately 30 to 35 percent efficiency . The efficiency of a power plant is that fraction of energy input that is ultimately converted to electricity. For a steam-electric power plant, the maximum efficiency is approximately 54 percent, which is not usually achieved because of the cost of improving efficiency to this point. However, by recovering waste heat, power plants can improve efficiency at the point of end use. For example, space heating is only 20 to 30 percent efficient with electricity, but is 75 percent efficient with power plant district heating.

The possibilities for utilizing this waste heat have gained attention only recently as fuel has become scarcer and more costly. However, as far back as 1952, Finland turned to a high pressure, hot water system which utilized the waste heat from electrical generation. Finland's heating season of 270 days is about the same length as Minnesota's. In Finland, district heating systems that use the waste heat from power plants are used primarily in cities of 70,000 to 100,000 people. They can result in considerable fuel savings.

In the Northern States Power experimental greenhouse heating system, the water from the condenser has a relatively low temperature of approximately 85^{o} F. This temperature maximizes the production of electricity. In Finland, the temperature of the condenser water is increased. This decreases the electrical generating efficiency, but increases the total efficiency of the system when this hotter water is used for heating. The total efficiency reaches approximately 80 percent, as compared to 40 percent in the best steam-electric generating plant.

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*Director, Research Division, Minnesota Energy Agency

In Finland, district heating plants are now operating in Tapiola, Kuopio, Haapaniemi, Tampere, and Naistenlahti, some using milled peat. Nevertheless, district heating systems are not cost effective; that is, implementation would not justify the investment. A government policy would therefore be required in order to utilize this energy efficient system. If such a system were used extensively, our present coal reserves would in effect be doubled.

SIDE EFFECTS OF NEW ENERGY SOURCES

ENVIRONMENTAL SIDE EFFECTS OF ALTERNATIVE ENERGY SOURCES, David Fradin*

Limited research has been done on the environmental impact of solar and wind energy. Since all energy production has some environmental impact, the essential question is: how much increased risk is society willing to accept?

There are three main environmental concerns with solar power: land use, thermal pollution, and natural resources. Solar energy is relatively clean; it produces no effluents, no toxic substances, no radiation or radioactive materials. But sunlight is diffuse and must be concentrated, which requires large land areas. Once the energy is concentrated, there is thermal pollution similar to that at any electrical generating plant. In addition, since the sun only shines part of the time, some sort of storage system is necessary. Also, numerous transmission lines are needed to bring the electricity to population centers.

The capital requirements for solar systems are large (about three to five times more than conventional systems).

The environmental impact of wind energy has also been minimally researched. Trees in front of the windmill might have to be removed. The visual impact of the windmill could be substantial, particularly in populated areas. The top speed of the rotor could possibly reach the speed of sound and cause a noise. As the wind passes through the windmill and energy is removed, there might be climatic changes on a micro-scale. Finally, the natural resources used in the construction of the windmills should also be considered.

These environmental problems should be studies in greater detail. Then we can adequately evaluate the environmental impact of solar and wind power in contrast with other ways of generating energy.

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*Executive Vice President, Environmental Balance Association

NUCLEAR ENERGY AND ENERGY FROM SPACE

LIQUID METAL FAST BREEDER REACTOR, Peter S. Van Nort*

Even if 25 percent of the energy used today were conserved, the growth in demand for energy would only be slowed down. Because much of the increased demand will be for electricity, we must find a means to provide increased electrical power. To do this, coal and uranium are the only sources of consequence.

Uranium 238, the predominant isotope, cannot be used in present day nuclear reactors; only the scare Uranium 235 can be used. The breeder reactor will make the more plentiful form of uranium usable by changing it into plutonium. The breeder reactor can produce more of this isotope than it uses in generating electricity, so it can supply another reactor with fuel.

Congress, the federal government, and most knowledgeable observers in the United States support the development of the liquid metal fast breeder reactor (LMFBR) technology. The economics, environmental impact, waste disposal, and safety of nuclear power and the breeder reactor should be evaluated. Economic analysis of nuclear power indicates that it saves the consumer money--over $2 million last year. A recent study concluded that breeder reactors in combination with other sources could save the country over $76 billion from 1990 to 2050.

The LMFBR technology will minimize the environmental impact of generating electricity. The breeder reactor would allow decreased mining. The wastes and the thermal discharge resulting from generating electricity are less with breeders than with either coal-fired or light water reactor plants. Although the disposal of radioactive wastes is a challenge, a number of possible technologies have been demonstrated and the methods presently being used are satisfactory.

Safeguards are necessary to protect weapons grade nuclear materials, but the procedures developed since 1940 have proven effective. If necessary, the level of security could readily be increased. With the highest possible levels of safety, the cost of electricity would only be raised by a fraction

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Project Director, Project Management Corporation of a mill per kilowatt.

There is no power which is as safe as nuclear power. The possibility of death in accidents of equal probability is 60 times greater with an oil-fired plant than with a nuclear one.

The Clinch River Breeder Project is designed to take the LMFBR technology from various European countries and show that it can be economically used in this country within a large utility system. At this point, no decision has been made to commercialize the breeder reactor. The supply of electrical energy must be increased in the manner which least affects the environment, is most economical, and is the safest. LMFBR technology can best do this.

CONTROLLED THERMONUCLEAR FUSION POWER, Jefferson O. Neff*

Programs to resolve our energy crisis are usually proposed in three different time spans--near term, mid term, and long term. Fusion power is identified as a long term energy source which can begin to supply energy in the 21st century.

The projected energy requirement for the United States between now and the year 2000 is from 2400 to 2900 quads (10^{15} BTU's), depending on the success of energy conservation. Because the estimated energy available through fusion ranges from one million quads to 10^{10} quads, fusion could supply the nation's energy needs for thousands of years.

The primary goal of the United States fusion program is to have a commercial demonstration of the fusion process by the year 2000. There should be an experimental fusion reactor by 1990 and a demonstration reactor by the late 1990's. A second goal is to explore using fusion to produce other energy fuels, e.g. hydrogen.

A fusion power system would function much as a conventional electrical plant, providing heat to produce steam which would run a turbine generator. The heat source is a fusion plasma, a highly charged gaseous mixture of deuterium and tritium contained inside a vacuum vessel. Deuterium is virtually unlimited as it exists in sea water and is economically recoverable. Tritium can be bred from lithium, but the current sources of lithium are limited. Lithium is also available from sea water in limitless supplies, but recovering it is not economical.

Fission splits a heavy atom into two lighter atoms, the masses of which are less than the weight of the original atom. This mass difference is converted into energy. Fusion takes two lighter atoms and fuses them into one atom of which the final mass is less than the itital masses. This mass difference again is converted to energy. In fusion systems, the formation of the plasma requires that enough energy be added that the atoms lose their electrons and form a state different from that of the original gas. Since these highly charged ions are repelled by each other, the key to fusion power is keeping a sufficient number close enough together for a sufficient length of time. The United States program has achieved all of the conditions for

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*Technical Assistant to the Director, Controlled Thermonuclear Research fusion but has not achieved them all together.

There are three potential ways of containing the particles to meet these conditions: magnetic confinement, gravitational containment such as the sun utilizes, and inertial containment. In the Energy Research and Development Administration, the emphasis is on a Russian program of magnetic confinement which shows the greatest promise of success.

Fusion power would be cheap; it should cost less than present power sources. Fusion would be safe, with almost no possibility of a runaway reaction and virtually no adverse environmental effects. Fusion uses no chemical combustion products and no weapons grade materials. The major problem with fusion is its economic and engineering feasibility. At this point, fusion is scientifically feasible, but the uncertainties in other areas are great.

In 1970, fusion was viewed as a basic research question and was funded with $30 million. Today, engineering feasibility is being explored and larger experimental machines are required; funding has grown to $200 million per year. In the future, with even larger reactors being built, the required funding will be on the order of the fission reactor program today.

SPACE COLONIES AND SOLAR ENERGY FROM SPACE, Keith Henson*

Hans Bethe, who discovered the nuclear reactions that power the sun, recently listed his objections to solar energy. His main objection was that the sun shines only part of the day. It is this, along with the diffuse solar flux at ground level due to clouds, that makes the cost of solar energy on earth at least five times higher than that of competing energy sources. That the sun shines only part of the time is only an earth-bound viewpoint. Two solar energy researchers, Peter   and Gordon Woodcock, have worked for several years on putting solar power plants in space where the sun shines almost all the time. The plants offer about a ten-to-one improvement in energy.

In a Solar Satellite Power Station several square miles of solar cells feed electricity into microwave generators located on the antenna. A microwave beam carries the energy to earth. A competing technique uses turbines to generate electricity. The solar heat for the turbines comes from several square miles of plastic film mirrors focussed into a central cavity. Solar energy from these systems would only cost about twice as much as energy now costs; ground-based solar energy systems could cost five times as much as energy now costs. The largest costs are in developing and building the rockets needed to haul construction materials from the earth--estimated at $44 billion.

Gerard K. O'Neill of Princeton University posed a question to a special seminar: "Is the surface of a planet the right place for an expanding technological civilization?" The conclusion was "No." Free space contains a lot of energy; materials can be obtained from the moon and asteroids; zero gravity and the roominess of space are advantageous. Furthermore, no exotic materials or unfamiliar techniques appear to be needed to build an earth-like environment. The size of the real estate that could be constructed from the asteroid belt is several thousand times that of the earth. Almost all the construction materials for the space colony could be obtained from the moon by an electromagnetic launcher. The moon's lack of atmosphere makes efficient machinery possible on the lunar surface.

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*President, L-5 Society

Last summer a task force assembled at NASA's Ames Research Center and looked at materials, transportation methods, special vehicles, mass budgets, life support systems, heat balances, configurations for a small colony, and interior designs. The task force found that the market for energy was so large and Solar Satellite Power Stations so profitable that the program could turn a nice profit while supplying clean energy. Such solar energy could cost as little as one-sixth the current cost for electricity. The projected investment is high--something in the vicinity of $100 billion or about one year's defense budget. The time required is fairly short--as little as 15 years from the start to the first energy return. A fleet of monster rockets won't be needed; a straightforward derivative of the space shuttle could do the job.

Commitment to the space colonies as an energy solution isn't desirable yet, but the colonies are a worthy project for investigation with more funds, perhaps $10 million. The supporters of space colonization generally support work on both fission and fusion. There are many uses for power in space.

ENERGY AND THE ENVIRONMENT, Dean Abrahamson, Ph.D.*

For the first time since about 1972, the public has begun to participate in the setting of national energy policy. It is impossible to separate considerations of energy policy from other aspects of our economic and social affairs. Energy availability, price, and other factors affect decisions about housing, transportation, agriculture, urban design, and life-style, to mention but a few. Decisions about energy policy will be made primarily upon social and ethical considerations.

Estimates of future energy demand should be based on detailed projections of the character and magnitude of specific uses of energy. Each potential energy source must be evaluated to determine its cost, availability, environmental impact, social impact, equity, and international policy implications. The results of energy decisions will not become apparent for a long period. For most of us energy is of little interest in and of itself. We are concerned with the goods and services which energy can produce. However, the energy supply sector and the various interests which provide the equipment and services associated with energy supply and use are interested in energy as a product to be marketed.

Two of the previous speakers have considered major new sources--nuclear fission using breeder reactors and nuclear fusion. Fusion might be an excellent energy conversion technology. The use of fusion would avoid the political and environmental stresses associated with fossil fuels. It would be based on a large fuel base and it could be utilized without fissionable materials. A problem, of course, is that it does not work! Fusion has been successful in thermonuclear weapons, but controlled fusion for energy production has not been demonstrated even in the laboratory. There are many students of the fusion program who question whether fusion will ever be a viable source of commercial energy; there are virtually none who anticipate the commercial use of fusion for at least 30 to 50 years.

The decision to allocate research and development resources to the fusion program should recognize the potential of fusion technology. But it should also recognize that the payoff is a long way off, that there are available

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*Professor of Public Affairs and Chairman, All-University Council on Environmental Quality, University of Minnesota

technologies capable of providing substantial quantities of energy, and that fusion, like fission, is suitable only for a highly industrialized economy, not for developing nations.

The breeder reactor situation is quite different, but what we have heard this evening is a gross caricature of the controversy surrounding the development of this technology. The political, social, environmental, and economic problems of fossil fuels would be avoided by the use of fission, but no decision on fission would permit any meaningful reduction in the tensions associated with petroleum or natural gas for at least two or three decades. The fuel resource base for fission would be sufficient for many hundreds of years if plutonium and uranium-233 were used and recycled. There is disagreement, however, as to whether the fission technologies--with or without the breeder reactor--are sufficiently well developed to provide energy on a commercial scale. The technology of fission is much like that of coal: it is well developed, but the extraction of the fuel and the management of the waste products still need to be mastered.

MINNESOTA'S ENERGY FUTURE

REMARKS by William Shepherd, Ph.D.*

A good deal more research in alternative energy and energy conservation needs to be done. Much of the European technology in bog management and peat harvesting might not be directly transferable to Minnesota. Some of the studies on the processing of biomass are on such a limited scale that the results are questionable when extrapolated to the real world. Studies need to be done on how energy crops can be raised on wetlands, how productivity can be enhanced, and what species are best. Studies should also evaluate the effects of the loss of nutrients and the changes in tilth when biomass is removed for energy production.

What is finally important is the technology transfer. The University, through its Agricultural Extension Service and its Experiment Stations, can serve as a model and transfer the developing technology to the local level.

The federal government's commitment to biomass is not very large. The Office of Management and Budget and some people within the Energy Research and Development Administration seem to discount biomass as a possible source of energy except in the long run. The Office of Management and Budget has recommended only $4.5 million for biomass research, including research in urban waste. This averages out to less than $100,000 per state, too little to have any impact. The Environmental Protection Agency has an additional $17 million for research in urban waste.

Congress does not understand the situation. Individuals who attend conferences like this must educate members of Congress and the state legislatures, if more governmental support is to be developed.

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*Professor, Electrical Engineering and Director, Space Science Center, University of Minnesota

REMARKS by Representative Willard Munger*

Minnesota's energy future will depend on allocation of our energy supplies and the kind of energy conservation program we are willing to support. Planning for the future must include a land use policy, restoration of lakes and rivers, and the utilization and conservation of natural resources such as minerals and timber, as well as the narrower concern of an energy policy. Energy use is directly related to pollution, land use, and exploitation of our natural resources. The experts warn that unless we change our orientation toward these interrelated subjects, our civilization will not survive.

In recent years, many acres of marginal land, including wetlands and forest land, have been put into agricultural production; between 1973 and 1974, over 8.5 million acres were added to our nation's croplands. One of the results of this is increased erosion; in some areas, estimates of erosion are from 15 to 100 tons of soil per acre per year. If this is continued, it will soon be impossible to grow a stick of firewood on these marginal lands. If this land were left in woodlots, the soil would not only be protected, but an additional supply of renewable energy would be available. A land use program is essential.

In the past, many alternative energy sources were used. Peat was used for heating and a number of district heating plants were built. Many farmers used windmills to pump water and railroads provided an efficient means of transportation. We cannot continue to use fossil fuels as we have in the past; our demand will have to adjust to the decreasing supply. In the meantime, we should go back to the methods used by our forefathers which, together with solar energy and conservation, will supplement our fossil fuel supplies.

Alternative energies must be turned to now, before drastic measures are necessary. Economic factors should not be the sole measure for evaluation, since the milleniums involved in producing fossil fuels are not considered in present day analysis. The question for the nation and the state is whether we take action now or wait until action is taken for us. The Minnesota Legislature has taken a step in the right direction by passing the Energy Conservation Act of 1976 which includes a $3 billion program to provide

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*Minnesota State Representative and Chairman of the House Committee on Environment and Natural Resources financial incentives for the homeowner who reinsulates his home. In addition, the Energy Agency will look at energy use in state buildings and has been authorized to turn off decorative gas lights and develop a program to replace pilot lights with electrical self-starter systems. There are many energy saving programs and many renewable energy sources, but steps must be taken now if they are to have an effect.

REMARKS by Senator Winston Borden*

The politics of energy conservation are the politics of frustration. Sweden and Switzerland have a standard of living comparable to ours, but use only half as much energy. In this country, we waste half of all the energy used. Yet, both federal and state governments have taken virtually no action on energy conservation and business, labor, industry, and the environmentalists have worked against each other.

We have made some progress. An energy agency was set up. However, other ideas, such as prohibiting non-returnable containers, have received a negative reaction from the special interests; everyone wants the changes to start with someone else. Take almost any issue in energy conservation and the special interests will be there--and will probably win since the public is either unaware of or unconcerned about the problem.

Minnesota will probably always be an importer of energy to some extent, but governmental incentives are needed to develop the state's energy resources. We are now developing solar power, but financial incentives, such as exempting solar units in the home from property and sales tax and providing an income tax credit, are needed. In addition, Minnesota should try to obtain the Solar Energy Research Institute.

Wind power is also a possible energy source for the state; it could supply up to 20 percent of Minnesota's electrical needs. Fuel wood along with agricultural residues and animal wastes is also a possible energy source. But research and research money will not be available until there is a public demand for it. Public awareness of these problems must be developed by all the people who are now concerned with them.

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*Minnesota State Senator and author of the Minnesota Solar Energy Bill

REMARKS by Donald E. Anderson*

One of the important factors in developing alternative energy sources is the amount of capital investment needed; developing most sources requires an investment of between $10 and $50 per million BTU's. To produce the amount of energy required in this country would take an investment equal to our annual gross national product.

A factor important to solar energy in Minnesota is the amount of sunlight. In Minnesota, the sun is rarely directly overhead, but radiation measured at the angle of the sun's rays is substantial, even in the middle of winter. In January, for example, a south-facing collector at a 45^{o} angle receives around 1200 BTU per square foot; in the Mohave desert, a collector at a 32^{o} angle receives around 1600 BTU per square foot, only about 30 percent more. So, substantial energy is available in Minnesota in the winter, when we really need it.

Using present efficiencies and technologies, the solar energy falling on one acre could produce the equivalent of 320 tons of oil. All the energy presently consumed in the state could be supplied by 200 square miles of solar collectors and all the state's electricity could be supplied by only 50 square miles of collectors. The problem is that it can't be done tomorrow.

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*Sheldahl, Inc.

<u>CONCLUDING REMARKS</u>

Perry L. Blackshear, Jr., Ph.D.*

Our Energy Agency's director, John P. Millhone, has shown the magnitude of the immediate problem of pending oil and natural gas shortages in the region by citing our dependency on Canada for half of our petroleum (a supply that is presently in jeopardy) and on Northern Natural Gas which predicts a five percent per year reduction in its supply in the near future. Since petroleum and natural gas respectively constitute 40 and 30 percent of the state's total energy budget, these anticipated reductions mean that alternative sources will be needed to supply 10 to 20 percent of our present state's energy use rate by the year 1985.

The current state's energy budget is 10^{15} BTU per year or 33 x 10^6 kW, at the mean yearly demand rate. Alternative sources discussed here were urban wastes (which could contribute 2 to 3 percent), windmills (4 to 18 percent), manure (which all told could contribute 3 percent), forest residues from the 16 million acres of forest land (which could contribute 23 percent), and field residues from agricultural land (43 percent of present rate).

The group has heard of the promise and costs of solar energy for residential heating as well as power generation (the 25 percent of our state's energy consumption used for comfort heating could be halved by the use of solar energy with a total capital investment of \$14 x 10^9 at present collector costs i.e. \$3400 per kW). In addition, the use of spoiled grain, currently prohibited as feed, fermented to ethyl alcohol added to unleaded gasoline in the amount of ten parts gasoline to one part alcohol has proven to be an effective fuel expander in Nebraska and shows promise for Minnesota.

The group has heard the Minnegasco proposal to build a 250 x 10^6 cubic feet per day pipeline quality gas plant utilizing Minnesota's peat. Twelve million tons of peat per year would be required to produce a total of 4.7 x 10^6 kW in total energy, 3 x 10^6 kW of which is in pipeline quality gas and the balance in energy-rich residues.

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*Professor, Mechanical Engineering and Director, Center for Studies of the Physical Environment, University of Minnesota

Discussion of the possibilities of using Minnesota's fast-growing cattails showed that about 300,000 acres of peat land planted in cattails could permit the continued operation of the gasification plant as the peat was exhausted. Similarly, 1.3 million acres of the land planted in tree farms could also suffice. For long-term considerations the possibilities of tree farming one third of the forest area (5.3×10^6 acres) for energy or alternatively double cropping the presently used agricultural land by sowing winter rye at fall harvest would supply 100 percent of the state's energy needs from existing farmlands without diminishing food productivity, and the winter rye would have a positive soil conservation effect.

The immediate as well as long-term needs seem to focus on convenience fuels for transportation and comfort heating.

In his summary, Mr. Millhone emphasized the inevitable deployment of our renewable resources of solar, wind, and biomass in the long run along with the immediate increase in use of coal. He further cited the technological and political uncertainties in the deployment of breeder or fusion reactors as reasons for not developing plans at present that rely on the certain availability of these long-term energy sources.

Finally, by far the most promising alternative resource appears to be our ability to conserve without impairing our productivity. Estimates made by the agency suggest that we are capable of saving up to 50 percent of our present consumption with very little in the way of capital needed and with the time needed to execute this saving, very short indeed.

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