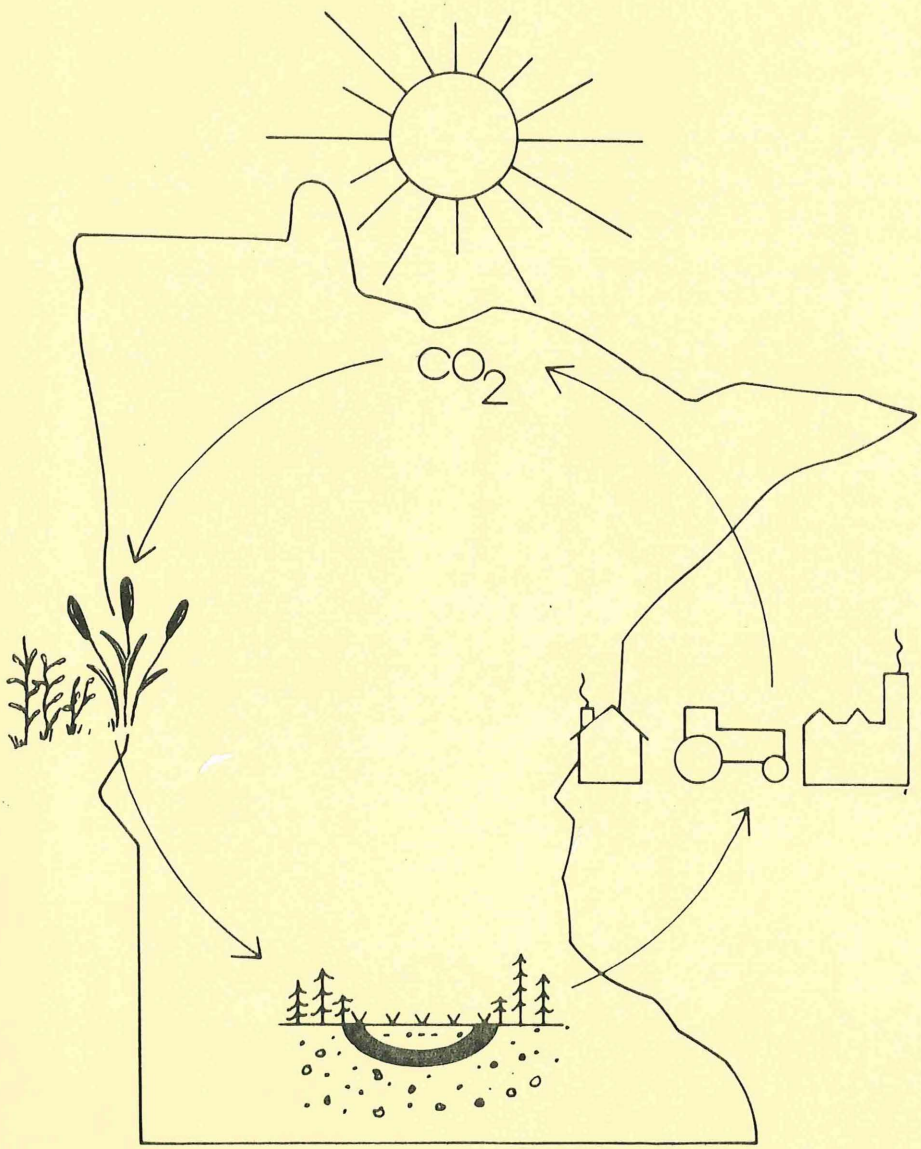
BIO-ENERGY IN MINNESOTA:
THE PEAT SPECIAL ENERGY PROJECT



FINAL REPORT

SLATIVE COMMISSION ON MINNESOTA RESOURCES

BIO-ENERGY IN MINNESOTA:
THE PEAT SPECIAL ENERGY PROJECT

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Final Report
to the Legislative Commission on Minnesota Resources
by the Department of Energy, Planning and
Development / Energy Division

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PEAT SPECIAL ENERGY PROJECT

I. The Peat Special Energy Project

I. THE PEAT SPECIAL ENERGY PROJECT

The State of Minnesota has approximately 5.2 million acres of peat and 3.5 million acres of wetlands which have potential for development. A major policy question confronting the State is what should be done with these lands. Should these lands be left in their natural state; or should they be developed for agriculture, foresting, mining or energy production? Energy production on these lands could entail the harvesting of peat, growing energy crops or some combination of both.

In late 1980 the Energy Agency (now the Energy Division of the Department of Energy, Planning and Development; DEPD/Energy), working with the Interagency Peat Task Force (IPTF), created a draft proposal for research related to the question posed above. Subsequent events at both the Federal and State level rendered the proposal obsolete. The Legislative Commission on Minnesota Resources (LCMR) then allocated $56,300 to the Energy Agency to revise the draft proposal such that it would address the current situation. The revised proposal would contain a recommendation on future special energy crop research in Minnesota. Funds from this project eventually provided monies to two related projects; the development of the Bio-Energy Research Project and the Virginia Peat Test Burn Project. The development and current status of these two projects is discussed in Parts II and III of this report.

Development of the Bio-Energy Research Project began in July 1981 with a revision of the original proposal. The proposal was subjected to a series of reviews by IPTF and the public which resulted in the final proposal which was presented to the LCMR in June 1982. Other activities included in the development efforts were a media campaign to promote bio-energy awareness in northern Minnesota, a public awareness survey, a series of public input

meetings and a project to map available peatlands (conducted by the Department of Natural Resources, DNR). The details on the project development are contained in Part II, Section 4.0. The final proposal was funded for $300,000 by the LCMR. The work outlined will occur over the next biennium (1983-1985).

The Virginia Peat Test Burn Project was announced in September 1981. The LCMR was amongst the several groups which were approached for funding ($10,000 from the Peat Special Energy Project was authorized for this project). Development of the project plan was completed in September 1982. Work began in October but was eventually halted due to the inability of the peat supplier to produce the required fuel peat. The project has been reorganized and will be completed in the latter part of 1983. Details regarding this project are presented in Part III of this report.

The Energy Division recognizes the importance of coordinating the bioenergy research to be conducted here with the projects to be implemented by the DNR and the Iron Range Resources and Rehabilitation Board (IRRRB). It will be necessary to meet with these groups to discuss the coordination of activities.

Information generated from these and other related studies will provide data dealing with several aspects of the biomass energy issue. These results will assist State decision makers in their efforts towards resolving the policy questions confronting the bioenergy issue. In addition, basic data will be provided for those who wish to become commercially involved in this emerging industry. As such, this project will make a valuable contribution to Minnesota's energy future.

II. The Bio-Energy Research Project

II. THE BIO-ENERGY RESEARCH PROJECT

1.0 INTRODUCTION

This project, developed by the Minnesota Interagency Peat Task Force, presents a plan to develop the peatlands/wetlands for biomass energy production. The original plan, as presented to the LCMR in June 1982, covered pilot-scale land preparation for biomass production, growth and productivity studies of biomass crops on peatlands/wetlands, an environmental impact assessment, a wetlands inventory, and site selection. The plan presented here, reflecting the reduced level of funding, concentrates principally on biomass production studies coupled with economic assessment of production systems. Wetlands inventory work is also retained. Some of the other project tasks will be performed as a part of the peatland work being conducted by the DNR and the IRRRB. It will be necessary to discuss these aspects further with these two groups such that all three projects are coordinated and compliment one another.

Providing sufficient energy to support the Minnesota economy, through either traditional fuels or synthetic fuels derived from coal, will continue to result in a significant drain on dollars from Minnesota to other states and nations. To compensate for this dollar drain the state has to increase production of agricultural, mineral, forestry and manufactured goods. Increases in these sectors will be difficult to achieve because of resource limitations and the negative influence of high fuel costs. A competitive, renewable-fuel industry in Minnesota and economic development based on Minnesota's traditional industries could provide support for each other. Development of a renewable-fuel industry would also increase employment opportunities in areas of the state where they are desperately needed.

Studies by the Energy Division of the Department of Energy, Planning and Development have shown that with present biomass technologies, substantial and workable renewable-energy systems are possible in Minnesota within a short time. Although Minnesota cannot produce large percentages of its energy needs from agricultural or forest lands on a sustainable basis, the 5.2 million acres of organic soils (peat) located in the northern part of the state represent a significant opportunity, as do the 3.5 million acres of non-peat wetlands.

Peat is an alternative fossil-fuel source that could be mined. Significant amounts of synthetic fuel could be produced from peat feedstock, although long term production would be limited by peat's non-renewable nature and by mining economics. More importantly, peat is also a soil that could be used for growing biomass. Biomass can be converted into the same fuels as the original peat, and it is renewable.

The lack of uniformity in Minnesota peatlands is a major consideration. Not all peatlands are peatbogs. Some contain a mixture of organic soil (peat) and wet mineral soils. This soil mixture is often scattered throughout any peatland region. Secondly, peat depths vary considerably within any given land area.

The State owns about fifty percent of the available peatlands, along with the majority of the wet mineral soil areas, and is thus in a position to control major wetland development. Since the State also implements environmental laws governing the use of Minnesota's resources, it is interested in the many effects of resource production and conversion. It is also interested in the engineering needed to develop conversion technologies, such as gasification. These two elements must be coordinated so that all effects of a total system can be defined when leasing decisions are made.

The plan presented in this document will help lead to energy production that is environmentally sound. Biomass production should be the long-run outcome of any peatland/wetland development. Seeking ways to optimize long-run productivity is a worthwhile goal.

2.0 CURRENT STUDIES

Current work on Minnesota bioenergy is being conducted by State agencies and the University of Minnesota. The federal government has sponsored additional work in conversion technology. The Interagency Peat Task Force was organized to coordinate these studies.

2.1 Other Federally Supported Efforts

The U.S. Department of Energy has sponsored several large studies of peat gasification through Minnegasco and the Institute of Gas Technology (IGT). This work concentrated on conversion technology assuming that a satisfactory resource could be made available. Work proceeded from laboratory-scale gasification tests to pilot-scale tests conducted at the IGT Process Development Unit (PDU). The DOE supported work aimed at determining whether the gasification process could be commercially feasible. DOE also supported a minor amount of work on lab-scale biological conversion of peat to methane gas and lab-scale gasification of biomass.

The U.S. Bureau of Mines completed a small amount of work on mining and dewatering technology. This work consisted of a single test and did not lead to any positive conclusions. Its results cannot be used as a basis for moving to a commercial-scale operation.

Minnegasco received a $4 million grant from DOE for a feasibility study of a peat gasification system. Their study was completed in 1982. The study concluded that the cost of producing synthetic natural gas from peat

was unacceptably high given the current market conditions. Minnegasco is continuing work in this area but has no plans to build a gasification plant at present.

Past federal efforts have been in the direction of building a large commercial scale gasification facility in Minnesota. A major question facing the State is whether it wants to support that sort of construction, or smaller, diversified, renewable systems. Past federal efforts can be characterized as a concentration on conversion technology with little or no emphasis placed on resource questions. It is, of course, these resource questions which are of primary interest to Minnesota.

2.2 State of Minnesota

The State of Minnesota, triggered by a Minnegasco lease request for peatlands, initiated studies of peatlands in 1976. These studies developed a baseline by measuring existing conditions. Work included an inventory of resources, measurements of environmental conditions, estimates of the economic effects of peat utilization, and research on legal aspects of the utilization of peat. The studies led to preliminary policy alternatives, which were considered by the Minnesota Legislature in 1978. Further studies of reclamation, inventory, and alternative uses, and development of more precise environmental measures are underway or have been completed.

In another project, the Iron Range Resource and Rehabilitation Board (IRRRB) purchased and installed a small-scale, low-Btu gasifier. Experiments are being conducted with this system using peat and combinations of peat and biomass, such as wood chips. The object of this work is to determine whether low-Btu gasification can be practical for a community-scale, co-generation system.

2.3 University of Minnesota

During this same period, the University of Minnesota, supported by the U.S. Department of Energy (DOE) and the State, was investigating the growth and productivity of both woody and herbaceous biomass crops on peat and mineral soils. The University Soil Science Department undertook a major DOE project to evaluate the growth and productivity of woody biomass species. The College of Biological Sciences, supported by the State of Minnesota and DOE, has been investigating the growth, productivity and chemistry of wetland plants for energy purposes. The plants receiving the most intense study are the common cattail, willow, alder and hybrid poplar. The current study effort is divided into four major topics: growth and productivity of the plant material, plant bio-chemistry, harvesting, and an analysis of the land areas that might be used to grow wetland plants.

During the summer of 1980, the work on both wetlands and woody biomass expanded greatly. The University of Minnesota developed propagation techniques for woody biomass that has allowed the researchers to move to acre-size plots. Several large areas of willows were planted at the IRRRB research farm at Zim. The wetlands plant work expanded at both Godward's wild rice farm, north of Aitkin, and at Zim. During 1981, 2.5 acres were prepared at Zim for studies of growth and productivity. In 1982, 2.5 additional acres were made available. The research on both types of species is now at the "field station" stage, and it is expected that plot sizes will increase dramatically in the future.

2.4 Information Expected From the Current Studies

Studies supported by the state and federal governments have allowed the compilation of a partial data base as follows:

1) Location of peat resources - Inventory work has defined

surface locations of peat resources and the approximate quantity of the resource available. More detailed inventories have been completed for southwest St. Louis, Aitkin and Koochiching counties.

2) Peatland locations that should be left in a natural state - Certain bogs should be preserved because of their unique characteristics. These areas, of course, subtract from the resource base available for other purposes.

3) Existing environmental conditions in peatlands - Studies have developed extensive data on baseline water chemistry, vegetation and wildlife characteristics in peatlands. This data will be used to evaluate the environmental effects of potential use.

4) Gasification of peat using one conversion technology - Gasification work supported by DOE concentrated on the "PEATGAS" process developed at IGT. Other conversion technologies, which could yield gas, liquid or solid fuels, have not been investigated at this level of detail.

5) Conceptual analysis of peat mining, dewatering and gasification - Feasibility studies conducted by Minnegasco have provided a conceptual basis for one peat gasification system. The conversion technology portion of this study was supported by empirical data, but the mining and dewatering portion was not, since little field work was underway.

6) Growth and productivity of cattails and other species on peat soils and in natural stands - Current work should define the potential size of several types of renewable biomass resources.

It can be thought of as the first phase in the development of a new industry.

7) Bio-gasification of biomass in laboratory scale equipment - A small amount of work is underway at IGT on the anaerobic digestion potential of some forms of biomass. Results are promising but still far from commercialization.

2.5 Information Not Provided by the Past or Current Work

Several important information areas are virtually untouched in past efforts. The most important of these areas are:

1) Methods for, and environmental effects of, peat mining, dewatering and transportation;
2) Biomass growth in large managed stands and the associated environmental effects;
3) How to combine peat mining and biomass production in order to optimize biomass growth;
4) Gasification of biomass and peat/biomass combinations, as well as conversion to liquid and solid fuels;
5) Analysis of methods for selecting a "best" energy production strategy using peatlands in the State of Minnesota.

3.0 POLICY SUMMARY

Peatlands are a valuable resource, capable of serving many uses, including horticulture, agriculture, forestry, energy, industrial chemicals, sewage treatment, recreation, scientific study, wildlife habitat, water filtration, and preservation. The Interagency Peat Task Force has recommended that peatlands be managed cautiously so that the resource can be used by future generations, and flexibly to allow for changing needs and expanded knowledge.

3.1 Peatland Uses

3.1.1 Peatland Protection and Preservation

Peatlands that have high potential for forestry, wildlife management, or natural area preservation should be preserved for such uses and not be offered for lease. The potential of peatlands for forestry should be considered when evaluating lease proposals. Existing and proposed wildlife management areas should be protected from incompatible development. The value of peatlands as wildlife habitat should be one of the criteria used to evaluate proposals for leasing peatlands outside of existing or proposed wildlife management areas.

Peatlands that contain endangered, threatened, and rare peatland fauna and flora, representative types of peatlands, and areas that have unique geomorphic features should be set aside. Peatlands that have significant scientific value are now under study by the Task Force. These peatlands should not be used until the appropriate management of these areas is determined.

3.1.2 Leasing

Peatlands available for leasing should be allocated for many uses so that the needs of a variety of developers can be met, and particular uses demonstrated.

3.1.3 Development Siting

Criteria to select peatlands for leasing include development interest, existing and potential use, available resource information, availability of transportation and utilities, existing disturbances, location in the state, peatland and watershed, and potential environmental effects.

3.1.4 Conflicting Uses

Certain uses of peat will preclude other uses. The need to set

priorities on extractive uses presently does not exist, given the current supply and demand. Should major use conflicts arise, it will be necessary to study and recommend the appropriate use.

3.1.5 Size

As a guideline, leases should not exceed approximately 3,000 acres (approximately five square miles) of peatland. The size of each lease should be based on the peatland, the watershed, and the mining method.

Leases for larger-scale development should not be granted until the technological, economic and environmental feasibility is well documented and demonstrated.

3.2 Environmental Management

3.2.1 Rules

It is recommended that the rules of the Environmental Quality Board be amended to require a mandatory Environmental Assessment Worksheet for:

1) conversion of 640 or more acres of peatland to an alternative use,
2) for the construction of a facility using 5,000 dry tons or more of peat per year to produce a fuel, and
3) for the construction of a peat mining operation which will use 160 or more acres of land.

It is recommended that an Environmental Impact Statement be required for the construction of:

1) a facility using 250,000 dry tons or more of peat per year to produce a fuel, and
2) a peat mining operation which will use 320 or more acres or land.

3.2.2 Permits

In order to protect the resource, as well as the public health, safety,

and welfare of the people of Minnesota, drainage of all peatlands should be subject to water permit rules promulgated under Minn. Statutes, Chapter 105, and other applicable legislation, and the water quality rules of the Pollution Control Agency. Rules have been promulgated for appropriation of water of the State that pertain to peatland.

Peatland development projects should also be subject to other applicable rules of the Pollution Control Agency regarding air quality.

3.2.3 Mitigation

Mitigation of potential adverse environmental effects should be required to protect water, wildlife, and air, and the public's health, safety and welfare.

3.2.4 Monitoring

Monitoring of air, water and land should be required in all leases. Before a lease is granted, an approved monitoring plan should be required. The leasee should be responsible for conducting or providing for all required monitoring.

3.2.5 Reclamation

To ensure the future land-use capability of peatlands, and to protect downstream and adjacent resources, reclamation should be required on lands disturbed by peat development activities.

To ensure adequate reclamation, a bond, security or other assurance should be required when there are reasonable doubts as to the operator's financial and technical ability to comply with the reclamation plan.

Reclamation should be staged over the term of a lease to enhance the process of reclamation and to reduce the environmental effects on unused disturbed peatlands.

3.2.6 Leasing

3.2.6.1 Rents and Royalties

So that the State receives an adeauate return for the resources, both rents and royalties should be charged for extractive uses. Only rents should be charged for nonextractive uses.

Royalties should be indexed to fluctuate with the rate of inflation so that the return to the State is commensurate with current dollars.

3.2.6.2 Competitive Bidding

Leases greater than 160 acres should be awarded through competitive bids. Minimum rents and royalties should be established so that the State receives the maximum return for the use of the resource. Negotiated sales may be employed for lease expansions when only singular interest or use is documented.

3.2.6.3 Speculation

Peatland speculation should be discouraged by requiring a certain amount of development to be performed on a leased area within a prescribed time.

4.0 DEVELOPMENT OF THE BIO-ENERGY RESEARCH PROPOSAL

The Interagency Peat Task Force was organized in 1979 to coordinate peat/biomass research efforts in Minnesota. The original Task Force was composed of members from all three divisions of the Department of Energy, Planning and Development (DEPD), the Pollution Control Agency (PCA), the Department of Agriculture (Ag), the Iron Range Resource and Rehabilitation Board (IRRRB), the Department of Natural Resources (DNR), the University of Minnesota (U of MN), the Minnesota Geological Survey (MGS), the Water

Planning Board, the Upper Great Lakes Regional Commission (UGLRC), and the Center for Urban and Regional Affairs (CURA). The Task Force has since been reformed into a commissioner level body with the Governor as chairman. The project has been developed as a cooperative effort, emphasizing input from each department represented, as well as input from the public.

Discussions with the DNR and the IRRRB will allow for the coordination of this effort with the work underway in those agencies.

4.1 Resource Development - The DOE/Minnegasco Proposal

Up to now, questions of peat development for energy have centered on the DOE and Minnegasco work on extraction and gasification in a large plant. The issue centered on saying "yes" or "no" to large-scale gasification. This development proposal assumed only minor participation by State agencies and concentrated on the use of peat as the fossil fuel feedstock for a gasification process. The proposal assumed DOE would participate in the construction of a demonstration plant. Since the conclusion of the feasibility study was unfavorable, and DOE had dimished their role in peat research, this proposal has been tabled.

The major shortcoming of this proposal was its lack of emphasis on resource development and production. This shortcoming could have been partially overcome by "paper" studies or evaluations of similar procedures in other parts of the world. However, this data would be suspect because it would not have related specifically to the company's permit application.

4.2 Resource Development - The Task Force Strategy Considered

Another development strategy leading to the same goal of new energy resources is the one presented in this project. This project, in conjunction with the work being done by the DNR and the IRRRB, will produce information in several important areas as described below.

The Task Force development strategy considers:

1) New resources - Biomass grown on partially excavated peatlands is evaluated as a feedstock for energy production.
2) Empirical data on the impacts of mining, dewatering and biomass production that will be collected early in the development process (elements of this will come from all three projects).
3) Direct combustion and gasification of peat, biomass or peat/biomass combinations (principally DNR and IRRRB work).
4) Minnesota based economic studies that will be completed.

The Task Force member agencies agree that their alternative is better because it:

- provides more data for decision-makers;
- develops more cooperation among State government agencies, private industry, the public and the federal government;
- allows for active participation by the State; and
- provides the opportunity for additional positive outcomes beyond using Minnesota's peat resources for nonrenewable energy production.

An evaluation of Minnesota's biomass resource might yield the economic benefits of energy production, plus the environmental benefits of using renewable resources.

4.3 Initial Discussion Draft

A discussion draft of the Bio-energy Proposal was developed by the Interagency Peat Task Force and was available for public comment on September 15, 1981. The Energy Division coordinated the development and review of this draft. Sections of the proposal were written by various

members of the Task Force. The draft proposal became the initial position of the Interagency Peat Task Force.

4.4 Public Awareness and Public Input

The Energy Division assigned a staff person to develop public awareness of the bioenergy research effort in the State. Approximately two months were spent with reporters from newspapers, radio and T.V. stations in both the Metro and Out-state regions. Reporters were assisted in scheduling interviews with researchers at the University of Minnesota, IRRRB, and State agencies. Feature articles were printed in many newspapers. There were numerous radio and T.V. programs that resulted from the effort. A scrapbook of news articles generated from this effort has been assembled.

Public meetings to review the proposal were held in cities in the peatland region. The meetings were attended by over 180 people. Notice of the meetings was published in advance and people interested in the project could request a copy of the draft proposal. Over 300 copies of the proposal were sent out for these five meetings. The meetings were held in International Falls, Hibbing, Thief River Falls, Aitkin and Bemidji. The program featured a presentation of the proposal by a representative of the Interagency Peat Task Force, a panel discussion that included local community leaders and public comment. The meetings were recorded and used to refine the draft proposal.

4.4 Biomass Energy Survey

A survey of the public was conducted to assess the impact of the public meetings and media effort. The survey focused on awareness of biomass energy options and how research to develop these options should be funded.

Two population samples were chosen. One group included residents of communities that received press or media attention only, and the other group

was chosen randomly from the whole state. The state-wide sample reflected the state's distribution of households by area code. The survey was conducted by telephone on weekdays in March during late afternoon and evening house.

The results of the survey included:

1) A high level of awareness of biomass, crop residues, cattails and willow, alder and aspen as an energy source among both groups of respondents.
   - 83% of the respondents in communities that received press or media attention and 64% of the state-wide sample were aware of these biomass/energy options.
2) Minnesota's natural resources are important as future energy resources.
3) Research should be done to develop these resources for energy, and the State should be involved in funding this research and development.

5.0 PROJECT DESCRIPTION

The intent of this project is to provide data pertaining to the use of peatlands, and other wetlands, for energy production. Results of this work, along with previous and current efforts by other groups, will assist State decision-makers in their efforts to plan for Minnesota's future energy needs.

The original project was defined by five major task areas: land preparation, biomass production, conversion technology, environmental effects, and systems evaluation. Major efforts were directed towards biomass resource production and environmental effects since these had not received adequate attention elsewhere.

The project, as it is planned now, still reflects the emphasis on biomass production although at a much reduced level of effort. It will be possible

to make up for some of the shortfalls of this project through careful coordination with the DNR and IRRRB efforts. This coordination will allow the State to achieve many of the original objectives referenced above although the emphasis, in the DNR and IRRRB programs, will be more on peat than biomass. Nonetheless, the Bioenergy Project will be able to derive benefit from the other efforts by being able to avoid a duplication of effort in some areas.

5.1 Task I - Land Preparation

This task has been eliminated from the project due to the reduction in the necessary level of funding. The intent of this task was to provide the land areas needed for expansion of field work. In proceeding towards commercialization of bioenergy crop production it becomes necessary to use large commercial scale sites on which to conduct experiments. The land preparation task would have produced these sites.

The field sites at Zim will continue to be used and new sites in Aitkin and Anoka counties are being developed. Development of new sites is desirabl to study the specific problems associated with the use of virgin production areas.

It may be possible to expand on this work through a coordinated effort with the DNR and IRRRB projects. Land preparation would consist of land clearing, establishment of water control and some peat excavation as required.

5.2 Task II - Biomass Resource Production

A few species of high productivity crops that can be grown on peatlands have been researched over the past three years. They are:

1) Cattail, reed, rush - State of Minnesota/University of Minnesota/DOE(SERI)
2) Willow and Alder - DOE(SERI)/University of Minnesota
3) Hybrid Aspen - U.S. Department of Agriculture

Several other promising special crop species have not yet been tested.

Preliminary data indicate that special energy crops can produce a renewable feedstock material with cost and conversion characteristics that may be better than the non-renewable peat on which they would be grown. However, little in the way of harvesting, processing and transportation tests have been conducted. From a long-term perspective, production of an economically competitive energy source on peatlands appears more desirable than peat mining.

The biomass energy option should be evaluated before allowing a peat mining technology that could harm the soil's biomass production potential. Also, preliminary information suggests that some peat removal may be desirable to reduce costs and facilitate the establishment of stands of biomass plants. It is the purpose of this task to generate productivity data for selected biomass species.

Task management will be the responsibility of the Bio-Energy Coordinating Office (BECO) at the University of Minnesota. The Energy Division will coordinate activities between this project and the DNR and IRRRB projects.

5.3 Task III - Biomass and Biomass/Peat Conversion

Peat gasification tests have been conducted at the Institute of Gas Technology (IGT) under DOE sponsorship. Preliminary energy crop conversion tests using digestive processes also have been conducted. Results of this work may be incorporated into a program making use of the IRRRB gasifier at Zim. Peat and biomass gathered during previous work, from this and the other peat projects, will be used as a feedstock for this test. Experimental work in this area would be carried out under the direction of the IRRRB, the U of M, the Energy Division, and/or consultants as needed. Such a program would be funded as a part of the DNR and IRRRB peat development efforts.

Use of peat and biomass as a solid fuel seems to hold the best prospects

for the near future. The Interagency Peat Task Force is conducting a test program, in cooperation with the Virginia Public Utility, to determine the feasibility of peat as a supplement to coal in medium size boilers. It may be possible to expand the scope of this program to include biomass fuels.

Data collected as a result of proposed and existing investigations will be used to make an economic evaluation of each of the basic technologies. Evaluations will be based on current technology and will reflect present possibilities or areas for further work. This work would be done by the Energy Division.

5.4 Task IV - Environmental Effects Monitoring

Data on current environmental conditions in the peatlands have been gathered over the past several years by the Department of Natural Resources. No empirical data exists on the environmental effects of biomass production in the State. It will not be possible to conduct an extensive environmental monitoring program due to the shortage of funds. Coordination with the DNR and IRRRB may produce an acceptable monitoring arrangement such that as least a portion of the desired data may be obtained.

5.5 Task V - System Evaluation

At present, one peatland energy production system (large-scale, thermal-chemical peat gasification) has been analyzed under a DOE grant. There has been interest expressed in medium-scale direct burning of both wet and dry peat for electric production, smaller-scale direct combustion of peat and/or biomass and biological conversion or peat and/or biomass. However, funding has not been available to analyze these processes. These processes are to be evaluated as a part of the DNR and IRRRB work programs. The Energy Division will use data from these three projects to study the economics of various energy production systems. This information can be used to evaluate

development options.

5.6 Project Management

Overall project management will be the responsibility of the Energy Division. It will prepare a detailed work plan showing designated tasks. It will also exercise budget control over the University research projects. The Interagency Peat Task Force will monitor the project, and provide advice and assistance to the project manager.

The University of Minnesota's Bio-Energy Coordinating Office will manage the biomass production projects. It will coordinate other University departments in their work on chemical analysis, agricultural methods, plant propagation, and growth and productivity.

6.0 PROJECT TASK LIST AND RESPONSIBILITIES

Task I. Land Preparation (DNR/IRRRB)

To be conducted as required by the goals and objectives of the peat projects. The bioenergy project will make use of these efforts where possible.

Task II. Biomass Resource Production (U of MN)

Note: The final form of this task will be determined after reviewing proposals to be submitted to BECO. The procedure used will be as follows:

1) Issue solicitation for proposals.
2) Assemble panel for review and evaluation of proposals (members from U of M, EPD, DNR, etc.).
3) Determine allocation of funding amongst accepted proposals.

4) Define specific workplans, for each accepted proposal, for approval.

5) Initiate work.

The tasks outlined below are a preliminary workplan based on the two projects which are currently in progress and are expected to be funded by this project. The program will be altered accordingly depending on the results of the BECO solicitation.

A. Emergent Aquatic Biomass Research

1) Stand management research

a) Monitor field plots for density, yield, nutrient content, fertilizer application, timing and rates, planting methods and species.

b) Establish experiments to compare several other promising wetland species in addition to cattail.

c) Monitor potential pest and disease problems.

d) Continue laboratory studies on wetland plant physiology.

2) Assessment of peatland reclamation utilizing biomass

a) Evaluate growing conditions.

b) Evaluate productivity of wetland species on excavated peatlands.

3) Equipment assessment and development

a) Development of aboveground harvesting equipment.

b) Continued work on belowground harvesting equipment.

c) Development of equipment for seeding, transplanting, fertilizing and other production operations.

B. Woody Biomass Research

1) Two research sites

a) St. Louis county (Zim).

b) Anoka county.

2) Cultivar selection

a) Willow

b) Poplar

3) Data collection

a) Plant growth.

b) Pest and disease problems.

c) Climatic data.

d) Nitrogen study.

4) Research plot maintenance

a) Weed control.

b) Fertilization.

Task III. Biomass and Biomass Conversion (DNR/IRRRB)

To be conducted as a part of DNR and IRRRB work programs. Bioenergy project will use data as an input to the work being done in Task V.

Task IV. Environmental Effects Monitoring (DNR/IRRRB)

To be conducted as a part of DNR and IRRRB projects with assistance from the bioenergy project as needed.

Task V. System Evaluation (DEPD)

A. System Economic Analysis

1) Resource production and conversion system.

B. Conduct Land Availability Studies on Wetlands

C. Conduct Market Research for Marketing Bioenergy Crops.

7.0 PROPOSED BUDGET BY TASK

		Amount
Task I.	Land Preparation	$ 0
Task II.	Biomass Resource Production	238,000[1]
Task III.	Biomass and Biomass/Peat Conversion	0
Task IV.	Environmental Effects Monitoring	0
Task V.	System Evaluation	7,000
Task VI.	Project Management	55,000[2]
		$300,000

[1] Includes $228,000 grant to BECO. Final allocation of these funds will be determined by the process described under Task II in Section 6.0.

[2] Includes salary for DEPD staff person.

8.0 SUMMARY

Minnesota has about 5.2 million acres of peatland and 3.5 million acres of other wetlands which could have potential for development. Before the State can make policy decisions regarding this type of development it will need specific information regarding the various options which could be pursued. Therefore, the LCMR provided funds to the Energy Division to develop a project designed to conduct research into the bioenergy option. These efforts resulted in the Bioenergy Project and the Virginia Peat Test Burn Project.

The Bioenergy Research Project will develop data regarding the production and the economies of producing biomass on wetland soils (both peat and mineral). Such information is needed before work on the commercialization of the bioenergy option can proceed.

Past federally sponsored programs have concentrated on the development

of a gasification process with the assumption that feed materials would be available. State efforts on the other hand have considered a more comprehensive approach. Work is continuing, or has been completed, in the areas of resource production, environmental effects and conversion. However before substantial benefit can be derived from this type of development there is more work to be done.

The IPTF has developed a policy recommendation relating to the use of peatlands. This policy considers the protection of peatlands as well as permitting, leasing, environmental monitoring and reclamation. This type of policy will be needed to prevent haphazard development from taking place. Such development, if allowed, could irreparably damage the State resource.

The Bioenergy Research Project was developed as a cooperative effort by all members of the IPTF. A proposal was developed and then marketed to both the public and the Legislature. A media campaign was conducted throughout northern Minnesota to promote awareness of bioenergy.

The final project developed reflects the biomass production emphasis of the original proposal although at a reduced level of effort ($300,000 of the needed $1,760,000 was allocated to the project). In addition to the production studies, the Energy Division will be assessing the economics of bioenergy systems. Production studies will be conducted through the University of Minneosta. Discussions will be held with the DNR and the IRRRB to decide how the three products can work together and complement one another.

Results of this project will provide the State's decision makers with additional information on bioenergy production. This will help them to decide what place such systems should have in Minnesota and how they will impact on satisying State energy needs in the future.

III. The Virginia Peat Test Burn Project

VIRGINIA, MINNESOTA PEAT TEST BURN: INTERIM REPORT AND REVISED WORKPLAN

1.0 INTRODUCTION

This revised workplan outlines the requirements for completing a project designed to study the use of fuel peat in a boiler at the Virginia municipal utility. Work on this project began in the fall of 1982, however a breakdown in the supply of fuel peat led to the suspension of work. This revised plan acknowledges this problem and provides an outline for completion of the project. This plan also includes a brief reporting of the available test results and a reaffirmation of the need for such a project.

Minnesota has, within its borders, a vast underutilized peat resource. The state's 5.9 million acres of peatlands comprise the second largest concentration in the continental United States; only Alaska has a larger resource. Development of these lands has the potential to supplement Minnesota's energy requirements while offsetting imports of fuel, providing opportunities for employment and business, and contributing to the economic well being of the state as a whole.

Numerous options for development have been identified, one of which is energy production. This type of development has two principle requirements; 1) the technology must exist to produce the fuel, and 2) the market must exist to consume the fuel product. Given that the technology does exist today it is therefore necessary to determine if a market exists. The existence of the market will provide incentive for development. However, it is apparent that the interrelationship between producer and consumer require that both exist simultaneously. To resolve this apparent dilemma the Minnesota Interagency Peat Task Force has proposed a project which will help to identify the market for fuel peat.

1.1 Project Goals and Objectives

The goal of this project is to study in detail the use of fuel peat in a given utility boiler. Results of this study will be used to determine the potential of fuel peat as an alternative to the coal which is currently burned. The information obtained can also be used to make some generalizations regarding the profiles of other potential fuel peat consumers. This profile will consider the acceptability of peat in the market place according to its quality as a fuel, cost, etc. In addition it is felt that this project can serve as a model test specification for studying the use of other alternative boiler fuels.

The goal stated above will be met through completion of the following objectives. These include a determination of:

1) boiler capacity, using peat, relative to its capacity using the fuel for which it was designed;
2) boiler efficiency;
3) furnace emissions (gases and particulates); and
4) other operational characteristics relating to fuel and ash handling, fuel storage, etc.

Information produced as a result of this project will be of use to both the prospective fuel peat producer and consumer. The consumer will be primarily interested in the operational aspects of fuel peat usage. The producer should be interested in the strength and weaknesses of fuel peat relative to the other fuels available today.

1.2 Project History

The following is a chronological account of the peat burn project. The proposed schedule of events required for completing the project is contained in section 2.3. The major events which have occurred are as follows:

September 1981 - August 1982: The peat burn project was announced

by Kent Eklund, Commissioner of Energy, Planning and Development, on behalf of the Interagency Peat Task Force (IPTF), at the Minnesota Peatland Development conference in Grand Rapids, Minnesota. The Department of Energy, Planning and Development (DEPD) was subsequently designated as the lead agency. A detailed proposal was developed and funding was sought from a number of sources. Funding was obtained from the Governor's Council on Rural Development (GCRD, $55,000); Iron Range Resources and Rehabilitation Board (IRRRB, $25,000); Legislative Commission on Minnesota Resources (LCMR, $10,000); Minnesota Power Company ($5,000); and the Department of Energy, Planning and Development (DEPD, $10,000).

July 1982 - August 1982: Based on the requirements outlined in the proposal a Request for Proposals (RFP) was published. Responses to the RFP resulted in the selection of the project team identified in section 2.2. Attempts to secure the necessary supply of peat were hampered by persistent bad weather making it impossible to gather and move peat from the field to the processing plant.

October 1982: Testing began at the Virginia municipal power plant. Two baseline tests were conducted using eastern and western coal (the test boiler was designed for eastern coal). These tests established the baseline operating condition. Test number three made use of a mixture of 25% peat pellets and 75% western coal. This test indicated satisfactory performance using this fuel blend (see section 4.0 for details). Aspenal, Inc. (the firm selected to supply fuel peat) experienced a fire in the control room of

their processing plant. This mishap was expected to delay peat fuel production by about two weeks.

November 1982: Production of peat fuel at the Aspenal plant ceased. Inability to secure a satisfactory source of raw peat was cited as the reason. Available peat was too wet to be handled by the handling equipment at the plant. After some investigation Aspenal was unable to locate a satisfactory source of raw peat for processing. Aspenal informed DEPD that they would not be able to produce peat fuel during the remainder of 1982.

December 1982: In an effort to keep the project going DEPD became involved and attempted to secure a suitable supply of raw peat for Aspenal, after it appeared that Aspenal had exhausted all of their possibilities. Two sources of peat were identified; one was at the IRRRB's Wilderness Valley Farm, the other was on private land. Peat from the private land was not accessible due to wet soil conditions. The warm weather had prevented frost from penetrating the soil and thus it was not possible to move equipment onto the bog. The decision was made to get peat from the IRRRB farm. A contractor was hired to prepare peat for hauling. The contractor's machine rotated previously windrowed piles of peat (peat was frozen and in milled form). This effort was unsuccessful; the attempt was a calculated risk which had a good chance of success. The machine was unable to reduce the particle size sufficiently such that the material could be handled at the processing plant. This prospect was not forseeable since the normal operation of the machine produces a grinding action which should have produced finely ground peat. Following a period of cold weather, which allowed the

ground to freeze, Aspenal was instructed to hire a contractor to move peat from the private land. However, disputes, between Aspenal and the landowner, over work done previously rendered this an unworkable solution. DEPD was not able to resolve this dispute and instructed Aspenal to search for any other options regarding the removal of peat from the IRRRB farm. Aspenal located a contractor who felt he could move the peat when the ground froze. Serious business related problems at Aspenal caused them to suspend work before any peat could be moved. Failure to resolve these problems led to the suspension of work on the project.

December 1982 - present: Work on the project was suspended. It was planned that the project be resumed and completed in the late fall of 1983.

1.2.1 The Minnesota Interagency Peat Task Force

The Minnesota Interagency Peat Task Force, under the lead of the Department of Natural Resources, coordinates peat policy for the State of Minnesota. The task force includes representatives from many groups concerned with the use of peat: the Department of Energy, Planning and Development, the Pollution Control Agency, the Department of Agriculture, the Iron Range Resources and Rehabilitation Board, the University of Minnesota Department of Soil Science and Botany, the Minnesota Geologic Survey,and the Center for Urban and Rural Affairs.

The Energy Division of the Department of Energy, Planning and Development is the lead agency for the peat test burn project. Its Energy Development activity, which has managed the state's district heating, biomass, and other engineering projects, will manage the project. The Department of Natural Resources will advise on peat harvesting and preparation, and other task

force members will provide advice as needed. Consultants have been contracted for test management, emissions testing and laboratory analysis, as needed.

The task force is currently in transition to becoming a commissioner level body which will be capable of responding more readily to the needs of peat development in Minnesota.

2.0 REVISED PROJECT WORKPLAN

The objectives stated in section 1.1 will be achieved through a series of six boiler tests. Each test will use a different blend of peat and coal. Results of these tests will provide a set of performance curves showing the boiler performance throughout the transition from all coal to all peat fuel. Appendix A.4 contains a set of theoretical performance calculations.

Three of the six proposed tests have been completed. The results of the testing is contained in section 4.0. The methodology for completion of the final three tests will be the same as that used for the first three. The test procedures are described in the following sections.

2.1 Method of Approach

The approach to this project is intended to conform to accepted industry standards, thus allowing for maximum use of the data collected. The required work can be grouped into four major areas as follows:

1) Test preparation - Consists of preliminary equipment inspection, and repair where needed, such that a base line condition can be defined. As testing progresses the equipment (of most interest is the condition of the boiler) will be inspected and any changes noted. The other item in this task is fuel mixture preparation. Fuel mixtures will be prepared according to the schedule presented in Table 1.

2) Testing - Testing will be done in accordance with the American

Society of Mechanical Engineers heat loss method. The method requires the determination of a number of heat losses and credits (see heat balance of a steam generator, figure 1). These values will be determined from a number of measurements to be taken during the course of the testing. A number of other parameters, besides those required, will be measured to establish the behavior of the system. A total of six tests will be conducted, the first two will be control burns using eastern and then western coal. Each test will require two to three days (approximately 24 hours actual burning time). Following each test the boiler will be shut down, cleaned and inspected.

3) Laboratory work - The major laboratory work required will be for fuel and ash analyses. These tests are required for determining the boiler efficiency. In addition to these analyses it is desirable to test for:
   a) particle size distribution of the fuel
   b) friability of the fuel
   c) grindability of the fuel
   d) free swelling index of the fuel
   e) pH of the ash

   These additional tests will assist in assessing the handling characteristics and use of the fuel in other boiler types (particularly in pulverized coal fired units).

4) Data analysis - Data will be analyzed according to standard engineering practices. Analyses will address the technical as well as economic aspects of using peat for fuel.

2.2 Personnel Needs and Facilities

The personnel required for this project have been drawn from the following sources:

1) Minnesota Department of Energy, Planning and Development Energy Division (Overall Project Management)
2) Virginia Public Utilities (Plant Operation Services)
3) Consultants as follows:
   a) FluiDyne Engineering Corporation (Test Management Consultant and Particulate Test and Stack Sampling Consultant)
   b) Interpoll Inc. (Laboratory Analyses Consultant)
   c) Lerch Bros. Inc. (Laboratory Analyses Consultant)
   d) Ekono (Program Review Consultant)

The consultant task of fuel peat preparation and delivery, which was included in the original proposal, has been dropped. This task has been changed from a consultant activity to a procurement function. The specificati contained in Appendix A.5 will be used to solicit bids from prospective suppliers. This change is possible because 1) the project now has a fuel peat specification, which was not available previously, and 2) there are an increased number of potential suppliers.

The testing will be conducted at the Virginia Public Utilities power plant in Virginia, Minnesota. Boiler number 5 will be used for testing. It is a 60,000 pound per hour steam boiler operating at 400 psig and 725^{o}F. The unit was manufactured at Edge Moor Iron Works and installed in 1949. Originally the fuel used was eastern coal which was fed with a Detroit Rotograte stoker. In recent years the boiler has been fired with western coal. There is overfire air provided as well as fly ash recirculation. The boiler has not been in regular service for several years due to emissions problems. A

sectional view of the boiler, figure 2, shows the major components of the unit. The relationship of this boiler to other plant components can be seen in figure 3.

2.3 Time Schedule

Figure 4 indicates the approximate time schedule to be followed for the completion of the project. Test burns are scheduled approximately one per week to allow for the possibility of unanticipated problems as the percentage of peat burned increases. To avoid the fuel peat supply problem, which halted the testing last fall, the peat will be stockpiled prior to the start of testing. In this way the testing schedule will not be dependent on the peat production schedule as it was last year.

The precise date for restarting the actual testing will be worked out during July and August with the various contractors involved. The startup date will in no case be later than November 1, 1983. This will allow completion of the project to occur no later than December and the subsequent publication of results by the end of January 1984. This late fall startup schedule is preferrable for the utility because the steam generated in boiler number 5 is not usable until turbine number 1 is placed in service during the late fall.

2.4 Budget

The budget for this project is contained in Table 2. The three columns of figures indicate the original budget allocations along with the expenditures to date and the remaining funds. Cost overruns, due to the severe problems caused by fuel peat delivery delays, have necessitated a request for additional funds. These funds have been requested by DEPD as a part of the department's operating budget for the next biennium.

3.0 ECONOMIC AND TECHNOLOGICAL CONSIDERATIONS

3.1 Economic Implications

This section discusses the economic benefits of processing northern Minnesota's peat resources. The value added in the production process, job creation, economic development and environmental benefits will be included in the discussion. Direct cost savings in energy production could be realized if peat is cheaper than coal. The purpose of this section is to discuss other economic benefits beyond the direct cost savings.

3.1.1 Value Added

This project will demonstrate the feasibility of burning Minnesota peat instead of coal imported from other states. If the project is successful, it will open the door to development of peat for energy production. If this development occurs, it will create a new industry with characteristics of the mining or agriculture industries.

At present, Minnesota's electricity and district heating are fueled primarily by coal. Western states such as Montana and North Dakota have enjoyed substantial economic benefits from coal and lignite production. One of those benefits has been the demand for labor in the mining sector. If peat is mined to replace coal, it will create jobs in Minnesota that would have gone to other states.

Peat development will also enhance the overall level of economic development in Minnesota. The value of the coal that would have been imported will be retained in the state instead. This will increase the vertical integration of the state economy. As a result, more wages, tax revenues and profits will remain in Minnesota. The benefits of this development will not be confined to northern Minnesota. Through the multiplier effect, the benefits will spread throughout the entire state.

If a dollar is spent on Minnesota goods instead of goods from another

state, that dollar is received as income by someone in Minnesota and is spent again on other goods. This process continues until the dollar is invested or spent on goods from another state. This multiplier effect spreads throughout Minnesota like ripples on a pond, increasing wages, economic output and tax revenues through the state.

The Department of Energy, Planning and Development has developed a quantitative measure of the multiplier effect. Every dollar spent on energy from an electric utility generates $1.61 of economic output within Minnesota. By contrast, a dollar spent on electricity from peat or biomass would generate between $1.00 and $3.00 of gross state output.

3.1.2 Environment

Peat generally contains much less sulfur than coal. This can lead to lower costs if less desulfurization equipment is required to burn peat. Less sulfur in the fuel can result in less sulfur in the atmosphere. Atmospheric sulfur can be captured by raindrops and fall to the earth as acid rain. As this rain runs into lakes, it increases their acidity, eventually killing fish, plant life and other wildlife in the lakes. A recent study by the U.S. Congress showed that 48% of northeast Minnesota's lakes are at risk of acidification. The effects of acidification on the tourist industry of northern Minnesota could be devastating. The use of peat instead of coal could reduce this risk substantially, in addition to reducing the cost of pollution control equipment.

Minnesota has 5.9 million acres of peat, 12% of which are in use for agriculture and other purposes. The remaining 5.2 million acres are available for development, except for perhaps 360,000 acres of state-administered land that could be set aside for wetlands preservation and protection.

One possible conflicting use is the extraction of sphagnum peat moss for horticultural use. Sphagnum peat comprises 2% of the total peat resource

in Minnesota. Thus, extraction for horticultural purposes of all sphagnum peat would still leave about 5 million acres of peat available for energy purposes.

Energy crops could be grown on peatlands, which might conflict with peat extraction. However, recent studies have shown that energy crop production could be enhanced by the removal of some peat. More research is in progress on energy crop production, but it does not now appear to be in conflict with peat extraction.

3.1.3 Concluding Remarks

The peat test burn at Virginia, Minnesota will demonstrate the feasibility of burning peat as fuel. If the test is successful, it could lead to the development of a peat mining industry in Minnesota. This industry could capture jobs, income and tax revenues that are presently benefiting other states. These economic benefits would concentrate in rural northern Minnesota, and would spill over to the rest of the state through the multiplier effect.

3.2 Technological Implications

The conversion of a boiler system from a given fuel to a new fuel is frequently not a simple matter. The situation can be particularly complicated if the new fuel is of substantially lower quality, as in the case of switching from gas to coal. However, a change from one solid fuel to another can, in some instances, be achieved with relatively few problems. One of the major purposes of the peat test burn project is to determine the problems associated with the change from western coal to peat and/or blends of peat and coal.

Major areas of concern in such fuel conversions can be grouped into three categories:

1) Fuel handling and storage problems,

2) Adaptability of the boiler system to the new fuel, and

3) Maintenance of adequate steaming capacity.

Each of these items requires careful consideration and must be studied in detail before any such fuel substitution can occur.

The fuel handling and storage system at a plant is designed for a particular fuel. Depending on location, capacity, etc. the system may be readily adaptable to a new fuel. An oversized system should present little difficulty in the handling of lower quality fuels. As systems increase in size the degree of flexibility decreases such that a large system for handling and stockpiling coal may not work for peat (consider that to store an equivalent amount of energy a stockpile of sod peat may be four times the size of a pile of western coal). Other handling considerations relate to the tendency of a fuel to dust, storability of fuel, etc.

Many boiler systems were designed to burn a specific fuel. Some systems are capable of burning one of several fuels. Single fuel systems will frequently require some modification to accomodate a new fuel. Due to the physical and chemical behavior of different fuels these changes may be needed at a variety of locations within the system. A few of these considerations are as follows:

1) Increased moisture content can lead to reductions in pulverizing capacity, increased volumes of flue gases, increased heat loss in the flue gas, etc. These can in turn require additions to pulverizing capacity, fan capacity and heat transfer surfaces.

2) Decreased density and heating values can lead to decreases in furnace heat release and fuel feeding problems. These

will lead to reductions in steaming capacity.

3) Slagging and fouling tendencies of ash vary and may cause additional maintenance problems on the fire side of tubes. A reduction in these tendencies can lead to increased scale build up on the water side of tubes. Some ash is less friable and hence difficult to remove from tubes. Problems in this area can require that tube spacings be increased, that water wall areas be increased and sootblowers be added. Slagging and fouling are complicated problems and need to be studied in detail prior to any fuel conversion.

There are numerous other areas for consideration; those presented here are some of the major ones relating to peat usage.

Derating of a boiler system is always a serious problem. This may present little difficulty in some plants but in others where capacity additions would be required it can be a major hindrance to conversion.

In conclusion, it is noted that there are many interacting variables which must be considered in order to bring about a successful fuel conversion. Failure to consider a particular variable can lead to a disastrous result.

4.0 INTERIM RESULTS

The following is a brief presentation of the results, to date, from the testing program. Three of the planned six burns have been completed. The first two burns were control tests using eastern and western coal. The third test used a blend of approximately 25% peat and 75% western coal.

Figure 5 indicates the efficiency and particulate emissions for each of the three tests. It is difficult to draw solid conclusions from this data at present, however a number of observations can be made. Boiler efficiencies for eastern, western and 25% peat/75% coal are about 75, 65

and 70% respectively. The lower graph suggests that the addition of peat will increase the efficiency whereas intuitively it should decrease. The placement and shape of the eastern and western coal curves seem appropriate for the particular boiler installation. In future tests it is expected that the peat blend curves will move progressively downward rather than upward as indicated here. Further observations and analysis will help to explain these curves. The upper graph is equally puzzling since the relatively light peat ash should be more difficult to collect and therefore should lead to increased particulate levels. It is apparent that some interaction between the two fuels has allowed this reduction. Here again it will require further analysis and observation to understand these curves.

Table 3 presents the as received fuel analyses for the various fuels used in the testing. Note the significant variation in moisture contents and heating values. The analyses for peat and western coal certainly do not support the analysis of the peat/coal blend. Again this presents an area for further investigation. The general trends of the eastern, western coal and peat analyses are as expected with the increase in volatile matter and decrease in heating values. The ash softening temperatures would indicate a slight potential fouling problem for the peat.

Data on several other parameters was gathered as well. This other data is not presented here however since a relative comparison is difficult with only one peat burn completed. These data indicate, as expected, a relatively lower grindability for peat and a poor particle size distribution for peat pellets alone. Blending peat pellets with coal however produces a satisfactory distribution. These data will be presented in some detail in the final report.

5.0 SUMMARY

This project has been developed around standard testing methods in order to make the results as useful and reliable as possible. The results allow the preparation of a series of performance curves indicating the relative behavior of fuel peat to coal. Curves for the first three tests have been presented. This information, along with that which will be obtained from the final three tests, can then be used in planning for the potential use of peat as a supplement to currently used coal supplies.

Besides the three major objectives; steaming capacity, efficiency and emissions; there are a number of things which have been observed. Among these are the handling behavior of peat and mixtures of peat and coal. Ash and ash handling characteristics have also been observed. Further work is needed before the significance of some of these results will be understood.

Completion of this project will help provide answers to some of the questions relating to fuel peat usage. It also helps to demonstrate the use of peat and allow the determination of the character of potential peat users.

TABLE 1: FUEL MIXTURES

Test	Peat:Coal	Tons of Peat	Tons of Coal	Tons of Fuel[1]
1	0:1	0	80	80
2	0:1	0	125	125
3	1:3	32.5	97.5	130
4	1:1	67.5	67.5	135
5	3:1	105	35	140
6	1:0	150	0	150
	TOTALS	355	325[2]	680[2]

[1]estimate of fuel required for 24 hour test

[2]does not include test 1 (test 1 = eastern coal)

totals do not include fuel contingencies

TABLE 2

DISTRIBUTION OF FUNDS FOR PEAT TEST BURN PROJECT

FUNDING RESOURCES:

Description	AID	Dollars
Rural Development Council	604066	$ 55,000
IRRRB	604033	25,000
Minnesota Power	604041	5,000
LCMR	603704	10,000
DEPD/Energy	603159	10,000
	Total	$105,000

FUNDING OUTLAYS:

Contracted Activities	AID	Budgeted Dollars	(As of 4/30/83) Liquidated	Remaining
FluiDyne (Test Management & Part. Sampling)	603159	$ 3,000	$ 3,000	$ 0
	604066	33,240	21,721	11,519
Aspenal[1] (Peat Supply)	604066	20,000	1,197.60	18,802.40
Interpoll (Lab Analyses)	604033	4,500	1,672	2,828
Lerch Brothers (Lab Analyses)	604041	4,100	392	3,708
Ekono (Program Review)	603704	2,000	0	2,000
Virginia Public Utility	603704	8,000	1,035.92	6,964.08
(Support Services)	603159	7,000	7,000	0
	Sub-Total	$ 81,840	$36,018.52	$45,821.48
FUEL PURCHASES:				
Eastern Coal	604033	$ 5,000	$ 3,059	$ 2,341
Western Coal	604033	14,600	5,476.15	9,123.85
	Sub-Total	$ 20,000	$ 8,535.15	$11,464.85
MISCELLANEOUS:				
Printing, Travel, Etc.	604066	$ 1,760	$ 933.15	$ 826.85
	604033	500	41.25	458.75
	604041	900	0	900
	Sub-Total	$ 3,160	$ 974.40	$ 2,185.60
	TOTAL	$105,000[2]	$45,528.07	$59,471.93

[1] This activity is being changed to a purchase since a fuel peat specification is now available.

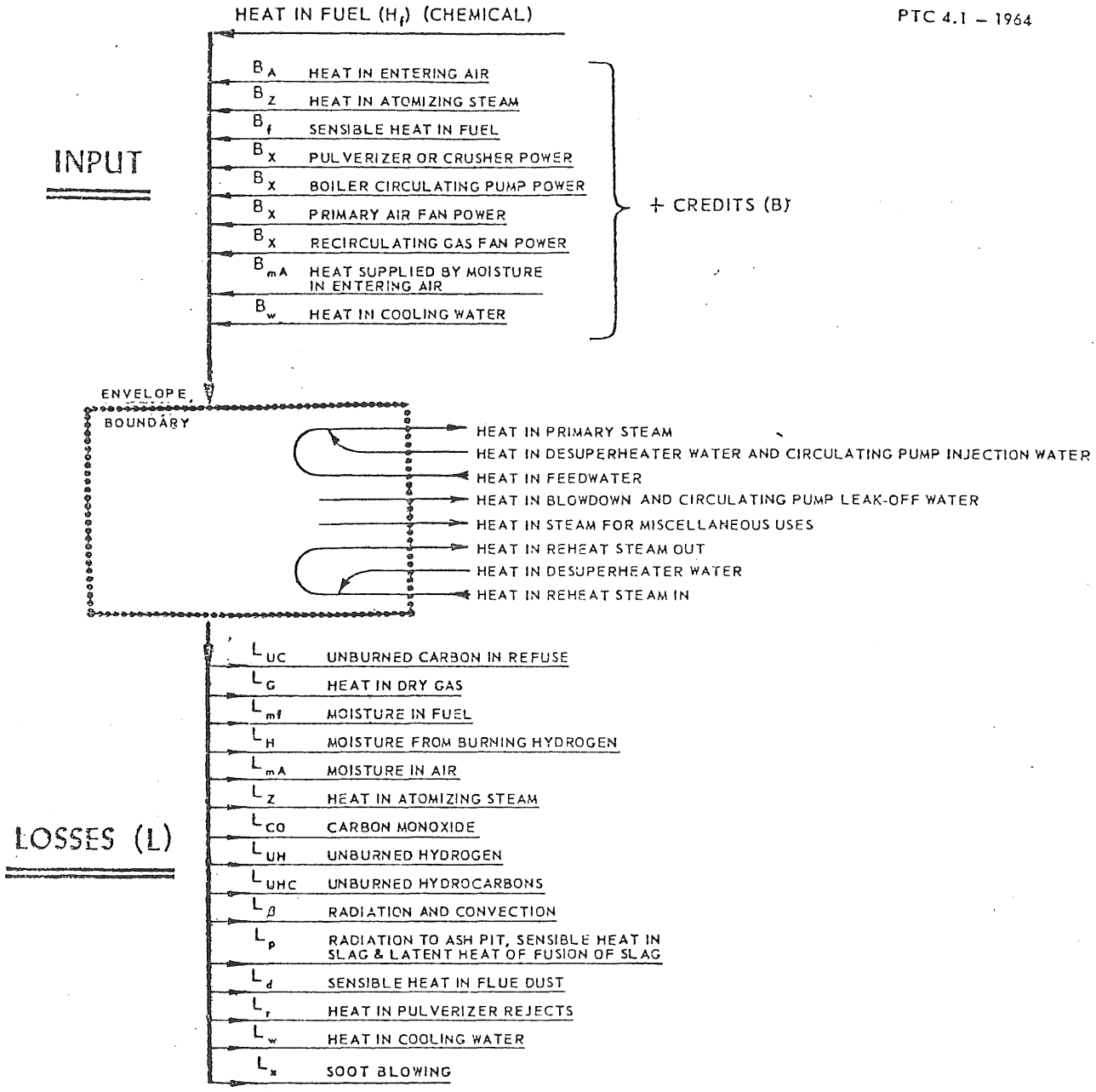
[2] DEPD has requested $10,000 as a part of the Department's 1984-85 budget request. These funds are needed to cover cost overruns due to delays in scheduled peat deliveries. These funds will be distributed as follows:

$ 8,000 Consultants
2,000 Travel, Printing, etc.
$10,000

TABLE 3

AS RECEIVED FUEL ANALYSES FOR THE
VIRGINIA PEAT TEST BURN PROJECT

	Eastern Coal	Western Coal	Peat Pellets	25% Peat/75% Western Coal
PROXIMATE ANALYSIS, WT%				
Moisture, Total	4.22	31.48	18.46	24.94
Volatile Matter	36.01	26.43	53.99	32.97
Ash	10.05	7.39	7.60	7.20
Carbon, Fixed (by difference)	49.72	34.70	19.95	34.89
Heating Value, Btu/lb	11,884	8,019	6,931	8,371
ULTIMATE ANALYSIS, WT%				
Hydrogen	4.65	3.17	4.38	3.63
Carbon	67.59	46.65	40.07	48.44
Nitrogen	1.15	.63	1.27	.80
Oxygen (by difference)	10.47	10.17	28.00	14.54
Sulfur	1.87	.51	.22	.45
Moisture, Total	4.22	31.48	18.46	24.94
Ash	10.05	7.39	7.60	7.20
Ash Softening Temperature (^{O}F)	2290	2405	2020	2200



$$\text{OUTPUT} = \text{INPUT} - \text{LOSSES}$$

$$\text{DEFINITION: EFFICIENCY (PERCENT)} = \eta_g\,(\%) = \frac{\text{OUTPUT}}{\text{INPUT}} \times 100 = \frac{\text{INPUT} - L}{H_f + B} \times 100$$

$$\text{HEAT BALANCE: } H_f + B = \text{OUTPUT} + L \quad \text{OR} \quad \eta_g\,(\%) = \left[1 - \frac{L}{H_f + B}\right] \times 100$$

Figure 1: HEAT BALANCE OF STEAM GENERATOR

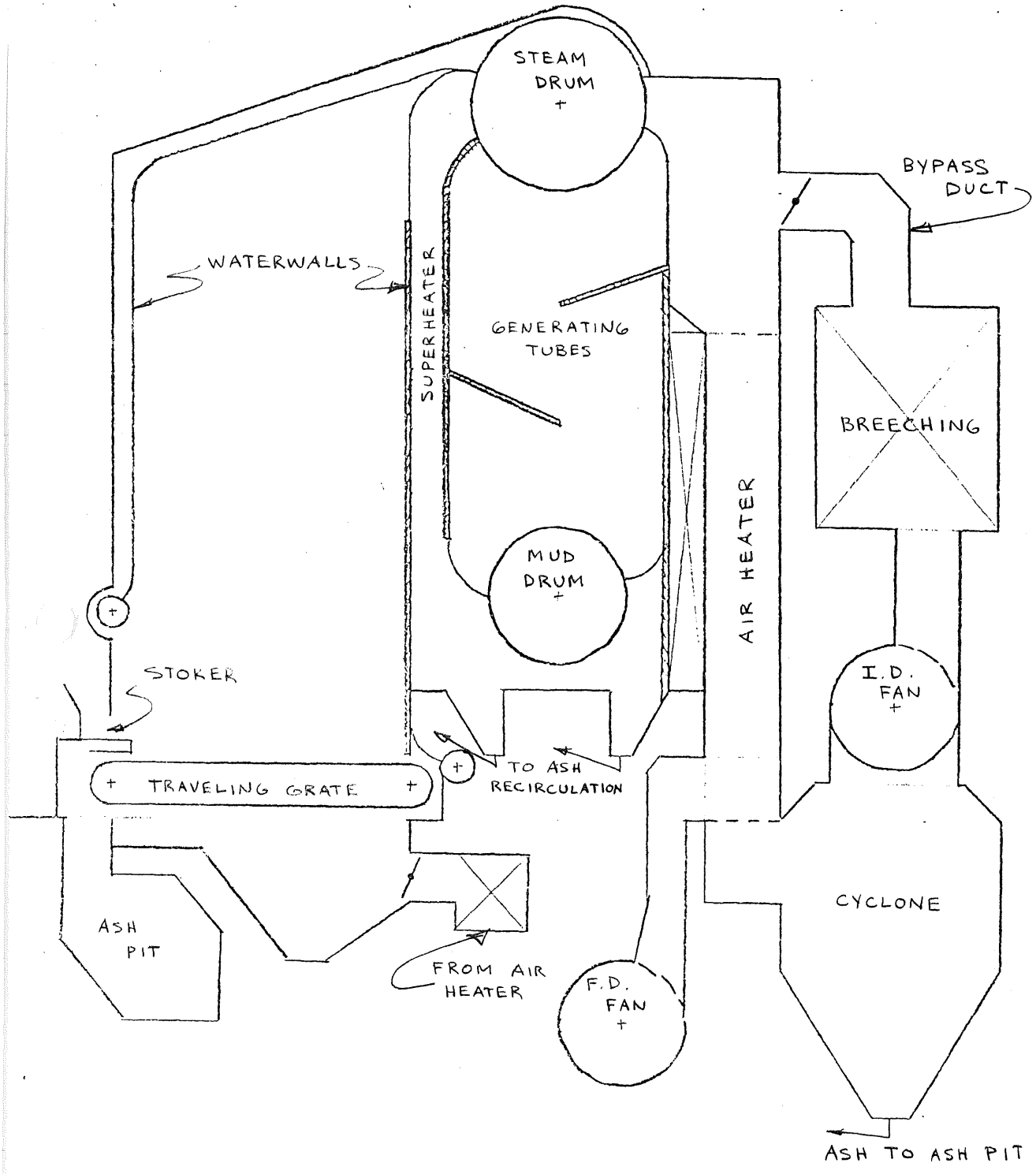


Fig. 2: General Layout of Test Boiler (V.P.U. Boiler #5)

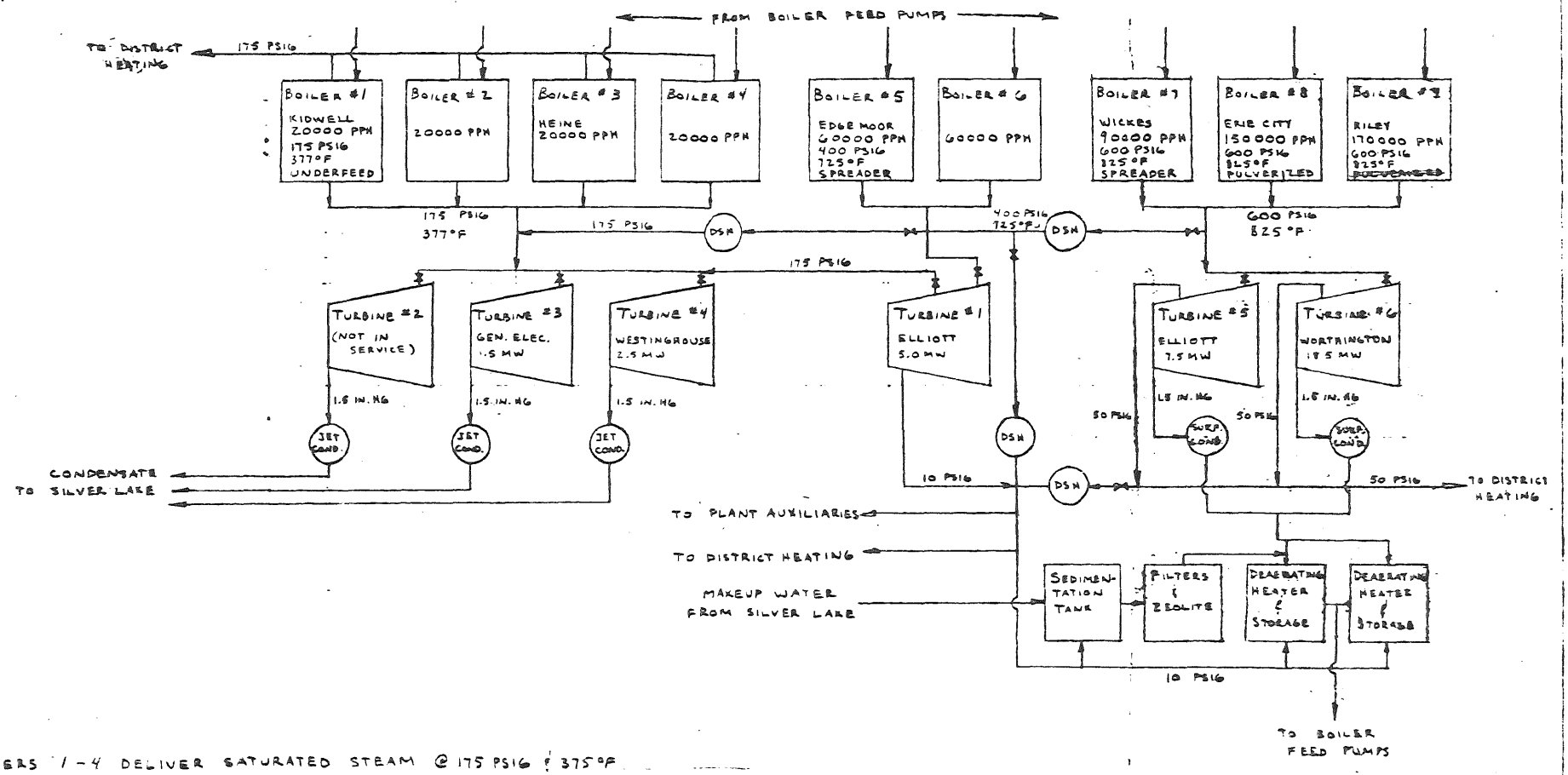


FIG. 3: PARTIAL FLOW DIAGRAM FOR VIRGINIA, MINN. POWER PLANT.

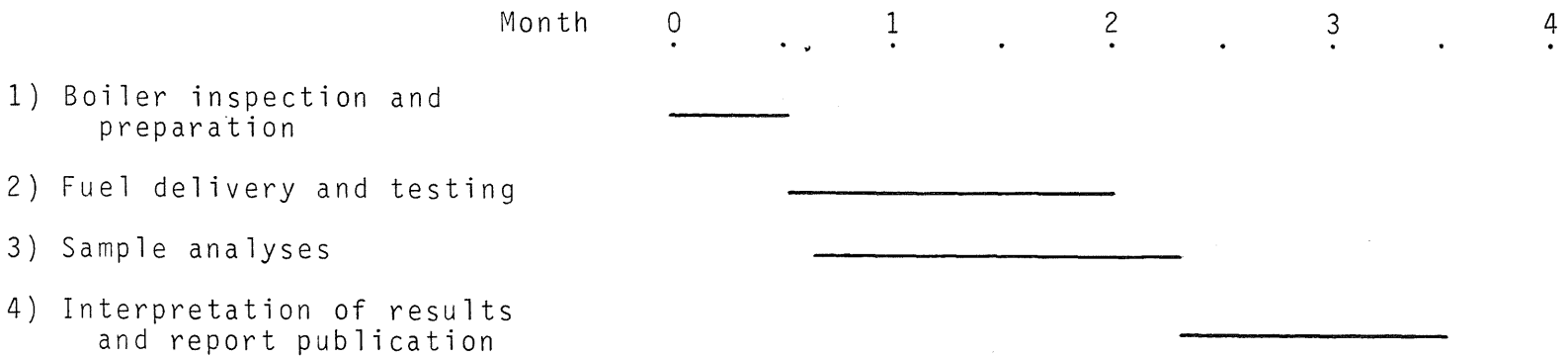
BOILERS 1-4 DELIVER SATURATED STEAM @ 175 PSIG & 375°F
" 5 & 6 " SUPERHEATED " @ 400 PSIG & 725°F
" 7-9 " " " @ 600 PSIG & 825°F

TURBINES 1 & 6 CARRY BASE LOAD (#1 IS OFF LINE DURING SUMMER)
" 2 IS OUT OF SERVICE
" 5 IS BACK UP FOR #6
" 3 & 4 PROVIDE EXTRA CAPACITY AS NEEDED
(GENERATORS 1, 5 & 6 OPERATE @ 13800 V)
(" 2, 3 & 4 " @ 2400 V)

PLANT AUXILIARIES USE 10 PSIG STEAM

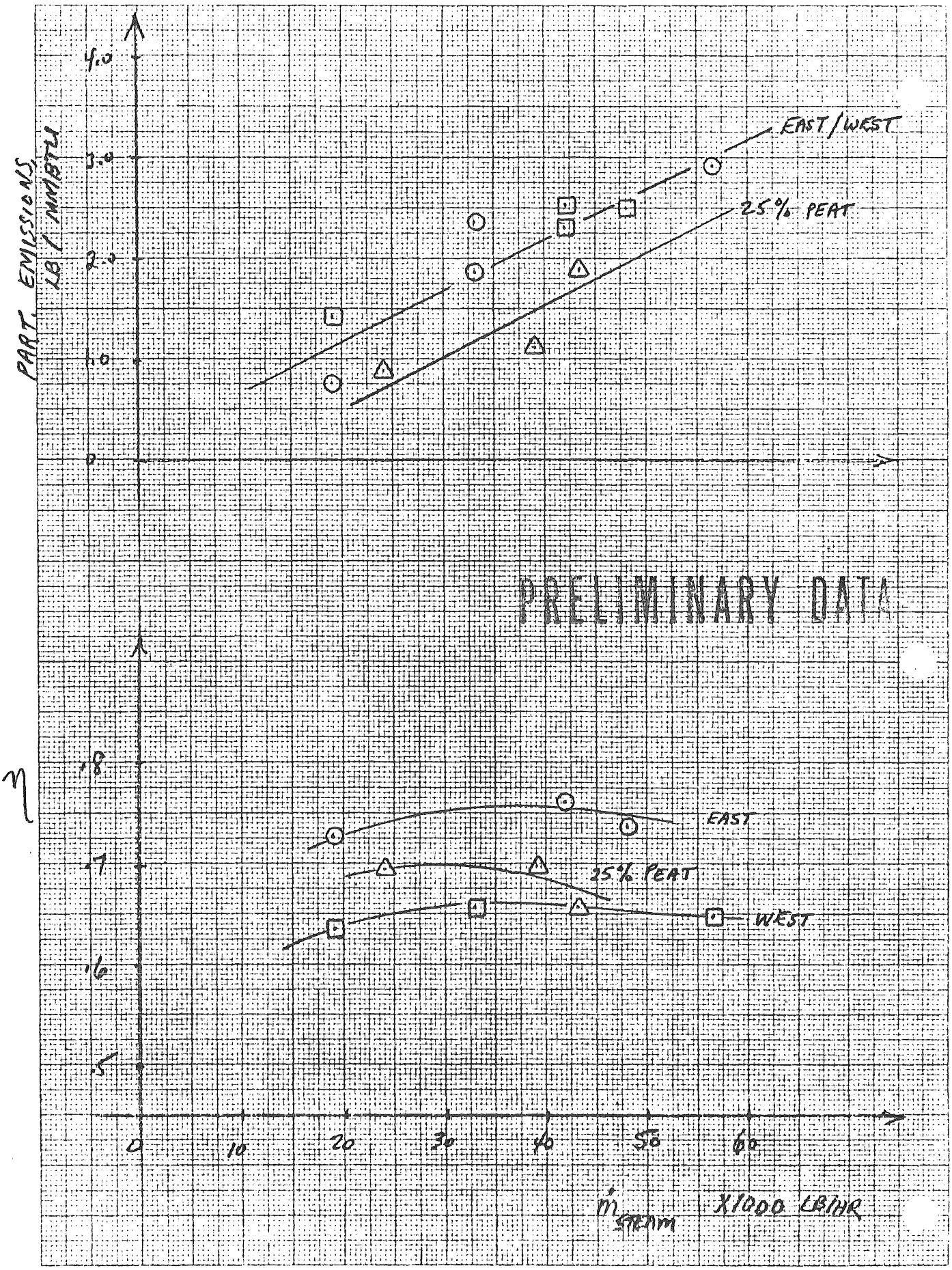
NOTES: 1) NOT ALL VALVES, PIPING, AUXILIARIES, ETC. ARE INCLUDED; DIAGRAM INDICATES MOST MAJOR COMPONENTS
2) DISTRICT HEATING USES 10, 50 & 75 PSIG STEAM
3) DSH INDICATES PRESSURE REDUCERS AND DESUPERHEATERS

FIGURE 4: TIME SCHEDULE



Note: Month 0 will be no later than October 15, 1983.
Fuel delivery and testing will begin no later than November 1, 1983, tests will occur at the rate of approximately one per week and will be concluded prior to December 23, 1983.

FIGURE 5:


PART. EMISSIONS, LB / MMBTU
4.0
3.0
2.0
1.0
0
EAST / WEST
25% PEAT
PRELIMINARY DATA
η
.8
.7
.6
.5
EAST
25% PEAT
WEST
0
10
20
30
40
50
60
ṁ STEAM X1000 LB/HR

APPENDIX A.1

STATE OF MINNESOTA

DEPARTMENT NATURAL RESOURCES

Office Memorandum

TO : Members of the Governor's Rural Development Council DATE: July 14, 1982

FROM : Dennis Asmussen, Chair
Interagency Peat Task Force PHONE: 296-4807

SUBJECT: The Larger Context for the Virginia, MN Peat Test Burn Proposal

The Virginia Peat test burn proposal is an issue with origins in research commissioned 5 years ago by the DNR Peat Program and is a project that has had wide discussion within the Governor's Interagency Peat Task Force, a group formed to provide a clearing-house function for all peat related issues and research proposals. The test burn project is an important effort for both concrete and symbolic reasons including: 1) the need to physically demonstrate the ability to burn peat in conventional boilers in Minnesota, 2) the importance of linking in one project harvesting, drying, densification, transportation and final combustion of peat, 3) the significance of peat to employment and industrial needs in a predominantly non-urban area, and 4) the symbolic importance of this first demonstration to a fledgling but potentially vital new industry. The larger context for this test is the over six years of work the DNR has invested in peat research. Also part of this context are the peat management policies the DNR and the Task Force developed to guide the management of Minnesota's Peatlands. These policies, now being implemented (see accompanying handout), were widely reviewed and discussed by the legislature and others during the 1981 Legislative Session. The policies are cautious about large-scale peat mining but supportive of small and moderate-scale enterprises along the lines developed by the Irish and Finns. The Virginia test burn is complimentary with this emphasis.

Development Opportunities (also see accompanying handout)

Minnesota's peat resources provide the opportunity to derive energy in several forms but the most important initial application is direct combustion as a substitute for coal. This is widely practiced in Ireland and Finland where significant percentages of electric generation and home heating depend on peat. Minnesota has a similar potential to satisfy a share of the state's energy requirements from peat or biomass, however, promotion and support is probably necessary to initiate movement toward this goal. In northern European countries the use of peat, especially in initial stages of development, enjoyed several forms of subsidy and incentive (low interest financing, grants, price restraints). In some form, and the Virginia Test Burn is an example, incentives must be provided in Minnesota too. In the future other forms of peat derived energy may be important. These include gas and liquid conversions that are discussed elsewhere.

Development Impacts

There can be both beneficial and negative impacts from peat mining and development. The latter, we are confident, can be mitigated or controlled for small and modest scale mining activities employing, for instance, water retention at drainage outlets and measures to control wind erosion of stockpiled peat. In addition, the DNR includes stringent reclamation requirements in all its peat mining leases.

The potential positive impacts of development have been lately much discussed: the stimulation of jobs and new industry in the depressed areas of northern Minnesota. There is a dramatic locational coincidence in northern Minnesota of peat and unemployment. Within fifty miles of the major Iron Range Communities, for example, there are several hundred thousand acres of peat with development potential. Job potential should not be overestimated, however. Peat mining employment will probably never replace the jobs lost in the declining iron mining industry. Instead, there is a potential 50 to 60 jobs created for every thousand acres of peat mined. This could total 5,000 to 6,000 jobs should we ever have 100,000 acres of peatland developed for mining and/or biomass production.

Cooperative Nature of Peat Planning Efforts

Neither the proposed Virginia Test Burn nor any other current peat or biomass endeavor is the sole province of one agency or group. What has distinguished peat development and management efforts, especially the past three years, is its intensely interactive and cooperative nature. In addition to the important roles of the two peat advisory groups (Peat Advisory Committee and the Interagency Peat Task Force) cooperation with local units of government has been a very important factor for the proposed test burn and other elements of peat planning. The Peat Program in the DNR in partnership with the Energy Division of DEPD has met on numerous occassions with local, county, and regional groups to discuss the opportunities for local peat development initiatives. Special emphasis has been given the identification of suitable peat resources in areas accessible to various northern Minnesota communities. Findings of this work have been widely shared (in Itasca, Koochiching, St. Louis, Aitkin, and Carlton counties and in various communities).

In summary, the Virginia Test Burn Proposal has significant statewide, regional, and local significance and its planning and implementation have been characterized by the intense cooperation of state, local and private concerns. If financial support permits the test to occur, we may expect several important benefits including, the promotion of a new industry with impacts on direct and indirect employment and, the beginnings of a trend to make Minnesota more energy independent. And this can occur in an area of the state with

high unemployment, rural character, and crying need for diversification and value-added enterprises. Parenthetically, support for the test burn proposal will not be at odds with or duplicate effects of the recently passed Iron Range emergency employment initiative. That legislation permits only 25% of total funds to be spent for long range development projects; the rest must be spent for immediate employment opportunities. The test burn proposal, in contrast, is part of a long-range plan to carefully develop peatland energy resources.

A.2.0 MINNESOTA'S PEAT/BIOMASS PROGRAM (July 1982)

A.2.1 Current Policies and Activities

A.2.1.1 Policies

The DNR has developed policies with respect to peatland resources based upon 5 years of field-based research and the review and comment of numerous agency staff, citizens groups, and legislative bodies. The Governor's (appointed) State Interagency Peat Task Force (led by DNR and including Agriculture, DEPD, SPA, PCA, LCMR, and others) has played a critical role in coordinating the development of these policies and continues to promote the rational management of the resource. Policies governing the leasing and management of the peatlands include the following points:

Peatlands should support a diversity of uses including energy, horticulture, agriculture, forestry, recreation and protection.

Development must be accompanied by proper environmental controls, among them, monitoring of air and water, mitigation of adverse impacts, and reclamation of mined areas.

For the present, and until technological progress and economic feasibility argue otherwise, lease tracts of a maximum of 3,000 acres will be offered in public sale. Lease area additions in subsequent years will be granted developers if need is demonstrated.

The Department is and has been encouraging concrete development proposals from the private sector; to date only one (Fleet Management) has surfaced. It is the Department's estimate that

economics, not state government policies, are the chief impediment to development

A.2.2 Current Management

The DNR and the Interagency Peat Task Force are proceeding on a number of fronts to promote reasonable peat/biomass development, a few of which will be mentioned here.

A.2.2.1 Mapping Resource Availability

The identification of peatland areas suitable for horticultural or energy mining (as well as other development types) is a principal management activity of the DNR Peat Program. Using information being gathered by the Peat Inventory Project we are identifying the depth, quality, extent, and location of Minnesota's significant deposits. To date, the important peat resource counties of St. Louis (the SW part), Koochiching, Aitkin, Beltrami (northern part) and Lake of the Woods have been surveyed and sampled. Reports describing peat characteristics in these counties are available for St. Louis and Koochiching, nearly available for Aitkin, with the balance of reports to be made available over the next 18 months.

The maps produced by the peat inventory project are excellent resource maps by themselves. However, we have added further to their utility by encoding their information in the LMIC computer files. This step permits the combination of peat resource information with the plethora of cultural and physical information existing in the LMIC files.

Computer maps can be produced through this means to show peat resource characteristics in combination with, for example, peatland ownership, accessibility, distance from cities, water proximity of peatlands, presence of forest cover types, and many other variables.

Recently, the program produced computer maps that identify peatlands satisfying three current state management needs, specifically:

- the need to protect some categories of peatland from development (examples - wildlife lands, forest resources, high amenity areas and areas of scientific interest)
- the need to identify areas of peatland available for immediate development
- the need to allocate the balance of the state's resource to a peatland reserve from which, should future requirements dictate acres could be withdrawn for a variety of uses.

The map following this narrative shows the peatlands in an eight-county region in northern Minnesota that appear to be suitable and available for immediate development. Of course, more detailed site analysis and inventory will be required to identify sites for concrete development proposals. Specifically, the map shows areas of peatland in the 8-county region that:

1. are at least 1000 acres of contiguous bog in size;
2. are no farther than 51 miles from one of the communities of International Falls, Grand Rapids, Duluth, Hibbing, Virginia, and Bemidji;
3. are within one mile of a road access point, but no part of the bog is farther than 6 miles from the road;
4. are not in recommended protected status (wildlife management areas, or unique areas);
5. are state-owned and, therefore, leaseable.

Peatlands with immediate development potential total nearly a million acres. However, due to technical difficulties in computer programming, we have not yet identified the depth factor for these peatlands (mining requires at least 5 feet). A guess would be that 20 to 30% of the total are peatlands greater than 5 feet in depth. Of course, the shallower acreages could have value for bioenergy crops, forestry or agriculture. In addition, there

are 123,000 acres of private peatland holdings and over 2.5 million acres of peatland reserve, which includes areas that are currently inaccessible, smaller than 1,000 acres, protected, or in protected ownership categories such as tribal lands, state and national parks, the BWCA and so on.

A.2.2.2 Virginia Test Burn

The Interagency Task Force on Peat is sponsoring the testing of peat in the boilers of the power plant in Virginia, Minnesota this summer. The test will establish the feasibility of burning densified peat as a substitute for coal. If successful, the City of Virginia has expressed interest in using peat if the costs are competitive with coal.

A.2.2.3 Current Leasing Activities

The DNR leased the peat in the West Central Lakes Bog in December 1981. In 1982 the Department plans to lease one or two additional deposits if demand warrants doing so. The Peat Program also has identified other horticultural bogs in four counties that appear to be suitable candidates for leasing and has had contact with the county boards of several of these counties to coordinate state and county leasing efforts.

A.2.3 The Prospects for Peat and Biomass Development

A.2.3.1 Companies and Concerns Expressing Interest in Peat/Biomass

The DNR and DEPD have been in contact with a number of parties interested in peat and/or biomass development. These include the American Peat Company of Hill City, Minnesota, Stott Briquett, Superior, Wisconsin (Bob Beaudin), Power-o-Peat (Gardner McKay in St. Louis County), Gene Harter of California (who owns 4,000 acres of peat near Zim), Control Data (interested in the future business a peat industry might represent) and one European producer (from Sweden). In addition numerous inquiries from consulting firms and interested companies from around the country signal that interest is high

in the potential of peat for energy production and in horticultural markets.

A.2.3.2 Potential Markets for Peat/Biomass

Peat can be converted into solid, liquid or gaseous fuels. The solid fuel market consists of existing large boilers and new boilers designed to burn peat.

The existing boiler will, in most cases, require a peat fuel which is quite dry and dense. A peat cube or briquette containing 10 to 20% moisture would probably be satisfactory. The fuel should cost about $30 to $35 per ton in order to directly compete with western coal. This price is lower than what can be reasonably expected from a new, relatively low volume industry. However, economic benefits gained from peat production may well justify a subsidy which could get the industry started.

New boilers would most likely be designed to burn milled peat. The use of peat in this form would reduce its cost. In the long run, conversion to milled peat could eliminate the need for purchase subsidies. A natural progression would be to start with densified peat in existing boilers, and over time convert to newer equipment as production economics dictate. In any case some form of help will be needed to get the new industry started. Liquid and gaseous fuel can be produced from peat through gasification and chemical synthesis. The first step in the process is gasification to produce a mixture of carbon monoxide and hydrogen. This mixture may then be reacted to produce methane (pipeline quality gas), methanol (a potential liquid fuel), or other chemicals. The cost of these fuels produced from peat could be competitive with deregulated natural gas, Alaskan, or newer more expensive petroleum. They will not compete at current prices, which are influenced by costs of older traditional energy supplies.

Potential markets are quite large. Pipeline quality gas could be injected into the existing distribution system to displace Canadian supplies.

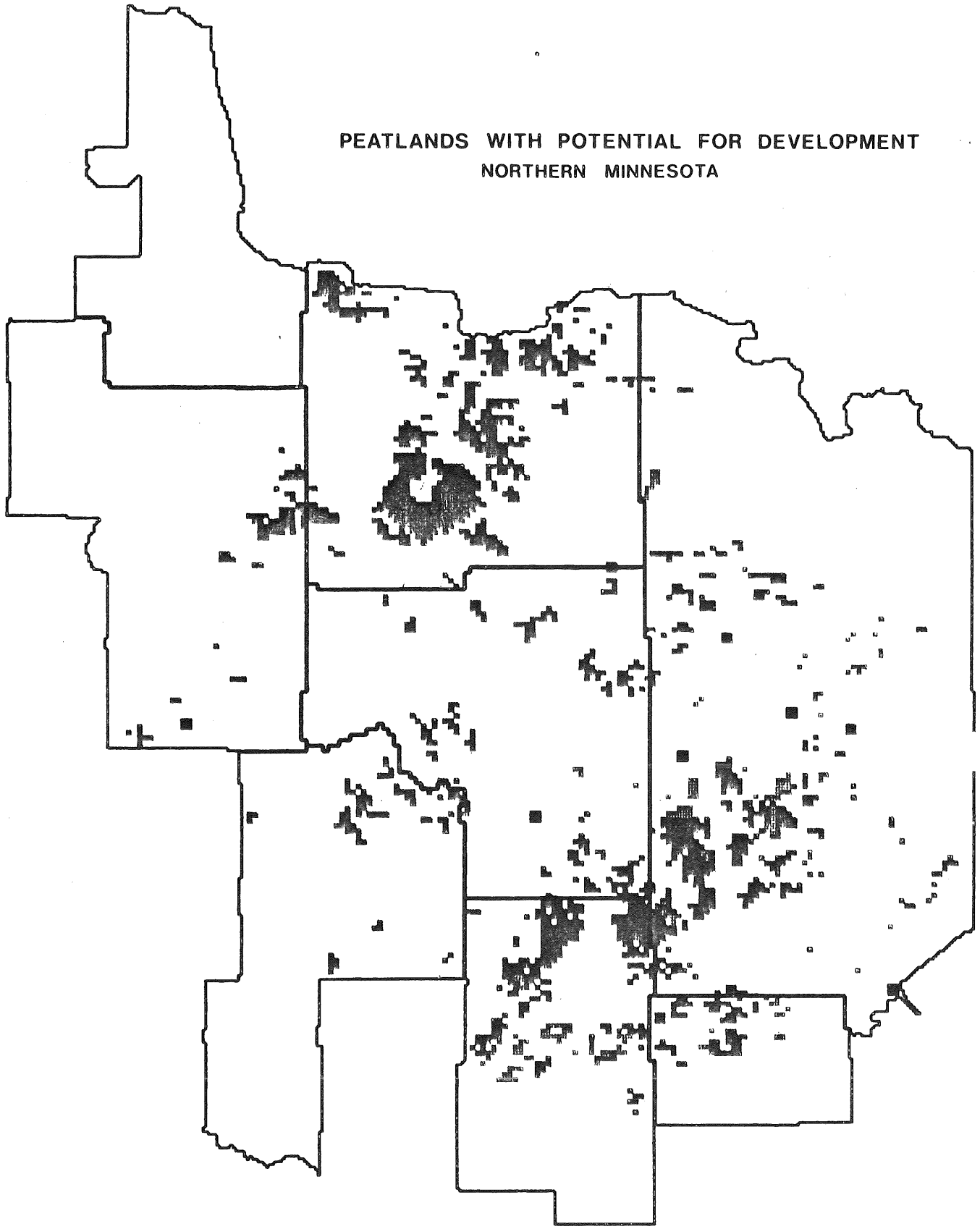
Methanol could be used by local refineries to improve the octane rating of unleaded gasoline.

Even a small substitution of locally produced fuel would create a large economic benefit in northern Minnesota. A 6 million gallon per year methanol plant could generate as many as 60 to 70 jobs and about $800,000 per year of income plus sales taxes. Ten plants of this size would constitute only 3 percent of Minnesota's gasoline demand. Peat, and in the longer run, biomass would provide a useable feed stock for these fuel production processes.

A.2.3.3 Long-term Research Needed

Looking beyond the immediate potential for mining peat for direct combustion we must plan for energy production from peatlands and other wetlands in the long run. Minnesota's best hope in this regard lies in renewable biomass crops -- willows, cattails, and other fast growing species that can thrive on marginal lands. The Interagency Task Force recently submitted a proposal to the LCMR to do hands-on-work in the field with growth and productivity of biomass crops and harvesting methods.

PEATLANDS WITH POTENTIAL FOR DEVELOPMENT
NORTHERN MINNESOTA



SYMBOL	COUNT	PERCENT	ACRES	LEGEND
■ 1	95	0.1	15200.0	CITIES: BEMIDJI, DULUTH, GRAND RAPIDS, HIBBING, INTERNATIONAL FALLS, VIRGINIA
■ 2	6334	6.8	1013440.0	STATE AVAILABLE
▦ 3	704	0.8	112640.0	PRIVATE
4	13445	14.5	2151200.0	OTHER PEATLANDS
5	72260	77.8	11561600.0	MINERAL OR WATER

APPENDIX A.3

The following discussion pertaining to the direct combustion of peat has been excerpted from the "Minnesota Peat Program Final Report".

DIRECT COMBUSTION

INTRODUCTION

Direct combustion of peat is a method of producing energy, which has been developed in Ireland, Finland, and the Soviet Union. Like coal and oil, peat is used as fuel to fire steam boilers. The steam turns turbines to generate electricity. The thermal efficiency of this process can be increased by also using the steam to heat water for district heating networks.

Peat used for direct combustion is usually mined by the milled-peat or sod-peat methods. Further processing of the peat depends on the type of boiler. Most boilers in Finland and Ireland use milled peat that has been dried with hot gas and pulverized. Sod peat and briquettes, which are milled peat that has been screened, dried, and pressed, are used in some boilers. Briquettes are also sold for use as a domestic fuel.

RESOURCE REQUIREMENTS AND AVAILABILITY

Peat-fired power plants in Europe are of various sizes: 20-MW, 30-MW, and 40-MW plants are common in Ireland; one of Finland's largest plants produces 60 MW of electricity and 117 MW for district heating; the Soviet Union has plants as large as 600 MW.

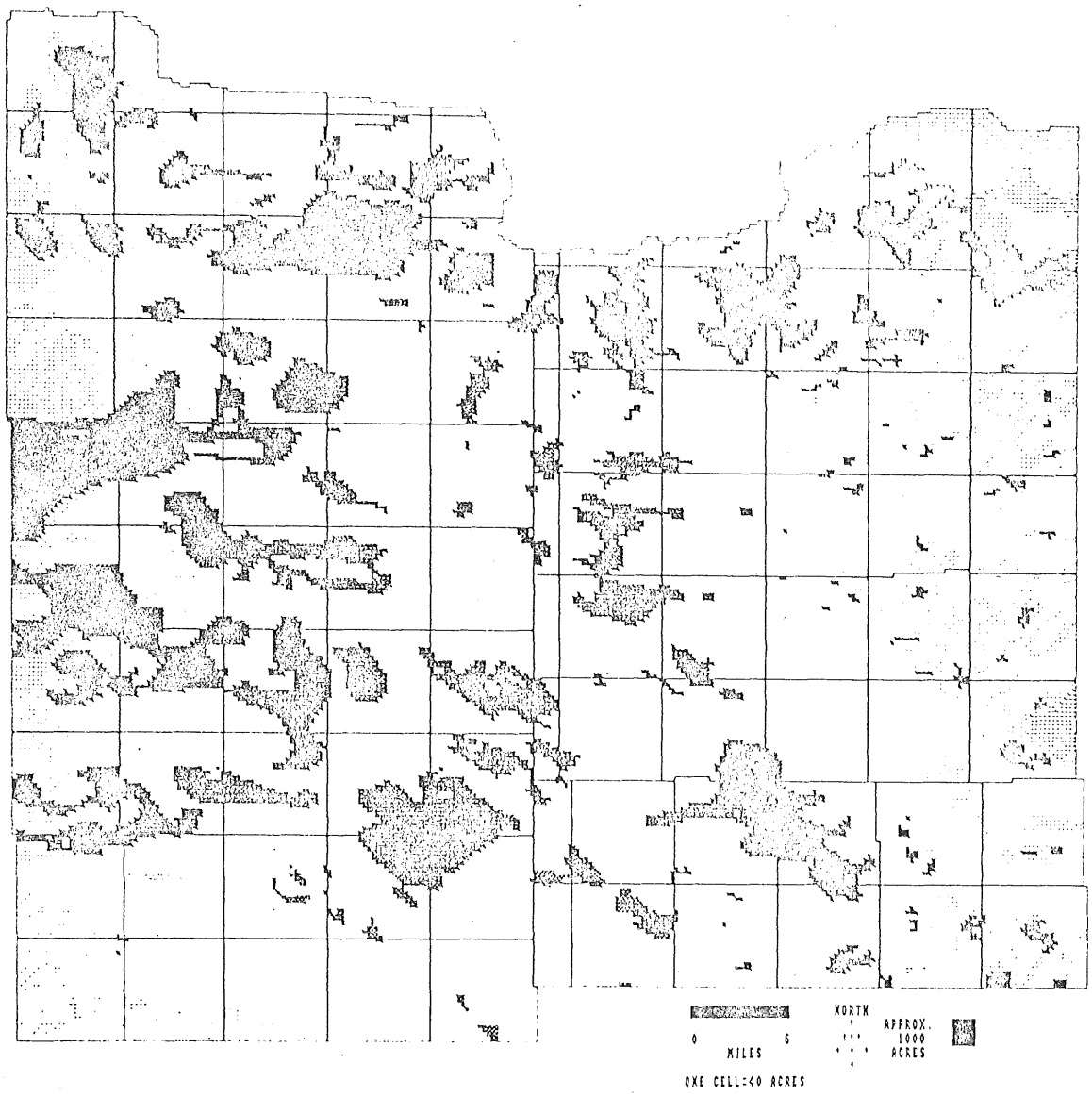
A 20-MW plant operating at 40% efficiency is estimated to consume 2,000 acres of peat 5 feet deep during a 20-year plant life. Given the same conditions, a 100-MW plant would require about 10,000 acres of peat.

Hemic and sapric peats are the peat types suitable for direct combustion. The greater the degree of decomposition, the greater the fuel value of the peat. However, the more decomposed sapric peats often contain large amounts of ash, which reduces the fuel value of the peat because it is not combustible. Thus, hemic peat generally has the highest fuel value. The U.S. Department of Energy (DOE) has set 25% ash content as the upper limit in their definition of fuel-grade peat.

DOE has set three other criteria for fuel-grade peat: (1) the peat must have a heating value of 8,000 Btu/lb (dry weight), (2) peat areas must have greater than 80 acres of peat/square mile, and (3) the peat must be more than 5 feet deep. Figures 9, 10, and 11 show the location of the peat resources, including fuel-grade peat, in the areas inventoried by the Minnesota Peat Inventory Project.

TECHNICAL FEASIBILITY

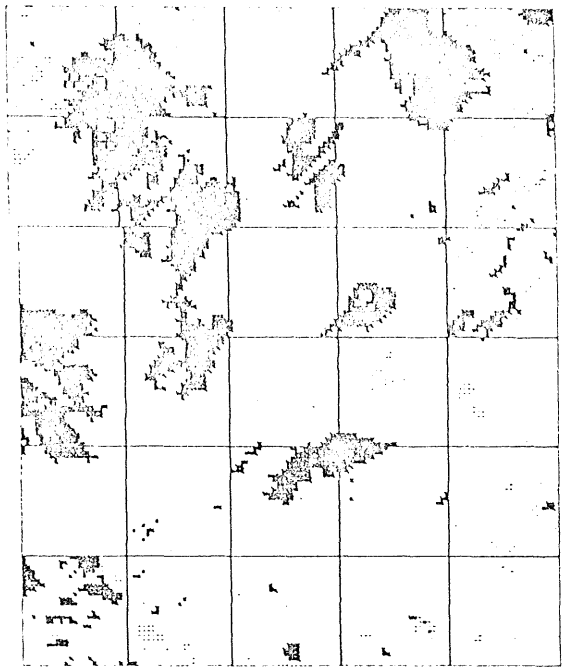
The technology of peat-fired power plants is well developed in Europe and the Soviet Union and is not



SYMBOL	PERCENT	AREA (ACRES)	DESCRIPTION
	19.5	399200	DEEP PEAT 150+ CM. (APPROX. 5+ FEET)
	36.6	748360	SHALLOW PEAT 0-150 CM. (APPROX. 0-5 FEET)
	42.8	876200	MINERAL SOIL
	1.1	22240	WATER

THIS STUDY IS BEING UNDERTAKEN BY THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES, DIVISION OF MINERALS, IN COOPERATION WITH THE MINNESOTA STATE PLANNING AGENCY, LAND MANAGEMENT INFORMATION CENTER.

Fig. 9. Peat Resources in Koochiching County



SYMBOL	PERCENT	AREA (ACRES)	DESCRIPTION
	16.1	109760	DEEP PEAT 150+ CM. (APPROX. 5+ FEET)
	23.8	162960	SHALLOW PEAT 0-150 CM. (APPROX. 0-5 FEET)
	59.2	404520	MINERAL SOIL
	0.9	6280	WATER

Fig. 10. Peat Resources in Southwest St. Louis County

significantly different from the technology of coal and oil-fired power plants. Ekono, Inc. investigated the feasibility for the Minnesota Peat Program of using peat in two existing power plants in Minnesota, in pelletizing kilns at the Eveleth Taconite Company, and in a new power plant that would be designed to use peat (Ekono, Inc. 1977).

Ekono, Inc. determined that the two power plants and the pelletizing kilns could be modified to burn peat. They also determined, however, that the advantages of using peat are most evident when a new plant can be designed and built specifically for using peat.

Peat mining technology for direct combustion is available if milled-peat or sod-peat methods are feasible. Wet mining methods, however, are still being developed. Furthermore, if a wet mining method is used, the peat must be dewatered, and these technologies are also still being researched.

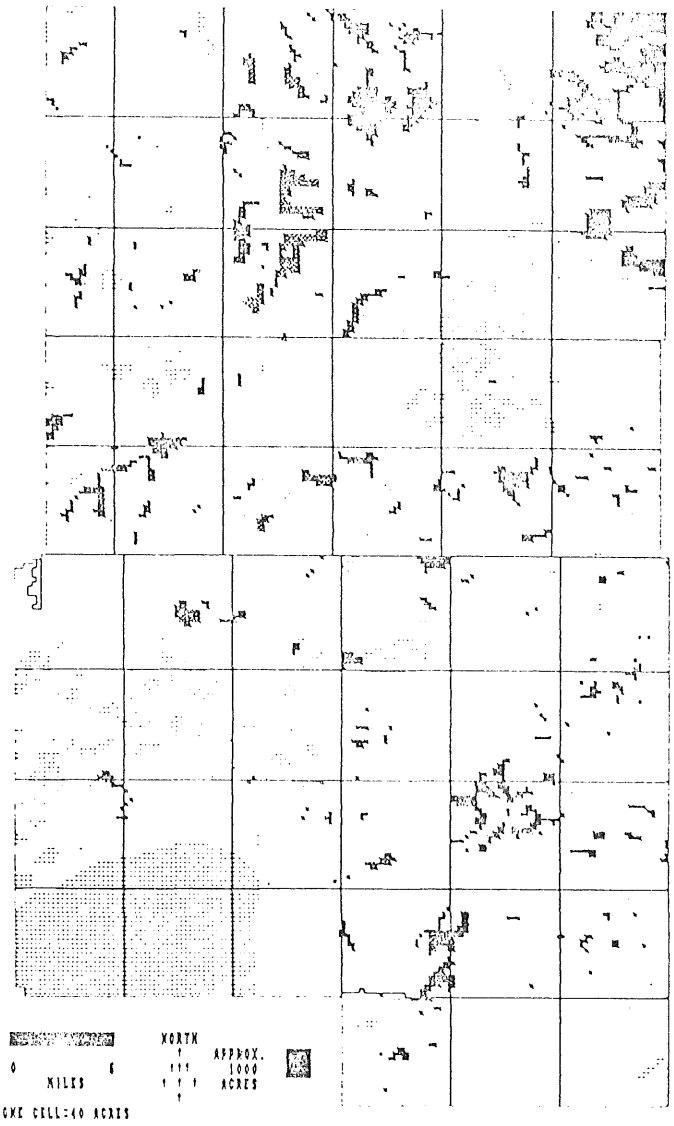
ONOMIC FEASIBILITY

A major barrier to using peat as a power-plant fuel in Minnesota is economic feasibility. Neither the modification of existing plants for peat nor the construction of new peat-fueled plants is likely to occur unless the cost of using peat is competitive with the cost of using other fuels.

Because peat has never been used as a fuel in the United States, it is difficult to determine its cost. The following factors will affect the cost:

- the cost of mining peat,
- the cost of transporting the peat to the plant, and
- the cost of reclamation and mitigation of environmental impacts.

While the cost of peat is probably the most important factor in determining the economic feasibility of using peat as a fuel, the cost of modification or construction of plants must also be figured in. For the four cases studied, peat would have to be $0.20 to $0.40 cheaper per million Btu than coal (Ekono, Inc. 1977).



SYMBOL	PERCENT	AREA (ACRES)	DESCRIPTION
	5.8	74600	DEEP PEAT 150+ CM (APPROX. 5+ FEET)
	27.0	345080	SHALLOW PEAT 0-150 CM. (APPROX. 0-5 FEET)
	59.3	757880	MINERAL SOIL
	7.9	100520	WATER

Fig. 11. Peat Resources in Aitkin County

APPENDIX A.4

Appendix: Theoretical Performance Calculations

Tables A1-A8 provide some estimates of boiler performance when different fuels are used (eastern coal for which the boiler was designed, western coal and peat). Representative analyses of the fuels (see Table A9) were selected and calculations based on the following assumptions:

1) combustion air @ 70°F, 45% relative humidity
2) flue gas temperature @ 300°F
3) steam @ 400 psig, 725°F (h_s = 1376 Btu/lb steam)
4) feedwater @ 240°F (h_w = 208 Btu/lb water)
5) unburned combustible @ 0.25 lb/100 lb fuel
6) maximum feed rate is limited to a volumetric flow of 240 ft^3/hr

Table A1 indicates efficiency estimates based on 300°F flue gas temperatures. If flue gas temperatures rose to 500°F the efficiencies would all drop about 5 percent (0.05).

The data in Table A2 can provide us with a comparison of fuel bed depths at equal boiler outputs. For example; a typical depth with eastern coal would be 2-4 inches, if sod peat at 20% moisture is used the depth would be 15-31 inches.

Table A3 contrasts the maximum steaming capacities with different fuels assuming that output is limited by the volumetric flow through the stoker. Note that densified peat at 20% moisture will provide only about 62% of the boilers rated output.

Table A4 shows a division of ash flows based on the ASME standard of 0.85 pounds of fly ash per 1000 pounds of flue gas.

Tables A5-A8 provide comparisons of some of the other important operating parameters. The cooler flame temperatures

in Table A5 could indicate a reduction in heat transfer in the boiler. Higher flue gas volumes indicated in Table A6 can cause problems in gas handling equipment and passages. Dewpoints and $C\emptyset_2$ differences may not be significantly different.

TABLE A1 THEORETICAL BOILER EFFICIENCY (decimal)

Fuel	% Moisture Content	@ 120% Theo. Air η	@ 120% Theo. Air f_e	@ 140% Theo. Air η	@ 140% Theo. Air f_e
Peat	20	0.808	0.934	0.800	0.933
	50	0.686	0.793	0.677	0.790
Western Coal	20	0.814	0.941	0.805	0.939
Eastern Coal	5	0.865	--	0.857	--

Note:

η = output/input

$f_e = \eta_x / \eta_e$

TABLE A2 THEORETICAL FUEL VOLUME (ft^3/100# steam)

Fuel	% Moisture Content	@ 120% Theo. Air $\dot{V}$	@ 120% Theo. Air f_e	@ 140% Theo. Air $\dot{V}$	@ 140% Theo. Air f_e
Sod Peat	20	1.62	7.71	1.64	7.81
	50	2.08	9.90	2.11	10.05
Densified Peat	20	0.65	3.10	0.65	3.10
	50	0.83	3.95	0.84	4.00
Western Coal	20	0.28	1.33	0.28	1.33
Eastern Coal	5	0.21	--	0.21	--

Note:

$\dot{V}$ = $ft.^3$ fuel/100# steam

$f_e = ft.^3{}_x/ft.^3{}_e$

fuel bulk densities calculated from:

density = dry density/(1-moisture content)
where the following dry bulk densities are used:
sod peat @ 10 pcf
densified peat @ 25 pcf
coal @ 50 pcf

TABLE A3 MAXIMUM THEORETICAL STEAMING CAPACITY (1000# steam/hr)

Fuel	% Moisture Content	@ 120% Theo. Air			@ 140% Theo. Air		
		$\dot{M}_s$	f_e	f_e'	$\dot{M}_s$	f_e	f_e'
Sod Peat	20	14.8	0.13	0.25	14.6	0.13	0.24
	50	11.5	0.10	0.19	11.4	0.10	0.19
Densified Peat	20	36.9	0.32	0.62	36.9	0.32	0.62
	50	28.9	0.25	0.48	28.6	0.25	0.48
Western Coal	20	85.7	0.75	1.43	85.7	0.75	1.43
Eastern Coal	5	114.3	--	1.91	114.3	--	1.91

Note:

$$f_e = lb_{s,x}/lb_{s,e}$$

$$f_e' = lb_{s,x}/60$$

Maximum steaming capacity is based on a maximum volumetric flow rate (for fuel) of 240 ft^3/hr (3 spreader stokers with a maximum capacity of 4000#/hr each; assuming a 50 pcf material density this yields 240 ft^3/hr for all 3 stokers together)

TABLE A4 THEORETICAL ASH FLOWS (#ash/100# steam; #ash/10^6 Btu)

Fuel	% Moisture Content	@ 120% Theo. Air $\dot{M}_{fl}$	$\dot{M}_b$	$\dot{M}_t$	f_e	f'_e	% 140% Theo. Air $\dot{M}_{fl}$	$\dot{M}_b$	$\dot{M}_t$	f_e	f'_e
#ash/100# steam											
Peat	20	0.12	1.32	1.44	1.38	1.42	0.14	1.32	1.46	1.39	1.42
	50	0.15	1.70	1.85	1.78	1.83	0.17	1.71	1.88	1.79	1.84
Western Coal	20	0.12	1.44	1.56	1.50	1.54	0.14	1.44	1.58	1.50	1.55
Eastern Coal	5	0.11	0.93	1.04	--	--	0.13	0.92	1.05	--	--
#ash/10^6 Btu											
Peat	20	1.03	11.30	12.33			1.20	11.30	12.50		
	50	1.28	14.55	15.83			1.46	14.64	16.10		
Western Coal	20	1.03	12.33	13.36			1.20	12.33	13.53		
Eastern Coal	5	0.94	7.96	8.90			1.11	7.88	8.99		

Notes:

fl = fly
b = bottom
t = total

$f_e = \dot{M}_{t,x}/\dot{M}_{t,e}$

$f'_e = \dot{M}_{b,x}/\dot{M}_{b,e}$

TABLE A5 ADIABATIC FLAME TEMPERATURES (^{o}F)

Fuel	% Moisture Content	@ 120% Theo. Air T_a	@ 120% Theo. Air Δ_e	@ 140% Theo. Air T_a	@ 140% Theo. Air Δ_e
Peat	20	3315	-246	2990	-185
	50	2747	-814	2513	-662
Western Coal	20	3308	-253	2972	-203
Eastern Coal	5	3561	-	3175	-

Note:

$$\Delta_e = T_{a,x} - T_{a,e}$$

TABLE A6 THEORETICAL FLUE GAS VOLUME (scf/1000 Btu & scf/100# fuel)

Fuel	% Moisture Content	@ 120% Theo. Air $\dot{V}$	@ 120% Theo. Air $\dot{V}'$	@ 140% Theo. Air $\dot{V}$	@ 140% Theo. Air $\dot{V}'$
Peat	20	13.4	9560	15.4	10969
	50	16.5	6762	18.7	7643
Western Coal	20	13.5	11128	15.6	12810
Eastern Coal	5	12.6	15735	14.6	18247

Note:

$\dot{V}$ = scf/1000 Btu

$\dot{V}'$ = scf/100# fuel

TABLE A7 THEORETICAL FLUE GAS DEW POINTS (^{o}F)

Fuel	% Moisture Content	T_{dp} @ 120 Theo. Air	T_{dp} @ 140 Theo. Air
Peat	20	126.2	121.6
	50	147.3	142.7
Western Coal	20	122.3	117.7
Eastern Coal	5	105.6	101.5

TABLE A8 THEORETICAL $C\emptyset_2$ (%)

Fuel	% Moisture Content	% $C\emptyset_2$ @ 120 Theo. Air	% $C\emptyset_2$ @ 140 Theo. Air
Peat	20	21.09	18.41
	50	19.51	17.19
Western Coal	20	20.37	17.72
Eastern Coal	5	20.72	17.94

TABLE A9 FUEL ANALYSES USED

	Peat	Eastern Coal	Western Coal
County	St. Louis	Allegheny	Carbon
State	Minnesota	Pennsylvania	Montana
C	53.0%	73.8%	59.8%
H_2	5.3	5.3	5.6
$Ø_2$	30.0	8.2	21.0
N_2	2.5	1.5	1.3
S	0.3	1.1	1.1
Ash	8.9	10.2	11.2
Gross Heating Value ($\frac{Btu}{lb}$ @ 0% MC)	9149	13217	10525

A.5 FUEL PEAT SPECIFICATION

The following specification will be used for the procurement of the fuel peat for this project. Given that different types of development are occurring; this specification has been written to include a slightly broader range of types of fuel peat. It is desired to encourage all fuel peat producers to study this specification and decide how their product relates to it. If a particular product does not precisely meet the specification the producer is encouraged to develop solid, rational arguments to support the use of his product. If accepted, the producers specification would replace the one cited here, for bidding purposes, and become the contract specification.

The following are the key dates which the peat supplier will need to be aware of:

August 31, 1983: Final testing schedule will be specified, test periods will be identified by the week in which they will occur.

September 30, 1983: Peat supplier will have the necessary fuel peat (minimum of 360 tons) stockpiled and ready to deliver.

November 1, 1983: Latest date by which testing will begin. Testing may begin as early as October 1, if possible. Fuel peat deliveries will occur during the period between this date and the end of testing (December 23, 1983 at the latest). Peat supplier will have to deliver the peat as it is requested since there are no facilities for stockpiling peat at the utility.

The following specification shall be adhered except in those instances where justifiable changes have been allowed following the negotiations referenced above.

Gross heating value $\geq$ 8400 Btu/lb @ 0% moisture content

Maximum moisture content $\leq$ 30% (wet basis[1])

Maximum ash content $\leq$ 10% (moisture free[2])

Minimum bulk density $\geq$ 15 lb/cu.ft. @ 0% moisture content[3]

Maximum particle size $\leq$ 2 inches[4]

Maximum percentage passing 0.25 inch screen $\leq$ 10%

Maximum sulfur content $\leq$ 1.0%

Notes:

[1] Wet basis moisture content is percentage of water (by weight) in the wet products calculation as:

$$\% \text{ MC} = \frac{\text{wet weight - dry weight}}{\text{wet weight}} \times 100$$

[2] Moisture free indicates the ash content in the dry product. This can be corrected as:

$$\% \text{ ash}_{MF} = \frac{\%\text{ash in wet product}}{1 - \frac{\%\text{moisture content}}{100}}$$

[3] Bulk density of the product can be corrected from any moisture content to 0% moisture content by:

$$\text{bulk density @ 0\% MC} = \text{bulk density @ given moisture content} \times \left(1 - \frac{\%\text{ moisture content}}{100}\right)$$

[4] Maximum particle size on any dimension should not exceed 2 inches