Energy from Peat

Subcommittee 8 Report to the
Minnesota Energy Agency

Alternative Energy Research and Development Policy Formulation Project

THE MINNESOTA ALTERNATIVE ENERGY RESEARCH AND DEVELOPMENT POLICY FORMULATION PROJECT

Subcommittee 8 PEAT

Prepared for:

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This report is submitted to the Minnesota Energy Agency by Subcommittee 8 of the Minnesota Alternative Energy Research and Development Policy Formulation Project. The participation of the individuals on the subcommittee listed below does not necessarily imply representation from any agency associated with any of these individuals.

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CONCLUSIONS AND RECOMMENDATIONS

Based on the information contained in this peat task force report, the following conclusions and recommendations are made:

CONCLUSIONS

1. Minnesota contains adequate fuel type reserves of peat for both large and small scale development. Many peatland areas are located near taconite plants and district heating plants.
2. Other countries in Europe have had experience utilizing peat as a heating source used for production of electricity.
3. Studies are currently underway in both industry and the Minnesota D.N.R. to determine the feasibility of peat gasification and the impacts of peat harvesting on the environment.
4. The high water content of peat is the most important deterrent to its use as a fuel.
5. Peat harvesting and production methods are now almost entirely mechanized, with costs of production decreasing with increased research. Alternative mining methods such as dredging and piping to a plant as a slurry may be more applicable to Minnesota than the milled peat process widely used in Europe.
6. Current studies are underway by the Institute of Gas Technology in Chicago to determine the technical feasibility of producing high quality pipeline gas (1000/Btu/scf) from peat, and a pilot plant will be in operation by 1978.
7. Environmental considerations must be examined in connection with harvesting of peat and gasification of peat.
8. Some socioeconomic studies have been made concerning the social and economic impacts of large-scale peat development and others are continuing.
9. The production of SNG from peat has several major advantages over that from coal. Peat is more highly reactive and has low sulphur content.

RECOMMENDATIONS

A. Surveys, Inventories, Resource Management and Analysis.

1. Detailed surveys are needed now for specific peatland areas of suitable quality and quantity located near cities with municipal heating plants, those located near taconite processing plants and those near paper mills or wood processing plants in Northern Minnesota. These surveys would be coordinated with the present D.N.R. peat inventory program. Minnesota Power and Light Company should be required to study the possible use of peat instead of coal in their proposed electric power generating plants.

2. The peat resource data now being compiled is to be supplied to the State Planning Agency for their MLMIS (Minnesota Land Management Information System) for analysis and data retrieval.

3. Peatland areas of sufficient size and suitability for biomass production (energy farms) for such species as cattails, sedges, grasses, lowland brush, etc., should be located in Northern Minnesota.

B. Applied and Directed Technical Studies, Research and Development.

1. New harvesting technology

a. Small scale

For local heating plants and small industries (taconite plants and paper mills), develop the technology and harvesting equipment needed to cut blocks of peat on the surface of peat fields where either native or domestic grass species are growing. The purpose of this drying technique is to utilize the process of transpiration in maximizing the loss of water through the plants in order to partially reduce the water content of the peat in the zone of plant root concentration. Harvesting equipment needs to be developed similar either to the vertical German peat cutter which could be modified to cut horizontally on the peat surface or modify the American cultured sod cutters to cut grass and the peat. These blocks containing grass and peat would be approximately 16" x 6" x 6" in size. Preliminary studies in 1976 using this method of drying peat were very successful and water contents were only 25 to 40% by weight when peat blocks were cut.

Proposed Research Needs

- Develop techniques for cutting and turning (90^{o}) peat sods with grass cover. Experimental cutters to be developed.
- Determine drying cycles.
- Study best harvesting; loading and transport.
- Study possibilities of reseeding grass for two or three crops per year.

This research could be done at the state facility in St. Louis county in the Fens bog area.

b. Large scale

For large-scale peat production such as for a high B.T.U. gasification plant or a large taconite plant, the use of large suction dredges in the peatlands and pipes for conveying the peat slurry to the plant is recommended. Equipment presently used in hydraulic mining operations could be used to demonstrate the feasibility of this mining technology using peat. Large-scale tests are suggested to evaluate the efficiency and economics of this type of mining.

2. Peatlands for Energy Crops

There is a need to study the possibility of producing several wetland species under proper management practices on peatlands. Such crops as cattails, sedges, wetland grasses and rushes all grow well on peatlands and if properly managed are capable of high yields of biomass.

Because of the potentially high yields of energy on peatlands, research is needed to determine methods of planting, water control, harvesting, drying, etc. The potential exists for harvesting entire plants (tops and roots) together with surficial peat (all burnable biomass) and replanting peatland for continued energy production on a partially renewable basis. Peatlands are extensive, they are flat and thus well adapted to machinery harvesting, they have optional available water for plant growth and these lands are not presently being utilized to any extent.

C. Demonstration Projects

1. Peat for Local Heating Plants

Using either a municipal heating plant such as in Virginia, Minnesota or a local paper mill such as Conwed Corporation in Cloquet, develop the following information:

a. Determine the total peat raw material needed for a specific plant such as the examples given above.

b. Locate a suitable peatland area with sufficient reserves available for energy.

c. Make a detailed inventory of the quality and quantity of peat in this area for energy.

d. Determine the harvesting technology to be used, transportation costs, lead time needed for peatland development and technology to be used at the plant.

e. Determine what drying technologies are needed and appropriate.

f. Estimate the royalties and rental fees that will accrue (assuming state or county lands) and determine the financial benefits to the local community resulting from this peat operation.

g. Make a complete reclamation plan for the peatland area prior to removal. Determine what crops have potential for recreation, forestry, wildlife, etc.

h. Predetermine any possible environmental problems.

2. <u>Peat Dewatering System Demonstration.</u>

The most difficult technological problem to overcome before peat is to become an economical fuel source is that of adequate dewatering. Two techniques that should be evaluated are the following:

a. Swedish wet carbonization method

This method was in a pilot plant stage for several years prior to 1965 and extensive tests were conducted with peat. The Swedish Energy Agency is presently reevaluating this process for use in their peat for energy research. It is recommended that the Minnesota Energy Agency obtain from Sweden all information pertaining to wet carbonization as a technique for dewatering peat and further establish contact with researchers in Sweden and Finland for the purpose of exchanging information with them on aspects of dewatering peat. Some sort of collaborative effort between U.S. and Scandinavian peat researchers should be established. Sweden has recently sent two different groups to the U.S. to obtain information regarding the use of peat as an energy source.

b. Demonstrate sludge dewatering systems using peat

The U.S. Bureau of Mines in cooperation with the Ingersoll-Rand Corp. and dredge manufacturers are planning several demonstrations on peatlands in South Carolina and Minnesota. It is recommended that this equipment be demonstrated in several bogs in Minnesota and that extensive trials be conducted in several locations with different peat types.

D. <u>Incentives And Institutional Concerns.</u>

1. <u>Incentives for Development - Economic Options</u>

It is to the economic advantage of the State of Minnesota that peat, our local source of fossil (or biomass - see incentive 2c below) energy, be given high priority considerations and incentives over sources of energy which must be imported into the state.

a. The State should support and encourage federally sponsored demonstration projects using peat as an energy source.

b. The possibility of obtaining Federal guaranteed loans for industrial peat development for energy should be considered.

c. The possible allocation of State-sponsored bonds similar to municipal bonds or industrial revenue bonds as an incentive should be considered.

d. Direct tax incentives to industry during the development phase should be considered.

2. Incentives for Development - Regulations

a. As a result of the probable high cost of mining and dewatering peat for energy use, particularly in the early stages of development, the royalty fees charged by the State and counties should be low enough to make peat competitive with North Dakota lignite and Western coals.

b. To meet the energy needs of Minnesota's future, most agree that additional energy plants will be needed both for gas (SNG) production and electricity. Present plans for such plants envision increasing use of both coal and nuclear energy. If peat is to be used to help alleviate our energy situation in the near future, early decisions are urgently needed regarding leasing policies and regulations.

c. Peat that is used as a source of energy will be replacing or used along with other fossil fuels that are considered minerals. Therefore, early action is needed to establish a definition of peat - Is it a mineral, or is it an agricultural or horticultural product, i.e. biomass? This is important for establishing a valid tax base.

d. Some land use ordinances or zoning regulations may need to be modified to allow the orderly development of peat lands for energy. Peat development should be compatible with other existing land uses.

3. Policy Options

There is a need to establish more meaningful dialogues between scientists working on technical aspects of alternative energy and groups such as legislators, government and public interest representatives who formulate policy. Policy makers need to be informed fully both of the potentialities of peat as an energy source and the technical problems associated with its development.

E. Information Collection And Dissemination.

1. A series of educational programs for policy makers and interest laymen should be planned and given. These could take the form of day-long seminars given at several towns throughout the state or short courses extending over a period of several weeks. The actual program could be tailored to fit the particular needs and schedules of the participants.

2. A central data source for the location of Peat Information should be established in the State. This data source would include computer tapes and microfiche as well as hard copy. The existing Renewable Energy Environment (TREE) Collection at the University of Minnesota is already a substantial store of information on alternative energy sources, their utilization, development and institutional problems. It is recommended that it be extended and expanded to become a central data source for peat energy as well.

3. There is a need for a thorough on-going analysis of the data on our peat resource now being collected by D.N.R. The data itself and analysis made on it should be freely available for dissemination to all interested parties.

4. Several European countries use peat extensively as an energy source for space and district heating and electrical generation. These countries have also successfully reclaimed their peat lands after harvest and the results of their experience is generally known. The State of Minnesota should set up an on-going program to monitor, collect and disseminate this information.

5. The Minnesota Energy Agency should appoint a half-time professional to work specifically on the Peat Alternative. This person would be required to work closely with the State's scientists and industry and also be involved specifically with recommendations D3, E1 and E4 above.

I. PEAT AS AN ENERGY SOURCE - INTRODUCTION

A. Background.

B. World Peat Use for Energy.

C. New Developments in Use of Peat as an Energy Source in Europe.

I. PEAT AS AN ENERGY SOURCE -- INTRODUCTION

A. Background

Peat has been used as a source of energy for many centuries but its large-scale use for electric generation, district heating plants and domestic (briquette) use has developed only in Russia, Finland and Ireland. In these countries peat does not constitute a very high percent of their total energy demand but is locally of considerable importance as a substitute energy source. The technology for mining and processing peat in these energy-poor regions of the world for fuel use has reached an advanced stage of development. In these countries peat is competitive with coal, oil, and natural gas and recently, since the Arab oil embargo (1973), it has become not only a feasible but also an economical alternative to traditional fuels. In all of these countries expansion of peat use for fuel is taking place at a rapid pace.

In the U.S. and Canada we have not used peat for fuel because of our complete dependence on oil, natural gas and coal, but in the future it might be necessary to carefully consider the use of peat as an alternative energy source for district heating, gasification (production of synthetic natural gas from peat) or for local electric or steam generation use in areas threatened by reduction in supplies of traditional fuels or faced with interruptible service.

While the United States contains vast reserves of peat, it utilizes very little. Only 615 thousand tons, or .3% of total world production, are produced annually. In comparison, the Soviet Union produces more than 200 million tons per year or 95% of the total production in the world.

Much has been said in the past two years concerning the world's energy and chemical resources and whether production of fossil fuels (including coal, lignite, and petroleum) are sufficient to meet current demands by consumers. It is obvious that, even though the immediate situation is not clear, a long range shortage is inevitable. This has led to speculation concerning possibilities of alternative fuel and chemical sources such as oil shale, tar sands, gasification of coals, etc. Little has been said until recently concerning the potential of peat as a fuel or chemical feedstock in the United States, although it has been used for centuries in Ireland, Europe, and Russia. With continued rising prices for conventional fuels and because of the possible ecological damage in strip mining western coals in arid areas, it is reasonable to consider peat an alternative, at least in Minnesota and the adjacent Upper Great Lakes states.

As recently as 1970 the Bureau of Mines, Department of the Interior, Bulletin 650 stated that "while peat is used as fuel in many countries, it is not used for this purpose in the U.S. because of our abundant supplies of high grade fossil fuels--lignite, coal, petroleum, and natural gas and our excellent transportation system (pipeline, rail, highways) for delivering these fuels to consumers". Research on peat in Minnesota and in other states in the U.S. has been pointed principally toward agricultural uses and not toward its use for fuel. In view of the present situation we need to determine the quantity and quality of our peat resources and pinpoint the location of potentially commercial peatlands.

B. World Peat Use for Energy

The first country to use peat on a large scale was the Soviet Union when, shortly after the revolution, they introduced a program to develop their fuel peat industry. Scotland, Germany and Sweden conducted considerable research on use of peat as a fuel but no large-scale developments resulted. Ireland was the second country to utilize peat as a fuel and they began to use fuel peat over 30 years ago. The recent energy crisis has forced several other countries to take a new look at peat resources for fuel. In 1971, Finland began fuel peat development, planning to increase their annual fuel peat production to 3 million tons by 1980 - a ten-fold increase in ten years.

Sweden has done much research on fuel peat production but discontinued it in the 1960's. They now are planning three new district heating/electricity generating power plants. Greece has plans for developing a deep peat bog for electric generation, and Canada has shown some interest in developing peat as a fuel particularly in Manitoba.

Although the present world use of fuel peat corresponds to only about 0.4 percent of that of fossil fuels, and has therefore a small overall impact on the world energy-supply situation, it is of considerable local significance in those countries where it is used. For instance, peat accounts for about 30 percent of Ireland's energy supply, for about 17 percent of the energy supply to the Leningrad district in the U.S.S.R., and about 2 percent of the total energy supply in the Soviet Union as a whole. Large power plants, generating electricity in the condensation mode of operation, presently consume more than 70 percent of the fuel peat produced in the world. The remainder is consumed by back-pressure power/heating plants and by domestic fuel production. A summary of world fuel peat is presented in Table 1.

Table 1. World Fuel Peat Use.

	(10^6 TONS)			
COUNTRY	1950	1960	1975	1980
U.S.S.R.	45.0	53.6	70.0	80.0
IRELAND	0.3	1.5	3.5	5.2
FINLAND	0.3	0.2	0.5	3.0
SWEDEN	0.1	0.1	---	---
OTHERS	1.0	0.5	---	---
TOTAL	46.7	55.9	74.0	88.2

Source: Suoninen, A. 1975.

As shown vividly in Table 1, the Soviet Union's fuel peat production dwarfs totals for the other countries, being over 90 percent of the total world production from 1950 to the present.

In addition to other reasons, which will be discussed later, one of the reasons for the Soviet Union's large use of peat can be seen by examination of the world peat reserves shown in Table 2.

If projections for 1980 are correct, the use of peat in the world for fuel will have almost doubled in the 30 years since 1950.

C. New Developments in Use of Peat as an Energy Source in Europe

1. IRELAND

   2 - 4 new electric generating plants using milled peat under construction. These plants are located in the central and western parts of the country one to two hundred miles from the main population centers.

2. SWEDEN

   The National Swedish Board for Energy Source Development was established in July 1975 for the purpose of research and development of alternate energy sources including peat. They plan to utilize about 5 million metric tons of peat per year by the year 2000 principally for electric generation. Appendix E includes a discussion of the Swedish Energy Board's proposal for the use of peat as an alternate energy source. It is interesting to note that a portion of their proposal closely parallels the Minnesota Energy Agency's alternative energy program in that wood products, plant biomass, wind, solar, peat and combustion technology are included.

3. FINLAND

   3 - 5 new district heat/electricity plants planned.

   30,000 tons/year peat coke plants. (Peat coke is used in the metallurgical industry.)

   Survey underway to locate high quality fuel peat deposits that are thick and readily accessible.

4. WEST GERMANY

   Several peat coke plants planned in N.W. Germany.

   Plan a symposium in 1979 concerned with technology of peat combustion and new mining methods.

   Have a new activated carbon plant using peat, for purification of foods and water treatment.

5. GREECE

   Plan a district heat and electricity plant on a deep (35 to 40 ft.) bog.

6. SOVIET UNION

   Peat powered electric generating plants to be increased soon from present 4000 MW_e (roughly the capacity of the present N.S.P. system) to a capacity of 6300 MW_e.

II. PEAT RESOURCES

A. World Peat Resources.

B. U.S. Peat Resources.

C. Minnesota Peat Resources.

D. Reserves and Potential Energy.

E. Classification and Properties of Peat.

II. PEAT RESOURCES

Estimates of the total extent of peatlands in the world and the quantities of reserves available are not accurate because of incomplete inventories by the various countries. However, estimates have been made in selected geographical areas from published information and are included in this report.

A. World Peat Resources

Data on world peat resources, although incomplete, has been compiled from several published sources and is shown in Table 2. From available data it is estimated that peatlands occupy 408.8 million acres of land in the world. The Soviet Union alone has about 228 million acres which is about 56% of the total world peat resource. Also the data shows that the Soviet Union annually produces some 205 million tons which constitutes over 95% of the world's annual production.

The latest published figures on the total acres of peatland in the U.S. give 52.6 million acres which ranks it second to Russia in extent of peat resources. Finland ranks third in total extent of peatlands and Canada ranks fourth. Data on total peat resources in Canada are very incomplete and probably would be much higher if more accurate inventories were made. Canada probably ranks second to Russia in total peat resources. Although the U.S. ranks second in world peat resources its present production is only 600,000 tons per year or 0.3 percent of total world production.

Only Russia, Ireland and Finland presently use large quantities of peat for fuel and most of this is being used for generation of electric power.

In Great Britain, Sweden, Germany, U.S. and Canada most of the peat produced is used for horticultural purposes. In the Netherlands and West Germany peat is used to produce activated carbon and coke and in Scotland for distilling Scotch Whiskey.

Table 2. World Peat Resources and Annual Production*

Country	Acres (millions)	Annual Production*** (%)	Annual Production*** (million tons)
U.S.S.R.	228.0	95.70	205.0
U.S.A.**	52.6	0.30	0.6
Finland	35.6	0.36	0.7
Canada (Excluding Arctic)	34.0	0.25	0.5
E-W Germany	13.1	1.00	2.0
Great Britain and Ireland	13.1	2.00	4.2
Sweden	12.7	0.15	0.3
Poland	8.6	--	--
Indonesia	3.3	--	--
Norway	2.6	--	--
All others	5.2	0.4	1.2
TOTALS	408.8	100.0	214.5

* Source: Proc. of Second Int. Peat Congress, 1963.
** C.N.I. Data Soil Conservation Service, 1967. Includes Alaska.
*** Suoninen, A. Proc. of I.P.S. Symposium, Kuopio, Finland, 1975.

These data represent the most recent data reported from the various countries.

B. U.S. Peat Resources

Earlier published estimates of U.S. peat resources by the U.S. Bureau of Mines and the Geological Survey were very inaccurate and were only partially complete. Those estimates indicated the U.S. had 18.7 million acres of peatlands exclusive of Alaska with a total reserve of 13.8 billion tons (air dried). Those reports showed that 90% of total peat reserves in the U.S. were in Minnesota, Wisconsin, Michigan and Florida. Minnesota was reported to have about 5 million acres and about 6.8 billion tons which is almost half the total U.S. supply. Such figures have been widely quoted in subsequent peat resource reports by federal and state agencies.

A more accurate inventory of U.S. peat resources is now available and has been published by the U.S. Soil Conservation Service, Dept. of Agriculture's Conservation Needs Inventory of 1967 which includes data for Alaska. Table 3 shows acreage of peat in the 28 states with the largest acreage and gives figures for total acreage of peat in all 50 states.

Total acreage of peat in the U.S. compiled from this 1967 inventory is 52.6 million acres. Alaska has 27 million acres outside of the arctic perma-frost areas which is more than any other state. Minnesota with 7.2 million acres has the largest acreage of any of the states in the "lower 48".

Table 3. U.S. peat resources.*

Midwest Region	
Minnesota	7,200,000 acres
Michigan	4,530,000
Wisconsin	2,830,000
Indiana	375,000
Iowa	118,000
Illinois	104,000
All others	6,000
TOTAL	15,163,000

South Region	
Florida	3,000,000 acres
Louisiana	1,800,000
North Carolina	1,200,000
Georgia	430,000
Alabama	115,000
South Carolina	75,000
Mississippi	75,000
Texas	10,000
TOTAL	6,700,000

Northeast Region	
Maine	772,000 acres
New York	648,000
Massachusetts	347,000
Virginia	312,000
New Hampshire	151,000
Ohio	122,000
New Jersey	113,000
Connecticut	100,000
All others	173,000
TOTAL	2,738,000

West Region	
Alaska**	27,000,000 acres
Hawaii	486,000
Washington	200,000
California	166,000
Montana	110,000
Oregon	67,000
All others	36,000
TOTAL	28,065,000

Total acreage peat in U.S. -- 52,666,000 acres

* Data compiled from conservation needs inventory of Soil Conservation Service, U.S. Department of Agriculture

** Alaska data excludes peat areas in Arctic where permafrost occurs.

Excluding Alaska the midwest region of the U.S. has the most extensive acreage of peat, some 15.2 million acres. The three northern lake states of Minnesota, Michigan, and Wisconsin together have over 14 million acres. Hawaii was reported to have nearly 0.5 million acres.

The potential energy available in the reserves of selected geographical areas of the U.S. is shown in Table 6.

C. Minnesota Peat Resources

Recent estimates indicate that the total acreage of peat in Minnesota is 7.2 million acres. The average depth of peat is approximately 7 feet although many of the deposits vary in thickness from 10 to 20 feet or more. The most extensive peatland areas occur in the northern and central areas of the state principally in the large glacial lake basins. Counties with large reserves include Aitkin, St. Louis, Koochiching, Beltrami, Itasca and the Marshall-Roseau county area in the Red River Valley region.

Table 4. Inventory of Minnesota peat resources.

Total Acres Peat		7,200,000
Percent of Total State Area		15.6%
Percent of Peat-Deep (5'plus)		75.8%
Percent of Peat-Shallow		24.2%
Present Utilization		
	Percent	Acres
Cropland	2.7	192,000
Pasture-Forage	10.7	759,000
Forest	60.4	4,321,000
Open (Sedge-Grass)	26.2	1,863,000

Source: Conservation Needs Inventory, SCS, 1967.

At the present time only 2.7% of the total peatlands are utilized for crop production -- Table 4. Research is currently ongoing to determine to what extent this figure can be increased. Over 60% of Minnesota peatlands are forested and 26% are open (treeless) areas with a cover mainly of sedges and grasses. Table 4 shows that 15.6% of the total state area is peatland.

Figure 1 is a peat resource map of Minnesota showing the location and distribution within the state. The most extensive area of contiguous peatland occurs north of the Red Lakes in Lake of the Woods, Beltrami, and Koochiching counties. Other large peatlands are located in the glacial lake plains of St. Louis, Itasca and Aitkin counties.

Smaller areas of peat occur in the Twin City area and in southern Minnesota. Many of these peatlands are used mainly for production of vegetables and turf grasses.

Table 5 shows the acreage of peat in the ten counties in northern Minnesota with the most extensive areas. Koochiching, St. Louis and Beltrami counties have the most extensive peatlands. The ten counties listed in Table 5 contain about 67% of the total state's peatlands. It is of interest to note that this is an area of the state that has a very high potential energy demand. The area has several large paper mills, taconite plants, and district heating plants. In view of the expanding taconite production and Minnesota Power and Light's electric power generation increased needs, it is an area fortunate to have such extensive peatlands nearby as an alternate energy source More details of this potential are given later in this report.

Table 5 shows the present utilization of the peat to be principally in native forests. Very little agricultural development has taken place on the

Fig. 1 **PEAT RESOURCES OF MINNESOTA**

GENERAL DISTRIBUTION MAP*

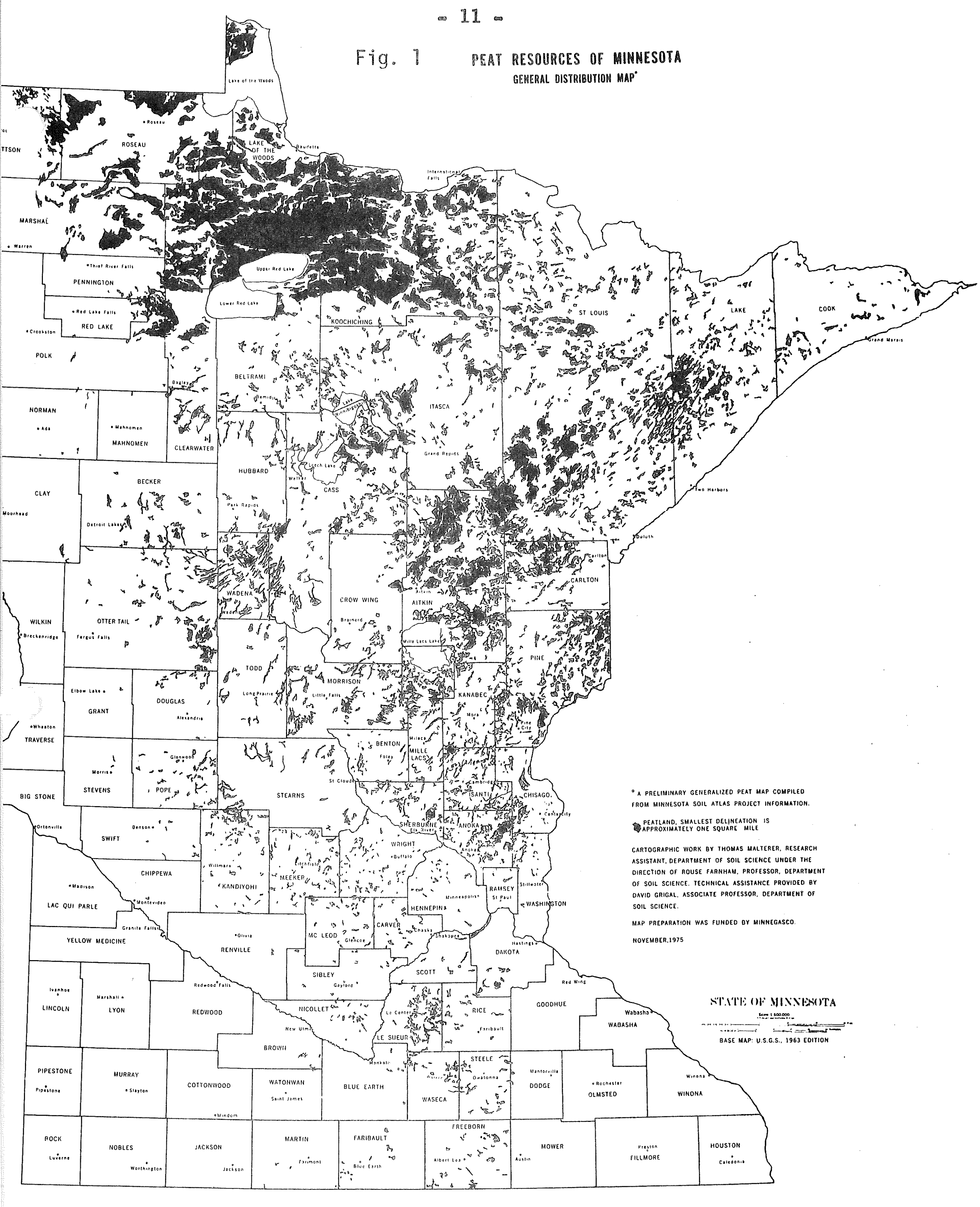

Table 5. Peat Resources and Present Use in Minnesota Counties With Most Extensive Acreage.

			% Peatlands		Peat Depth		Present Utilization			
Rank*	County	Peat Area (acres)	County	State	5' Plus	Less than 5'	Cropland	Pasture-Forage	Open	Forest
1	Koochiching	1,154,900	60.0	16.1	90.1	9.9	0.0	0.3	0.0	99.7
2	St. Louis	810,000	26.6	11.3	67.9	32.1	0.0	0.2	15.6	84.2
3	Beltrami	786,000	51.9	11.0	84.8	15.2	0.0	3.0	20.4	76.6
4	Lake-of-Woods	483,000	58.8	6.7	84.0	16.0	2.5	1.2	59.8	36.5
5	Aitkin	394,000	34.9	5.5	58.4	41.6	0.0	2.9	47.3	49.8
6	Itasca	357,000	26.4	5.0	60.5	39.5	0.0	1.0	0.7	98.3
7	Roseau	245,000	23.4	3.4	79.0	21.0	2.3	1.1	43.9	52.7
8	Cass	200,000	20.1	2.8	78.7	21.3	0.0	4.8	64.3	30.9
9	Ottertail	192,000	15.9	2.7	95.2	4.8	0.9	28.4	52.4	18.3
10	Pine	174,000	20.0	2.4	80.8	19.2	0.5	12.7	26.8	60.0
	Totals	4,795,900		67.0						

* Counties ranked in decreasing order of peat extent.

Source: Conservation Needs Inventory, Soil Conservation Service, U.S.D.A. (1967)

Table 6. Estimated Reserves of Peat and Potential Energy in Selected Geographical Areas*

Geographic Area	Estimated Reserves: Acres (millions)	Estimated Reserves: Quantity (billion tons)	Potential Energy: Quads** (Assuming a uniform depth of 7 feet)
World	408.8	915.7	11,000
Russia	228.0	510.7	6,000
U.S. (including Alaska)	52.6	117.8	1,410
U.S. (minus Alaska)	25.6	57.3	690
Midwest Region U.S.	15.2	34.0	409
Southern Region U.S.	6.7	15.0	180
Northeast Region U.S.	2.7	6.0	72
Western Region U.S.	1.0	2.2	26.9
Minnesota	7.2	16.1	193
Michigan	4.5	10.1	121
Florida	3.0	6.7	80
Wisconsin	2.8	6.3	75
Louisiana	1.8	4.0	48
North Carolina	1.2	2.7	32
Maine	0.77	1.7	20.7
New York	0.65	1.4	17.4
Hawaii	0.48	0.9	12.9
Koochiching Co. Minn.	1.15	2.6	30.9
St. Louis Co. Minn.	0.81	1.8	21.4
Beltrami Co. Minn.	0.78	1.7	20.9

* Estimates from published survey data of known peat resources. Basis of reserves and potential energy: peat contains 35% moisture, bulk density equals 15 lbs/cu ft, caloric value equals 6,000 B.T.U./lb. Assuming 2% ditch losses, one acre of peat 7' deep equals 2240 tons or 26.9×10^9 B.T.U. of energy.

**1 Quad = 10^{15} B.T.U.

Compiled by the Soil Science Department, University of Minnesota.

peatlands of Northern Minnesota. Thus these peatlands are available for large-scale gasification as well as for possible direct burning to produce electricity and for district heating purposes.

Table 6 shows total acres in selected counties in several Minnesota regions as well as present utilization. Use of peatlands in Northern Minnesota is principally for forest production with very little agricultural development. In the Northwest region there is considerably more use of peatlands for crops, pasture and forage production.

The East central and southern regions of Minnesota use the highest percentage of their peatlands for crop production. Crops such as potatoes, carrots, onions, radishes and turf grass are grown.

D. Reserves and Potential Energy

The importance of peat reserves in selected geographic areas of the world as a significant energy source has not been fully evaluated. Table 6 shows the estimated reserves of peat in the world, in several countries including U.S. totals as well as regions, states and some Minnesota counties with extensive resources and gives the potential energy available. These data were compiled from recent estimates in the literature.

The total estimated reserves of peat in the world shown in this table are 408.8 million acres containing over 915 billion tons with a potential total energy source of 1.1×10^{19} B.T.U. or 11000 quads. Russia has about 56% of the world's peat resources and the U.S. including Alaska about 14%. The total potential energy from peat in the midwest U.S. is about 409 quads, Minnesota has an estimated 7.2 million acres containing some 16.1 billion tons (at 35% moisture) with a caloric value of 6000 B.T.U. per pound. This quantity of peat has a potential energy equivalent to 195 quads. At the present rate of energy consumption in Minnesota of 1.15 quads per year, and if the total supply of peat were used, it would provide all our energy needs for over 160 years. This obviously would not be possible because of development problems and competing uses for the resource. However, if we used only 10% of Minnesota's peatlands for energy (720,000 acres) the amount of energy available would be 19.5 quads or enough energy to satisfy all our needs for 16 years.

Several counties in Minnesota such as Koochiching, St. Louis and Beltrami contain large reserves of peat (Table 7) and if only a small percent were used as an alternate energy source it would have a significant impact.

Table 7. Peatland Utilization in Selected Counties in Various Minnesota Regions.*

	Peat Acres	Present Utilization (Percent)			
		Cropland	Pasture-Forage	Open Peatlands	Forest
N. Minnesota					
Koochiching	1,154,900	0.0	0.3	0.0	99.7
St. Louis	810,000	0.0	0.2	15.6	84.2
Aitkin	394,000	0.0	2.9	47.3	49.8
Carlton	143,000	0.0	4.6	8.8	86.6
W. and N.W. Minnesota					
Roseau	245,000	2.3	1.1	43.9	52.7
Marshall	234,360	-	-	-	-
Ottertail	192,000	0.9	28.4	52.4	18.3
Becker	113,500	0.7	13.5	59.8	26.0
E. Central					
Anoka	73,000	3.6	6.5	88.7	1.2
Hennepin	39,334	13.8	14.4	70.6	1.2
Sherburne	43,290	1.7	40.6	41.7	16.0
Wright	55,181	6.0	28.8	63.6	1.6
Southern					
Freeborn	48,420	68.1	14.7	16.8	0.4
Rice	16,625	33.3	37.0	29.7	0.0

* Counties where acreage shown is underlined, give data from detailed surveys.

Source: Conservation Needs Inventory, Soil Conservation Service, U.S.D.A. (1967)

This is because that area of the state is where energy demands are increasing rapidly due to taconite production and the high costs and predicted shortages of conventional fuels such as natural gas, oil and coal.

E. Classification and Properties of Peat

The classification of peat shown in Table 8 gives the principal systems used in the world at present. The systems are very similar and are based primarily on degree of decomposition of peat material and the amount of plant fiber.

Table 8. Classification of peat related to fuel value.

U.S. Class system1/	Fibric			Hemic			Sapric			
	percent									
Soviet Union system2/	10	20	30	40	50	60	70	80	90	100
	H value									
Swedish system3/	1	2	3	4	5	6	7	8	9	10
Comments	Not suitable for fuel			Best for fuel Has low ash			Good for fuel But may have high ash			

1/ Three grade system U.S.D.A. Soil Class System.
2/ Developed by INSTORF (the Soviet Peat Institute).
3/ von Post, L. and E. Granlund (1926). Peat Resources in the S. of Sweden. Suer. geol. Unders, Ser. C, No. 335. System widely used in Europe.

Correlation by the Soil Science Department, University of Minnesota (1976)

Three classes of organic material are recognized. These are fibric, hemic and sapric listed in order of increasing state of decomposition. Briefly, these peat materials have the following properties:

1. Fibric Organic Material - least decomposed type, has lowest ash content and bulk density, highest saturated water content and greatest amount of plant fiber. Three well defined subtypes include the very acid, relatively raw Sphagnum moss peat type, the less acid Hypnum moss peats and the reed-sedge type peats not suitable for fuel.

2. Hemic Organic Material - moderately decomposed type of organic material. Have medium bulk density values, saturated water contents and fiber content, and are variable in acidity. Best suited for fuel.

3. Sapric Organic Material - most decomposed type. Have high bulk density values, relatively high ash contents, lowest fiber content and saturated water values. Acidity is variable. Good for fuel if ash content is low.

The International Peat Society has over the past few years attempted to develop a world-wide peat classification system. Just recently they have adopted a system which is essentially the same as the one used in the U.S.. Poland has been using a similar system for several years for their peat surveys. This new peat classification system is being used in the present Department of Natural Resources inventory of Minnesota peatlands.

Table 9. Bulk density - water relationships of peat.

Peat type	Bulk Density (oven dry)					Saturated Water Content
	kg/m^3	lbs/ft^3	lbs/yd^3	yd^3/ton		Weight Basis
				oven dry	40% H_2O	- - - percent - - - -
Fibric	48	3.0	81	24.0	-	95.3
	80	5.0	135	15.0	-	92.2
Hemic	128	8.0	216	9.2	5.3	87.7
	159	10.0	270	7.4	4.6	84.7
	192	12.0	324	6.1	4.1	81.8
Sapric	225	14.0	378	5.3	3.2	79.1
	256	16.0	432	4.6	2.6	76.2
	320	20.0	540	3.7	2.1	70.7

Source: Soil Science Department, University of Minnesota (1975).

Table 9 shows the relationship between bulk density and water content and the number of cubic yards per ton for the various peat types. Fibric types are least decomposed and lowest in bulk density (weight/volume); the hemic types are intermediate in decomposition and in bulk density; the sapric types are highest in decomposition and also in bulk density. The latter two types are suitable for fuel. For example, a hemic type peat of 10.0 lbs per cubic foot (oven dry) will require 7.4 cubic yards per ton but at 40% water content will be only 4.6 yds/ton. The more decomposed sapric types are much denser and the ratio of volume (cubic yards) to weight (1 ton) is much less. In fact, the volume to weight ratio of highly decomposed sapric peats is about the same as coal. The heavier a given peat is relative to its volume the higher is its fuel value relative to high-grade coal and the more valuable it is as a fuel especially if it is to be transported long distances. Sapric type peats with low ash contents are therefore the most valuable for fuel uses.

The reserves of fuel peat in Minnesota are calculated on the following basis:

1 acre foot of peat = 43,560 cu. ft. or 1600 cu. yards. This equals 200 to 400 tons of peat depending on the water content. Six acre feet of peat (one acre to a depth of 6 feet) = 10,000 yards or 1350 to 2700 tons at bulk densities of 10 to 20 lbs/cu. ft.

1000 acres = 1,350,000 to 2,700,000 tons.

1,000,000 acres = 1.35 billion to 2.7 billion tons.

3,000,000 acres = 4 billion to 8 billion tons.

III. PEAT AS AN ENERGY SOURCE -- TECHNOLOGY

A. Fuel Value of Peat and Coals.

B. Use of Peat as a Fuel.

C. Methods of Obtaining Energy from Peat

1. Direct burning.

2. Peat briquettes.

D. Conversion Technology.

E. Future Potential Sources of Hydrocarbons.

F. Peat for Low BTU Gas - A Case Study.

III. PEAT AS AN ENERGY SOURCE -- TECHNOLOGY

A recent study in 1975 gives data on energy values of various Minnesota peats and evaluates the potential of peat as an alternate energy source. The formation of peat in wetland environments constitutes an energy- capturing natural ecosystem as well as a nutrient sink. Bog plants through the process of photosynthesis function to capture the sun's energy and store it through accumulation and preservation of biomass as peat.

The relatively high caloric values of peat have led to their use in several countries in Europe where conventional fuels are in short supply. Suoninen in 1975 gave figures for peat fuel production in Europe. Russia by far leads all countries in production of peat for fuel but in Finland and Ireland use of peat for electric and steam generation provides a significant and economical alternative to expensive imported coal, oil and natural gas. The energy situation in these latter two countries is much like ours in Minnesota. i.e. a lack of conventional fuels coupled with an abundance of peat.

Energy values of specific Minnesota peat types are shown in Table 10.

Table 10. Energy values of specific Minnesota peat types.

Peat type	Location	Energy Value B.T.U./lb.
Hemic	St. Louis Co.	8900
Hemic	Roseau Co.	9700
Sapric	St. Louis Co.	8300
Fibric (Sphagnum Moss)	St. Louis Co.	7900
Sphagnum Moss (Green)	St. Louis Co.	6800

Source: Soil Science Department, University of Minnesota.

These data show that the hemic or partly decomposed peat types have the highest energy values. Sapric types are relatively high but they are higher in ash content than hemic types. The fibric Sphagnum Moss type, which is very valuable as a commercial horticulture peat, has the lowest energy value of all peat types and thus should not be used for fuel production.

The best types as fuel sources are those peats with a moderate to high degree of decomposition, low ash content (Hemic type of Table 10) and a bulk density of 10 to 20 pounds per cubic foot (dry basis)--Table 9. There are an estimated 3 million acres of these types of peats in Minnesota that average over 60 feet in thickness. Mostly they occur in the northern and central counties in the large, glacial lake plains. Many of the bogs often exceed 20,000 acres in size and the peat types are remarkably uniform as to type and quality over extensive areas. Several of these large bogs are located very near the Iron Range areas of St. Louis and Itasca counties where the demand for energy is increasing because of the recent expansion in taconite production facilities.

A. Fuel Value of Peat and Coals

The total energy content in the world's peat reserves is not an insignificant amount. Assuming a total world supply of the order of 915 billion tons, and an oven-dried caloric value of about half that of oil (about 10,000 BTU per pound), the hydrocarbon equivalent may be calculated at around 455 billion tons of oil. This is about 80 percent greater than the total known oil reserves today. An appreciation of the caloric value of peat can be seen by referring to Table 11, in which the caloric value of peat is compared with that of other common fuels.

Table 11. Comparative Heating Value of Peat and Other Fuels.

Type of Fuel	Moisture Content	B.T.U. lb.
Wood	As Received (Variable)	5,760
Cut Peat	Air Dried (40%)	6,840
Machine Peat	Air Dried (30%)	7,290
Lignite	As Received (40%)	6,500
Lignite	Air Dried (20%)	7,500
Bituminous Coal	As Received	14,000
Anthracite Coal	As Received	13,000

Source: The Occurrences and Uses of Peat, in the U.S. Bull. 728, Dept. of Int., 1922.

An important point to be noted is that the caloric value of peat is about the same as that of lignite, of the order of 7,000 BTU per pound, or about half the heating value of the higher ranked coals. The importance of fuel peat as an energy reserve in the United States should also not be underestimated. For instance, the recoverable energy reserves of fuel peat amount to about 690 Quads (690 x 10^{15} BTU's) which compares quite favorably with anthracite coal with a reserve of about 100 Quads, crude oil with a reserve of 200 Quads, and natural gas with a reserve of about 300 Quads.

The latest figures on fossil fuel resources are shown in Table 12.

Table 12. U.S. Fossil Fuel Resources - 1975*

Resource	Proved and Currently Recoverable (10^{15} B.T.U., or Quads)
Natural Gas	300
Crude Oil	200
Coal	4800
Shale Oil	400
Peat**	690

*Source: Linden, H. L. Perspectives on U.S. and World Energy Problems, Inst. Gas Technology (1976), August.

** Data on Peat: Calculated from Conservation Needs Inventory, Soil Conservation Service, 1967. Excludes Alaska. Assumes total is recoverable.

Table 13 shows the elemental composition and energy values for each stage of coal formation. Peat is lower in carbon and higher in oxygen and coals. Lignite and peat are similar in composition and caloric value.

Table 13. Elemental Composition and Energy Values for Each Stage of Coal Formation.*

	Percent by Weight			Caloric Value
	C	H	O	(B.T.U./lb-dry)
Wood	50.0	6.2	42.7	7000
Sedges, Grasses	--	-	--	7500
Peat	57.0	5.1	36.8	9500
Lignite	65.0	4.0	30.0	9500
Low Bituminous	79.0	5.4	14.0	10300
High Bituminous	91.7	4.5	2.2	13000
Anthracite	95.0	2.1	1.9	14000

*Source: Linden, H. L. Perspectives on U.S. and World Energy Problems, Institute of Gas Technology (August, 1976).

The effect of the water content of peat on its value as a fuel is the single most important deterrent to its use. In its natural state peat contains from 70 to 95 percent water (Table 9) and the technology of harvesting and processing peat is chiefly concerned with reducing this water content to at least 50 percent and preferably to 15 to 20 percent by air drying methods in the field or by artificial drying methods.

The magnitude of the problem can best be understood by referring to the relation between dry solids content and water content as peat is reduced from 90 percent water content (undrained bog) to an oven dried state (0 percent water). The data shows that in drying from 90 to 80 percent (this is the normal reduction on drainage) there is a 55 percent reduction in the weight of water. Air drying on the bog to 50 percent water content reduces the weight of water per ton of wet peat from 1800 pounds to 200 pounds of oven dried peat. This is important to know as natural air drying on the bog is the most economical way to lower the water content. The heating value of peat with any water content up to 50 percent (this is maximum for fuel) may be determined by deducting for each percent water one percent from the heating value determined on oven dried peat. For example, if the heating value of an oven dried peat is 9000 BTU per pound it will be 40 percent less for 40 percent water content peat or a value of 5400 BTU per pound. Obviously it is an advantage for the producer to reduce the water content of peat as much as is economically practicable.

Table 14 shows the fuel value of a typical N.W. Minnesota peat to a depth of 5 feet. The ash content of this reed-sedge peat is very low and its fuel value is very high. Many peatland areas containing uniform peat deposits such as this occur in northern Minnesota.

Table 14. Analyses and Fuel Value of Typical Peat Profile (to 5 feet) in a Sedge-Grass Peatland - N.W. Minnesota (Roseau County)*

Depth (inches)	pH	Ash Content (%)	Organic Content (%)	Fuel Value (oven dry) cal/gm	Fuel Value (oven dry) B.T.U. /lb
0-12	6.3	8 - 10	90 - 92	5140	9252
12-24	6.2	6.0	94.0	5220	9396
24-36	6.2	5.3	94.7	5405	9730
36-48	6.8	5.7	94.3	5450	9810
48-60	7.0	6.1	93.9	4750	8514

*Source: Soil Science Department, University of Minnesota, 1976.

B. Use of Peat as a Fuel

The use of peat as a fuel may be listed as follows:

1. Direct Burning
   a. Electricity Generation
   b. Steam Heating

2. Gasification
    a. Low B.T.U. - Taconite Drying or as a source of heat for drying
    b. High B.T.U. - Pipeline Quality Gas (S.N.G.)
3. Wet Combustion - Zimpro Process (Steam)
4. Briquettes (Home Heating)
5. In Combination with Other Fuels for Conversion Processes
    a. Biomass: Wood, Cattails, Sedges, Grasses and Peat Mixtures
    b. Lignite or Coal admixtures for Conversion to Gas

Peat can be used directly when dried for the production of electricity and for district heating to produce steam. It also can be converted to gas in either low or high B.T.U. forms for industrial or home use. A wet combustion process utilizing peat is being studied by the Zimpro Company of Rothschild, Wisconsin to produce steam. If perfected this system would not require drying of the peat. Briquettes are presently being produced in Russia and Ireland for domestic use for home and factory heating. Peat also could be used either in combination with biomass such as grasses, sedges, cattails, etc. or it could be mixed with conventional coals and lignites for gas production, by a thermo-chemical conversion process.

Table 15 shows the quantity of peat available in Minnesota peatland areas varying both in size and thickness. Calculating a 7 foot average thickness for peat and assuming the entire 7 million acres to be used for fuel, Minnesota has a supply of peat that would satisfy our energy demands for over 160 years based on the present annual energy use of 1.15 Quads.

Table 15. Nomogram Showing the Quantity of Peat and Energy Available in Peatland Areas Varying in Size and Thickness*

	five feet			ten feet		
Size (Acres)	Volume (cu.yds.)	Weight (tons)	Potential Energy (B.T.U.)	Volume (cu.yds.)	Weight (tons)	Potential Energy (B.T.U.)
1	8.07×10^3	1.63×10^3	1.96×10^{10}	1.61×10^4	3.27×10^3	3.92×10^{10}
10^2	8.07×10^5	1.63×10^5	1.96×10^{12}	1.61×10^6	3.27×10^5	3.92×10^{12}
10^3	8.07×10^6	1.63×10^6	1.96×10^{13}	1.61×10^7	3.27×10^6	3.92×10^{13}
10^4	8.07×10^7	1.63×10^7	1.96×10^{14}	1.61×10^8	3.27×10^7	3.92×10^{14}
10^5	8.07×10^8	1.63×10^8	1.96×10^{15}	1.61×10^9	3.27×10^8	3.92×10^{15}
10^6	8.07×10^9	1.63×10^9	1.96×10^{16}	1.61×10^{10}	3.27×10^9	3.92×10^{16}
7×10^6	5.65×10^{10}	1.13×10^{10}	1.37×10^{17}	1.13×10^{11}	2.26×10^{10}	2.74×10^{17}

* Calculations based on data from the Soil Science Department, University of Minnesota: an average of 15 lbs/cu.ft. for 35% moisture peat, 1613 cu. yds/acre foot and 6000 B.T.U./lb (35% H_2O peat). NOTE: Minnesota's Annual Energy Use = 1.15×10^{15} B.T.U.

The data in this table shows that even relatively small peatland areas of 1000 to 10,000 acres contain significant amounts of energy.

Table 16 shows the amount of peat required in tons and the acres needed for potential selected energy demands. For example, the municipal heating plant at Virginia, Minnesota would use annually 120,000 tons of peat and require an 80 acre peatland if only 5 feet thick and only 40 if 10 feet thick.

A taconite plant producing 5 million tons of pellets per year would use 5.0 million tons of peat in 20 years for drying the pellets. This would require a total of 3000 acres of peat 5 feet thick but only 1500 acres if ten feet thick.

The proposal by Minnegasco to build a large-scale gasification plant in northwestern Minnesota would require from 60 to 120 thousand acres of peatlands for 20 years of operation.

It is obvious from these data that these proposed operations will require only a fraction of the total peat resources available in the state. One proposal worth considering is that maybe we should consider using no more energy than is produced by natural means. This means that we might limit our annual consumption of peat as an energy source to that amount produced annually by nature, i.e. approximately 10 million tons. This would require mining only 3000 acres of peat to a depth of 10 feet each year. Another 10 million tons of biomass could be produced from energy farms on 0.5 to 1 million acres of peatlands. The 20 million tons of combustible organics (peat and biomass) would provide 3.0×10^{14} B.T.U. of energy per year which is equal to one fourth of Minnesota's present annual energy consumption and three fourths of our yearly natural gas consumption. This is not an insignificant contribution and is an idea worthy of further study. It would certainly constitute an interim or short term solution to the State's present critical energy situation and would make possible the utilization of our large peat reserves for other purposes such as food and fiber production, preservation of natural areas and wildlife. It is possible that in the long run these peatlands will become more valuable for production of animal feed, especially high protein sedges and grasses. Also the potential of peat as a source of raw chemical feedstock is a viable alternative.

Table 16. Peat Required for Potential Selected Energy Demands.*

Location and Type of Plant	1 year supply: Tons Needed	1 year supply: 5' Depth (acres)	1 year supply: 10' Depth (acres)	20 year supply: 10^6 Tons Needed	20 year supply: 5' Depth (acres)	20 year supply: 10' Depth (acres)
1. Municipal Heating Plant Virginia, MN-steam heat	120,000	80	40	2.4	1,600	800
2. Paper Mill Potlach, Cloquet (Drying Paper)	160,000	100	50	3.2	2,000	1,000
3. Taconite Plant Iron Range 5 million tons capacity Low B.T.U. Gas for drying pellets	250,000	150	75	5.0	3,000	1,500
4. Electric Generation Iron Range area (Direct Burning)						
100 MW cap.	200,000	120	60	4.0	2,400	1,200
500 MW cap.	1×10^6	600	300	20.0	12,000	6,000
1000 MW cap.	5×10^6	3,000	1,500	100.0	60,000	30,000
5. Gasification N.W. Minnesota-Red Lake Area Synthetic Natural Gas High B.T.U. Gas	12×10^6	6,000	3,000	240.0	120,000	60,000

* Source: Soil Science Dept., University of Minnesota (1976).

C. Methods of Obtaining Energy from Peat

1. Direct Burning: The lack of native deposits of coal, wood, or oil made the use of peat as a fuel an attractive source for some European countries. Ireland, in particular has long depended on the direct burning of peat to produce heat and electricity. Heat is the primary product of burning peat briquettes which will be discussed in more detail later. Electricity is the product of large scale burning of peat, particularly milled peat, in steam boilers. The milled peat is burned in much the same way as pulverized brown coals. A chemical analysis comparing the two fuels shows that peat has a higher proportion of volatiles and oxygen. Of more importance is the greater fluctuating moisture contents and variations in bulk density. These two negative characteristics

of peat generally occur together and mean that oil-ignition burners must be used in the process. The typical compositions of the milled peat fuel used and the net caloric value are:

Ash Content	1 - 5 %
Moisture Content	40 - 65 %
Net Caloric Value	6000 B.T.U./lb.
Bulk Weight	15 - 30 lb/cu.ft.

Plant sizes are dictated by the economics of utilizing peat versus coal or oil fuels. If the plant is kept small to match the supply capacity of a given bog, then the peat can compete with the coal and oil. Plant sizes range on the order of 20 - 40 MW, which corresponds to an operational life of 20-25 years.

2. Peat Briquettes: Traditional production of heat from peat has been from the burning of briquettes. This practice is widely used in the USSR, Ireland, and other European countries. The peat briquette is a very convenient type of fuel as compared to coal or wood for home heating. Some of its advantages are: a constant thermal property allows the briquettes to be fed into the furnace in accordance with demand; the absence of dust and a negligible amount of fines is an advantage over coal; its thermal density is 2.5 - 3.5 times as efficient as firewood. The thermal equivalent of one ton of peat briquettes is approximately 0.6 tons of conventional fuel, so its use is dictated by the scarcity of other sources of economics.

The process by which the briquettes are produced is outlined below.

1. Blending - Mixing higher quality peats with poor quality to produce a more uniforn mixture.
2. Screening - Reduces the particle size, thereby increasing surface area for drying.
3. Drying - Low pressure steam coupled with fans or pneumatic gas driers reduce the moisture content from an initial 50% (milled peat) to ensure a product with 9 - 12% moisture.
4. Presses - Reciprocating presses compress the peat into bars (3" x 7") with bulk density of 14 lb/cu.ft. - 21 lb/cu.ft.

Plant sizes in the USSR, which is the largest producer of peat briquettes, range from 30,000 - 200,000 tons per annum. Annual production in 1963 was 2,100,000 tons with an expected output of 20,000,000 tons in the early 70's.

What this means in the total energy picture for the USSR is illustrated by the calculations below:

Heating Value

20,000,000 tons x 2000 lbs/ton x 7600 BTU/lb = 3.04×10^{14} BTU

Annual Energy Consumption USSR

Per Capita Consumption = 130,000,000 BTU

Population = 250,000,000

Annual Consumption: $1.3 \times 10^{8} \times 2.5 \times 10^{8} = 3.25 \times 10^{16}$ BTU

Percentage of Total USSR Energy Used for Heating

Assuming same percentage as U.S.: 11% or $32.5 \times 10^{16} \times 0.11 = 3.58 \times 10^{15}$ BTU

Impact on Heating

Percentage = .304/3.58 x 100 = 8.5%

That is: 8.5% of the energy required for heating could be supplied by the peat briquettes.

D. Conversion Technology

Carbonization: Coking or carbonization of peat to produce an energy source will not have a great impact on the total energy picture. Nevertheless, its impact on the chemical and metallurgical industries in some countries is sufficient to warrant additional discussion. In Norway, for instance, the scarcity of coal requires the use of peat for the production of coke used as a reducing agent by the metallurgical industries.

The carbonization process used to obtain the char, charcoal, or coke is essentially a process of submitting the peat to high temperature (700-14000°F) and pressure (350 psi).

Additional by-products can be obtained from this process as shown by Table 17.

Table 17. Carbonization Analysis of One Ton of Florida Saw Grass Peat.*

Ash Content	21%	
Heat Content	10,000 BTU/lb.	Recoverable: 6280 BTU/lb.
Coke	800 lb.	Efficiency: 63%
Gas (320 BTU/c.f.)	14,800 c.f.	
Tar	48 lb	
Ammonia	42 lb	

* Source: Davis, J. H., The Peat Deposits of Florida (1946).

The quantity of ammonia and gas obtained is much greater than that from coal, but coal yields more coke and tar. Therefore, large scale production of coke from peat could prove more economical than production from coal, because of the revenues received from the by-products.

Gasification: The effect of the moisture content on the heating value of peat is illustrated by the Table 18 below. Conventional methods to obtain energy from peat must contend with this negative characteristic.

Table 18. Effect of Moisture Content on Heating Value of Peat

% Dry Peat	% Water	BTU/lb
5	95	460
10	90	920
15	85	1400
45	55	4130
65	35	6000
90	10	8250
100	0	9170

With gasification, the presence of water for processing purposes is a positive characteristic. In fact, one of the limitations upon gasification of the Western coal deposits is the lack of water for large scale operations.

Gasification to produce a natural gas substitute involves the reactions of steam, hydrogen, carbon monoxide, carbon dioxide, and methane in contact with the solid carbon in peat. Chemical equations describing the reactions are given below:

1. Carbon (in peat) + water (as steam) = carbon monoxide + hydrogen
   $$C + H_2O \rightarrow CO + H_2$$
2. Carbon monoxide + water (as steam) = carbon dioxide + hydrogen
   $$CO + H_2O \rightarrow CO_2 + H_2$$
3. Carbon (in peat) + hydrogen = methane
   $$C + 2H_2 \rightarrow CH_4$$

Overall process
$$2C + 2H_2O \rightarrow CO_2 + CH_4$$

All gasification processes require the addition of heat in some form to meet the thermal needs of the steam carbon reaction. The heating value desired in the output gas determines the form in which this heat is added. If a high heat content (1000 BTU/cubic foot) gas is desired then the heat is produced by oxygen and steam. This gas can be used for chemical synthesis, i.e., ammonia, methanol, or as a substitute for natural gas. It is also possible to produce a gas having a lower heat content (175 BTU/cubic foot). In this case the heat is added in the form of superheated steam.

Only high-BTU natural gas is presently used in the United States. Low-BTU gas can be produced at a significantly lower cost per unit of heat, but due to its lower energy content, the cost of pipeline transmission is several times higher. In addition, low-BTU gas cannot be used in equipment designed for high-BTU gas without modification. If low-BTU gas could be used near the point of gasification, i.e., electrical power plants or large industrial installations, then it will likely have an economic advantage. High-BTU gas has the additional requirement of an oxygen gas plant for its gasification process, which demands a large scale operation to make it economical.

The approaches to peat gasification are still in the research stages. There are a number of processes for the gasification of coal, from which the best process for peat will undoubtedly arise. Some of these processes have reached the pilot plant stage and are described in more detail. The chemical composition of peat is very close to that of the lignite or brown coals as illustrated by the table below. The major difference affecting the gasification process is in the volatile matter content. Peat's higher content means the gasification will occur at a lower temperature.

Table 19. Composition of the Main Types of Humic Coals

	Dry Basis					
Types	% C	% H_2	% O_2	% N_2	% H_2O	Volatile Matter
Peat	45-60	3.5-6.8	20-45	.75-3	70-90	45-75
Brown Coals & Lignite	60-75	4.5-5.5	17-35	.75-2.1	30-50	45-60
Bituminous Coals	75-92	4-5.6	3-20	.75-2	1-20	11-50
Anthracites	92-95	2.9-4	2-3	.5-2	1.5-3.5	3.5-10

The approaches to making the high-BTU gas may be categorized according to the composition and mode of producing the systhesis gas as follows:

- Processes which carry out the steam carbon reaction to produce synthesis gas in one unit coupled with another unit to carry out the reaction forming methane, since the methane requires much lower temperatures for its formation. The energy required for the steam carbon reaction (reaction 1) is supplied by electricity (1/6 of the energy in the final gas product). The Hygas-Electrothermal (Institute of Gas Technology) process falls in this category.
- Processes similar to the one above, but which use oxygen to produce the heat required for the steam-carbon reaction. The Bigas (Bituminous Coal Research, Inc.) process is a promising one in this category.
- Processes which add hydrogen to the steam in order to improve methane formation. The heat from methane formation is in turn used to produce more hydrogen from the steam-carbon reaction. The U.S. Bureau of Mines

initiated this Hydrogasification process, but lags in its stage of development.

- Processes which involve the use of dolomite (limestone) to provide the heat for the steam-carbon reaction while at the same time removing CO_2 and increasing the amount of hydrogen. The CO_2-Acceptor Process (Consolidation Coal Co.) is being studied in a pilot plant operation at Rapid City, S.D.

Ranking of the various proposals on an economic scale is not possible until such time as more pilot plant data is available. Table 20 below summarizes the methane yield as a measure of performance and the devolatilizing temperatures. The lowest temperature consistent with an adequate rate is desirable.

Table 20. Relative Comparison of Gasification Processes (High BTU Gas)

Process	Yields*	Devolatilizing Temperatures
Hydrogasification	0.53	1650° F
Hygas-Electrothermal	0.40	1300 - 1500° F
Bigas	0.40	1400 - 1700° F
CO_2 Acceptor	0.34	1500° F

* Yield = Methane in final pipeline gas/carbon in solids feed stream to gasifier.

As with high-BTU gas, a number of processes exist for the production of low-BTU gas. In low-BTU gas the objective of the process is to produce a synthesis gas whose primary combustible constituents are hydrogen, carbon monoxide and to a lesser extent methane. The chemical reactions which take place are essentially the same as in the production of high-BTU gas except there is no catalytic methanation step and the gases leaving the gasifier must be cleaned to remove sulfur and other undesirable compounds.

The most advanced of the low-BTU processes is the Lurgi Gas Producer. An analysis of this process combined with a gas turbine-steam power plant is shown below.

For a 1000 Megawatt plant (70% operating factor):

INPUT: Coal Consumption = 6700 tons/day

OUTPUT: Gas Produced = 703,000,000 cu.ft./day (156-173 BTU/cu.ft.)

$$\text{Overall Efficiency} = \frac{\text{Energy in Electric Output}}{\text{Energy in Coal}} = 0.35$$

Comparison of low-BTU gas with direct use of coal for power generation on the basis of fuel costs shows:

Low-BTU Gas: 58¢/Million BTU

Coal: 20¢/Million BTU

It is possible that substitution of peat for the coal could reduce the low-BTU gas costs. However, the gasification of peat may not be economically competitive with the direct burning of coal.

E. Future Potential Sources of Hydrocarbons

Much attention has been given recently to problems of supplying our future needs of liquid and gaseous hydrocarbons for both fuel and non-fuel uses. The present fossil sources of hydrocarbons include natural gas, petroleum, coal, shale oil, tar sands, lignite and peat. Potential sources in the future include plant biomass (both land and water plants), sewage, solid waste, agricultural wastes, wood products, food processing and certain industrial wastes. The key fixation process is the natural one of biomass production by photosynthesis utilizing solar energy. Directly or indirectly plant biomass is the source of food, cellulosic materials, agricultural and urban wastes and the parent material in formation of peat.

Figure 2 shows, in simplified form, the natural carbon cycle that over the course of many millions of years has drawn CO_2 from the atmosphere, by

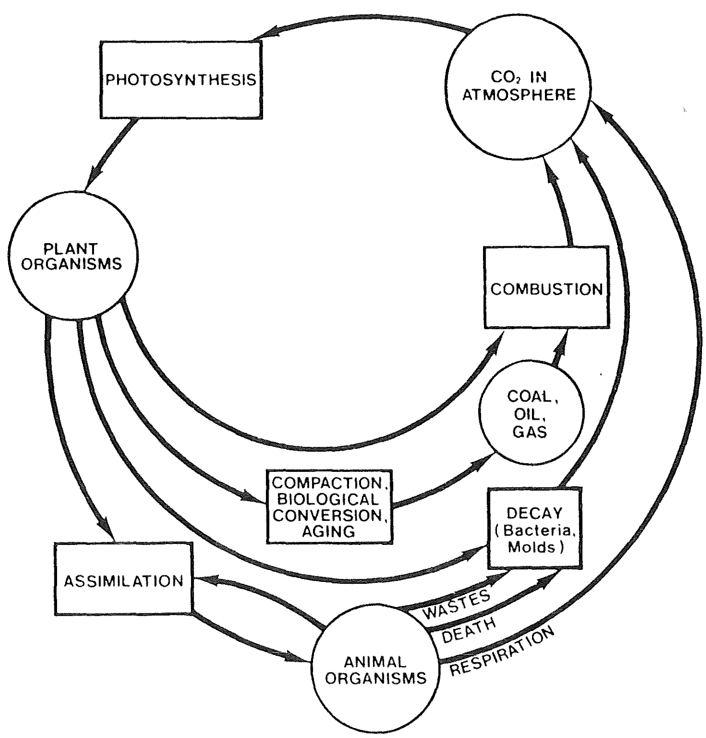

Figure 2. **CARBON CYCLE**

means of photosynthesis, to produce plant materials. These have sustained animal life, throughout its evolutionary course, and in addition, provided carbonaceous materials which, through compaction, aging, and biological conversion, have been converted to our originally extensive resources of coal, oil and gas. However, the natural processes for conversion to fossil fuels are so extremely slow that significant replenishment over short historical periods can not be contemplated.

Through combustion, or some equivalent process, these fossil fuels as well as some of the plant materials have been directly oxidized to return CO_2 to the atmosphere and generate energy for man's use. Also, the natural processes of respiration and decay of both plant and animal organic wastes restore CO_2 to the atmosphere.

It would appear that as our fossil fuel deposits approach exhaustion, a modified carbon cycle must become operative if we are to meet the substantial requirements of liquid and gaseous hydrocarbons for fuels and other uses. Such a cycle is shown in Figure 3 in which gasification of biomass is utilized to produce methane or synthesis gas.

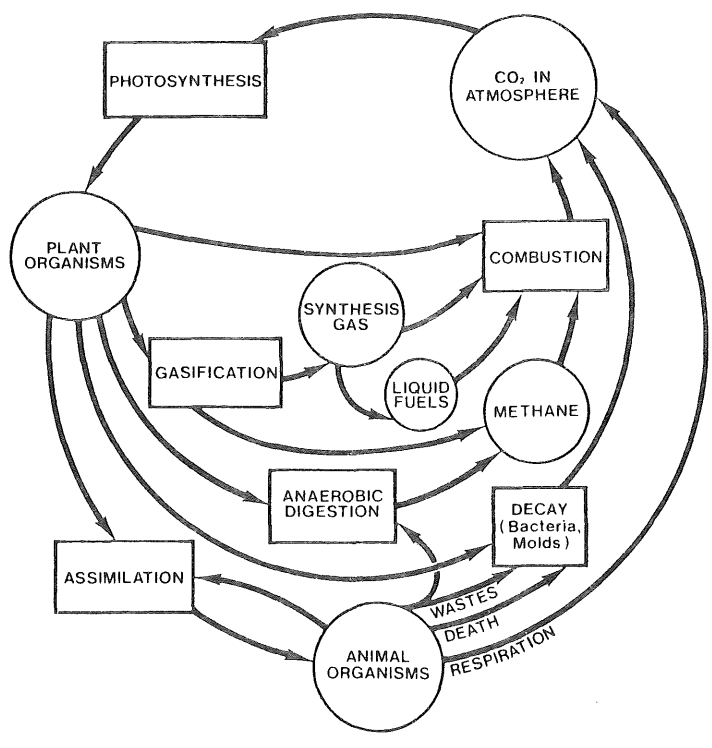

Figure 3. **MODIFIED CARBON CYCLE** 87608165C

The synthesis gas can be used directly as a low BTU gas to provide industrial energy, or as a starting material to produce hydrogen or readily storable fuels such as methanol and liquid hydrocarbons. Low BTU gas made with air rather than oxygen represents a useful fuel as well as an intermediate material for ammonia manufacture. This will likely become an important route in the future since at present most of the ammonia for fertilizer is from methane or light petroleum fractions.

Processing techniques for conversion of biomass to useful fuels and other energy products are listed in Table 21. Many of these processes are also applicable to the processing of peat and organic wastes. It has been estimated that if all of the organic wastes generated could be converted to energy it would equal 40% of the current natural gas consumption in the U.S..

Together with peat these sources constitute a significant amount of energy and represent an important extension to the life of our conventional fossil fuel resources. Also, these processing techniques require only moderate capital outlays and the plants are economical to operate and efficient from a net-energy standpoint.

Table 21. Processes for Conversion of Biomass to Fuels and Energy*

Processes	Energy Products
Combustion	Heat Steam Electricity
Pyrolysis	Char Oil Gas
Hydrogasification	Methane Ethane
Partial Oxidation	Synthesis Gas
Steam Reforming	Synthesis Gas
Chemical Conversion with Carbon Monoxide	Oil
Catalytic Gasification with Alkaline Carbonate	Methane
Anaerobic Digestion	Methane
Acid Hydrolysis	Ethanol
Enzyme Hydrolysis	Ethanol
Biophotolysis	Hydrogen

* Source: Institute of Gas Technology, Chicago, Illinois, (1976).

F. Peat for Low BTU Gas - A Case Study for the Taconite Industry in Minnesota. A Study Reflecting Mining Costs, Filtration, Pelletizing and the Low BTU Gasification Process of Peat for the Taconite Industry.)

This section of the Peat Task Force Report is a summary of a study prepared for the taconite industry in July 1974 by James D. Duncan, a consultant with Gulf Chemicals. Mr. Duncan kindly gave us permission to use it in our report to the Minnesota Energy Agency. The figures reflecting costs of mining, transporting and processing of peat for kiln heat for taconite processing are those of Mr. Duncan's. However, it is the opinion of the Peat Task Force that the costs given are realistic figures and we suggest that this use of peat as an energy source by the taconite industry for drying purposes should be seriously considered as an alternate energy option.

SUMMARY

Mr. Duncan's report outlines a complete procedure for the use of peat as an energy source for heating purposes in the taconite industry of Minnesota.

This proposal gives all the details of a process for the use of peat in the kiln drying of taconite pellets. It includes techniques for mining by dredge, transportation to plant by pump and pipeline, processing peat by filtering, extruding and pelletizing, artificial drying using waste heat and complete gasification using the Wellman-Galusha low BTU gasifier.

COMMENTS

The apparently favorable economics of Mr. Duncan's proposal are due to the continuous mining possibility not affected by season or weather, the ability to mechanically de-water peat to 70% moisture, and the artificial drying of peat with waste heat from the taconite processing industry.

Another advantage of this process is the proximity of large peatland areas containing high quality fuel peat reserves near the taconite plants of Minnesota's Iron Range (see Figure 4).

SUGGESTED IMPACT OF THIS PROPOSAL ON TACONITE INDUSTRY AND PEAT RESOURCE NEEDS FOR THIS UTILIZATION

Mr. Duncan's proposal appears to offer a particularly attractive alternative energy source for drying taconite pellets. Presently the taconite industry uses natural gas for this drying, but they will be cut off from this source in the near future (2 - 3 years). They are planning to convert to Western coal or lignite in the future so this proposal is very timely and should be given serious study and consideration. The following figures can be used as a guide to put in perspective the impacts of such a proposal:

Figure 4.

PEATLANDS NEAR TACONITE PLANTS

1. MINTAC - Mountain Iron
2. ERIE - Hoyt Lakes
3. EVELETH TACONITE - Forbes
4. BUTLER TACONITE - Nashwauk
5. NATIONAL STEEL - Hibbing

A. <u>Tons of Taconite Pellets Dried</u> (large-scale plant)

Per hour: 600 tons taconite pellets

Per day: 14,400 tons taconite pellets

Per year: 5,000,000 tons taconite pellets

B. <u>Peat Needed for Drying Taconite</u>

Per hour: 30 tons (oven dry)

Per day: 720 tons

Per year: 252,000 tons (dry) or 2 million (wet)

<u>Acreage of Peatland Needed</u>

Per Year: 44 acres - 15 feet deep (60 acres - 10 feet deep)

Per 20 years: 880 acres - 15 feet deep (1200 acres - 10 feet deep)

Only 1200 acres of peatland (10 feet deep) would be needed to supply 20 years of heat energy to dry 5 million tons taconite pellets per year at one of our Iron Range Taconite plants.

There are many high-quality fuel peat bogs located within 5 to 10 miles of the existing taconite plants.

For example, the Eveleth Taconite Plant located at Forbes is situated adjacent to a large high-quality fuel-type peatland containing approximately 60,000 acres of peat averaging 10 feet in depth.

Likewise, there are many bogs close to the other large taconite plants on the Iron Range which would be equally suitable to produce peat, cheaply and efficient for use in drying taconite pellets. The peat map of Figure 4 shows the locations of peat deposits in respect to existing taconite operations.

IV. RESEARCH NECESSARY TO DEVELOP PEAT AS A SOURCE OF ENERGY IN MINNESOTA

A. Research on Converting Peat to a Useful Type of Energy.

B. Peat Mining Research.

C. Research on Environmental Effects of Production of Energy From Peat.

IV. RESEARCH NECESSARY TO DEVELOP PEAT AS A SOURCE OF ENERGY IN MINNESOTA

Prepared by A. M. Rader, Asst. V.P., Research, Minnesota Gas Company, December, 1976.

If peat is to become an important source of energy in Minnesota or the United States, we must find an economical method to convert peat into a form of energy that is in popular use, such as natural gas, oil or electricity. If we tried to get our people to use peat briquettes to heat homes or to cook, we wouldn't get very far. Partially dried peat has been used in Europe and Russia in large quantities to produce electricity (about 17% of Ireland's and about 2% of Russia's electrical requirements.) It has not been economical in the United States to use peat as a source of energy but, with predicted energy prices, peat should be competitive with coal and lignite in the future.

Minnegasco has been conducting research and studies since September 1974 on the feasibility of converting Minnesota peat into synthetic natural gas. We made a public announcement of our interest in gasifying peat on July 24, 1975, and on that date we applied to the Minnesota Department of Natural Resources for a 25-year lease on State-owned peat land in northwestern Minnesota.

The lease application covers State-owned land in a 491-square mile tract located in Koochiching, Beltrami and Lake of the Woods counties, and we estimate that it contains at least 200,000 acres of peat that could be used for commercial energy production. This would represent less than 3% of Minnesota's total peat acreage but would supply a full-sized commercial synthetic natural gas plant producing 250 million cubic feet per day for twenty years.

To make peat competitive with other solid fossil fuels, research will be needed in three major areas: Conversion of peat to a useful type of energy, Peat mining research, and Research to make the mining and conversion of peat environmentally acceptable.

A. Research on Converting Peat to a Useful Type of Energy

The sale of natural gas is the principal business of Minnegasco, so it is obvious that we are most interested in converting peat into pipeline quality natural gas. Our first phase studies and research conducted on peat gasification, completed in the Fall of 1976, indicate that peat can be converted to natural gas using existing coal gasification technology. The efficiency of peat conversion to natural gas plus its by-products (Hydrocarbon liquids, ammonia and sulfur) would be about 70%, or about double the efficiency of conversion of peat to electrical energy. However, this comparison can become less attractive when considered from source to end use. The end uses of electricity can be much more efficient than the end uses of natural gas.

Research on conversion of coal and lignite to natural gas has been going on for about 25 years, with the expenditure of many millions. This research is continuing at an accelerated rate and is still needed, as no commercial plant construction has been started to convert coal or lignite to natural gas.

Minnegasco presented a proposal to the Energy Research and Development Administration (ERDA) in January 1976, for assistance in our second phase research on peat gasification. The "Experimental Program for the Development of Peat Gasification" was approved for joint funding by ERDA on June 30, 1976. The joint Minnegasco-ERDA program is presently funded for $1,240,000. The work on this research program is being performed by the Institute of Gas Technology (IGT) at Chicago and will be completed in two years. At the successful completion of this second phase, we will then be ready for the third phase, tests on an existing ERDA operated integrated pilot plant (such as the Hygas pilot plant at AGT). The pilot plant tests would require at least six months and would probably cost an additional 3 to 6 million dollars. ERDA assistance would also be solicited for the pilot plant run on peat.

The engineering studies and pilot plant run would provide engineering data necessary for the design of a prototype commercial demonstration peat gasification plant. Minnegasco presently would plan to build a plant that would produce 80-million cubic feet of natural gas per day, that is estimated to cost at least 250-million dollars and would require about 2½ years to construct. The plant probably would be expanded to full commercial size - 250-million cubic feet of natural gas per day - when additional capacity is needed. Such a full-sized plant would have an annual energy output greater than the total amount of electrical energy used in Minnesota in 1974, and would only utilize about one-half of the fuel that was required to generate the electric power. The annual output of such a plant would approximate one-fourth of the natural gas consumed in Minnesota during 1974.

The 80-million cubic foot per day demonstration plant would use about 6,000,000 tons (30% moisture) of peat per year; this is about equal to the annual use of peat for fuel in Ireland. The 250-million cubic foot per day plant would use about 18,000,000 tons of peat per year, three times the Irish use, or about one-fourth of the present World annual use of peat for energy.

Research and studies may also be conducted to convert peat to other forms of useful energy, such as low BTU gasification, conversion to chemicals, production of liquid fuels, or direct combustion for production of electricity, as is presently practiced in Europe and Russia.

Midwest Research has made a proposal for a Research-demonstration project to use peat to produce steam for an Iron Range Municipal Heating plant.

B. Peat Mining Research

The Bureau of Mines, Twin Cities Mining Research Center has a study under way with an objective of developing a research program that would demonstrate an economically and ecologically acceptable peat mining system to supply peat feedstock for a commercial peat gasification plant. The study should be completed very soon.

We have hopes that a peat mining research project can be developed for joint sponsorship between the Bureau of Mines and Minnegasco. It is estimated that this research would require about 2½ years and would cost about $750,000. This program would probably include studies of all methods that apply to: removing peat from the bog, removing water from the peat, and preparing the peat in the size or form needed for gasification or energy plant use. The methods that are environmentally and technically acceptable will be evaluated and at least one method would be tested in a pilot mining operation to furnish information for design of a full-scale mining operation to supply 18,000 tons of peat per day for an 80-million cubic foot per day peat gasification plant.

Peat deposits occur on the surface, so no over-burden removal is needed. But, as peat exists in the bogs, it contains 80 to 90% water and this water is very difficult to remove from the peat. Present methods of harvesting peat as used in Europe and Russia, more closely resemble farming than they do mining operations. Two methods are used: the milled peat and machine peat processes both depend on solar energy to dry peat on the surface of fields. Using the European methods, which are both highly dependent upon the weather, would require farming about 100,000 acres to produce the peat required for an 80-million cu ft per day deomonstration plant, and as these operations are only practical during the summer, it would require huge stock piling of dried peat for winter operation of the gasification plant. It seems very unlikely that the present European methods would be economically or environmentally acceptable for our operation. If peat is to become a major source of energy supply for Minnesota, it will be necessary to develop new mining and preparation methods for peat.

The study recently completed by Midwest Research for the Minnesota Department of Natural Resources has included an up-dating review on peat mining methods being used in Europe and Russia. This study still does not show that European methods would be economically or environmentally acceptable in the United States.

C. Research on Environmental Effects of Production of Energy from Peat

This will be very important. Both the gasification research and the mining research will need to consider environmental acceptability at every step. When information for any phase of the process is ready for plant design work, then this information will be used to prepare an environmental impact statement for that operation. In this way, environmental impact statements should be ready at least as soon as plant or mine designs are ready for construction. We know that we will need to protect the environment in any peat removal or plant operation. We also feel that the land can be upgraded after the peat is removed, so that it can be used for crop production, tree farming or recreational purposes.

Midwest Research considered environmental effects of use of peat for energy in its recent study that has just been completed for Minnesota DNR.

Midwest Research Institute has recently completed a preliminary socioeconomic study related to peat gasification for Minnegasco. See Appendix I. We have not tried to make any estimate of the total costs that might be involved in environmental related research that will be needed.

The three research phases described would need to be completed before a demonstration plant could be designed. Also, leases for peat reserves and permits would be needed before construction could be started on a demonstration plant. If the peat research is successful, Minnesota could change from an energy dependent State to an energy producing State.

I think, from this, it is apparent that peat research needs to proceed full speed ahead. Minnegasco is prepared to continue its peat research program, but we will certainly need Federal and State assistance in developing Minnesota peat as an alternate source for producing natural gas.

V. PEAT HARVESTING TECHNOLOGY

A. History

B. Introduction

C. Cleaning

D. Drainage

E. Production Methods

   1. Sod Peat Method

   2. Milled Peat Method

   3. Peat Excavation

V. PEAT HARVESTING TECHNOLOGY

A. History

Peat has been harvested as a fuel source for centuries in Germany, Scotland, Ireland and the Netherlands. Individual peat sods were removed with special spades called "slanes", left to dry in the elements, and stacked in ricks. From two to three weeks' work was normally required for an individual to remove sufficient peat for winter use as fuel for heating and cooking. Near the end of the nineteenth century, peat harvesting was mechanized by the Germans, who developed machines which kneaded and shaped peat material into sods which were firmer and more dense than slane-cut peat. The milled peat harvesting process was developed in the 1930's by Russian scientists and is a surficial rather than an excavation process.

Methods of peat harvesting in Europe have become highly mechanized and efficient in recent years. Two methods of peat harvesting are currently employed: the sod peat and milled peat processes. Other methods not commonly used but which may prove feasible are bulk harvesting methods, such as hydraulic mining dredging, and bucket-wheel or dragline excavation.

B. Introduction

Prior to development of peatlands for fuel peat production, a detailed survey is needed which includes identification of surface vegetation, determination of the surface and basal contours of the peat deposit, and the nature of the mineral substratum. In addition, an inventory of the quantity and quality of the resource is required which includes the depth, degree of decomposition, density, mineral content and caloric value of the peat over the extent of the deposit. Once a survey is complete and results show that the area contains peat suitable for development, the best methods of drainage, clearing and harvesting can be determined. The most suitable peat for use as fuel should contain at least five feet of harvestable peat with an intermediate or high degree of decomposition, a low mineral content and a high caloric value.

C. Clearing

Before a bog is suitable for peat harvesting, the surface vegetation, including buried stumps and large wood fragments must be removed. The expenditure for clearing open peatlands is obviously much less than that for forested areas. In the U.S. conventional excavating and earth-moving equipment is employed for bog clearing. In Europe, clearing machines are often used which are designed specifically for that purpose. For example, the

Finns have developed a multi-purpose "base machine" that can be equipped with attachments for dozing, grubbing, leveling, ditching and harvesting. The Soviet Peat Industry has developed a universal excavator with attachments for clearing timber and also harvesting peat. They also have several single-purpose machines which remove and collect stumps and large wood fragments from the peat. Costs of clearing range from $20/acre for open sedge bog to $100/acre for forested areas (1970 figures).

D. Drainage

Since peat deposits occur in wet environments, some degree of drainage is normally required before the bog surface will support large equipment. For peat which is saturated, or nearly so, removal of from 10 to 15% of the volumetric water content is required prior to use of clearing and harvesting equipment. The most common method of bog drainage is by ditching. The water level lowering which results is strongly dependent on ditch spacing and freedom from encroaching runoff waters. New ditches are normally deepened gradually to minimize the subsidence and slumping which accompany the process. Ditching in Ireland and Finland is done primarily by rotating disc machines which are able to excavate a five foot ditch at up to 600 yards per hour. In the U.S. ditching is commonly done using either dragline or bucket-wheel excavators. Drainage requirements vary depending on the peat harvesting method employed. Sod peat production requires only a relatively small working area relative to that required for production of milled peat. In Ireland a typical drainage system for sod peat production utilizes main ditches 750 to 820 feet apart with subdrains 210 to 280 feet apart. A Milled peat drainage system normally requires a ditch spacing of 50 feet between fields which are 800 to 2000 feet long. Depth of ditches for fully developed peat production areas range from four to eight feet, depending on the peat type, its density and stratigraphy, and the purpose of drainage. Perimeter ditching is normally required for both production methods in order to prevent encroachment of adjacent runoff water. Ditching cost (1970) using a small dragline has been estimated at $0.15 per cubic yard.

E. Production Methods

1. Sod-Peat. In sod peat production, peat is excavated from a deep vertical trench by a bucket dredger, which in Ireland is called a "bagger". This machine mascerates the peat and extrudes it into long ribbons by means of a spreader arm. Cutting discs drawn behind the bagger cut the peat into

sods which are approximately 14 inches long and 5 inches square. After an extensive drying period the sods are collected into ricks and loaded onto narrow-gauge railway cars. In Ireland an average season produces two harvests of sod peat at approximately 35 percent water (total wt basis). Methods of sod peat production in the USSR are similar to those used in Ireland. The entire production cycle consists of excavation, extrusion, spreading, windrowing and harvesting. The caloric value of sod peat at 35 percent water is approximately 5700 BTU per pound.

In Finland sod peat production is employed only when the milled peat process is unfeasible. Production of sod peat is limited by high labor costs and a short production season, difficulties which have been partly overcome by the use of surficial instead of trench excavation. Production of sod peat in Europe has become highly mechanized. From 1960 to 1971 Irish sod peat productivity has increased from 300 to 550 tons per man-year. Primary disadvantages of the sod peat process are the high labor and capital costs incurred and the limited harvesting season.

2. Milled Peat. European peat producing nations are largely phasing out production of sod peat in favor of the milled peat process, because the latter can be completely mechanized and has lower capital and labor requirements. Milled peat is that which has been finely shredded by a toothed rotating drum and left to dry on the production field surface. Milled peat production is a multi-step process which consists of milling, harrowing, ridging and stockpiling. In good weather the harvest cycle requires from two to three days. In order to be of suitable quality for use as fuel, milled peat should have water and mineral contents less than 55 and 10 percent of total wt., respectively. In Ireland an average of 12 harvests are obtained per season, representing an average yield of 73 tons per acre. The smallest production area used by that country for milled peat production is 2800 acres, at least one quarter of which is required for railways, turning and storage fields.

Several years are normally required to bring a bog into production. The Irish found that four to five years of drainage was needed to reduce drainage ditch water levels to at least four feet. The first few production years also require restricted production to avoid damage to the bog surface and ditch edges.

Development of the pneumatic, or vacuum, harvestor by Russian technologists caused a significant advance in milled peat production. Use of vacuum enables the collection of only the driest peat, thereby reducing the drying and harvest cycle from two or three days to one day.

3. Peat Evacuation

A. Hydro-Peat. In this process peat is reduced to an aqueous suspension by the action of water under high pressure. The peat slurry is pumped by suction through pipelines onto drying beds. When excess water has been removed (water content less than 85 percent of total wt.), a special machine travels over the peat, cutting it into sods. The process has been used chiefly in the USSR. In a normal production season, hydraulic separation of peat occurs for three months, followed by a two-month drying period. Annual production was reported to be about 50 tons per acre. This process has been replaced by milled peat production because of high power, labor and equipment costs, low peat recovery efficiency, and high water requirements.

B. Dragline. Dragline excavation of peat is not presently used for fuel peat production, but the process has certain advantages nonetheless. A crawler-mounted dragline can work effectively in small areas and on rough terrain. Larger units called walking draglines are mounted on circular tubs. This type of mount permits use of very large equipment which has a low bearing pressure. Depending on the efficiency of the process, dragline excavation costs have been estimated at $0.70 per cubic yard (1970 figures).

C. Bucket-Wheel Excavators. This is a continuous excavator that digs and discharges material simultaneously. This type of equipment is currently used to mine coals, lignite, phosphate rock, and other medium-hard materials. Frozen materials have been mined successfully in Canada, Germany, Russia and the U.S. There are several advantages associated with use of the bucket wheel excavators, chiefly related to flexibility of operation.

D. Hydraulic Dredging. Hydraulic dredges are designed for excavation of submerged materials and transport of the resulting slurry to a discharge outlet. An hydraulic excavation system might be barge-mounted and the unit floated next to or over a flooded portion of peat to be removed. This type of equipment is not presently used in peat harvesting but could be adapted for the purpose. Operating costs of dredge equipment vary with the size of dredge, the type of material excavated, and the distance to discharge. Dredging costs for removal of light, easily dug material such as peat have been estimated at $0.27 per cubic yard (1970 figures).

Removal of peat by excavation has certain advantages over surface mining. In general, excavation processes are less labor intensive, they permit longer season operation, require a relatively small working area, and may not require extensive drainage. The primary difficulties associated with excavation are reclamation following peat removal and mechanical peat dewatering.

VI. RECLAMATION OF PEATLANDS

A. Europe

1. Ireland

2. Germany

3. Finland

4. Soviet Union

5. Scotland

6. Poland

B. Reclamation Potentials for Minnesota Peatlands.

C. Causes of Failures in Peat Development.

D. Potential Profitable Peat Development.

1. Agricultural Development.

2. Fuel Peat Development.

VI. RECLAMATION OF PEATLANDS

. Europe

Reclamation of peatlands in several European countries is a common practice in areas where peat has been extracted for fuel and horticultural purposes. Many peatland areas in those countries where peat has been removed have been dramatically transformed into productive agricultural and forestry lands or even used for a variety of other purposes. In most European countries including the Soviet Union, there are laws pertaining to the utilization of harvested peatlands. Usually agricultural research institutes provide the technical assistance to the various government or private peat companies in their reclamation efforts. These institutes assist in selecting suitable crops or trees for a particular area and suggest the best management practices to be applied such as fertilizer needs, drainage requirements, land preparation etc. They also help in selecting and surveying the peatlands which offer the best development potential.

The potential uses for these reclaimed peatlands include crop and tree production, nature conservancy areas, wildlife habitats, lakes and ponds for fish production and waste treatment and recovery.

1. Ireland

Ireland has some 3.5 million acres of peatlands of which a considerable acreage over the years has been converted into grass and arable land by farmers as the deep peat was cut away over the centuries for domestic fuel.

Bord na Mona (Irish Peat Development Authority) was established in 1946 for the purpose of developing the peatlands. During the intervening years they have developed over 130,000 acres of peatland varying in depth from 6 to 25 feet primarily for the production of peat fuel (electricity generation, peat briquettes) and horticultural peat moss. Due to the importance of agriculture to the Irish national economy and the necessity to bring into production every available acre of land, the government requires that all lands where peat has been removed be reclaimed and utilized for various agricultural purposes.

The responsibility to carry out research on these harvested peatlands and to investigate the production potential and cultural problems involved was assigned to the various national agricultural institutes located near the peatlands. Since about 1960 they have conducted many experiments regarding vegetable crops, grass and forage crops and beef cattle production as well as suitable tree species and forest tree nurseries on peatlands.

Reclamation Practices in Ireland

On some peatlands the peat has been removed to 20 inches minimum depth but in areas with very deep peat as much as 5 to 10 feet of peat remain after the fuel peat harvest.

Researchers at the Agricultural Institute of Ireland, with the cooperation of the Bord na Mona, have mainly investigated production techniques and/or cultural problems involving mined peatlands. Research has pertained to such items as grasslands, forage, vegetable, and to some extent tree production. Outlined results from the Clonsast Work Project are as follows:

a) General Crop Production

1. Trials have indicated that fen peats, (sedge-wood-reed types) found below the sphagnum layers, are a choice selection for vegetable production.
2. Removal of peat to within twenty inches or less of the mineral subsoil causes numerous soil problems -- impeded drainage, high lime content, poor rooting zone for plants, and increased stoniness.
3. Field trials, under choice peat conditions, have demonstrated two to four times as much fertilizer is needed for the first year of production as compared to the rates used in subsequent years.
4. Trials have indicated that deep peats, eighty inches or more, but under the older sphagnum layer, have a greater moisture holding capacity, greater aeration, better drainage, and a lower rate of fixing phosphorous.
5. Experimental data has shown comparable vegetable yields can be obtained on sedge type peats as on mineral soils.
6. Nutrients
   Nitrogen - Very unstable until the C:N ratio is stabilized. About a 12:1 ratio is desired.
   Phosphorous - May become unavailable if the water table fluctuates substantially. Placement of phosphorous near the seed has resulted in a significant increase in growth and vigor of crops grown on peat material.
   Micro-nutrients - Peat is nearly deficient in all micro-nutrients and therefore must be supplied according to the crops requirements. Deficiencies were noted especially during the first years of production on reclaimed peatlands.

b) Grassland research by the Bord na Mona on peat.

1. Tests indicated normal grazing management is possible and that cattle made satisfactory weight gains when compared to mineral soil grassland grazing.
2. Summer cattle grazing - Cattle blood samples indicated a copper deficiency to be prevalent when grazing on peat grasslands. Deficiency was corrected by feeding supplemental minerals.

3. Animal parasitic problems were encountered with a higher frequency on peat grasslands as compared to mineral soil grasslands.

4. Pasture establishment on peat with ryegrass and white clover was excellent.

5. Soil tests indicated an increase in fertility with time when under grass management.

6. Nitrogen response was observed to be greater on peat than on a mineral soil. It was also noticed that a nitrogen deficiency is quickly observed on peat grasslands.

As indicated previously, reclamation practices are under consideration from the time of peat removal to when the harvested peatland is in production. Summarized practices are as follows:

a) Peat Removal - Peat is removed to a minimum depth of twenty inches according to governmental regulations, except that in areas of very deep peat deposits, forty to eighty inches may remain.

b) Drainage Systems - Drainage systems are constructed primarily to remove surface runoff water. (e.g. rain water)

Types:

1. Tiled drains - Usually placed at fifteen to fifty foot intervals at a depth of two feet. This method was found to be relatively ineffective due to the low water permeability in the peat substratum.

2. Surface channels or ditches - Usually placed one to three hundred foot intervals with an average depth of three feet which is dependent upon the water table level desired. The advantage in this type is the assurance of rapid removal of rain water.

3. Combination of tile drain and surface ditches - Combination of the two previous types, except surface ditches are placed at four to five hundred foot intervals. The main advantage is the water table level can be controlled more efficiently. There also is more land available for agricultural use because some surface ditches have been eliminated.

c) Grading - Most harvested peatland areas require leveling and some should be chambered between the surface ditches for better surface runoff. Leveling with a gradient slope of one or two percent is sometimes practiced, but is not necessary if the gradient slope of the peatland is surveyed and drained accordingly.

d) Intermixing - Intermixing is the practice of mixing the sedge-wood-reed type peats with the underlying mineral soil layer. The desired result is a firmer soil for seedbed preparations, but may cause a severe acidic soil condition.

e) Crop Production - Crop production practices include:

1. pH adjustment by adding lime if below a pH of 5.
2. High fertilizer application rates which have an analysis of phosphorous and potassium to correct the nutrient deficiencies especially during the first year of production on a reclaimed peatland.
3. Application of micronutrients according to crop requirements.

Additional practices, including tillage and weed control are similar to the practices on a mineral soil.

2. Germany

The large developed bogs in N. Germany are located mostly on an extensive glacial sand plain which extends northward to the North Sea and westward into Holland. Many of these large bogs have been used for production of fuel and horticultural peat for many years. The government required the peat producers to leave at least 0.5 meters of peat in the bogs.

Research by the several agricultural institutes concerned with crop and forest production have led to the utilization of these harvested peatlands for vegetables, forage and trees. The Peat Institute at Bremen, which is one hundred years old, has been in the forefront of this reclamation effort. Also a sister agricultural institute at Groningen, Netherlands has been interested in development of peatlands for agriculture and horticulture.

Earlier efforts at reclamation included mixing of underlying sandy soil with peat to improve the productivity of the resulting soil.

In more recent times they grow crops on the remaining shallow peat and have learned the best management practices for successful crop production.

In the past 5 years near Bremen they have been applying sewage sludge from their larger cities onto the surface of drained and harvested peatlands with reasonable success. This practice not only solves a pollution problem but results in a by-product (peat-sludge compost) which is a valuable horticultural fertilizer.

3. Finland

The primary use in Finland for reclaimed peatlands is for forestry purposes. Forest products industries in Finland are the chief exporters for such items as paper, paper products, wood products, etc. Therefore use of peatlands in forestry is most important to their economy. The Finnish forest industry has many research stations all over the country who do research in peatland forestry. The major tree species grown on peatlands in Finland are the Scotch pine, Norway spruce, aspen and birch. These are all used in some form in the wood products industries.

The Finnish government plans to increase the production of fuel peat fourfold by 1980 and thus has instituted an intensive survey of its peatlands for fuel as well as other uses. The Finns pay particular attention to the reclamation potential of a bog once the peat has been removed for either fuel or horticultural purposes. They require the peat producers to leave at least 0.5 meters of peat on the mined peatlands.

The Finnish Technical Research Institute is engaged in peatland forestry research, studies drainage, hydrology, and environmental factors of peatlands as well as vegetative growth rates under various management practices. They have a very active peat survey group which includes soil scientists, foresters, geologists and agricultural engineers. They have surveyed and classified all their peatlands at least once or twice and are presently making very detailed surveys of peatlands especially suited to large-scale fuel peat production. They also utilize peatlands for waste water treatment of municipal wastes and have about 20 active systems in operation as of the present.

They have regional water quality laboratories that cooperate with peat specialists in determining any possible water quality problems in peat development and the suitability of peatlands for waste treatment.

The Finnish Technical Research Institute has developed a dry peat material which is used to collect oil spills on water (such as in harbors) and thus combat this form of pollution.

4. Soviet Union

The Soviet Union is the largest producer of peat of any nation in the world. In the NW part of Russia at least 200 million metric tons of 40% moisture peat are utilized yearly for fuel and agriculture - fifty million tons for fuel and 150 million tons for agricultural fertilizers. They produce a fortified organic fertilizer from peat which is utilized on farms much like manure in the U.S..

The Soviet Union has a reclamation law that requires that at least 0.5 meters (20") of peat must be left in a bog where fuel or agricultural peat has been removed. These harvested peatlands are being reforested and some put into crop production. All bogs in natural condition that are less than 1.5 meters (60") in thickness are not used for harvesting but are used for agriculture and forestry.

5. Scotland

Scotland probably has some of the oldest reclaimed peatlands of any country in Europe. Many peatland areas have been used for fuel (hand cut), grazing of sheep etc. since before Roman times. Consequently, many areas of peatland had all the peat removed over the years and these areas are now some of the best agricultural lands in Scotland.

Various reclamation practices for burned over or removed peatlands have been used. They have learned about proper drainage, fertilizer and lime requirements, etc. as well as cultural practices and early recognized the potential agricultural value of peatlands.

The Macaulay Institute for Soil Research in Aberdeen, Scotland has a peat survey and research section which has the primary responsibility for research relating to use and development of peatlands for agriculture.

Scotland has about 2 million acres of peatland and they feel peat has potential not only for cropland but also as raw material for a range of industrial products (chemicals, etc.). They estimate that about 30 to 40% of these peatlands could be developed for crops and industrial products while the remainder are either unworkable or of unsuitable type for development.

The soil scientists in Scotland feel that removal of peat from land improves its use for agriculture. They argue that the texture, structure and organic matter content of underlying soils would be improved.

As a haven for wildlife, they feel that the peatlands of Scotland probably constitute the largest area of natural or semi-natural habitat in the country. But they contend that their peatlands are not notably rich in variety of species. The red deer is a common peatland species as is the red grouse.

The Forestry Commission of Scotland is the largest single user of peatland. They investigate the potential of establishing and maintaining various commercial tree species on peatlands.

6. Poland

The total extent of peatlands in Poland is 3,250,000 acres or about 5% of total area of the country. The eutrophic Fens-type peatlands occupy 89% of the total peat-covered acres while only 11% are considered transition or raised bogs (oligotrophic or acid in character). The fens-type peats are much less acid than the sphagnum-covered raised bogs. The range in pH for these fen-type peats is 5.5 to 6.5 and they contain a high content of calcium and nitrogen.

Peats in Poland are classified much the same as in the U.S. and the classification system now officially recognized by the International Peat Society (action by I.P.S. Council of 1976) was based primarily on these two systems which were developed independently. The basic criteria of the I.P.S. and Polish peat classification system is as follows:

A) Degree of Decomposition

1. Fibrous type (designated R_1) - fibric of U.S. system. These are the least decomposed peats.
2. Mesic type (designated R_2) - hemic of U.S. system - moderately decomposed
3. Amorphous type (designated R_3) - Sapric in the U.S. system - highly decomposed peat.

Determination of the above basic decomposition types is made in the field based on the humus - fiber ratio and the structure of the peat mass.

B) Classification for cultivated peats

A - deep, slightly decomposed, slightly mucked peats; water conditions: wet

AB - deep, slightly decomposed peats with underlying moderately decomposed peats; water conditions: periodically wet.

B - deep and moderately deep, moderately decomposed and slightly to moderately mucked; water condition: moist.

BC - deep, moderately decomposed peats, over highly decomposed; moderately deep and shallow, moderately decomposed; moderately mucked; water conditions: periodically arid.

C - moderately decomposed of varying depths. Highly and moderately mucked; water conditions: arid.

C) Surface Layer Humification (mucking degree)

Mt I - poorly mucked

Mt II - moderately mucked

Mt III - highly mucked

The above three-grade scale is based on thickness and character of the surface layer which may influence available water, air and nitrogen content for grassland vegetation.

The above classification system used in Poland facilitates the grouping of peat soils into suitability classes for land reclamation and agricultural management. In reclaimed peatlands the Polish agriculturalists can use this classification system in their peat surveys in planning for reclamation and cultivation.

In Poland they are presently using 82% of their peatlands for agriculture and plan to reclaim some of their additional large undeveloped areas in the future. About 99% of the cultivated peatlands are occupied by grasslands and about 1% by vegetation and field crops. The Polish government insisted on giving high priority to grasslands on peat soils because grasses help preserve these soils by reducing shrinkage losses which could be considerable with vegetables and row crops. Also use of commercial fertilizers is less with grass crops as the mineralization of nitrogen inherent in peats is facilitated when these soils are drained and cultivated. Grasses need large amounts of nitrogen as well as water and growing these crops allows the natural production potential of these soils to be most fully realized and at the same time their conservation and preservation assured. Using these peatlands for intensively farmed vegetables and row crops would only hasten their destruction as agricultural lands.

Thus it appears that the Polish agricultural scientists have set a precedent on planning for use of a natural resource (peatlands) unlike any other country of the world. Other countries planning reclamation of natural peatlands or mined lands should take notice of their progress in agricultural development of peatlands.

B. Reclamation Potentials for Minnesota Peatlands

The northern Minnesota peatlands have great potential for production of forage crops, high-protein grasses, vegetables, seed crops, commercial forests and wild rice to name a few. Recent experiments on peatlands in Polk and Roseau counties, Minnesota, used for production of forage grasses showed that under proper fertilizer practices yields of 3 to 6 tons (dry matter) were possible--many of these grasses contained up to 25 to 28% protein and total protein yield per acre was over 2000 pounds in some instances.

Should the state develop some of these peatlands as an energy source, their reclamation and use for such crop production after removing some of the surface peat should be considered. The technology for crop production on peatlands has been well researched and is available in technical bulletins.

Things to consider in evaluating a peatland site for agricultural or other type developments are as follows:

1. For grassland farming it is suggested that about 12 to 18 inches of peat should be left after mining so that the organic matter can be mixed with the underlying mineral soil. A grass cover crop is suggested for a period of time which gives good structure to the soil, prevents wind erosion, keeps down weeds, and requires

only minimal amounts of commercial fertilizer.

2. For vegetable crops leave about 3 to 5 feet of peat at the bottom so that water levels can be better controlled and the roots are growing in peat.
3. If all the peat is removed the area can be developed into ponds and lakes for water fowl and recreation uses.
4. The type of mineral substrate should be known prior to development. Substrate may be marl, lake muds, stony, sticky clay, or poor quality sand. These conditions are poorly suited for crop production and should be avoided.
5. All of the peat deposits in Minnesota, due to the abundance of high lime content of underlying glacial drift, become less acid with depth. The pH of many Northern Minnesota peats normally are in the 3.5 to 4.5 range (very acid) in the surface but increase to 5.0 to 7.0 at the bottom near the mineral contact. This means the lower layers of peat deposits are more suitable for cropping (require no lime additions) especially for the lime-loving forage grasses that are well-suited to peatlands.

It is recommended that detailed inventories of peatland areas to be mined for either fuel or horicultural peat be made well in advance of development in order to evaluate and plan for the type of reclamation suited to a particular deposit. If the area is to be used for crop production it is necessary to know the thickness of the peat, the kind of mineral substrate, the potential for drainage and the chemical and physical properties of the peat which affect crop plants.

C. Causes of Failures in Peat Development

The development of peat for use as fuel or for agriculture (food and fiber crops) in the past has in many cases resulted in complete failure. These failures cannot in any way be attributed to the properties of peat or its potential for a specific use. The success or failure of these attempts to develop a peat enterprise were directly related to such matters as lack of technical knowledge and planning, poor choice of sites, insufficient capital investment, and failure to transfer technology from European countries. Many potential developers have lost interest because of the well known failures despite the fact that many very successful agricultural developments have occurred in the U.S. in recent years and the fuel peat industry in Europe is not only very successful but is expanding rapidly at present.

The ill-advised drainage schemes in northern Minnesota in the 1915-20 period are good examples of why agricultural development failed. Many of the drainage ditches were constructed on peatlands unsuited to crop production, in areas that were not readily accessible and the development was planned without the technical assistance and consultation of the agricultural experts familiar with problems of crop growing on peatlands at that time. Fertilizers which were essential for crop production on peatlands such as potash, and phosphorous were not being produced commercially at that time in the U.S.. Without these fertilizers and the presently available micronutrients such as copper, manganese and boron as additives to peat very poor crop yields resulted.

D. Potential Profitable Peat Development

There are many factors governing profitable utilization of peat for agricultural and energy development. Following are some suggestions for peatland development.

1. Agricultural Development

Successful development of peatlands to be used for crop production must consider the following factors:

a. Location of peatland
   Accessibility and transportation
b. Quality of peat
   Suitability for specific crop plants
c. Drainability of specific area
d. Market for crops produced

e. Choice of suitable crop species
   Crops must be suited to peatland soils, weather conditions and must be high yielding.
f. Sufficient capital investment
g. Availability of labor
h. Development must be large scale
i. Must utilize all available technology for production of crops on peatlands

Management practices for production of vegetables, sod, grasses (forage) and special crops including innovative technologies are available in bulletins from the U.S.D.A., and several agricultural experiment stations including Cornell (N.Y.), Florida, Michigan, Indiana, California, Wisconsin, and Minnesota for example.

Many farmers familiar with crop production on our mineral soils who attempt agricultural development of peatlands often fail to obtain adequate information before attempting to farm these peatlands and failure is inevitable. The technologies used on our mineral upland soils cannot be directly transferred to peatland soils without some modifications in management practices.

2. Fuel Peat Development

The development of peatlands for fuels has not taken place in the U.S. and Canada but in Europe the following factors are important to successful development:

a. Availability of peat of good quality and sufficient quantity for fuel purposes.
b. Market for fuel products. Need for electricity, synthetic natural gas, or substitute fuels in energy poor countries such as Ireland, Finland and portions of N.W. Russia has necessitated the use of peat as an economical substitute fuel in place of oil, coal, etc.
   (In other words, "necessity is the mother of invention".)
c. Adequate capital for development.
d. Good transportation facilities
e. Location near areas in need of substitute energy sources
f. Use of best existing technology for harvesting, processing, transporting and combustion of peat.
g. Environmental protection during development.
h. Sound long-term planning.

VII. ENERGY FARMS ON PEATLANDS

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One alternative energy source which may be substituted for a part of our decreasing fossil fuels is plant biomass. The production of biomass through the process of photosynthesis is an example of indirect use of solar energy. Plants have provided food or energy for animals since time began, and in addition, furnished carbonaceous materials which, after preservation, compaction and biological activity, have been converted to our originally extensive resources of peat, lignite, coal, oil and gas.

Peatlands are particularly suited for the production of many high-yielding wetland species such as cattails, sedges, reeds, grasses, hybrid aspen and lowland brush. Table 22 shows average yields for several wetland plant species grown on peatlands. Yields shown were mostly from unfertilized and natural stands. Only the reed-canary grass and quackgrass crops were partly drained and lightly fertilized. The potential is great for increasing the yields of many of these crops if they are fertilized and managed properly.

Table 22. Biomass Productivity on Peatlands and Wetlands.

		Yield (Dry Organic Matter)	
Location	Species	Tons/Acre/Year	Standing Crop (Total) Tons/Acre
Minnesota	Reed-Canary Grass	5-6	--
Minnesota	Quackgrass	6-8	--
Minnesota	Scirpus Sedge	7-10	--
Minnesota	Cattails (Shoots)	8-10	--
Minnesota	Cattails (Total Plant)	30-40	--
Minnesota	Fen Bog	3.0*	15.0
Minnesota	Swamp Forest	4.5*	67.5
N. Carolina	Wetland Shrubs	8.0*	--
Michigan	Alder Swamp	2.8*	23.0
Washington	Red Alder	10.0*	--
W. Germany	Reed-Sedge	20.5*	--

* Yields accurately measured, as obtained from the literature. All others are estimated values by the Soil Science Department of the University of Minnesota (1976).

Table 23. Energy Values for Minnesota Peatland Vegetation.*

Vegetation Type	Location (county)	Energy Value (oven dry)		
		cal/gm	Ave.	B.T.U./lb
Calamagrostis Grass	Aitkin	4028 4017 4068	4037	7266
Carex Sedge	Aitkin	3999 4009 4017	4008	7214
Scirpus Sedge	Aitkin	4283 4301 4287	4290	7722
Cattail	Aitkin	4360 4380 4349	4363	7853
Phragmites	Koochiching	3833 4168 4205	4068	7322
Sphagnum Moss	St. Louis	3800		6840
Peat (Hemic Type)	Roseau	5000- 5400		9000- 10000

* Source: Soil Science Department, University of Minnesota.

Peatlands are not presently being used to any extent for the production of food and fiber crops. Thus the opportunity exists for large-scale production of suitable wetland species on peatlands as an energy crop without competing with food production on Minnesota's prime agricultural lands.

Peatlands may be considered both a nutrient and an energy sink and are well-suited both physically and chemically for production of many types of wetland vegetation. They are easily managed for crops adapted to wetlands because areas are large, level, and easily cultivated.

Plants growing on peatlands are never under moisture stress, as is common periodically on upland mineral soils, and the peat soils provide a readily available supply of water for optimal plant growth. Many native species of grasses, sedges, reeds, and wetland brush grow naturally on peatlands without any management inputs. If properly managed substantial increases in yields could be expected with minimal inputs of labor, fertilizer, etc.

Harvesting of biomass on a large scale on peatlands with special equipment would be relatively easy and inexpenisve. This is because of the flat topography, organic nature of soil allowing for ready drainage, and the large contiguous areas. Many areas are 10,000 acres or more in one bog and some are 50 to 100,000 acres. There is an excellent opportunity for developing some of the extensive peatlands in Minnesota for large-scale energy farms both as a renewable and as an alternative energy source. The production of biomass on these farms could be used for direct burning to produce heat and electricity at a district heating plant or for conversion to low B.T.U. synthetic gas and also for ammonia production. This plant biomass could be used alone or in combination with peat, wood and other available combustibles such as solid wastes.

Table 23 shows energy values obtained for several peatland plant species in some Minnesota counties. All species except Sphagnum moss have energy values over 7000 B.T.U./lb. Compared to peat these plants generally contain 20% or so less energy.

The data shown in Table 22 is from various published papers in the literature concerning productivity of several plant types in wetland environments. Very high productivity values for marsh and peatland ecosystems also have been reported by other investigators which indicates that these habitats are excellent for plant growth of adopted species and generally exceed values reported for upland species. These studies report a range in total standing crop yields from 6 to 80 tons per acre. Many Minnesota peatlands have large amounts of standing crop biomass including such plants as woody shrubs, alder, willow, moss hummocks, etc. These usually occur on relatively large and open (treeless) peatlands located in St. Louis, Aitkin, Itasca and Carlton counties in an area that could use additional fuel sources for electric generation, drying purposes, and for district heating. Most of these lands are not presently used for anything although their potential for biomass production is great.

Although accurate measurements of the productivity of plants have not been made a single harvest of the standing crop on these peatlands could be expected to provide large amounts of energy which would otherwise not be utilized.

Data in Table 24 shows expected yields of biomass on peatlands from perennial plants and gives potential energy available in areas of one, 1000, and 10,000 acres in size. For example, if the present standing crop in one of these areas yielded 40 tons of dry biomass per acre, then a 10,000 acre area of peatland might provide 5.6×10^{12} B.T.U. of energy. This amounts to about one tenth of the annual energy used by the iron mining industries of Minnesota. This standing crop could be harvested at any time after the combustion technology has been developed for its use as a fuel. If combined with peat development, the harvesting of these crops prior to drainage and preparation of peatland for mining would hasten such development. In essence this would constitute the first stage of peatland development for energy. The lands would then be cleared of vegetation and ready for further development. In addition, harvesting of the surficial peat containing the plant roots would add considerably to the total. A six inch cut of surficial peat and roots where top growth had been removed would yield about 150 to 160 tons per acre of combustible organics. Following this harvest, the peatland could then be prepared for conventional peat harvesting.

Table 24. Estimated Biomass Yields and Potential Energy for Peatland Plants.*

Yield Estimates of Biomass (tons/acre)-dry	Potential Energy (B.T.U.) Area (acres) 1	1000	10,000
10	1.4×10^8	1.4×10^{11}	1.4×10^{12}
20	2.8×10^8	2.8×10^{11}	2.8×10^{12}
40	5.6×10^8	5.6×10^{11}	5.6×10^{12}
80	11.2×10^8	11.2×10^{11}	11.2×10^{12}

* Assumes caloric value of 7000 B.T.U./lb. for plant biomass and complete removal of above-ground standing crop.

Source: Soil Science Dept., University of Minnesota.

Following is a development scenario using existing biomass in combination with peat:

Step 1. Locate from 1,000 to 10,000 acres of brush-covered peatlands containing a dense stand of wetland shrubs and marsh vegetation. This land could easily be found within 20 to 30 miles of Iron Range cities, or near paper mills at Grand Rapids, International Falls or Cloquet (see enlarged area peat maps).

Step 2. Using a harvesting machine especially designed for cutting on peatlands, clearcut the standing crop of biomass to ground level. This operation could be done in fall or winter when land is frozen.

Step 3. In the spring, slice or cut the surface 6 inches of peat including the plant roots. A cutting machine would need to be designed for this operation. The design could be based on conventional sod cutters presently used on peatlands or could be like the German peat cutter used in Europe.

Referring to data in Table 24 it can be seen that if the yield of above-ground biomass was 40 tons/acre, a 1000 acre area would total 40,000 tons and 10,000 acres 400,000 tons of dry biomass. The 6 inch layer of peat and plant roots would yield 150 tons of 35% moisture peat per acre, 150,000 tons on 1000 acres and 1.5 million tons on 10,000 acres. The total amount of energy from this combined harvest on 1000 acres equals 0.56×10^{12} B.T.U. for biomass and 2.36×10^{12} B.T.U. for the 6 inch layer. If the area was 10,000 acres the total potential energy available would equal 29.2×10^{12} B.T.U. which is about one-half the energy used each year by the Iron Range taconite industry. This initial operation could be done in a very short time, possibly 2 or 3 years, and would greatly expedite the eventual development of energy farms as a renewable energy source, as well as conventional peat mining.

Step 4. On the peatlands cleared of a standing crop and the root layer on the surface of the bog, plans can now proceed for peat mining and energy farming using suitable plant species. If a 10,000 acre tract of peatland has been prepared in this manner, then a portion of it should be selected for continuous biomass production on a renewable basis and the remainder prepared for peat mining. The total potential energy from these combined operations could be about 19×10^{12} B.T.U. each year. Peatlands might best be used in this manner as an energy resource for both economic reasons and for conservation and wise use of our peat resources. Additional peatlands could be added as needed and the harvesting of the standing crop on these lands could eventually lead to rather large-scale peat mining and energy farms which could make a significant contribution to the State's energy needs.

Estimated lead times for the above peatland developments are as follows:

Standing crop biomass (single harvest)	1 - 2 years
Biomass energy farms on peatlands	3 - 5 years
Peat mining for direct combustion	1 - 2 years
Peat for gasification or conversion	3 - 6 years

VIII. ENVIRONMENTAL CONCERNS IN PEAT DEVELOPMENT

VIII. ENVIRONMENTAL CONCERNS IN PEAT DEVELOPMENT

Large-scale development of peatlands for energy and other uses should conform with the State of Minnesota's land use policies and pollution control regulations. Peatland clearing, drainage, mining and other activities should be carefully planned well ahead of time with due regard for any possible harm to the natural environment.

Selection of peat areas least likely to create any environmental problems is the first step. This can be accomplished by making detailed inventories including the location, type and quality of peats, the native vegetation present and the hydrology of the area. An environmental assessment can then be made of a specific area suitable for development. Site selection should be based on land suitabilities as determined by environmental resource inventory and analysis. Trade-offs must be determined between uses of peatlands and water for energy development versus uses for wilderness preserves, hunting and recreation, and other competing uses such as agriculture and forestry.

Some of the more important environmental concerns that must be evaluated are the following:

a. Water quality effects.
   1. Turbid waters to receiving streams from draining peatlands.
   2. Acid waters to receiving streams.
   3. Sedimentation of receiving streams from runoff of peatlands.
   4. Erosion and stream alterations.
   5. Pollutants toxic to fish.
b. Flooding due to ditching peatlands.
c. Effects on regional and local water-table levels.
d. Effect on water recharge aquifers.
e. Effect on native vegetation and wildlife.
   1. Migration of species.
   2. Destruction of habitat.
   3. Food chain effects on wildlife and water fowl.
f. Fear of destruction of unique peatland types and rare bog plants.
g. Possible destruction by fires.
h. Possibilities of air and water pollution from gasification plant.

Many of the above concerns will not be of any consequence if the detailed peat, vegetation, and wildlife inventories have been made prior to any development.

Also, the experiences in peat development in Europe have shown that large-scale operations have not caused any serious environmental problems. In Sweden, Finland and Ireland, they have strict regulations pertaining to peatland development. Most of these countries have laws specifically to protect the environment. Also they stipulate that only so much peat can be removed or mined and it then the land must be replanted to trees, crops, used for wildlife, or ponds must be created. On the basis of European experience, properly managed peat mining systems have not caused wind erosion, nutrient pollution, degradation of water or any other adverse environmental problem.

Any development of a peat extraction enterprise for energy should be compatible with a wise land use policy and a water resource management program. Experiences in both U.S., Canada and Europe have shown that where peatlands have been drained and mined the wildlife habitats have been measurably improved. Peatlands in their natural condition are rather poor habitats for most wildlife other than affording protection for moose and deer in the winter and providing food for beaver, sharp-tail grouse and a few other species in the summer. Drained peatlands, on the other hand, provide some open water in the many ditches for waterfowl to breed, a better food supply for deer, moose, and grouse. and an improved habitat for a variety of wildlife. Minnesota's experience with wild rice paddies is an example of transforming unproductive natural bogs into productive waterfowl and wildlife habitats through man's activities. Reclamation of mined peatlands should produce the same improvement in habitat.

Controversies concerning the utilization of peat as an energy source probably will surface but if we carefully evaluate the options in terms of human values and needs and exercise prudent environmental constraints there is no reason why some of these vast peat resources should not be developed as an alternate energy source.

Development of new sources of energy such as peat, biomass grown on peat, and others is urgently needed now. Conversion processes to gas or solid fuels may soon be a feasible alternative. Many important decisions regarding the development of peatlands as an energy source while maintaining the integrity of the environment need to be made soon. Environmental, social and economic studies as well as the inventories of peatlands are urgently needed.

Conservation and preservation of some of our peatlands useful for scientific and educational purposes should also be a high priority in any planning decisions. Perhaps those in decision-making positions should ask the question -- How much energy available in Minnesota peatlands should be developed in the future to help alleviate impending shortages?

IX. SOCIOECONOMIC CONSIDERATIONS IN PEAT DEVELOPMENT

A. General Considerations

1. Sociological Concerns

2. Economic Concerns

B. Published Socioeconomic Studies Concerned with Peat Development.

C. Revenues from Peat Development

D. Pros and Cons Regarding Peat Mining

1. Environmental Issues

2. Socioeconomic Issues

E. Local Concerns

1. Lake of the Woods County

2. Koochiching County

IX. SOCIOECONOMIC CONSIDERATIONS IN PEAT DEVELOPMENT

A. General Considerations

Since the announcement by Minnegasco in July of 1975 of their intention to construct a large-scale gasification plant to eventually utilize over 100,000 acres of peatlands in Beltrami, Lake of the Woods, and Koochiching counties there has been much speculation concerning the social, economic and environmental impact on the area.

Social, economic and environmental impact studies are needed to evaluate the local, regional and state-wide effects of such development and to provide a general policy to be followed for this and any future developments.

County, regional and state resource development commissions and planning agencies working together are in the best position for collecting baseline data, assaying public attitudes and evaluating the potential impacts on specific communities, areas and regions.

1. Sociological Concerns

Since all the large peatlands in Minnesota occur mainly in sparsely populated, rather remote areas, any development will have its most effect on rural residents such as isolated farmers and small rural communities. A sudden influx of workers in an area due to large-scale peatland development for a large gasification plant, for example, would likely have the following influences:

a) Demands for more public services.

b) Demands for increased health care and safety systems.

c) Increased needs for more utilities.

d) Provision for more roads.

e) A need for an improved infrastructure.

f) Increased recreational facilities.

g) Changes in land-use zoning ordinances.

h) Provision for adequate housing.

i) Provisions in case of ethnic diversity.

j) Immigration problems.

2. Economic Concerns

The main economic impacts that must be evaluated include the following:

a) Employment/unemployment.

b) Economic base characteristics.

c) Tax revenues and expenditures.

d) Personal and business income.

A thorough study of these economic concerns should be made by appropriate planning commissions and the local citizens informed of both the benefits and disadvantages of this industrial expansion potential.

B. <u>Published Socioeconomic Studies Concerned with Peat Development</u>

There have been three studies published recently concerning the impacts of large-scale peat development and several additional studies are presently underway. The studies which particularly emphasized socio-economic problems were as follows:

1) Peat Development. Report No. 1 by the Headwaters Regional Development Commission, Bemidji. August 20, 1975.
2) Socioeconomic Impact Study. A preliminary assessment of Minnegasco's proposed peat gasification project. Midwest Research Institute, March 1, 1977. (See Appendix I.)

The first report prepared by the Headwaters Regional Development Commission was a preliminary study to provide a summary of information regarding both the benefits and problems associated with peat development in Economic Region II of Minnesota. Many of the social and economic problems were discussed and recommendations were made that should be considered by governmental leaders and citizens in the area in order to better prepare in the event of peat development.

The second report, prepared by Midwest Research Institute for Minnegasco, is a rather complete socioeconomic study dealing with the various impacts of a proposed peat gasification plant in N.W. Minnesota--in a portion of Koochiching, Lake of the Woods and Beltrami counties. In the summary of their report they state the following:

> "In addition to the obvious economic benefits that would be derived from the gasification plant operation, such as increased employment, growth of the economy, enhanced municipal services, and broadening of the tax base, consideration was given to the attendant problems that would arise during the plant construction and operational phases. The anticipated influx of people during the constructional phase and, to a certain extent, during the operational phase, will lead to the necessity of providing planning for housing, expansion of municipal facilities, and educational services. The pros and cons of development were thoroughly considered, and a detailed discussion of the anticipated impacts is presented in this report."

As a result of their study they recommend the following:

a) Increased dissemination of information to the public regarding plans for edvelopment.

b) Suggested that Minnegasco assist in the local, county and regional planning processes in order to provide lead time for implementation.

c) Evaluation of other impacts such as environmental, ecological and aesthetic.

d) Continue more detailed socioeconomic studies as more technical information becomes available.

Another published report entitled "Peat Report - Phase I. Environmental effects and preliminary technology assessment" was prepared by Midwest Research Institute for the Minn. Department of Natural Resources with funds provided by the Upper Great Lakes Regional Commission. Some of the recommendations in this report concerned with policy and socioeconomic problems were as follows:

a) An intensive study of possible peatland policy options should be performed. This study should be made with inputs from the general public, state legislators, regional development commissions and state and county officials.

b) The regional development commissions should coordinate county and municipal zoning ordinances pertaining to peat areas.

c) An effort should be made to support a peatland development policy that would promote a broader based local economy and that would offer year-round employment benefits.

d) A policy should include provisions for financial support for expanded public services.

e) Suggest more public information meetings be held in areas likely to be affected.

C. <u>Revenues from Peat Leases</u>

The anticipated economic benefits to an area that would result from leasing public peatlands (state and county) in any large-scale peat development were not considered in any of the published peat development studies. It is only possible to give a rough estimate of lease charges to be collected by the state in the future for mining peat as changes in their leasing policie are even now being considered in anticipation of increased demand for peat. At present there is only one large-scale lease on a producing peatland. This is a horticultural peat lease on a production area of nearly 1000 economic problems having developed. At a 30¢/ton severance tax rate for 12 million tons per year the annual revenues from this tax would amount to $3,600,000 and if accrued for the 20-year life of the lease would total $72 million dollars. If the local governments got a fair share of the revenues from leasing they would realize as much as 6 to 8 million dollars each year in addition to taxes paid by the gasification plant, increased property and income taxes, etc.

D. Pros and Cons Regarding Peat Mining

If Minnesota is to seriously consider using peatlands as an alternative energy source, at least for its short-term energy needs, it must address itself to several main issues including both real and imagined conflicts. Following is a list of some of the more important issues confronting state decision makers.

1. Environmental Issues

There appears to be a continuing debate between those who want to protect the environment and those who want to increase energy supplies. This is particularly true in the case of strip mining of coal and many people feel the same problems would exist in the case of mining the surface of peatlands. The mining techniques for peat are much different from coal and don't require removal of large quantities of overburden material which requires expensive and difficult reclamation projects to restore the land.

In the case of peat it is felt that from experiences in Europe we can provide some much needed energy and also protect the environment. There are many options available to us for successful reclamation of mined peatlands. In many cases reclaiming mined peatlands would improve the peatlands for agricultural and forestry purposes as well as provide a better habitat for wildlife or create lakes for fish and water fowl.

Energy developers are concerned about the many restrictive amendments to existing or future regulations that would deter or delay peat mining. Let us avoid if possible the type of confusion that delayed construction of on-land taconite tailings disposal by Reserve Mining Company and the controversies over nuclear energy development. The only winners in these conflicts are the activist lawyers. We must, if possible, speed up the process of public hearings, eliminate long and needless studies and better facilitate issuing of permits and reduce the time necessary to obtain leases on state-owned peatlands. Interim leasing policies on peatlands could presently be used in the short term which could be changed in the future when the state develops a more meaningful leasing procedure for long-term large-scale development. It will be 5 to 8 years before any large-scale development could possibly occur and in the meantime for the few thousand acres needed at present the state has a leasing policy they are using for horticultural peat leases that could be adopted.

A long-time lease on public lands for large-scale energy development (such as Minnegasco's gasification project) should require the following for the state to evaluate a lease application:

1) Plan of development

This would include the proposed mining technology as well as plant construction, transportation systems, etc.

2) Monitoring the environment

This would include water quality and air quality monitoring as well as disposal of waste products such as stack emission and ash removal at an on-land disposal facility.

3) Reclamation plan

Plans for reclaiming peatlands after mining the peat should be included in the application. Type of reclamation would be based on detailed survey of area and would consider quality of peat, type of mineral soil below peat, suitability for a particular crop or use.

2. Socioeconomic Issues

The development of large-scale peat mining such as required by a large gasification plant (Minnegasco's Proposal) conjures up rather exaggerated fears in the minds of some local citizens in the area. People are primarily concerned with changes in lifestyles, opportunities for local employment, changes in tax structures, revenues generated, supply of energy for local use, need for expanded schools and social services and what is to be the fate of th area after the 20 year lease period. Most of these expressed fears are unfounded for the following reasons:

1) Industrial development probably would not be aesthetically acceptable to a few citizens but would be welcome by many who are presently unemployed and for the young who would prefer to stay in the area after finishing school.

2) The benefits that could accrue because of development far outweigh the disadvantages. The economic benefit to the area might equal or exceed the impact of taconite development on the Iron Range. During the construction phase of a gasification plant, for example, an estimated $83 million dollars in wages received by workers would have a

great impact on retail sales and services. Monies received from the leased land would be returned to local units of government and school districts in the area. Assuming royalties of 70¢ per ton for peat, a large-scale, 250 million cubic foot per day, plant would use 12 million tons per year and would return $8.4 million to the local economy. Part of this revenue could be used as a severance tax or a special tax could be levied to be used to reclaim the peatland for future production uses. This would assure maintaining or improving the integrity of the area and allay the fears of some that the area would become an abandoned unproductive wasteland. Also money from this special tax could be used for rehabilitation purposes such as relocating unemployed workers, establishing new industries such as agricultural or forest product enterprises.

3) A gasification plant would more than likely extend beyond 20 years as predictions are that the need for gas will probably be greater in the future than it is now.

4) Many people in northern Minnesota believe that agriculture and forestry on reclaimed peatlands would be a failure. This belief is based partly on the fact that the earlier attempts to drain and farm peatlands in the 1920's were not successful. These ill-advised drainage schemes were doomed to failure from the start. The science of peatland farming has greatly improved since those development schemes failed. Fertilizers were not available then, drainage was inadequate for crops, and farmers did not manage economic units. Present technology of agriculture on peat is well developed and operations are very successful in Europe, Russia, and the U.S. as a result of research on these soils. In fact, Europeans feel that reclaiming mined peatlands creates more productive agricultural land than clearing, draining and farming existing undeveloped peatlands. This is particularly evident in Ireland where reclamation of mined peatlands produces better crops than on native undrained bog lands.

E. <u>Local Concerns</u>

1. <u>Lake-of-the-Woods County</u>

Prepared by Gary Lockner, Planning and Zoning Administrator

Mr. Lockner has the following comments regarding local and state-wide energy needs and the use of peat as an energy source:

a) He feels that each locally available source of energy (wood, hydro, solar, wind, imported western coal, etc.) should be used considering when, where and how it can best be used.

b) He feels that large peat bogs could be used to develop large-scale gasification or electric power generation to be exported to the Metropolitan (Twin City) areas where most of the need exists.

c) The smaller bogs (less than 50,000 acres) could be used for production of energy for local consumption in the region either by local industries (such as Boise-Cascade at International Falls) or for municipal heating purposes.

d) He feels that electrical or gas energy production from peat could be controlled and only used periodically to supplement other energy sources as needed for metropolitan areas during periods of either peak demand or during periods when other energy raw materials are not readily available.

Concerns of local citizens regarding peat development in Lake of the Woods County are summarized as follows:

1) Possible environmental damage

   a) Possibilities of air and water pollution from mining and processing peat for energy

   b) Reclamation of mined peatlands should be planned before mining begins.

2) Local citizens are concerned about their own energy needs. The local people are worried about any future reduction of their energy supplies and are more concerned about local energy development. Could they use some of the mined peat locally for energy?

3) They are concerned about what would happen to the local economy if peat mining (for gas or electric) ceased if other energy sources became plentiful again in the future.

4) They are concerned about revenues received locally from royalties on peat mined on county or state land.

5) They are concerned about the effects on the local political scene if development takes place.

6) Mr. Lockner strongly supports an inventory of peatlands by the state D.N.R. to determine the areas of peatlands best suited for energy, agriculture and forestry. He feels we should conserve our peat resources as long as possible and mine only what is absolutely necessary.

7) He considers peat a renewable resource even though its rate of growth is slow and suggests we investigate the possibility of growing wetland grass, sedge and other type plants for biomass production on peatlands.

8) Mr. Lockner raises the question of how can we best use peat relative to the State's total energy use program in the future.

9) He feels that the answers to most of the local concerns can be found rough sound land-use planning and public information meetings.

2. Koochiching County

Prepared by Ruth McLinn, Koochiching Co., Zoning Administrator

a) Local Concerns -- General

The local citizens of Koochiching County have expressed their concerns regarding what effect a large-scale peat development such as Minnegasco's proposal would have on them--their lifestyles, possible environmental damage, pollution control plans, economic advantages, such as increased employment, taxes, revenues from peat mining, etc.

Their immediate concerns about the development included:

1) When is the development to begin

2) Where is it to be located and what is it all about as might effect them locally.

Some of the most frequent questions asked fall in the following categories:

b) Environmental Effects

1) Water pollution due to plant operation and peat harvesting

2) Flooding of local streams due to drainage

3) Air pollution caused by plant operation

4) Believe E.I.S. is necessary

5) Effect of harvesting peat on existing wildlife and want to know what changes in wildlife species will result

6) Effect of large-scale clearing on reduction of hunting areas, recreation (snowbiling, hiking)

7) Have strong feelings about preserving some of the peatlands for future generations.

c) Economic and Social Effects

1) Increased employment due to mining and processing peat. They want to know how many additional jobs and skills needed.

2) Effects on tax structures.

3) Effects on revenues. To whom paid. How much royalty does the County realize from primary peat. How much goes to state.

4) Effects on local services.

a. schools

b. roads - how many new roads. where?

c. fire protection

d. transportation - bus service, etc.

5) Waste disposal plant needs.

6) Water supply.
7) Schools.
8) Law enforcement
9) Hospitals and health care.
10) Effect of peat development on existing forest products industry. Is it compatible?

d) Other Concerns

Local energy needs.

1) Local people want assurance that their energy needs are met and that all the synthetic natural gas produced in their area is not transported to Minneapolis - St. Paul area.
2) Some concern about whether some of the peatlands should be used for other uses such as direct combustion (e.g. such as a district heating plant at International Falls). Also, since Canadian fuels will soon be curtailed the Boise-Cascade plant which now uses 20,000 cu.ft. of natural gas (Canadian) per day, might conceivably convert from natural gas to peat as a substitute.

X. REFERENCES

REFERENCES

1. Bay, Roger R. 1967. Factors influencing soil moisture relationships in undrained forested bogs. International Symposium on Forest Hydrology. Penn. State Univ. pp. 335-443. (Pergamon Press)

2. Boelter, Don H. 1969. Physical properties of peats related to degree of decomposition. Soil Sci. Soc. Amer. Proc. 33:606-609.

3. Boelter, D.H. 1974. The hydrologic characteristics of undrained organic soils in the Lake States. In Histosols: their characteristics, use and classification. Soil Sci. Soc. Amer. Spec. Publ. No. 6.

4. Cederquist, K.N. and P. Bering. 1952. Wet combustion: a process for the utilization of peat. Acta Polytechnica No. 105. Sweden.

5. Classification of Peat. 1976. Report of Commission I, Intl. Peat Society. Helsinki, Finland.

6. Davis, C.A. Uses of peat for fuel and other purposes, Bureau of Mines. Bull. 16, p. 110, 1911.

7. Davis, John H. The Peat Deposits of Florida. Florida Geological Survey Bulletin No. 30, State of Florida. 1946.

8. Farnham, R.S. 1963. Classification of peat in the U.S. 2nd International Peat Congress. Leningrad, Russia.

9. Farnham, R.S. 1964. Peat resources of Minnesota, W. Central Lakes Bog, St. Louis Co., Minnesota. Report of Inventory No. 1, Iron Range Resources and Rehabilitation.

10. Farnham, R.S. and D. Grubich. 1964. Peat resources of Minnesota, Cook Bog, St. Louis Co., Minnesota. Report of Inventory No. 2, Iron Range Resources and Rehabilitation.

11. Farnham, R.S. and H.R. Finney. 1965. Classification and properties of organic soils. Advances in Agronomy, Vol. 17, pp. 115-160.

12. Farnham, R.S. and D. Grubich. 1966. Peat resources of Minnesota, Red Lake Bog, Beltrami Co., Minnesota. Report of Inventory No. 3, Iron Range Resources and Rehabilitation.

13. Farnham, R.S. 1967. Potential of Minnesota's Peat Resources. Minnesota Science, Vol. 23, No. 3.

14. Farnham, R.S. 1968. Classification system for commercial peat. 3rd Intl. Peat Congress. Quebec, Canada.

15. Farnham, R.S. and D. Grubich. 1970. Peat resources of Minnesota potentiality report, Fens bog area, St. Louis Co., Minnesota. Iron Range Resources and Rehabilitation.

16. Farnham, R.S. 1974. Classification criteria for a Minnesota peatland. Intl. Peat Soc. Spec. Symposium. Glasgow, Scotland.

17. Farnham, R.S. et al. 1975. Minnesota's peat as an energy source - quality and quantity. Intl. Peat Soc. Proc. of Symposium of Comm. II. Combustion of Peat. Kuopio, Finland. pp. 25-33.

18. Farnham, R.S. 1976. Influence of intensive agriculture on water quality in peatlands. Proc. 5th Intl. Peat Congress. Poznan, Poland.

19. Farnham, R.S. and D.H. Boelter. 1976. Minnesota's peat resources: their characteristics and use in sewage treatment. Agriculture and Energy. A national symposium on freshwater wetlands and sewage effluent disposal. Univ. of Michigan, School of Natural Resources. Ann Arbor, pp. 241-255.

20. Grubich, D.N. and R.S. Farnham. 1972. Inventory of Minnesota peatlands. 4th International Peat Congress; Helsinki, Vol. 1, pp. 461-469.

21. Moore, P.D. and D.J. Bellamy. 1973. Peatlands. Springer-Verlag Co., New York. 221 pages.

22. Kazakov, George. 1955. Soviet Peat Resources: a descriptive study.

23. Proceedings 2nd Intl. Peat Congress, Leningrad. 1963.

24. Proceedings 3rd Intl. Peat Congress, Quebec. 1968.

25. Proceedings 4th Intl. Peat Congress, Helsinki. 1972.

26. Proceedings 5th Intl. Peat Congress, Poznan, Poland. 1976.

27. Soil Conservation Service, U.S.D.A. 1967. Conservation needs inventory.

28. Soper, E.K. 1919. The peat deposits of Minnesota. Minn. Geol. Survey Bull. 16.

29. Soper and Osbon. 1922. The occurrence and use of peat in the U.S. Bull. 728. Dept. of Interior, U.S. Geol. Survey.

30. Suoninen, A. 1975. A short review of the use of fuel peat in the world. I.P.S. Symposium, Combustion of Peat. Kuopio, Finland.

31. U.S.D.A. 1975. S.C.S. Soil Taxonomy Agriculture Handbook No. 436.

32. Verry, E.S. and Don H. Boelter. 1972. The influence of bogs in the distribution of streamflow from small bog-upland watersheds. Presented at the UNESCO Intl. Symp. on the Hydrology of Marsh-Ridden Areas. Minsk, Byelorussian SSR, July 17-24, 1972.

XI. APPENDICES

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APPENDIX A

Minnesota's Peat Resources: Their Characteristics and Use in Sewage Treatment, Agriculture and Energy

Rouse S. Farnham and Don H. Boelter

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1976

ABSTRACT

Minnesota has three million ha (7.5 million acres) of peatlands, the most of any state in the conterminous United States. The most extensive areas of these peatlands are located in the large glacial lake plains in northern Minnesota. A few of the largest areas are vast expanses of peat ranging up to 200,000 ha in size and only a very small percent of them are presently being utilized for agriculture or forestry.

One of the more important resources of peatlands is water and the headwater areas for several major river basins are located in the northern forested regions of Minnesota on these peat-covered wetlands. The hydrologic role of peatlands may not be as significant as once thought. Rather than being giant sponges soaking up snowmelt and early spring rains and gradually releasing runoff through the summer, peatlands often play a less significant role in the seasonal distribution of runoff with a large portion of the annual flow occurring prior to June 15.

Drained and fertilized, these organic soils are productive for both field and forest crops. They are particularly suited to the production of vegetable crops, seed crops, forage crops, wild rice and other specialty crops although their present use for these crops is limited.

The unique physical properties of peat materials, especially Sphagnum types, suggest several potential uses for harvested peat. Their high water storage capacity and low density makes them very useful as a soil amendment to improve the physical properties of mineral soils or as a horticultural

medium for plant growth. The relative high caloric values of peat have led to their use as fuel in Europe and similar potentials exist in Minnesota

Peat materials have been used successfully as filter systems for treatment of campground sewage wastes in several national forests. Renovation of wastewaters is quite good using a combination of the filtering and absorbing action of the peat and the harvest of plants growing on the filter beds for assimilation and removal of nutrients.

INTRODUCTION

The most unique type of freshwater wetland in Minnesota is the 3 million ha (7.5 million acres) of peatland, the largest acreage of peatland in any state in the conterminous United States. Much of Minnesota's peatland is located in the northern forested regions. However, they are often considered wastelands of low value and produce very little merchantable timber compared to their upland counterparts.

Although limited information is available on the use of organic soils for sewage waste treatment, there is some evidence indicating they may be good sites. The exchange or adsorption capacity of organic materials is usually quite high and the organic material under proper physical conditions provides an ideal medium for biological activity, often an important factor in the recycling of nutrients. Further, the low timber productivity is due in part to ombrotrophic conditions, thus nutrients added by way of sewage wastes may have a beneficial fertilizing effect on plants.

The need to understand the renovation process is particularly evident as it relates to waste disposal on organic soils. The unique properties of peat materials and organic soils raise problems not necessarily common to waste disposal on mineral soils. The proximity of peatland areas to streams and lakes makes it evident that even more caution is necessary to insure that these waters are not degraded.

Although peatlands generally have only minor effects on the seasonal distribution of streamflow, they do demonstrate a temporary storage and slow release of storm flows due partly to the nearly level topography and also the large physical detention storage of peat materials (Verry and Boelter, 1972). This leveling of storm flow runoff is another factor that could enhance the ability of peatlands to improve the quality of run-off waters, providing greater opportunity for physical, biological, and chemical systems to adsorb nutrients from the water.

Farnham and Brown (1972) described a method of wastewater filtration using peat materials over sand. Later, Farnham (1974) showed that when peat filter beds were cropped to quackgrass, nearly all the N and P could be removed by plant uptake. These basic studies have led to the construction of several peat filter beds at campgrounds in the Chippewa National Forest of northern Minnesota. A recent unpublished paper by Brown and Farnham (1976) gives the design criteria for peat wastewater filtration systems and suggests modifications to improve their efficiency.

CHARACTERISTICS OF PEAT

Peat is a rather unique natural resource which occurs in a wetland ecosystem that favors accumulation of plant biomass and storage of energy from the sun through the process of photosynthesis. Peatlands may be considered a natural nutrient sink as well as an energy-capturing system.

The classification of organic soils in the U.S. is based on the decomposition stage of the several peat material types. The three peat types are fibric, hemic, and sapric, respectively listed in order of increasing decomposition. Briefly, these peat materials are characterized as follows:

1. Fibric - least decomposed type, lowest ash content and bulk density, highest saturated water content and greatest amount of fiber. Three distinct subtypes include the very acid, relatively undecomposed Sphagnum moss peat, the less acid Hypnum moss types and the reed-sedge-grass peats.
2. Hemic - moderately decomposed type, moderate bulk density values, medium saturated water contents and fiber contents and variable in acidity.
3. Sapric - most decomposed type, highest bulk density, lowest fiber and saturated water content and highest in ash; acidity is variable.

The hydrogeologic characteristics of the peatland area are also significant. Bay (1967) identified two hydrogeologic types of small bogs in north-central Minnesota, perched bogs and groundwater fens. Perched bogs would appear to have the most potential for sewage effluent disposal. Water level control is probably more feasible as their only source of water is precipitation as compared to the groundwater fen where there is a continual supply of water from the groundwater basin. Furthermore, in the case of the perched bog, the only output of water from the watershed system is that occurring at the outlet which can easily be monitored for changes in water quality. In the case of groundwater fen, the relationship with the overall water system is much more complex and it would be much more diffucult to monitor for changes in groundwater quality resulting from sewage application.

The results of a three-year study of water table levels in both raised bogs and fen areas in the large glacial lake peatlands of northern Minnesota showed a direct relationship to the difference between total precipitation and actual evapotranspiration. Measured water table levels in these peatlands during summer and fall were essentially the same as calculated values using rainfall data and estimated evapotranspiration rates. The hydrologic events in large northern Minnesota peatlands can be characterized seasonally as follows:

Spring - maximum runoff from snowmelt, saturated conditions and highest water table levels.

Summer - water table a function of precipitation minus runoff, tending towards falling water levels in late summer.

Fall - lowest water table with normal precipitation, less evapotranspiration and a tendency towards equilibrium conditions.

Winter - equilibrium conditions occur after surface freezing, constant water levels.

Peat should be considered a renewable resource even though its growth rate is extremely slow. Values given in the literature showing the rate of peat formation vary greatly from place to place but average values of the annual incremental increase range from 0.1 to 0.2 cm. Expressed as dry weight of biomass this amounts to 1 to 2 tons per acre per year. A reed-swamp type of wetland community in Germany as reported by Moore and Bellamy (1973) was shown to be extremely productive. Scirpus lacustris growing on a German peatland had an annual net production of 4600 gm/m^2 (20 short tons/acre) on a dry basis. This productivity figure obviously is very high for peatland environments and it far exceeds most agricultural crop production rates. Typha latifolia (cattail) also is reported to produce very high biomass on wetlands. The potential for very high biomass production on managed peatlands should be investigated as an alternate energy source.

UTILIZATION - PRESENT AND POTENTIAL

When properly drained and fertilized peatlands are well suited to a variety of crops. These include certain vegetable crops, forage and grain crops, certified grass seed production, wild rice, cranberries, turfgrass and many others. In northern Minnesota the cool summer climate limits the kind of crop grown. The potential exists for several new crops to be grown on organic soils such as the new hybrid wheats, sugarbeets and new seed crops.

Peats are presently used to a limited extent as soil conditioners, mulches and as a growing media for greenhouse crops. The horticultural peat industry is well developed in several European countries and the demand for various peat products for this use is expanding rapidly. In Minnesota, there are several peat producers but they are using less than 2,000 ha of peatlands for their harvesting operations. Michigan produces the largest amount of horticultural peat in the U.S. but the potential exists for large scale development of this industry in Minnesota because of the large reserves of high-quality peat. The U.S. Bureau of Mines (1974) tabulates the production figures for U.S. peat.

The present use of peatlands estimated by the Soil Conservation Service in their conservation needs inventory (1967) were as follows:

A. Cropland: 192,000 acres or less than 3% of total peatland acreage. This includes row crops such as potatoes, vegetables and field crops.
B. Forage and pasture: 750,000 acres or about 10% of total acreage.
C. Forests: 4.3 million acres or about 60% of total - commercial forests of black spruce, northern white cedar and tamarack occupied 2.4 million acres. Non-commercial forests occupied 1.9 million acres. These include lowland brush types.
D. Open peatlands: Estimated at 1.8 million acres.

Total peatland reported by this inventory was 7.2 million acres (2.9 million hectares). About 76% were over 1-1/2 meters in thickness.

As an energy source, in these times of rising energy costs, peat can now compete with lignite and coal. Although its caloric value is only about one-half to two-thirds that of high quality coal, it is about equal to lignite. Caloric values for peat on a dry basis range from 4000 to as high as 5300 cal/gm. A recent study by Farnham et al. (1975) suggests the potential of peat as an alternate or interim source of energy in Minnesota is probably feasible if the environmental integrity of peatlands can be maintained.

In addition to utilizing the peat itself for energy, peatlands are well suited for the production of several high-yielding native species of sedges, reeds, grasses and other wetland species that could be grown as a renewable energy source. Annual biomass yields as high as 30 to 50 metric tons per hectare have been reported in the literature. Many of these native species are particularly adapted to peatlands under existing natural conditions and with improved management it is possible to significantly increase their productivity. In Minnesota many large, continuous peatlands are available for such production of biomass and some exceed 10,000 ha in size.

The potential exists for large-scale energy farms on peatlands of Minnesota as a renewable and alternative energy source to be used both for production of synthetic natural gas and for direct burning to produce electricity and heat at selected northern Minnesota heating plants.

The value of peat as an energy source at present day fuel costs should be emphasized. Although the caloric value is lower than coals, peat has an advantage over fossil fuels in that it may be considered a slowly renewable resource, it is more highly volatile, and less polluting. Even considering its very slow growth rate (1 to 2 tons/acre/year), the total annual production of peat could be as high as 7 to 15 million tons. The delivered price for high grade eastern coal to northern Minnesota cities is presently about $60.00 per ton. Assuming peat to have 50% of the heating value of coal and 15 million tons annual productivity on peatlands, the value of peat as fuel would amount to 450 million dollars. Should this much peat be used each year for fuel, we could then utilize the existing resource for other things such as in agriculture, water storage, forestry, horticultural peat production, conservation of natural peatlands, wildlife and for wastewater treatment without depleting the present peat resources.

Since most of Minnesota's peatlands are public lands managed by either the Minnesota Department of Natural Resources or the U.S. Forest Service it is most likely that a State and Federal peatland policy will be forthcoming. This would assure wise use of these resources in the future and that ill-advised development does not occur which would pose an environmental threat and lead to eventual destruction of this valuable resource.

PEAT FOR WASTEWATER TREATMENT

Peat Sand Filter Systems

Peat filter beds constructed by the National Forests for treatment of secondary treated campground sewage effluent are being monitored to determine how well they are working. A filter bed at North Star Lake on the Chippewa National Forest has been observed most closely. The facility became operational in 1973 but vegetation on the bed wasn't well established until 1974.

The filter bed at North Star is the only filter bed that is built in a till-like material which permits the collection of all the discharge from the bed. Thus all inputs and outputs can be measured and a budget constructed for water and nutrients. Data is now available for 1973 and 1974; however, analysis of 1975 samples has been delayed by lack of funds.

Looking at the phosphorus balance sheet for 1974, 3.93 g/m^2 of phosphorus were added in the effluent and another 0.01 g/m^2 in rain for a total phosphorus input of 3.94 g/m^2. Only 0.11 g/m^2 of phosphorus were discharged in the outflow while 3.49 g/m^2 were removed by the vegetation. This leaves a difference of 0.33 g/m^2 which we are assuming was stored in the soil. If the 0.34 g/m^2 of phosphorus were absorbed in the surface 10 cm of peat it would result in only an 0.01 percent increase in phosphorus content by weight.

The renovation efficiency for phosphorus was around 99 percent. The harvested vegetation removed approximately two-thirds as much phosphorus as that added with the effluent. However, the organic soil itself could probably retain the phosphorus even if there was no vegetation growing on it. This may not be the case with nitrogen.

Nitrogen input in 1974 includes 15.62 g/m^2 added as effluent and 0.40 g/m^2 as rainfall for a total input of 16.02 g/m^2. The discharge water contained 1.82 g/m^2 of nitrogen. Harvested vegetation removed 18.00 g/m^2. Thus the total nitrogen output was 3.90 g/m^2 more than the total nitrogen input.

It's interesting to note the role the vegetation plays in removing the nitrogen with about 90 percent of the nitrogen discharged being accounted for by the vegetation. It appears the vegetation plays a more significant role in nitrogen removal than the phosphorus removal.

If the vegetation is significant to nitrogen renovation, there is a question relative to how the vegetation should be managed to most efficiently use nitrogen. Also, we found that as the vegetation got taller it seemed to fall over due either to lodging because of high nitrogen content or perhaps being physically beaten down by the water from the sprayer. At any rate, when this occurred, the grass would become matted to the surface of the filter bed and actually get moldy and kill itself out.

In 1974 we tried several different cutting systems to see if this could be avoided. We divided the bed into three parts and mowed the grass whenever it reached 4 inches on one part, 6 inches on another part, and 10 inches on the third part. We found that no lodging occurred when the grass was mowed at 4 inches. Some still occurred with mowing at 6 inches.

The 1974 yield is highest for the material that was cut at 4 inches. Next was the 10-inch and intermediate was the 6-inch. Preliminary data shows that the nitrogen content is also highest with the 4-inch cut material and the 10-inch is lowest. Presumably the shorter grass is more lush and green and has a higher nitrogen content than the taller grass which is at a more mature stage when cut.

The frequent mowing necessary to maintain 4-inch maximum height of rough-stalked bluegrass does add to the cost of maintenance of the filter bed. It's hoped that another kind of vegetation can be found which will not lodge if allowed to grow taller, and will still efficiently use nitrogen in its growth.

Ditched Peatlands

About a dozen peatland areas were being used for waste disposal in Finland in 1971 (Kamppi). Today there are over 20 ditched peat systems in operation there. In most cases, the effluents are municipal wastes from small villages but two instances involved food processing industires - one a dairy and the second a potato processing plant. A summary of data from seven disposal areas in operation during 1970 showed the following reductions: total phosphorus - 39%, total nitrogen - 62%, B.O.D. - 80%, coliforms - 99%, and enterococci - 95%. Significantly better results for phosphorus and nitrogen reduction were reported for one area at the Kesalahti church village with reduction of 82% and 90% respectively (Surakka and Kamppi, 1971).

Each of the peatland disposal areas in Finland were first drained to lower the water levels and thus force the waste material through the more decomposed peats in lower layers (Surakka, 1971; Surakka and Kamppi, 1971; and Kamppi, 1971). Boelter (1969) has demonstrated the differences in detention characteristics of peats which appear to make some drainage necessary for sewage treatment. Undecomposed peats usually found in surface or near surface horizons have large pores which permit very rapid flow of water, very likely too rapid to permit effective removal of nutrients. The deeper horizons of peat usually are more decomposed, having many small pores which do not permit the rapid movement of water. Kamppi (1971) noted that one of the serious problems of the Finnish disposal systems was overflow of effluent through the porous horizons during periods of high water tables.

Modified Peat Systems

The possibility exists for modifying the present peat systems by adding lime ($CaCO_3$) to the surface peat and adding a layer of saturated peat below the sand (Brown and Farnham, 1976). These modifications will promote efficient, long-term phosphorus and nitrogen removal by calcium phosphate precipitation and biological denitrification, respectively.

SUMMARY AND CONCLUSIONS

Peat and peatlands have been shown to have a variety of uses in agriculture, forestry, horticulture, waste treatment and as an alternative energy source. Minnesota has large reserves of peat that are not developed at present. We badly need accurate inventories of these resources as well as technological and environmental studies of peatland areas with greatest potential for development. The use of peat for waste treatment should be given high priority.

There is a real need for more consistent definitions pertaining to wetlands. Such terms as swamp, bog, marsh, peatland, wet meadow etc. currently used in professional scientific publications are often quite misleading. We suggest that those concerned with these terms work through intersocietal committees to develop meaningful as well as uniform terminology.

REFERENCES

Bay, Roger R. 1967. Factors influencing soil moisture relationships in undrained forested bogs. International Symposium on Forest Hydrology. Penn. State Univ. pp. 335-443. (Pergamon Press)

Boelter, Don H. 1969. Physical properties of peats related to degree of decomposition. Soil Sci. Soc. Amer. Proc. 33:606-609.

Brown, J. L. and R. S. Farnham. 1976. Use of peat for wastewater filtration - principles and methods. Submitted for publication. Fifth Int. Peat Cong., Warsaw.

Farnham, R. S. and J. L. Brown. 1972. Advanced wastewater treatment using organic and inorganic materials. Part I. Use of peat and peat-sand filtration media. Proc. 4th Int. Peat Cong., Helsinki. Vol. 4, pp. 271-286.

Farnham, R. S. 1974. Use of organic soils for wastewater filtration in Histosols: their characteristics, use and classification. Soil Sci. Soc. of Amer. Spec. Pub. No. 6. pp. 111-118.

Farnham, R. S. et al. 1975. Minnesota's peat as an energy source - quality and quantity. Int. Peat Soc., Proc. of Symposium of Comm. II. Combustion of Peat. Kuopio, Finland. pp. 25-33.

Kamppi, Armas. 1971. (Studies of waste water disposal on peatland forest basin infiltrations systems which were in effect in Finland in 1970.) National Board of Waters, Finland: Report A4, 120 pp. (Finnish-English Summary).

Moore, P. D. and D. J. Bellamy. 1973. Peatlands. Springer-Verlag Co., New York. 221 pages.

Surakka, Seppo. 1971. (Some observations on the possibilities to infiltrate waste water in peatland according to results obtained at Kesalahden Town, Finland.) Vesitalous 3(5):26-31. (Finnish-English Summary).

Surakka, Seppo and Kamppi, Armas. 1971. (Infiltration of waste water into peat soil.) Suo 22:51-58. (Finnish-English Summary).

U.S. Bureau of Mines. 1974. Peat in U.S. Bureau of Mines Yearbook. Washington, D.C., U.S. Govt. Printing Office. Soil Conservation Service. 1967. Conservation Needs Inventory. Minnesota.

Verry, E. S. and Don H. Boelter. 1972. The influence of bogs on the distribution of streamflow from small bog-upland watersheds. Presented at the UNESCO Intl. Symp. on the Hydrology of Marsh-Ridden Areas. Minsk, Byelorussian SSR. July 17-24, 1972.

MINNESOTA'S PEAT AS AN ENERGY SOURCE--
QUALITY AND QUANTITY

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ABSTRACT

Minnesota has 3 million hectares of peatlands. Most of the extensive peatland areas occur in glacial lake plains in the northern part of the State. A few of these areas are large contiguous peatlands that range up to 200,000 hectares in size. These peatlands are remarkably uniform as to quality and sufficiently deep to be well suited for fuel peat production as an alternative energy source. Preliminary data on the energy value of Minnesota peats shows a range of 4000 cal/gram to almost 5000 cal/gram for a wide variety of peat types in the State.

Large-scale utilization of Minnesota's peat resources as an alternative energy source in an energy-poor State could be a significant resource development project. Detailed surveys of these peatlands would aid in the development of these resources.

INTRODUCTION

Minnesota's peatlands, which total about 3 million hectares might well be considered one of our most important undeveloped natural resources. At the present time, only about 3.5 percent (100,000 hectares) of the total reserves are utilized and these mostly for agricultural production. A few of the areas are very large contiguous peatlands that range up to 200,000 hectares in size. These extensive peatlands occur in large glacial lake plains in the northern part of the State.

Preliminary data on the energy value of Minnesota peats shows a range from about 4,000 to 5,000 calories per gram for a wide variety of peat types. This compares favorably to energy values reported for peat in several European countries.

Large-scale utilization of Minnesota's peat resources as an alternative energy source in an energy-poor State could be a significant and timely resource development project. Detailed surveys of these peatlands as well as economic and environmental assessments would greatly aid in the development of these resources.

This paper includes a discussion of the geographical distribution of Minnesota's peat and gives the development potential by peat areas. It also compares the classification of peat types in the world with that of the new United States classification system as they relate to energy value. Data is presented showing the energy values of Minnesota's peats related to type of peat, ash content, depth, and volume weight.

DISTRIBUTION AND DEVELOPMENT POTENTIAL OF MINNESOTA'S PEATLANDS

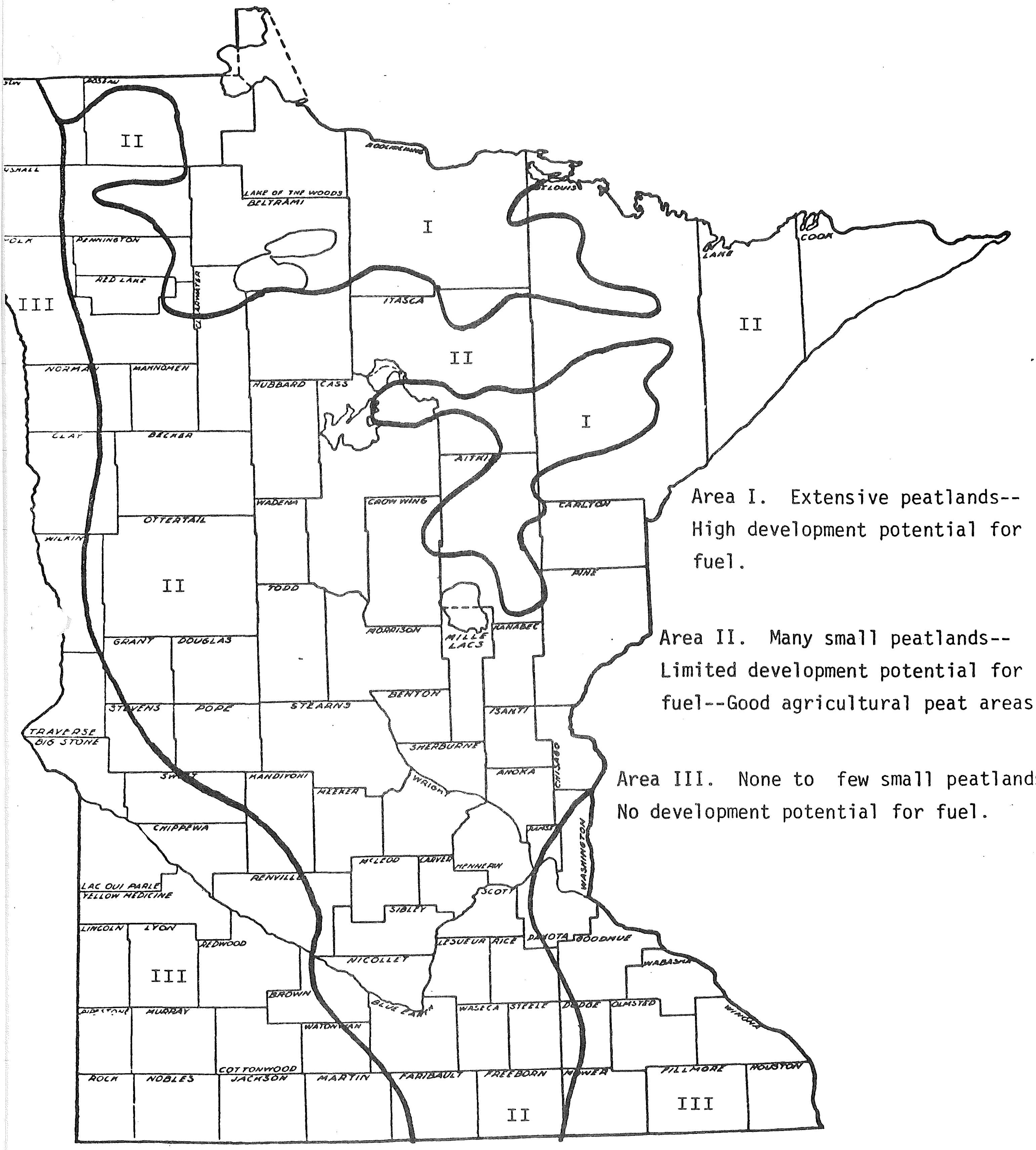
The distribution and extent of Minnesota peatlands is shown on Figure 1 as well as the relative development potential for fuel use. Peat area I, located in the large glacial lake plains in northern Minnesota, has the most extensive peatland areas. Many individual peatland areas exceed 40,000 hectares in size while some are as large as 100,000 hectares in total area of contiguous peat broken only by deeply entrenched streams. These large peatland massives are essentially very gently sloping, plateau-like peat deposits occurring 8 to 15 meters above stream levels on dissected lake plains--Glacial Lake Agassiz, which extends northward from Minnesota into Canada contains the largest peatlands of any area in the State. These occur mostly in Roseau, Lake of the Woods, Beltrami, Koochiching, and North St. Louis counties. Large peat areas also occur in Aitkin, Itasca and South St. Louis counties in lake plains of glacial lakes Aitkin and Upham.

The development potential is very high for many of the large peatlands in peat area I.

Peat area II, which occurs in the central and northeast portions of Minnesota contains many small peatland areas. These peats have developed principally in depressions of rolling glacial moraines. Some individual areas may be as large as 10,000 hectares in size but most of them are less than 1,000 hectares in extent.

Peats in area II have limited development potential for fuel production because many are shallow, small in size and high in ash content. They are,

Fig. 1. DISTRIBUTION AND DEVELOPMENT POTENTIAL OF MINNESOTA'S PEATLANDS



however, excellent peatlands for agricultural and horticultural corp production. One 10,000 hectare area in extreme southern Minnesota near the Iowa border has been developed for over 40 years and is a highly productive area for vegetable crop production. Other intensively farmed peats are located near Minneapolis-St. Paul in Anoka County where special vegetables and bluegrass turf are the main crops grown.

Area III, Figure 1, contains only a very few small peatlands. It offers no peat fuel development potential. The area consists of rolling, highly dissected loess-covered areas in southeast and southwest Minnesota and the flat silt and clay areas in Glacial Lake Agassiz of northwestern Minnesota.

ENERGY VALUES OF MINNESOTA PEAT

The value of Minnesota peat as a fuel or energy source is related to type of peat, ash content, volume weight, and stage of decomposition. A comparison of relative energy values as related to the major classification systems in use today is shown in Table 1.

Table 1. Classification of peat types related to energy value.

Classification	Decomposition Classes		
System	Low	Medium	High
U.S.D.A. System 1/	Fibric	Hemic	Sapric
	------percent------		
Soviet Union System 2/	10, 20, 30	40, 50, 60	70, 80, 90, 100
	------H values------		
Swedish System 3/	1, 2, 3	4, 5, 6	7, 8, 9, 10
I.P.S. System 4/	Light Peat	Dark Peat	Black Peat
Relative Energy Value	Not well suited	Best for fuel Low ash	Good for fuel, may have high ash

1/ System developed by U.S. Department of Agriculture and Agricultural Experiment Stations.

2/ Developed by INSTORF (Soviet Peat Institute)

3/ Von Post - Sweden

4/ International Peat Society System - 1973

The general classification systems shown in Table 1 are very similar although the criteria used to develop individual classes in the various countries were different. They all show that the medium and highly decomposed peat types are best suited for fuel use. Those types with low ash have higher energy values than those with high ash.

Table 2 shows some energy values of specific Minnesota peat types from several localities.

Table 2. Energy values of specific Minnesota peats related to type of peat.

Peat Type	Location Minnesota	Energy Value cal/gm
Hemic 1/	St. Louis Co. N.E.	4940
Hemic	Anoka Co., S.E.	4830
Hemic	Polk Co., N.W.	4580
Sapric 1/	St. Louis Co., N.E.	4600
Sapric	Aitkin Co., N.C.	4400
Fibric (Sphagnum peat)	St. Louis Co., N.E.	4400
Sphagnum moss (green)	St. Louis Co., N.E.	3790

1/ Classification from U.S. Department of Agriculture.

The highest energy values shown in Table 2 are for hemic type peats and for the sapric types. The fibric (Sphagnum types) have the lowest fuel value. This is apparently a function of the degree of decomposition of the peat. All of the peats shown in this table had relatively low ash content and the main difference in them was stage of decomposition. Also, there probably is a relationship to type of plants forming peat.

Table 3 shows the effect of varying ash content on energy values of Minnesota's hemic and sapric peats.

Table 3. Energy values of Minnesota peat related to ash content.

Peat Types			
Hemic (Partly Decomposed)		Sapric (Highly Decomposed)	
Percent Ash	Energy Value cal/gm	Percent Ash	Energy Value cal/gm
9.86	4600	23.81	3823
6.04	4898	15.83	4216
7.08	4878	13.34	4373
5.37	4816	9.85	4718
4.20	4903	10.75	4597
5.26	4872	17.01	4355
7.07	4621	20.60	3940

The data in Table 3 clearly shows that for both hemic and sapric type peats the lower the ash content the higher is the energy value. For example, the hemic type with an ash content of 9.86 had only 4600 calories per gram of energy while the one with only 4.2 percent ash was highest with 4903 cal/gm. The same relationship holds for the sapric peat types. The sapric peat with an ash content of 23.81 percent had an energy value of only 3823 cal/gm, while that with 9.85 ash content had an energy value of 4718 cal/gm.

From these and other data obtained on Minnesota peats it appears that the energy value is increased or decreased about 60 cal/gm. for each decrease or increase in ash content of 1.0 percent.

In other data comparing the energy values of peat related to depth, the differences obtained were related to different peat types in the strata of a deposit. Many of the less decomposed surface peats were lower in energy values than the more decomposed peats below.

Table 4 shows the relation of energy yield of peatlands to weight per unit volume of a specific peat type.

Table 4. Energy yield of peatlands related to volume weight of the peat.

Type of Peat or Peatland	Volume Weight (oven dried) gms/l	Volume Weight (oven dried) lbs/cu. ft.	Yield/Acre Foot Weight O.D. Peat (pounds)	Yield/Acre Foot Energy Value B.T.U.
Sphagnum Moss Peat (Fibric)	60	3.75	163,350	1.3×10^9
Reed-Sedge Peat (Hemic)	150	9.36	407,721	3.67×10^9
Decomposed Peat (Sapric)	240	15.00	653,400	5.4×10^9

The data in Table 4 shows that as the weight per unit volume (bulk density) of peat increases, the energy yield on a volume basis also increases and in direct proportion. This has obvious economic impact in harvesting operations and peatland site selection for fuel peat production. A given thickness of decomposed peat (sapric) contains over 4 times the energy value as the same thickness of Sphagnum moss peat.

MINNESOTA'S PEAT RESOURCES AND POTENTIAL USES

In absence of reliable data on the peat resources of Minnesota and their utilization estimates have been made of potential uses, total reserves of fuel peat, growth rate of peat, and use of peatlands as energy farms.

A. Potential Uses for Peatlands

Estimates of the potential utilization of the 7.5 million acres of peatlands in the state are as follows:

1. Energy Production - 40% of total or 3 million acres. These are deep peats, more than 6' in depth and moderately decomposed. Have high energy value.
2. Crop Production - 30% of total or 2.25 million acres. These are both shallow and deep peats, moderate to well decomposed and suitable for agricultural drainage. They are potentially suitable for production of commercial vegetables, forage crops, commercial forest tree species such as black spruce, cedar and tamarack.
3. Horticultural Peat Production - 20% of total or 1.5 million acres. These are relatively undecomposed Sphagnum moss peat deposits and reed-sedge types suitable for production of horticultural peat moss used on lawns and gardens and as growing media.

4. Natural Peatlands - 10% of total or about 0.75 million acres. These are unique or critical peatland areas that should be preserved. They have either educational value, contain rare plants, are unique peatland types, or are unusual or scarce habitats for certain wildlife.

B. Peat as an Alternative Energy Source

Calculations

Total fuel peat = 3,000,000 acres (40% of total peatlands)

1 acre foot = 400,000 pounds (ave. density 10 lbs/cu. ft.) or
200 tons of oven dry peat.

1 acre 6 foot thick = 1200 tons of dry peat

1 million acres 6' thick = 1.2 billion tons of peat

3 million acres 6' thick = 3.6 billion tons of peat

Fuel Value

Coal 14,000 B.T.U.'s/lb.

Peat (oven dry) 9,000 B.T.U.'s/lb.

Peat (30-40% water) 7,000 B.T.U.'s/lb.

3 million acres fuel peat in Minnesota have a potential heating value of 3.6 billion tons x 2000 (lbs/ton) x 9,000 (B.T.U.'s/lb).
equals 648 x 10^{14} B.T.U.'s total energy resource.

Minnesota's annual energy consumption equals approximately
12 x 10^{14} B.T.U.'s.

648 x 10^{14} divided by 12 x 10^{14} equals a 54 year supply of fuel--using peat (only 3 million acres of total).

C. Peat as a Renewable Energy Resource

Peat unlike lignite, coal, oil and natural gas can be considered a renewable energy resource. The average annual growth rate or accumulation of peat on surface of bogs is about 0.2 cm per year. Calculated in terms of dry matter this equals approximately 2 tons per acre per year. Therefore, the 7.5 million acres of peatlands (less those in cropland - 3.0%) will produce 15 million tons of dry peat each year (30 billion pounds) with a heating value due to annual production of 30 B. pounds x 9,000 B.T.U.'s/lb = 2.7 x 10^{14} B.T.U.'s. This is an energy value equal to 3/4 the annual heating value of all natural gas consumed in Minnesota each year (natural gas consumption is equivalent to 4 x 10^{14} B.T.U.'s). Even if we utilized only the amount produced naturally in our bogs each year, the potential fuel value for peat is very significant and we would have an unlimited supply--a steady state situation.

D. Peatlands for Energy Farms

Peatlands are will suited for the production of several high-yielding native wetland species such as cattails, sedges, reeds, and grasses, which could be grown as a renewable energy source. Yields as high as 15 to 20 tons per acre per year have been reported in Germany, Canada and elsewhere. Peatlands are particularly well suited for these wetland crops as they occur in very large and contiguous areas (i.e. 40 to 50 thousand acres in a single bog), are very uniform as to type and can be easily managed for maximum crop production. Also most peatlands are not presently being used for anything and could be readily brought into production for these energy crops.

SUMMARY

Minnesota has very large reserves of high quality peat that at present are not being utilized. The potential of these peat resources to produce energy, food and fiber crops and a variety of other uses is great.

To realize these development potentials we need accurate inventories and surveys of these peatlands as well as technological and environmental studies of the areas with greatest potential for development. For an effective assessment of these peat resources it is essential that both the government and the private sector be involved.

APPENDIX C

STATUS OF PEAT RESEARCH IN MINNESOTA

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Jan. 1977

INTRODUCTION

Minnesota's peat is without question our most undeveloped natural resource. It is a resource which has received only token research support until just recently. Perhaps it is a resource whose "time has come" for consideration of development. Whatever happens in regards to peat development in the future, we certainly have extensive reserves-an estimated 7.2 million acres (equal to some 12 to 15 billion air dry tons). If these resources are developed wisely with due regard to any impacts on the peatland environment it could be a tremendous asset to our state. If future predictions are realistic regarding impending shortages of food, especially protein, and scarcity of energy sources then let us seriously and systematically evaluate the potential of peat development even if it is only an interim solution to these shortages.

To properly evaluate the potential of our peat resources we must learn more about them. We not only need to know the location and quality and quantity of peatlands, but we need to know much more about peatland environments, development potentials and suitability for various uses in agriculture, forestry, energy production as well as for natural preservation areas and for wildlife. Obviously a well planned and coordinated peat inventory program is necessary if we are to achieve the above objectives.

The pioneer efforts in peat research begun many years ago by the Minnesota Agricultural Experiment Station and later by the State of Minnesota, Iron Range Resources and Rehabilitation were very significant but were quite limited in scope and often sporadic. However, the knowledge gained in these early research efforts and the data obtained might well serve as a sound basis for future peat research. Thanks to excellent support from our state legislature, state officials and the important grass roots (local) support peat research is now being expanded. Federal support has also been most helpful.

What is needed are good inventories to assay the quality and quantity of our peat resources and their suitability for various types of development and/or no development (Preservation) as the case might be. A new inventory program financed both by state and federal funds under the guidance of the Department of Natural Resources is presently underway. Such studies have long been neglected, except on a limited basis, and their success will be assured only if agencies and individuals competent in the field of peat research coordinate their efforts and work as a team to determine peatland development potentials, assay future peatland policy options for state decision makers, and at the same time protect the public trust. Can we afford to do less?

This paper includes a review of past and current peat research studies and suggests priorities for future research needs.

PEAT RESEARCH

Research on peat in Minnesota has included both basic and applied studies. The early research efforts attempted to characterize various types of peat as to their potential for use in agriculture, horticulture, forestry and as raw material for chemical products. At that time no attempt was made to study the use of peat for fuel. This is indeed unfortunate in view of our present fuel situation.

BASIC PEAT RESEARCH EFFORTS

Over 20 years ago a project was started in Minnesota titled "Chemical products from peat" which was a joint effort by the Iron Range Resources and Rehabilitation, State of Minnesota and the University of Minnesota's Chemistry Department in Duluth, The Chemical Engineering Department in Minneapolis and the Soil Science Department in St. Paul. This program led to some selected peat sampling and surveying of representative peatlands mostly in Northern Minnesota. The samples were used both for characterization studies and for organic chemical analyses. As a result of these studies a new classification system was developed and the proposed system was described in a paper presented at the 2nd International Peat Society Congress held in Leningrad, Russia in 1963 (6). Details of the system were later published in 1965 (9). A paper was presented to the International Peat Societies Committee on Classification in 1974 (16) which described the classification criteria for a Minnesota peatland. Following this, the U.S. National Cooperative Soil Survey (U.S. Soil Conservation Service and the State Agricultural Experiment Stations) became interested in this peat classification system. After several years of trial mapping all over the country, testing the system and numerous modifications by committees it finally became the adopted system by this group for classifying peat or organic soils in the U.S. Canada soon accepted this system for use in soil inventories made by the Canada Department of Agriculture. This organic soil (peat) classification system is officially published now as part of the U.S. Department of Agriculture's Comprehensive Soil Classification (25).

This system is relatively simple and is based principally on the degree of decomposition of peat material and the amount of plant fiber. Three classes of organic material are recognized. These are fibric, hemic and sapric listed in order of increasing state of decomposition. Briefly, these peat materials have the following properties:

1. Fibric Organic Material - least decomposed type, has lowest ash content and bulk density, highest saturated water content and greatest amount of plant fiber. Three well defined subtypes include the very acid, relatively raw Sphagnum moss peat types, the less acid Hupnum moss peats and the reed-sedge type peats.
2. Hemic Organic Material - moderately decomposed type of organic material. Have medium bulk density values, saturated water contents and fiber content, and are variable in acidity.
3. Sapric Organic Material - most decomposed type. Have high bulk density values, relatively high ash contents, lowest fiber content and saturated water values. Acidity is variable.

The International Peat Society has over the past few years attempted to develop a world-wide peat classification system. Just recently (5) they have adopted a system which is essentially the same as the one used in the U.S. and Canada. Poland has been using a similar system for several years for their peat surveys. This new peat classification system is being used in the present Department of Natural Resources inventory of Minnesota peatlands.

Estimates on the amount of peat or organic soils in all of the counties in Minnesota have been made by the Soil Conservation Service in their 1967 Conservation Needs Inventory (22). This inventory included the depth of the peat and its present utilization. Table 1 shows the results of this inventory on a statewide basis.

Table 1. Inventory of Peatlands (Organic Soils), State of Minnesota.

Total Acres Organic Soils	7.2 Million
Percent of Total State Area	15.6%
Deep Peat (5 ft. +)	75.8%
Shallow Peat	24.2%
Present Utilization	
Cropland	2.7%
Pasture-Forage	10.7%
Forest	60.4%
Open Peatlands	26.2%
	100 %

Table 2 shows counties in Minnesota with the most extensive peatlands. Three counties in Northern Minnesota with the largest acreage of peatlands are Koochiching, St. Louis and Beltrami.

Table 2. Peat Extent in Minnesota by Counties.*

Rank	County	Acres	% of County	% of Peat in State
1	Koochiching	1,154,900	60.0	16.1
2	St. Louis	810,000	26.6	11.3
3	Beltrami	786,000	51.9	11.0
4	Lake of the Woods	483,000	58.8	6.7
5	Aitkin	394,000	34.9	5.5
6	Itasca	357,000	26.4	5.0
7	Roseau	245,000	23.4	3.4
8	Cass	200,000	20.1	2.8
9	Ottertail	192,000	15.9	2.7
10	Pine	174,000	20.0	2.4

*Counties in N. Minnesota with most extensive peatlands. Conservation Needs Inventory, SCS-USDA, 1967.

A peat distribution map of Minnesota showing the distribution and location of peatlands was completed in November 1975 and copies can be obtained from the Department of Natural Resources in St. Paul. This map was compiled from actual survey data obtained from the Minnesota Soil Atlas Project.

The early studies in chemical products from peat resulted in the development of some new analytical techniques useful for peat studies. Investigations included use of peat as an oil well drilling mud, as a binder for taconite, as source of humic acids and other high-molecular weight organics. The agricultural phases of this project included the use of peat in greenhouses as a growing mix, as a plant growth stimulant and for soil conditioning. Some of the data from these studies is included in a bulletin published by Michigan State University (21).

Concurrent with these chemical studies the Iron Range Resources and Rehabilitation in cooperation with the University of Minnesota Soil Science Department began some detailed inventories of selected Northern Minnesota peatlands suitable for production of high quality commercial type horticultural peat. There is a rapidly expanding market in the U.S. for both Sphagnum moss peat and reed - sedge peat used in horticulture for growing mixes, potting soils and improving garden soils.

The demand for these horticultural peat products would continue to increase in the future and the potential for expansion of commercial horticultural peat operations in our state is excellent. The several surveys of peatlands containing high-quality horticultural-type peat completed to date indicate that adequate reserves of this type of peat are located in St. Louis, Beltrami, Koochiching, Itasca and Carlton counties. Several detailed reports of these peatlands have been published over the past few years (7, 8, 10, 13). A classification system for commercial peat was published in 1968 (12) and later specifications were issued by A.S.T.M. giving test procedures and definitions. Grubich in 1972 (20) presented a paper describing the peat inventory procedures we used for locating and surveying peat areas for horticultural peat development. Additional surveys are needed to determine the quality and quantitiy of this type of peat so as to provide prospective developers with the necessary information. The Department of Natural Resources presently has a few leases on public lands for this development and more requests are anticipated.

Some basic hydrologic studies have been made near Grand Rapids by the U.S. Forest Service, Northern Conifers Laboratory (1, 26). These studies included runoff characteristics in peatlands, water table levels and management of bog conifers on peatlands.

Other basic studies have included use of peat in wastewater filtration and energy values of peats. Also some water quality studies were made in an intensively farmed peatland area in Anoka county (18). Most of these basic studies logically have led to applied research on production of food and fiber crops grown on peatlands, evaluation of peat filter systems and the potential of peat as an alternate energy source.

APPLIED PEAT RESEARCH

Field experiments on vegetable, sod and grass crops (forage) have received the most attention over the years. Most of these applied studies have been cooperative with other University departments and other agencies. It has been found that where drained, fertilized and properly managed many crops are well adapted to production on peatlands. Some of the problems peculiar to peatlands have been minimized as a result of such studies. Several new crops such as wild rice, bluegrass for sod and seed, as well as wheat and sugarbeets have proven to be highly productive on peatlands. A rather recent discovery is the possibility of producing high protein grasses on Northern Minnesota peatlands. Yields of protein were as high as 1 ton per acre and several grasses, including quackgrass contained over 30% protein. Grass yields are as high as 4 to 5 tons per year under prescribed cutting practices and adequate fertilizer.

A paper published in 1967 (11) discusses the potential of Minnesota's peat resources especially for crop production and horticultural peat development. This applied research as it pertains to agriculture is a good example of how scientists and farmers working together can help solve some of the production problems. The Anoka peatland project near the Twin Cities and the Hollandale peat project in Southern Minnesota are good examples of applied peat research conducted on a cooperative basis in problem solving.

The research on use of peat for wastewater treatment has been a very rewarding experience. This work, cooperative with the Iron Range Resources and Rehabilitation was conducted at the Virginia, Minnesota sewage plant in the late 1960's. It involved the use of peat over sand to remove organic and nutrient pollutants from wastewater. There are now several of these peat filtration systems, based on the results of the original basic research, that are presently in operation. The U.S. Forest Service is operating several of these in Minnesota, Wisconsin and elsewhere at waste treatment facilities at lake campgrounds.

The details of this peat filtration system have been described in several publications (2, 14, 15). A recent article (3) discusses the principle and methods of the filtration system and suggests the possibility of certain improvements to increase both phosphate and nitrate removals.

In Finland, municipal wastewaters are piped to natural peatlands that have been ditched and engineered to filter out pollutants (24). They now have over 20 of these peatland filter systems in operation and they are performing very well. Some of them have been in operation over 15 years. These ditched systems appear to be performing satisfactorily and they are both inexpensive and effective wastewater treatment alternatives to conventional systems. Such systems might have a place in Minnesota especially where towns and food-processing industries are located near suitable peatlands.

PEAT AS AN ENERGY SOURCE

A recent study in 1975 (17) gives data on energy values of various Minnesota peats and evaluates the potential of peat as an alternate energy source. The formation of peat in wetland environments constitutes an energy-capturing natural ecosystem as well as a nutrient sink. Bog plants through the process of photosynthesis function to capture the sun's energy and store it through accumulation and preservation of biomass as peat.

The relative high caloric values of peat have led to their use in several countries in Europe where conventional fuels are in short supply. Suoninen in 1975 (23) gave figures for peat fuel production in Europe. Russia by far leads all countries in production of peat for fuel but in Finland and Ireland use of peat for electric and steam generation provides a significant and economical alternative to expensive imported coal, oil and natural gas. The energy situation in these latter two countries is much like ours in Minnesota, i.e., a lack of conventional fuels coupled with an abundance of peat.

Energy values of specific Minnesota peat types are shown in Table 3.

Table 3. Energy values of specific Minnesota peat types.

Peat Type	Location	Energy Value B.T.U./lb.
Hemic	St. Louis Co.	8900
Hemic	Roseau Co.	9700
Sapric	St. Louis Co.	8300
Fibric (Sphagnum Moss)	St. Louis Co.	7900
Sphagnum Moss (Green)	St. Louis Co.	6800

These data show that the hemic or partly decomposed peat types have the highest energy values. Sapric types are relatively high but they are higher in ash content than hemic types. The fibric Sphagnum Moss type, which is very valuable as a commercial horticulture peat, has the lowest energy value of all peat types and thus should not be used for fuel production.

Table 4 lists the various uses of peat as fuel. Peat can be used directly when dried for the production of electricity and for district heating to produce steam. It also can be converted to gas in either low or high B.T.U. forms for industrial or home use. A wet combustion process (4) utilizing peat is being studied by the Zimpro Company of Rothschild, Wisconsin to produce steam. If perfected this system would not require drying of the peat. Briquettes are presently being produced in Russia and Ireland for domestic use for home and factory heating. Peat also could be used in combination with biomass such as grasses, sedges, cattails, etc. for conversion to gas and it could be mixed with conventional coals and lignites for conversion to gas production.

Table 4. Use of Peat as Fuel.

1. Direct Burning
   a. Electricity Generation
   b. Steam Heating

2. Gasification
   a. Low B.T.U. - Taconite Drying or as a source of heat for drying
   b. High B.T.U. - Pipeline Quality Gas (S.N.G.)

3. Wet Combustion - Zimpro Process (steam)

4. Briquettes (Home Heating)

5. In Combination With Other Fuels for Conversion Processes
   a. Biomass: Wood, Cattails, Sedges, Grasses and Peat Mixtures
   b. Lignite or Coal admixtures for Conversion to Gas

Table 5 shows the quantity of peat available in Minnesota peatland areas varying both in size and thickness. Calculating a 7 foot average thickness for peat and assuming the entire 7 M. acres to be used for fuel, Minnesota has a supply of peat that would satisfy our energy demands for 166 years based on the present annual energy use of 12 x 10^{14} B.T.U.

Table 5. Quantity of Peat and Energy Available in Peatland Areas Varying in Size and Thickness.*

	5'			10'		
Size (Acres)	Volume (cu. yds.)	Weight (Tons)	Potential Energy (B.T.U.)	Volume (cu. yds.)	Weight (Tons)	Potential Energy (B.T.U.)
1	8,000	1,600	19.2×10^{9}	16,000	3,210	38.4×10^{9}
100	800,000	160,000	19.2×10^{11}	1.6 M.	320,000	38.4×10^{11}
1,000	8 Million	1.6 M	19.2×10^{12}	16 M.	3.2 M.	38.4×10^{12}
10,000	80 M.	16.0 M.	19.2×10^{13}	160 M.	32 M.	38.4×10^{13}
100,000	800 M.	160.0 M.	19.2×10^{14}	1.6 B.	320 M.	38.4×10^{14}
1,000,000	8 Billion	1.6 B.	19.2×10^{15}	16 B.	3.2 B.	38.4×10^{15}
7,000,000	56 B.	11.2 B.	134×10^{15}	112 B.	22.4 B.	268.8×10^{15}

* Calculations based on 15 lbs/cu.ft. for 35% moisture peat, 1600 cu. yds/acre foot and 6000 B.T.U./lb. (35% H_2O peat). NOTE: Minnesota's Annual Energy Use = 12×10^{14} B.T.U.

The data in this table shows that even relatively small peatland areas of 1000 to 10,000 acres contain significant amounts of energy.

Table 6 shows the amount of peat required in tons and the acres needed for potential selected energy demands. For example, the municipal heating plant at Virginia, Minnesota would use annually 120,000 tons of peat and require an 80 acre peatland if only 5 feet thick and only 40 if 10 feet thick.

A taconite plant producing 5 million tons of pellets per year would use 5.0 million tons of peat in 20 years for drying the pellets. This would require a total of 3000 acres of peat 5 feet thick but only 1500 acres if 10 feet thick.

The proposal by Minnegasco to build a large-scale gasification plant in Northwestern Minnesota would require from 60 to 120 thousand acres of peatlands for 20 years of operation.

It is obvious from these data that these proposed operations will require only a fraction of the total peat resources available in the state. One proposal worth considering is that maybe we should consider using no more energy than is produced by natural means. This means that we might limit our annual consumption of peat as an energy source to that amount produced annually by nature, i.e., approximately 10 M tons. This would require mining only 3000 acres of peat to a depth of 10 feet each year. Another 10 M tons of biomass could be produced from energy farms on 0.5 to 1 M acres of peatlands. The 20 M tons of combustible organics (peat and biomass) would provide 3.0 x 10^{14} B.T.U. of energy per year which is equal to one fourth Minnesota's present annual energy consumption and three fourths of our yearly natural gas consumptio..

This is not an insignificant contribution and is an idea worthy of further study. It would certainly constitute an interim or short term solution to the state's present critical energy situation and would make possible the utilization of our large peat reserves for other purposes such as food and fiber production, preservation and wildlife. I am convinced that in the long run these peatlands will become more valuable for production of animal feed, especially high protein sedges and grasses. Also the potential of peat as a source of raw chemical feedstock is a viable alternative.

Table 6. Peat Required for Potential Selected Energy Demands.

	1 Year Supply			20 Year Supply		
Location and Type of Plant	Tons Needed	5' Depth	10' Depth	Tons Needed	5' Depth	10' Depth
		acres			acres	
1. Municipal Heating Plant Virginia, MN - steam heat	120,000	80	40	2.4M	1600	800
2. Paper Mill Potlach, Cloquet (Drying Paper)	160,000	100	50	3.2M	2000	1000
3. Taconite Plant Iron Range area 5 M tons capacity Low B.T.U. Gas for drying pellets	250,000	150	75	5.0M	3000	1500
4. Electric Generation Iron Range Area (Direct Burning)						
100 MW cap.	200,000	120	60	4.0M	2400	1200
500 MW cap.	1.0 M.	600	300	20.0M	12000	6000
1000 MW cap.	5.0 M	3000	1500	100.0M	60000	30000
5. Gasification N.W. Minnesota-Red Lake Area Synthetic Natural Gas High B.T.U. Gas	12 M	6000	3000	240.0M	120000	60000

SUMMARY

In summary it has been shown that peat has a number of uses. When and where development of Minnesota peatlands will occur is not known. There are many potential uses of peatlands and in this paper I have attempted to evaluate the past, present and future research efforts that would be helpful in making this development a reality. Peatlands can be utilized in agriculture for the production of food and fiber crops and for harvesting of horticultural-type peat as soil conditioners and growing mixes. They are potentially suitable for the production of energy either as direct fuel sources or for conversion to synthetic gas. They are well suited to cropping of cattails, sedges and grasses as sources of biomass production on energy farms. Peats and peatlands can be used for wastewater filtration, sludge disposal and for removal of toxic heavy metal pollutants from effluents. They also are a potential source of organic chemicals as a substitute for present petrochemicals.

Conservation and preservation of some of our peatlands should also be a high priority in any planning decisions.

Development of new sources of energy, possibly biomass or peat, is urgently needed now. Conversion processes to gas or solid fuels may soon be a feasible alternative. Perhaps most important of all, consumers of energy must give serious and practical consideration to public decisions that must be made relative to energy resources and environmental concerns. These decisions will not be easily made. In closing, I am pleased to announce that the VIth International Peat Society Congress is to be held in August 1980 at the Duluth Arena-Auditorium. We are proud that the I.P.S. has chosen Duluth as the site for their next Congress and those of us engaged in peat research are looking forward to it with great interest and anticipation.

Finally, since I obviously do not have all the answers perhaps I can end by posing a pertinent question: How much of the energy available in Minnesota's peatlands can be diverted to the support of our most important single species: man?

LITERATURE CITED

1. Boelter, D.H. 1974. The hydrologic characteristics of undrained organic soils in the Lake States. In Histosols: their characteristics, use and classification. Soil Sci. Soc. Amer. Spec. Publ. No. 6.

2. Brown, J.L. and R.S. Farnham. 1972. Advanced wastewater treatment using organic and inorganic materials. Part II: Immobilization of phosphate by calcareous, mixed media filtration. Proc. 4th Int. Peat Cong., Helsinki. Vol. 4. pp. 287-298.

3. Brown, J.L. and R.S. Farnham. 1976. Use of peat for wastewater filtration-principles and methods. Proc. 5th Intl. Peat Congress. Poznan, Poland.

4. Cederquist, K.N. and P. Bering. 1952. Wet combustion: a process for the utilization of peat. Acta Polytechnica No. 105. Sweden.

5. Classification of Peat. 1976. Report of Commission I Intl. Peat Society. Helsinki.

6. Farnham, R.S. 1963. Classification of peat in the U.S. 2nd International Peat Congress. Leningrad, Russia.

7. Farnham, R.S. 1964. Peat resources of Minnesota, W. Central Lakes Bog, St. Louis Co., Minnesota. Report of Inventory No. 1, Iron Range Resources and Rehabilitation.

8. Farnham, R.S. and D. Grubich. 1964. Peat resources of Minnesota, Cook Bog, St. Louis Co., Minnesota. Report of Inventory No. 2, Iron Range Resources and Rehabilitation.

9. Farnham, R.S. and H.R. Finney. 1965. Classification and properties of organic soils. Advances in Agronomy, Vol. 17, pp. 115-160.

10. Farnham, R.S. and D. Grubich. 1966. Peat Resources of Minnesota, Red Lake Bog, Beltrami Co., Minnesota. Report of Inventory No. 3, Iron Range Resources and Rehabilitation.

11. Farnham, R.S. 1967. Potential of Minnesota'a Peat Resources. Minnesota Science, Vol. 23, No. 3.

12. Farnham, R.S. 1968. Classification system for commercial peat. 3rd Intl. Peat Congress. Quebec, Canada.

13. Farnham, R.S. and D. Grubich. 1970. Peat resources of Minnesota potentiality report, Fens bog area, St. Louis Co., Minnesota. Iron Range Resources and Rehabilitation.

14. Farnham, R.S. and J.L. Brown. 1972. Advanced wastewater treatment using organic and inorganic materials. Part I. Use of peat and peat-sand filtration media. Proc. 4th Intl. Peat Congress., Helsinki. Vol. 4. pp. 271-286.

15. Farnham, R.S. 1974. Use of organic soils for wastewater filtration. In Histosols: their characteristics, use and classification. Soil Science Soc. of America Spec. Publ. No. 6. pp. 111-118.

16. Farnham, R.S. 1974. Classification criteria for a Minnesota peatland. Intl. Peat Soc. Spec. Symposium. Glasgow, Scotland.

17. Farnham, R.S. et al. 1975. Minnesota's peat as an energy source - quality and quantity. Intl. Peat Soc. Proc. of Symposium of Comm. II. Combustion of Peat. Kuopio, Finland. pp. 25-33.

18. Farnham, R.S. 1976. Influence of intensive agriculture on water quality in peatlands. Proc. 5th Intl. Peat Congress. Poznan, Poland.

19. Farnham, R.S. and D.H. Boelter. 1976. Minnesota's peat resources: their characteristics and use in sewage treatment. Agriculture and Energy. A national symposium on freshwater wetlands and sewage effluent disposal. Univ. of Michigan, School of Natural Resources. Ann Arbor, pp. 241-255.

20. Grubich, D.N. and R.S. Farnham. 1972. Inventory of Minnesota peatlands. 4th International Peat Congress; Helsinki, Vol. 1, pp. 461-469.

21. Lucas, R.E., Paul Rieke, and R.S. Farnham. 1965. Peats for soil improvement and soil mixes. Ext. Bull. No. 506. Michigan State University.

22. Soil Conservation Service, U.S.D.A. 1967. Conservation needs inventory.

23. Suoninen, A. 1975. A short review of the use of fuel peat in the world. I.P.S. Symposium, Combustion of Peat. Kuopio, Finland.

24. Surakka, Seppo. 1971. (Some observations on the possibilities to infiltrate wastewater in peatland according to results obtained at Kesalahden Town, Finland.) Vesitalous 3(5):26-31. (Finnish-English Summary).

25. U.S.D.A. 1975. S.C.S. Soil Taxonomy Agriculture Handbook No. 436.

26. Verry, E.S. and Don H. Boelter. 1972. The influence of bogs on the distribution of streamflow from small bog-upland watersheds. Presented at the UNESCO Intl. Symp. on the Hydrology of Marsh-Ridden Areas. Minsk, Byelorussian SSR, July 17-24, 1972.

POTENTIAL AND ECONOMIC IMPLICATIONS OF LARGE-SCALE PEAT DEVELOPMENT IN THE NORTHERN LAKE STATES - U.S.A.

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ABSTRACT

The Upper Great Lakes Area of the U.S. including portions of Minnesota, Wisconsin and Michigan has some 6 million hectares of peatlands which are virtually undeveloped. Many of these peatlands are very large in size and have great potential for large-scale peat development. None of the areas have been developed for fuel peat production at present even though the potential for such development is enormous.

The development of these peatlands must be orderly with due regard to the ecology, hydrology and natural vegetation of the areas. In addition, development should be both economically sound and in the best interest of the public. The potential of these peat resources is great and the economic implications obvious to the region and to the nation.

INTRODUCTION

The Upper Great Lakes States of the U.S. including Minnesota, Wisconsin and Michigan have extensive peatland areas, which are virtually undeveloped. No accurate inventories of these peatlands have been made, but estimates indicate that these three states contain up to 6 million hectares (15 million acres) of peat. Minnesota alone contains about 3 million hectares (7.5 million acres) with several very large deposits of over 40,000 hectares occurring in the northern part of the state. These extensive peatlands have formed principally in large glacial lake plains such as glacial lake Agassiz, Upham, and Aitkin in northern Minnesota.

The potential for large-scale development of these peat resources is great when one considers the large size of individual deposits in the region as well as the quality, drainability and economic implications resulting from such developments.

Nearly all of the large Minnesota peatlands are State owned and the

Department of Natural Resources has responsibility for their use and management. Any development of these peatlands, therefore, can be planned and regulated carefully with due regard to possible environmental and other constraints.

Traditionally, peatlands in the U.S. have been utilized mainly for specialized vegetable crop production, forage crops and harvesting of black spruce (Picea mariana) for Christmas trees and for raw material (pulp) in making paper. More recently, there has been a great increase in demand for use of Minnesota's shallow peatlands for wild rice (Zizania aquatica) production. A few thousand acres of Minnesota peatlands are presently being leased by the State Department of Natural Resources for production of horticultural-type peats (peat moss and reed-sedge type peats). Development of peatlands for energy production has not taken place at present even though the Northern Lakes States of the U.S. depend entirely on importing their fuels such as oil, coal, and natural gas from other distant areas of the U.S. or from western Canada.

The feasibility of utilizing the vast resources of peat in the Region as an alternative energy source for the production of synthetic natural gas, fuel for electric or steam generating plants should be very seriously and carefully considered in all of its aspects including both economic and environmental concerns.

ECONOMIC IMPLICATIONS OF PEAT DEVELOPMENT

Large-scale peatland development for fuel in the Region could conceivably include at least tens if not hundreds of thousands of acres of peatlands. This scale of development could have considerable economic impact in the areas of these States, which presently have little employment except in the iron ore and taconite mining areas. These northern regions of these three States are not well suited to agricultural development and have few people employed in agricultural enterprises. Forest products industries are located in these areas but employment is limited and harvesting of trees is usually a seasonal occupation. Peat development in the Region would provide summer and fall employment for harvesting operations and would supplement the winter logging operations.

As an example, a large peat harvesting operation using 100,000 acres (40,000 ha) would employ between 3,000 to 4,000 workers for mechanical harvesting, handling and processing peat as raw material for a large synthetic natural gas plant. In addition, this large synthetic natural gas plant would employ at least 1,000 workers year around to operate the plant. If one considers the multiplier effect of such an operation, including equipment repair and service industries, the economic potential of such a peat enterprise becomes readily apparent.

ENVIRONMENTAL CONCERNS OF PEAT DEVELOPMENT

The development of peatlands on a large-scale is not without its concerns as to the possible effects on the environment. Drainage of large tracts of these wet peatlands might have some possible detrimental effects on the vegetation, wildlife, hydrology, and water quality of specific locations. On any of these peatlands where development is considered favorable from the standpoint of location, quality and size of the deposit, and drainage potential the State Department of Natural Resources should make a careful environmental assessment or appraisal before development is allowed to proceed.

A list of possible environmental concerns should include the following:

1. Effect of peatland drainage on flooding of streams.
2. Effect of drainage on water quality and fish in receiving waters.
3. Effect of drainage on present natural vegetation and wildlife.
4. Effect of drainage on local and regional water tables.
5. Possible air pollution from fuel plant.
6. Possible water pollution from fuel plant.
7. Avoid destruction of unique peatland types and unique bog plants such as orchids and rare species of wetland vegetation.

Inventories or surveys of all large peatland areas of the Region are very badly needed in order to determine the location, size, quality, ecology and hydrology of potentially developable peat areas. These surveys are needed now to properly assess the development potential and environmental concerns.

In addition to the various inventories, several studies should be made, which would result in an environmental assessment report to be submitted to all local, state, and regional authorities. Also, the results of these environmental, technical and economic studies should be made available to the public through a series of hearings. Results of such studies would be extremely helpful in formulating a State policy on use and regulation of State-owned peatlands. This policy would include leasing of State peatlands, regulations governing peat development and reclamation of these lands after harvesting has been finished. In Europe, several large fuel-peat harvested areas have been very successfully planted to forests, agricultural crop production and nature conservancy areas.

The participation of other state and federal agencies such as Agriculture, State Planning, Economic Development and Energy in decisions concerning the development of peatlands should be encouraged.

APPENDIX E.

Proposal for Use of Peat for Energy in Sweden

List of units used in the report:

Unit	Meaning
kcal	calories x 10^3 or kilocalorie
Gcal	calories x 10^9 or gigacalorie
tonne	metric ton, or 1000 kg
hectare	10,000 square meters
Skr	Swedish Kroner; One American dollar is approximately 6 Kroners
toe	tons oil equivalent
TWh	watt-hours x 10^{12}, or terra watt-hours
MW	megawatt, or Watts x 10^6

APPENDIX E

Proposal for Use of Peat for Energy in Sweden

TABLE OF CONTENTS

1. SUMMARY

Sweden's peat is an important raw material for energy. It can be converted to electrical and heating energy using thoroughly tested technology at a cost which is reasonable in relationship to the present price of oil. A functioning peat industry contains rich possibilities for development. Consequently, its competitiveness vis-à-vis oil can be expected to increase as time passes. At the same time, developments can lead to an important chemical industry and to attractive activities in the exploited peatlands. This raw material for energy can constantly be renewed if rapidly growing trees are cultivated on the areas which are emptied of their peat resources to a suitable extent.

The report provides information on the occurrence of peat, on the industrial development situation and on development possibilities. It deals with the effects of the peat industry on the natural environment and on man and provides information on laws and regulations. Together with the program plan for peat, the report is intended to describe the prerequisites for exploiting peat and to propose measures for an expanded peat industry in Sweden.

1.1 Peat, types and properties

Peat has been formed in a low-oxygen environment through the action of bacteria, fungus and chemical compounds on dead plant material. It occurs in <u>bogs</u> with bog moss as an important element and in <u>fens</u>, formed in a salt-rich environment in hollows with running water. Sedge species dominate. The degree of compostation (humidification) is an important property. The dry peat substance, which contains 50-60% carbon, has a chemical composition which places it between lignite and wood and a calorific value of 4 500 - 6 000 Kcal/kg. Unprocessed peat contains 90% water. Draining the bog can reduce the water content to 80%. The remaining water consists, on average, of 25% water which can be squeezed out under pressure, 40% water which is bound in capillary form, 25% water which is bound in colloidal form and 10% water which is bound chemically. This means that even if all of the water which can be squeezed out under pressure and which is bound in capillary form were to be removed mechanically, the water content of the peat would still remain around 60%. Even if the water bound in colloidal form were to be removed, the product would still contain 25% water. The water problem is the dominating problem in peat technology. Air drying on the bog is the chief dewatering method applied. This leads to a peat substance with an average of 50% water. This state - peat with 50% moisture content, effective calorific value 2 Gcal/tonne- is the state normally referred to when speaking of peat in the industrial process.

1.2 Peat in Sweden, its occurrence and exploitation

Ten percent of the area of Sweden consists of bog areas with a peat thickness of more than 0.3 m, making a total of 5.4 million hectares of which 75% are located in northern Sweden, 14% in central Sweden and 11% in southern Sweden. The age of the marshes varies from a few thousand to ten thousand years. The rate of increment is 0.1-0.5 mm per annum. This means that peat is a resource which cannot, in practice, be renewed. (Rapidly growing trees and bushes can, on the other hand, be cultivated on exploited bogs, thus continuously producing an organic substance, biomass).

Bog areas occur partly in the form of large coherent districts (e.g. northwestern Scania through western Småland and Västergötland almost up to Lake Vänern, northern Upland, the north-western tip of Dalarna, Dalarna north of Siljan, Jämtland and Lappland), partly in occasional, large or closely located bogs, partly in small dense areas and partly in sparse deposits.

The inventory of peat in Sweden is deficient, particularly in Norrland. Information on the quantity and quality of the peat is, consequently, unreliable. The quantity of peat in Sweden is said to amount to 15 thousand million tonnes 50% peat corresponding to 3 thousand million tonnes of oil in calorific value. Only part of this quantity can be included in the raw material base for an industry. How large this part is cannot be assessed at present. Both overall and local inventories must be started immediately.

Peat is removed either as block peat (machine-macerated peat) or in finely broken-down form such as milled peat. The latter method now dominates in the main peat producing countries (Ireland, USSR and Finland) due to its superior economy. This method entails milling a thin layer (1-2 cm) from the peat surface. The milled peat is air dried and turned a couple of times in conjunction with this, is collected and stacked. The number of harvests per year amounts to about ten.

The maximum annual production in Sweden (1.3 million tonnes) was reached towards the end of the Second World War. At present about 300 thousand tonnes of peat are produced a year. This peat is used as a fertilizer. (By way of comparison it can be noted that Ireland produces approximately 5 million tons per year, Finland approximately 1 million tonnes per year, a figure which is now being expanded, and the USSR approximately 200 million tonnes per year, of which 70-80 million tonnes are used as fuel).

The following approximate values apply to peat production in accordance with the milling method:

peat winning	100-200 tonnes/year and hectare bog under processing
milling depth	1-2 cm, 10 layers per season
air-dried milled peat	moisture content 50%
	calorific value 2000 Kcal/kg
	volumetric weight 0.3 t/m^3
Production cost (stacked at bog edge)	SKr 60-79/tonne (SKr 300-350/toe)

1.3 Energy, production and preparations for crises

The quantity of peat in Sweden is sufficient to replace all of our present oil consumption for 100 years. In reality, only part of our peat resources can, however, be exploited.

We can aim at supplying communities and industries with heat, combined with the production of counter-pressure power. Only peat bogs located in the vicinity of the energy user can be utilized in this alternative. With a scope of 5 million tonnes (1 million toe) of peat a year, an industry of this type would have a major importance for Sweden in several regards, such as

- energy balance
- job opportunities
- possibilities for developing a peat-based chemical industry
- the increased freedom of choice which would result with regard to industry and commerce and energy supply.

The development of an energy-producing industry to a level of 5 million tonnes of peat per year could be carried out during the 1980s-1990s. By the year 2 000 10 TWh calorific energy would then be generated. In an emergency situation it would be possible to multiply a production of this size within about a year on condition that emergency measures had been taken at the peat bog and in the combustion plants.

The level of ambition can be raised for the exploitation of existing sources of energy. Peat would become particularly important for the supply of energy from domestic fuels if it could be utilized for superheating steam produced in nuclear power reactors fired with natural uranium. A production of 50 TWh electrical energy per year in a system of this type would consume slightly more than 600 tons of natural uranium and 13 million tonnes of peat. Peat bogs located at a considerable distance from the energy user could be used for electrical production of this type.

1.4 Development to diversified industry

A basic prerequisite for an industrial development is that an efficient and reliable process be available for dewatering the peat. Consequently, research and development in this sector are extremely important.

Other particularly important lines of development are the hydration of unprocessed turf and the gasification of dewatered turf to form a synthetic gas. These methods open paths leading to energy carriers such as oil products, methanol and hydrogen. Chemical products, such as ammonia, can be produced. The report mentions, by way of example, that 2 million tonnes of 50% peat can be converted to 500 thousand tonnes of methanol. A quantity of this magnitude would permit intermixing to a level of 15% in all petrol in Sweden.

A combination of chemical industries can be developed in those parts of the country which do not have industries of their own. This would create considerable employment and production assets. The technology available today could be used to produce briquettes and coke, an excellent fuel and an excellent reducing agent respectively for the chemical industry.

1.5 Reclamation and use of peat areas after exploitation

Peat areas can be reclaimed as wet areas, can be converted to forest land or, as the case is in Ireland, to meadows and arable land. The mini-rotation forestry system provides an interesting possibility. This would mean that the exploited bog could be used for the continuous production of raw material for energy, hopefully 10-40 tonnes of dry substance per hectare and year corresponding to 5-10 toe per hectare and year. This can be compared with the exploitation level during the peat-winning period, i.e. on an order of size 20-40 to/hectare and year.

The combined use of exploited peat areas for industry and commerce and for recreation can mean that its market value will become higher than it was before the peat was removed. In other words, the value of the remaining natural resource can be increased at the same time as a raw material is converted into energy and products.

1.6 Nature and environment

Winning peat will have a marked effect on the landscape, hydrology and the plant and animal world. These conditions must be thoroughly studied before an extensive peat industry is started. The considerations which have been made and the experiences obtained from Sweden, Finland and Ireland indicate that negative consequences can be counteracted so that in favourable cases, the total effect becomes positive for the landscape and the environment.

The peat industry gives rise to emission problems in the form of air and water pollution. These are probably non-malignant, however, compared with other fossil fuels. The environmental problems must be thoroughly penetrated when planning the peat industry.

1.7 Time aspects

Regional and local inventories of the occurrence of peat must be started immediately.

The first generation of heat and heat-electric stations should utilize milled peat and thoroughly tested combustion technology. Experts are available within Sweden and excellent contacts have been established with peat industries in Finland and Ireland. It is important that this know-how be used in conjunction with the development of the peat industry, i.e. that a decision be made during 1977 that two units be constructed and put into service at the beginning of the 1980s and that activities be continuously developed after that.

Parallel with the first generation of energy producing units built with thoroughly tested technology, intensive research and development work should be carried on concerning

- peat dewatering
- energy production in combined systems with a development of combustion technology
- peat-winning methods
- gasification, hydration and, possibly, microbiological methods for producing chemical products.
- basic research concerning peat and its properties.

Industrial products should be implemented successively as technical material is produced for R&D work. New procedures and products should be compared with the continuation of developments in accordance with tested technology. The program should be adjusted as necessary.

A program based on tested technology can be started immediately. A proposed objective would be to have an installed thermal output of approximately 2 000 MW by the year 2 000 for the conversion of 5 M tonnes of peat per year, mainly milled peat, to 10 TWh calorific energy and, partly, electrical energy. The number of units could amount to approximately 25, distributed amongst, say, 10 districts. The extra investment (in excess of the investment which would have been required for oil-fired plants) is on an order of size of SKr 1 300 million. The continous employment effect of this investment should correspond to more than 2 000 job years, to which should be added extensive employment in conjunction with the development of the industry.

A reasonable objective should be that the R&D program be extended over a 5 year period to a scope corresponding to an average of SKr 20 million per year and should be retained on this level (in 1976 monetary value) as long as it gives a satisfactory yield.

Investments in the development of power stations and industries based on peat as a raw material can become extensive during the second half of the 1980s and during the 1990s. If this development be fabourable, a sum on the order of SKr 5 thousand million for a 10 year period, in addition to the investment which would have been made without the exploitation of peat in the form of oil-based or uranium-based industrial buildings and power station buildings, will become possible.

1.8 Organization of a peat industry

The peat industry in Ireland is organized in an enterprise which produces and sells fuel peat to the power industry and briquettes to households. A corresponding organization could be made in Sweden. Another possibility is that an energy producer (power enterprise) or chemical industry carries on integrated activities starting in the bog. Or that a combination of these forms be used.

No matter what the industrial structure, state participation will be required to guarantee the peat consumer a price which is suitably adjusted in relationship to the price of the alternative fuel (oil). A peat producer who guarantees a certain price would have considerable significance for extending peat exploitation, even to small heating units such as small communities.

The inventory activities must be rooted in a central body, e.g. within the Geological Survey of Sweden, and should utilize the resources available in Sweden, particularly in firms of consultants.

R&D work will be variegated and will require participation from industry, institutes of technology, universities and research institutes.

1.9 Economic aspects

Available information indicates that if peat be utilized in steam-production combustion plants it will mean an equivalent oil price of SKr 400-450/tonne. Rationalization and development will make it possible to keep increases in the cost of peat lower than the expected increases in the price of oil. An effect of this type can only be achieved in an operating peat industry of a certain size. Thus, the powerful national arguments for rapidly starting a peat industry must be supplemented with the desirability of creating prerequisites for developing an economically profitable peat-based industry.

GASIFICATION OF PEAT

Prepared by

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February 1975

GASIFICATION OF PEAT

The several routes for gasification of coal, lignite, and other hydrogen-deficient carbonaceous materials should also be applicable to peat. While the higher-rank materials are more suitable for combustion to produce heat and electrical energy, the lower-rank materials are notable for their higher degree of reactivity, especially toward gasification with steam to produce combustible gases. The types of carbon bonds or linkages in these lower-rank materials enhance the reactivity, and lower the activation energies and heats for reaction.

GASIFICATION METHODS

The principal routes to gasification may be set forth as follows:

Partial Combustion

$$C + 1/2\ O_2 \longrightarrow CO$$

Partial combustion with air will produce a gas of carbon monoxide with nitrogen as a diluent. Such a gas is commonly called "producer gas" and may have a Btu-rating of only around 100 Btu/cu ft, though a theoretically-higher rating is possible. At ratings of around 160 Btu/cu ft the gas can be used as feed to a gas turbine, and further converted to electricity. It is also possible to burn the gas directly in a furnace.

Direct Hydrogenation

$$C + 2H_2 \longrightarrow CH_4$$

This route would produce methane under relatively severe conditions of pressure, which favors the reaction. The principal difficulty lies in the production of the necessary hydrogen. This must be obtained from reaction with steam:

$$C + H_2O \longrightarrow CO + H_2$$

$$CO + H_2O \longrightarrow CO_2 + H_2$$

$$C + 2H_2O \longrightarrow CO_2 + 2H_2$$

Separation of the CO_2 leaves a stream of hydrogen. Other methods are availabl but they are all energy intensive and largely unproven. Active hydrogen can also be generated from CO and steam.

The energy requirements are outlined next.

Indirect Hydrogenation

$$C + H_2O \longrightarrow CO + H_2$$

$$CO + H_2 \longrightarrow 1/2\ CO_2 + 1/2\ CH_4$$

or $$CO + 3H_2 \longrightarrow H_2O + CH_4$$

The first of the above reactions requires large quantities of heat to sustain the reaction. Classic methods involve cyclic blowing with air. More modern continuous methods utilize oxygen. On a tonnage basis, however, the oxygen requirements are formidable: about 0.95 ton of O_2 per ton of carbon converted to CO.

The second-mentioned reactions are the methanation steps, requiring nickel catalysts. Using other catalysts and conditions, a variety of hydrocarbons and oxygenated compounds can be produced, including methanol or gasoline fractions.

In turn, the methane-forming reactions give off great quantities of heat--enough, in instances, to support the $C-H_2O$ reaction. Unfortunately, the reactions occur at different temperature levels; for this, and other reasons, the waste-heat cannot be all utilized.

Direct Methanation

$$C + H_2O \longrightarrow CO + H_2$$

$$CO + H_2 \longrightarrow 1/2\ CO_2 + 1/2\ CH_4$$

$$\overline{C + H_2O \longrightarrow 1/2\ CO_2 + 1/2\ CH_4}$$

By using a multiple catalyst of alkali and nickel, the reaction sequence can be made to go all the way in one stage. The alkali reduces the temperature required for initiation, and the nickel catalyst consumates the sequence. Furthermore, the overall reaction tends to be in heat balance, *i.e.*, autothermal, especially for lower-ranked materials.

AREAS FOR RESEARCH AND DEVELOPMENT

The reactions of peat to produce the various product gases require investigation. This would include reaction with hydrogen, with CO and steam, with uncatalyzed steam, and with multiple catalysts--particularly the latter.

In the initial stages of investigation, the studies could be at bench-scale levels. If a particular method has virtues, then scale-up would be advisable.

Previous studies on direct methanation of coal and organic wastes indicate considerable promise. The overall reaction occurs even at atmospheric pressure, materially reducing operational requirements and interfacing with known technology in fluidized and ebullating beds.

With development of proper feed-systems, a slurry could be used. The water would be vaporized and superheated, injecting pulverized peat mixtures with alkali into and through a bed of ebullating nickel catalyst. (An ebullating bed has uniform catalyst particles. A size distribution as in a fluidized bed would cause retention of the smaller particles.

The CO_2 produced can be separated by known technology, and recycled to produce crops or more carbonaceous material for use as fuel, all under controlled greenhouse conditions, the so-called indirect utilization of solar energy.

Moreover, the techniques applicable to peat may also be used for gasifying the organic components of municipal refuse and also of agricultural wastes.

APPENDIX G

PEAT FOR PROCESS GAS

by

James D. Duncan
Gulf Chemical Co.

July 17, 1974

SYNOPSIS

This report is the result of investigations into the feasibility of utilizing peat as a raw material for heating gas for the taconite industry.

The report outlines a complete procedure for the handling of peat, such as: mining by dredge, transportation by pump and pipeline, processing by filtering, extruding, pelletizing, artificial drying and complete gasification by air or oxygen with the resultant product burned for kiln heat.

The favorable economics of this process are due to continuous operations, the ability to mechanically de-water peat to 70% moisture, and the artificial drying of peat with waste heat from the taconite process which alleviates any dependency upon the weather.

THE HISTORY OF PEAT

The peat of Minnesota owes its origin directly or indirectly to the influence of glaciation which altered the surface of this land by forming basins or damming up drainage channels. Peat, which has been formed in these basins, is the result of the decomposition of aquatic plants, sedges, herbs and mosses. It is found in low, wet areas called bogs, swamps, or marshes. It varies in consistency from a fibrous, matted material to a highly decomposed mud generally having a moisture content of 88 to 93 percent.

Peat bogs vary greatly in depth but in estimating the area that could be profitably worked, only areas of 5 feet depth or greater were considered. On this basis, Minnesota has about 5 million acres of commercial bog with a peat reserve of about 7 billion tons. This estimate is considered to be conservative.

An approximate analysis of peat would be:

Volatile matter	Fixed carbon	Ash	S	N	BTU value H_2O free
66.25	23.96	11.80	.29	2.18	8535

In this day of public outcry against air pollution, the low average sulfur content of peat is of considerable importance. It also makes it extremely desirable as a heating gas for the taconite industry which is concentrated in the area of highest peat tonnage in northeastern Minnesota.

COST OF CONVERSION OF PEAT TO PRODUCER GAS

350 Days/Year

Downdrift Gasifier - $300,000.00 @ 20 Yr. Amortization	$ 15,000.00
Labor	50,000.00
Peat Required - 252,000 dry tons @ $2.9536/ton	744,000.00
Power	48,000.00
Maintenance	30,000.00
Total Cost of Conversion	902,000.00
Cost of Conversion:	
Per Ton of Peat	3.579
Per MBTU @ 85% Efficiency or 14.62 MBTU/Ton	0.245

PEAT MINING COSTS

Operating Costs

Cover - 2,000,000 KW @ $0.02/KW	$ 40,000.00
Maintenance - 10% Equipment Cost	36,000.00
Labor -	
Dredge Operator - 350 days @ 24 hours/day	42,000.00
Dredge Helper - 350 days @ 24 hours/day	37,800.00
Labor - 350 days @ 24 hours/day	29,400.00
Supervision	16,800.00
Miscellaneous	10,000.00
Total Operating Costs	$ 212,000.00

PEAT MINING COSTS

Cost Per Ton

Equipment amortization	$ 36,000.00
Operating Costs	212,000.00
Bog Costs	13,200.00
Total Yearly Costs to Mine	
2,520,000 Tons Raw Peat	261,200.00
Cost Per Ton:	
Raw Peat	0.1036
Dry Peat - 252,000 tons/year	1.036

PEAT PELLET PREPARATION

Plant Cost ($2,500,000.00 @ 20 years Amortization)	$ 0.50
Raw Peat Mined at 90% Moisture	0.1036
Filtering - 90% to 70% Moisture	0.95
Extruding and Pelletizing @ 70% Moisture	0.80
Drying (No Heat) @ 70% Moisture	0.60
Total Pellet Preparation @ 0% Moisture	2.9536

HEAT BALANCE

Water Content of Peat Pellets (30 TPH)	$\frac{60{,}000\#}{.30} \times \frac{\text{w. of } H_2O}{.70}$	=	140,000#
Heat Required to Vaporize H_2O in Peat	1100 BTU x 140,000	=	154,000,000 BTU
Heat Required to Heat Peat Pellets	75 BTU x 60,000	=	4,500,000 BTU
Total Heat Required to Dry Peat Pellets			158,500,000 BTU

HEAT BALANCE

Heat available from 30 TPH peat pellets		516,000,000 BTU
Wellman-Galusha Gas producer @ 85% efficiency		439,000,000 BTU
Heat needed to dry 600 TPH taconite pellets		360,000,000 BTU
Surplus BTU		79,000,000 BTU
Recovered heat W-G producer @ 60% efficiency		46,000,000 BTU
Heat needed to dry 30 TPH peat pellets @ 90% efficiency		176,000,000 BTU
Taconite kiln heat lost in stack @ 90% efficiency	36,000,000 BTU	
Heat recovery from stack @ 60% efficiency	22,000,000 BTU	
Recovered W-G heat	46,000,000 BTU	
Surplus BTU	79,000,000 BTU	
Available heat for drying peat pellets		147,000,000 BTU

APPENDIX H - Temporarily deleted pending permission to reprint excerpt from "Wet Combustion: A Process for the Utilization of Peat", by K. N. Cederquist and P. Bering.

APPENDIX I.

Excerpts from the March 1, 1977 Final Report --

Socioeconomic Impact Study

A Preliminary Assessment of
Minnegasco's Proposed Peat
Gasification Project

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In the interest of brevity, portions of the M.R.I. Minnegasco report appear in this section. The reader is referred to the report itself for details. The Table of Contents has been included here for that purpose. Appendix I also contains the report's summary, and conclusions and recommendations.

The Minnesota Energy Agency is indebted to the Midwest Research Institute for the material that follows in this appendix.

SUMMARY

Presented in this report is a summary of the socioeconomic impacts associated with Minnegasco's proposed peat gasification plant facility in central northern Minnesota. The gasification project will be carried out in two phases. Initially, a demonstration plant having a capacity of 80 million cubic feet of synthetic natural gas (SNG) per day will be constructed. The second phase would be the construction of a full-scale plant having a capacity of 250 million cubic feet of SNG per day. This report is concerned mainly with the construction and operation of the demonstration plant. As the project progresses and more data become available, detailed consideration can also be given to the full-scale plant. The report contains a description of the impact region, a brief history of that region, a socioeconomic profile of the region today, the results of a public opinion survey regarding the proposed development, a conceptual description of the gasification plant, and an analysis of the socioeconomic impacts of the proposed gasification plant on the region.

The impact region consists of four counties--Lake of the Woods, Beltrami, Itasca, and Koochiching Counties--which were selected because of their economic interdependence and their location relative to the proposed lease site.

Today, the average citizen of the impact area lives in an economy which suffers from widespread seasonal unemployment and by underemployment. During the winter months the unemployment rates in the counties range from 7 percent to 11 percent. The median income per family in the area is about 36 percent below that for the state, with about 14 percent of the population in the target counties below the poverty level. Between 1930 and 1970, the population in the impact area increased by about 25 percent; the state population increased by almost 50 percent during that interval. Between now and the year 2000, the populations of Itasca, Koochiching and Lake of the Woods Counties are expected to remain relatively constant with only Beltrami County showing an increase.

The introduction of a large industrial operation such as the proposed peat gasification plant into the impact area would create short- and long-term effects that would have impacts far greater than the impacts associated with a similar plant in a more populated area.

In addition to the obvious economic benefits that would be derived from the gasification plant operation, such as increased employment, growth of the economy, enhanced municipal services, and broadening of the tax base, consideration was given to the attendant problems that would arise during the plant construction and operational phases. The anticipated influx of people during the construction phase and, to a certain extent, during the operational phase, will lead to the necessity of providing planning for housing, expansion of municipal facilities, and educational services. The pros and cons of development were thoroughly considered, and a detailed discussion of the anticipated impacts is presented in this report.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were prepared as a result of the preliminary assessment of the socioeconomic impacts associated with Minnegasco's proposed peat gasification plant facility. They are the product of Midwest Research Institute and do not necessarily reflect the opinions or attitudes of Minnegasco. However, MRI believes that Minnegasco should evaluate and give careful consideration to these findings, so that if the proposed peat gasification project proceeds, the results will be beneficial not only to Minnegasco but to the citizens of the impact region and the state of Minnesota in general.

As a result of this study, MRI believes that it has a good understanding of the socioeconomic impacts that could possibly result during the construction and operation of the demonstration gasification plant. Our recommendations are meant to provide a basis for constructive and productive actions by Minnegasco. Another product of this study could be a series of recommendations for the State of Minnesota and for the county and municipal governments in the impact region; however, because Minnegasco has sponsored the study, it would not be appropriate to suggest recommendations that are beyond the control of the sponsoring company.

Conclusions

1. Present Economic Status

Today, the average citizen of the impact area lives in an economy which suffers from seasonal unemployment and chronic underemployment. Income in the impact region is considerably below the state average and state median range. The median family income in the impact region is about 36 percent below that for the state. The proportion of individuals in the impact region living below the poverty level in 1970 was quite high--almost double that of the state in general. Between 1930 and 1970 the population growth for the impact region was only about one-half of the state's rate.

2. Direct Employment Effects

The construction of the proposed demonstration plant would directly employ about 700 individuals. Of the 700 direct employees it is estimated that approximately 60 percent will be recruited from outside the impact area; the remaining 40 percent would be recruited locally.

During the operation phase the plant and mine* are expected to provide direct employment to 435 individuals. An estimated 40 percent of direct plant employees would be recruited outside the impact area. Both skilled and unskilled labor would be required during the construction and operation phase.

3. Indirect and Induced Employment Effects

In addition to the jobs directly created by the construction and operation of the demonstration plant, it is estimated that 350 additional jobs would be indirectly created or induced during the three-year construction phase. During the operation phase approximately 782 jobs would be indirectly created. The net number of direct and indirect jobs created during the construction phase would total 1050. The total number of jobs created during the operation phase would be 1217.

New jobs would also bring new residents to the area. Approximately 1068 new residents could be expected during the construction phase; a total influx of 669 new residents could be expected during the operation phase. After the operative work force is established and the employment multiplier has taken hold it is estimated that 10 to 11 million dollars in salaries would be added to the local economy annually. During the initial years of operation the salaries generated are likely to be in the 5 to 6 million dollar range.

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* Mining in this instance refers to the removal of peat from the ground using dredges or large earthmoving equipment. The peat would probably be removed to an average depth of 4 to 8 feet; the process would not resemble strip mining or deep pit mining.

4. Citizens' Concerns

In general, many of the community leaders are extremely concerned about each community's ability to absorb new residents and provide municipal services for them. Many of the towns in the impact region have municipal services which could not withstand additional users or have facilities which are already inadequate. However, several of the people expressed the positive attitude that their communities could handle large-scale growth if they were given enough lead time. Almost all the people were in agreement that new jobs are needed in the area, and that the development of a peat gasification plant would create jobs for the local workers. In this regard, however, the people expressed concern over potential hiring policies and a question of labor union involvement. There is a strong feeling in the area that local people should be given preference in hiring if the plant is to be built. In past construction projects in the area labor was imported, and some residents still hold bitter feelings against these kinds of hiring practices.

The public opinion survey conducted in this study revealed that most people believe a peat gasification plant would create jobs, thus enabling young people to stay in or return to the area. The overriding concern of many participants in this survey was with the youth in the impact area. Of all the comments we received, over 10 percent dealt with the subject of youth.

5. Citizens' Attitudes Toward Changes in Lifestyle

The general attitude of many of the long-term residents of the area, who have seen their children leave for jobs in other parts of the state or county, is that the added influx of people and creation of new jobs associated with the gasification plant activity would be a positive change. There are, however, some people living in the area who moved there because they enjoyed the tranquility of rural life and wanted to leave the pressure that they had encountered in the cities. These people would consider any increased or special activity to be a negative feature. We believe that, although these people are in the minority, their feelings should be considered.

The "Boom-Bust" Phenomenon

Many of the people in the area hold the belief that the gasification plant activity will last only twenty years, and then the plant will be shut down.* Some residents hold strong opinions about industry entering an area, using the local natural resources, and then abandoning the area when the resources are consumed. Older people in the region experienced this boom-bust type of development during the logging days. Although concern over boom-bust development was not the most frequently voiced concern, it was by far the most vehement. There were strong feelings against any development which might be of the boom-bust nature.

Recommendations

1. Increased Dissemination of Public Information

Although the purpose of our interviews in the northern Minnesota communities was to gather information, we soon realized that the people also were looking for information on the gasification project. Because of the economic conditions in the region and the publicity that the gasification plant has received, many people are eager to learn as much as possible about the planned activities in their region. Therefore, MRI strongly recommends that Minnegasco put forth an intensive public information effort. This could include more news releases, public meetings, and additional interviews with local citizens.

During public information meetings, three criteria should be met: 1) let the participants be heard; 2) respond to their concerns with factual data; and 3) solicit comments. The last can be very useful and can often be best handled with a carefully worded questionnaire in which people can state their opinions. We have found that eventually most people will

* This belief probably resulted from Minnegasco's published statements regarding the lease term and the depreciation life of the proposed plant. It is entirely possible that the plant could be operated much longer than twenty years.

forget the facts; but they will remember the opinions they formed based on these facts. If the facts were incorrect or incomplete, then people will form opinions based on misinformation.

2. Minnegasco's Assistance in County and Community Planning

Although community planning in relation to the gasification plant facility is not the responsibility of Minnegasco, MRI believes that Minnegasco can assist the impact communities by providing them with information and sufficient lead time to allow for proper planning for the increased demand for services and increased economic activity created by the influx of new workers. Previous and current experiences in Rock Springs, Wyoming, and Gillette, Wyoming, have shown that a boom can disrupt the public sector. A somewhat chaotic situation occurred in those towns because complete and timely information was not furnished to the public officials about the magnitude and distribution of the anticipated population increase.

We believe that if the public officials are kept informed of the developments associated with the Minnegasco gasification plant facility, they will put forth the necessary resources and effort to plan for the development, to control the physical application of residential activity, and to secure the financial resources to invest in public facilities. In addition, because of the widespread concern that a bust phenomenon could follow the boom, it is essential that Minnegasco analyze in detail the actual expected life of the gasification plant operation. If it is indeed to extend beyond the commonly believed lifetime of 20 years--say to 30 or 40 years, which has been the case with many large industrial operations--the people should be informed of this fact. In addition, if the current energy crisis persists and if the gasification plant operation is successful, it is quite likely that other gasification plants would be planned for Minnesota. If Minnegasco considers this to be a definite possibility, this fact should be taken into consideration during the coming years.

3. Evaluation of Other Impacts

MRI believes that Minnegasco should begin planning now to investigate other anticipated impacts in addition to the socioeconomic factors discussed in this report. Consideration should be given toward the environmental, ecological, and aesthetic impacts that would be associated with construction and operation of the gasification plant facility. MRI has sensed that people in the impact area are already beginning to voice concern in these areas. If these concerns are not addressed in an early stage in the development, incorrect information about the potentially harmful impacts associated with the development could outweigh information about the largely beneficial socioeconomic effects.

4. Continuing Socioeconomic Studies

As the technical efforts proceed on the program and more information becomes available with respect to the gasification process, mining methods, confirmation of lease site, plant size, location, and work force required, a continuing program of socioeconomic evaluation should be carried out. The information obtained from these studies should be made available to the public in the public information program suggested in the first recommendation.

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INTRODUCTION

General

In mid-1974 the Minnesota Gas Company (Minnegasco) initiated a project to examine the technical and economic feasibility of gasifying peat to produce pipeline-quality synthetic natural gas. According to Minnegasco, the primary impetus for initiating the research program was Minnegasco's increasing concern over the limited gas reserves of Northern Natural Gas (Minnegasco's supplier) and the increasing demand for natural gas by users in Minnesota. Minnegasco has estimated that the total heating value of Minnesota's peat resources (assuming a calorific value of 8500 Btu/lb, dry basis) amounts to approximately 80×10^{15} Btu. They believe that such a resource, even if only a part of it is used for energy production, could make a significant contribution to Minnesota's energy supply in the future.

Gasification Research

As part of the peat project, Minnegasco commissioned the Institute of Gas Technology to undertake an evaluation of the technology and economics of peat gasification. The preliminary phase of IGT's study was completed in August 1975, and Minnegasco subsequently applied to the Energy Research and Development Administration (ERDA) for additional funds to continue the gasification research on a larger scale. These funds were awarded to Minnegasco on June 30, 1976. Since then IGT has increased the level of its research effort.

Lease Application

On July 24, 1975, Minnegasco applied to the Minnesota Department of Natural Resources for a 25 year lease, under Minnesota Statutes § 92.50, Subdivision 1, to take and remove peat from all state-owned lands located in the following townships (shown in Figures 1 and 2):

Koochiching County

North 1/2 of Township 153 North, Range 27 West
Township 153 North, Range 28 West
Township 153 North, Range 29 West
Township 154 North, Range 27 West
Township 154 North, Range 28 West
Township 154 North, Range 29 West
Township 155 North, Range 28 West
Township 155 North, Range 29 West
Township 156 North, Range 28 West
Township 156 North, Range 29 West
South 2/3 of Township 157 North, Range 29 West

Beltrami County

Section 1 through 7
Sections 9 through 12 and
Section 18 of Township 155 North, Range 30 West

North 1/2 of Township 155 North, Range 31 West
Township 156 North, Range 30 West
Township 156 North, Range 31 West

Lake of the Woods County

South 2/3 of Township 157 North, Range 30 West

Minnegasco estimates that the state-owned lands within the boundaries of the lease site include approximately 200,000 acres of commercial peatland that could be used for the production of synthetic natural gas.

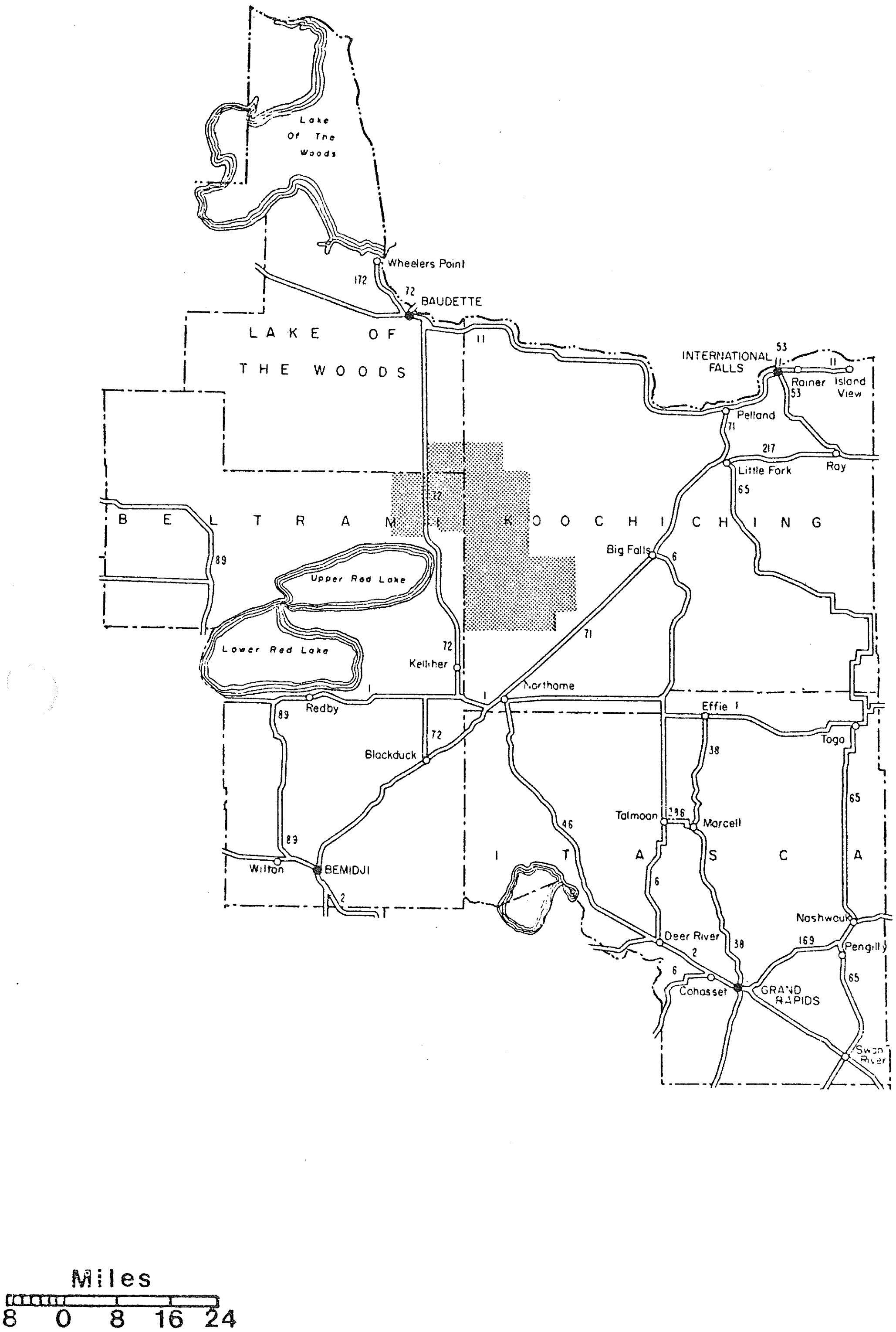

Figure 1. Lease Site In Relationship To The Four County Impact Area

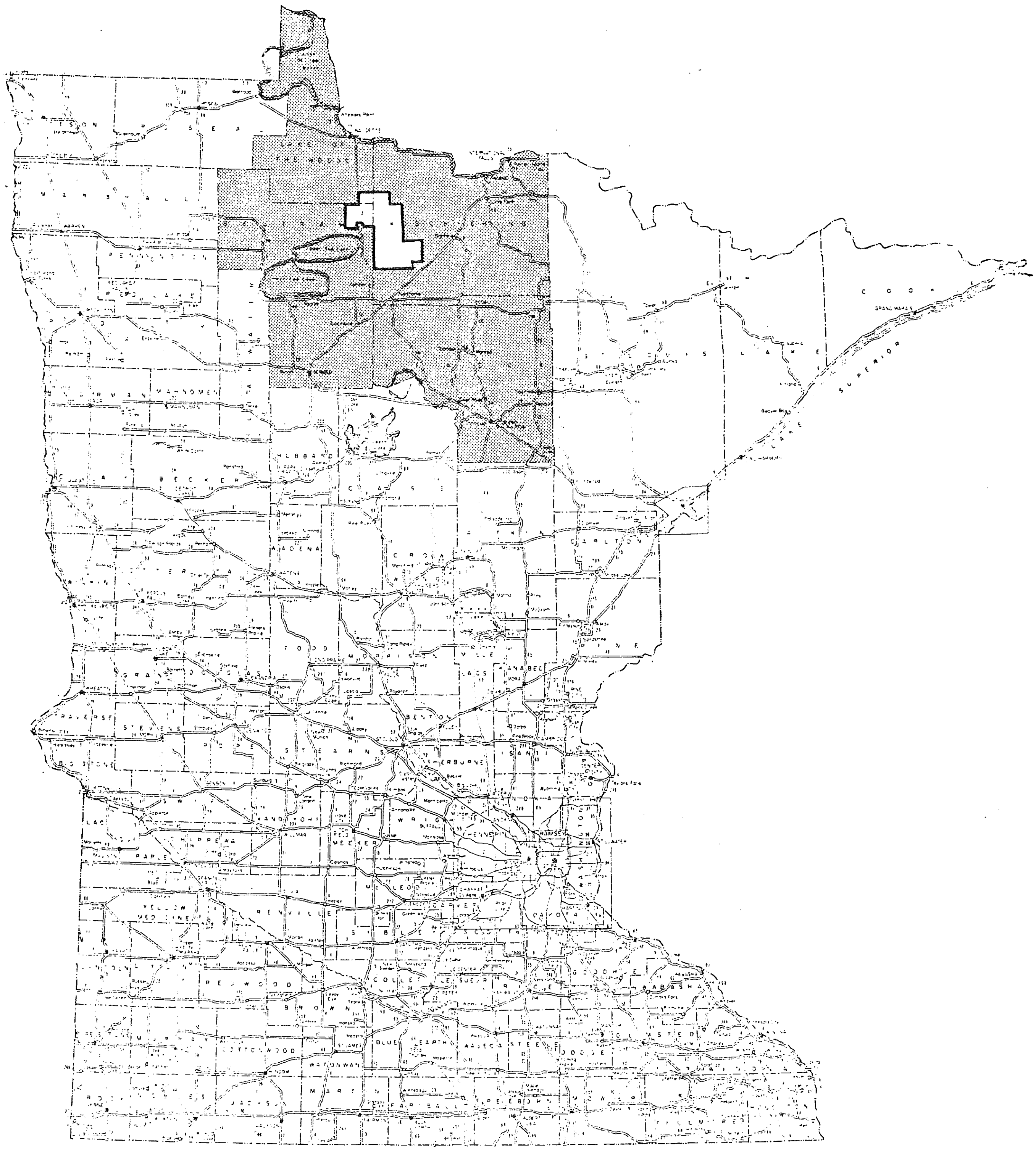

Figure 2. Relationship Of Lease Site And Impact Area To The State Of Minnesota

PEAT MINING COSTS

Raw Material

Peat to be Mined 2,520,000 tons per year

Assumptions:

Peat in Bog (90% H_2O)
Average Depth of Bog - 15'
Type of Mining - Year round dredging
Transportation - Pump and pipeline
Raw Peat Storage - 72 hr. supply
Operations - 350 days/year, 7 days/week, 24 hours/day
Raw Peat Weight - 60 lb./cu.ft.

Peat to be Mined:

2,520,000 tons @ 90% H_2O = 252,000 tons dry
2,520,000 tons ÷ 350 days = 7200 tons/day
7200 tons ÷ 24 hours = 300 tons/hour
300 tons ÷ .80 cu. yds. = 375 cu. yds/hour
375 cu. yds. x 202.2 ÷ 60 min. = 1264 gal/min.

Bog Area to be Cleared:

Raw Peat = 60#/cu.ft.
2,520,000 tons @ 15' depth = 210,000 sq.yds.
210,000 sq. yds. = 44 acres

Bog Clearing Costs:

44 acres @ $300.00/acres = $13,200.00

PEAT MINING COSTS

Equipment

20 Yr. Amortization

Mining, Transportation, and Storage Equipment

Dredge - 6" hydraulic cutter, mounted with a 4'x16' Drag Classifier for scalping wood, a 4'x16'x8' surge sump, an 8" slurry pump, 200' of 8" flexible hose, a small air compressor and a 3" water pump.	$ 200,000.00
Pipeline - 8" plastic pipe 2600' @ $8.00/ft.	20,800.00
Raw Peat Storage - 400' x 100' plastic lined pond	40,000.00
Substation and Power Line	100,000.00
Total Equipment Cost	$ 360,000.00

Gasification Plant

Minnegasco plans to build a $250 million demonstration plant producing 80 million cubic feet of SNG (synthetic natural gas) per day, with construction estimated to start about 1980 and completion scheduled for 1982. If the demonstration plant operation is successful, it could then be expanded to a full-scale plant that would produce 250 million cubic feet of SNG per day. The construction of this plant could start about 1983, with full-scale operation beginning about 1986. The full-scale plant could operate for at least 20 years on the peat available from the lease area requested. The target dates for construction and operation are only estimates that could change, depending upon many factors such as: form and content of Minnesota's peatland policy, regional energy and supply and demand, the outcome of laboratory and pilot-scale experiments on peat gasification, and development of successful peat mining and drying techniques.

It is estimated that about 18 million tons of air-dried peat (at 35 percent moisture) would be required for the full-scale plant each year. Over the 20-year lifetime of the plant, this would require the complete harvesting of an area of approximately 200,000 acres.

More details on the gasification process itself, and on peat mining and transportion are presented in Appendix A.

Socioeconomic Research

Minnegasco contracted for the services of Midwest Research Institute's Center for Peat Research to perform a preliminary assessment of the socioeconomic impacts of the construction and operation of the demonstration gasification plant. The objectives of this study were threefold:

1. Describe the socioeconomic environment of the impact area in historical perspective, and as it presently exists.
2. Determine the attitudes of the local population with regard to the facility, and the socioeconomic changes that would occur as a result of the facility.

3. Describe in as much detail as information allows the probable and identifiable socioeconomic changes that would occur as a result of the new facility.

Impact Area

Before research on this project was initiated an appropriate impact region was selected. That impact region served as the focal point for the entire study. Several criteria were established to aid in selecting the primary impact region. The criteria which were taken into account included the relationship of the lease site to existing political boundaries, a determination of an impact population, and the relationship of the lease site to existing functional economic units, socio-cultural composition, and existing laborshed patterns. After these and other relevant criteria were taken into account and weighed against each other, the primary impact region was selected. The impact area referred to in the following discussions encompasses Beltrami, Itasca, Lake of the Woods, and Koochiching Counties. The size, population, and geographic location of these counties satisfied the criteria which were established for selection of the primary impact area.

Contents of Report

This report presents the results of Midwest Research Institute's preliminary analysis of the socioeconomic impacts that could occur as a result of Minnegasco's plans to construct a peat gasification plant in central northern Minnesota. The report is divided into three major sections. The first section describes and defines the social, physical, cultural and economic setting of the impact area in historical perspective and as it exists today. Presented in the second section are the results of MRI's public opinion survey. Highlights of the results are mentioned along with interpretation of the attitudinal survey. The final section of the report contains MRI's analysis of the social and economic impacts associated with peat gasification.