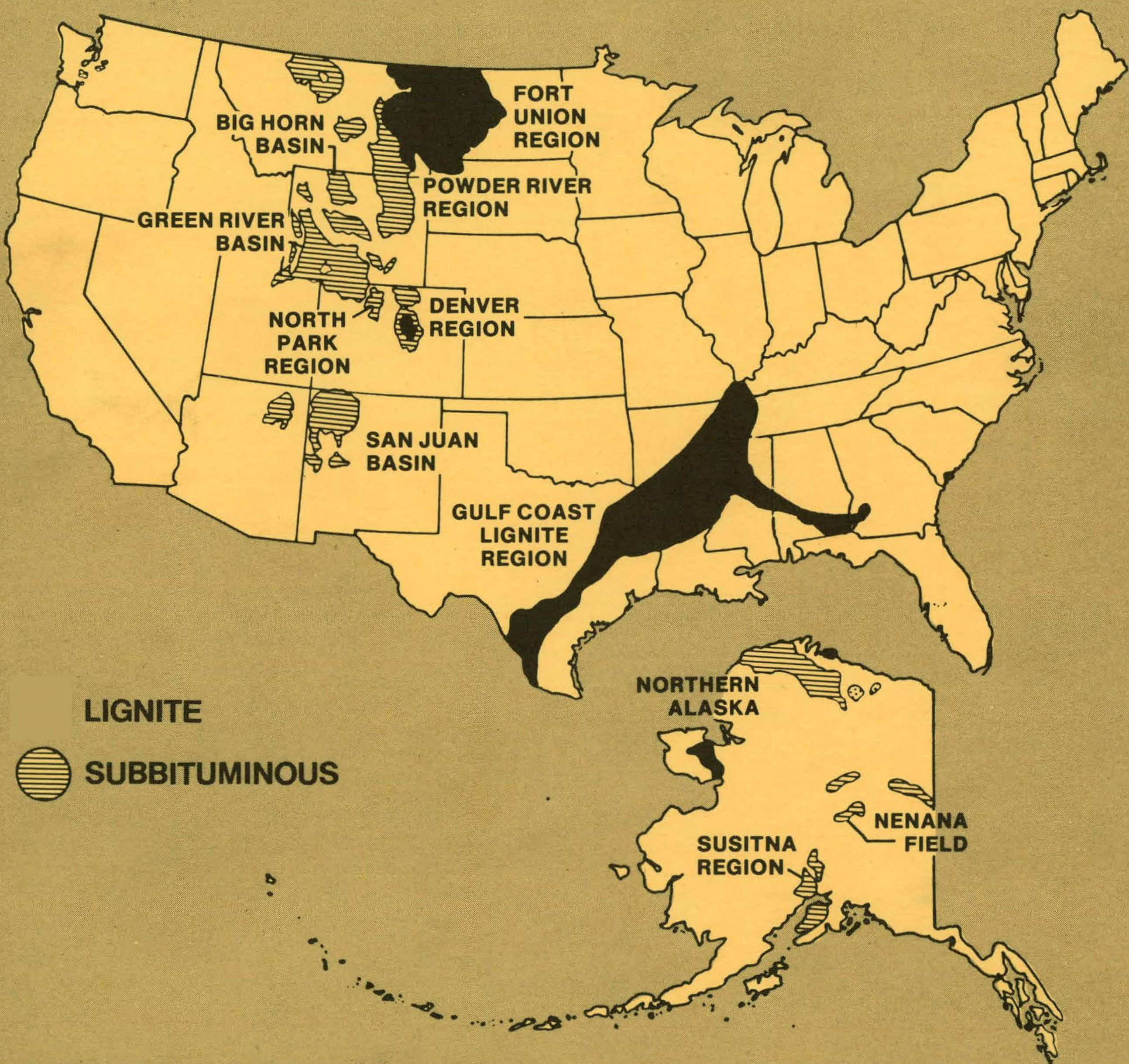
DOE/FC/10066-T1(Vol.6)

LOW-RANK COAL STUDY

NATIONAL NEEDS FOR RESOURCE DEVELOPMENT

MASTER

PEAT



The United States has over 1 trillion tons of identified low-rank coal resources; the strippable reserve base exceeds 100 billion tons. Major lignite deposits exist in the Fort Union Region and the Gulf Coast Region. The largest subbituminous coal deposits are in the Powder River Region, the San Juan Basin, and Northern Alaska.

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LOW-RANK COAL STUDY
National Needs for Resource Development

Volume 6 - Peat

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Energy Resources Co., Inc.
Walnut Creek, California

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PREFACE

This is volume six of a six-volume "Low-Rank Coal Study." Overall, the report presents a comprehensive analysis of the technical, environmental, and economic constraints to expanded development of U.S. lignite, subbituminous coal, and peat resources. The primary objective of the study was to propose a comprehensive national research, development, and demonstration (RD&D) program focusing on technology development for enhanced utilization of these resources. The report is organized as follows:[a]

Volume 1 - Executive Summary
Volume 2 - Resource Characterization
Volume 3 - Technology Evaluation
Volume 4 - Regulatory, Environmental, and Market Analyses
Volume 5 - RD&D Program Evaluation
Volume 6 - Peat

This study was directed by the Grand Forks Energy Technology Center (GFETC), which has the lead mission within the Department of Energy for technology "applications for low-rank coals." G. H. Gronhovd (Director) and E.A. Sondreal (Deputy Director) of GFETC provided technical direction and review of all aspects of the study. The work was performed by Energy Resources Company, Inc. (ERCO) under a contract initiated on May 16, 1979, and completed on September 30, 1980. The study approach is summarized in Table P-1, which shows the eight major contract tasks and the approximate percentage allocation of funds to each. The study schedule is summarized on Figure P-1.

Because of the scope and complexity of the effort, GFETC enlisted a task force of recognized experts on the technical and regional issues germane to the study. These individuals are listed in Table P-2; their contributions to the quality and direction of the study were highly significant. The task force met with the study team at four critical points to review interim results and to lead working groups which established the emphasis, priorities, and methodologies for the analysis. Primarily through the efforts of the task force members, useful data inputs and critiques of working draft materials were received from a number of organizations as the study progressed.

Individual contacts and contributions made during the course of the study are too numerous to list. The following (in addition to the task force members) contributed significantly to the review of part or all of the document: G.H. Gronhovd, E.A. Sondreal, W.G. Willson, and H.H. Schobert of GFETC; W.R. Kube of the University of North Dakota and GFETC; S. Alpert, K. Clifford, S. Ehrlich, T. Lund, C. Aulisio, D. Giovanni, and R. Wolk of the Electric Power Research Institute; W. McCurdy, S. Freedman, L. Miller, M. Kopstein, L. Ludwig, E. Burwell, W. Schmidt, M.N. Rosenthal, J. Nardella, and J. Turner of DOE; W.R. Kaiser of the University of Texas at Austin; and P. Averitt (retired) of the U.S. Geological Survey.

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[a] Volumes 2 through 5 address lignite and subbituminous coal; Volume 6 addresses peat; and Volume 1 summarizes the conclusions and recommendations of the total study.

Figure P-1

Low-Rank Coal Study Schedule

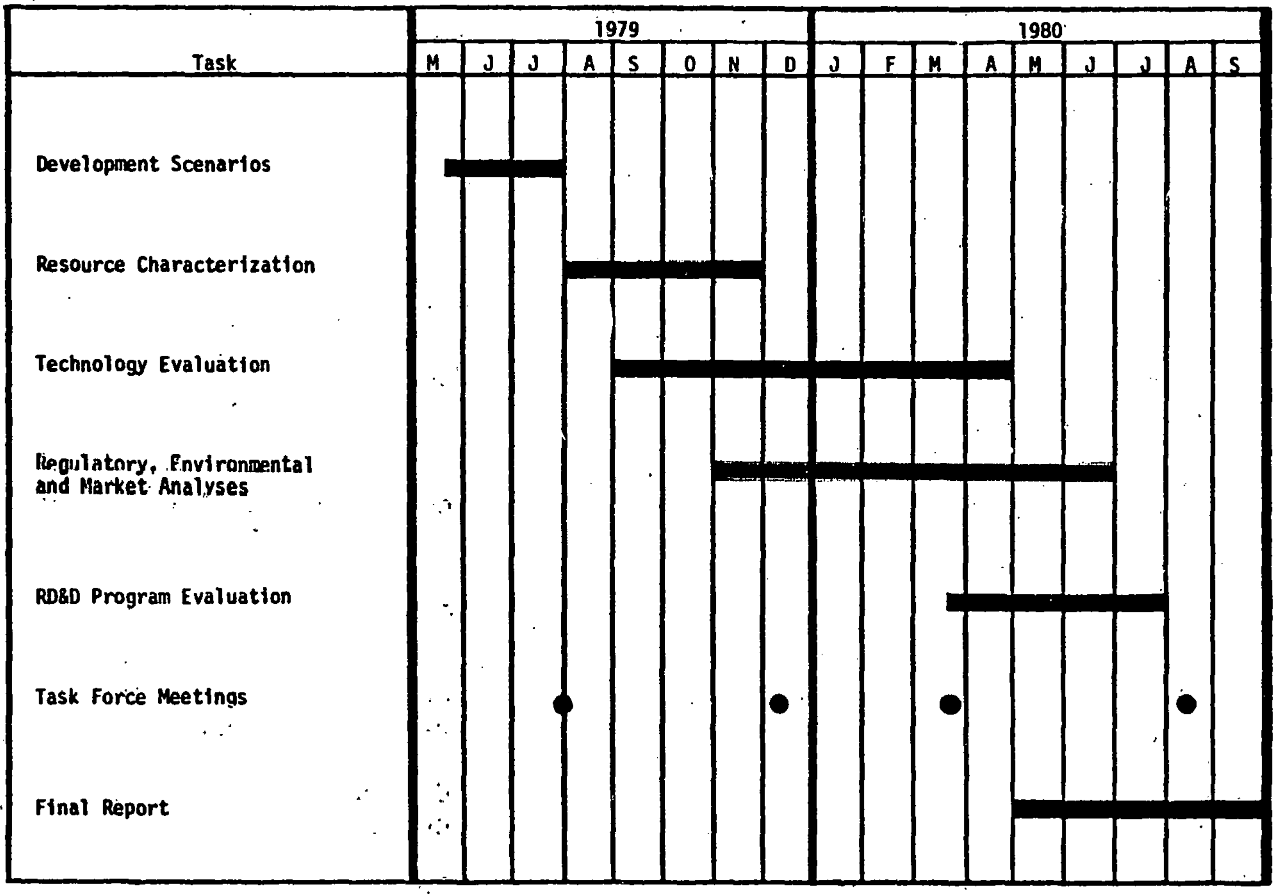


Table P-1

Major Tasks in the Low-Rank Coal Study

1. Low-Rank Coal Development Scenarios (6%)
   - 1.1 Literature Review
   - 1.2 Technology Definitions
   - 1.3 Regulatory/Environmental/Market Definitions
   - 1.4 Low-Rank Coal Data Base
2. Resource Characterization (8%)
   - 2.1 Occurrence
   - 2.2 Properties/Characteristics
   - 2.3 Classification
3. Technology Evaluation (42%)
   - 3.1 Extraction
   - 3.2 Transportation Systems
   - 3.3 Preparation, Handling, and Storage
   - 3.4 Processing and Utilization
   - 3.5 Environmental Control Technology
4. Regulatory Requirements/Constraints (4%)
   - 4.1 Definition
   - 4.2 Roadmap
   - 4.3 Effects on Development
5. Environmental Impact Analysis (3%)
   - 5.1 Land Use/Reclamation
   - 5.2 Air Quality
   - 5.3 Water Quality
   - 5.4 Ecological Effects
   - 5.5 Socio-Economic Effects
6. Market Analysis (6%)
   - 6.1 Existing Markets and Penetrations
   - 6.2 Potential Markets
7. RD&D Program Evaluation (11%)
   - 7.1 Definition and Priorities
   - 7.2 Review of Current RD&D Programs
   - 7.3 Cost and Impact Analysis
8. Task Force Utilization (20%)
   - 8.1 Development Scenarios Evaluation
   - 8.2 Technical Analysis Evaluation
   - 8.3 RD&D Program Definition
   - 8.4 RD&D Program Impacts and Recommendations

Table P-2

Low-Rank Coal Study
Task Force Participants

Participant	Affiliation
1. Dr. Martin A. Elliott Houston, Texas	Consultant, Texas Eastern Gas Transmission Co.
2. Professor George R. Hill Salt Lake City, Utah	University of Utah Department of Chemical Engineering
3. Mr. James Jonakin Birmingham, Alabama	Consulting Engineer (Retired from Combustion Engineering, Inc.)
4. Mr. Paul W. Crutchfield and Mr. David J. Beecy Washington, D.C.	U.S. Department of Energy Office of Policy and Planning
5. Professor Donald E. Severson Grand Forks, North Dakota	University of North Dakota Department of Chemical Engineering
6. Mr. David M. White Austin, Texas	Texas Energy and Natural Resources Advisory Council
7. Mr. Kurt Yeager and Dr. Charles R. McGowin Palo Alto, California	Electric Power Research Institute

The ERCO Program Manager on this effort was Dr. John Kotowski. Mr. George Wiltsee was the Assistant Program Manager and Technical Director. Other ERCO personnel who provided major contributions to the effort include Paul Goodson, Randall Smith, Wayne Simmons, Barbara Acker, Jeffrey Feerer, Timothy Buscheck, and Myron Burr. In addition, special thanks should be extended to Lydia Felix and Jennifer Spinello of the administrative staff for their support and assistance in the preparation of this report.

ABSTRACT

The requirements and potential for development of U.S. peat resources for energy use are reviewed. Factors analyzed include the occurrence and properties of major peat deposits; technologies for extraction, dewatering, preparation, combustion, and conversion of peat to solid, liquid, or gaseous fuels; environmental, regulatory, and market constraints; and research, development, and demonstration (RD&D) needs. Based on a review of existing research efforts, recommendations are made for a comprehensive national RD&D program to enhance the use of peat as an energy source.

1. INTRODUCTION AND SUMMARY

The material presented in this volume has been prepared from over 80 references covering the entire topical range of peat resources and development for energy. Every facet of the peat fuel cycle has been examined and categorized into the following chapters:

- Resource Characterization -- locations of domestic and global peat deposits, tonnage estimates; explanations of peat deposition histories, peat types, and peatland types; properties and composition of peat.

- Technology Evaluation -- extraction methods, such as sod peat, milled peat, and hydraulic harvesting; dewatering methods, including mechanical, thermal, and alternative wet processes (wet carbonization, wet oxidation, solvent extraction); utilization technologies such as combustion and gasification.

- Environmental Analysis -- detailed biological and chemical description of peat and peat waters; impacts from peatland harvesting and utilization on water quantity and quality, and on air quality; possible reclamation options for post-harvesting recovery and use of peatlands.

- Regulatory Analysis -- emission control regulations applicable to the peat fuel cycle; permitting responsibilities pertaining to water and air-related variances produced by peat harvesting and processing.

- Market Analysis -- identification of potential users of peat fuel according to the various product forms of processed peat (e.g., briquettes, SNG). Estimate of market penetration for the various peat fuel products.

- RD&D Program Evaluation -- identification and priorities of current RD&D activities; recommendations for new research.

1.1 RESOURCE CHARACTERIZATION

Peat bogs are estimated to cover about 400 million acres of the world's land surface, and 95 percent of this resource is found in the European and North American continents. The Soviet Union has approximately 228 million acres of peat, the largest peat deposits of any country. Second only to Russia is the United States, with 52.6 million acres. Based on a 35 wt. percent moisture content, this acreage represents a domestic resource of 120 billion tons, equivalent in energy content to 240 billion barrels of oil. These energy reserves exceed those estimated as available from uranium, oil shale, natural gas, or petroleum. Although peat is found in all 50 states, about 90 percent of the resources are concentrated in seven states: Alaska, Minnesota, Michigan, Florida, Wisconsin, Louisiana, and North Carolina. Most of the states rich in peat resources do not have significant reserves of other fossil fuels. Therefore, peat represents an important indigenous resource for those states.

Compared to lignite, peat contains about 60 percent more volatile matter and has 25 percent less heating value. Typical proximate analyses and heating values of peat and other coals are listed in Table 1.1. A trend is evident that, with increasing rank (geologic age), the volatile matter content of these fuels decreases while fixed carbon contents and heating values increase. A comparison of typical ultimate analyses (Table 1.2) show that peat is low in sulfur but high in oxygen and nitrogen.

Table 1.1

Proximate Analyses and Heating Values Of Peat and Coal Samples

	Volatile Matter Wt. %	Fixed Carbon (m.a.f. basis)	Calorific Value Btu/lb. (m.a.f. basis)
Peat	71	29	9,200
Lignite	44	56	12,200
Subbituminous	40	60	13,300
Bituminous	35	65	15,000
Anthracite	3	97	15,100

Source: Reference 44

Table 1.2

Ultimate Analyses of Peat and Coal Samples

Sample	Ultimate Analysis (wt.% dry ash free basis)				
	C	H	S	N	O*
Reed Sedge Peat	56.8	5.6	0.3	2.7	34.6
Montana Lignite	71.8	3.7	0.6	1.1	22.8
Bituminous Coal (HVA)	81.8	5.6	1.5	1.4	9.7

*(by difference)

Source: Reference 44

Peats are classified into three general categories according to the degree of decomposition: fibric, hemic, and sapric. Other nations have developed different classifications, yet they are based on the same idea of increasing decomposition. Of the three types, hemic peats are the most widely distributed and are best suited for energy use.

All three types of peat can be found in two main depositional environments, bogs and fens. Peat bogs are located above the water table and receive no water through the soil. All water for the bog is received by precipitation, be it snow or rainfall. Because of the relatively pure rainwater and the covering of sphagnum mosses, bog waters are usually acidic. Fens are generally meadow-like in appearance, with less tree cover compared to bogs. The primary water source is groundwater, which increases the nutrient content and reduces the fen-water acidity. Another peat environment is swamps, although these resources are insignificant in terms of energy usage.

1.2 TECHNOLOGY EVALUATION

Extraction

European harvesting methods for peat fuel have been developed for either sod peat or milled peat harvesting. Both approaches first require the construction of ditches so the bog can drain. After draining, the bog surface can support machinery for tree removal, levelling, and finally, extraction of peat. Sod peat is formed by digging the peat, macerating it by machine, and extruding it into blocks the size of long bricks. The bricks are turned occasionally and left on the field to dry. The dried bricks (35-50 wt.% moisture) are then used in small stoker-fired boilers, or in home furnaces.

Milled peat is produced by cutting a half-inch layer from the bog surface and leaving it on the field to air dry. Drying is fast, and the fluffy layer of peat can be skimmed or vacuumed off and used directly as fuel in pulverized power boilers.

An alternative to these drained-bog methods is currently being investigated by U.S. and Canadian agencies. In the proposed approach, peat would be harvested directly from the cleared bog as a peat-water slurry. The Western Peat Company in Vancouver, B.C. is presently harvesting peat by wet-dredging from a barge. This approach circumvents the problems associated with clearing and draining large acreages of wetlands, and has the potential for year-round harvesting.

Dewatering

Because of peat's high affinity for water, in-place peat resources may contain up to 95 percent of its weight as moisture. Its use as a fuel requires that this percentage be reduced to about 50 percent for combustion, and 35 percent for gasification processes. The drained-bog harvesting methods (sod and milled peat) can achieve these values, given suitable dry weather. Mechanical dewatering can reduce the moisture content to about 60-70 wt.%, using a filter press concept similar to ones used to dewater washed coal and pulp (paper industry).

There are several "wet" approaches to peat dewatering that use heat and pressure to destroy the colloidal bonds binding peat solids to water. Wet carbonization is one in a family of wet technologies. In this process, high pressure steam heats a water-peat slurry to a point where the colloidal bonds break. The resulting peat sludge can then be mechanically pressed to remove much more water than if the incoming peat slurry was filtered by the presses alone. If further dewatering is necessary, waste heat from the carbonization plant can thermally dry the peat to almost any level desired.

Combustion

Peat has been used successfully as a feedstock for various types of furnaces in Europe. The choice of sod peat, milled peat, peat briquettes, or pellets depends upon the furnace, be it stoker, pulverized, or FBC. The established trends in Europe favor sod peat for small stoker-fired boilers (5-20 Mw), and, milled peat for pulverized boilers (20-40 Mw). Conversion of boilers now firing coal to use with peat (or peat/coal blends) may encounter problems with ash fouling, lower ash softening temperatures ($\sim$2100°F for peats)[76], and incomplete combustion. NO_x emissions from peat will generally be higher than from lignite combustion. Cyclone furnaces appear to be well suited for peat combustion; fluidized bed combustion is another potential firing method, although some of FBC's unique properties (such as SO_2 removal by an alkaline bed material) may not be fully utilized with peat fuels. Peat and peat/lignite blends have been tested with comparable results to lignite combustion tests in a 6-inch AFBC.[86]

Gasification

Tests conducted at the Institute of Gas Technology (IGT) show that peat has a higher reactivity for gasification than lignite, and more carbon is converted directly to hydrocarbon gases in a short-residence time hydrogasifier than is converted with other coals. Therefore, less severe operating conditions will be adequate for converting peat to synthetic natural gas (SNG). Also, peat hydrogasification gives a high yield of hydrocarbon gas at relatively low hydrogen partial pressures. Both of these factors contribute to favorable economics and production efficiency.

IGT has developed a gasifier configuration designed specifically for peat and has called it a PEATGAS reactor. In this concept, steam and oxygen are fed into a char gasifier section to produce a hydrogen-rich gas. This hydrogen-rich gas is used to convert the peat to raw products in the primary gasifier section of the same reactor vessel. Down-stream units recycle char to the char gasifier, separate raw product liquids from raw product gases, recover sulfur compounds and ammonia, and convert raw product gases to combustion heat or synthetic products such as SNG.

The PEATGAS process can offer significant flexibility in product distribution: as the raw gas enters the CO-shift conversion step, the ratio of hydrogen to carbon monoxide (CO) can be adjusted to maximize production of SNG, or gasoline blending feedstocks, or almost any balance of fuel products.

Another hydrogasifier reactor distinct from IGT's PEATGAS reactor has been proposed by Rockwell. In this short residence time (SRT) entrained flow hydrogasifier, the application of rocket engine injection and mixing techniques is used to accomplish rapid mixing and reaction of hot hydrogen and peat. This SRT reactor utilizes higher pressures and temperatures (about 50 atm and 1660°F, compared to 10 atm and 1000-1600°F for the PEATGAS reactor) and reduced residence times (2.9 seconds compared to 5-7 seconds) than in IGT's PEATGAS process.

1.3 ENVIRONMENTAL ANALYSIS

Water and Air Quality Impacts

Peatland development, as with any large-scale surface disturbance, will impact the local aquatic and terrestrial plant and wildlife ecosystems. Of particular concern is the fragile ecology of peat bogs, which may in some locations be considered protected wetlands.

The Minnesota Department of Natural Resources has conducted numerous studies to characterize the biological nature of undisturbed peatland regions. Results indicate that the acidic qualities of peat bog waters may be toxic to downstream aquatic ecosystems unless sufficient dilution occurs. Such contamination could occur during initial bog drainage procedures prior to harvesting. Similar toxification could occur if peat dewatering effluents were released untreated into receiving waters.

Preliminary studies also found concentrations of heavy metals such as mercury in peat, at levels similar to those found in coal. More studies are planned to further investigate the possibility that peat bogs behave as environmental filters for heavy metals.

Peatland harvesting will necessarily affect water flows through the bog. Vegetation removal, actual drainage (for milled peat harvesting), and peat extraction will affect discharge rates, although preliminary assumptions are conflicting as to whether net discharges will ultimately increase or decrease. Coastal peatland drainage could create additional problems due to the potential intrusion of saltwater.

Air-related environmental impacts are less of a concern than water-related impacts, although dust problems may arise from milled or sod peat harvesting techniques. Harvesting machinery may emit products of combustion from diesel or gasoline powered engines, but these types of impacts present no unique or insurmountable problems.

Peatland Reclamation

Large-scale peat development presents an unprecedented opportunity to transform an area of unused land into a productive agricultural area or a high-diversity wildlife refuge, with the option of retaining some of the original character of the peat bog area. Because peat bogs are, in most instances, under-utilized, sparsely populated areas, peat harvesting operations can proceed with little effect on current land use patterns. However, more information is needed to determine the precise role natural peatland have in the regional ecology. An unintentional destruction of one link of the area's wildlife or aquatic food chain may create eventual environmental repercussions that cannot be reversed.

Four reclamation options are discussed: 1) Tree farming; 2) agricultural cropland; 3) renewable energy farming; and 4) development of a diversified wildlife refuge. The final choice among these and any other alternatives will depend on the local economic climate, as well as on topographical, climatic, biotic, and hydrological factors.

1.4 REGULATORY ANALYSIS

Peatland disturbance and peat fuel utilization will encounter regulatory obligations somewhat similar to those for low-rank coal developments (see Volume 4, Section 4.2:Regulatory Analysis). More emphasis will be placed on wetlands issues and water quality controls in peat development than with coal development.

As in most energy projects, the magnitude of the development will determine the degree of complexity in obtaining the necessary regulatory approvals. The primary regulatory hurdles for any scale of peatland development will be the state and Federal regulations for wetlands protection, surface water pollution discharges, and air quality maintenance standards. The secondary regulatory issues will focus on hazardous waste disposal, health and safety, coastal zone management, and broad NEPA regulations.

1.5 MARKET ANALYSIS

The acceptance of a new energy development industry, such as peat fuels, is necessarily founded on a proven and reliable market for its products. In the case of peat, energy products can be made from raw peat to enter any one of three fuel market areas, perhaps more. The three discussed in this volume are: pulverized peat fuel, substitute natural gas (SNG), and peat pellets or briquettes.

Pulverized Peat Fuel

Pulverized peat has been a reliable fuel source in Finland, Ireland, and Russia for many years. Recent U.S. experimental firings of peat and coal blends have exhibited favorable results, although no utilities have as yet decided to utilize peat/coal blends on a continuous basis. Because of the relatively straightforward (though somewhat costly) conversion of coal burners to peat or peat/coal burners, several industrial applications have been studied for their economical potential for such a conversion. The results are somewhat ambiguous due to unknown peat prices and unstable prices of conventional fuels. In every case, however, the lower heating value of milled peat as suitable for pulverizing requires that any industrial peat user must be located close to the peat fuel source. Transportation costs remove peat from economic consideration whenever the distances are over 50 to 100 miles.

There is another factor working against the future pulverized peat fuel market: milled peat harvesting, which produces a peat fuel form suitable for pulverizing, has met environmental opposition due to its need for large-scale peat bog draining. In Minnesota, the favored harvesting approach appears to be by hydraulic methods, which would cause less widespread ecological disruption. However, both the hydraulic harvesting process and the subsequent dewatering technique remain to be perfected. In North Carolina, milled peat harvesting may be the desired method.

If the environmental concerns about harvesting and reclamation can be resolved, and technology for cost-competitive production of peat fuel proves out, then peat would have very favorable market prospects. Peat would have to be utilized locally to produce steam or electricity. Large peat resources are located very close to major eastern and midwestern energy markets where high-cost oil and gas are currently used heavily. Low sulfur content might help to give peat a significant competitive advantage over eastern and midwestern bituminous coal in these areas.

SNG

If favorable economic projections for production of SNG from peat are borne out by further development work, a large potential market for this fuel exists. Unlike peat used directly as fuel, SNG is easily and cheaply transportable, and an extensive natural gas pipeline infrastructure is in place. Market development will depend on the competitive costs of SNG from peat, SNG from other fuel sources, and on the price and availability of natural gas.

Peat Briquettes/Pellets

There is little information available at this time on U.S. development of a peat briquetting or pelletizing industry, although both milled peat and peat pellets have been produced experimentally at First Colony Farms in North Carolina. Similar processes are currently active in European peat countries. It is anticipated that economic evaluations may indicate that until domestic coal and firewood prices increase, peat pellets and briquettes will not become a viable energy competitor. Results from ongoing research in these areas will provide more information on process economics.

1.6 RESEARCH, DEVELOPMENT, AND DEMONSTRATION (RD&D) ACTIVITIES

The Department of Energy has provided substantial funding for peat RD&D activities in the following areas: resource characterization; harvesting; dewatering; gasification; environmental; and socioeconomic evaluations. Of these areas, the primary support has been directed towards developing a large-scale peat gasification technology. The results of this effort should lead to actual production at a commercial scale within the decade.

The DOE Energy Technology Center in Grand Forks, North Dakota, is conducting limited research on the potential for peat combustion and dewatering technologies. Ash fouling problems have been evaluated for peat firing and peat/coal blends, using peat charges from Minnesota and North Carolina.[86]

The Minnesota Department of Natural Resources (MDNR) has been a major supporter of peat RD&D in the state. The MDNR has recently received additional state funds, as well as DOE funding, to continue its work in environmental, socioeconomic, technological and reclamation studies. The MDNR emphasizes the protection of the states wildlife and environmental resources in and around potential peat development areas. By the time harvesting operations actually commence, Minnesota should have a clear understanding of the consequences and should be able to provide invaluable assistance to developers so as to minimize adverse effects.

Recommended RD&D projects for peat are shown on Table 1.3. In the priority I area, environmental impact studies of large-scale peat harvesting and utilization operations are needed. Harvesting techniques need development for application to U.S. peatlands. Dewatering techniques should be studied.

Conversion processes to derive energy from peat that deserve high-priority attention are the wet peat conversion processes, combustion processes, and gasification.

Peat resources in the U.S. need to be characterized in detail to provide data for harvesting and environmental impact studies.

Effluents from peat processing, across the board, need to be characterized, and control systems need to be adapted to any special problems.

Health and safety aspects of peat harvesting and utilization need to be studied to determine if any special problems exist.

Priority II recommendations for peat RD&D include: 1) development of crushing and grinding techniques; 2) briquetting and pelletizing of peat fuel; 3) handling and storage of dried peat, to prevent dust or spontaneous heating problems; 4) solid waste disposal from peat utilization; and 5) development of liquefaction processes for peat, including direct hydrogenation and oxidative depolymerization.

Table 1.3

Recommended RD&D for Peat

Priority I	Priority II
1. Environmental Impacts of Large-Scale Peat Utilization	10. Peat Comminution Techniques
2. Harvesting Techniques: Hydraulic, Milled, Sod	11. Briquetting and Pelletizing of Peat Fuel
3. Peat Dewatering Techniques	12. Handling and Storage of Dried Peat
4. Wet Peat Conversion Processes: - Wet Oxidation, Wet Carbonization, Anaerobic Digestion, Aqueous Phase Liquefaction	13. Solid Waste Disposal from Peat Utilization
5. Peat Combustion Techniques: - Stoker, Pulverized Peat, Fluidized Bed Combustion	14. Liquefaction of Peat by Direct Hydrogenation and by Oxidative Depolymerization
6. Gasification of Peat: - High-Btu Gas, Medium-Btu Gas, Low-Btu Gas	
7. Peat Resource Characterization	
8. Characterization and Control of Effluents from Peat Processing: - Heavy Metals, SO_2, NO_x, Particulate, Organics	
9. Health and Safety Aspects of Peat Harvesting and Utilization	

2. RESOURCE CHARACTERIZATION

2.1 INTRODUCTION

Peat resources are found throughout the world and are estimated to cover about 400 million acres of land, or approximately one percent of the earth's surface. Of these peatlands, relatively few have been extensively surveyed and quantified; it is safe to assume, however, that the peatlands of Europe and North America account for over 95 percent of the estimated worldwide resources. Domestic peatlands are estimated to cover 52.6 million acres, which represents about 120.3 billion tons (based on peat dried to 35 percent moisture content). Assuming a nominal heating value of 6000 Btu/lb (at 35 wt. percent moisture), the total potential energy available from known peat resources is over 1440 quads (10^{15} Btu). This estimate of potential energy is not as precise as those calculated for other domestic fossil-fuel resources, primarily because less than one percent of the peatlands have been surveyed in detail. The value of 1440 quads has more meaning when compared to the potential energy estimates of other energy resources, as illustrated in Figure 2.1 It is important to note, however, that the peat estimate is based on total resources, whereas all the other values are based on proven and currently recoverable deposits.

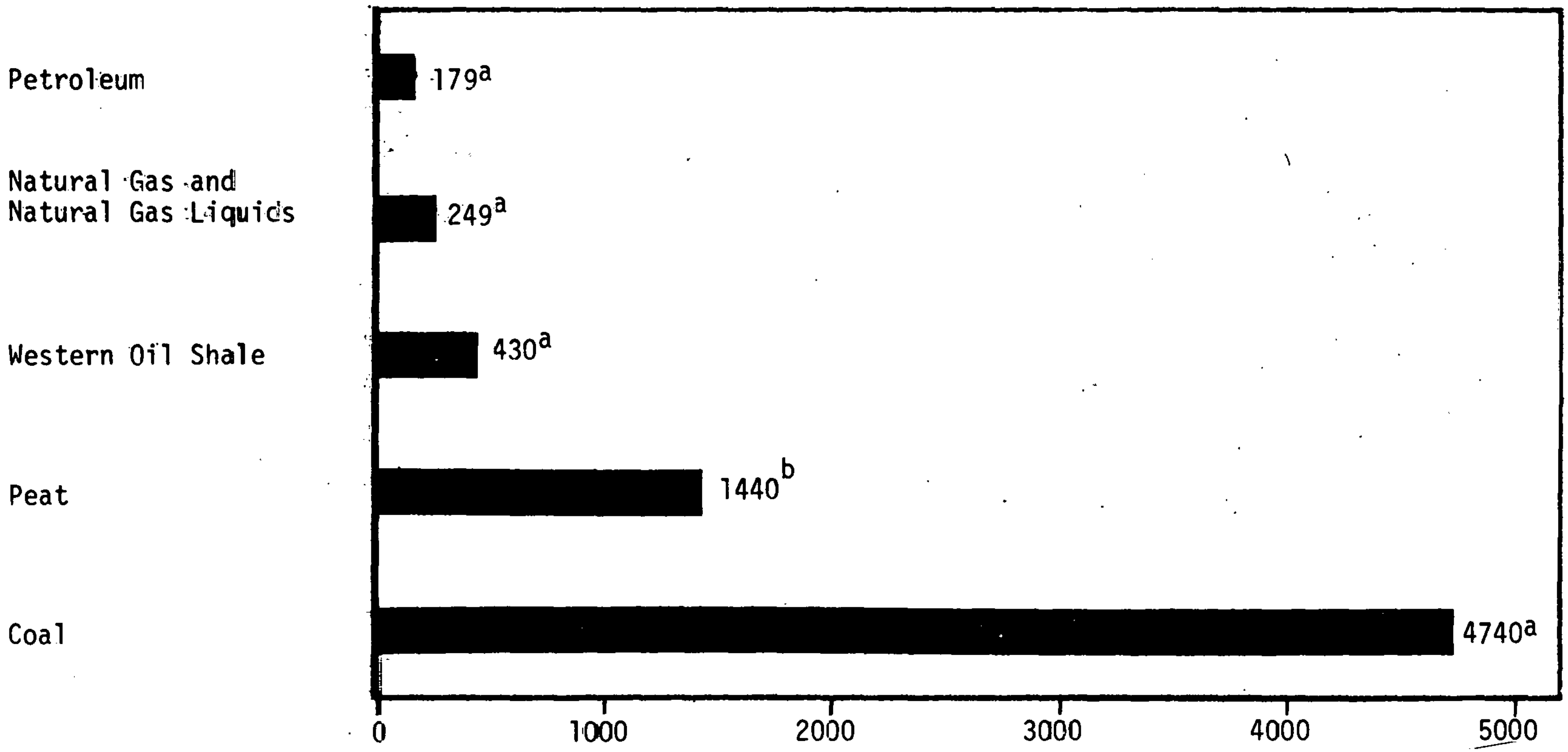
Peat has been used for centuries in European countries as a fuel supply. Presently, Russia produces about 2 percent of its energy requirements from peat with most of it being used for electric generation. Ireland uses considerably less peat than Russia, but its use for energy represents about one fourth of that nation's energy supply.[15] Peat as a fuel has not been actively pursued in the United States due to the relatively low cost and availability of more conventional fuels. With petroleum prices rising and other fuel stock prices following suit, peat can now be considered a viable domestic energy resource.

Peat is generally considered a "young" coal in that its state of partial decomposition of plant matter represents an early phase in the slow coalification process. When compared to older coals (see Table 2.1), air-dried peat retains a higher moisture content and a somewhat higher nitrogen content than the higher ranks of coal. Due to the environmental nature of peat deposition, virtually all peats are low in sulfur (about 0.1 percent at 50 percent moisture). This makes peat an attractive fuel supply for industrial and utility boilers that must meet the strict SO_2 emission standards.

There are different grades, or ranks, of peat just as there are different grades of subbituminous or bituminous coals. Within any particular peat bog, three types of peat can usually be identified. These three types, according to U.S. definitions, are fibric, hemic, and sapric. Fibric peats are almost invariably found as the upper layer in peat bogs and consist primarily of sphagnum and other mosses.

Figure 2.1

Comparison of Domestic Energy Resources



[a]Proven and currently recoverable.
[b]Estimate of total resource.

Sources: References 75 and 77

Table 2.1

Comparison of As-mined Peat, Lignite, and Coal Analyses
(weight percent)

	Peat[a]	Lignite[b]	Subbituminous[b,c]	Hi-Vol Bituminous[c,d]	Anthracite[e]
Moisture	50.0	36.8	22.2	14.4	4.3
Hydrogen	2.8	6.9	6.9	5.8	2.9
Carbon	26.4	40.6	53.9	59.7	79.7
Nitrogen	1.2	0.6	1.0	1.0	0.9
Oxygen	15.6	45.1	33.4	20.1	6.1
Sulfur	0.1	0.9	0.5	3.8	0.8
Ash	3.9	5.9	4.3	9.6	9.6
Heating Value, Btu/lb	4000-5000	7000	9610	10,810	12,880

[a]Typical milled peat sample, reference 2
[b]McLean County, North Dakota, reference 14
[c]Sheridan County, Wyoming, reference 14
[d]Sangamon County, Illinois, reference 14
[e]Lackawanna County, Pennsylvania, reference 14

Hemic peat is the most widely distributed and largest quantity peat type in the United States.[2] This peat type is older and more decomposed than fibric peat. Sapric peat is decomposed to the point that its original plant origins are not recognizable.

This section on Resource Characterization identifies the global and domestic peat resources; the composition of peat; the various types of deposits; and the historical nature of peatland formation. The material has been highly summarized for this report. More detailed information can be obtained from the references cited at the end of the report.

2.2 OCCURRENCE

2.2.1 Global Resources

Global resources of peat are mostly located in the Northern hemisphere, with over 95 percent of the worldwide resources in Europe and North America. Surveys of peat resources in various countries have been limited and quite variable. For example, the Soviet Union reports only exploitable reserves; European countries that are presently utilizing their peat resources have fairly accurate estimates; other countries make gross estimates on the basis of the extent of muskeg swamps.

It is estimated that the Soviet Union has approximately 60 percent of the world's exploitable peat reserves. The northern European nations of Finland, Sweden, Poland, East and West Germany, together with Ireland and Great Britain, have large resources of peat (see Table 2.2). Approximately one-third of the total area of Finland is considered peatland. Sweden's total peatland is estimated at 14.5 percent of that country's total area. Some countries have large deposits of peat that do not substantially add to the total world reserves. Nonetheless, they are significant to those individual countries and can still be considered potentially valuable for energy.[2]

Although peatlands occur worldwide, only a few countries are currently extracting peat for energy or agricultural purposes. In particular, the Soviet Union and Ireland have extensive energy utilization programs for peat; they consume approximately 95 percent and 2 percent, respectively, of the world's annual harvest. Table 2.3 lists these percentages and those for other peat harvesting countries.

Table 2.2

World Peat Resources

Country	Acres (Millions)
Soviet Union	228.0
United States*	52.6
Finland	35.6
Canada**	34.0
East and West Germany	13.1
Sweden	12.7
Poland	8.6
Ireland	7.3
Great Britain	5.8
Indonesia	3.3
Norway	2.6
All Others	5.2
TOTAL	408.8

*Estimate includes non-permafrost peatlands of Alaska.
**Estimates does not include Arctic Canada Peatlands.

Source: Reference 1

Table 2.3

World Extraction of Peat

Country	Percent of World Harvest
Soviet Union	95.2
Ireland	1.9
East and West Germany	1.1
Finland	0.6
United States	0.2
Netherlands	0.2
Sweden	0.2
Canada	0.1
Norway	0.1
Others	0.4
	100.0

Source: Reference 2

2.2.2 Domestic Resources

The majority of domestic peat resources is located within three geographical regions: Atlantic Coastal, North Central, and Alaska. There are also substantial deposits of peat in New England, especially in Maine. The largest U.S. peat resources are found in Alaska. Excluding permafrost areas, Alaska contains over half of the nation's peat. Peat within the permafrost regions is not included in the peat reserves due to the overwhelming problems associated with its extraction.[2]

The regional locations of domestic peat resources are illustrated in Figure 2.2, and Table 2.4 lists peat tonnages and acreage for the more significant state resources. In all, the U.S. peat resource base is approximately 120.3 billion tons and covers 52.6 million acres of land.[a]

Within the contiguous United States, the North Central region--Minnesota, Michigan and Wisconsin--contributes approximately 14.5 million acres of peatlands, which is the majority of peatlands outside Alaska. Of these, Minnesota has the largest estimated peat reserve (7.6 million acres of peatland with a total of 16.4 billion tons).

The Atlantic Coastal region extends south from New Jersey to Florida. The large wetlands of Florida, including the Everglades, are estimated to contain the fourth largest reserve of peat in the United States. Similarly, large deposits have been located in isolated coastal areas in Georgia, North Carolina, South Carolina, and Virginia.

The remaining deposits of peat are scattered throughout the country, with potentially exploitable reserves located in Louisiana, Indiana, Massachusetts, and Hawaii.

2.3 PROPERTIES AND CHARACTERISTICS

2.3.1 Composition

Peat is a heterogeneous material of partially decomposed plant matter and inorganic minerals that has accumulated in water-saturated environments over a period of several thousand years. A water-saturated

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[a]These tonnage estimates assume the peat is dried to 35 weight percent moisture, is found in beds 7 feet thick and has a bulk density of 15 pounds per cubic foot. By these values, one acre of peat 7 feet deep equals 2287 tons.

Figure 2.2

Geographic Regions Containing Significant Amounts of Peat Resources

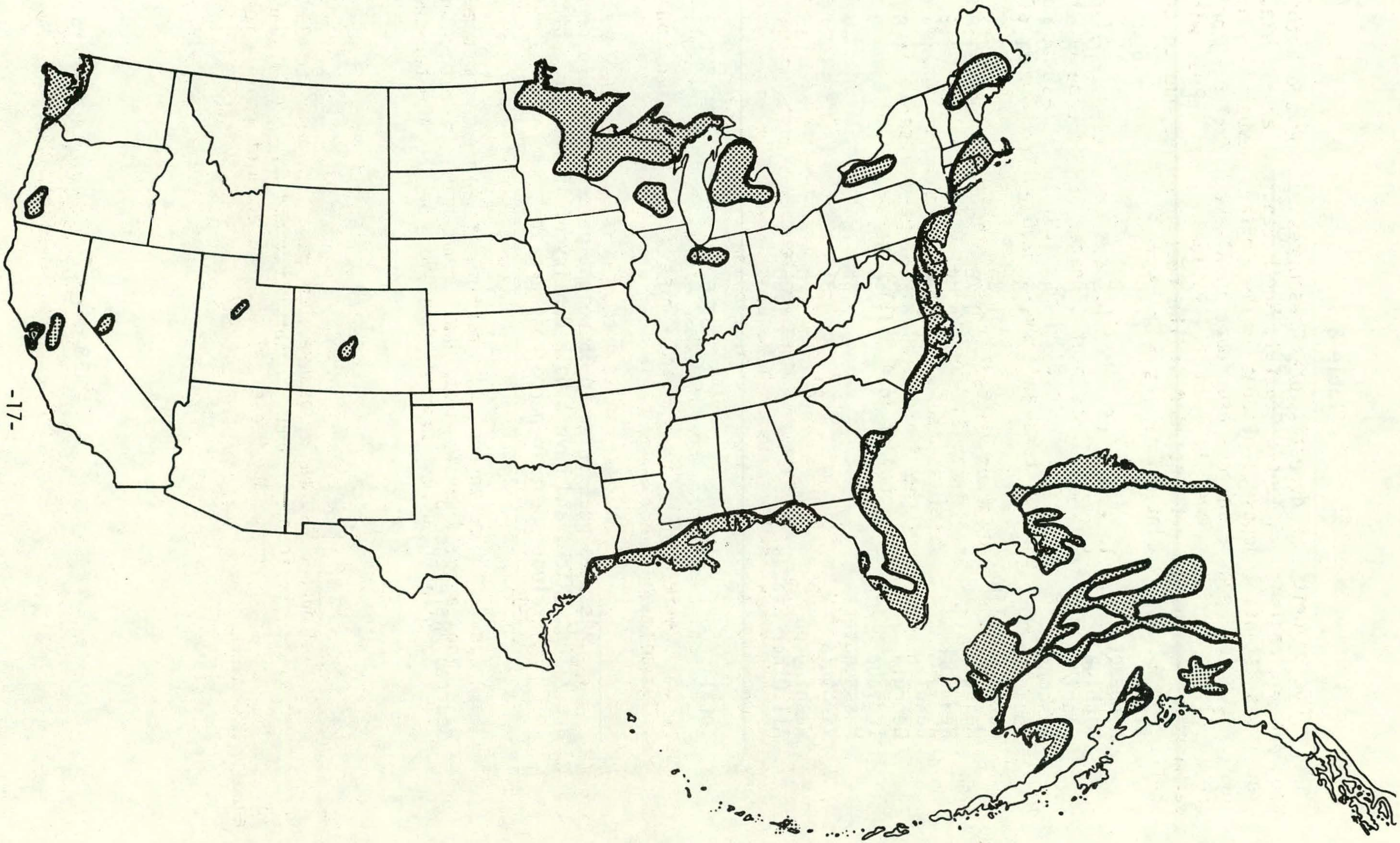


Table 2.4

United States Peat Resources

State	Acres (Millions)	Quantity[a] (Billions Tons)
Alaska	27.0[b]	61.7
Minnesota	7.2	16.5
Michigan	4.5	10.3
Florida	3.0	6.9
Wisconsin	2.8	6.4
Louisiana	1.8	4.1
North Carolina	1.2	2.7
Maine	0.78	1.8
New York	0.65	1.5
Hawaii	0.48	1.1
Georgia	0.43	1.0
Indiana	.38	.9
Massachusetts	.35	.8
Virginia	.31	.7
Washington	.20	.5
All Other States	1.50	3.4
Total	52.6	120.3

[a]Assumes peat dried to 35 weight percent moisture deposits are 7 feet thick, and have a bulk density of 15 lbs per cubic foot.

[b]Excludes peat in permafrost areas.

Source: Reference 3

environment inhibits active biological decompostion of the plant material and promotes the retention of carbon and oxygen that would normally be released as gaseous products from decomposition. As peat continues to age under relatively constant conditions, there is a gradual increase in the fixed carbon (carbonization). Hydrogen and oxygen are converted more quickly to water, carbon dioxide, and methane. The increase in fixed carbon is accompanied by a reduction in the volatiles. This is the basic process for producing coal (coalification), hence peat is considered to be a young coal. As an indicator of its "youth," it is interesting to note that most peat deposits are less than 5000 years old, whereas established subbituminous or bituminous coal deposits have taken 50-100 million years to develop.

Because of its development in a water-saturated environment, as-received peat samples can contain up to 95 percent water. Even after drainage and solidification, peat can still retain over 70 percent of its weight as water. Air drying will reduce the water content to between 30 and 50 percent.

A typical composition of air-dried peat is shown on Table 2.5. At a 50 percent moisture level, the energy content of a pound of fuel peat is 4000-5000 BTU. The chemical composition of peat and its energy content can vary--both between separate deposits and within the same deposit.

Table 2.5

Typical Composition of Air-Dried Peat

Component	Percent By Weight
Ash	3.86
Carbon	26.39
Hydrogen	2.77
Oxygen	15.63
Nitrogen	1.23
Sulfur	.12
Moisture	50.00

Source: Reference 2

This variation in composition is due to the degree of decomposition and the methods of accumulation.

Peat is typically lower in sulfur and higher in nitrogen than most coals. Sulfur concentration generally varies from negligible to less than one percent in dried peat. On the other hand, the ash content of peat can vary greatly as a result of the manner in which water is supplied to the peat bog. If water comes purely from precipitation, the ash will be very low. If the bog is fed by surface waters that periodically flood and carry heavy sediment loads, the ash will be high. Ash contents vary from 2 percent to 70 percent in reported assays of dry peat from a variety of sources. Obviously, the higher the ash content, the less desirable the peat is for use as an energy source.

The composition of peat ash, like the total percentage of ash, will depend on the history of the peat bog. Few analyses have been performed; two such analyses are presented in Table 2.6.

2.3.2. Classification

2.3.2.1 Peat Types

Peats are classified into three general categories according to the degree of decomposition and biological origin. These categories are:[2]

1. Fibric (peat moss) which is composed of sphagnum, hypnum, and other mosses;

2. Hemic (reed-sedge) formed from reeds, sedges, swamp plants, and trees;

3. Sapric (humus) which is composed of materials that are decomposed beyond botanical recognition.

Another U.S. method of classification, ASTM Standard D2607-69, lists five major types of peat according to genesis and fiber content: 1) sphagnum moss peat; 2) hypnum moss peat; 3) reed-sedge peat; 4) peat humus; and 5) other peats not classified under this standard. However, the former classification is more commonly used.

Fibric peats are normally young peats that are light in color as compared to other peat categories. The organic fraction of the peat consists of more than two thirds recognizable plant fibers of either sphagnum, hypnum, or other mosses. Fibric peats are normally found as

Table 2.6

Four Peat Ash Analyses

Sample	Ash Analysis, dry wt. %								
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	Na_2O	K_2O
Minnesota Reed-Sedge Peat[a]	40.3	9.6	6.4	0.4	--	19.0	5.8	0.8	1.4
Minnesota (Hill City)[b]	68.6	13.3	6.6	0.6	1.0	6.2	1.6	1.8	1.8
Minnesota (Red Lakes)[b]	47.2	8.9	4.6	1.0	1.6	31.0	3.9	0.9	1.2
North Carolina (First Colony Farms)[b]	43.8	9.1	4.9	0.8	1.8	33.2	4.1	1.1	1.2

Sources: [a]IGT (Reference 44)

[b]GFETC (Reference 86)

the latest succession within bogs and swamps. Since the fiber content is still fairly high, decomposition has not progressed to the point where these peats would be valuable as fuels. Due to the fiber content not being biologically or mechanically broken down, fibric peat has a high water-retention capacity. Fibric peats have low densities and normally have very little ash.

Hemic peats are somewhat older and more decomposed than fibric peats. These peats have at least one third to two thirds of the organic fraction as identifiable fibers with the majority of the fibers coming from reeds, sedges, and other plants not of the moss family. Hemic peats are considered to be intermediate between fibric and sapric in degree of decomposition, bulk density, and ash content.

Sapric peats are the oldest and most decomposed peats. Their color is normally brown to black. Less than one third of the organic fraction of the peat is recognizable fibers. Normally, sapric peats are the first peats formed in the filling of a basin. Consequently, sapric peats are the most dense and colloidal.[4] Due to their colloidal strength, sapric peats take on less water but retain it more strongly than other peats. The ash content of sapric peats varies from as little as 2 percent to as high as 60 percent.[5]

Peat classification systems vary somewhat between peat producing countries. The U.S. system just described (fibric, hemic, and sapric) differs from the other widely used systems from the Soviet Union and Sweden, as shown in Table 2.7.

Table 2.7

Comparison of Peat Classification Systems

System (country)	Peat Type									
United States		Fibric			Hemic			Sapric		
Soviet Union	10	20	30	40	50	60	70	80	90	100
Sweden (von Post)	1	2	3	4	5	6	7	8	9	10

Source: Reference 13

In both the Soviet and Swedish systems, which are numerical, the higher numbers refer to greater degrees of decomposition (humidification). The types of peat most suitable for use as fuel are the partially decomposed hemic (reed-sedge) and the more highly decomposed sapric types, which have von Post numbers of 7 and higher. These fibric types are more valuable as a horticultural soil conditioner.[13]

2.3.2.2. Peatland Types

Fibric, hemic, and sapric peats can be found simultaneously within particular peat deposits, and there are distinct classifications of peatlands based on the depositional environment. Peatlands can be divided into three main physiognomic classes: bogs, fens, and swamps. A fourth class, marsh, by definition does not accumulate significant amounts of peat.[6] The classes are defined by plant cover, water chemistry, and peat type.

Bogs. This types of peatland is usually dominated by a surface covering of sphagnum moss, a layer of low shrubs, and a tree layer of black spruce or tamarack. Common shrub species are leatherleaf, bog rosemary, bog laurel, and cranberries. When accumulations of sphagnum moss are rapid enough to result in a dome-shaped or convex area above the surrounding peatland, the bog is called a raised, or perched bog. Precipitation is the major source of water for the bog surface; bogs watered solely by precipitation are known as ombotrophic bogs. Mineral soil waters do not usually penetrate the bog because it is raised above the water table. Rainfall is relatively pure, so the water available to plants on the raised bog surface has a low nutrient content. Because of the sphagnum mosses and pure rainwater, surface bog waters and peat are usually highly acid.

Fens. Fens are peatlands with surface layers of poorly to moderately decomposed sedge peat. Fens are usually meadow-like, containing sedges and occasional dwarf birch and stunted spruce or tamarack. Sphagnum moss is rarely present, and the water and peat in fens are less acidic than those in bogs. Fens are also higher in nutrients because the water comes from the mineral soils rather than only from precipitation. Fens of this type are termed minerotrophic.

Swamps. Swamps are wooded wetlands where standing or gently flowing surface water persists for long periods. While most swamps are dominated by trees some are dominated by shrub thickets. The waterlogged substrate is a mixture of mineral and organic sediment or peat, and is mildly acidic with little or no deficiency in oxygen or mineral nutrients. Swamps typically contain the highest mineral content in peat; their utilization as a peat resource is less attractive than bogs are fens. They are also floristically richer than either bogs or fens and may even be productive forests.

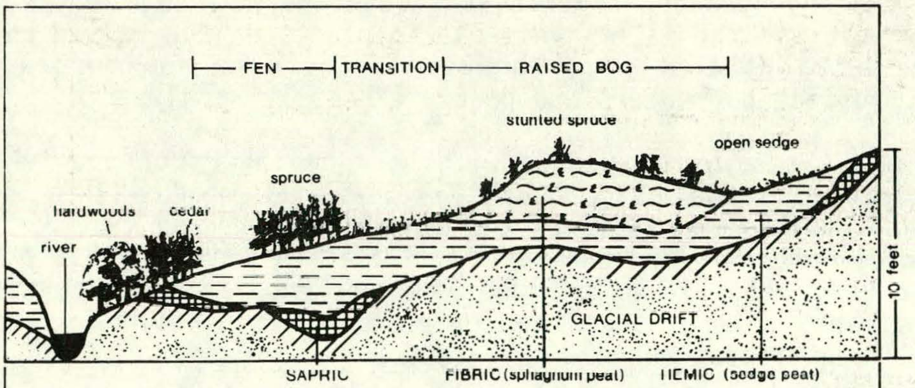
2.3.2.3 Peatland Formation

Peatlands have formed primarily in two ways, one by the filling of small lake basins (lakefill) and the other by the outward spreading of wet environments across uplands (paludification).

Paludification (Swamping). This term refers to the outward spread of wet, peat-forming environments over adjacent areas. This process is responsible for the formation of many huge peatlands in the North Central region. It began with the onset of a cooler and wetter climate about 3500 years ago. Because of poor drainage on flat or gently sloping land (such as old glacial lake beds), reed-sedge peat began to accumulate, followed by a growth of sphagnum moss. The development of paludification is illustrated in Figure 2.3. The various peat and peatland types discussed earlier are indicated to clarify the chronology of formation. Also note that the scale of the drawing represents a gradual (10 foot) rise in surface height over a 10 mile cross section.

Figure 2.3

Paludification Process

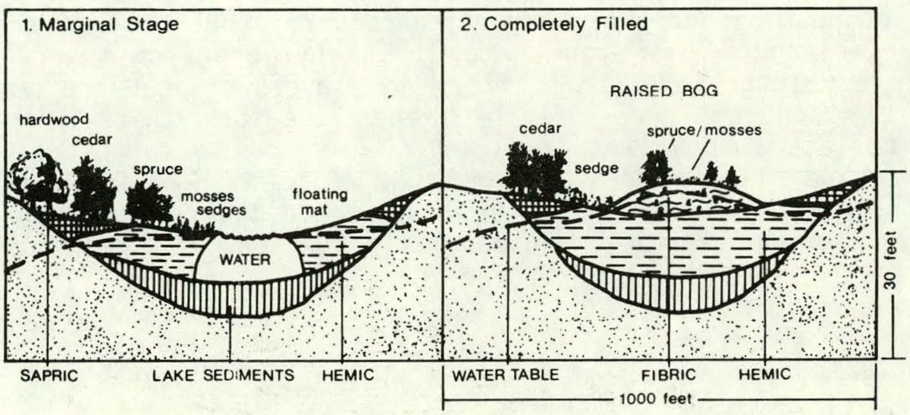


Source: Reference 7

Lakefill. This process begins as sedges grow towards the center of small lakes and basins from the shore, forming a floating mat of vegetation. Expansion of the mat into the lake allows other plants to migrate onto the older, more stable portions. First in succession are the semi-aquatic plants, followed by mosses, shrubs and herbaceous plants, and finally trees such as tamarack, black spruce, and white cedar (see Figure 2.4). Dead plant and animal matter collect as peat beneath the thickening mat. Eventually the mat comes to rest on top of the accumulated peat, while the young leading edges continue to grow outward to ultimately cover the entire lake surface.

Figure 2.4

Lakefill Process



Source: Reference 7

3. TECHNOLOGY EVALUATION

3.1 INTRODUCTION

Within this section are descriptions of both proven and experimental methods for use in each operation of peat fuel development. The three general operations are extraction of the peat; dewatering; and utilization.

Extraction

Extraction first involves clearing the bog of surface vegetation. Depending on the harvesting method selected, this initial step will be followed by either bog drainage or bog flooding. Bog flooding would be used for hydraulic harvesting methods, where a peat-water slurry is formed and pumped from the bog to dewatering facilities. This harvesting approach disturbs less surface area at any time, and has the potential for year round operation.

Milled peat or sod peat harvesting requires that the bog be drained prior to harvesting. This process may take anywhere from several months to more than a year to complete. Entire top layers of peat are removed in one "harvest", and are generally less than one-inch thick (for milled peat). To collect enough peat for use by a medium- to large-scale operation, many square miles of peat bog must be skimmed in one harvest. This requires a large land commitment, and is unavoidably dependent on dry weather to assure a dried fuel. Seasonal fluctuations may restrict harvesting activities to several months of the year.

Dewatering

Dewatering techniques are being investigated in parallel with hydraulic harvesting, since this method of peat extraction delivers a water/peat slurry. Mechanical filter presses can remove peat moisture to levels near 60-70 wt.% moisture; further dewatering is necessary for suitable use of peat in combustion and thermal gasification. Air drying of peat using pre-heated gases is very effective in drying peat to almost any level desired. However, unless a hot waste stream is used from a nearby process, thermal drying alone is prohibitively expensive, and would result in a negative energy gain (i.e., more heat is used to dry the peat than could be gained from the dried product).

Several designs are being investigated for dewatering peat with high pressure steam. High pressures and temperatures break the peat-water colloidal bonds and facilitate further dewatering by conventional mechanical and thermal methods. Such processes include wet carbonization and wet oxidation. Another approach, solvent extraction, is also under investigation.

Utilization

Combustion

Peat combustion is an established practice in Russia, Finland, and Ireland. Various forms of peat fuel are used: sod peat, peat briquettes or pellets, and pulverized peat. Selection of the most suitable form of peat fuel depends on the size of burner. Generally, sod peat and peat briquettes are produced (in Europe) for small grate-fired boilers, although they can be burned in different types of boilers constructed of solid fuels other than peat. At large plants, peat is pulverized and burned in suspension boilers. On the bottom of the furnace, there is often an after-burning grate, and fuel oil is used to complete combustion of the peat fuel.

Cyclone burners have proved to be one of the best combustion methods in medium-sized peat-fired plants because of their ability to handle variations in milled peat quality and moisture content.

Whether or not European experience in peat combustion can be applied to U.S. peat development depends on the type of harvesting and the ability to economically convert existing coal or oil-fired burners to handle a domestically unproven peat fuel.

Gasification

Two methods of gasification are presented: thermal gasification and biomethanation. Thermal gasification of peat resembles more technically advanced efforts at coal gasification, and is, in fact, a direct descendant of coal gasification technologies. Peat biomethanation is an adaption of anaerobic digestion of biomass. The advantages of biomethanation are that raw peat does not need to be dewatered before entering the reactor vessel, and that biomethanation can occur at mild temperatures and near-atmospheric pressures. The present disadvantage is that gas production occurs at a very slow rate -- probably too slow for large-scale commerical application.

3.2 EXTRACTION

Due to the water-saturated environment associated with peat resources, peatlands must undergo various levels of preparation prior to any harvesting activities. The first steps in preparing a peat bog for harvesting (by European methods) are to dredge, clear surface vegetation, and provide roads for access. A carefully designed network of ditches and waterways through the bog collects much of the water and routes it away from the harvesting area. If surface streams are associated with the peat bog, these must also be rerouted. As the bog dries, it can be cleared of debris and leveled. This initial bog preparation activity can take up to several years to complete. However, once the bog is prepared, different methods can be used for harvesting. The four harvesting methods to be discussed here are: (1) manual; (2) sod peat; (3) milled peat; and (4) hydraulic harvesting.

3.2.1 Manual Harvesting

The simplest way to harvest peat is to cut and lift chunks of surface layers from the bog and let them sun-dry until they are burnable. This labor-intensive approach is suitable, if not ideal, for small peat bogs in rural areas, where fuel demand is for village-scale heating needs. Commercial-scale utilization of peat resources will require a more mechanized approach if consistent and substantial supplies are to be harvested.

3.2.2 Sod Peat Harvesting

The oldest mechanical method of harvesting peat is sod peat harvesting, extensively used in Ireland, Finland, and Germany. The sod peat production system is based on air-drying blocks of peat which have been cut from the bog and mechanically extruded or stacked on the surface of the bog to dry. Specialized equipment has been designed to cut vertically into the surface of the peat to macerate the top layer and extrude either blocks or rolls of solid peat onto the surface of the bog to be air-dried.

The first stage of the cycle is to clear the surface of loose mossy peat and prepare it in an even fashion for the sod peat cutter to pass over during the production cycle. To accomplish this, a screw cutter or profiler machine is used to level the surface of the fields.

In Ireland a continuous bucket excavator and macerator, mounted on wide tracks, is used to cut and extrude blocks of peat onto a spreader which lays the peat blocks in an orderly fashion for air-drying. Maceration helps to mix the surface layers of peat with the more highly decomposed bottom layers of peat. The maceration of the peat compacts the extruded material and, once dried, the peat is more impervious to moisture build-up. In Finland, sod peat cutting is used only when milled peat methods are not technically feasible due to the nature of the deposit. The Finnish sod machine produces 5 cm diameter sods by extrusion of peat through nozzles in the rear of the cutting machine. The cylindrical sods are left on the surface of the bog for air-drying until they have approximately 75 percent moisture content, at which time they are stacked into windrows to continue the air-drying process.

The preparation of windrows is necessary to clear the bog surface for the next production cycle while allowing the peat to continue air-drying and a specially designed plough is used to lift and turn the sods as it piles them into windrows. After the upper layer of the windrows has dried to 55 percent moisture content, the same machine is used to turn over the windrow to permit the sods in the lower portion of the piles to be exposed to air-drying. After additional drying days, the windrows are ploughed and turned by a collecting machine which gathers the sod peat for loading and transport.[8]

3.2.3 Milled Peat Harvesting

Milled peat harvesting can be accomplished by way of two different technical approaches: collecting the milled peat into ridges for collection, or vacuuming the milled peat directly off the bog surface. Both approaches are discussed here.

Milled Ridge Harvesting

Milled ridge peat harvesting is based on the air-drying of a fine surface layer of fluffed peat to roughly 55 percent moisture content and ploughing into strings (ridges) in the center of the production fields. The ridges of peat are then transported, by various methods, to either a bogside storage facility or directly to a thermal power plant, or other industrial users.

The first operation profiles the fields such that they slope at approximately one in twenty towards a drainage system, which assists the surface runoff of rain water during the production season. After this operation has been completed, the first operation in the production cycle is the milling of the surface layer of peat to a depth of approximately one half inch. This layer is then left to dry until it has reached approximately 65 percent moisture content at the surface. This is usually accomplished within one day.

Once the top of the milled layer is air-dried to 65 percent moisture content it is turned over by a spoon harrow to expose the underside of the surface layer to air-drying. It can take several harrowings and a period of two to three drying days to lower the moisture content to approximately 55 percent and extra harrowing may be required if rain intervenes during the drying process.

Once the peat has dropped in moisture content to approximately 50-55 percent, the surface layer is ploughed into ridges in the center of each production field, which can then be handled by larger capacity harvesting equipment. European peat producers average 15 harvests or passes per season.

The two principal methods for transporting peat from the production fields are the Peco and Haku systems. Both systems utilize similar pieces of equipment but transfer the peat differently to the storage piles.

Under the Peco transportation system the field ridges are transferred laterally from field to field until all of the production is placed into a central storage pile, increasing in size as additional strings are collected. In Ireland, the central piles are sometimes covered with the plastic sheets to await loading and transportation throughout the year on a narrow gauge railroad system. This railroad system includes a permanent rail track along the bog side and temporary track which is laid across the fields containing the central storage piles. These temporary tracks are quite simple to move and can be relocated without difficulty.

In Finland, where Peco is used, removal from the central field is by bog-dumper or direct loading to transport vehicles.

In the Haku system the peat is taken directly from the strings by either "harvesting" or direct loading to tipper wagons. The peat is then stockpiled at the edge of the bog until it is transported by conventional means to a thermal power station.[8]

Milled Vacuum Harvesting

The milled vacuum peat harvesting method is similar to the previously described milled ridge method except that the collection methods for the peat differ. Under the vacuum peat production method the air-dried surface layer is gathered by a vacuum collector using front or side-mounted air suction mouths. A milling device is usually towed behind the unit to prepare the next surface layer. The air dried peat then passes through a cyclone where it is settled into a storage tank. The tank, located under the cylone, is side-dumped into a storage pile at the end of the field. From there the peat is transported by conventional trailers or dumpers to the final storage area. The milled vacuum peat mining method completes several operations in one cycle, namely; milling, harrowing, harvesting, stockpiling and transportation.

Usually a single harrowing is sufficient to dry the thin layer of peat to the required 50 percent moisture level. Vacuum collection can result in a reduction of the drying cycle from two or three days to one day when compared with the ridge method. This is achieved because only the drier peat particles are picked up by the vacuum collector as it passes over the fields. The moisture content of the collected peat can be controlled by adjusting the ground clearance of the vacuum mouth. The surface layer picked up by this method is approximately 0.15 inches on average, but is not as even as the ridged method.

Field production stockpiles are located at the end of each field. As in the ridged peat production method the stockpiles are compacted and sometimes covered with thin plastic to protect the peat from moisture build-up and wind loss. The piles measure 12-15 feet in height and vary in length.[8]

Either of these milled harvesting approaches eliminates the laborious turning of sods and provides a larger surface for faster drying of the harvest. With milled peat harvesting, for example, an average season in Ireland yields twelve harvests. Recognizing this advantage, the Irish, who had started to use sod peat in 1950 for generating electricity, decided in 1953 to design all future peat-powered electric plants for milled peat. Other peat-producing European countries also favor milled peat harvesting.

Because of the European success with such methods, the vacuum mining method has been selected for the first fuel peat production operations for steam generation in Canada.[a]

A drawback to milled peat is the environmental pollution by suspended particulate matter. In the language of the U.S. Clean Air Act, this is a "criterion pollutant" and strict regulations limit concentrations that may be emitted to the atmosphere. This constraint is important, since strong winds have been observed to carry milled peat dust twenty to thirty miles on a gusty day.[19] Another major drawback is the tendency of the milled peat process to bog fires, which can burn out of control for several months. These and other environmental problems associated with peat harvesting and utilization are discussed in section 4.

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[a]Montreal Engineering Company, Ltd., conducted technical and economic assessments of current peat mining methods throughout the world. These assessments were supported by the Canadian Department of Energy, Mines and Resources. Their report (1979) is listed as reference 8.

3.2.4 Hydraulic Harvesting

The hydraulic mining method is an alternative which may become more attractive in the future for fuel peat production if certain technical problems associated with it can be resolved. One hydraulic harvesting technique that is regarded as developmental is slurry peat harvesting, currently being studied in western Canada and Minnesota. As this mining method does not rely on solar drying, it is basically independent of climate conditions and can be used in many regions where peat production was not thought to be possible. Hydraulic harvesting also avoids the need for initial drainage and maintenance of large tracts of peat lands associated with milled or sod harvesting. With the milled peat method, for example, it is estimated that up to 400 square miles of peat land would have to be drained and devegetated for nearly 25 years in order to fuel proposed peat-fired power plants (such as Minnegasco's proposed 250 MM fts/day SNG plant).[9] A hypothetical single-pass peat harvesting system would have the advantages of faster startup (no drying/milling step required), faster reclamation, and would require an annual land use of only about 5 percent of that required for the milled peat method. However, to accomplish the necessary dewatering associated with one-pass harvesting, mechanical dewatering techniques must be used -- a process technically unproven for use on fuel peat production.

A single-pass peat harvesting system would harvest the peat from cleared and flooded bogs (as compared to drained bogs for conventional peat harvesting), then transport the peat/water slurry to a dewatering station. A method proposed here by the U.S. Bureau of Mines (Minneapolis) would use hydraulic dredges, pumping stations, dewatering facilities, and a closed-loop water return to the bog.[10]

In operation, the hydraulic dredge very much resembles a household vacuum cleaner with a cutting head. A heavy-duty centrifugal slurry pump powered by a diesel engine is mounted on a floating platform that sucks up cut peat from the pond through a movable tube as the platform is swung through the cutting arc.[11] The slurry is then discharged into the transport system and pumped through a floating pipeline to the mechanical dewatering plant.

Dewatering consists of passing the peat slurry through a roller press similar to those used in the paper industry. Thermal drying follows to bring the moisture content down to around 50 percent.

Preliminary field tests of this harvesting method using prototype equipment encountered problems with clogging of the cutting head, which required frequent shutdowns for manual cleaning.

Another hydraulic mining method, the hydro-jet harvester, uses water jets mounted on top of a floating platform to wash peat from the stringy roots and stumps in the bog. The relatively thin slurry (0.75 to 1.5% solids) is then pumped to the dewatering plant. This process has been used by Western Peat Moss, Ltd., British Columbia, since the 1930's.[12]

The suitability of any one harvesting technique to a particular peatland depends on technical feasibility, climate, and environmental impact, as well as economics. For example, peat harvesting (for fuel production) has been investigated in the two major U.S. peat areas, Minnesota and North Carolina. First Colony Farms (FCF) of North Carolina has tested sod and milled peat harvesting equipment from Russia and Finland. FCF peat deposits are highly decomposed and exhibit favorable characteristics as a fuel peat, yet the deposits contain large quantities of buried timber which interferes with harvesting. Hydraulic harvesting of these peatlands would not be suitable because of the large amounts of timber; therefore, First Colony Farms has engaged Suokone Oy in Finland to develop prototype harvesting equipment designed especially for these North Carolina deposits. This new equipment can harvest peat by either the sod or milled process, to accommodate the dry top layers and to process the buried wood debris.[16]

The Department of Forest Resources, University of Minnesota, evaluated various harvesting techniques for Minnesota peatlands. Their recommendations favor hydraulic harvesting methods over the milled or sod peat method due to environmental concerns. Harvesting by initial drainage of the peat bogs would produce adverse impacts from increased water flows and large commitments for exposed lands. Peat fires might become a serious problem.

3.3 PEAT DEWATERING

Peat's high affinity for water presents significant technical difficulties in removing the water by mechanical solid-liquid separation techniques. Even the best of filter press-type dewatering processes can only reduce the moisture content to 60-70 percent by weight. Thermal drying alone, other than that resulting from in-field drying by milled or sod peat harvesting, would require more heat input per pound of raw meat than is available in the resulting moisture free fuel product. Unless this large heat requirement is met by solar heating or exhaust heat from a nearby industrial process, thermal drying of peat is not practical except when used downstream of other dewatering processes.[a]

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[a]It is interesting to consider that the amount of solar energy required to remove the water from raw peat down to a weight percent of 40-50 percent may be more than twice the amount of energy received and stored by the original vegetation from the sun ages ago.[18]

As an alternative to conventional dewatering (and its limitations), there is a family of wet processing technologies that convert peat to more useful forms while it is contained in a water slurry. These processes utilize elevated temperatures and pressures to attack the colloidal gel which binds moisture to the peat. Structural changes occur, gaseous and liquid products and by-products are evolved, and the resultant slurry can be mechanically dewatered to a much greater extent than a raw peat slurry. Technologies considered as alternative wet technologies include: wet oxidation, wet carbonization, and solvent extraction. It is important to realize that these wet technologies do not necessarily eliminate the need for mechanical (and sometimes thermal) dewatering processes; rather, they alter the peat's chemical structure so as to make mechanical dewatering much more effective.

The current goals for moisture reduction operations are dependent on the particular use for the peat fuel: for direct combustion of peat, 50 wt. percent moisture in the peat fuel feedstock represents the approximate maximum percentage of water allowable; for the production of substitute natural gas (SNG), a peat fuel with less than 35 wt. percent moisture content is preferred.

This section describes the mechanical and alternative wet technologies considered applicable to the dewatering of peat.

3.3.1 Mechanical Dewatering

There are several mechanical dewatering technologies suitable for application to peat, such as filter discs, drums, and roller presses. Filter-oriented dewatering processes are basically similar in concept: dewatering is accomplished by placing a filtering medium (cloth, screen, etc.) in the slurry and applying a suction to draw the water and solids to the filtering surface. Water passes through the surface, leaving a filter cake (the dewatered solids) on the surface. This filter cake is then removed by reversing the pressure on the filter surface and/or by the use of mechanical scrapers.

The most promising mechanical dewatering method utilizes a filter press approach similar to that used by the pulp and paper industry. The Bureau of Mines recently completed an investigation of suitable peat harvesting methods for the U.S.,[10] and as part of this investigation they evaluated many mechanical dewatering processes. The following description is of a currently operating mechanical dewatering process located at Western Peat Moss, Ltd., in Vancouver, British Columbia. The process, known as the Vari-Nip Twin Roll Press (developed by Ingersoll-Rand, Inc.), was selected by the Bureau of Mines as the most suitable mechanical process for dewatering peat.

The Vari-Nip press consists of two horizontal porous rolls mounted in a sealed vat and rotating at the same speed toward each other. One roll is fixed, while the other is movable to allow for variable nip openings. If the mat thickness varies, the variable roll automatically follows this change and maintains a constant moisture discharge. Figure 3.1 illustrates the Vari-Nip process.

The slurry, at an incoming consistency of approximately 2 to 5 percent solids (normal 3.5 %), enters the sealed vat at approximately 3 to 20 psig pressure. The slurry then drains by pressure filtration and forms a mat on the roll surfaces that is carried forward into the nip by the rotation of the rolls, where further dewatering occurs.

Immediately beyond the nip, the dewatered slurry is scraped off the rolls and guided into a top-mounted screw-type shredder conveyor. The material is then gravity discharged at the rear end of the machine for conveyance to subsequent processing. The pressate (water) flows through the roll faces and is discharged at the bottom of the press.

Laboratory results predicted that peat could be dried to less than 70 percent moisture by weight. Due to the angle change with large roll diameters, the Vari-Nip press is somewhat difficult to scale up from laboratory findings. However, using a truck-mounted field demonstration unit, a test was conducted in northern Minnesota in October 1977. The results were significant, and a second test was scheduled for April 1978 at a unique sphagnum peat harvesting operation (a hover barge equipped with a traveling screen and a backhoe) in British Columbia--Western Peat Moss, Ltd.

The April 1978 results showed the Vari-Nip capable of dewatering peat slurry to less than 70 percent moisture, but because of a buildup in the vat, production was less than 20 percent of what had been predicted. This may be rectified using agitator or multiple ports.

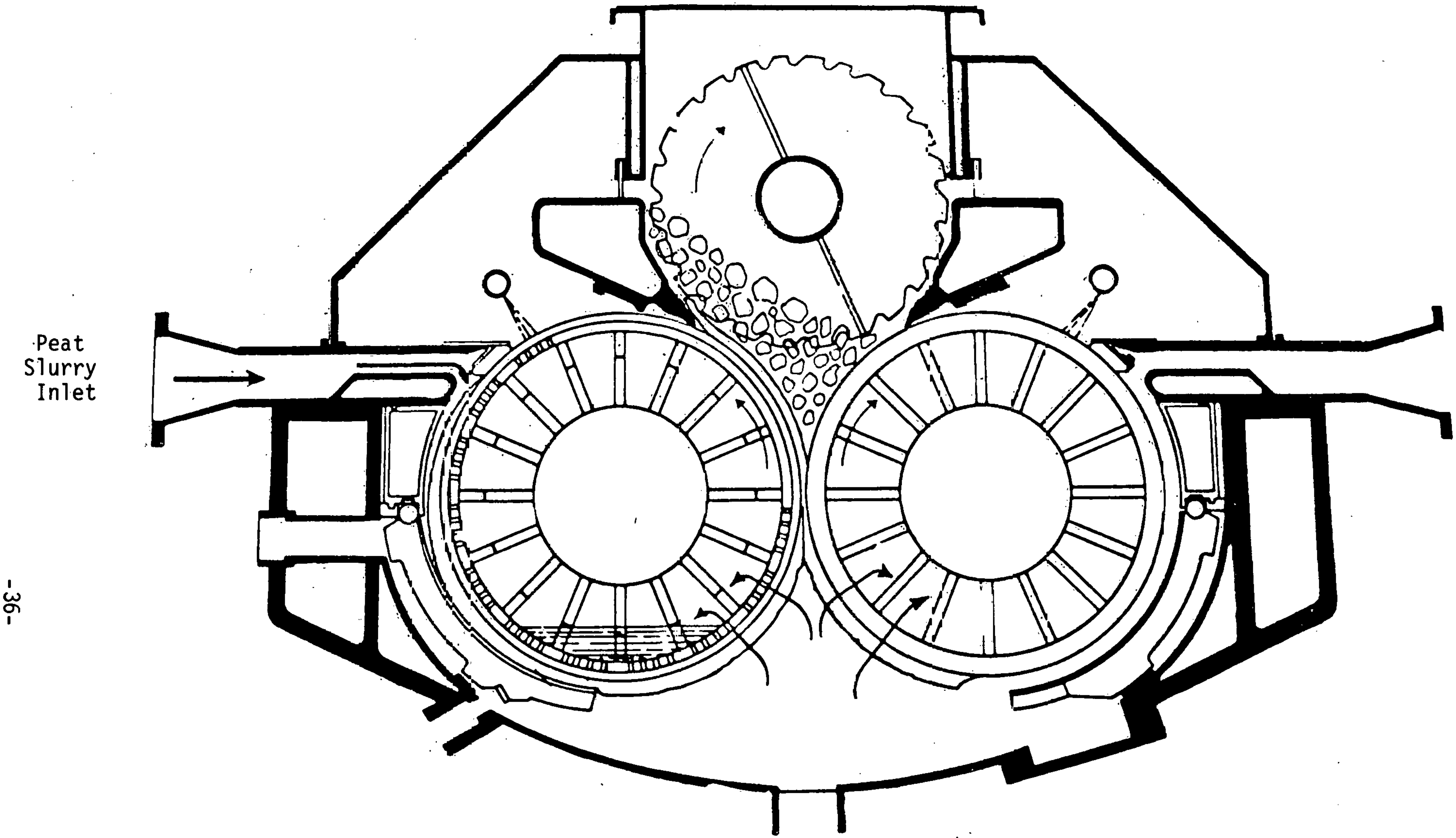
Although the first-step mechanical press could not dewater the peat down to the target of 50 weight percent moisture, the press removes approximately 17 pounds of the incoming 19 pounds of water (per pound of dry peat). The second stage would require a thermal type of dewatering to reach 50 weight percent moisture and would hopefully utilize excess industrial heat from gasification, electrical generation, or taconite pellet drying.

3.3.2 Thermal Dewatering

Even after wet carbonization a partial wet oxidation processing of peat, mechanical filter presses cannot reduce the moisture content below 50 weight percent. Thermal drying must therefore be used if

Figure 3.1

Schematic of Ingersoll-Rand Vari-Nip Press Machine



Source: Reference 10

additional moisture reduction is required. Little information is available that details thermal drying operations for peat; however, it is assumed that conventional drying processes established with coals and biomass feedstocks are suitable for peat feeds with minor modifications.

Two types of thermal drying processes are discussed here: 1) direct contact between drying medium and the feed, as in an entrained flow dryer; and 2) indirect contact by way of steam or hot air/feed heat exchanger. The latter method has been used to dry peat down to about 10 weight percent moisture for peat briquetting in Ireland, and has been in operation for over 40 years. The direct-type dryers are currently used in the United States (e.g., by Down East Peat Co., Maine) for preparing peat for agricultural use. Direct dryers are also used in the U.S. to dry bituminous coal, and with various high-moisture biomass feedstocks such as cotton and agricultural wastes; in Russia with peat feedstocks; and in Europe with brown coals.

Entrained Flow Dryers

In entrained flow dryers, the material to be dried is mixed (entrained) in a turbulent hot gas stream that carries the material through a drying column during which time moisture is evaporated from the feed and carried off by the hot gas. The degree of moisture removal is dependent upon several factors, including: the level of humification of the peat; residence time in the drying column; inlet temperature of the hot gas (500^{o}-1200^{o}F, or usually whatever is available as an exhaust stream from another process); and the mass velocity of the drying gases. The dried feed leaves the dryer and is removed from the gas stream by a cyclone separator. Careful monitoring and handling of the dried peat is required to minimize the risk of spontaneous combustion or dust explosions.

Indirect Drying

A full-scale example of an indirect peat drying process has been operating at an Irish peat briquetting plant since 1935.[20] The Peat Fuel Company designed the system to dry 55 weight percent moisture content milled peat efficiently to 10 weight percent water for briquetting. In this system, screened peat is fed by screw conveyor to the base of the first of five vertical spiral tubed dryers, arranged in series. The tubes of the first two dryers are jacketted by water at 150^{o}F and the final three dryers are jacketted by desuperheated back pressure (BP)-steam at 0.2 to 3 atmospheres and 280^{o}F temperature. The peat is blown up through the spiralled dryer tubes by a fan and is reduced to 10 weight percent by the time it leaves the final dryer.

The peat is cycloned out after each dryer with a gravity flow through an airlock and sent on to the next. The vapor and some dust is vented to the atmosphere from the cyclones of the water heated dryers.

The steam heated dryers are followed by cyclones and a scrubber/heat exchange system by which the higher grade heat in the evaporated vapor is passed to the jacket water of the first dryers. By this means a double effect usage of BP steam is obtained with resulting economy in drying.

Dried peat poses significant potential for spontaneous combustion; to mitigate this danger, the oxygen content of the 50/50 air/vapor mixture used to entrain and convey the peat is maintained at a low 11 percent, and the temperature kept at 180°F. Another problem is erosion of tube entries from the peat/air suspension. In this particular system the peat particles travel at about 40 ft/sec, and the erosive effect of fast moving sand and gravel particles in the peat can ruin tube plate within 2 or 3 years. This erosion problem is reduced by cupro nickel tube inserts that shield tube entry walls from the abrasive peat. These inserts last up to 8 years before they need replacement.

3.3.3 Alternative Wet Technologies

Wet Carbonization

For many years, the Soviet Union has used a wet carbonization process with milled peat to produce marketable quantities of furfural,[a] a dried peat fuel, and a clarified filtrate suitable for fermentation to alcohol.[21] A batch process is used, in which about 15 tons of peat are loaded into a large autoclave, steam is added, and the mixture is held at about 365°F for twenty to thirty minutes. The carbonized peat is then dewatered to about 37 percent moisture in large plate filter presses, and is used as a solid fuel.

Steam leaving the autoclave contains 0.5 percent furfural which, after neutralization with lime water to remove carbon dioxide and traces of formic and acetic acids, is continuously distilled. Various streams from the distillation process contain increasing concentrations of furfural. The waste stream from the still is 0.03 to 0.04 weight percent furfural; the furfural-rich phase is removed and shipped to market.

Water from the filter presses is vacuum filtered to clarify the organic-rich filtrate. Removed solids are returned to the peat filter presses. The clarified filtrate is then fed into fermentation tanks using yeast cultures especially acclimatized for the purpose. After several fermentation cycles, the resulting liquid consists of 93 to 94 percent ethanol.

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[a]Furfural is an oily liquid derived from cellulosic waste materials (usually oat hulls, rice hulls, corn cobs, bagasse, etc.) and used for solvent refining of lubricating oils, butadiene, and other organics; and in the manufacture or refining of many other materials.

A batch process of this type is not applicable to U.S. market conditions. The Soviets had nearly completed development (through pilot plant testing) of a continuous process using the above principles in 1958;[21] however, further reports of this development have not been obtained.

Professor Bertel Myreen of Ra-Shipping Ltd. Oy (Finland) has developed a "peat fuel" process using wet carbonization, which is illustrated in Figure 3.2. As shown, raw peat is first cleaned and homogenized to a pumpable slurry. After preparation, the slurry passes through a series of preheaters which raise its temperature to about 285°F. Each preheater stage utilizes different process or waste heat sources to maximize the overall system energy economy. In the particular case shown, the first stage is heated by secondary hot water, the second by back-pressure steam, and the third by heat transfer from hot carbonized peat slurry in a patented preheating tower. The fourth stage of heating is provided by live high-pressure steam injected to the carbonization reactor.

Othmer has pointed out that large-scale heat exchange of the type shown is impractical because of the nature of the material and the fouling of heat transfer surfaces.[18] Myreen addresses this problem, stating that the fouling occurs at temperatures above 150°F, which is not exceeded in the two rotating-tube-bundle heat exchangers (patented) in his process.[22] In any event, efficient heat exchange is clearly required if this process is to be economical, and technical difficulties in obtaining reliable, efficient heat exchange are to be expected.

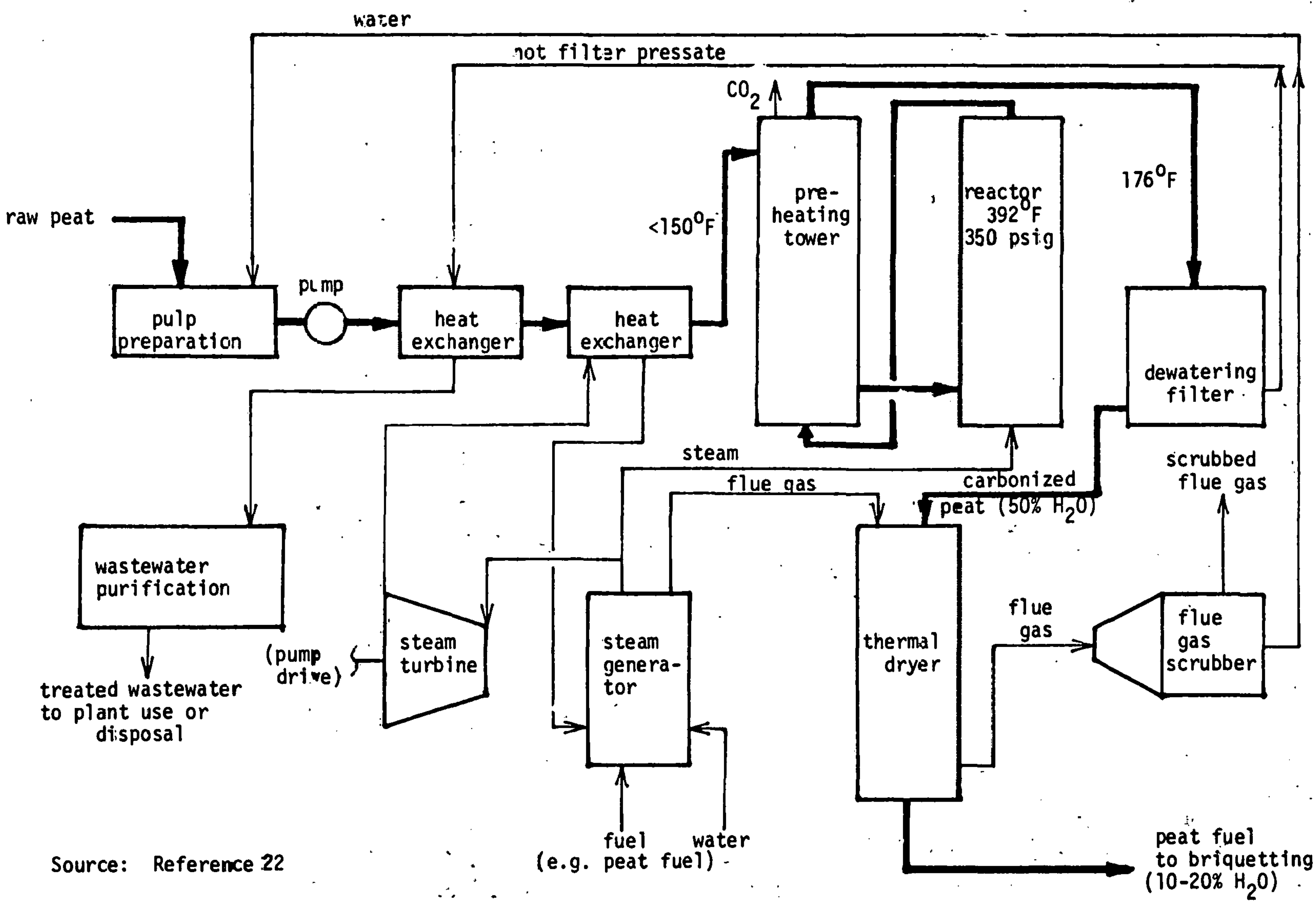
The preheated peat slurry and live steam are fed to "specially designed" carbonizing reactors where a "favorable" residence time for peat particles is provided. The pressure of 350 psig is partially due to CO_2 formed in the reactor as the colloidal bonds are broken. The carbonized peat slurry is then flashed and cooled in the patented multi-stage preheating tower. The slurry is then dewatered by pressure filters, which reduce the moisture content of the peat to about 50 weight percent. Further moisture reduction is obtained by thermal drying with flue gases from the steam boiler, ultimately producing a peat fuel with a heating value of 12,000 to 14,000 Btu/lb. Special precautions are required to avoid dust explosions in the thermal dryer.

Wet Oxidation

Wet oxidation of peat has been proposed by Othmer, either as a partial oxidation process to give a dry marketable fuel, or (preferably, according to Othmer) as a complete combustion system to produce steam and hot combustion gases for power generation.[18] Wet oxidation is the most widely used non-biologic process to destroy relatively small amounts of organic materials as solids or liquids in aqueous solution or suspension. Examples are the wet oxidation of sewage waters or sludges, and munitions plant wastes. The technology, design data, and engineering/operating know-how are well established for the wet oxidation of almost any

Figure 3.2

Simplified Process Flow Diagram for Wet Carbonization of Peat



Source: Reference 22

organic material. Many variations of possible processes and equipment may be used. The technology has not been commercially applied to peat; however, small-scale testing of wet oxidation (with alkali addition) is being performed as a pretreating step in DOE's peat biomethanation project.

One possible version of a wet oxidation plant (adapted from Othmer) is presented in Figure 3.3 for illustration. The slurry preparation step and the initial heat exchange with hot filter pressate (wastewater) are essentially the same as in the wet carbonization process. However, air is compressed (or separated to provide pure oxygen) for injection into the slurry in a controlled amount to provide the remaining process heat by oxidation of the peat. This heat (under pressure) breaks the colloidal peat-water bonds and generates steam in situ. If the process is operated in a partial oxidation mode, CO_2 and combustion gases are released, and the wet pulverulent peat fuel product is readily dewatered by filtration to 35-50 percent moisture. Additional thermal drying could be provided as was illustrated in the wet carbonization flow sheet; this is not shown on Figure 3.3.

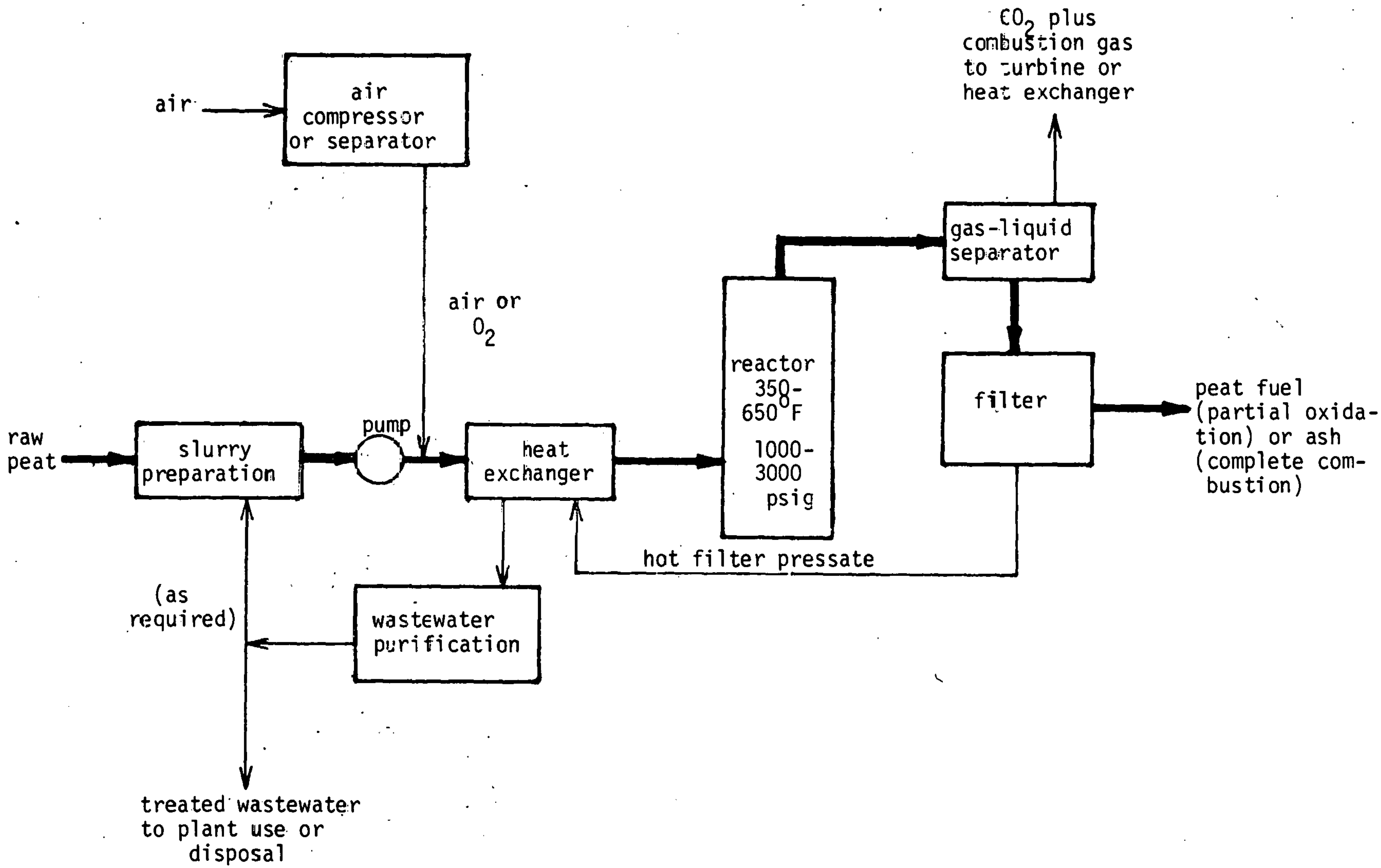
Alternatively, in the configuration preferred by Othmer, complete oxidation of the peat slurry produces high pressure steam and other combustion gases which can be expanded through turbines for power production. Maximum obtainable steam pressures are approximately 800 psig (the reactor would be about 3500 psig) although an initial plant of this type would probably produce steam at about 250 psig and 405°F (this would require wet oxidation reactor conditions of about 500°F and 1000 psig).

The peat is burned in the slurry at a temperature between 350° and 650°F to carbon dioxide and water. Any sulfur in the peat feed is converted to the sulfate form in the aqueous phase. The water phase also contains dissolved and suspended inorganics in completely oxidized form; the combustion products discharge to a separator which yields a condensate phase and a gaseous phase of steam and uncondensible gases. Organic nitrogen in the peat is converted to ammonia and its salts, so there is neither SO_x or NO_x in the gases ultimately discharged (according to Othmer).

The aqueous liquid passes through a heat exchanger to preheat the incoming peat slurry. The liquid is usally acidic due to sulfuric acid formed from the sulfur in the peat. It can be neutralized with lime or other alkali and reused in the peat slurry or treated further and discharged.

Figure 3.3

Simplified Process Flow Diagram for Wet Oxidation of Peat



Source: Adapted from Reference 13

Solvent Extraction

Solvent extraction of peat is presently studied as a means of dewatering the peat, of liquefying the peat into a distillable oil, or as a means of both dewatering and producing bitumen from the peat feed. Relatively little detailed information is available on these procedures, although several German and American patents,[23,24,25] as well as more recent technical articles,[26,27,28,29] describe conceptual processes that have been proposed as early as 1937.

In the case of solvent extraction for peat dewatering, a peat-water slurry is mixed with an organic solvent. Water is extracted from the peat by the organic phase. The two-phase water-solvent system is cooled and separated, with the solvent recycled after the absorbed water is stripped. The extracted water is reused in the slurry preparation operation as needed, disposed of following treatment. Figure 3.4 shows a conceptualized process flow diagram for one such dewatering method, which involves elevated temperature and pressure. Other methods being explored contact the peat and the solvent at ambient conditions.

There has been recent bench-scale work initiated on a process that performs two functions in one vessel: peat dewatering, and liquid phase hydrogenolysis.[30] The researchers have shown that at pressures around 1000 psig and temperatures of 525^{o}--660^{o}F, a peat-water mixture was converted to a segregated aqueous phase consisting primarily of the peat moisture, and to a heavy mixture formed by the bitumen[a] and solid residue.

The experimental work was conducted in a one liter autoclave equipped with an automatic temperature controller. The charge of raw peat into the autoclave was 200 grams (6.4 ounces). Since the moisture content of the raw peat was 85.1 percent and the ash content 8.1 percent (relative to the dry matter in the peat), the 6.4 ounce charge contained less than one ounce of organic materials. Once the system was closed and flushed with nitrogen, the reactor was pressurized with carbon monoxide (CO) and subsequently heated to reaction temperature where the hydrogenolysis reaction was carried out for two hours.

After cooling the autoclave to room temperature, the gaseous phase was purged through a series of traps and a wet test meter; the aqueous phase was easily separated from the heavy organic material by simple decantation. Results from the products analyses indicated that the major gaseous products were hydrogen and carbon dioxide. The elemental analyses of the original peat, the bitumen, and the portion of the bitumen not soluble in toluene (residue) are given in Table 3.1. The

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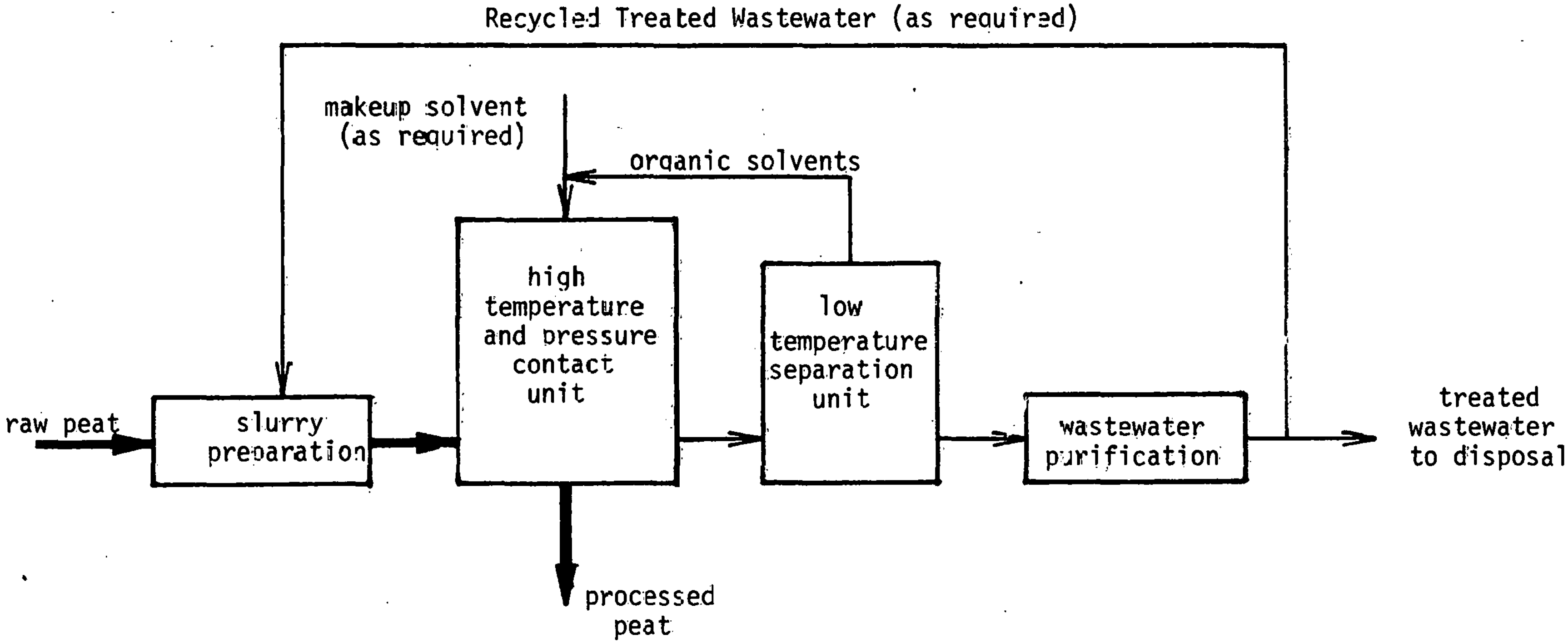
[a]Bitumen is a semisolid organic material obtained as an asphaltic residue from the distillation or other conversion of coal, wood, peat, or similar material.

Figure 3.4

Simplified Process Flow Diagram for Solvent Extraction Dewatering of Peat



Source: Adapted from Reference 1

Table 3.1

Elemental Analyses of Peat, Bitumen and Toluene Insoluble Residue from Exp. No. 8

	C%	H%	O%	N%	S%
Peat	55.0	5.8	31.7	2.1	0.25
Bitumen	80.1	9.3	7.1	1.8	0.10
Residue	15.6	1.1	17.2	0.3	0.70

Source: Reference 30

increase in the hydrogen content of the bitumen relative to the original peat and the considerable reduction in oxygen and sulfur are quite significant and would facilitate further hydrogenation of the material.

Potassium carbonate (K_2CO_3) was added in some experimental runs to determine the need for a catalyst for the shift reaction. The experimental results suggested that there is little or no influence of the K_2CO on the conversion[a] but that there might be some influence on the bitumen yield,[b,30] Comparison of tests with and without K_2CO_3 additions indicated fairly similar rates of shift conversion, suggesting a possible catalytic role associated with the inorganic matter present in the peat.

Within the range of variables studied, temperature played the most significant role, and the mathematical model derived from the factorial design suggests that higher temperatures increase bitumen yields. Temperature also seems to be a more important variable than pressure in both conversion and bitumen yields.

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[a]Conversion is defined in the conventional ways as:

$$C(\%) = \frac{\text{wt. of maf peat} - a}{\text{wt. of maf peat}} \times 100$$

where

a = $y_s - 2.4$

y_s = toluene insoluble solid residue (g) excluding the amounts present as solid residue in the aqueous phase.

2.4 = ash present in the moisture-free peat.

wt. of maf peat = organic material present in the raw peat.

a = wt. of organic material still present in the toluene insoluble solid residue.

[b]The bitumen yield, Y_b, is simply defined as the toluene soluble material divided by the maf peat.

Source: Reference 30

3.4 UTILIZATION

Peat has been an important fuel in many countries for centuries. It was first used on a large scale in Germany, Denmark, and the Netherlands, but due to the exhaustion of peat reserves and especially to the competition provided by other fuels, these countries no longer use peat as a fuel.

The present users of peat fuel are primarily the Soviet Union, Ireland, and Finland. Each county represents an interesting example for the following reasons: the Soviet Union represents large, absolute consumption volumes of peat, yet peat provides only a small overall percentage of the country's total energy production; Ireland on the other hand, supplies a significant proportion of its total energy needs with peat, although the actual quantity is relatively small; Finland has only begun its peat development within the past decade, yet the rapid rate of development has already made peat fuel a significant contributor to the nations' energy diet.

The United States has yet to significantly develop its indigenous peat resources as a fuel, although experimental work has been active for several decades. It is important, therefore, to become acquainted with foreign peat fuel experience as well as recent domestic studies. This section first presents an historical summary of foreign development, followed by descriptions of applicable combustor and boiler technologies. In addition to the actual technical experience from these European activities, U.S. research (primarily in gasification) activity is highlighted since these efforts appear to be the most applicable for domestic peat development.

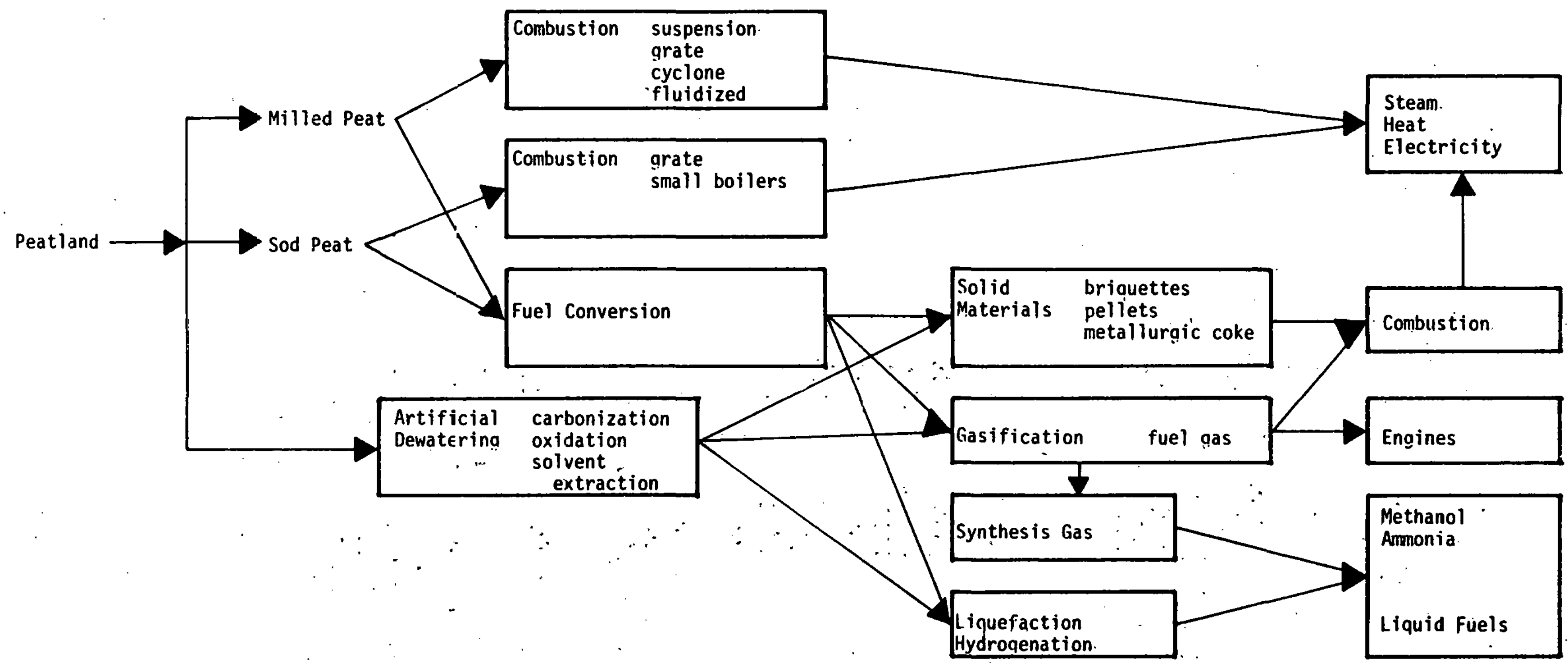
A graphical representation of possibilities for energy production from peat is shown in Figure 3.5, and provides an outline for the utilization technologies to be discussed.

3.4.1 Foreign Peat Development

The first country to use peat on an industrial scale was the Soviet Union when, after the Revolution, the Soviets introduced a program (the GOELRO electrification plan) to develop their fuel peat industry. This plan, adopted in 1920, envisioned the construction of 20 power plants, including five power stations running solvely on peat and supplying about 10 pecent of the nation's energy. The five plants were built, and the first one came on line in 1922.[13] Sod peat (see section 3.2.2) was the form of peat material used by these first power plants, reflecting the common harvesting method at that time. In 1931 the first district power plant utilizing milled peat began operation. This successful shift to milled peat for electric generation stations in turn provided the impetus

Figure 3.5

Alternatives For Producing Energy From Peat



for a rapid development in milled peat harvesting technology in the Soviet Union, accompanied by a conversion of several existing sod peat-fired plants to milled peat utilization.

At the present time 80 million tons of peat are consumed by 76 power stations in the U.S.S.R. According to 1977 figures, peat fired power generating capacity was approximately 5000 MW, which represents about two percent of the total.[31] The Shaturskaja electric power station is currently the largest peat powered plant in the Soviet Union with an output capacity of 723 MW (electric). Several new power plants, with an output of 600 MW each, have recently been constructed, and there are plans to increase the total national capacity to 6300 MW.[13]

In Ireland, peat has been used as a domestic heating and cooking fuel for over a thousand years. Although mechanical briquetting operations have now replaced much of the hand cutting and drying, peat remains a common domestic heating fuel. The use of peat for power generation was initiated in 1950, following the formation of Bord na Mona which nationalized the indigenous fuel peat development activities. Since then, Ireland's peat-fired generating capacity is now over 420 MW, representing about 30 percent of the total generating capacity. Another 160 MW will be added to the current peat fired output by 1984. This will bring the annual peat production to a level of six million tons. The earliest small peat-fired boilers were grate fired, but since 1958 all boilers have been fired on pulverized peat.[31]

The country most active in developing its peat resources is Finland, where in the past few years peat has assumed a 2 to 3 percent share of the raw energy market and is continuing to expand.[31] Although peat has been used as a fuel in Finland since the 1940s, no large power plants were constructed until 1972, in response to rapidly rising costs of imported oil. Finland has emphasized district heating utilization of its power plant waste heat; one such dual-function facility has been operating since 1972, and six more plants are either in construction or in planning.[13] In 1977 and 1978, Finnish consumption of peat was distributed into various sectors: industry, 33 percent; district heating, 56 percent; and space heating and other uses, 11 percent.

3.4.2 Combustion

Besides required capacity, the type and quality requirements of peat are significant in the selection of peat combustion methods. In Table 3.2, peat combustion methods are roughly selected according to the design capacity and the type of fuel peat, based on European experience.

Table 3.2

Matching of Combustion Method with Peat Fuel Product

Method	Capacity	Type of Peat[a]
Pulverized Firing	30 - 200 MW	milled peat
Grate Firing	3 - 60 MW	milled or sod peat
Grate Firing	- 3 MW	peat briquettes or pellets
Cyclone Firing	3 - 15 MW	milled peat
Fluidized Bed Firing	10 - 100 MW	milled or sod peat

[a]Peat fuel produced by the previously discussed alternative wet technologies can be formed and burned like sod peat or briquettes. Other possibilities include grinding and blending in fuel oil and burning as a slurry.

Source: Adapted from Reference 32

Generally, sod peat and peat briquettes are produced (in Europe) for small grate-fired boilers, although they can be burned in different types of boilers constructed for solid fuels other than peat. At large plants, peat is pulverized and burned in suspension boilers. On the bottom of the furnace there is often an after-burning grate, and fuel oil is used to complete combustion of the peat fuel.

Cyclone burners have proved to be one of the best combustion methods in medium-sized peat-fired plants because of their ability to handle variations in milled peat quality and moisture content. Fluidized-bed combustors offer additional advantages due to extremely effective heat release and relatively low furnace temperatures.

All of these combustion technologies are discussed in more detail in the following paragraphs.

Grate Firing

Grate firing of peat occurs in stoker furnaces, where the fuel peat is introduced to the combustion zone on a grate, allowing air to mix with the peat from below. Furnace grate designs are generally similar to those used with other solid fuels (coal).[31] However, peat fuel requires slight modifications to the grate design:[31] The free grate area (that area exposed due to complete combustion of fuel) must be kept lower with peat fuel than with other fuels - 4 to 8 percent lower on inclined grates, and 12 to 18 percent lower in traveling grates to avoid flyash blow-away. This constraint results in high fuel layer thicknesses, up to four feet on traveling grates and the need for steeper angles of inclination with inclined grates. The main concern is not only to reduce the fouling of boiler passes and particle emissions, but specifically to minimize the danger of a dust explosion in the furnace.

The temperature of primary air and the overall thermal load must be kept low in order to avoid fusion which, among other inconveniences, also leads to extreme wear of moving grate parts.[31]

The long luminous flame characteristic to combustion of peat, combined with the low fusion point of flyash, produces a high but rather narrow furnace column. Furnaces fired with pulverized peat often require an afterburning grate at the bottom of the furnace because of incomplete pulverization of larger wood particles in the fuel. Narrow traveling grates and stationary grates with dumping grate sections have been used in European peat fired boilers.

Grate firing of peat does not require any pretreatment of the fuel because all the necessary treatment for final combustion takes place on the grate.[31]

Cyclone Firing

Cyclone furnaces designed for milled peat firing have been developed over the last 10 years by Kymi Kymmene Metalli in Finland. Presently, most of the medium-sized district heating plants in Finland firing with milled peat are delivered by Kymi Kymmene.

The cyclone furnace is a cylindrical chamber with the inside surface either coated with a refractory lining or made completely of firebrick. Milled peat and combustion air are blown tangentially into the cylinder, creating a swirling combustion flame.

Cyclones are classified into two types, dry or molten ash, depending on whether the slag from peat melts in the cylone or whether it remains dry. The oldest cyclones were dry ash furnaces. The slag accumulating on the cyclone walls had to be removed by raising the combustion temperature beyond the slag melting point and draining the molten slag from the furnaces. Another problem with the dry cyclone furnace was the wide variations of moisture in peat. Peat with over 49 percent moisture did not burn satisfactorily because the temperature in the cyclone could not be raised sufficienty. Excessively dry peat, on the other hand, caused the temperature to exceed the ash-softening point, which resulted in slagging.[33]

These problems are avoided by using molten ash cyclones. Gas temperatures within the cyclone reach up to 3000°F, which is sufficient to melt the ash into a liquid slag. The centrifugal forces created by the swirling air and fuel maintain a thin layer of slag on the furnace walls, which in turn holds incoming peat particles as they become combustion products and molten ash.

The heat release rate per cubic foot in a cyclone furnace is very high, but the small furnace surface area is partially insulated by the covering slag layer. The combination of high heat release and low heat absorption assures the high temperatures necessary for complete combustion and for maintaining the liquid slag layer on the furnace walls.

Reaching and maintaining the necessary combustion temperature of 2250-2730°F is not consistently possible without pre-drying the peat. Flash drying with flue gases has proved to be the best solution, according to Kymi Kymmene.[33] With flash-drying, the flue gases of a peat-fired boiler may be cooled nearly to the dewpoint because the sulphur content of the peat is low (0.2%). The efficiency of the boiler is at about the same level as that of an oil-fired boiler, i.e. 85-90 percent.

Figure 3.6 presents the principle of flash drying and combustion in a molten ash cyclone furnace. From the silo (1) the peat is discharged, for example, with the help of screw feeders (2) and via a rotating valve (3) to the wind sieve (4) which finally screens out stones and stump pieces. Flue gases from the boiler (the temperature of which may be regulated) (5) are also led into the wind sieve. The peat and the drying gases gases stream through the drying channel (6) to the peat separator (7), where the peat falls into the ejector (8) and is then blown with the help of air into the cyclone (9). The temperature in the cylone is kept so high that the slag melts and runs continuously through the slag channel (10) into the quench basin (11). Slag removal is completely automatic. The flue gases are cleaned with a multi-cyclone separator(12).

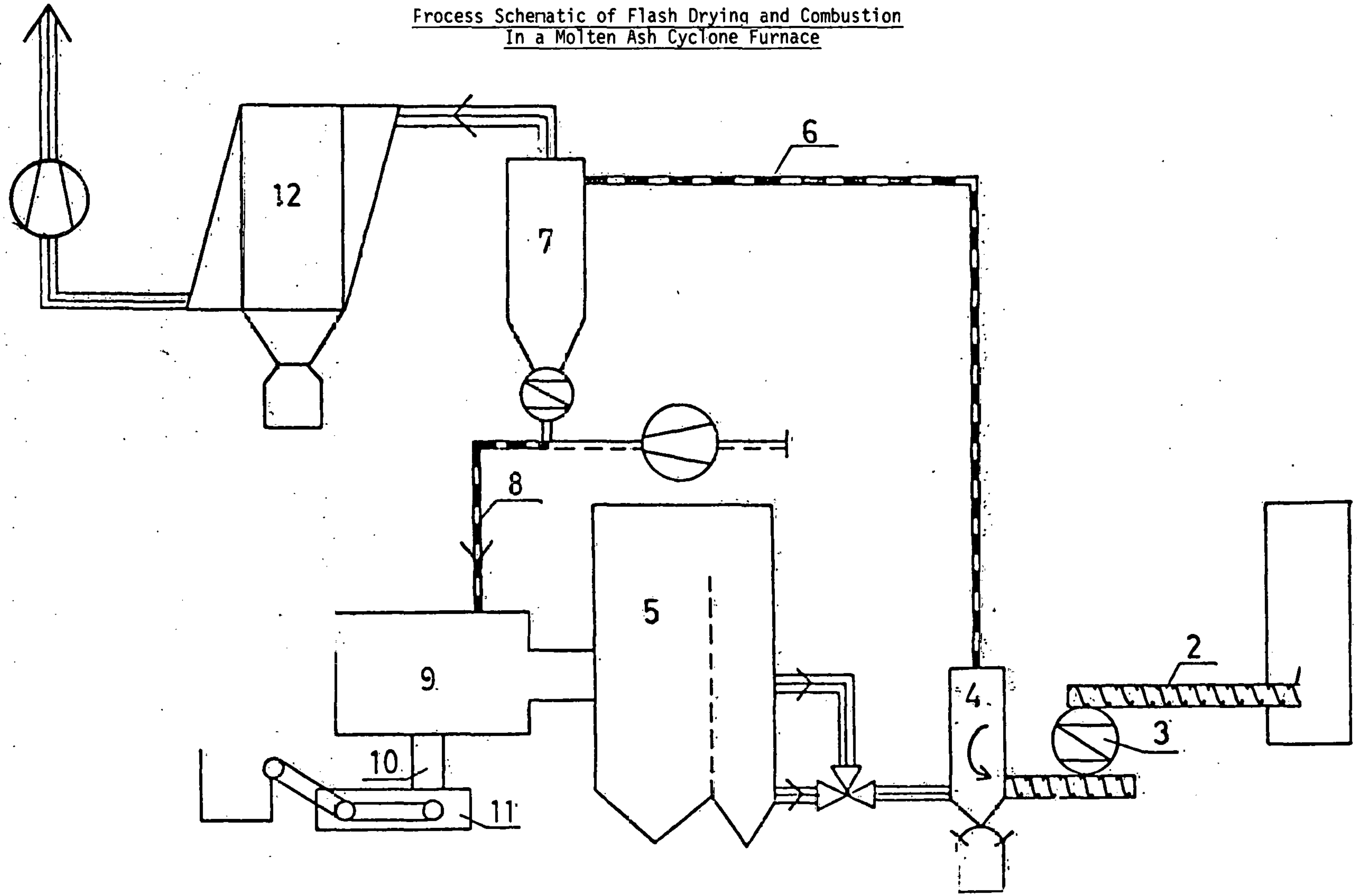
The advantages of the molten ash cyclone furnace and flash-drying include the following:

- Because of the high combustion temperature, the combustion of peat is even and complete. The quantity of extra air may be restricted considerably.

- More reliable combustion requires less control.

Figure 3.6

Process Schematic of Flash Drying and Combustion
In a Molten Ash Cyclone Furnace



Legend:

1 Silo
2 Screw Feeder
3 Rotating Valve
4 Wind Sieve
5 Boiler
6 Drying Channel
7 Peat Separator
8 Ejector
9 Cyclone
10 Slag Channel
11 Quench Basin
12 Flue Gas Scrubber

Source: Reference 33

- The cyclone acts as a coarse particle separator; separation grade is as high as 90 percent. The furnace heat surfaces are kept clean.

- Ash from the cylone is removed automatically.

- The ash which has granulated in the cooling basin is like gravel and easy to handle.

- Wetter peat may be burned without failures.

- Because of flash-drying and the molten ash cyclone, an efficiency of 85-90 percent is reached.

A disadvantage is that combustion in a molten ash cyclone furnace causes extra strain on the brickwork. This is avoided by using suitable types of bricks and refractories as well as a water-cooled cyclone.

Pulverized Firing

For pulverized peat firing, peat must be dried and equalized in one or more stages. Chunks of wood, always present in peat, must be screened out and eventually crushed. Flue gas or hot air is used to reduce the moisture content from the delivered 40 to 55 wt. percent down to the 20 to 25 wt. percent suitable for firing. When ordinary pulverizer equipment is used (see Figure 3.7) the drying takes place in the pulverizer and the peat-gas suspension is blown to the burners. The pulverizers used are of the hammer or beater type, either combined with a blower wheel or equipped with a separate fan.

One of the recent improvements has been the removal of the pulverizer. In this modified system (as shown in Figure 3.8), peat is dried in a flash dryer and blown to the burners with primary air.[31]

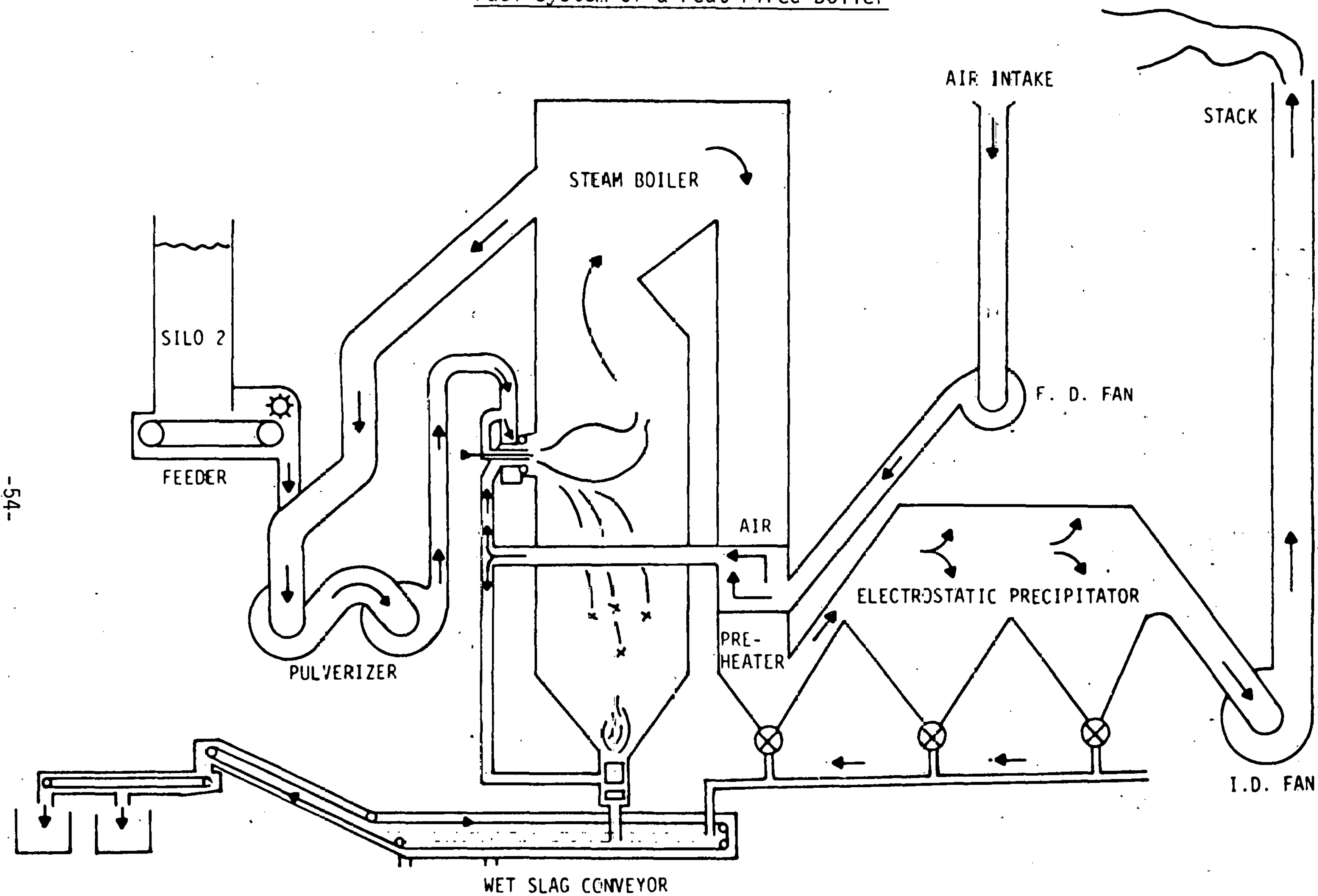
Fluidized-Bed Combustion

The fluidized-bed combustor (FBC) is a versatile one, and can well be used for peat. As with pulverized coal firing, FBC provides large fuel surface area and long contact time between gas and solid particles. Complete combustion of the fuel can thus occur at temperatures below ash softening temperatures, and the "fluidized" nature of the bed eliminates hot spots that could initiate slag formation.

There are two primary types of fluidized bed combustors; atmospheric and pressurized. As the name implies, atmospheric fluidized combustors (AFBC) operate at atmospheric pressure. Pressurized combustors (PFBC) operate at about 10 atmospheres. The objective of the PFBC system is to utilize the energy of the hot, pressurized flue gas to drive a gas turbine for additional power generation and higher thermodynamic efficiency. AFBC systems, which are closer to commercial utilization, provide conventional steam turbine power only.

Figure 3.7

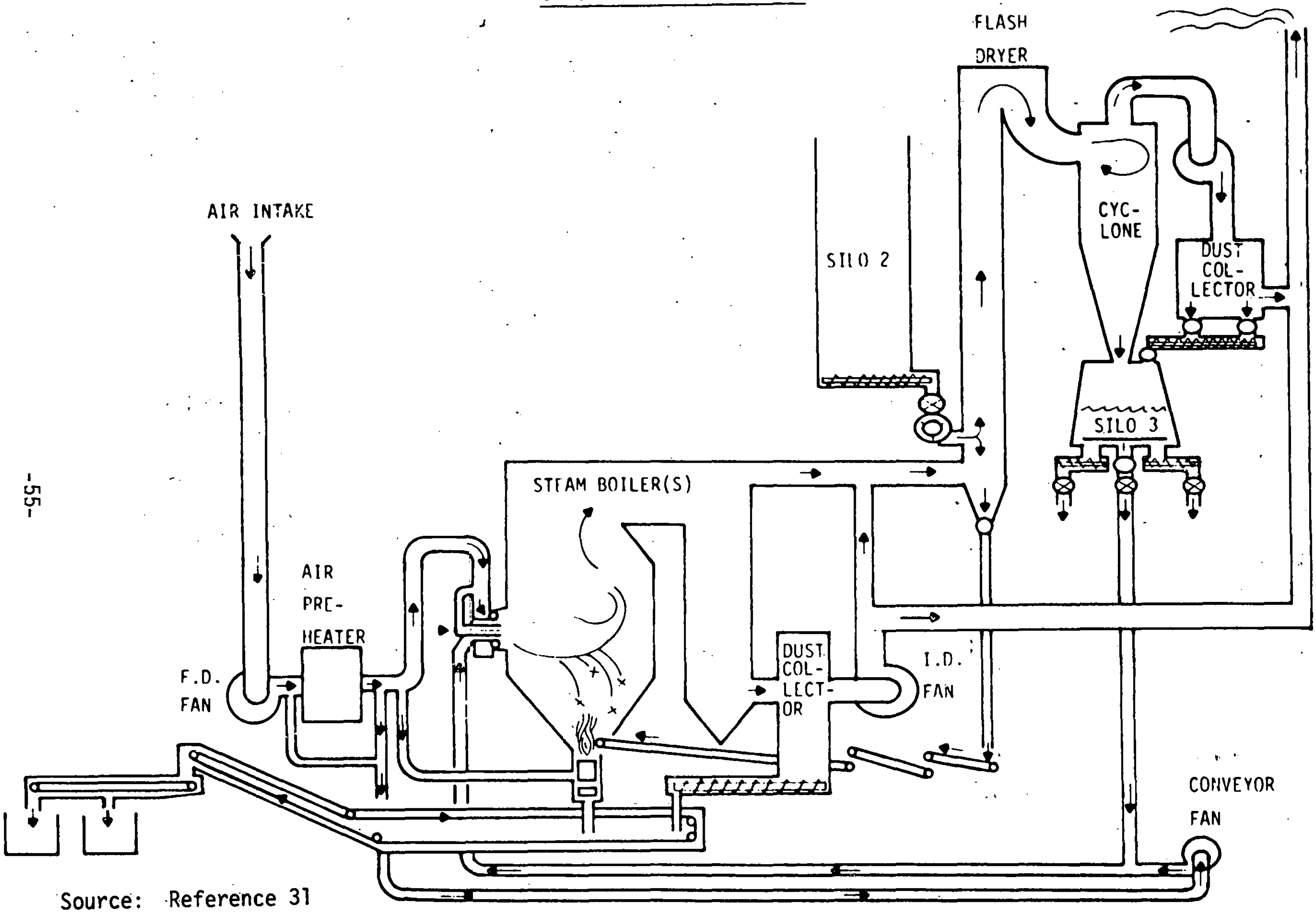
Fuel System of a Peat Fired Boiler



Source: Reference 31

Figure 3.8

Pulverizerless Fuel System of a Peat Fired Boiler



Source: Reference 31

Figure 3.9 is a schematic diagram of an atmospheric pressure fluidized bed boiler. Within the boiler, the bed consists of a mixture of crushed limestone, dolomite, or inert material, and large ash particles, all of which are "fluidized" by the stream of air and combustion gases rising from the supporting grid beneath the bed. Original particle size of the bed material is about 1/8 inch. The gas velocity is set so that the bed particles are partially suspended and move about in random motion, but do not blow away. Under these conditions, a gas/solid mixture behaves much like a boiling liquid in that it seeks its own level and can be moved readily through channels.

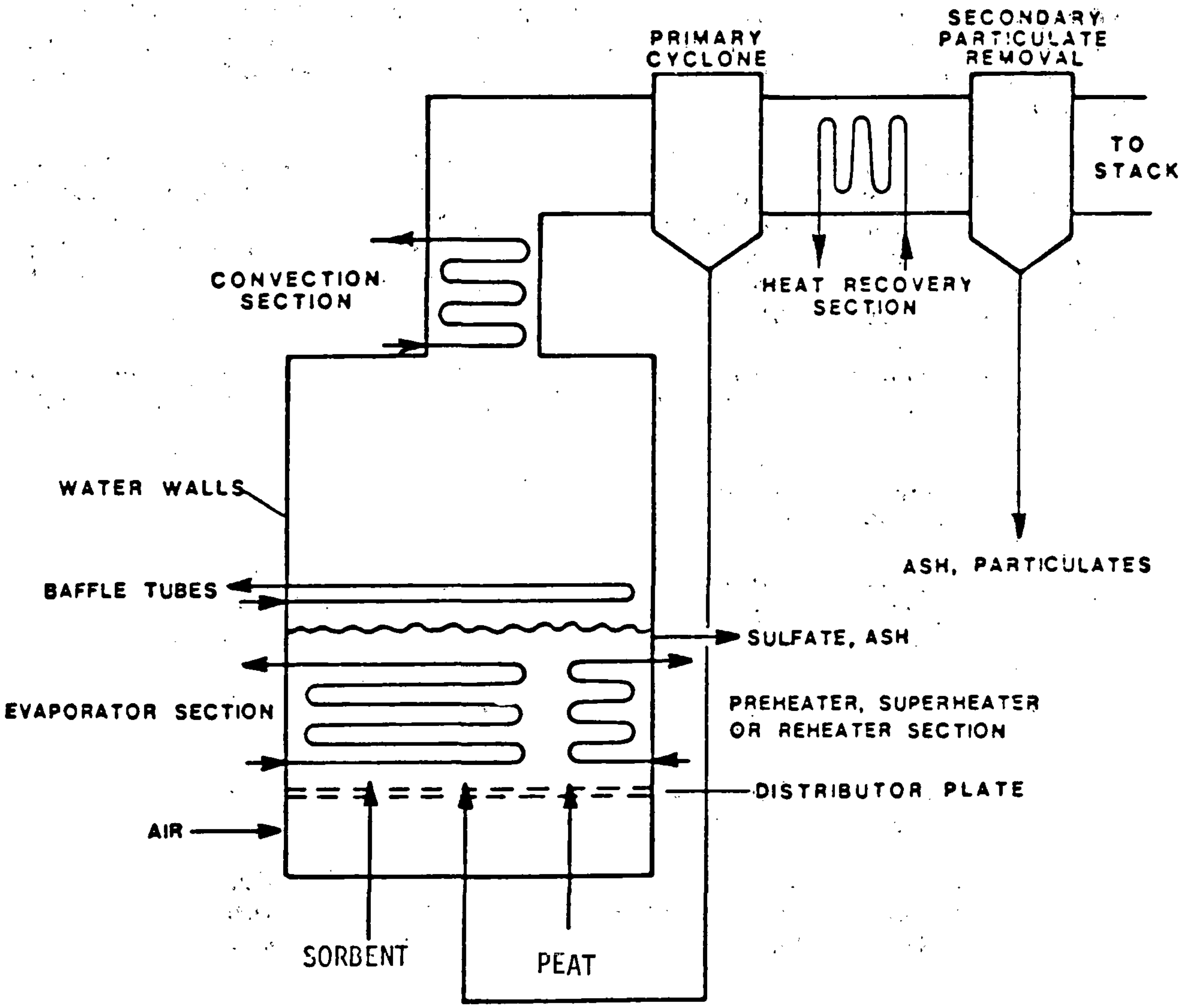
Boiler tubes can be submerged in the bed to help maintain a bed temperature of 1400 to 1600°F. However, in the fluidized combustion of milled peat, Finnish experience has shown that it is not necessary to remove heat from the bed because the furnace temperatures can be kept within desired limits by cooling the upper part of the furnace and by regulating the amounts of primary and secondary air.[24]

Advantages of the fluidized bed combustion of peat, based on recent experiences at Outokumpu Oy's Kokkola works (Finland),[34] are:

- The intensive gas/solid contact gives a high efficiency of combustion at low temperatures; over 99 percent
- Combustion temperature can be controlled within the desired limits and thus avoid troubles caused by the melting of ash
- An equal temperature prevails over the whole cross-section of the bed
- The low combustion temperature reduces the NO_x content in the flue gases
- The high mass transfer rate in the bed makes it possible to remove sulfur from combustion gases by adding limestone or dolomite to the bed
- Fuels with moisture fluctuations and of different type can be burned in the same unit
- No pre-drying and milling of fuel is required
- There are no movable parts in the furnace
- No supporting fuel is needed

Figure 3.9

Atmospheric Fluidized Bed Combustion Boiler



Source: Reference 35

3.4.3 Biomethanation

Anaerobic digestion is similar to wet oxidation in that it is a well-known and widely-used technology for treatment of sewage sludge and many other biomass materials. With proper care and nutrition, certain types of bacteria digest these organic materials, breaking them down into a disposable solid phase composed primarily of single-cell proteins (which in many cases can be used as animal feed), and releasing relatively pure methane gas in the process. This technology is also similar to wet oxidation in that it has not been used on a commercial basis to convert peat to more useful forms, despite its long and widespread use as a waste conversion process.

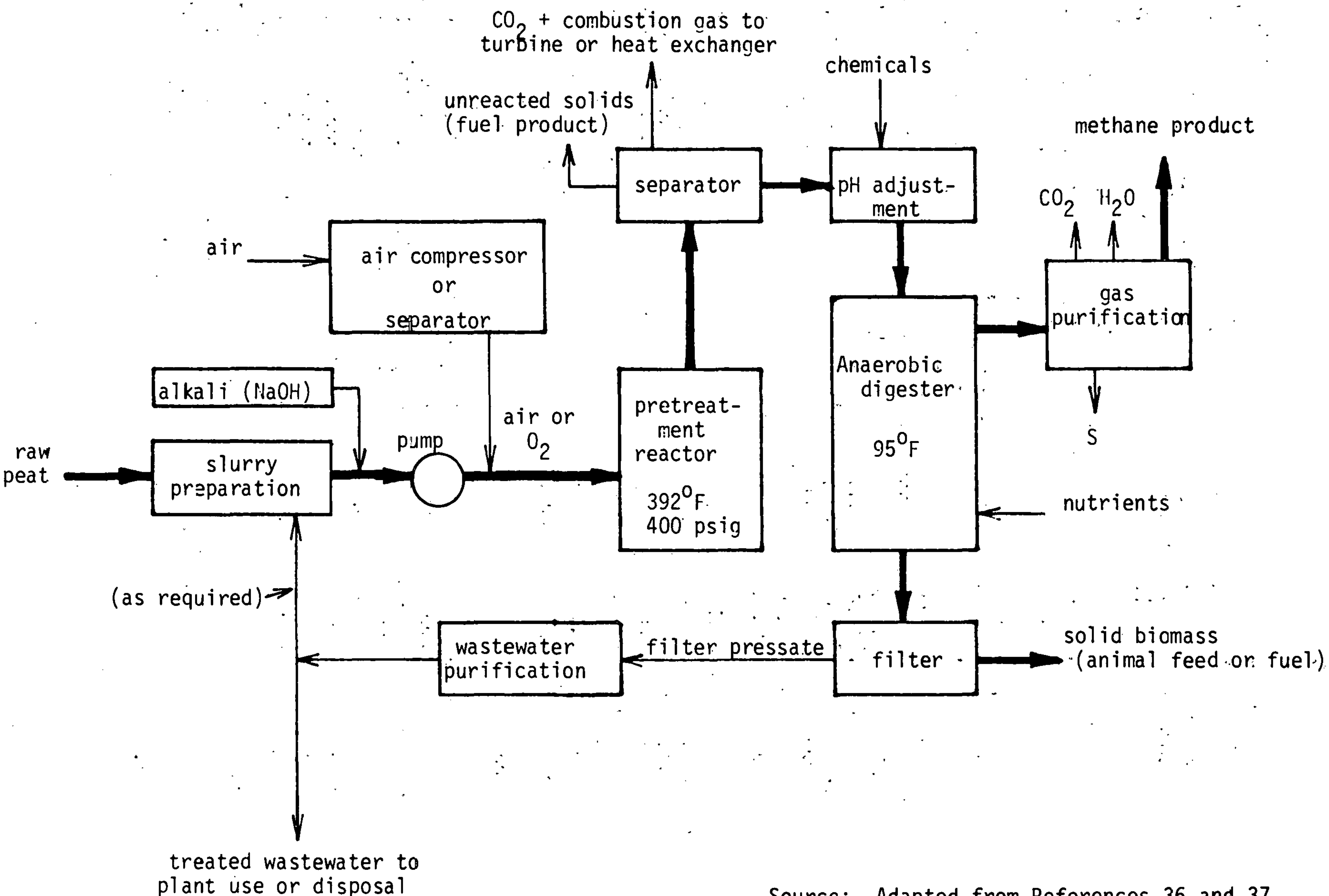
A simplified process flow diagram for a peat biomethanation process is presented in Figure 3.10. Following harvesting of the peat and preparation of the slurry feed, the first stage in the process is a wet alkaline oxidation pretreatment. (The reaction conditions shown - 392°F, 400 psig - are not necessarily optimal but were selected as typical of those conditions which have been reported by Dynatech[36] to give good overall bioconversion yields.) Essentially all of the lignaceous material (60-70 percent of the peat) is broken down by the partial oxidation, heat, pressure, and alkali (NaOH or other) into water soluble aromatic acids and other organic compounds. These low-molecular weight organics are ideal feedstocks for the anaerobic digestion step.

The effluent from the pretreatment reactor is separated into its three phases - CO_2 plus partial combustion by-product gases, the aqueous phase containing dissolved organics, and the unreacted peat solids (cellulosic fraction). The gas phase is treated as necessary (to recover any useful energy and to remove or convert any pollutants) prior to discharge to the atmosphere. The filtered solids (35-50% moisture) are used or sold as fuel (as in the previous two processes described, this peat fuel product may be briquetted). The peat pretreatment liquor stream is treated as necessary to adjust its pH and temperature, and fed to the anaerobic digestors.

Anaerobic digestion of peat has been the subject of experimentation since 1926, when the Swedish Royal Institute of Technology conducted tests at mesophilic temperatures (25 to 30°C). Among other findings, it was shown that thermal pretreatment and the addition of alkali materials enhanced the digestion of peat and the production of methane. The Soviets conducted research on anaerobic digestion of peat at thermophilic temperature (56°C) during the 1950's. More recently, a research project was initiated at IGT in 1975, with Dynatech R/D Company and Stanford University becoming involved in the project in 1977. The results of bench-scale batch testing have been sufficiently encouraging that this DOE-sponsored project is now in its third phase, in which a continuous bench-scale process will be tested to provide scaleup data for a 1 ton/day (dry peat) process development unit, which would be built and operated in phase 4.[36,37]

Figure 3.10

Simplified Process Flow Diagram for Biomethanation of Peat



Source: Adapted from References 36 and 37

In the Dynatech experimental program, fermentation has been conducted at mesophilic (35°C) conditions. (IGT's earlier work found higher methane yields at thermophilic conditions of 55°C.)[37] Approximately equal parts of pretreated peat slurry and primary sewage sludge were combined in the Dynatech digestors. The sludge served at the source of both anaerobic microorganisms and nutrients. Depending on the pretreatment conditions, a wide range of biomethanation yields was observed. Untreated peat was virtually unused by anaerobic microorganisms to produce methane. However, the bugs (which were not previously acclimated to the alkaline heat-treatment products of peat) converted up to 53 percent of the solubilized peat heating value to methane. The researchers expect that higher yields (on the order of 5 scf methane/lb MAF peat) will be obtained using recycled microorganisms previously acclimated to the peat products.[36]

The methane-rich gas from the digestors (containing small amounts of CO_2, H_2O, and H_2S) is treated for conversion and/or removal of the impurities, and the resulting pure methane is sold as substitute natural gas (SNG). The solid biomass filtered from the digestor effluent slurry is sold as animal feed[a] or as fuel. Waste water from the filters is treated as necessary for reuse in the plant and/a disposal.

3.4.4 Thermal Gasification

The production of gas from peat has received much experimental attention since the mid 1800's, when sod peat was gasified under normal pressure in Russia. After the Second World War about 2 million tons of sod peat a year was gasified in the USSR by a process resembling the Wellman-Galusha process. This process may be considered a commercial one, as it is offered by several manufacturers (e.g. Integral, in Austria, and Motala Verkstaden, in Sweden).[38]

No other peat gasification processes are considered commercial at this time. However, prior to the 1960's, peat has been gasified in the laboratory or in pilot plants using both gasifier processes in commercial use with other feedstocks and experimental processes not yet considered commercial. The "commercial" gasifier processes studied include: Lurgi, Koppers-Totzek, Winkler, and the Soviet sod peat gasifier. The "non-commercial" group includes processes designed for peat gasification with research results obtained from experiments in the laboratory or on a pilot plant scale.

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[a]This is true for products resulting from digestion of certain biomass feedstocks. It has yet to be established for peat.

Tests were made in Germany with Ir sh peat in pilot plants for the Lurgi, Koppers-Totzek, and Winkler processes.[39] The Lurgi and Koppers-Totzek reactors performed successfully with peat feedstocks, but difficulties were experienced in maintaining a fluidized bed in the Winkler reactor. Successful fluidized bed peat gasification has been reported from English and Russian experiments.[40,41] Tests in England were conducted to produce water-gas using indirect heat by fluidizing with steam at temperatures up to 1650°F and fluidization velocities of 1 to 2 feet per second.

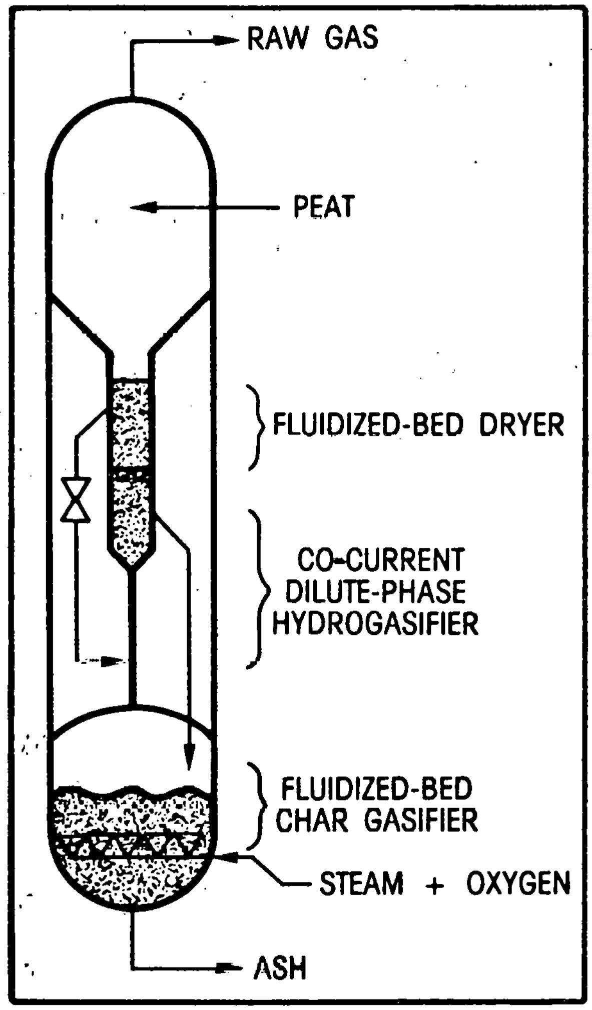
The Institute of Gas Technology (IGT) has been conducting a peat gasification program since 1976. Supported by funding from DOE and the Minnesota Gas Company, IGT has proposed a hydrogasification system consisting of a three-zone reactor vessel, as shown in Figure 3.11. In this reactor, termed a PEATGAS reactor by IGT, peat would be slurried (with toluene or water) and fed into the fluidized bed slurry dryer, to be heated by the product gases coming up from the hydrogasifier. The heated peat would be picked up by synthesis gas generated in the fluidized bed char gasifier and entrained into a vertical cocurrent dilute-phase hydrogasifier with a residence time of a few seconds. Char produced in the hydrogasifier would be gasified with input steam and oxygen in the lower fluidized bed char gasifier section.

For the production of SNG the preferred operating pressure range for the PEATGAS reactor is between 200 and 500 psig. Lower pressures promote oil and decrease methane yield. Higher pressures do not increase methane production significantly, but do lead to costly equipment. The preferred operating temperature range for the hydrogasifier is between 1400° and 1600°F. Lower temperatures reduce methane and increase oil yield whereas higher temperatures promote cracking to form coke and reduce both oil and methane yields. The preferred operating temperature range for the steam-oxygen char gasification zone is between 1700° and 1900°F. Lower temperatures increase the steam required because the hydrogasification section requires a certain amount of heat and more steam is required to carry this heat if the char gasifier is operated at lower temperatures. Higher temperatures cause cracking of oil in the hydrogasification section. Therefore, the slagging gasifiers which require temperatures in excess of 2600°F for making synthesis gas are not preferred for the production of SNG from peat.[43]

Experiments with peat gasification at IGT were conducted in a cocurrent dilute-phase short residence time (SRT) reactor similar to one used for gasification tests with coal. The results of these tests show that the fraction of carbon converted during the SRT gasification is about 2 1/2 times higher than that converted during lignite gasification. The maximum level of carbon conversion in peat is achieved at a few hundred degrees less than that required for lignite - 1400°F for peat as compared

Figure 3.11

Schematic of IGT Peat Hydrogasification (PEATGAS) Reactor



Source: Reference 42

to 1600°F for lignite. Results also show that not only is more total carbon converted during the SRT peat gasification, but the fraction of carbon converted to hydrocarbon gases (methane, ethane, and ethylene) is about four times greater than that for lignite and represents approximately 40 percent of the feed carbon. These results are illustrated in Figure 3.12.

Tests also show that during peat hydrogasification, a high hydrocarbon gas (HG) yield is obtained at relatively low hydrogen partial pressures. The yield of light hydrocarbon gases at temperatures above 1350°F averaged about 20 percent of the feed carbon, or about 57 percent of the cumulative gasification product yield, with no evidence of a hydgrogen pressure effect over the 4 to 70 atmosphere test range (see Figure 3.13).[42] Using a typical composition of synthesis gas for hydrogasification,[a] a total pressure of about 500 psig is adequate. Unlike coal gasification, it is therefore not necessary to operate a peat gasifier at 1000 psig to achieve high HG production.[44]

A simplified PEATGAS process flow schematic is illustrated in Figure 3.14. According to preliminary mass balance estimates,[45] a commercial-scale 80 billion Btu/day PEATGAS plant would produce 85.4 x 10^6 std. cubic feed of SNG per day, along with 151 tons of ammonia, 1350 tons of oil (approximately 6400 barrels), and 15.7 tons of sulfur (14 long tons). With this mass balance, a product summary based on one ton of bone-dry peat is listed in Table 3.3.

Table 3.3

PEATGAS Mass Balance Based on One Ton of Bone-Dry Peat

		10,500 Ft^3 SNG at 950 Btu/scf
One Ton Bone-Dry Peat	=	33.2 gallons residual oil
		3.9 lbs. sulfur
		37.2 lbs. ammonia

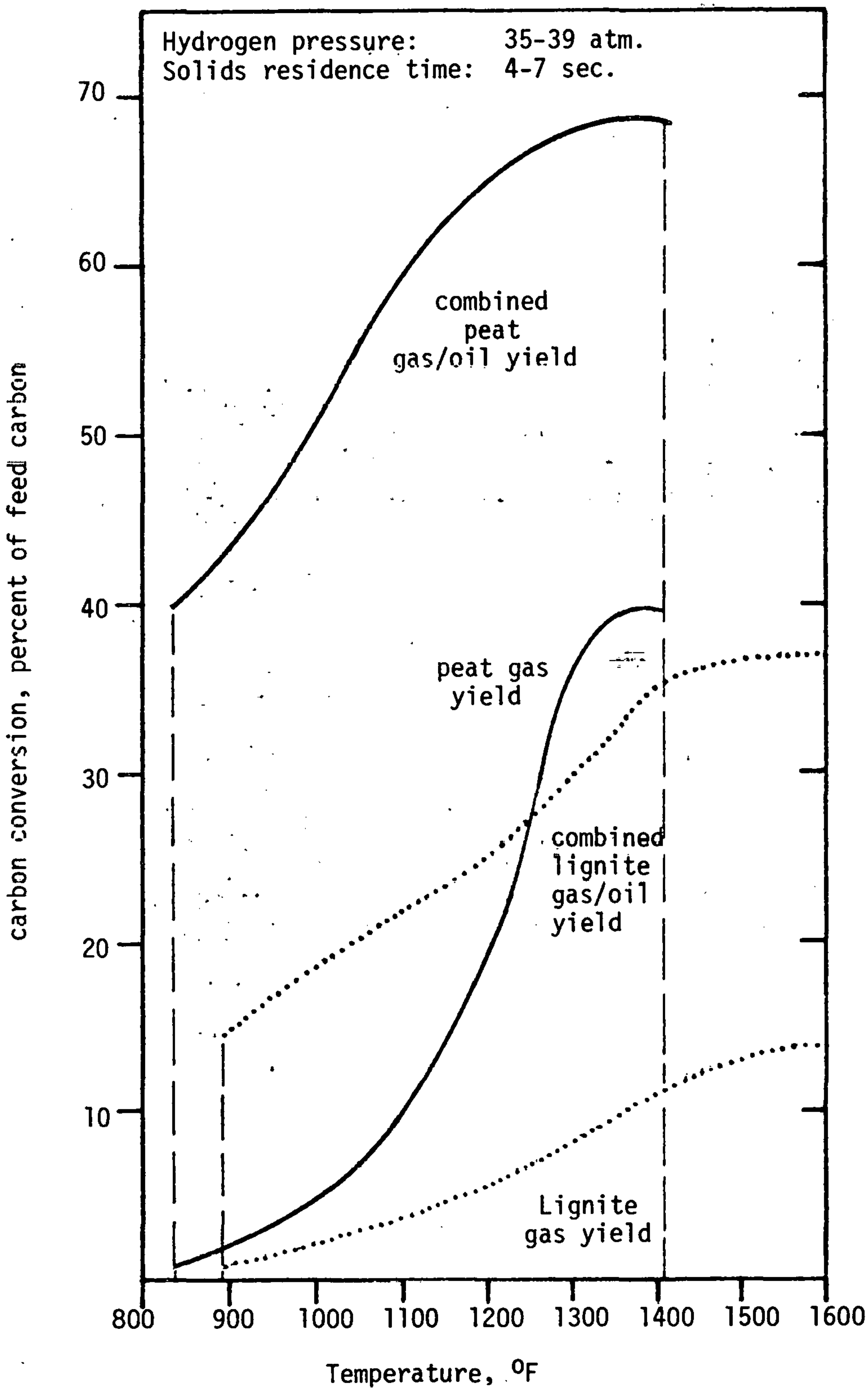
Source: Based on Reference 45

[a] A typical synthesis gas composition is the following (mole %):

CO	CO_2	H_2	CH_4	H_2O
13.3	19.3	28.2	0.9	38.3

Figure 3.12

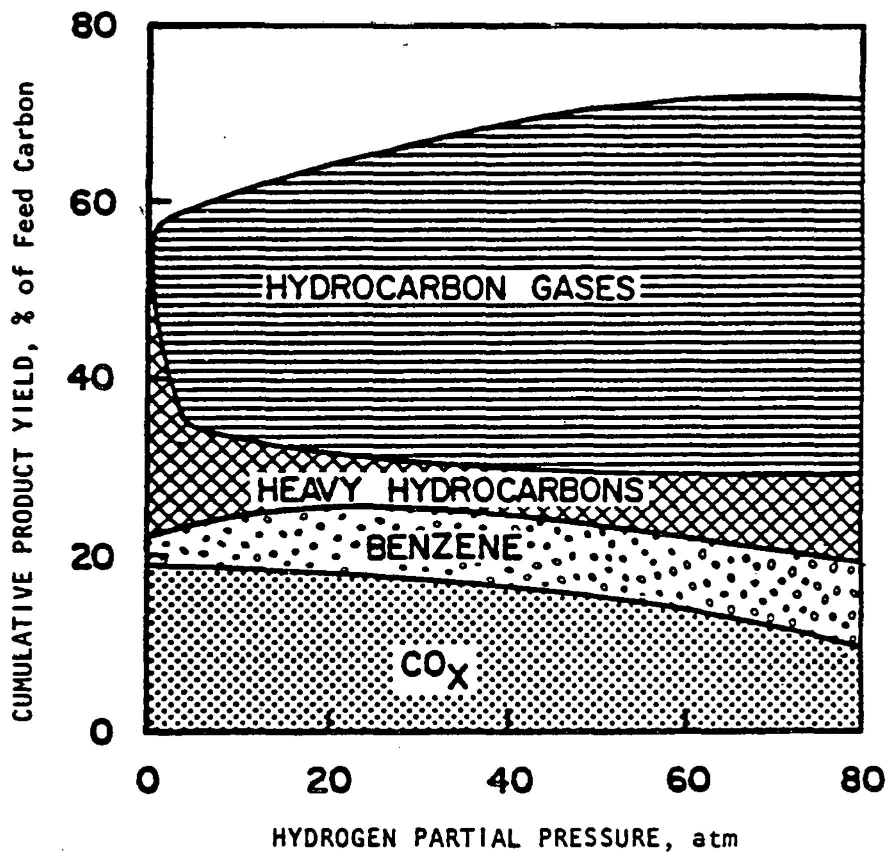
Comparison of Hydrocarbon Gas and Total Carbon Conversion During Rapid Hydrogasification of Peat and Lignite



Source: Adapted from Reference 44

Figure 3.13.

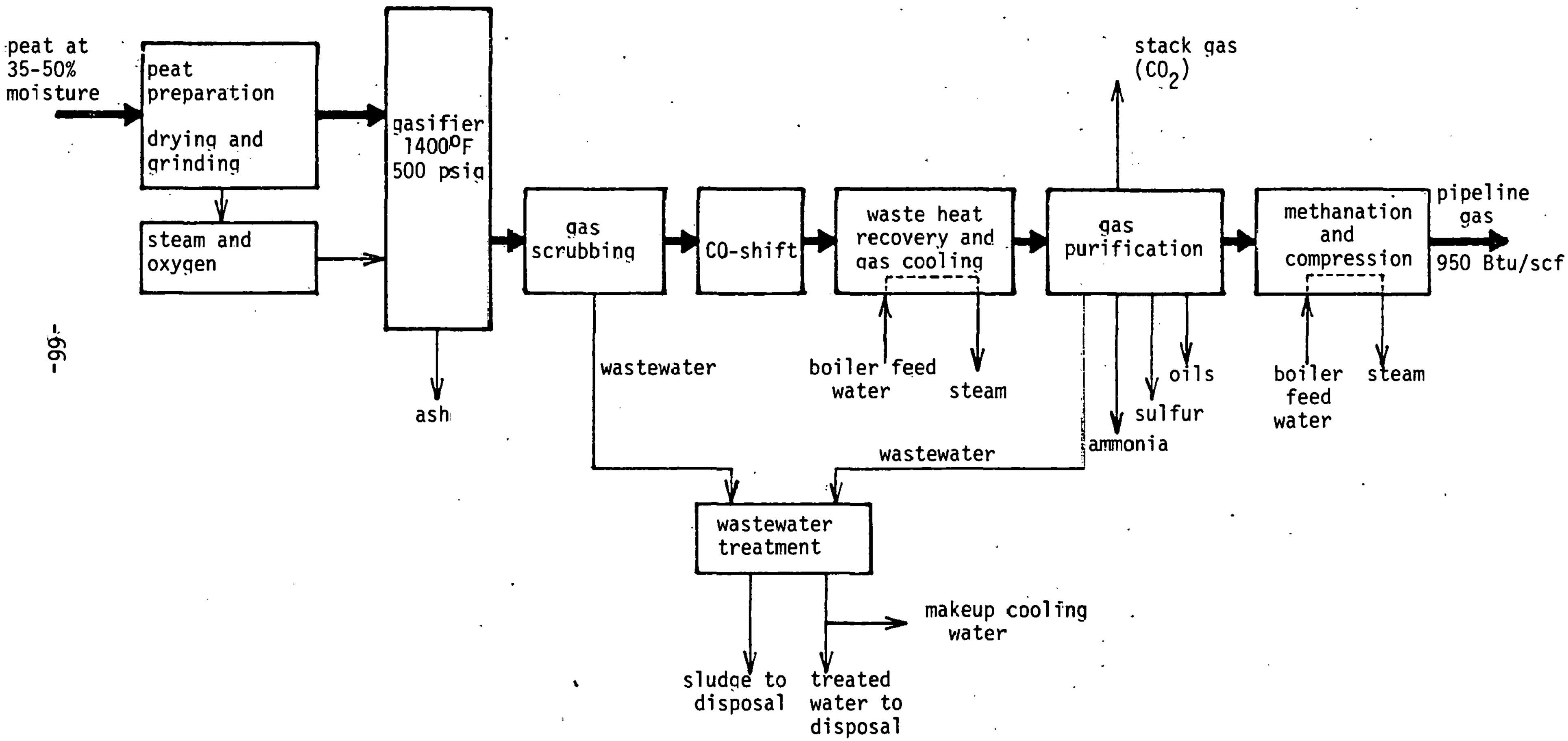
Effect of Hydrogen Partial Pressure On
The Product Yield Obtained During Peat Hydrogasification



Source: Reference 43

Figure 3.14

Simplified Process Flow Diagram for PEATGAS Process



Source: Adapted from Reference 45

Another hydrogasifier reactor distinct from IGT's peat hydrog-gasifier has been proposed by Rockwell. In this short residence time (SRT) entrained flow hydrogasifier, the application of rocket engine injection and mixing techniques is used to accomplish rapid mixing and reaction of hot hydrogen and peat. Experimental work has been conducted by Rockwell on a variety of coal feedstocks, including peat.[46]

Bechtel Corporation has utilized the Rockwell-type injectors for mixing the reactants in an entrained down-flow hydrogasifier.[47] This process, illustrated in Figure 3.15 consists of a reactor that has an upper vessel containing a shell and tube heat exchanger and a lower section hydrogasifier and cyclone separator. The process concept utilizes pure feed hydrogen from a separate char reactor unit. The hydrogen is heated in the upper vessel by heat exchanged with the hot product gases. Conceptually, peat feed is mixed with the heated hydrogen in nozzles, undergoes reaction, and flows in an entrained manner down the central tube to the cyclone separator. Unreacted char is separated from the product gases in the cyclone. The char is collected at the bottom of the gasifier and withdrawn to provide feed material for hydrogen production. The particle-free product gases flow upward in the annular space around the central tube to the upper heat exchanger vessel. The cyclone can be moved vertically to control reaction times in the hydrogasification zone. Hydrogen can be supplied by char gasification or methane reforming.

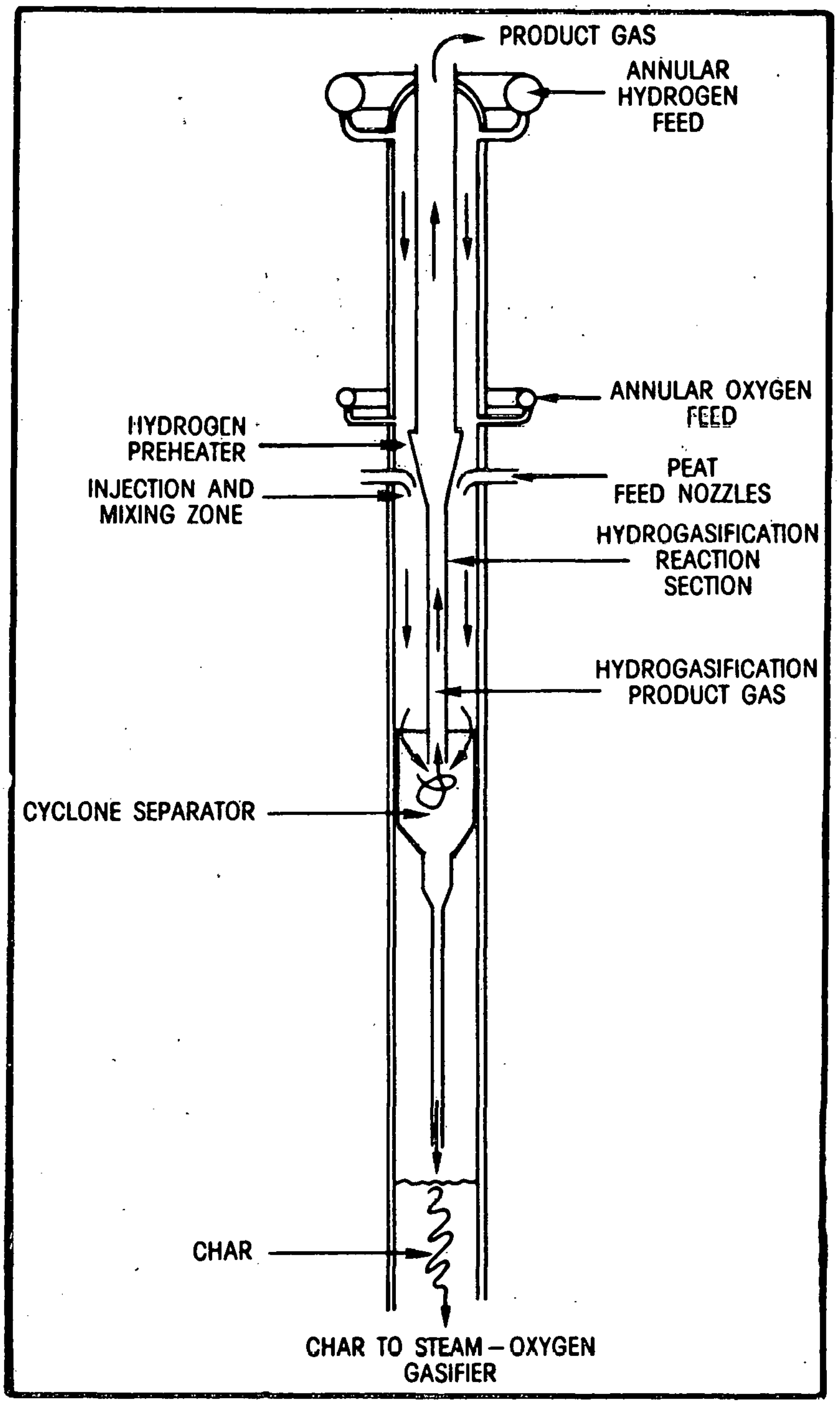
Peat gasification might also be attractive using either a pressurized fluid bed gasifier (Westinghouse) or a pressurized upflow entrained gasifier (Bacock and Wilcox). Figure 3.16 shows a schematic of the latter, entrained flow gasifier. The basic chemical reactions are unchanged regardless of the reactor configuration. The fluid bed or upflow entrained flow gasifiers can be operated with either air or oxygen.

The fluidized bed gasifier maintains a well-mixed, churning solid bed. This is accomplished by the flow of gases upward to lift and agitate the solid particles. If this gasifier were used for peat, product gases would transport feed peat to the coaxial oxidant tube. Oxygen and steam would be fed to the outer annulus of the oxidant tube. The feed peat would be devolatilized as it exits the oxidant tube. Char fines (particulate matter) from devolatilization and char recycle would be gasified and separated from agglomerating ash in the fluidized agglomerator. Further, hydrocracking of liquid hydrocarbons would also take place in the fluidized agglomerator. Agglomerated ash would collect in the annular space around the oxidant tube annulus.

An upflow entrained flow gasifier would be of annular tube construction with feed, recycle char, steam and air/oxygen fed to the gasification section. Lockhoppers would be needed to raise peat pressure before entrainment in steam or air/oxygen for feeding the gasifier. The raw gas and entrained char would exit at the top and the molten ash slag at the bottom through a water quench/lockhopper system.

Figure 3.15

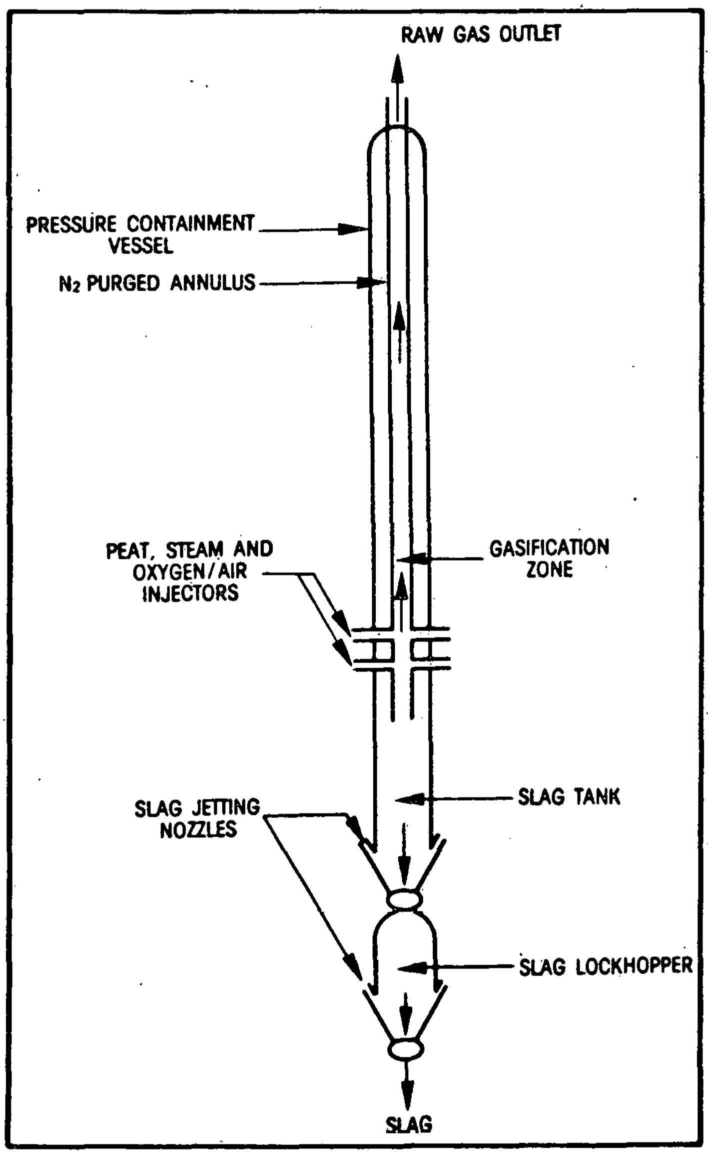
Schematic of Short Residence Time Hydrogasification Reactor



Source: Reference 2

Figure 3.16

Schematic of Pressurized Upflow Entrained Hydrogasification Reactor



Source: Reference 2

4. ENVIRONMENTAL ANALYSIS

4.1 INTRODUCTION

The projected development of domestic peat resources will draw energy-related industries into wetland areas previously untainted by human activity. Many environmental concerns are potentially at stake: Peat wetlands have a unique aquatic ecosystem, containing waters much more acidic than neighboring streams and lakes. Any alteration in the existing discharge rates from peatlands could introduce damaging changes in downstream water chemistries. The same concern applies to heavy metals. Some scientists report that peatlands act as regional scrubbers for air- and water-borne metals such as mercury, lead, and arsenic. These metals remain in the peat until disturbed (by extraction and/or combustion).

There is little empirical data from peatland disturbances, although sufficient experimental work has been performed to estimate the possible impacts. Like other energy developments begun after the environmental crusade of the 1970s (e.g. low-rank coal development in the Gulf Coast Region, slurry pipelines in the West), the environmental consequences are being evaluated before development begins. This logical approach not only avoids irreversible natural damage, it also saves the developer costly process alterations later in development.

This chapter first reviews the pre-development biological and chemical characteristics of peatlands; secondly, impacts from peat harvesting and utilization activities are postulated and outlined according to their effects on the atmospheric and aquatic ecosystems. The final section presents four potential options for successful reclamation of harvested areas. There is a highly dependent relationship between harvesting and reclamation methods: For example, the selection of hydraulic harvesting techniques will strongly favor a lake-oriented reclamation plan (for recreation and/or wildlife sanctuary). The four plans discussed here are for: Tree farms, renewable energy farms, agricultural farms, and a diversified wildlife area. Each plan has its merits, and the appropriate choice can only be determined after a site-specific analysis of the entire extraction, utilization, and reclamation approach.

4.2 BIOLOGICAL AND CHEMICAL CHARACTERISTICS OF PEATLANDS

As a preface to the following sections on impacts of peat harvesting, it is important to understand some of the biological characteristics unique to peat deposits.

Section 2.0 (Resource Characterization) discusses the depositional history of various peat environments and compares the characteristics of ombotrophic (precipitation-based waters) and minerotrophic (groundwater-fed) deposits. This section includes material deemed most appropriate as part of the environmental analysis of peatland utilization, since the resulting impacts will be largely due to these characteristics. Three specific topics are discussed: peat water chemistry, heavy metal adsorption, and water yield characteristics.

4.2.1 Peat Waters

The chemical compostion of waters from ombotrophic bogs and minerotrophic fens are quite different. Bog waters exhibit low conductivity, low pH, and high color values as compared to fens. Low conductivity indicates low concentrations of dissolved mineral ions, primarily because the ions in bog waters are obtained almost exclusively from atmospheric precipitation. The low pH and high color values, however, result from contact with the humic soil. The relatively high acidity (pH 3 to 4) of the bog waters affects the solubility and hence the concentration of many minerals, which in turn affects the ion concentrations. Acidity may also be influenced by anaerobically produced hydrogen sulfide which diffuses to bog pools where it is oxidized to sulfuric acid.[48] High color values of bog waters appear to be caused by humate or iron-humate compounds derived from decomposing organic material.[49]

While perched bogs exhibit higher concentrations of organically derived ions (organic N, ammonia N, nitrate N, P, Cl, Fe, K, Na, and Al), studies indicate that fen waters have higher concentrations of mineral ions such as Ca, Na, Mg, Mn, Cu, Zn, Si, and sulfate due to groundwater flow.[50] The inflow of calcium bicarbonate accounts for the near neutral pH of fen water. Since the solubility and concentration of Fe and Al are inversely influenced by pH, the higher pH of fens results in their reduced concentrations.[17]

There is a substantial volume of literature attesting to the toxicity of aqueous humic substances towards plants and animals. This could become a significant concern if large-scale bog drainage is considered for peat harvesting. Below are highlights of several of these reports.

Polyphenolic humic acids are known to be strong chelating agents for inorganic ions, and may prevent their uptake by aquatic plants.[51]

Two University of Florida researchers[53] found that water forced out of peat swamps is highly toxic and repellent to fish that inhabit receiving lake water. In related studies a Soviet researcher[54] reported that water staters (Ascellus aquaticus) died within 24 hours when placed in peat bog water, probably due to low pH. Studies in Wisconsin blackwater lakes fed by peat bogs show that fish are "slow growing and stunted."[55]

The Freshwater Biological Institute at the University of Minnesota conducted a series of tests to determine the degree of bog water toxicity towards prey fish (e.g. fathead minnows).[42] They concluded that considerable volumes of bog water must enter watersheds before toxicity to prey fish is observed. Toxicity effects probably follow pH effects. Although the effects from dissolved compounds may also be significant. Lake water acts as a buffer on the acidic bog waters; additional tests at the Institute conclude that lake water can receive at least an equal amount of bog water before lowering of the lakewater pH is observed.

The apparent overall conclusion from these various studies indicate that bog waters may be highly toxic to plants and animals not accustomed to bog environments. Adverse effects would result during bog drainage, as released waters enter streams, watersheds, and nearby lakes. However, once mixed with these other aquatic systems, the diluted bog waters have a greatly reduced toxic impact. In fact, tests at the Freshwater Biological Institute imply that diluted bog waters may actually stimulate the production of phytoplankton in receiving lakes.[52] This would create an environmentally advantageous impact, especially in the nutrient-starved lakes of northern Minnesota.

4.2.2 Metal Adsorption

The established practice of using peat as a wastewater filtering medium is a clear indicator of peat's ability to adsorb organic and mineral effluents. Scientific experimentation has confirmed that peat has a tremendous capacity to adsorb metals and metal ions. One such study concluded that peat mosses can be used to reveal regional distribution of heavy metal pollution. The Finnish researchers[56] observed high concentrations of Pb, Cd, Hg, Fe, Zn, Ni, and Cr in peats.

Mercury in wastewater can be recovered with peat. For example, waters containing 500 ppm of Hg were treated with peat in suspension yielding treated water containing .015 ppm of Hg.[57]

Studies on Minnesota peats found that mercury concentrations were as great or greater than the average concentration for coal (about 1 ppm).[52] Since burning of coal is now a major source of atmospheric Hg, burning of peat may also be expected to be a significant source of Hg pollution. An unanticipated finding by the Institute's studies was that the peat samples lost their mercury on simple air drying, implying that the mercury in peat may be in its elemental or some other very volatile form. Thus, the mere harvesting (milled peat method) and/or drying of peat will ultimately release the peat-bound Hg to the atmosphere.

Until more research is done in this area, it is too early to assess the extent of Hg concentrations in domestic peatlands and to evaluate its environmental significance. The preliminary results do seem to indicate that peatlands probably serve an environmentally useful function in removing heavy metals from potential concentrations within food webs.

4.2.3 Water Yield Characteristics

Contrary to popular myth, peat bogs do not regulate the annual distribution of water flow by holding water and then releasing it during dry periods. By nature of its water-saturated environment, peat bogs generally retain a consistent level of water throughout the years, and possess no depositional ability to release water, except by way of evaporation. Minor variations may occur due to early summer increase in evapotranspiration rates (due to growth of new plants), and winter freezing of bog water outlets. Short-term regulation of snowmelt and stormflows takes place as runoff is delayed by the peatland's relatively flat topography and short-term detention storage.[58]

The water balance of fens has not been studied as thoroughly as that of perched bogs primarily because of the difficulty in measuring the amount of groundwater flowing into and out of the peatland. Fens act as a discharge point for the regional groundwater system and receive a more constant supply of water than ombotrophic bogs. This results in a more uniform seasonal distribution of streamflow.[58]

4.3 ENVIRONMENTAL IMPACT ANALYSIS

Once harvested and dewatered, peat fuel utilization produces environmental impacts not unlike those associated with low-rank coals. Harvesting activities are the processes that create unique impacts and, for this reason, harvesting-related impacts are addressed as a separate topic.

4.3.1 Peat Harvesting

4.3.1.1 Hydrologic Consequences

Little information exists concerning the hydrologic effects of peat harvesting. The information that is available is often conflicting. For example, milled peat harvesting in the USSR has not adversely affected the subsequent use of the peatland for parks, forestry, hunting grounds, or fisheries.[59] Yet, in Poland, peat harvesting and associated drainage reportedly has detrimental impacts on the peatland and the surrounding region.[60]

The following discussion is divided into three topics for clarity: 1) effects of vegetation removal; 2) effects of drainage; and 3) effects of peat extraction. Within each topic, the specific effects from milled peat and hydraulic harvesting techniques will be compared, where appropriate. Much of this material has been taken from research funded by the Minnesota Department of Natural Resources.[17]

Effects of Vegetation Removal

The cumulative effects on water flows due to initial vegetation removal are highly speculative, although specific effects can be adequately estimated. (These effects result from milled peat harvesting, where large surface areas are cleared at once; hydraulic harvesting would create relatively insignificant effects.) For instance, vegetation removal will reduce evapotranspiration from the area in proportion to the amount of vegetation removed. This may in turn diminish the rate at which groundwater levels drop in summer, thus reducing the potential "storage" capacity for storm/flood waters. This could ultimately lead to increased runoff into streams. Conversely, evaporation from the soil surface may increase due to: increased solar radiation reaching the soil surface; increased vapor pressure gradient due to increased wind velocity at ground surface; and reduced reflectivity of the evaporating surface (dark soil as compared to varied plant cover). This increase in evaporation may overcompensate the decrease in evapotranspiration, though it is expected that the opposite will occur, resulting in slightly increased runoff.

There are additional factors that could lead to higher rates of water runoff. One water-retaining feature destroyed by vegetation removal is interception loss. Vegetation is capable of intercepting snow and rainfall before it reaches the ground. Water trapped in this fashion evaporates to the atmosphere. The impact of reduced interception loss is to increase the amount of precipitation which reaches the soil surface and thereby increase runoff. Other effects increase runoff due to the snowmelt delay caused by forest cover and by changes in frost formation and thickness.

Based on these arguments, the initial bog-clearing process will result in increased water runoff from the peatlands. However, this conclusion is based on the isolated activity of vegetation removal; in actual bog preparation for milled peat harvesting, this initial step is soon followed by drainage procedures. This second step in the harvesting process could have two significant impacts on the previous conclusion: bog drainage will rapidly drain the top 2 to 4 feet of the peat layer, thus 1) rendering the effects of evaporation and transpiration to insignificant levels, and 2) substantially altering the water-retention behavior of the drained bog during high storm-water flows. The more significant impacts from bog drainage are discussed below.

<u>Effects of Drainage</u>

Drainage represents one of the greatest potential impacts associated with peat harvesting. Drainage (for sod or milled peat harvesting) lowers the peatland water table while simultaneously releasing large volumes of water into nearby lakes and streams. Depending on the streamflow levels at the time of release, the acidic and potentially toxic nature of bog waters may endanger downstream ecosystems and existing fisheries, and would create indirect effects on terrestrial animal life by upsetting the balanced aquatic food chain. At the same time, changes in the groundwater balance may alter the area so that future uses are limited.

Alterations in peatland water levels will affect discharge rates, though once again, conclusions are conflicting. Increased maximum discharge could be attributed to the network of drainage ditches throughout the bog. As expected, deeper ditches and closely spaced ditches tend to increase peat flows.[61,62] Maximum discharge may, however, decrease is substantial storage were created by the lowering of the water table.

Minimum discharges may increase as a result of bog drainage. Lower water table elevations tend to reduce evaporation losses which are particularly evident during the summer minimum flow period. This means more water is available for runoff. Though the hydraulic gradient, which provides the driving force for water movement is increased as ditches increase the head over the length of flow, movement of subsurface water is slowed by flow through deeper denser peats. The combination of increased available water during the low flow period and the slower movement of that water results in increased minimum discharge[17]

Coastal peatland drainage could create additional problems due to the potential intrusion of saltwater. Development at the North Carolina First Colony Farms has indicated that saltwater encroachment can pose a potential problem for development in coastal areas.[63] Peat harvesting could induce inland saltwater encroachment as the result of drainage canals, the reduction of groundwater recharge, and the lowering of the groundwater level.

Hydraulic harvesting methods can create runoff changes almost opposite of those associated with milled peat harvesting. Instead of draining the bog, dikes are often built and areas of the bog are flooded. The peat removal mechanism then floats in the bog as it harvests the peat beneath it. Water discharge rates from the bog are controlled as necessary to maintain the proper flood level in the bog, which could potentially eliminate all discharges from the flooded area. This effect is mitigated to a certain degree by the fact that only fractional areas of the entire bog are (intentionally) flooded at any one time. The unharvested portions can be left as-is to control water flow and plant life as a natural peat bog. The harvested areas can be immediately developed into various reclamation success stories, as discussed in later section.

Effects of Peat Extraction

In milled peat harvesting, few hydrological consequences occur after drainage procedures. Variations in peat composition (or decomposition) encountered as successive dried layers are removed may affect maximum and minimum discharges, though not to any significant degree when compared to the drainage activities discussed previously.

Hydraulic peat extraction results in reduced interception losses and increased available storage within the basin created by extraction. As subsurface flow from the surrounding peat fills the basin, the available moisture storage in the peat surrounding the pond may increase. Evaporation from the pond may exceed evapotranspiration losses from the previously undisturbed peatland.

The above impacts become particularly important if an outlet, either natural or artificial, drains the harvesting pond. If an outlet exists, maximum discharge from the harvest site may increase due to the quicker outflow response of a free water surface as compared to the original peatland. This may be particularly true when extraction is halted or completed with no further increase in storage. A decrease in minimum discharge from the harvest site may also be attributed to the quicker runoff response. Minimum flow and total water yield may be decreased if evaporation rates increase.

If no outlet exists, the impacts of undrained peat harvesting may be diminished as discharge will probably occur through the surrounding peat, similar to the undisturbed peatland. Maximum discharge from the harvest site may not be significantly changed. However, minimum flow and total water yield from the harvest site would be reduced if evaporation losses increased.

The impacts of undrained peat harvesting (with outlets) on watershed discharge characteristics, like drained harvesting methods, may also depend upon location of the harvest site. If located near the headwaters of the watershed, the harvest site may increase maximum discharges from the watershed. If the harvest site is not extensive and if located near the bottom of the basin, a decrease in maximum flow from the watershed may occur.

For watersheds which contain harvest ponds (without outlets), the impacts on watershed discharge may be minimal. Maximum discharge is not expected to change significantly due to pond outflow, which must flow through peat material. Minimum discharge and total water yield, however, are expected to decrease if evaporation increases; the magnitude of decrease depends on the size of the harvest area.[17]

4.3.1.2 Water Quality

The quality of surface waters discharged from a peatland have characteristic quality parameters that to some degree control the onsite and downstream aquatic habitats and water uses. In a general relative decreasing order of importance the foreseen water quality problems are from the discharge of water having the following characteristics:[64]

1. Low pH

2. High BOD/COD

3. Nutrients

4. Organic Compounds

5. Collolidal and Settleable Solids

6. Heavy Metals

7. Carcinogenic and Toxic Materials.

The potential biological response from discharging water with these characteristics could cause species shifts and possibly a reluctance on the part of downstream domestic water users to use the water.

1. Low pH. The nature of peat water pH levels has been mentioned in section 4.2. The release of additional volumes of low-pH drainage water can further stress an already poor quality surface water system. The depression of surface water pH value can generate significant changes in the aquatic ecosystems. These changes can be in the form of species specific fertility problems, morbidity, mortality, and mobility problems, as well as other physical and physiological problems. Overall, these factors may affect shift in species diversities and general habitat vigor.

2. High BOD/COD. Oxygen deficiencies caused by the release of soluble and insoluble oxidizable materials may exceed existing state and federal standards if not treated appropriately. Most of this impact is due to post-processing effluents, not from harvesting activities.

3. Nutrients. Peat has been shown to store nitrogen and phosphorus and is considered suitable for use as a filter in wastewater treatment processes. Consequently, during drainage (and processing), high loadings of these nutrients could be released to the receiving water system. The net effect would be an increase in eutrophication rates and associated changes in the aquatic ecosystem.

4. Organic Compounds. Fatty acids, humic acids, amino acids, tannic acids, and other organic acids are integral constituents of peat. The presence of these chemicals lowers the pH of drainage waters and may have a toxicological effect on aquatic organisms downstream of the bog.

5. Colloidal and Settleable Solids. The disturbance of peat during ditching, drainage, and harvesting, may release some of these materials into receiving waters. Because of the nature of these materials and the adsorbed constituents, such releases would probably increase BOD/COD levels and eutrophication rates, and disperse potentially toxic heavy metals.

6. Heavy Metals. As just mentioned in the above paragraph (and in section 4.2), peat contains trace metals that may be toxic to downstream ecosystems. The release of such elements during harvesting activity will prove difficult at best, and must be further evaluated to understand the extent of the inevitable impacts.

7. Carcinogenic and Toxic Materials. Besides those materials previously mentioned, phenols and complex organic compounds may be released during harvesting. The toxic and carcinogenic risks of these effluents can only be ascertained after their production mechanisms and environmental rates are defined.

4.3.1.3 Air Quality

There are only three potentially significant air quality impacts associated with peat harvesting, and both result from milled peat, drainage-type methods, not hydraulic harvesting. The three impacts are fugitive dust, mercury vaporization, and the possibility of bog fires.

All stages of milled peat harvesting are dusty, with the milling and harvesting being the dustiest stages. Wind erosion of milled peat is another significant fugitive dust generating mechanism that is difficult to control. Because fugitive dust pickup from milled peat production depends strongly on the topography and meteorology of the specific site, it is very difficult to quantify the extent of this problem in general terms. It has been estimated that uncontrolled fugitive dust emissions could be as high as 10 percent of the total peat harvested.[65]

An impact closely related to peat dust is bog fires. Drained peat bogs are susceptible to bog fires, which can be ignited by harvesting equipment or careless handling of smoking material. Fires not only create large volumes of air pollutants, they consume the peat fuel resource and pose serious worker health and wildlife hazards. The ubiquitous nature of ignition sources make dust suppression the most effective control measure.[64]

Probably the least investigated and understood impact is from the evaporative release of heavy metals such as mercury. Control of this kind of release, even if found to be a significant concern, would be nearly impossible. The only alternatives immediately practical are to avoid the milled peat method (in favor of hydraulic harvesting), or abandon harvesting at those areas containing significant Hg concentrations.

4.3.2 Utilization

The direct combustion or gasification of peat fuel produces aqueous and atmospheric effluents similar in composition to effluents from coal combustion and gasification processes. Unlike current coal research activity, peat liquefaction has not been extensively tested; combustion and gasification are the most promising peat conversion technologies and this section confines discussions to impacts from these two areas.

4.3.2.1 Water-Related Impacts

As in coal combustion and gasification, peat conversion to steam, electricity, or SNG requires similar volumes of water for process cooling. For example, coal gasification using the HYGAS process (the model process for the PEATGAS gasifier) requires anywhere from 3 to 6 million gallons/day for a 250 million SCF/day gasification plant.[66] This range normalizes to 15 to 24 gallons/10^6Btu of produced pipeline quality gas.

The chemical nature of peat process wastewaters is generally similar to coal-based wastewaters. Both wastewater streams may contain suspended solids, organic acids, phenols, polynuclear aromatics, and other constituents.

Water treatment will undoubtedly be required if the effluents are to meet existing 5-day BOD and COD standards prior to release in receiving waters. Following treatment, and depending on the harvesting method utilized, the treated water not recycled into plant processes may be returned to the bog. Naturally, this approach is only applicable to hydraulic harvesting methods.

Water treatment technologies suitable for peat-based waste streams can be readily adapted from existing uses with coal-based waste streams, and thus should pose no insurmountable environmental impacts.

4.3.2.2 Air-Related Impacts

Peat Combustion

Combustion of peat will release quantities of CO, CO_2, NO_x, SO_x, particulates, hydrocarbons, water vapor, and trace elements into the atmosphere, in quantities exceeding existing standards unless properly controlled. Peat, with its generally low sulfur and mineral content, would have comparably low emissions of SO_x and particulate air pollutants. Particulate emissions would be controlled through conventional air pollution control technology. Collected flyash has been demonstrated to be a safe soil conditioner and could be used for soil reclamation.[64]

Nitrogen oxides, particularly nitric oxide (NO), are formed whenever fuels are burned in air. Emissions tend to increase with increasing temperatures, heterogeneity of combustion composition, and fuel nitrogen. There is concern that the relatively high nitrogen content inherent in peat could result in increased NO_x formation during combustion. This potential impact is somewhat offset by the low peat combustion temperatures.[64]

Peat Gasification

Potential air pollutants associated with peat gasification (such as the hypothetical PEATGAS process) include SO_x, NO_x, hydrocarbons (HC), particulates, CO, and CO_2. An estimate of particulate, SO_x, and NO_x emissions from a PEATGAS plant producing 80 billion Btu/day of SNG is shown in Table 4.1, compared to a 976 megawatt coal-fired electric power plant and an 80 billion Btu/day (85 MM SCF/day) synthane coal gasification facility, all normalized to an equivalent energy output. The electric power plant appears to emit the largest quantities of pollutants, but this is partly due to the somewhat misleading basis of normalization. The generation of electricity has an overall thermal efficiency half that of gasification (approximately 33 percent as compared to about 67 percent for gasification), which artificially boosts the pollutant tonnage per product Btu. Synthane gasification values have been proportionally reduced from estimates for a 250 MM CFD (237 billion Btu/day) plant, and are roughly similar to peat-based effluents from the PEATGAS process. NO_x emissions appear higher for peat than for coal.

The mercury content in peat has been mentioned previously in this report. For a hypothetical 80 billion Btu/day PEATGAS Plant, about 17 percent of the peat is consumed to supply process steam and power. Approximately 85 to 95 percent of the mercury contained in this peat is volatized to the stack gases,[69] resulting in mercury emissions from an 80 billion Btu/day PEATGAS facility comparable to those produced by a 140 MW coal-fired power plant.[46] The fate of the Hg in the remaining 83 percent of the peat fed into the gasifier will be similar to that of Hg in coal gasification. According to researchers at IGT,[70] a series of "worst-case" calculations based on 0.3 ppmn Hg concentration in the feedstock and on theoretical thermodynamic and vapor pressure considerations indicates that about 5 pounds of Hg enters the gasifier with raw peat per day. After treatment with cold acid gas removal systems, (90 percent removal) about 0.5 pounds per day remain in the produce SNG. This corresponds to a concentration of about 80 ug/m^3, a lower level than that encountered in several natural gases.[45]

4.4 PEATLAND RECLAMATION

Large-scale peat development presents an unprecedented opportunity to transform an area of unused land into a productive agricultural area or a high-diversity wildlife refuge, with the option of retaining some of the original character of the peat bog area. Because peat bogs are, in most instances, under-utilized, sparsely populated areas, peat harvesting operations can proceed with little effect on current land use patterns. Unlike coal mining, peat resources lie at (or just under) the surface and generally are no more than 15 feet deep, so overburden problems associated with coal are not a problem.

The method of peat harvesting will have a profound effect on the approach to post-harvesting peatland reclamation. Milled peat methods commit the entire harvestable surface to production throughout the duration of extraction activity. For a large-scale conversion facility, up to

Table 4.1

Estimated Air Pollutant Emissions from the PEATGAS Process Compared to Coal Gasification and Electricity Production from Coal

Pollutant	Conversion Process Emission Rates[a] (Tons/Day)		
	PEATGAS[b] Peat Gasification	Synthane[c] Coal Gasification	Coal-Fired Electric Power Plant
Airborne Particulates	3.47	2.8	11.4
Sulfur Oxides (SO_x)[e]	1.74	4	14.3
Nitrogen Oxides (NO_x)	15.6	8.6	80.0

[a]All emission rates have been normalized to an equivalent energy output of 80 billion Btu/day.

[b]Excluding peat harvesting operation.

[c]Values represent the high end of ranges presented in reference 68 and normalized to 80 billion Btu/day output. The computed ranges are as follows:

Particulates: 0.8 - 2.8
SO_2 : 1 - 4
NO_x : 3.8 - 8.6

[d]Based on 0.5 wt % S coal.

[e]All processes employ flue gas desulfurization units.

Source: Adapted from References 67 and 68 several hundred square miles could be exposed for 20 or so years in order to provide sufficient solar-dried peat fuel supplies.[9] Reclamation activities could not proceed until all harvesting was completed.

Hydraulic harvesting represents an attractive alternative in this sense. The total peatland area required is limited only by the depth of the peat rather than by solar drying rate considerations. For example, a PEATGAS plant producing 80 billion Btu/day of SNG would require almost 100 square miles of peat bog over a 20-year life, assuming an average peat depth of seven feet.[67] Since peatland disturbance will be initiated over an extended period (unlike milled peat harvesting), reclamation should proceed as each area is harvested. Reclamation of small areas will provide opportunities to test various reclamation plans and/or various biologic combinations, and in any case will reduce the overall time scale of peatland disturbance.

Four different peatland reclamation options are discussed here. Each possibility results in a more productive and/or more beneficial use of the land as compared to its pre-harvested state.[a] The four options are: 1) tree farming; 2) agricultural cropland; 3) renewable energy farming; and 4) development of diversified wildlife refuge. The final choice among these possiblities will depend on the local economic situation as well as on topographical, climatic, biotic, and hydrological factors.[6] In areas reclaimed as lakes (a likely option following hydraulic harvesting), the peat will be removed down to mineral soil; where agricultural or tree-farming plans are contemplated, the lowest 0.5 to 1.5 feet of peat will be combined with the underlying mineral soil to form a rich base for plant growth.

Tree and Agricultural Farming

Tree and agricultural farming options share common requirements for subsurface water level control and may require artificial fertilization and liming. Actual tree and crop species selected will depend on the local situation. Among the various species suitable for reforestation of peatlands, spruce, fir, pine, and aspen trees appear to have the most promise.

Black spruce is shade tolerant and grows on dry or wet soils, which makes it adaptable where drainage cannot always be ideally controlled. This species is easily reproduced naturally, grows rapidly and is long lived.

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[a]To say that the area is "improved" by harvesting is a premature conclusion based on a human-needs viewpoint, not on a complete ecological, global analysis. As with any major biological disturbance (such as coal or uranium mining, etc.), the long-range and subtle impacts cannot be fully determined. A potential case-in-point may be the environmental "filtering" characteristics of peatlands for heavy metals. It does appear, however, that when compared to other solid fuel extraction processes, peat resources produce fewer environmental impacts (as presently measured by society) in the immediate and near future.

Red pine and Jack pine are native and locally adapted to the area's conditions of low pH, poor soil nutrient content, and climate. Both of these species do better in well-drained soils than in water-logged areas. Scotch pine is a species widely used in Europe for reclamation of peat bogs and is adapted to conditions in northern U.S., if adequate drainage is provided. Balsam fir is locally successful and can tolerate wet microsites.

Aspen is fast growing and is locally adapted. This species accounts for around 45 percent of the annual pulp wood production of the Lake States. Aspen is shade intolerant; will tolerate moist conditions and reproduces readily by suckering. With careful management this species can form the basis for a successful forestry practice. Another positive aspect of an aspen plantation is its utilization by wildlife, particularly deer. Aspen is a pioneer species, and if the site is left to natural succession, birch and a spruce-fir association is eventually possible.[71]

In a site such as the Florida peat occupies, forestation is also a viable option. Species will be different and the extent to which soil modification, fertilization and drainage will be needed will be dependent upon the species chosen. While a greater choice of plants will be available in the South, more intensive management will be required to prevent invasion of competitive, undesirable species. As in the Minnesota area, insects and disease must be controlled and a careful monitoring program should be implemented.

Agricultural crops adapted to northern Minnesota peatlands include: root and vegetable crops such as radishes, carrots, potatoes, cabbages, cauliflower, and celery; livestock forage crops such as grasses and legumes; berry crops such as cranberries and blueberries; cultural lawn sod; forage and lawn grass seed; and wild rice.[67] The frost-free growing season in northern Minnesota ranges from about 100 to 110 days. This relatively short season limits the harvest of most crops to one mature crop per year, with the exception of radishes and other similar vegetable crops that mature in significantly shorter periods.

Cranberry and blueberry production on reclaimed northern peatlands has been practiced for over 25 years by Western Peat Moss Ltd, near Vancouver, British Columbia.[72] Berry plants thrive on the acidic soil, and the 470 reclaimed acres yield about 5 million pounds of cranberries and about 1 million pounds of bluebrries each year.

Major crops adapted to Florida peatlands include: sugarcane, vegetable crops such as sweet corn, celery, radishes, carrots, parsely, and leaf vegetables such as lettuce, cabbage, etc; forage grasses for livestock, and lawn sod. Rice is also an adapted crop and, after a significant absence, interest in rice production is again developing. Southern Florida has a year-round growing season for many crops although occasional frost may occur during the winter months. Conditions in the other continental U.S. peatlands will fall between these two extremes.[67]

In North Carolina, First Colony Farms conducted a reclamation experiment in 1977 to assess the value of harvested peatland for farmland. To simulate the end result of harvesting operations, a two acre tract of peatland was stripped of some 5 1/2 feet of covering peat. After liming (for pH adjust) and plowed the exposed mineral soil, soybeans and sorghum were planted. Within two months the crops had fully grown, and produced a soybean yield of approximately 35 to 40 bushels per acre[73] (which is above the USDA national average yield of 32.2 bushels per acre).

Energy Farms

Another land reclamation option that deserves consideration is the establishment of a renewable energy farm on harvested peatlands. Such areas are particularly suited for the production of many high-yielding wetland species such as cattails, sedges, reeds, grasses, hybrid aspen, and lowland brush. The production of energy from these species through biomass produced by the process of photosynthesis is an example of the indirect use of solar energy.

Experimental results indicate that sustained yields of up to 20 dry tons of biomass per acre per year might be attainable in a managed operation based on reed-sedges or cattails. If this proves feasible on a large scale, an 80 x 10^9 Btu/day SNG plant could conceivably operate in perpetuity on a 175,000 acre energy farm--about 3 1/2 times the area required for the same size plant utilizing hydraulic harvesting techniques. However, the cultivation, harvesting, and gasification of raw biomass of this sort are areas that have not been investigated experimentally. Peat's similarity to coal, which enables relatively easy adaptation of coal gasification technology, probably will not carry back to raw plant material. The large land area requirements, associated deforestation and water-quality problems, and the uncertainty of harvesting and conversion technology suggests that energy farming on peatlands is a highly speculative development option.[67]

Wildlife Refuge

A particularly intriguing land reclamation option, which fits in well with the techniques of hydraulic peat harvesting, is the establishment of a diverse habitat wildlife refuge. In a hydraulic peat harvesting operation, peat will be completely removed down to mineral soil (an average of 7 feet), creating a shallow lake. During the preharvest phase, trees will be removed from the area and the roots snagged and piled aside to facilitate peat removal. In northern peatlands the tree-cutting operation may be done in winter when the frozen surface will make the area more accessible. The discarded tree roots may be used to form the bases for islands scattered throughout a shallow lake.

The open water interrupted by islands of plant debris should form the basis for a potentially successful wildlife refuge. The piles of roots may provide nesting sites and cover for wildlife inhibiting the area or migrating through it. These islands should also aid in the establishment of a variety of plant species which might be expected to colonize the new lake area.

At the National Symposium on Wetlands, sponsored by the National Technical Council in Disneyworld, Florida, on November 6-10, 1978, Major General Charles G. McGinnis of the U.S. Army Corps of Engineers reported that the Corps has incorporated the practice of deliberately creating emergent islands from dredged materials and now finds that these areas are some of the "greatest aviaries along the Texas coast." The corps is presently continuing research into this promising method of wildlife conservation. In establishing productive aquatic ecosystems in Sweden, it has been beneficial to create a mosaic of habitats. Relatively deep areas of open water alternate with islands where vegetation is available for wildlife cover and food.[71]

At the same Wetlands Symposium at Disneyworld, Dr. Milton W. Weller of the University of Minnesota reported that his research indicates that an optimum number of bird species occurs in an area where 75 percent of the habitat is open water. Almost 100 different birds have been identified in peatland environments, including ducks, eagles, the Great Blue Heron, hawks, and owls.[74] It is obvious that the ecosystem diversity provided by open water, islands, woodlands, and forested areas will be beneficial for a large and varied assortment of bird life in the projected refuge.

Many mammals can be expected to utilize the post-harvest area. Moose, already present in certain northeastern bog areas, are said to have a variety of habitat preferences. Coniferous forest is one type of moose habitat, while willow, aspen, and bog birch shrub stands are another.[75] A post-harvest refuge plan would certainly enhance the habitat variety in many bog areas and should result in an increase in moose utilization.

Whichever reclamation option is selected, the decision must be an integral factor of the overall peat harvesting plan. The plan should be fully detailed prior to any preharvesting operations so that both harvesting and post-harvesting operations can be completed with a minimum of environmental and social conflict. Peatland reclamation has the unique potential among solid-fuel extraction technologies to actually improve the productivity and value of the harvested land. The realization of this potential, however, will require a continuous and active commitment from energy planners, land owners, community leaders, and from all tiers of governmental involvement.

5. REGULATORY ANALYSIS

5.1 INTRODUCTION

The extraction and utilization of U.S. peat resources will encounter a multitude of regulatory constraints. Peat development for energy, unlike domestic coal development, is accelerating after establishment of the regulatory milieu. Controls on coal, on the other hand, have been applied long after coal extraction and utilization practices were established. For this reason peat development, with its inherent requirements for energy facility siting, surface harvesting, wetlands disruption, air and water discharges, and reclamation, should expect to receive vigorous regulatory scrutiny.

As in most projects, the magnitude of the development will determine the degree of complexity in obtaining the necessary regulatory approvals. The primary regulatory hurdles for any scale of peatland development will be the state and Federal regulations for wetlands protection, surface water pollution discharges, and air quality maintenance standards. The secondary regulatory issues will focus on hazardous waste disposal, health and safety, Coastal Zone Management, and broad NEPA regulations.

Existing and developing Federal, state, and local environmental regulations are expected to require few modifications to meet the new challenges of peat energy development. Certain unique aspects of peat utilization can be expected to necessitate some modifications to regulations once the significant environmental issues and processes are well characterized.

The regulatory issues must be addressed on a site-specific basis as the need arises, not only because of local variances, but also due to the fluctuating status of certain regulatory requirements. Therefore, the objective of this section on Regulatory Analysis is to introduce the general issues and mention the appropriate regulations that must ultimately be addressed by the responsible parties. Table 5.1 matches potentially applicable Federal regulations with peat fuel extraction, combustion/conversion and land reclamation activities. The list is by no means exhaustive; specific state and local regulations, as well as other Federal regulations (unique peatlands, Indian lands, etc.) may create additional constraints upon peat fuel activities.

A large part of the material for this regulatory discussion has been summarized from material appendixed in reference 64. It is assumed that the reader of this section has a basic understanding of current U.S. environmental regulations.

Table 5.1

Potential Regulatory Environmental Issues Associated With Peat Fuel Development

Law/Regulation	Peat Development Activity: Harvesting	Combustion/ Conversion	Reclamation
Clean Air Act	●	●	
Clean Water Act	●	●	●
Toxic Substances Control Act		●	
National Environmental Policy Act		●	
Occupational Safety and Health Act	●	●	
Endangered Species Act	●	●	●
Resource Conservation and Recovery Act		●	
Wilderness Act	●	●	●
Protection of Wetlands (E.O. 1990)	●	●	●
Mining Safety and Health Act	●		

5.2 WATER RESOURCES ISSUES

Modification of Surface Water Flow Patterns

Within a peatland, the rearrangement of surface drainage increases the potential for downstream flooding, reduced streamflow, or saltwater intrusion. For these reasons, state and federal laws have been enacted to minimize the downstream flooding and other effects caused by altered surface flow patterns. The agencies who would evaluate drainage changes are state and federal environmental protection agencies, fish and wildlife services, water resource commissions, Corp of Engineers, and local soil and water conservation commissioners.

Since peatlands are located in the north central, north, and southeastern U.S., the riparian doctrine of water use allocation does not specifically forbid the increase of minimum streamflows. Under this doctrine, if the flow increases do not lead to direct or indirect impacts on downstream water users or adversely affect water quality, the increased flows will be allowed.[64]

The release of additional surface water to a riverine or estuarine system must be analyzed to determine net effects on downstream water users. Facility and field drainage water discharges would require state and federal water quality discharge permits and an evaluation of the net effects of these discharges on the downstream water resources. The issuance of these individual permits is closely reviewed by public interest groups and downstream water users.

5.3 WATER QUALITY ISSUES

Waters from drainage, dewatering facilities, and process discharges must meet state effluent discharge standards for pH and BOD/COD levels, chemical and metal compounds, and settleable solids.

Changing ambient stream pH values has become an important issue in fossil fuel development. Due to the relatively low pH of peat bog waters, all discharges from peat development will have to be controlled to meet existing state and federal discharge standards and not alter pH values of the receiving stream from established criteria.

Both the Federal government and states have effluent standards governing BOD and COD discharges. Presently, no applicable federal effluent standards under the National Pollution Discharge Elimination System (NPDES) for release of process water from peat harvesting and processing have been established. With the development of large-scale operations water pollution standards governing BOD and COD discharges would be expected in order to maintain designated stream water quality classifications. Through state and federal permit procedures, public interest in the project impacts on water quality would be reviewed through local public hearings.

At present, there are no effluent or water quality standards for organic acids. Organic compounds can cause taste and odor problems for humans and have been shown toxic towards aquatic plants and animals.[52] Standards for organic acid concentrations, however, are more qualitative than quantitative.

Heavy metals discharge from industrial processes is governed under the state and federal effluent standards. These standards are designed to reduce net effluent discharges and comply with state water quality classifications. However, no effluent standards currently exist for peat processing facility discharges.

Research conducted in Minnesota has shown that mercury, arsenic compounds, and other elements are present in peatlands. These products could be released by harvesting into the aquatic environment. With the Toxic Substance Control Act (TSCA), Resource Conservation and Recovery Act (RCRA), and the amendments to the Water Pollution Control Act, there is a growing awareness of potential toxic and carcinogenic properties of liquid waste streams. These acts require a thorough study of direct wastewater streams to isolate and identify toxic products and necessitate development control strategies to prevent their release.

State and federal water effluent standards govern the discharge of total dissolved solids and settleable solids from various industrial processes. The discharge standards are established on an industry by industry basis and are formulated on the amount of process material. There is a lack of effluent standards for peat harvesting and energy production. Until such standards are developed, effluent standards for mining and forest products industrial sectors would probably be used.

5.4 AIR QUALITY ISSUES

The list of air quality concerns from peat resembles a similar list associated with coal mining and utilization activities. Significant emissions will include: fugitive dust, CO, CO_2, NO_x, SO_x, particulates, hydrocarbons, and metals. State Implementation Plans (SIP) will provide the basis for specific control programs.

Most areas in the U.S. have reported local or area-wide violations of National Ambient Air Quality Standards (NAAQS) for total suspended particulates (TSP), including most peat-rich areas. Prevention of Significant Deterioration (PSD) review may be required for fugitive dust emissions exceeding 10 tons per year. Peatlands may be near PSD Class I areas due to their remote wilderness locations, wildlife values, and proximity to Indian reservations. No New Source Performance Standards (NSPS) exist for peat operations.

Ambient levels of nitrogen dioxide generally meet NAAQS in peat-rich areas. In the future, NO_2 may be included in emission controls designed to control ambient oxidant levels. Oxidants (as well as TSP) are on the EPAs control priority list and PSD review is required for NO_2 emissions exceeding 10 tons per year. This is of particular concern for peat combustion since NO_x levels appear to be higher for peat than for coal combustion. Similar NSPS for NO_x from lignite-fueled steam generators is 0.60 lb/MMBTU. There are no emission standards specifically for synfuels plants; this, however, is expected to change as commercialization occurs.

NAAQS for SO_2 is met in almost all peat-rich areas. The proximity of Class I areas to peat-rich areas may cause difficulties in obtaining air quality related permits. Peat combustion facilities should not be located in areas experiencing ambient SO_2 problems or in areas with known adverse meteorological conditions that would result in ambient SO_2 problems if new emission sources were introduced. SO_x emissions from burning peat or peat-derived fuels may have to be controlled to correct noncompliance with environmental requirements.

NAAQS for non-methane hydrocarbons (NMHC) are exceeded in many urban areas and are grossly exceeded by existing coal conversion facilities. Hydrocarbons by themselves do not produce a direct health hazard, but they do contribute to the formation of oxidants that can damage vegetation and cause irritation to the eyes and throats of humans. They are one of the reactants in the formation of photochemical smog. Peat conversion facilities will probably not emit enough NMHC to create a significant problem. Emissions of NMHC from storage vessels at peat synfuels plants should comply with environmental requirements. Polycyclic aromatic hydrocarbons (PAH) emissions from peat combustion and from peat synfuel plants should be in compliance with health related requirements.

Trace metal emissions are currently not subject to NSPS for fossil fuel combustion. However, metal emissions are currently undergoing extensive regulatory review and new standards are being considered.

A computer simulation of air pollutant dispersion from a hypothetical 80 billion BTU/day PEATGAS plant located in northern Minnesota or in Dade County, Florida, shows that SO_2 and TSP emissions will not exceed PSD regulations for Class I areas outside a 10-mile radius of the project facility, and for Class II areas at the project facility. The simulation model studies also indicate that the impacts on ambient CO, HC, and NO_x levels will not be significant. Mercury emissions from a PEATGAS plant would be comparable to those from a coal-based SNG plant and will not cause a health hazard.[67]

6. MARKET ANALYSIS

6.1 INTRODUCTION

This section presents a highly summarized discussion of peat fuel in the future energy marketplace. As mentioned in earlier sections in this volume, peat fuel can take on several forms: substitute natural gas (SNG), pulverized peat, or pelletized/briquetted peat. The potential markets vary with each form of peat fuel product.

For example, Minnesota Gas Company hopes to produce SNG from peat within the next several years; the market for SNG exists and is already influenced by gas company activities. The markets for pulverized peat are less obvious and more site-specific. EKONO, Inc., prepared a feasibility study for the Minnesota Department of Natural Resources to assess several potential users of pulverized peat in Minnesota. The study, performed in 1977, illustrates not only the technical constraints involved in certain fuel conversion situations, but it also indicates how rapidly inflation and fuel prices can alter economic predictions. A large portion of their findings is included in this section.

An interesting side effect may occur as a result of increased peat development. Peat is presently used as a soil conditioner, and commands a bulk price around $13/ton. Smaller quantities (50 or 100 pound units) have considerably higher per-pound prices. If advanced peat harvesting techniques, developed for the energy industry, succeed in reducing the deliverable price of peat, agricultural use of peat should increase and would compete with energy interests for the harvested product. Even though the peats most suitable for energy use are generally more decomposed than the "peat moss" variety, there is enough similarity between the peat types to make almost any peat suitable as a soil conditioner.[78]

The future for peat fuel in the U.S. is promising: peat gasification studies are currently well developed and will probably represent the first large-scale commercial usage of domestic peat resources. However, compared to the available tonnages of western low-rank coal and lignites, peat is generally less attractive on an economic basis. Peat deposits will begin to be significantly harvested later in this century, as petroleum fuel prices continue to race ahead of inflation.

The following market analysis is organized according to the possible peat fuel products: substitute natural gas, pulverized peat, and peat briquettes/pellets.

6.2 SUBSTITUTE NATURAL GAS FROM PEAT

Although peat represents a significant fraction of domestic energy resources, its utilization as a future fuel supply depends heavily on available local markets. As a comparative example, consider the present utilization of Texas lignite: because of its low heating value, the current economical approach to its use is to build large lignite-fired power plants at the mine site. Similar constraints are encountered with peat, primarily in Minnesota and North Carolina, where U.S. peat fuel development is most active.

For this reason, Minnesota Gas Company (Minnegasco) is currently finalizing plans for a 250 billion Btu/day peat gasification plant, to be constructed adjacent to extensive peatlands in northern Minnesota. There are two immediate advantages to this peat utilization approach. First, peat transportation costs are reduced simply by reducing the distance between peat harvesting activity and the gasifier. Whether the peat is harvested hydraulically or as milled peat, short distances will keep transportation costs low. Second, high-Btu gasification of peat (as with SNG from low-rank coal) produces an immediately marketable fuel product - substitute natural gas (SNG), which can be fed directly into the existing natural gas pipeline network.

Of course, SNG from peat must be produced at a price competitive with natural gas prices to succeed in the marketplace, and the actual price of SNG is sensitive to the price of harvested peat. Until peat harvesting operations begin in the U.S., harvesting costs cannot be reliably determined. In a report to DOE by Minnegasco (reference 79), the largest single annual cost in peat gasification is for the peat. At an assumed unit cost of 75 cents/10^6 Btu, the total is $118 million for peat alone, which represents 37.2 percent of all costs. In addition, a one-cent increase in peat costs results in about a two-cent increase in the price of SNG per million Btu. The high sensitivity results from the fact that only 52.4 percent of the peat value appears as product SNG. (By-products include benzene, crude aromatics, ammonia, and sulfur.)

Minnegasco estimates that with milled peat at 75 cents/10^6 Btu, the 20-year average price of product gas will be approximately $3.06//$10^6$ Btu.[79] This price, computed in early 1978 dollars, includes credits from the sale of marketable by-products.

The conversion of peat to SNG represents a solution to the transportation problems associated with peat fuel. By upgrading the peat to a high-Btu gas, existing pipelines can be utilized. Since the SNG will effectively displace equivalent volumes of natural gas, the impacts on available gas supplies will be felt throughout the pipeline network. In this sense, the SNG from peat will cover a customer area much larger than the area immediately surrounding the peat deposits.

Large-scale peat gasification, though a significant first step towards peat utilization, cannot take full advantage of much of the domestic peat resource. "Minemouth" peat gasifiers, as with minemouth power plants for lignite, are dependent on a steady supply of fuel from the immediate resource area. In other words, only large continuous peat deposits are suitable for a 20-year SNG project. Smaller deposits will be untapped unless smaller-scale developments are utilized.

6.3 PULVERIZED PEAT

Pulverized peat has been successfully fired in conventional boilers, and as a coal/peat blend. Future commercial use of peat in this manner will depend on the close proximity of suitable boilers to the peat harvesting site. It is not likely that peat will be shipped to distant consumers (over 100 miles away) and remain competitive with conventional fuels.

EKONO, Inc., prepared a feasibility study to locate and evaluate some of the more suitable peat fuel use situations in Minnesota.[80] The preliminary screening was done in cooperation with the Department of Natural Resources (MDNR), the Department of Iron Range Resources and Rehabilitation (IRR&R), Minnesota Energy Agency, and EKONO. The main criteria for the selection were the following:

- A satisfactory source of peat should be available within a reasonable distance (not more than 100 miles from site). In most cases this distance is much less than 100 miles.
- The potential user must have long operation time per year since the capital cost of the equipment is high.
- The existing equipment should be easily convertible.
- The selection should also include known possibilities for new plants.

A combined visit to selected sites was made by EKONO, MDNR and IRR&R. As a conclusion the following locations were chosen for study:

1. City of Biwabik
   District heating plant (new district heating plant)
2. City of Hibbing
   Existing district heating power station (conversion of existing boilers)
3. Eveleth Taconite Company
   Pellet Plant (conversion of rotary kiln to peat fuel)
4. City of Virginia
   District heating power station (new power station as a case study using existing steam and power consumptions).

EKONO's report presents detailed economic comparisons for each of the above locations, using peat, coal, oil and/or natural gas as competing fuel sources. Since the publication of this study (1977), fuel prices and construction costs have increased to the point where EKONO's conclusions are no longer economically reliable. The following pages summarize EKONO's findings and update their conclusions based on 1980 fuel prices.

1. Biwabik, Minnesota, peat fired district heating plant:

Biwabik is a small town of 2500 residents and 850 houses (1977). EKONO estimated the costs for a peat-fired district heating plant, and compared the results to an oil-fired unit.

The heat consumption of the town was estimated for three load levels:

	Per Customer Btu/hr	Total (850 units) 10^6 Btu/hr	(MW)
Peak load	44,000	37.4	(11.0)
Average load	32,000	27.4	(8.0)
Minimum load	5,000	4.1	(1.2)

The total heat and power loads are too low for a district heating power station. The only solution to be studied further was a district heating plant producing 250°F hot water, which would be pumped to the customer and returned. Each consumer would need a substation with heat exchangers for warm water and heating and also heat consumption meters. This substation, according to Finnish practice, would belong to the supplier.

In order to get an idea of the magnitude of the costs involved in a pure peat-fired station compared to an oil-fire unit, an evaluation was prepared. One single unit would cover the whole heat demand. The unit would include hot water boiler, all necessary piping, pumps, instrumentation, fuel receiving and unloading systems. It would be a complete heating plant, but excluding the district heating piping network. The peat boiler would have a cyclone or grate for firing peat and a mechanical dust collector. The fuel would be in the form of pulverized peat.

At assumed fuel prices of 40 cents/gallon ($2.67/$10^6$ Btu) for No. 2 fuel oil and $1.00-$2.00/10^6 Btu for peat, the annual energy production costs are shown in Table 6.1. The values shown include fixed costs and fuel costs, and are calculated for three annual operating levels.

Table 6.1 shows that if the peat price is $1.00/million Btu, the price of heat from the plant will be cheaper than with oil-firing when the operating time is more than 3000 h/yr. With a peat price of $1.50/million Btu, the break even point is 4750 h/yr. When the peat price is $2.00/million Btu, the price of heat will always be higher than with oil.

Table 6.1

Production Costs of District Heat Using Oil and Peat-Fired Systems (1977 dollars)

Operating Hours		3000	4000	5000
		$/million Btu		
Oil[a]	($2.67/$10^6$ Btu)	5.6	5.0	4.7
Peat[a]	($1.00/$10^6$ Btu)	5.5	4.5	3.9
	($1.50/$10^6$ Btu)	6.3	5.2	4.6
	($2.00/$10^6$ Btu)	7.0	5.9	5.3

Notes: [a]Yearly efficiency, oil-fired boiler : 80 percent
peat-fired boiler: 70 percent

Source: Reference 80

1980 prices for available fuels in Minnesota are listed in Table 6.2. Note that the price of fuel oil has more than doubled while natural gas and electricity costs have remained close to EKONO's estimates. Because of the rise in fuel oil prices, EKONO's cost comparisons make peat more attractive than oil at annual operating levels substantially lower than shown in Table 6.1.

Table 6.2

Fuel Costs in Minnesota, 1980

No. 2 fuel oil	81.25 cents/gallon	$5.80/$10^6$ Btu
Natural gas	25.52 cents/100 ft^3	$2.60/$10^6$ Btu
Electricity	3.82 cents/kwh	

Source: Reference 81

2. City of Hibbing, existing District Heating Power Station

The Public Utilities Commission of Hibbing operates a district heating power station, which consists of three coal-fired steam boilers and four turbines. District heating is supplied by steam extracted from the turbines. Because of the district heating and the electric supply to the city, this power station has a relatively high loading through the year. The boiler constructions are convertible to peat-firing since they have been operating with coal and espeically with low grade western coal. The plant configuration was estimated to be suitable for a possible conversion to peat-firing.

	Inlet Steam	Configuration	Power
No. 1	600 psig	15 psig extra./cond.	10 MW
No. 2	400 psig	15 psig extra./cond.	5 MW
No. 3	400 psig	15 psig extra./cond.	2.5MW
No. 4	175 psig	backpressure	1.5MW

The average power production in wintertime has been 12.5 MW and 9.6 MW in summer. In addition, the city has purchase power from Minnesota Power and Light, 96,000 kWhr/day (4.0 MW) at a price of 2.8 cents/kWhr.

District heating is with 15 psig steam at a temperature of 280°F. An average winter load has been 140,000 lb/hr and 30,000 lb/hr in summertime. Approximately 70 to 75 percent of the condensate is returned from the customers back to the power station in a temperature range of 140°F to 170°F. The number of customers is 1400.

The price of the steam is $3.50 per 1000 lbs of condensate which equals approximately $3.50 per million Btu. Normally the plant uses Montana or Wyoming subbituminous coal with a heating value of 8,600 Btu/lb as received. The price (1977) is $18.2/ton which equals $1.06 per million Btu.

The firing of peat will reduce the capacity of the boilers by approximately 20 percent due to the reduced energy density of peat as compared to coal. The annual peat consumption is estimated to be 279,000 tons.

The estimated fuel costs are listed in Table 6.3

The results indicate that with the existing coal price the peat cannot break even with a price of $1.00/million Btu. If coal costs $1.7 per million Btu, the total cost would be about the same with peat when its price is $1.50/million Btu. To break even, peat must be approximately 17 cents per million Btu cheaper than coal.

Table 6.3

Estimated Fuel Costs for Hibbing, Minnesota District Heating Power Plant[a]

Fuel	Price ($/$10^6$ Btu)	Specific Fuel Cost	Incremental Equipment Cost	Total
			$/$10^3$ Btu/hr	
Coal	1.06	13.1	--	13.1
	1.70	20.9	--	20.9
Peat	1.00	12.3	2.1	14.4
	1.50	18.5	2.1	20.6
	2.00	24.6	2.1	26.7

[a]Based on average boiler loading, 8600 hr. operating time/year.

Source: Reference 80

3. Eveleth Taconite Company. Pellet Plant.

Eveleth Taconite Company (Eveleth, Minnesota) requires a large amount of energy for steam generation and for the rotary kilns. They have two 250 hp oil-fired steam boilers, which are not convertible to peat-firing. No. 2 fuel oil had also been burned in the two rotary kilns until they were converted to coal several years ago (1977, 1978). These kilns are capable of conversion to peat.

Table 6.4 shows the production capacity and specific heat consumption for the two rotary kilns.

Table 6.4

Production Capacity and Process Heat Demand, Eveleth Taconite Company Rotary Kilns

	Production Capacity 10^6 tons/yr	Process Heat Demand 10^3 Btu/ton product
Kiln No. 1	2.3	700
Kiln No. 2	3.6	500

Source: Reference 80

For the pelletizing process, a temperature of 2350 to 2400°F is needed at the dryer inlet. It is possible to achieve this requirement with peat firing. The peat should be pre-dried but for this purpose there is a lot of heat available in the gases from the cooling of the pellets after the kiln. The amount of cooling gases is estimated to be 200,000 cfm at a temperature of 1000°F. In kiln No. 2, these hot gases are circulated back to the traveling grate, which explains the lower specific heat consumption in that kiln. In such a case the flue gases might be used for the pre-drying of the peat.

Table 6.5 shows a cost comparison of coal and peat firing in the two rotary kilns. The comparison shows that if the price of peat is $1.00 per million Btu, this fuel will be the cheaper alternative including conversion and operating costs. It also indicates that peat is competitive with a price of $1.50 per million Btu compared to a local price of $1.70/million Btu (Eastern coal). The break even point in this case is approximately 3000 operating hours. Normally the operating is continuous and thus, 8600 hours per year.

Table 6.5

Heat Production Cost Comparison for Coal and Peat-Fired Rotary Kilns

Fuel		Total Heat Production Cost $ per Btu/hr[a]
Coal, Eastern	($45/ton)	17.3
Western	($20/ton)	13.0
Peat	($1.00/$10^6$ Btu)	11.7
	($1.50/$10^6$ Btu)	16.0
	($2.00/$10^6$ Btu)	20.3

[a]Values include fixed costs (in $/Btu/hr) of 2.7 for coal
3.1 for peat

Source: Reference 80

4. City of Virginia, Minnesota. Case Study for a New Peat-Fired District Heating Power Station

The advantages of a new fuel technology will be most evident in a new plant, specifically built for it. In Finland, the experience is, that peat as a fuel will show its greatest potential in community energy systems of sufficient size. In centralized heating systems the benefit of a domestic, possibly local fuel is often worth pursuing, even if the cost on a strictly Btu-basis might be higher than for imported fossil fuel. Combining heat generation with power generation is desirable from a heat utilization point of view but it is also important as a means of getting to a bigger unit size with associated benefits. In particular, the expensive handling of a bulky material such as peat makes a sufficient plant size necessary for economical operation.

To explore the competitiveness of a new peat-fired district heating station with co-generation of power, EKONO made a cost estimate for a new unit for replacing all the existing units at the City of Virginia. It has been assumed that the heating capacity is the same as at present but a hot water system is installed to replace the present steam heating system. A power plant for a hot water system will be slightly more expensive to build but the yield of by-product power is significantly larger. No costs for rebuilding the distribution system have been included.

Table 6.6 lists a summary of the fuel consumption and outputs for the conceptual Virginia peat unit.

Table 6.6

Design Criteria and Fuel Consumption of Virginia Peat-Fired District Power Plant

Nominal steam output	400,000 lb/hr
Nominal heat output	415 x 10^6 Btu/hr
Average steam output	190,000 lb/hr
Peat burning capacity	37 tons/hr 884 tons/24 hrs
Oil burning capacity	14.7 tons/hr
Efficiency of full load, combined moisture (46 percent peat moisture)	78 percent
Annual peat consumption	206,000 tons
Annual oil consumption	8,700 tons
Oil input of total (as heat)	14 percent
Peat input of total	86 percent

Source: Reference 80

Because of the very high winter peak load, it is hardly feasible to design the boiler for 100 percent output on peat. EKONO suggested that 2/3 of the nominal load can be generated with peat, the rest being heavy fuel oil. This will save considerable investment capital and will not affect the peat utilization very much because the duration of loads greater than 2/3 is small.

It is estimated that some oil will be needed as support fuel during peat burning as well. This is mainly for safety reasons. The minimum use of oil will be approximately 3.2 gallons per minute.

Specific heat production costs are listed in Table 6.7. These values assume operation of the plant 6000 hours per year and an oil price of $\$2.7/10^6$ Btu - about 40 cents a gallon.

Table 6.7

Specific Heat Production Costs for Proposed Virginia City District Heating Power Plant (6000 hr/yr operation)

	Oil	Peat		
Fuel Price $\$/10^6$ Btu	\$2.70[a]	1.00	1.50	2.00
Fuel cost $\$/10^3$ Btu/hr	19.1	9.7	13.1	16.5
Fixed cost $\$/10^3$ Btu/hr	9.5	15.0	15.0	15.0
Total $\$/10^3$ Btu/hr	28.6	24.7	28.1	31.5

[a]Equivalent to about 40 cents/gallon.

Source: Reference 80

Additional results are shown in Table 6.8, where operating hours are varied to determine break even points with different peat fuel prices. When the plant is operating more than 3500 hr/yr on peak load, the heat produced by peat is cheaper than by oil when peat price is \$1.00 per million Btu. With the peat price of \$1.50, the time limit is 5600 hr/yr. If the price of peat is \$2.00 per million Btu, the heat price will always be higher than with oil. Note that the oil price is assumed to be 40 cents/gallon; the price in 1980 has more than doubled, which makes the peat alternative all the more attractive than that shown in the table.

Table 6.8

Specific Heat Production Costs as a Function of Operating Time

		Operating Time (hr/yr)			
		3000	4000	5000	6000
Oil only	$/10^6 Btu	6.0	5.5	5.1	4.7
Peat ($1.00/10^6 Btu)	$/10^6 Btu	6.6	5.3	4.6	4.1
($1.50/10^6 Btu)	$/10^6 Btu	7.1	5.9	5.2	4.7
($2.00/10^6 Btu)	$/10^6 Btu	7.7	6.5	5.7	5.2

Source: Reference 80

The alternative of using coal has not been specifically studied. The fixed costs are only slightly lower than in peat-fired power station which means that the fuel price is the main factor in the comparison. If western coal is used, there is hardly any difference in boiler price. The main difference comes from the peat handling equipment. A rough estimate is that a peat-fired unit would need $4 million more capital than a coal plant. This means 1.2 $/MBtu/year higher fixed heat production cost.

With a projected coal price of 1.7$/per million Btu, the produced heat would always be cheaper than the heat from a peat-fired station, when the fuel price is higher than $1.50 per million Btu. The break even point to the advantage of peat would be approximately 2200 hr/yr operating time with a peat price of $1.00/million Btu.

6.4 PEAT BRIQUETTES/PELLETS

Peat in briquetted form provides an alternative fuel for wood and certain coal-fired units. Domestic home heating with firewood can be immediately switched to briquette burning with no alteration of equipment. However, peat briquettes would have to compete with firewood prices, which can range from $100 or more per cord ($5.25/10^6 Btu) in urban areas all the way to free for rural users who collect their own wood supplies. An additional disadvantage is that peat bogs generally occur in (or near) forested areas, where adequate sources of firewood are readily available.

Several peat processing technologies, such as the Koppelman process and other wet carbonization techniques, produce a fuel product that is easily pelletized for use in direct combustion applications. The heating value of these pellets is very high - around 12,000 to 14,000 Btu/lb. A premium low-sulfur fuel product like peat pellets could be transported long distances (over 100 miles) before transportation costs became a large fraction of the delivered cost.

7. RESEARCH, DEVELOPMENT, AND DEMONSTRATION (RD&D) PROJECTS IN PEAT DEVELOPMENT

Current RD&D activities in peat fuel development are described below and listed according to the sponsoring organization. Following the presentation of ongoing work are recommendations for further research to stimulate and accelerate the development of domestic peat resources for energy.

7.1 EXISTING RD&D PROGRAMS

U.S. Department of Energy

- Resource Estimation

The DOE objective is to determine the amount and location of fuel-grade peat that may be harvested and utilized in an environmentally acceptable manner. DOE has been encouraging the participation of states having significant peat deposits, and which are interested in determining the energy potential of peat, in the federal peat program. At the present time, eleven states (Maine, Minnesota, Michigan, North Carolina, South Carolina, Alaska, Rhode Island, Florida, Massachuetts, Louisiana, and New York) are participating in joint DOE/State Peat Resource Estimation projects. The state contributions are in the forms of money, personnel, and/or equipment.

Each state has put in priority order its peat bogs to be surveyed. DOE has generated a work statement for these projects. The methodology consists of several steps:

1. Use of topography maps prepared by the United States Geological Survey to estimate the size of sample areas
2. Use of tracked vehicles, helicopters, boats, etc., to traverse the bog areas
3. Mechanical collection of peat samples to various depths and from various locations within a bog area (using Davis & McCauley samplers)
4. Analysis of bog samples
5. Formation of a fuel-grade peat grid that identifies the quantity of peat at various locations and depths.

6. Computer analysis of the grids to project detailed maps and calculation of the total quantity of fuel-grade peat in each bog

Approximately three years will be required to obtain a precise estimate of the U.S. peat resource. The DOE Peat Resource Estimate will become more national in scope as it is expanded to include other states (Florida, Wisconsin, Georgia, Louisiana, etc.). The results will enable DOE to incorporate peat into the national energy plan. They will also allow the states to assess the magnitude and quality of their peat deposits and to plan intelligently the utilization of their peat for energy purposes.

- Harvesting

The U.S. Department of Energy will develop a commercial-scale technology for the hydraulic harvesting of peat. The methodology must be economical, environmentally acceptable, and complementary to a commerically feasible peat dewatering and gasification operation. Hydraulic harvesting will also be a required procedure for other peat uses, e.g., liquefaction, combustion, etc.

Parallel to the peat hydraulic harvesting development, DOE may perform additional studies of the milled peat and machine sod peat procedures. It is conceivable that these procedures may have applications in small-scale non-gasification peat uses. One example would be the use of sod peat for home heating in remote regions of Alaska.

- Dewatering

The most significant technical obstacle to gasifying peat is the reduction of its moisture content to acceptable levels (approximately 50 percent). Peat dewatering poses a severe technical obstacle for direct combustion, liquefaction and other energy applications.

The U.S. Department of Energy is supporting the development of alternative peat dewatering techniques:

Wet Carbonization - Minnegasco is jointly supporting this task (performed by IGT) to study the chemistry (kinetics, selectivity, etc.) of wet carbonization. Peats from Minnesota, Maine, and North Carolina are being tested in laboratory-scale equipment. In addition, the gasification kinetics of the "peat coal" (product of wet carbonization) and the impact of wet carbonization upon the cost of converting peat to SNG will be determined. Further development of peat wet carbonization will be supported by DOE is the laboratory-scale work and preliminary economics are encouraging.

Solvent Extraction - Minnegasco is also providing joint support for this task. The major focus of this investigation will be testing the performance of various organic solvents in removing water from peat. Preliminary economics will be estimated. The results of this laboratory-scale project will determine the scope and level of future DOE support for peat solvent extraction.

Long-range Research and Development - In the future, DOE will be sponsoring studies for determining the nature of the affinity of peat for water, e.g., colloidal, hydrogen bonding, etc., and the development of novel dewatering techniques. It is not expected that these will have near-term impact on the commercialization of peat gasification.

Peat Biogasification - This task is described below. It is mentioned here because it is a concept that circumvents the need for dewatering.

- Gasification Development

There are several DOE gasification projects that are being performed in parallel. It has already been determined that peat is very reactive to gasification. (Minnesota, Maine, and North Carolina peats are two to three times as reactive as Montana lignite for a broad range of temperatures, pressures, and gas-phase substrate composition.) A considerable amount of information that has been derived from the operation of coal gasification pilot plants will be judiciously extrapolated and utilized for the special case of peat gasification. It is expected that the equipment required downstream of a peat gasifier to process the raw product gas would be virtually identical to the downstream processing requirements for coal-derived raw product gas.

The following gasification projects address directly the technical concerns associated with gasifying peat and reflect the DOE position to develop promising long-range alternative technologies for converting peat to substitute natural gas:

DOE/Minnegasco Peat Gasification - This study (performed by IGT) is to determine the kinetics and fluid mechanics of peat gasification. The preliminary economics of converting peat to substitute natural gas are also being estimated. A sophisticated kinetic model has been formulated and verified with peats from Maine, North Carolina, and Minnesota. Subsequent work will include the testing of peats from Florida, Alaska, and other states, as well as pilot plant support activities.

DOE/Minnegasco Low Severity Hydropyrolysis - The chemistry of peat gasification is being studied at lower temperatures and pressures. It is of particular importance to understand the effect of gasification conditions upon the yield of liquids (benzene and other gasoline blends). IGT is performing this investigation.

DOE/Minnegasco Peat Biogasification - This is a laboratory-scale project to develop the concept previously described for converting peat directly to methane using a partial oxidation reactor and biological reactor (bacterial digestion). Dynatech Corporation will be focusing on the effect of the specificity of the partial oxidation reactions on the performance of the biological reactor. The technical and economic feasibility of this gasification will be more evident at the conclusion of this project in 1981.

Rockwell Peat Gasification - A task has been initiated to study the gasification of peat in the Rockwell short residence time (SRT) entrained bed gasifier. The results will complement the IGT kinetic work and complete the peat kinetic envelope (since the experiments will be performed at severe conditions of temperature and pressure). Preliminary testing of peat in the Rockwell reactor was favorable in terms of operability and gasification performance (conversion, gas yield, etc.).

UOP/SDC Peat Gasifier Assessment - UOP/DOE, as part of its support contract to DOE, will recommend a peat gasifier configuration (fluidized bed, entrained bed, etc.) for testing in a DOE peat gasification pilot plant project. This recommendation will be based on a review of available peat gasification results and application of fundamental chemical reaction engineering principles. Available information on the performance of coal gasification configurations (CO_2 Acceptor, HYGAS, BIGAS, SYNTHANE, etc.) is being utilized in this determination.

Pilot Plant Modifications - DOE is preparing to conduct peat gasification tests at a pilot-plant scale. These preparations include the procurement of equipment necessary to modify the pilot plant selected for these studies. This equipment includes a peat dryer and grinder, and a peat storage and preparation facility. Further modifications will include a dual lockhopper feed system and a peat gasifier, depending on results of independent UOP/SDC study.

- Environmental Impact Assessment and Socioeconomic Impact Assessment

Each of these project areas will be performed in three phases:

Phase I. Identification of Problems and Issues: UOP/SDC (Environmental) and Radian Corporation (Socioeconomic) are identifying the problems and issues associated with large-scale peat gasification. A list of items to be considered will be prepared. UOP/SDC and Radian Corporation will also establish a mechanism whereby the states participating in joint projects (resource estimation) can address the identified issues.

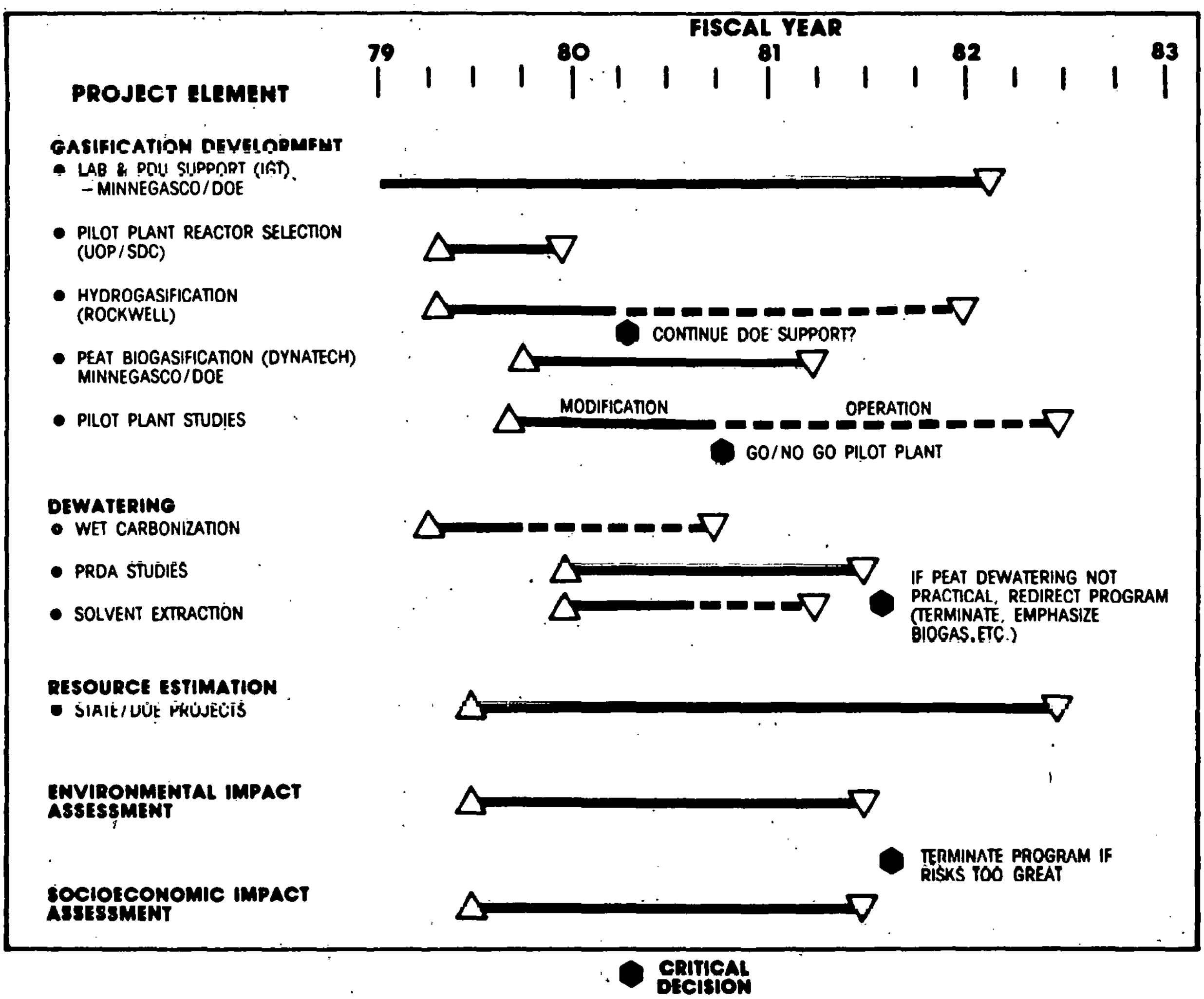
Phase II. Gathering Data on Identified Issues: The joint DOE/state projects will be expanded to include tasks to gather the environmental and socioeconomic data for the issues identified in Phase I. These data will serve as inputs for Phase III.

Phase III Overall Environmental and Socioeconomic Impact Assessments: Several case studies will be performed to assess the environmental and socioeconomic impacts of an integrated gasification process in representative regions. The evaluation criteria will be uniform for each case study. This approach is designed specifically to provide a reasonable cross section of environmental circumstances. This will enable localities to interpolate between case studies to extract information, which is applicable to their peatland, in order to formulate specific environmental and socioeconomic impact assessments. The intent is for the complementary environmental and socioeconomic impact assessments to provide information that would be required for a locality to decide whether to utilize its peat resources. The contracts to perform these assessments will be awarded in the beginning of Fiscal Year 1981.

A go/nogo decision concerning DOE support of a peat gasification pilot plant project will be made during Fiscal Year 1980 (see Figure 7.1). The decision about whether to commence pilot plant testing at the beginning of Fiscal Year 1981 will depend upon the preliminary results from the dewatering, environmental, and economic impact assessment tasks.

Figure 7.1

DOE Peat Program Milestones



U.S. DOE/Grand Forks Energy Technology Center (GFETC)

Peat utilization projects at GFETC emphasize one of two major project objectives:

1) To develop techniques and processes for conversion of peat into more convenient and useful energy forms while satisfactorily meeting environmental standards.

2) To test and evaluate the potential of peat in combustion, gasification, and liquefaction processes by modification of equipment and procedures available at GFETC.

The specific objectives of this project for FY 1980 are as follows:

- Conduct additional preliminary pilot plant combustion tests to evaluate a Minnesota and a North Carolina peat as potential boiler or atmospheric fluidized bed combustor (AFBC) fuel.

- Conduct pilot plant combustion tests of peat/coal blends as a boiler fuel.

- Develop moisture reduction techniques as follow-up to FY 1979 solvent extraction studies.

- Evaluate potential utilization of wet peat processes (oxidation, carbonization, and biomethanation) for energy or fuel generation.

- Provide support for DOE Peat Program and other energy-related peat activities.

Minnesota Department of Natural Resources[82]

The Minnesota Peat Program, directed by the Department of Natural Resources (DNR), has designed and initiated a comprehensive program to study the peatlands of Minnesota. The goals of the program are to present peatland policy and management alternatives to the legislature for their consideration. During the initial biennium (1978-1979) of the program, studies in the following project areas were initiated:

- Natural Environment Studies

  1. Peat Inventory Program

  2. Biology Studies on Peatlands

3. Water Resource Studies

4. Air Quality Studies

- Socioeconomic Studies

1. Socioeconomic Impacts of Peat Development of Northern Minnesota

2. Regional Development Commission Reports

3. Peat Utilization and the Red lake Indian Reservation

- Feasibility Studies

1. Chemical Industrial Utilization of Peat

2. Agricultural/Horticultural Uses of Peat

3. Feasbility Study of Peat as a Power Plant Fuel

4. Evaluation of Gasification Research

- Reclamation Studies

1. Agricultural Reclamation of Peatlands

2. Forestry Reclamation of Peatlands

3. Peatland Reclamation Demonstration at Wilderness Valley Farms

- Governmental Studies

1. Peatland Policy Study

2. Peat Taxation Study

3. Peat Lease Format

4. Royalties for Extracted Peat

- Public Relations Programs

The Minnesota Peat Program has received additional funding from the state legislature to continue its studies through the 1980-1981 beinnium. Research will emphasize more detailed studies in bog hydrology and reclamation. Energy farms (cattails) is a particular reclamation objective under study. The DNR also plans to complete a thorough heavy metal survey of peatland deposits.

Others

RD&D activities listed here have been recently completed by private concerns.

- First Colony Farms (FCF)[83]

First Colony Farms has performed the following tests and studies, using only private capital:

1. Testing of European harvesting equipment (sod and milled peat) on North Carolina peatlands.

2. Experimental peat reclamation plot for row crop agriculture.

3. Feasibility studies on optimum power plant size based on FCF peat reserves.

4. Economic analysis of electricity generation from peat.

5. Environmental effects of peat utilization in Northeastern North Carolina.

In addition, Southern Engineering Company conducted a study regarding the construction of a prototype peat-fueled power plant at First Colony Farms. This effort was funded by the North Carolina Electric Membership Corporation (NCEMC), a system of 28 utility coops from North Carolina. The objective is to have a 150-megawatt unit in service at FCF by 1982.

- SRI/Koppelman Peat Dewatering Process[84]

The Stanford Research Institute, in conjunction with Mr. Edward Koppelman, is developing a peat dewatering and upgrading process based on wet carbonization. The prepared product, known as "K-fuel", has a heating value up to 14,000 Btu/lb., depending on ash content and severity of treatment.

- Process for Wet Carbonizing of Peat[85]

Bertel Myreen (Finland) has received a U.S. patent (No. 4,153,420) for his wet carbonization process designed specifically for peat feedstocks. Specific design differences between this process and to Koppelman process cannot be illustrated due to the proprietary nature of the developments.

7.2 RD&D RECOMMENDATIONS

A preliminary listing of recommended RD&D projects is presented here. These projects, for the most part, build on the ongoing research efforts described in the previous section. The relative importance of the various research topics to enhancing the development of peat resources for energy production is indicated by their classification into Priority I and Priority II groupings.

Priority I Topics

1. Environmental Impacts of Large-Scale Peat Utilization

   The potential effects of major peat harvesting projects on the ecology and hydrology of peatlands needs to be studied further before such projects are undertaken. In addition, studies are needed to determine potential environmental impacts from all other steps in the peat utilization cycle, including dewatering, preparation and handling, combustion, wet and dry conversion to improved fuels, and disposal of liquid and solid wastes.

2. Harvesting Techniques

   Three methods have been developed for peat harvesting: hydraulic, milled and solid. The milled and sod techniques are well known in Europe, but the hydraulic technique is not as advanced, and may have particular application in wet peat processes. Each of these methods should be examined for use with specific reserves in the United States.

3. Peat Dewatering Techniques

   Due to the high moisture levels in raw peat, many utilization and conversion systems cannot process peat without some pre-treatment step which reduces moisture level. Techniques for achieving this include mechanical, chemical (solvent extraction) and thermal dewatering. The energy intensive nature of dewatering processes and their importance as a preparation step makes the development of effective, economical processes a very high priority item.

4. Wet Peat Conversion Processes

An alternative to drying peat for use in combustion and gasification systems is the direct use of the high moisture peat in oxidation, carbonization, biomethanation and aqueous phase liquefaction systems. These alternative peat utilization technologies are being investigated in various DOE-supported projects, which should be continued until reliable process designs and economic forecasts can be prepared.

5. Peat Combustion Techniques

The unique properties of peat will require different conditions than used for coal combustion in stoker, pulverized peat and fluidized bed combustion. The effects of these properties during combustion are being investigated at GFETC, and design studies are being conducted by First Colony Farms in North Carolina.

6. Gasification of Peat

As with coal, peat may be used as a feedstock for high-, medium-, or low-Btu gasification. Several studies are being conducted by various organizations to determine the feasibility of using peat in these systems. This work is essential to peat gasification development and should be continued until reliable economic estimates can be made.

7. Peat Resource Characterization

Accurate determination of the amount, type and location of peat reserves is an essential part of planning peat development. As described in Section 7.1, the DOE is participating in resource estimation programs with eleven states. This work must be continued until adequate definition of the resource has been made.

8. Characterization and Control of Effluents From Peat Processing

Safe development of peat utilization will require an accurate understanding of effluents from peat plants and developments of control techniques. Environmental effects of peat gasification and several wet peat processes are currently being investigated. These efforts should be expanded to include direct combustion, liquefaction and pyrolysis of peat.

9. Health and Safety Aspects of Peat Harvesting and Utilization

Protection of workers and the public from hazards associated with peat development must be based on knowledge of safety and health effects of these activities. Some of these effects may be inferred from a knowledge of the type and amount of emissions involved (see Topic #8 above), while others may require long term animal studies.

Priority II Topics

10. Peat Comminution Techniques

Because of its significantly different physical nature, the comminution of peat is expected to have different requirements than either high- or low-rank coals. Differences may be noted in throughput capacity, grinding energy, materials requirements and possibly equipment design. Efficient methods for peat comminution will have to be developed if peat is to significantly contribute to the nation's energy supply.

11. Briquetting and Pelletizing of Peat Fuel

Peat fuel produced from wet carbonization or oxidation processes has an attractive heating value and may be beneficially used in applications requiring briquettes or pellets. Methods for producing these agglomerates may differ from those used to produce coal or charcoal briquettes and therefore will require investigation to determine appropriate techniques.

12. Handling and Storage of Dried Peat

Problems encountered in the handling and storage of low-rank coals may also be encountered under similar circumstances with peat. These include self heating, spontaneous combustion, and windage loss, but may not be limited to these. Expansion of peat utilization will require knowledge of proper handling and storage procedures for dried peat.

13. Solid Waste Disposal From Peat Utilization

Toxicity, leaching, compaction and stability are solid waste disposal problems of concern with disposal of peat utilization and conversion wastes. Studies similar to those being done for low-rank coal solid waste characterization should be performed for peat conversion wastes.

14. Liquefaction of Peat by Direct Hydrogenation and by Oxidative Depolymerization

Direct hydrogenation of peat (which requires a dry feedstock) and oxidative depolymerization (which requires a wet feedstock) are two alternative approaches to peat liquefaction. Based upon laboratory determinations of process yields, a preliminary study of the economic potential of both liquefaction processes should be performed, with continued process development if warranted.

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The current status of power generation from peat is reviewed with respect to its proportions and role in three European countries: Ireland, Soviet Union, and Finland. Considerable attention is paid to combustion equipment and their design parameters in order to prove the prompt availability of a variety of established techniques. Burners and combustors, being the essential items of the combustion process, are discussed in some detail. Aspects of co-firing with other fuels and retrofitting to peat are presented as means of a rapid introduction of the new fuel. Facilities for receiving, conveying, and storing peat are also discussed, with special attention to the aspects of dimensioning and design for safety.

2. Punwani, D.V. "Synthetic Fuels from Peat", presented at the Management Assessment of Peat as an Energy Resource conference, Arlington, Virginia, July 22-24, 1979.

This paper discusses thermal peat gasification processes currently studied by organizations such as the Institute of Gas TEchnology (IGT), Rockwell International, the Royal Institute of Technology (Sweden), and the Technical Research Center (Finland). IGT gasification results are presented for Minnesota, Maine, and North Carolina peat samples. Although the Minnesota peat had the lowest heating value, it produced the highest hydrocarbon gas yield.

The paper includes a discussion of IGT's PEATGAS reactor, its operating parameters, process design, and economics.

3. <u>A Report on European Peat Technology</u>, Minnesota Department of Natural Resources, St. Paul, Minnesota, reprinted August, 1978.

Presented in this report is a summary of European peat technology based largely on firsthand knowledge gained during a visit to Europe in the fall of 1975 by a delegation from Minnesota. Those attending included representatives from various state energy and natural resources agencies, and members of both state legislative bodies. The trip to Europe was carried out as part of Midwest Research Institute's program to study European peat technology and provide policy makers with information helpful in furthering the development of a Minnesota peatland policy. The program has been funded by the Upper Great Lakes Regional Commission and is being monitored by the Minnesota Department of Natural Resources.

The report summarizes current activities under four general headings: Research; Harvesting; Energy; and Reclamation.

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At the request of the Department of Energy, UOP/SDC has conducted a study to characterize the environmental issues that would arise from an extensive peat utilization program. The Environmental Assessment project consists of three phases; this report is the initial phase. The environmental issues and concerns identified will be dealt with in detail during Phase II, when state and federal interagency efforts will concentrate on data collection, data analysis, and further environmental research.

This preliminary report: identifies the environmental issues and potential problems; examines the significance of issues in the geographical regions where peat use could be developed; and establishes a methodology by which issues can be resolved or clarified through future coordinated private, state, and federal programs.

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