RL

64
P39
11446 #
#2
Keep

HW
MN DOC #

0111-76

A REPORT ON

ok

EUROPEAN PEAT TECHNOLOGY

MRI

A Report On

EUROPEAN PEAT TECHNOLOGY

For

PEAT PROGRAM-PHASE 1

For

UPPER GREAT LAKES REGIONAL COMMISSION

And

MINNESOTA DEPARTMENT OF NATURAL RESOURCES

Prepared By

Center For Peat Research

MIDWEST RESEARCH INSTITUTE

MRI

May 17, 1976

3100 38th Avenue South
Minneapolis, Minnesota 55406

PREFACE

Presented in this report is a summary of European peat technology based largely on firsthand knowledge gained during a visit to Europe in the fall of 1975 by a delegation from Minnesota consisting of the following people:

Representative Irvin Anderson, Majority Leader, Minnesota House of Representatives

Senator Norbert Arnold, Chairman, Finance Committee, Minnesota Senate

Senator Roger Moe, Chairman, Natural Resources and Agriculture Committee, Minnesota Senate

Representative Willard Munger, Chairman, Environment and Natural Resources Committee, Minnesota House of Representatives

Mr. Robert Herbst, Commissioner, Minnesota Department of Natural Resources

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

Professor Rouse Farnham, Professor of Soil Science, University of Minnesota

Mr. Roy Larson, Head, Center for Peat Research, Midwest Research Institute

The trip to Europe was carried out as part of Midwest Research Institute's program to study European peat technology and provide policy makers with information helpful in furthering the development of a Minnesota Peatland Policy. The program has been funded by the Upper Great Lakes Regional Commission and is being monitored by the Minnesota Department of Natural Resources.

The group attended the *Combustion of Peat* Symposium in Kuopio, Finland, and visited the following European facilities:

Finland:	*Technical Research Centre of Finland* (Helsinki) *Outokumpu Company Copper-Nickel Mining and Smelting Facilities* (Oravikoski and Harjavalta)
U.S.S.R.:	*Soviet Peat Institute* and *Thermal Station No. 15* (Leningrad)
Sweden:	*Swedish Peat Industry* (Sösdala and Hasselholm)
Germany:	*Brown Coal Industry* (Cologne)
Scotland:	*Westfield Development Centre* (Edinburgh) *Macaulay Institute for Soil Research* (Aberdeen)
Ireland:	*Irish Peat Industry* (Dublin and Midlands) *Lullymore Agricultural Research Institute* (Lullymore)

The program is being carried out by Midwest Research Institute's Center for Peat Research under the direct supervision of Roy Larson. Major participants in the research effort include Roscoe Colingsworth, Associate Ecologist; Edward Miller, Senior Resource Specialist; and Tom Stern, Assistant Analyst, with the collaboration of Professor R. S. Farnham of the University of Minnesota.

Center for Peat Research
MIDWEST RESEARCH INSTITUTE

Roy E Larson

Roy E. Larson, Head

Approved:

A E Vandegrift

A. E. Vandegrift, Director
North Star Division

ACKNOWLEDGMENTS

A considerable amount of planning and coordination was necessary to arrange for the tour, and indeed the trip would not have been as successful as it was without the generous assistance of several organizations and numerous individuals. Midwest Research Institute is pleased to acknowledge the assistance provided by the following people:

Professor Veikko Rauhala and *Mr. Erkki Ekman* of the Technical Research Centre of Finland who hosted the tour of their Research Centre and also coordinated our participation in the International Peat Society Symposium at Kuopio.

Mr. Esa Anttila of the Finnish Embassy in Washington and *Mr. Raunio* of the Outokumpu Company who helped plan the details of the visit to the Outokumpu copper-nickel facilities, and *Mr. Lars Wetzell*, Manager, Kotalahti Mine, and *Mr. Esko Nermes*, Plant Manager, Harjavalta, who hosted the visits.

Dr. Erkki Kivinen, President, and *Mr. A. Garkin*, Secretary General of the International Peat Society, who facilitated obtaining the visas and coordinating the visits to the Soviet Union.

Mr. Olle Uddgren, Head, Svensk Torvförädling, who guided our tour of the Swedish peat Industry facilities in Sösdala and Hasselholm, Sweden.

Mr. Manfred Hagelüken and *Mr. Dieter Veutgen* of the German Brown Coal Industry who arranged for the tour of their mining operation near Cologne.

Mr. C. Percival and *Dr. Brian H. Thompson* of the International Gas Consultancy Service of the British Gas Corporation who arranged for the tour of the Westfield Development Centre gasification plant in Scotland, and *Dr. Dennis Hebden*, Program Director, who hosted the visit.

Dr. R. A. Robertson of the Macaulay Institute for Soil Research, Scotland, who welcomed us to Scotland and arranged for the visit to his Institute in Aberdeen.

Mr. Lewis Rhatigan, Managing Director, *Mr. Jerry Healy*, and *Mr. Jim McNerney* of Bord na Mona of Ireland for their hospitality during the tour of the Irish Peat Industry, and *Mr. Andy Cole* who hosted our visit to the Lullymore Agricultural Research Institute.

Special recognition is due also to the trip participants, whose dedication and singleness of purpose made the trip a success. The participation of the Minnesota legislators--*Representative Irvin Anderson, Senator Norbert Arnold, Senator Roger Moe,* and *Representative Willard Munger*--added immeasurably to the recognition and attention shown to the Minnesota delegation. *Commissioner Robert Herbst, Dr. James Carter,* and *Professor Rouse Farnham* added the technical insight that was essential in interpreting the information provided by the European peat specialists. Much of the information presented in this report was extracted from trip reports prepared by members of the Minnesota delegation.

MRI moreover wishes to acknowledge the important contribution provided by *Mr. Mike Pintar* of the Minnesota Governor's Office and the Upper Great Lakes Regional Commission who arranged funding for the trip and assisted in planning the itinerary.

Finally, an especially warm thanks is extended to the many people of Finland, the U.S.S.R., Sweden, Germany, Scotland and Ireland whose generous hospitality we wish to repay someday. It is hoped that the information contained in this report will be useful to those who are interested in the development of Minnesota's peat resources.

CONTENTS

1. INTRODUCTION

BACKGROUND

It is estimated that peatlands cover roughly 400 million acres of the world's land surface, with approximately 80 percent of these peatlands lying within the borders of the Soviet Union, Finland, and Canada. The rest are more scattered, but current estimates place U.S. peatlands at approximately 19 million acres (exclusive of Alaska), of which 90 percent is located in the states of Minnesota, Wisconsin, Michigan, and Florida. It is estimated that Minnesota's peatlands total about 7.5 million acres, of which only 2.7 percent (roughly 200,000 acres) is presently being used, mostly for forage and vegetable crop production, and for producing relatively small quantities of horticultural peat.

Peat is the partially decomposed remains of plants. It varies in structure from the only slightly decomposed and fibrous moss peats to the black, sticky, highly decomposed peats usually found in the deepest strata of a bog. The most extensive peat deposits in the world occur where glaciation has produced topographic depressions and/or gently sloping lake plains, and where abundant and well-distributed rainfall, high humidity, and cool temperatures tend to retard the decomposition of plant material produced in water-rich areas.

Peat is a highly versatile resource. It can be combusted in process steam boilers, electrical generating plants, and in combined district heating/power operations. It can be milled and compressed into briquettes to be used as a domestic heating and cooking fuel, and it can be processed to produce activated carbon, peat coke, tars, phenolic by-products, and wax. It can be used, when properly treated, as a medium for absorbing oil spills and as a filtration material. Natural and reclaimed peat bogs can be drained, prepared, and used *in situ* for the production of vegetables, grasses, grass seed, and many varieties of trees. After harvesting and drying, peat can also be used as a potting soil and soil conditioner, and when fortified with fertilizer it can be spread on fields like manure. The list of actual and potential uses for peat is extensive, and research is continually lengthening it.

In addition to predicted energy shortages, which could be partially overcome by using peat as an energy supply, present and predicted world shortages of food, fertilizer, and fiber crops point to the enormous potential Minnesota's peatlands hold for these other uses as well. This potential should be carefully examined. It is equally important to study, and to weigh against the pressures of man's needs, the value many of these peatlands have as unique natural and scenic areas.

In response to the emerging interest in peat as an important natural resource in Minnesota and the other Upper Great Lakes States (Michigan and Wisconsin), the Upper Great Lakes Regional Commission awarded a grant to the Minnesota Department of Natural Resources (DNR) to initiate a peat research program. The DNR subsequently contracted with Midwest Research Institute (MRI) to carry out the study. The major objective of this continuing research program, which was initiated in June 1975, is to provide information pertaining to policies for regulating large-scale peat developments. The MRI study, which is being monitored by the DNR and a twenty-member Advisory Committee, is a preliminary attempt to examine the technology of peat development and assess the impact which that development might have on Minnesota's environment, economy, and "way-of-life."

As an important part of the study, a Technology Transfer Program was planned to study European peat harvesting and combustion technology. To accomplish this objective a technical study trip was arranged by Midwest Research Institute and Professor Rouse Farnham of the University of Minnesota to visit several European peat producing countries. It was intended that the information collected in the course of this trip be transmitted to interested parties in Minnesota and the other Upper Great Lakes States by means of a series of seminars, which have already taken place, and this trip report.

PURPOSE OF TRIP

The European peat industry has been in active operation for almost fifty years, and European peat technology therefore represents by far the most advanced state of the art. The technical study trip provided an opportunity for Minnesota legislators, state officials, and scientists to review the current status of peat technology in Europe with an eye to evaluating the implications that such technology might hold for peat development in Minnesota. The purpose of the technical study trip was fivefold:

1. Attend a symposium of Commission II of the International Peat Society at Kuopio, Finland, September 23-26, 1975, on *Combustion of Peat* and present two papers. Also, participate in a field trip to peat areas and power plants.

2. Obtain firsthand information from research scientists and technicians in Finland, the Soviet Union, Sweden and Ireland concerning technology of peat harvesting, handling, processing, transport, storage, and combustion.

3. Study land use, reclamation, and leasing procedures of peatlands now practiced in Ireland and Finland. In addition, study the land reclamation procedures associated with the brown coal (lignite) operations in the Cologne, Germany area, which can be directly related to peat operations.

4. Visit copper-nickel mining and smelting operations in Oravikoski and Harjavalta, Finland, and study their environmental effects.

5. Visit the coal gasification facility at Westfield Development Centre in Scotland.

ITINERARY

The trip started on Friday, September 19, leaving Minneapolis at about noon. The entire itinerary is shown below.

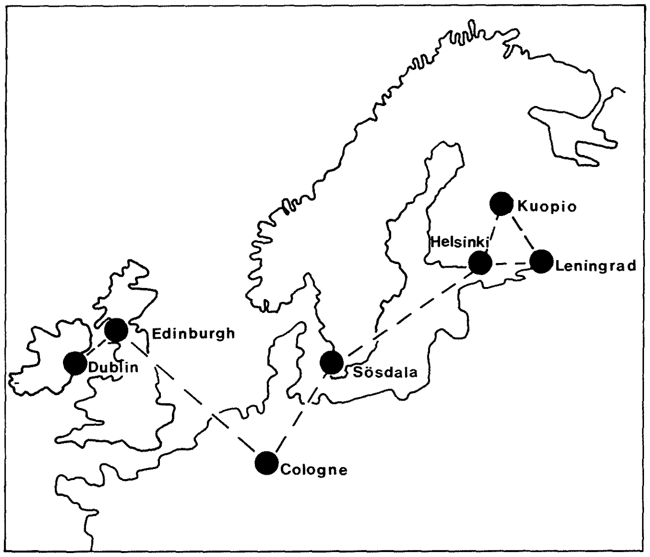


Figure 1.1
ROUTE OF TRIP

Friday, September 19	Depart Minneapolis for Helsinki
Saturday through Monday, September 20-22	Helsinki, Finland: Technical Research Centre of Finland
Tuesday through Friday, September 23-26	Kuopio, Finland: International Peat Society *Combustion of Peat* Symposium
Wednesday and Friday, September 24, 26	Oravikoski, Harjavalta, Finland: Outokumpu Company Copper-Nickel Operations
Saturday and Sunday September 27, 28	Leningrad, U.S.S.R.: Soviet Peat Institute and Leningrad Power Station No. 15
Monday, September 29	Hasselholm, Sösdala, Sweden: Svensk Torvförädling, Swedish Peat Industry
Tuesday, September 30	Cologne, Germany: Brown Coal Operations
Wednesday and Thursday October 1, 2	Edinburgh, Scotland: Westfield Development Centre Aberdeen, Scotland: Macaulay Institute for Soil Research
Friday through Sunday, October 3-5	Dublin, Midlands, Ireland: Bord na Mona, Irish Peat Industry Lullymore Agricultural Research Institute
Sunday, October 5	Depart Dublin for Minneapolis

OVERVIEW

On Monday, September 22, the Minnesota delegation visited the Technical Research Centre of Finland, located near Helsinki. The hosts for the visit were *Professor Veikko Rauhala,* Director, Fuel and Lubricant Research Laboratory, and *Mr. Erkki Ekman,* a senior staff member in the laboratory. The group was briefed on the research activities of the Laboratory, which are mainly in the areas of peat storage and combustion, the use of peat for oil-spill cleanup, and lubrication research.

Air transportation was provided later in the day to the *Combustion of Peat* Symposium at Kuopio, Finland. Kuopio is about 225 miles north-northeast of Helsinki. The symposium was organized by the International Peat Society (IPS) Commission II together with the Finnish National IPS Committee and the City Electricity Works in Kuopio, Finland. The Chairman of the Organizing Committee was *Mr. T. Illmonen,* and the Secretary *Mr. E. Ekman* of the Technical Research Centre. The symposium was held at this time because of the present critical international fuel situation. About 150 representatives of science and technology from Canada, England, Finland, the Federal Republic of Germany, Ireland, the Netherlands, Norway, Sweden, the U.S.A., and the U.S.S.R. attended the symposium.

During the symposium many useful contacts were made with peat researchers from the major peat-producing countries in the world, and final arrangements were made for the visits to the Soviet Union and Sweden.

The program of sessions was as follows:

1. Review of the present use of peat as fuel in different countries and estimates of the future competitive use of peat as an energy source

2. Quality standards for fuel peat, and the possibilities of using different peat qualities

3. Receiving, handling and storage of fuel peat at site

4. Combustion equipment and boilers

5. Control of combustion

6. Ash handling and emission

7. Safety arrangements and regulations

8. Peat burning power plants

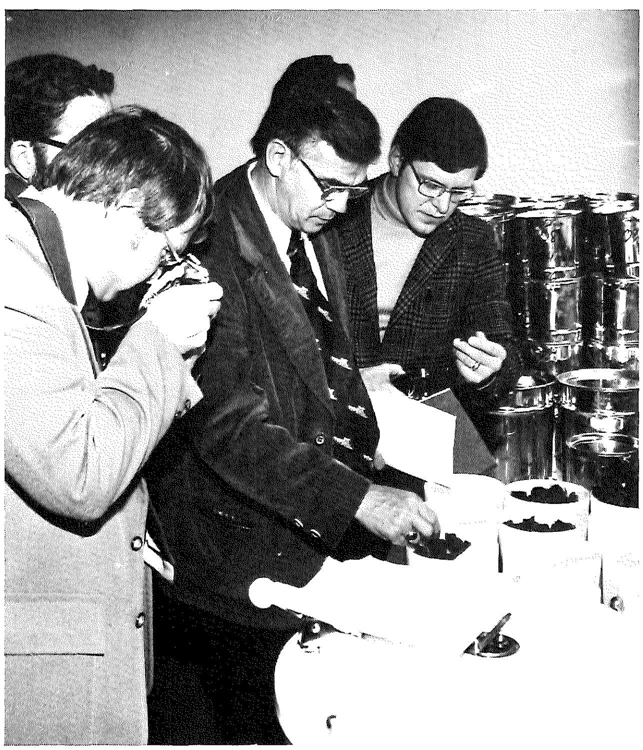


Figure 1.2
AT RESEARCH CENTRE

Figure 1.3
AT RESEARCH CENTRE

Figure 1.4
AT RESEARCH CENTRE

Professor E. Kivinen, President of the IPS, reviewed the history of IPS and of its present program. At the Opening Session of the symposium, *Mr. P. Rekola* addressed the participants on behalf of the Ministry of Trade and Industry of Finland, and *Mr. T. Heikkilä* greeted participants on behalf of the city of Kuopio. A review of the present fuel peat production in Finland was made by *Mr. K. Ranta,* Managing Director of the State Fuel Centre.

The papers presented by the Minnesota representatives were as follows:

1. *Minnesota's Peat as an Energy Source--Quality and Quantity,* by *Rouse Farnham, Roy Larson,* and *James Carter* (presented by Professor Farnham).

Figure 1.5
SITE OF SYMPOSIUM

2. *Potential and Economic Implications of a Large-Scale Peat Development in the Northern Lakes States--U.S.A.* by *Robert Herbst, Michael Pintar,* and *Peter Gove* (presented by Commissioner Herbst).

A tour of the Kuopio peat burning district heating plant was made on September 24. The sessions were followed by a two-day excursion on September 25 and 26. On the first day, the Rastunsuo fuel peat site of the State Fuel Centre at Rautalampi and the boiler plant of the G. A. Serlachius Company of Mäntä were visited and plans for a municipal district heating power plant in Tampere were presented. On the second day, the participants visited the peat-fired heating power plant of the Finnish Defence Forces in Niinisalo, and the W. Rosenlew factory in Pori, where the "Kemiklon" furnace was shown.

On Wednesday and Friday, several of the study group members travelled to the copper-nickel mining and smelting operations carried out by the Outokumpu Company in Oravikoski and Harjavalta, Finland. *Mr. Anttila* of the Finnish Embassy in Washington and *Mr. Raunio* of the Outopumpu Company main offices in Helsinki arranged for the visits. The group visited the Kotalahti Mine at Oravikoski, about 20 miles from Kuopio, on Wednesday. During the tour, *Mr. Lars Wetzell,* Manager, and *Messrs. Vaajoensuu* and *Niitti* briefed the group on the mining activities carried out at Kotalahti. On Friday, the copper nickel smelting activities at Harjavalta were visited. Harjavalta is about 125 miles northwest of Helsinki and the group left the excursion Thursday night at Tempere to travel to the facility. *Mr. Esko Nermes*, Plant Manager, described the various smelting operations performed at his plant.

Figure 1.6
AT SYMPOSIUM

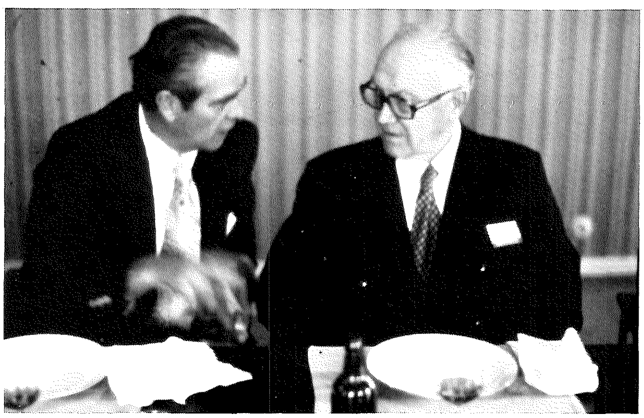


Figure 1.7
AT SYMPOSIUM

Finland is one of the few areas in the world where significant amounts of both nickel and copper are found. These operations are now of particular importance to Minnesota because they share common problems of land reclamation and environmental effects with peat operations. The details of this portion of the trip are presented in a separate report prepared by

Figure 1.8
ON TOUR

Commissioner Robert Herbst of the Minnesota Department of Natural Resources.*

The copper-nickel group joined the remainder of the Minnesota delegation at Helsinki on Friday and the group departed by air to Leningrad, U.S.S.R.

On Saturday, September 27, the group visited the Soviet Peat Institute in the morning and Thermal Station No. 15 in the afternoon, both of which facilities are in Leningrad. Recent Soviet peat research activities were described by *Dr. Victor I. Chistyakov*, Director, All-Union Scientific Research for Peat Industry, and three members of his staff: *Mr. Vladymyr S. Kortchunov*, *Mr. Anatoly I. Doubrovsky*, and *Ms. Irina P. Roullae*. The peat-fired power plant functions were discussed with *Mr. Boris I. Rylov*, Chief Assistant, Leningrad Electricity Board; *Mr. Aleksandr P. Goustchik*, Manager, and *Mr. Youry V. Gryzlov*, both of the Thermal Station.

The Minnesota delegation toured the peat harvesting and production facilities of Svensk Torvförädling (Swedish Peat Industry) in Hasselholm and Sösdala on Monday, September 29. *Mr. Olle Uddgren*, who is in charge of these operations, hosted the group during this visit. All Swedish peat production is for horticultural uses.

*Robert L. Herbst, *Technical Visit to Ontokumpu Oy Copper-Nickel Mining and Smelting Facilities*, Minnesota Department of Natural Resources, October 17, 1975.

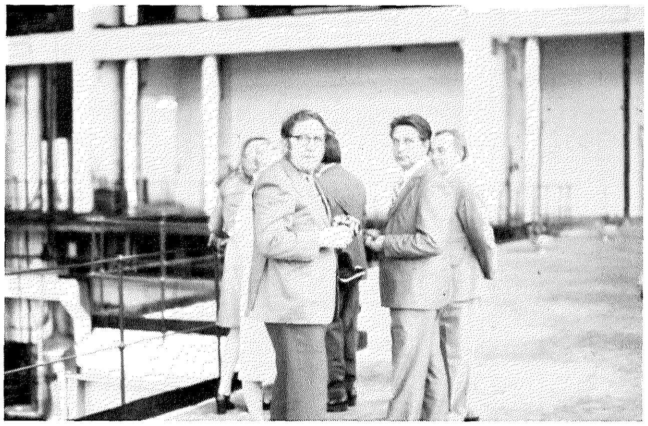


Figure 1.9
AT THERMAL STATION NO. 15

On Tuesday, September 30, the Minnesota delegation toured the German brown coal operations near Cologne. In addition to studying the land restoration methods and the planning and regulatory procedures employed in the peat areas of Finland and Ireland, much useful additional information was obtained by observing the efforts to ameliorate environmental impacts associated with large-

Figure 1.10
WITH GERMAN HOSTS

scale surface mining of brown coal (lignite) in West Germany. Many of the problems are common with peat harvesting operations and the German efforts in land reclamation are exemplary. The details of the visit to Germany were worked out with *Mr. Dieter Veutgen* and *Mr. Manfred Hagelüken* of Deutscher Braunkohlen-Industrie (German Brown Coal Industry). *Mr. Veutgen* and *Mr. Hagelüken* guided the group on the tour and a meeting was also held with *Dr. Roman Kurtz* and *Dr. Peter Kausch* of Rheinische Braunkohlenwerke Aktiengesellschaft (German Brown Coal Research Institute).

After leaving Germany on the evening of September 30, the group travelled to Scotland to visit the Westfield Development Centre north of Edinburgh. The British Gas Corporation has operated a Lurgi coal gasification plant there since the early 1960's. In light of Minnegasco's announced intention to build a peat gasification plant in northwestern Minnesota, a visit to Westfield was thought to be most appropriate. The visit to Westfield was arranged by *Mr. G. Percival* of the International Gas Consultancy Service of the British Gas Corporation, who is stationed in the United States, and *Dr. Brian H. Thompson* who is in the London office. The visit to the gas facility was hosted by *Dr. Dennis Hebden,* Program Director. Various members of his staff guided the tour, and several informative conversations were held with *Mr. Eddie Aitken.* While the tour group was visiting Westfield, Professor Farnham visited the Macaulay Institute for Soil Research at Aberdeen. *Dr. R. A. Robertson* briefed Professor Farnham on the current peat research activities of his Institute. In addition, he provided several informative preprints and reports describing peat research in Scotland.

On Thursday afternoon, October 2, the group left for Dublin, Ireland, to visit peat operations on Friday and Saturday. Visits were made to Bord na Mona (Irish Peat Industry) and to the Midland peat harvesting areas. The visit was arranged by *Mr. Jim McNerny* and the group was hosted by *Mr. Lewis Rhatigan,* Managing Director of Bord na Mona. Various members of *Mr. Rhatigan's* staff, including *Mr. Jerry Healy,* joined the group on tour of the Midland peat operations. *Mr. Andy Cole,* Director of the Agricultural Research Institute at Lullymore, described the agricultural operations that are being carried out on reclaimed peatland areas.

The group departed Dublin for Minneapolis at 12:30 p.m. on Sunday, October 5.

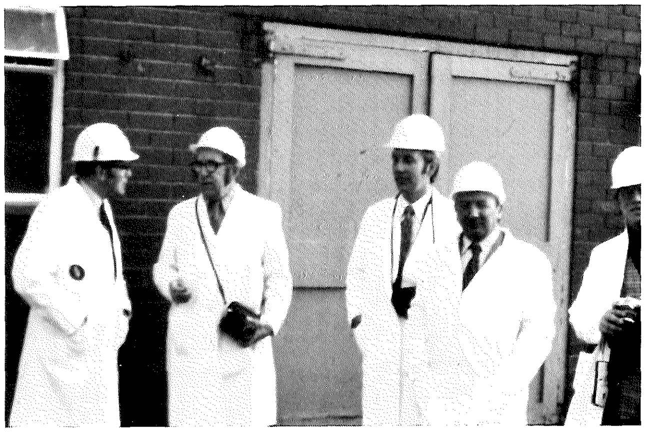
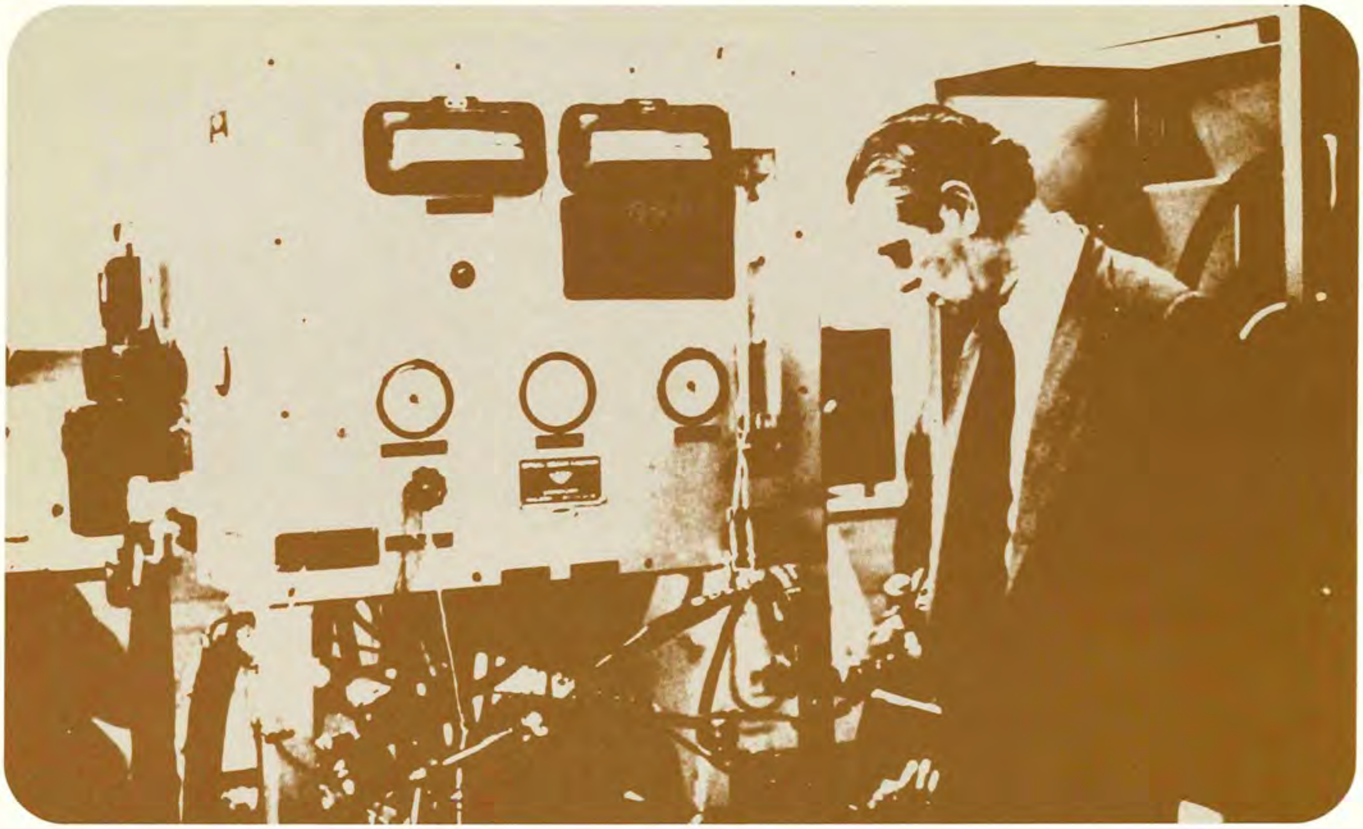


Figure 1.11
AT WESTFIELD PLANT

THE REPORT

A summary of the information and technical data obtained on the trip is presented in this report. Included is a discussion of peat research activities, peat harvesting techniques, energy and combustion technology, and land reclamation procedures in Finland, the Soviet Union, Ireland, and Scotland. Additional materials relating to German brown coal operations and the Outokumpu copper-nickel plants in Finland were also collected, including pamphlets, photographs, brochures, and miscellaneous notes. These data are available for study at the Minnesota Department of Natural Resources, the Minnesota Energy Agency, and the Center for Peat Research, Midwest Research Institute, in Minneapolis.



2. RESEARCH

ORGANIZATIONS

All of the peat-producing countries in Europe have active peat research efforts. Most of this research is carried out by research organizations having divisions specializing in peat studies. The research facilities visited by the study group included the following: Technical Research Centre of Finland (Finland), Soviet Peat Institute (U.S.S.R.), Macaulay Institute for Soil Research (Scotland), and Bord na Mona and Lullymore Agricultural Research Institute (Ireland). Organizations such as these have been largely responsible for the development of European peat technology.

FINLAND

The Technical Research Centre of Finland, which has research facilities in Helsinki, Tampere, and Oulu, was founded in 1941. It now employs about 1300 people and has an annual operating budget of 18 million dollars. The purpose of the Research Centre is to conduct testing of materials and devices, carry out technical and economic research, and promote the harmonious development of technology and society.

The Research Centre is organized into four major divisions, consisting of 32 laboratories, representing a broad range of technologies and including research related to the use of peat as an alternative energy source. This peat research is being conducted by personnel of the Fuel and Lubricant Research Laboratory in the Division of Materials and Processing Technology. The research activities of the Fuel and Lubricant Laboratory are concentrated in the following areas:

Peat Research

1. Peat Production and Processing
2. Influence of Production and Stockpiling on the Quality of Fuel Peat
3. Development of Quality Control and Sampling Methods for Peat

Oil Research

1. Fuel and Lubricant Quality
2. Spent Oil and Regenerating Processes
3. Oil Spills
4. Exhaust Gases

The Centre also has an active program to study peat coking processes. In cooperation with the German firm, Koppers Totzek, the Research Centre has built a peat-coke pilot plant in Helsinki which can produce 80 to 90 pounds of coke-peat per hour. The test results from this pilot plant have been used in the design of a large peat-coke factory now under construction. This plant will produce 30,000 tons of peat-coke per year and will consume 120 to 150 thousand tons of sod peat. The estimated cost

Figure 2.1
PEAT COKING PILOT PLANT

of constructing the plant was initially 5.8 million dollars, but inflation has escalated the price. The majority of the peat-coke produced in Finland is used in the metalurgical industry and is currently sold for about $145 to $160 per ton.

The Research Centre, moreover, has carried out research in the production of activated carbon from peat-coke by means of a fluidized bed technique using steam. Peat-coke produces a top quality activated carbon product with a high porosity (500,000 square feet of surface area per pound). The activated carbon, which represents only 1/8 the weight of the initial peat, is sold at $.30 to $1.30 per pound, the lower price being for activated carbon used in water purification.

Research has also been carried out on the effects of storage on peat quality, and on the self-heating problems associated with peat storage. Sod peat is normally stored in stacks 12 to 16 feet high and between 1/2 to 1 mile long, and during the storage period, which is usually one winter season, the internal temperature of the stacks is monitored to measure self-heating. This self-heating, which is due primarily to bacterial activity, can lead to spontaneous combustion since during storage the water content of the inner portions of the peat piles drop to about 30 percent. Although self-heating can cause a loss of 5 to 6 percent of the energy content of the peat, some studies have shown that self-heating actually produces a higher quality fuel by increasing its heating value and improving its physical properties.

Two research efforts of note carried out by the Research Centre include studies of peat for use in wastewater treatment and for use as a fuel in district heating/power plants.

Considerable effort at the Research Centre has been directed toward the purification of wastewater by using peat as an absorbing media. Studies at the Centre have shown that peat, if properly treated, can be used to absorb oil from wastewater if the oil content of the water is between 5 to 200 milligrams of oil per liter. The effective use of peat for treatment of wastewater requires that the water sorption efficiency of the peat be reduced to as small a value as possible. This reduction in the peat's sorption efficiency is achieved by means of drying and heat treatment. Peat rendered hydrophobic by heat treatment has completely displaced other sorbants used in combating oil pollution in Finland.

In a recent comparative study covering several commercial oil-sorbing agents--plastic, mineral wools, volcanic glass, and wood hydrolysis waste--the hydrophobic peat was proven fully competitive, and in certain respects it turned out to be superior.

Figure 2.2
WATER-OIL SAMPLES

The other major research effort at the Centre has been directed toward the use of indigenous fuels--wood and peat--for boiler operations. Much of the early fuel research in Finland concerned the use of wood chips in boiler operations using a grate-and-screw feeder combination. More recently the research effort has shifted toward the use of peat as a fuel. The Centre is now carrying out combustion studies using a boiler built for burning milled peat and combustion systems having horizontal cyclone units and horizontal melting-grate systems. Research is also being carried out on the influence of moisture content on the combustion process and on the heating value of the fuel.

SOVIET UNION

The Soviet Peat Research Institute (VNIITP) has four branches, located in Leningrad, Kalinin, Moscow, and Kirov. The Institute at Leningrad was established in 1922, and was located there because the city had long been an important technical center in the Soviet Union. The Institute is also located near several peat deposits, and in the early years the major research emphasis focused on the development of fuel peat. In the 1950's and 1960's, work was directed toward three major objectives:

1. Full mechanization of the fuel peat industry as well as mechanization of chemical by-products plants.
2. Development of new methods of producing and dewatering peat and of producing chemical by-products.
3. Modification and improvement of existing peat harvesting methods and equipment.

As a result of the Institute's activities, new and highly efficient techniques have been developed for harvesting and drying peat. Current research efforts at the Leningrad facility also cover a broad range of other areas, including the use of peat as a feedstock in producing chemicals such as furfural, fumic acids, phenols, and alcohol, as a soil conditioner and fortified organic fertilizer, and as a biological growth stimulant.

The Soviet Union has also carried on research pertaining to the gasification and wet carbonization of peat. The by-products of the gasification process are phenolic compounds, ammonia, and tars. The wet carbonization efforts are being carried out at a pilot plant at Boksitigorsk where artificial de-watering of peat is being studied. The peat is heated at 150°C under pressure and, as the pressure is lowered, the water content is reduced to 40 percent. The quality of artificially de-watered peat is the same as sod peat. The by-products from this process are primarily furfural and alcohol.

SCOTLAND

The researchers at the Macaulay Institute estimate that 30 to 40 percent of Scotland's 2 million acres of peatland possesses a potential for either agricultural or industrial (chemical) production, although they also recognize that these peatlands constitute the country's largest natural and semi-natural wildlife habitat.

The Institute has primary responsibility for research relating to the use and development of peatlands for agriculture and has jurisdiction over peatland surveying. Soil scientists in Scotland believe that peat harvesting improves a bog's agricultural potential since many previously harvested peatlands are now some of the best agricultural lands in the country.

IRELAND

Research work at the Lullymore Agricultural Research Institute commenced in 1955 at Lullymore (County Kildare) and Clonsat (County Offaly). The Research Institute presently has experimental fields for the production of vegetables, ornamentals, and grass, and for cattle raising on harvested bogs. Institute personnel have had considerable success in raising onions, carrots, and other crops. A variety of fertilizer treatments has been used, moreover, to maximize livestock production on the peatlands converted to pasture.

Figure 2.3
EXPERIMENTAL GRAZING AREA

Figure 2.4
EXPERIMENTAL ONIONS

Research carried out at Lullymore and Timahoe (County Kildare) on the growing of agricultural, horticultural, and industrial crops has proved the suitability of harvested peatlands as a growing medium. Allied to this work is a large-scale survey program, examining and identifying the subsoil and lower peats of the bogs. This research will enable experimental cropping results to be matched to the peat subsoil conditions and ensure that mechanized peat production will not inhibit in any way the future cultivation of the harvested areas.

Experience has shown that grass and beef output on harvested bogs equals that from good mineral upland soils in Ireland. Some water ponding and drainage problems, as well as soil acidity and plant nutrient problems, have been encountered but researchers believe that all of these difficulties can be overcome with proper management and cultural practices.

Figure 2.5
EXPERIMENTAL ORNAMENTALS

The Institute is carrying on experiments with vegetable crops such as onions, potatoes, carrots and some trials with several ornamental shrubs--spruce, pine, and cedar, as well as camellias, azeleas, and other plant nursery stock. The onion experiments have led to the development of a variety of selections suitable for Irish peatlands, including a marketable variety with good characteristics.

As a result of past experience, Bord na Mona is satisfied that it can develop the harvested bogs emerging from peat production to a state of fertility with production capacity approaching the best agricultural land. The produce from this land is totally exportable and thus will make an important contribution to the national economy.

3. HARVESTING

HISTORY

Peat was harvested for centuries in Germany, the Netherlands, Scotland, and Ireland where it was hand cut with spades called "slanes." A strong man working for about two weeks could cut enough brick-like peat sods to last an entire winter as fuel for cooking and heating. The cut sods were left to dry in the wind and sun, and were then brought in from the bog and stacked in ricks for further drying and storage. The mechanization of peat production received its first impetus in Germany toward the end of the nineteenth century. With the rapid expansion of industry, fuel became scarce and costly, and the possibility of harvesting peat by some mechanical method was actively pursued by engineers. The first peat cutting machines were actually kneading and shaping machines into which peat had to be fed and from which it had to be taken by hand. These experiments with kneading and macerating showed that peat which was mixed in this manner produced a much firmer and denser sod, when air-dried, than did slane-cut peat.

Although improvements in excavating, macerating, and drying techniques altered some of the early sod cutting procedures, these primitive machines, which were steam operated and which pulled themselves forward on rails by means of a winch, were the forerunners of the modern "Bagger" excavators currently used in the U.S.S.R., Ireland, and Finland.

In the 1930's the advent of milled peat production further changed the nature of peat harvesting techniques. The milled peat process,

Figure 3.1
HAND CUTTING PEAT

which was developed by Soviet technicians, was more like harvesting than excavating and was essentially a "surficial" process which removed only a thin layer of peat from the field being worked. These two techniques, modified by some recent developments, are now universally used in peat production.

PRE-HARVEST STEPS

SURVEYING

Before a bog is drained and prepared for harvesting, it is carefully surveyed to determine the nature of its vegetative cover, the depth and stratigraphy of the peat, and the most effective drainage system. These surveys, which are normally very detailed, represent a continuing effort in all the European peat producing countries. The Irish first mapped their peatlands in 1810-1814, and Finnish surveyors have just completed their third inventory. After surveys have been completed, measures are taken to effect preliminary drainage, clearing, stump and root removal, leveling, and final ditching of the bog.

In Ireland, where Bord na Mona has developed over 130,000 acres of peatland, survey work is usually completed well in advance of bog preparation and drainage. A survey is first taken to determine the areal extent of the deposit and the stratification of the peat itself. Levels are taken at 100 yard intervals--and sometimes more frequently--along section lines 250 yards apart in "raised" Midland bogs and 100 yards apart on the blanket bogs found mostly in the west of Ireland. The depth of the bog at each level control point is determined by the use of a Swedish-type tube bore which can be coupled in one-meter lengths. The lower tube is fitted with a special rotating head that enables half-meter samples from any depth to be extracted.

In addition to other properties of the peat, samples are analyzed for moisture content and degree of decomposition. If the peat is to be used as fuel, the degree of decomposition is an important factor, and various classification systems have been devised to specify the degree of decomposition. The most widely used systems are the Soviet, Swedish, and U.S. ones (Table 1).

U.S. CLASS SYSTEM	FIBRIC			HEMIC			SAPRIC			
SOVIET UNION SYSTEM	10	20	30	40	50	60	70	80	90	100
SWEDISH SYSTEM (von POST)	1	2	3	4	5	6	7	8	9	10

Table 1.
PEAT CLASSIFICATION SYSTEMS

In both the Soviet and Swedish systems, which are numerical, the higher numbers refer to greater degrees of decomposition (humification). The types of peat most suitable for use as fuel are the partially decomposed hemic (reed-sedge) and the more highly decomposed sapric types, which have von Post numbers of 7 and higher.

The borings in Ireland have shown that the strata nearest the surface of the Midland bogs are almost invariably of the younger *sphagnum* moss type (fibric in the U.S. classification system) exhibiting lesser degrees of decomposition. These relatively raw moss types (von Post H_1 and H_3) are not suitable for fuel because they have low bulk densities and low heating values, but their value as a horticultural soil conditioner has long been recognized in both Europe and the United States. The older peat which exists below the younger *sphagnum* exhibits a degree of humification between H_4 and H_6. The peat closest to the bog floor normally shows the highest degree of decomposition--between H_7 and H_{10} (sapric in the U.S. classification system). If these more decomposed peats have a high mineral content, they also are not suitable for fuel use because they produce high ash residues when combusted. They nevertheless make valuable cropland when the upper layers of less decomposed peat are removed.

Whatever the case, it is essential to determine the stratigraphy of a bog before it is drained. Because the hydraulic conductivity of highly decomposed peat is considerably less than the hydraulic conductivity of the more fibrous and spongy surface peat, the stratigraphy of the peat will influence drainage and water level draw-down rates.

When mapped, the depth and stratification data provide profiles of the bog along the transverse lines. The bog surface and bog floor contours are reduced to isopleths on tracings of 6 inch/mile maps of the bog area. Measurements have shown that many Irish bogs vary in depth from 10 feet to more than 40 feet, although the majority of the soundings mark between 15 feet and 25 feet.

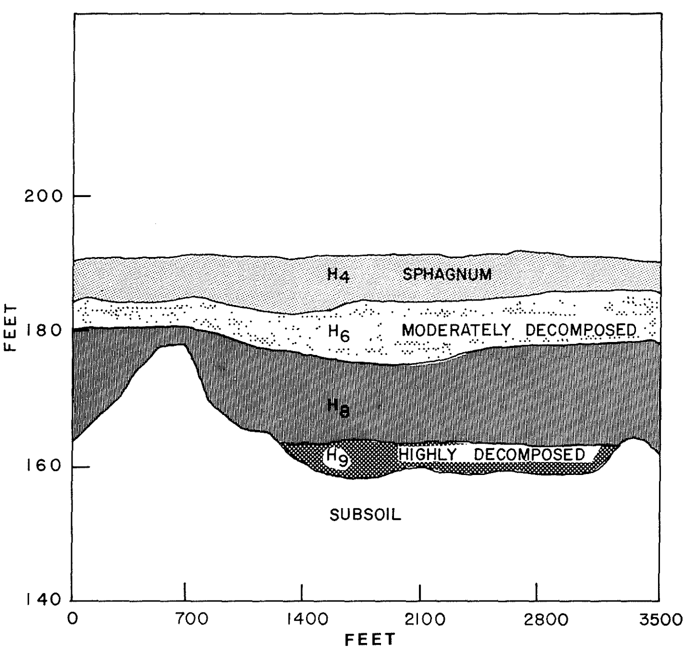


Figure 3.2
BOG CROSS SECTION

In addition to the survey of the bog itself, Bord na Mona carries out detailed surveys of all the minor streams and minor rivers carrying waters from the bogs to the main rivers. This information, combined with the contour and stratigraphic data, allows design of the drainage system for the bog area. The bog area as revealed by the initial survey is studied in conjunction with the bog sections and the surface and floor contours to determine the best orientation for the main ditches and for the "cross outfall" (lateral) ditches within the bog area which carry away the bog water to the nearest stream or small river. The main ditches and lateral ditches are then set out preparatory to plowing. The surveys of the minor rivers carrying the bog waters are studied to determine the practicability of gravity drainage for the peat deposits.

Finland has also surveyed its peatlands in considerable detail, recently paying particular attention to the location and extent of peat suitable for fuel use. In a report published in December 1973,* the Committee on Fuel Peat Bogs recommended a complete inventory of Finnish peatlands and recommended that regulations and procedures be established to set apart fuel peat bogs for production purposes. The Committee recommended that the inventory be made at a scale of 1:20,000 and that all bogs larger than 48 acres in the southernmost part of the country and all bogs larger than 240 acres in the northern part be included. In a study carried out by the Finnish Geological Research Institute for the State Forestry Industry, it was determined that the average depth of Finland's peat deposits is somewhat more than seven feet. Data pertaining to the degree of decomposition at various strata indicated that slightly over 60 percent of the peat (normally occurring in the lower part of the deposit) might be suitable for fuel peat use.

PREPARATION

The average water content of peat in a bog is approximately 94 percent, the amount varying from 97 percent at the bog surface to about 90 percent at the bog floor. The specific gravity of most peat averages only slightly more than that of water, and for most peat it remains constant between 97 percent and 90 percent moisture content. In drying from 97 percent moisture to 90 percent moisture, therefore, peat shrinks about 60 percent in volume at the surface where the peat has a von Post rank between H_1 and H_3 (*sphagnum*).

This shrinkage rate plays an important role in determining how rapidly the bog ditches can be deepened. The shrinkage of the peat, which

*"New Committee Report on the Peat Situation," *The Marsh*, Volume 25, 1:5-7, 1974.

occurs when the water level in the bog has been lowered by ditching and the peat above the water level in the drainwall dries, takes place slowly because the cells within the peat fibers are reluctant to release moisture. Also, if the bog ditches are deepened too rapidly, they will collapse. In general, a new ditch in an Irish bog will be opened to a depth of about four feet below the surface in the first year. Thereafter, the ditch might be deepened at a rate of 1 to 2 feet per year depending on the stratigraphy of the peat, the rate of drainage, and the rate of peat removal.

The bog drainage and layout procedures for sod peat production and milled peat production are somewhat different because the field area drained and worked in sod peat production is considerably less extensive than that required by the milled peat procedure. Also, sod peat is cut from the face of a trench which gradually encroaches on the bog as the peat is cut, while milled peat is removed in very thin layers from the bog's surface. The latter method requires a working area sufficiently extensive to allow for the efficient use of discing, milling, and harvesting machines and to maximize production.

The total length of open ditches on Bord na Mona's 130,000 acres is approximately 17,000 miles. In addition to this, there is a considerable length of "mole" drain, which is a subsurface drain made by pulling a bullet-like projectile through the peat. The ditches are first opened with a Cuthbertson plough, pulled by tractor at a speed of 1/2 to 1 mile/hour, to a depth of about 20 inches with a trapezoidal section of 30 inch top width and 12 inch bottom width. The ditches are then deepened by rotating disc machines, which can ditch at speeds up to 600 yards/hour, to a depth of 5 feet. A special screw pump mounted on a tractor is used to remove debris and slurry from the ditches.

Finnish engineers have developed a highly versatile "base" machine for use in their peat harvesting operations. This base machine forms a common platform for other machines that are used both for bog preparation and harvesting operations.

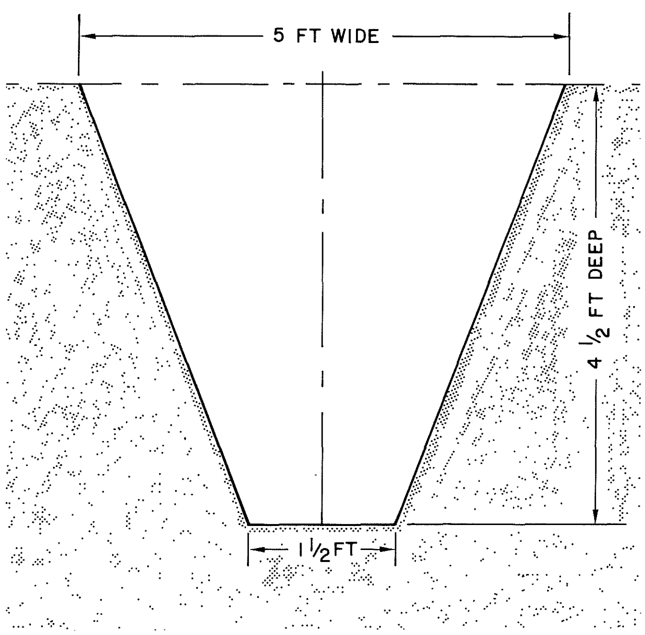


Figure 3.3
DITCH CROSS SECTION

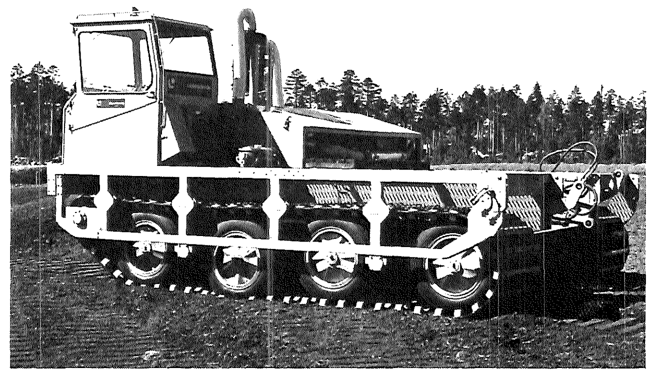


Figure 3.4
FINNISH BASE MACHINE

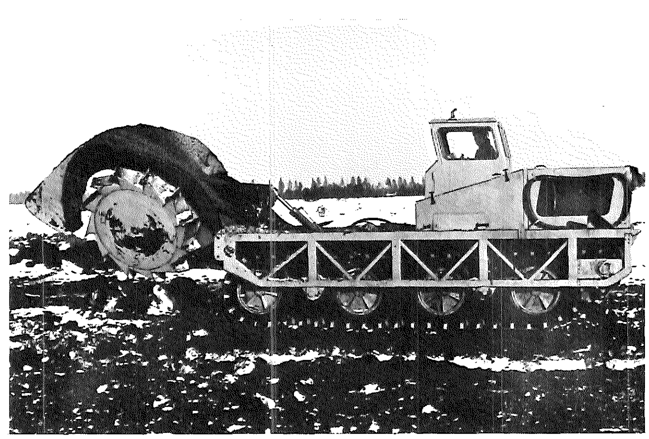


Figure 3.5
FINNISH DITCHER

Leveling of the bog surfaces is accomplished by specially designed screw levelers which have a lower bearing pressure and work at a rate of 1 acre/hour, depending on the conditions.

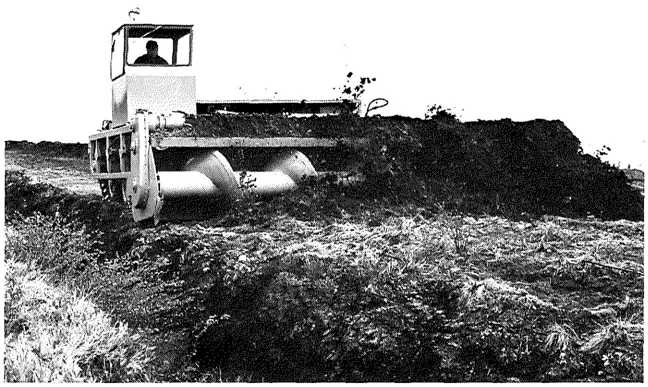


Figure 3.6
FINNISH SCREW LEVELER

The drainage of peatlands presents problems which are very different from those encountered in draining mineral soil. Draining a bog, it has been found, is always complicated by shrinkage, subsidence (a lowering of the bog surface), compaction, and frequently a decrease in hydraulic conductivity, all of which problems make for difficulties in the drainage operation. The colloidal properties of peat also make it particularly susceptible to weather, which is another variable that must be anticipated and dealt with in designing a drainage system. A considerable amount of research effort in the European peat producing countries has been devoted to developing efficient drainage techniques and to studying the effects of these techniques on the bog, on the bog's vegetation, and on the flow levels of receiving ditches and streams. One of the priorities in such reseasch has been to determine the most effective depth and spacing of drains. The "most effective" depth and spacing will vary, moreover, according to the type of peat, its bulk density and stratigraphy, and more importantly, according to the purpose of the drainage--whether to enhance tree growth, to allow for cultivation, or to prepare the bog for harvesting.

The hydraulic conductivity of decomposed peat varies but is usually very low (1.5×10^{-4} cm/sec in vertical and 2.0×10^{-5} cm/sec in horizontal), which places it in the class of "slow permeable" soils. For this reason, peat is not as easily drained as mineral soils having higher hydraulic conductivities.

Experiments have demonstrated, in fact, that improperly spaced ditches will have little effect on water levels in a peat bog. It has been further demonstrated that, irrespective of ditch spacing, very little lowering of the water level in a bog occurs at distances greater than 6 to 16 feet from the ditch edge and that any overall lowering of the bog's water levels, *beyond the influence of the ditch*, is invariably due to seasonal differences in precipitation and evapotranspiration and not to ditch spacing. Water level profiles developed by researchers in several countries, including Ireland and the U.S. (Minnesota), have demonstrated that the water level in a ditched bog is a function of distance from the drain. Researchers in Ireland found that in order to effectively lower the water level in an Irish blanket bog, a ditch spacing of 12 feet was necessary. The data from the Minnesota studies indicate that a ditch spacing of between 30 and 50 feet might be sufficient to effect water level control.

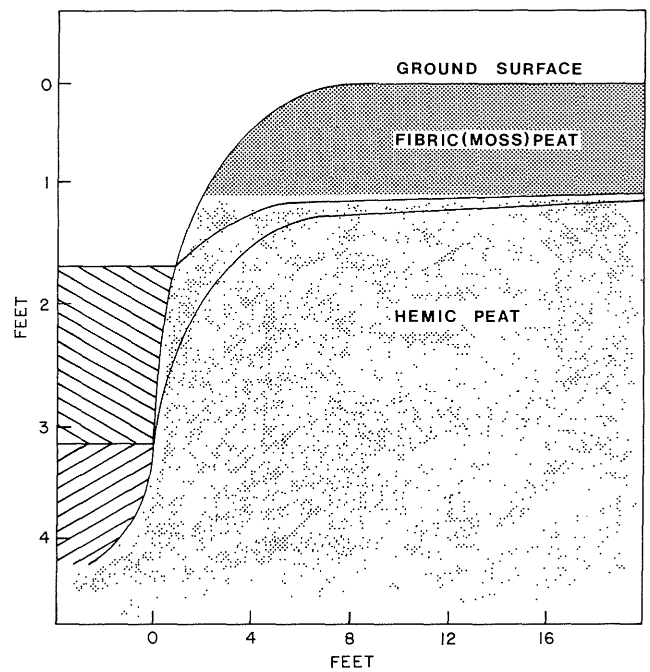


Figure 3.7
WATER PROFILE

Experiments in Finland likewise confirm the importance of ditch spacing in effecting water level control. In studies carried out at Liesneva in Southern Finland, it was found that the lowest water levels in a forested bog were obtained where the ditch spacing was 50 feet and that a gradual rise in bog water levels occurred as the spacing was increased to 200 feet. In the Finnish studies it was found that surface runoff from ditched open-fen bogs was greater than evapotranspiration where the ditch spacing was less than 130 feet and that evapotranspiration was greater than surface runoff where the ditch spacing was greater than 130 feet. On ditched forested bogs, it was observed that evapotranspiration was always greater than surface runoff, no matter what the ditch spacing, although surface runoff increased as ditch spacing decreased. Finnish studies have also shown that ditching improves timber production on forested bogs.

In Ireland the drainage system for *sod peat* production consists of main ditches 750 to 820 feet apart with subdrains spaced 210 to 280 feet apart. A center subditch between main ditches is often installed. Lateral ditches at right angles to the main ditches are usually introduced at a spacing of 100 to 160 feet,

prepare them as spread grounds. At this stage, care must be taken in leveling, draining, and in the disposal of gravel spoil from main drain excavations so that future development of cutaways for agricultural or horticultural use will not be inhibited. When final drainage levels in the bog drains are below the receiving rivers, screw or axial pumps are installed. A total of 20,000 acres is now pump-drained based on a runoff figure of 1.1 gallons/minute/acre.

The drainage system for *milled peat* production normally calls for closer ditch spacing. The entire working area is divided by parallel open ditches into fields 50 feet wide. The field ditches, which are usually between 800 and 2000 feet long, flow into pipe drains which run at right angles to the open ditches and which themselves discharge into the nearest natural outlet. Beyond the pipe drains a machine turning ground 80 feet wide is always provided.

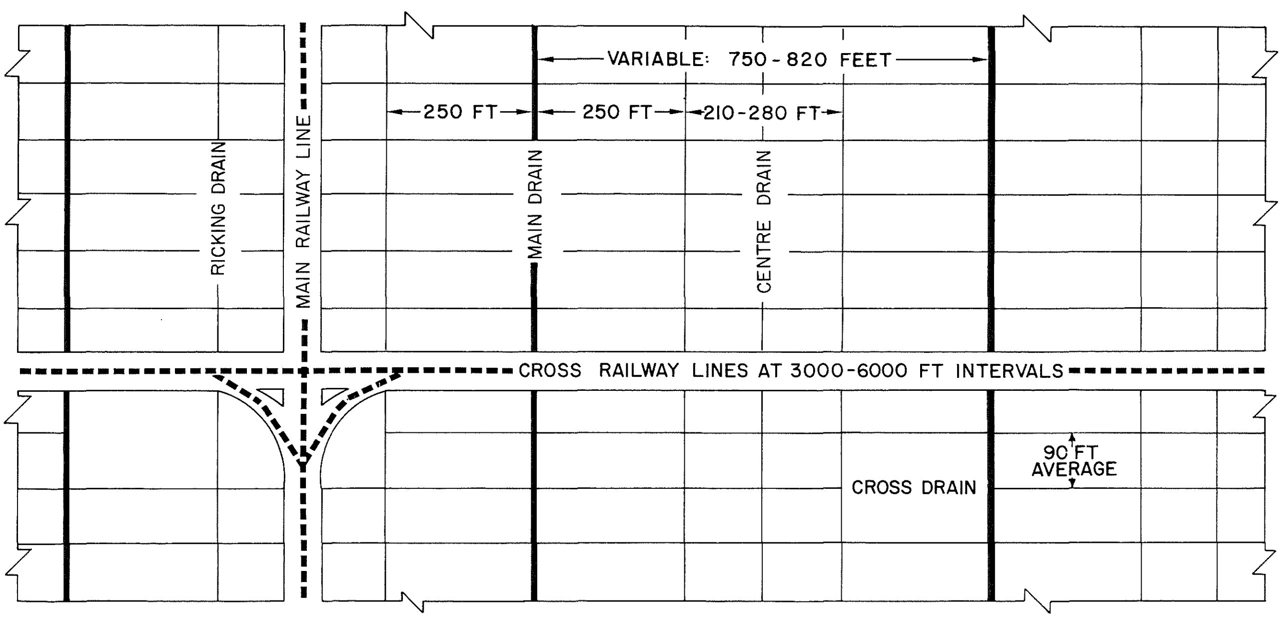


Figure 3.8
SOD PEAT DITCHING

depending on the conditions. Initial drainage on sod peat bogs is installed to establish stable cutting faces and dry spread grounds. As the sod peat bog is cut away, the area of high bog available for spreading to take place diminishes continually. Main ditches must be deepened and the cutaway leveled and graded by special low ground pressure bulldozers to

When fully developed, the open field ditches have a depth of 4 feet 6 inches and a top width of about 5 feet. The field ditches are excavated and maintained by machines called "disc ditchers." The disc ditcher consists of a cutting disc carried on an arm offset from a tractor unit. The tractor runs on timber swamp shoes and front rollers, and the bearing

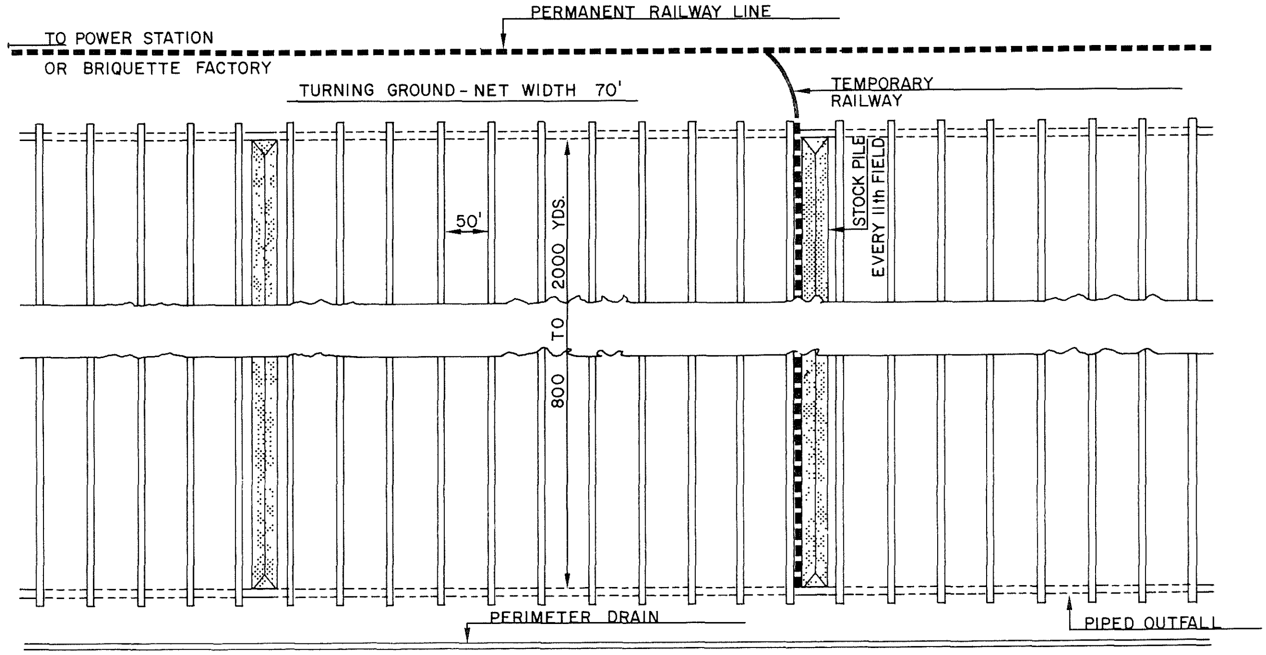


Figure 3.9
MILLED PEAT DITCHING

pressure is only about 1.6 pounds per square foot although the complete machine weighs 17 tons. The working forward speed can be adjusted from 70 to 650 yards per hour, as required by working conditions.

Figure 3.10
FINNISH DITCHER

In Ireland, a permanent narrow-gauge railway runs outside the turning ground joining the various bog areas and leading to the power station or briquette factory, with spur lines to work centers, workshops, and fuel storage areas. For production purposes the bog area is divided into units of 11 fields comprising a

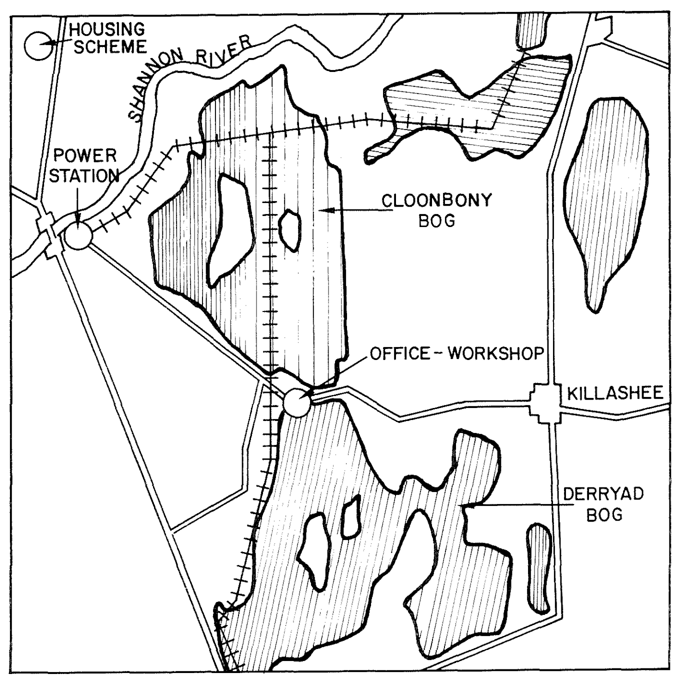


Figure 3.11
REPRESENTATIVE AREA

central stockpile field with 5 production fields on each side. The produce of the 10 production fields is stored on the stockpile field which can accommodate from 10 to 20 harvests of milled peat, depending upon peat density. When it is decided to sell a stockpile, a temporary railway track is layed alongside from the permanent line. On completion of loading, the temporary track is lifted and relaid along another stockpile and the procedure is repeated.

The drainage technology used in Sweden by Svensk Torvförädling in their milled peat operations is essentially the same as that used by Bord na Mona. But Swedish engineers have made some modifications in an effort to improve the techniques and reduce the power requirements of the machinery.

FUEL PEAT

SOD PEAT

In sod peat production the peat is excavated by a specially designed bucket dredger which in Ireland is called a "Bagger." After the peat has been cut away from the face of the trench by the Bagger, it passes through a macerator and is extruded onto an attached spreader arm which deposits it in a wide ribbon on the surface of the bog. Cutting discs drawn behind the spreader arm cut each ribbon of peat into 140 sods. When these sods have dried sufficiently to allow them to be handled, they are mechanically gathered in windrows or are raised by hand labor into small heaps known as "footings." This stacking is done in order to facilitate air drying.

When dry, these windrows are collected mechanically into continuous ricks on the edge of the spread ground. From these ricks the sods are loaded onto narrow-gauge rail cars pulled by diesel locomotives which transport them when sold. Depending on weather conditions, the harvesting cycle for sod peat production extends for a period of from six to eight weeks. Approximately two harvests are obtained each season. The total annual production of sod peat in Ireland has now surpassed 900,000 tons (35 percent moisture).

Sod peat production techniques in the U.S.S.R. are very similar to those employed in Ireland. As a matter of fact, the Irish patterned most of their techniques, and most of their machinery, after Russian prototypes. The Russian production cycle, like the Irish one, consists of excavating the raw peat by means of a Bagger machine and then extruding, spreading, drying, windrowing, and harvesting the peat. The Russian Bagger excavator cuts peat away from the bog at a 65 degree angle to guard against crumbling and collapse of the trench wall. All the Russian machines, as is the case with the Irish machinery as well, have a very low bearing pressure (3.55 pounds per square inch) to allow them to maneuver on the spongy surface of the bog. The Russian Bagger, like its Irish counterpart, is electric powered. The Russians use electric drive for their harvesting and loading machines as well, while the Irish equivalents of these machines are diesel-driven.

The procedure for sod peat harvesting can be divided into seven steps:

- *Stripping*
- *Cutting and Spreading*
- *Windrowing*
- *Turning*
- *Collection*
- *Stockpiling*
- *Loading and Transport*

The following is basically a description of the Irish sod peat harvesting process; however, the basic process is similar in all countries.

Stripping. The first stage in production is the removal of the overburden of mossy peat from the surface of the cutting trench. In Ireland this is done by a screw cutter mounted on a 45 h.p. diesel track machine which cuts to maximum depth of 2-1/2 feet and throws the spoil onto the cutaway. The width of the cut is 8 feet and the machine has a maximum forward speed of 1000 feet per hour. When the depth of overburden exceeds 2 feet 6 inches, a dragline excavator is employed to do the stripping.

Cutting and Spreading. The Irish Bagger consists of a fully tracked continuous bucket excavator and macerator cutting a 6-1/2 foot width of bank, 10-12 feet deep. It is a tracked machine, weighing about 45 tons and having a bearing pressure of 2 pounds per square inch. In addition to the bucket excavator and macerator, the Bagger has a chain plate conveyor called a "spreader arm." The spreader arm is mounted on tracks and rollers at right angles to the main unit and moves forward by means of a push-pull mechanism. The Bagger is electrically driven, the supply being brought to the machine by means of flexible trailing cable coupled to a three-phase overhead line system operating on 3300 volts. The buckets discharge into a conveyor which delivers the peat to the macerator.

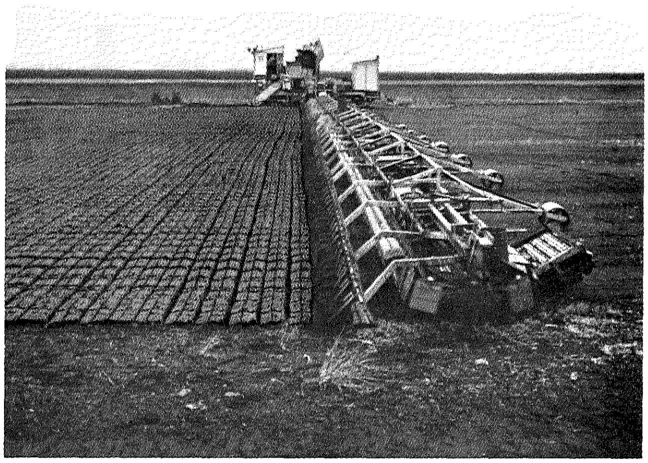


Figure 3.12
IRISH BAGGER

The macerator consists of a casing enclosing twin counter spirals with mixing blades, revolving at 182 rpms, each carrying an assembly of transport screws and mixer blades made to mix, macerate, and extrude the peat onto the spreader. The macerated peat is extruded from the macerator at a rate of 350 to 500 cubic feet per hour (11 to 16 tons of dry turf) through a double orifice which forms it into two rows of continuous sods, each 5 x 3-1/2 inches in cross-section. Maceration improves the quality of the peat by mixing the "light" top peat with the more highly decomposed bottom peat. The maceration also makes for a more dense and compact sod which is very impervious to rewetting once it has dried. The sods are extruded onto the spreader, which when fully loaded trips automatically and deposits the rows of sod on the bog surface. The rows of sod are cut by trailing discs into sods 12 to 15 inches long.

The normal production season in Ireland extends from mid-March until the end of July, after which they get more rain. During that period the Baggers work on a three-shift basis and are normally operated by a two-man crew. They cut the available trench length several times per season, depending on weather conditions.

In Finland, sod peat production is employed only where it is technically impossible to use milled peat techniques because it has been found that productivity in sod peat operations is reduced by the short harvesting season and higher labor costs. To mitigate these difficulties, Finnish technicians experimented with "surficial" excavation (as opposed to the deeper Bagger excavation technique) and small-sized sods. Finnish technicians have developed several types of "slit milling" machines that produce sods by surficially removing a 1 to 3 foot layer from the bog's surface as they move along, extruding the peat through nozzles behind.

Figure 3.13
FINNISH SOD PEAT MACHINE

Windrowing. Windrowing is carried out when the spread peat has dried to a moisture content of 75 percent to 81 percent. It is performed by special plows forward-mounted on a 35 h.p. fully tracked tractor. These plows lift and turn the sod and form them into windrows.

After a lapse of three to four days, during which the top sods dry to 68 percent to 69 percent moisture, the windrows are split by the same machine, and previously covered sods are turned to dry. The combined rate for windrowing is 45 to 55 tons per work hour.

The development of the plow windrower was the greatest single factor in increased sod peat mechanization in Ireland.

Turning. Turning is a conditioning operation in which the windrowed sods are lifted and screened by fully tracked twin or triple turners equipped with potato chain elevators which lift the windrows, screen, and replace them on the ground. The twin turner has a throughput of 40 tons per work hour while a newly developed triple turner has an average output of 60 tons per work hour.

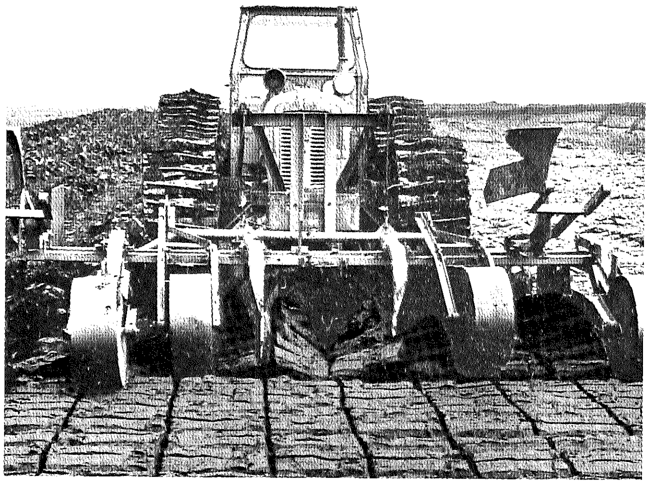


Figure 3.14
IRISH WINDROWER

Figure 3.15
SOD PEAT

Collection. Before the peat is collected it must be gathered into larger windrows to be lifted by the collecting machine. This is done by the twin turner, which can be adjusted to lift two windrows and place them on adjacent windrows, thus building up final rows at 30 foot centers. In very good conditions it can also be done by angle dozing the smaller windrows into final rows by a vee blade on a fully tracked bulldozer. At this state the moisture content of the peat is about 50 to 55 percent.

The peat is collected into stockpiles by an electrically powered 180-foot self-propelled conveyor, fed by bucket or potato chain elevators which pick up the final windrows and feed them to the stockpiles at the edge of the spread ground at a rate of 50 tons per hour. As spread grounds vary in width, the collector can be varied to lift six, five, four or three rows by removing sections.

Loading and Transport. When the stockpiles are being loaded, a temporary rail track is laid along the rick with a rail-laying machine that consists of a tractor fitted with a train jib. The loading machine has a scraper elevator which lifts the peat onto a cross conveyor mounted at right angles to the direction of travel. The cross conveyor discharges the sods onto the waiting cars at a rate of 100 tons per hour.

Transport of sod peat is by narrow-gauge railway in trains of sixteen 10-cubic-yard cars or twelve 20-cubic-yard cars, hauled by diesel locomotives. At the receiving power stations carloads can be fed to bunkers or stockpiles, and for other sales the peat is delivered to tipheads where the cars are end-tipped into receiving trucks by hydraulic car tippers.

For industrial consumption the main criterion in quality is low moisture content (25 to 40 percent) with an upper limit of 4 percent on ash content. In addition, while most of the sod peat is burned in sod form, 50,000 tons are crushed to a maximum size of 3-1/2 inches for hopper units and low ram stokers. The calorific value of sod peat at 35 percent moisture content is 5,700 BTU per pound.

Sod peat production is now a highly mechanized process. The labor input has fallen considerably in recent years and productivity has increased from 300 tons per man in 1960 to 550 tons per man in 1971.

MILLED PEAT

Bord na Mona presently has six bogs which produce milled peat, a process fundamentally different from sod peat production. In this method of production the bog is layed out in a series of 50-foot-wide drying fields and the surface of each field is cut into small particles by a milling machine. This machine operates a rotating drum fitted with small spikes which turn up the bog surface to a depth of 1/2 inch.

After a short period the layer of milled peat is harrowed in order to accelerate drying and when it has been air dried to approximately 55 percent moisture it is scraped mechanically into ridges along the center of each drying field. These ridges are then transferred by harvesting machines into center piles, each of which takes the output from 10 drying fields.

The harvesting cycle covers approximately two to three days in good weather and an average of 12 harvests per season is obtained under normal weather conditions.

Milled peat is transported by rail, either to power stations where it is used to fuel specially designed furnaces for the production of steam, or to briquette factories where it is further processed and compressed into briquettes which are in high demand as an industrial and domestic fuel. Bord na Mona's three briquette factories, which are situated at Lullymore, County Kildare, and at Berrinlough and Croghan in Offaly, produce over a quarter million tons of briquettes each year. The briquetting process is a relatively expensive one but it enables peat to be made available for sale in its most acceptable and highly developed form.

The term "milled peat" describes peat in crumb or powder form. It has a mean particle size of about 1/4 inch in diameter, ranging from about 1/2 inch to fine dust. When air dried to a moisture content of 55 percent by weight it has a loose bulk density of between 9 and 25 pounds per cubic foot, depending upon the degree of decomposition. Milled peat has an anhydrous calorific value of about 9500 BTU per pound.

Milled peat is produced over the entire working area of the bog by slicing off a thickness of about 1/2-inch at a time. The moisture content of the 1/2-inch layer at this stage is about 80 percent. After this step, the crop is air dried and stockpiled at 45 percent to 50 percent moisture content. In an average season 12 such crops are harvested, representing a yield of 73 tons per worked acre.

An important consideration in deciding whether a bog is suitable for the milled method is the total workable area of the bog. In Ireland, the smallest bog developed for milled peat has a gross area of about 2800 acres and a net working area of about 2100 acres. The unharvested portion of the bog is used for railways, turning grounds, storage fields and the like. The Irish believe that the bog should have an average depth of at least 6-1/2 to 10 feet with reasonably level bottom contours. Other factors that are considered are large concentrations of timber or frequent small lakes or ponds, both of which increase development costs and present serious difficulties at production stage. It is desirable that the peat should have a humification number on the von Post scale of at least H_3, which corresponds to a decomposition of about 15 percent and a loose bulk density of about 11 pounds per cubic foot at 55 percent moisture content. In general the higher the humification the better, but the Irish experience shows that peat of humification H_6 to H_8 is best for briquetting and power station burning. It is desirable that the anhydrous ash content should not exceed 5 percent. In Ireland, moisture content before drainage is about 94 percent by weight. By the time production starts, the upper 4 feet have been reduced to 90 percent moisture content, while the surface moisture content at milling is about 80 percent.

An undrained bog requires 4 to 5 years progressive drainage to get field drains down to a stable depth of 4-1/2 feet. In the final years of development, the heather is removed and the field surface is cambered by leveling machines and bulldozers. After a final deepening of field drains the bog is ready for initial production. For the first two or three production years, yields are low due to the high moisture content of the surface and the deformation which occurs in the early years. Production must be restricted in the first few years to avoid permanent damage to the bog surface and drain edges. In general it requires 6 to 8 years of careful development and semi-production to bring the bog from the undrained state to a stage at which standard yields can be expected. Throughout the production life of a bog, field profiles and field ditches are maintained by cambering, leveling, and disc ditching. Field drains in production areas are ditched twice a year, while leveling and cambering by bulldozer are carried out as required and vary considerably depending on the production age, peat quality, and depth of the bog area concerned.

In Ireland the milled peat production season can commence any time after mid-April, if weather and bog conditions are suitable and if sufficient drying has taken place to enable machines to travel on the bog surface.

Milled peat production started in Finland in 1951. By 1963, milled peat accounted for roughly 20 percent of Finland's total annual production of peat. At that time, however, Finnish technicians realized the advantages of this type of harvesting and planned the expansion of their peat industry around this method. By 1970, milled peat accounted for almost 90 percent of total annual peat production in Finland.

The number of production days in Finland for milled peat varies from 30 to 40 days per season and the average number of harvests is usually about sixteen. In 1974, a very wet year, the number of harvests dropped to eight, but in 1975, which was an excellent harvesting year, the number of harvests jumped to twenty-four. The average drying cycle is two days, but during long dry periods the cycle can be reduced to one day. Milled peat production usually starts sometime in early June and terminates in mid-August.

At the Rastunsuo fuel peat site near Kuopio, milled peat is produced by the same method used in Ireland. During the 1975 production season 70 persons were employed directly in the peat operation and 20 persons in supporting industries to work a field area of about 1000 acres. The fuel peat produced at Rastunsuo is transported to the district heating/power plant at Kuopio, 47 miles away. To deliver the peat to Kuopio, four transport trucks work two shifts a day for the duration of the season. In 1975 the Rastunsuo site produced 1.3 million cubic feet of milled peat on an area of just over 1000 acres.

The Irish milled peat operation consists of seven basic operations; the descriptions also apply to similar operations carried out in Finland and the Soviet Union:

- *Offset Milling*
- *Milling*
- *Harrowing*
- *Ridging*
- *Harvesting*
- *Stockpiling*
- *Loading and Transport*

Offset Milling. For the start of production proper and again after every four or five harvests, the Irish production fields are cambered along the drains by an offset miller which consists of a cutting or milling drum mounted on a tractor. The cutting drum is 6 feet long and is fixed at a horizontal angle of 60 degrees to drain edge so that in cutting, the peat is directed towards the center of the production field where it can be harvested with the main crop which is milled as described in the next section. The offset milling drum is also set at an angle to the horizontal and is adjustable up to a maximum of 18 degrees. This arrangement gives a milling cut which is wedge shaped in section and allows the depth of cut at the drain edge to be varied as required. In practice the cut varies in depth from 2 to 8 inches at the drain edge running out to nothing at the inner edge of the cutting drum. The main purpose of offset milling is to ensure that drain edges are cambered toward the drain to facilitate runoff of rainwater in the production fields.

Milling. This is the cutting or milling operation that is carried out in Ireland by an attachment mounted behind a half-track tractor powered by a diesel engine. The attachment consists of three milling drums covering a total cutting width of 22 feet 9 inches so that two runs of the miller span the entire field width. The milling drums carry a series of steel pins 1-1/4 inches long which mill the bog surface to a depth of about 1/2 inch, leaving behind a layer of milled peat. The milling drums revolve at a speed of 350 revolutions per minute and the forward speed of the machine is about 5 miles per hour. The attachment is supported by ground rollers and hydraulically operated depth control castors. The milled layer is allowed to remain undisturbed until its surface is dry, which requires about 0.15 inch of evaporation as measured in the standard American-type pan evaporimeter. This represents the amount of drying which takes place between about 8:00 a.m. and 3:00 p.m. on a typical drying day in summer in Ireland.

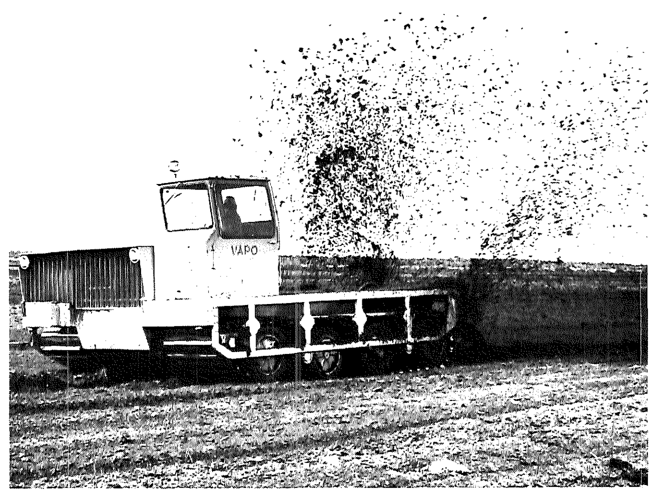


Figure 3.16
FINNISH MILLER

Harrowing. The milled layer is then turned over and corrugated by a spoon harrow. The Irish harrow is drawn by an agricultural tractor fitted with half-tracks and consists of 88 steel spoons mounted at 6 inch centers on a tubular steel frame. At first harrowing, peat moisture content is typically 68 percent to 72 percent. Thereafter, harrowing is repeated at evaporation intervals of about 0.1 inch until the moisture content is down to 50 percent, after which the crop is allowed to remain for a further 0.15 to 0.2 inch of evaporation, reducing the moisture content to about 45 percent before ridging. In dry weather the number of harrowings required per crop can vary from 2 to 5 depending upon evaporation and bog conditions. If rain intervenes, however, many more harrowings may be required.

Figure 3.17
SOVIET HARROW

Ridging. When the moisture content is down to about 45 percent, the peat is angle dozed into triangular shaped piles or ridges in the center of each production field. A typical ridge averages about 37 tons per mile of length at the standard moisture content of 55 percent. The ridger has two blades mounted on a half-track tractor powered by a diesel engine. The blades form a V-shape in plane behind the tractor and are set at an angle of 30 degrees to the direction of travel. Together they span the production field with a gap between them of 3 feet to accommodate the ridge. The blades are made up in hinged sections to follow the contour of the bog surface. The ridger has a working speed of about 5 miles per hour.

Harvesting. When ridges have been formed on all ten production fields they are transported into the central stockpile field by a harvestor. The harvestor unit is mounted on a fully-tracked tractor powered by a diesel engine. The machines pick up the ridge by means of a spiral unit positioned on one side of the tractor. The spiral delivers the peat onto a belt which conveys it to the center of the next field. In this way the ridges are transferred field by field toward the center stockpile, each ridge being deposited on top of the next adjoining ridge until finally a large ridge containing the peat from all five production fields on one side is delivered into the stockpile. Harvesting completes the production cycle and the miller, following the harvestor, commences the next cycle. Each cycle is known as a "harvest" and yields just over 6 tons per acre. In fine weather conditions it takes about three days and about 0.6 to 0.7 inches of evaporation to obtain a harvest. Evaporation of about 0.22 inches per 24 hours is typical in anticyclonic conditions during the summer months.

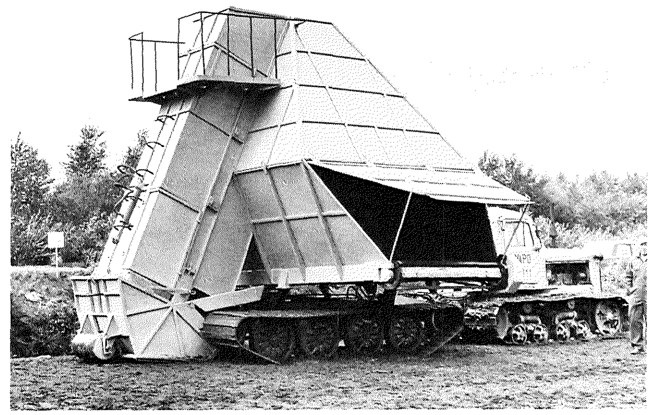


Figure 3.18
FINNISH MECHANICAL HARVESTER

A significant advance in milled peat production techniques has been developed by Russian technicians and introduced into production procedures in Finland and Sweden. This advance was pneumatic harvesting. The objective of pneumatic harvesting, in which large vacuum harvesters comb the harrowed fields picking up a very thin layer of milled peat particles, is to reduce the normal drying/harvesting cycle (2 to 3 days) to one day. This is possible because only the drier peat particles are picked up by the harvesting machine when it passes over the field. Pneumatic harvesting not only makes milled peat production less dependent on the weather, it eliminates the need for ridging and excessive harrowing and allows for a more mechanized operation throughout.

Finnish technicians started experimenting with pneumatic harvesting in 1960. Their first small specially built machine showed considerable promise, appeared relatively cheap to build, and seemed capable of dealing with inclement weather conditions. Since then, several generations of pneumatic harvesters have been developed and tested. In these tests is has been found that milled peat harvested pneumatically differs noticeably from milled peat harvested mechanically. The moisture content of pneumatically harvested peat tends to be lower, and more even, and it does not contain any very coarse particles. These factors in turn influence average particle size, pore volume, and volume weight. The most recent version of the pneumatic harvester is a modular machine which can be easily attached to and detached from the multi-purpose base machine. It weighs 127 tons, has a traveling speed of about 4 miles per hour, and in 40 production days can harvest 1,225,000 to 1,400,000 cubic feet of milled peat. One persistent problem with pneumatic harvesting is the dust raised by the cyclone's operation.

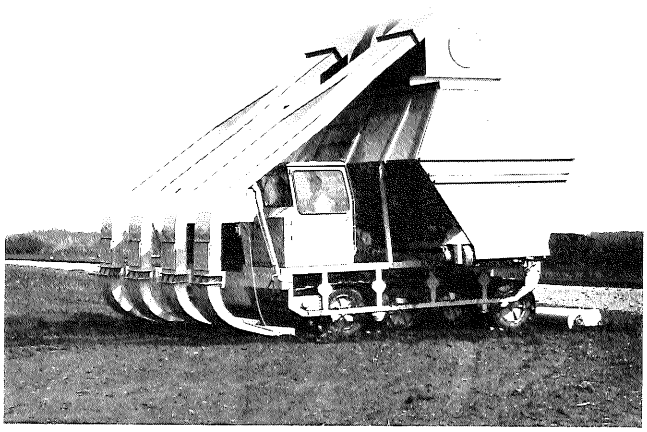


Figure 3.19
FINNISH VACUUM HARVESTER

Stock Protection and Compaction. During the production season stockpiles are compacted by articulated rollers after every two to three harvests to reduce the stockpile size and to provide some protection against the high wind. At the end of the season, stockpiles are covered by light-gauge polyethylene film to protect them from rain and wind and to inhibit spontaneous combustion in certain types of peat. A typical completed stockpile is roughly triangular in section but with rounded top due to the compaction rollers. It contains about 14 harvests, has a base width of about 25 feet, a height of about 10 feet, and weighs about 3 tons per linear yard.

Loading and Transport. All bog areas are served by narrow-gauge permanent railway systems from which temporary spur lines are laid alongside the stockpile as required for loading. The loader consists of a tractor with a 25-foot-wide ground spiral mounted in front, feeding a bucket elevator which discharges onto

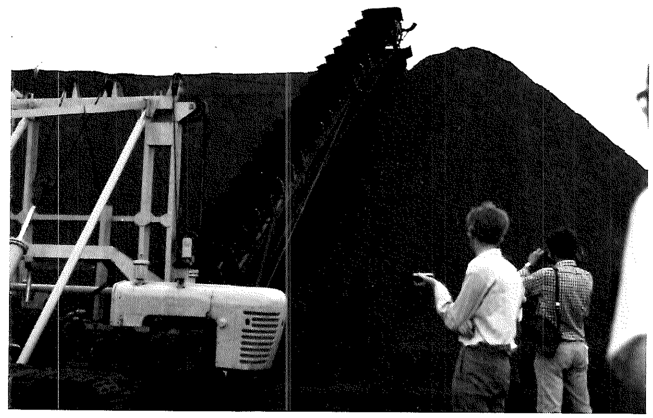


Figure 3.20
MILLED PEAT IN SOVIET UNION

a belt conveyor carried along a jib and delivering the peat into 20-cubic-yard cars. The loading machine's forward speed is about 90 feet per hour, giving a loading rate of 90 tons per hour. The normal train consists of fifteen 20-cubic-yard cars hauled by a locomotive with a diesel engine. Rail cars are joined by rotary couplings and each can turn through a vertical angle of 360 degrees so that tippling is carried out at power stations or briquette factories without uncoupling the cars, each car being emptied individually in a rotary tippler while still coupled to the remainder of the train. Transport of milled peat takes place night and day on every day of the year. An 80 megawatt power station can consume up to 4000 tons of peat per 24 hours, while the larger briquette factories use about 1000 tons in the same period.

HORTICULTURAL PEAT

SWEDEN

In Sweden, where Svensk Torvförädling (Swedish Peat Industry) produces only horticultural peat, the milled peat process is used exclusively. The Swedish technicians, who have attempted to increase productivity through automation, have developed most of the harvesting equipment they use, including disc-type ditching machines, shallow pinmillers, deep millers, and vacuum harvesters. After the peat is harvested, sometimes mechanically and sometimes pneumatically, a narrow-gauge railway using a small radio-controlled diesel locomotive is employed to transport the peat from large storage piles (over a mile long) to the processing plant where it is automatically unloaded in a below-ground pit. From there the peat is conveyed up into the plant by belt conveyors and eventually mixed in large bunkers. A very efficient blending operation, developed by Swedish technicians, is here used to blend peat from different bogs having different qualities. The blending results in a more uniform product for processing. This quality control measure is very important in the production of high-quality horticultural peat.

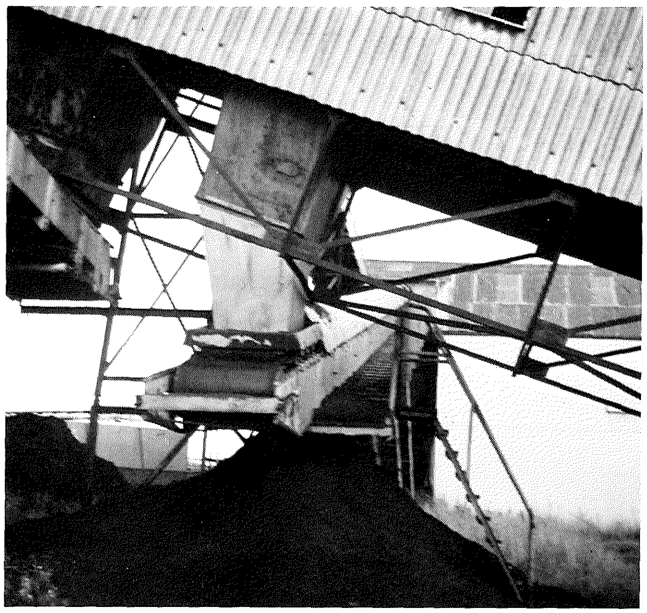


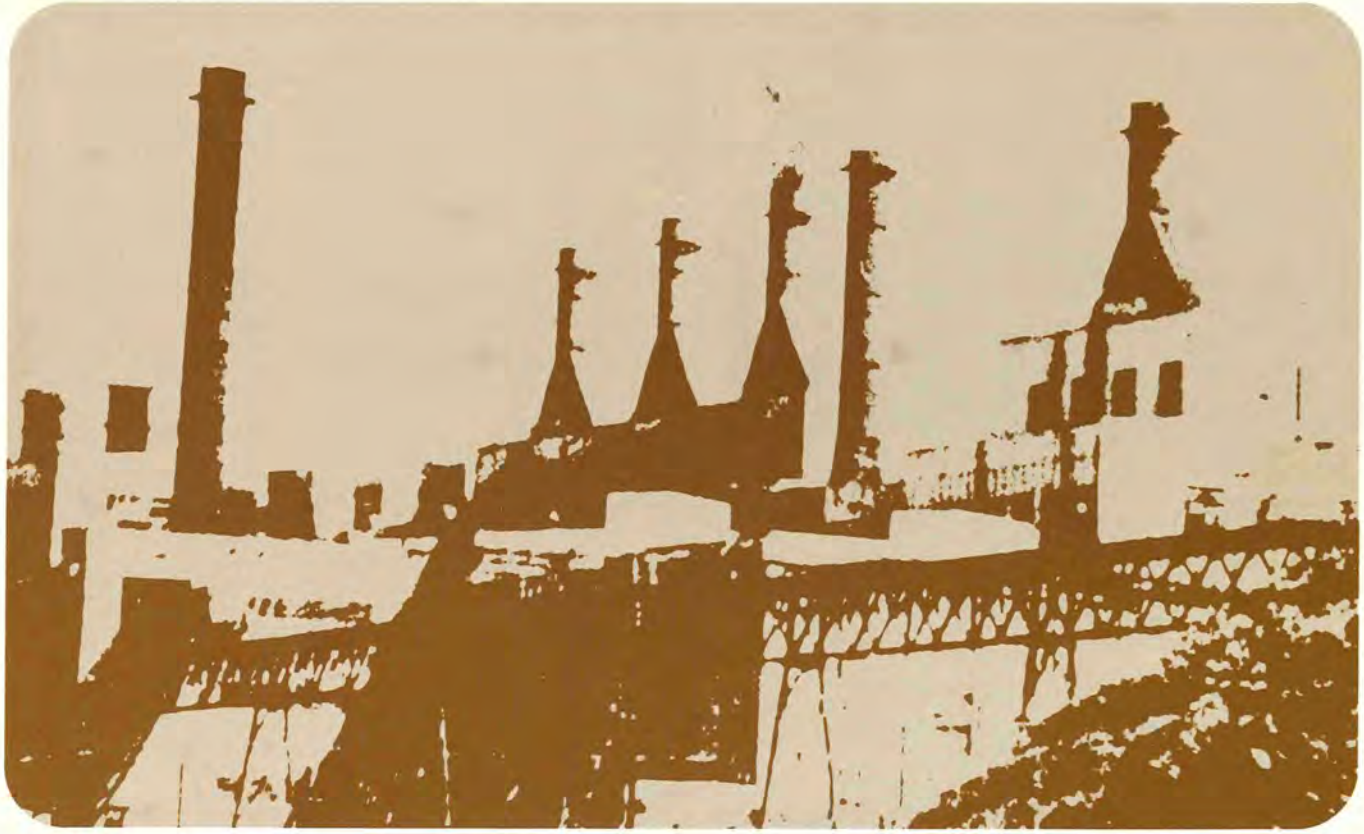
Figure 3.21
SWEDISH PEAT PLANT

After mixing, the peat is split into two batches: one a standard unfertilized peat moss, and one fertilized with a mixture of nitrogen, phosphorus, and potassium. The peat is then baled and conveyed to trucks for hauling to market. Fertilized peat is becoming very popular with European flower and vegetable growers, and Svensk Torförädling is now expanding its plant at Sösdala to respond to the increasing demand for horticultural peat. The Sösdala plant will probably be second only to the Klasman plant located in West Germany near the Dutch border. Svensk Torvförädling is a private company by U.S. standards, and is taxed as such, but it was started in the 1940's through a long-term low-interest loan from the Swedish government.

IRELAND

Ireland also produces moss peat for horticultural use. Although moss peat has been produced in Ireland for almost a century, it was not until establishment of Bord na Mona that large-scale commercial development started. The moss peat, which is more fibrous than milled horticultural peat, is cut from the moss growth found in the upper layers of *sphagnum* bogs. The peat is cut mechanically and dried on the bog by sun and wind. The moss peat is then transported to a plant where it is graded, compressed, and packaged. The moss peat produced in Ireland is used as a soil conditioner, as a propagating material for seeds and cuttings, as a deep litter for poultry, and also as a packing material for early tomatoes. Bord na Mona has developed two bogs exclusively for moss peat production, one near Kilberry (County Kildare) and one near Coolnamona (County Laois). Together they produce more than 1,000,000 bales of moss peat annually, most of which is shipped to Great Britian, the United States, the Channel Islands, and elsewhere.

Figure 3.22
IRISH SOD MACHINE



4. ENERGY

WORLD PEAT USE

Peat has been an important fuel in many countries for centuries. The Romans mentioned its use at the time of their conquest of northern and western Europe. They observed that the people of these regions dug "soil" from the marshlands with their hands, dried it, and then burned it to cook their food and keep themselves warm. It was first used on a large scale in Germany, Denmark and the Netherlands, but due to the exhaustion of peat reserves and especially to the competition provided by other fuels, these countries no longer use peat as a fuel.

The first country to use peat on an industrial scale was the Soviet Union when, shortly after the Revolution, the Soviets introduced a program to develop their fuel peat industry. The Irish were the next to recognize the importance of fuel peat and started a rapid expansion of their fuel peat use about 30 years ago. The recent energy crises have forced several other countries to take a fresh look at their neglected peat reserves. In 1971, Finland initiated fuel peat development, planning to increase their total annual production to 3 million tons by 1980, about a tenfold increase in production over 1971. No other countries use peat as a fuel at the present time, but Sweden, which ceased fuel peat production in the 1960's, is now planning three district heating/electricity generating power plants. Greece has plans for utilizing a deep peat bog for electricity generation, and Canada has shown some interest in fuel peat as a potential domestic fuel.

Figure 4.1
PEAT CUTTING AREA IN IRELAND

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

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

Table 2.
WORLD FUEL PEAT USE

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

In addition to other reasons, which will be discussed later, one of the reasons for the Soviet Union's large use of peat can be seen by examination of the world peat reserves shown in Table 3.

COUNTRY	PEAT - 10^9 TONS
U.S.S.R.	200
CANADA	35
FINLAND	18
U.S.A.*	14
SWEDEN	9
POLAND	6
F.R.G.	6
IRELAND	5
GREAT BRITAIN	4
OTHERS	6

*Does not include Alaska

Table 3.
WORLD PEAT RESERVES

The U.S.S.R. possesses about 60 percent of the world's peat resources, or approximately 200 billion tons. The total world peat deposits are estimated to cover about 375 million acres; this is approximately 1 percent of the earth's total land surface. The peat reserves in Canada, Finland, and the United States are also appreciable, with the U.S. having about 14 billion tons, not including Alaska, which is estimated to have about 100 million acres of peatlands.

An appreciation of the total energy content in the world's peat reserves can be obtained by making a comparison with oil. Assuming a total world supply of the order of 300 billion tons, and an oven-dried calorific value of about half that of oil (about 9500 BTU per pound), the hydrocarbon equivalent may be calculated at around 155 billion tons of oil. This is about 55 percent greater than the total *known* oil reserves today. The calorific value of peat compared with the calorific values of other common fuels is presented in Table 4.

TYPE OF FUEL	MOISTURE CONTENT	BTU/lb
WOOD	AS RECEIVED (VARIABLE)	5,800
PEAT	AIR DRIED (30%)	7,300
PEAT	OVEN DRIED (0%)	9,500
LIGNITE	AS RECEIVED (37%)	7,000
LIGNITE	AIR DRIED (20%)	7,500
SUB-BITUMINOUS	AS RECEIVED (14%)	10,300
BITUMINOUS COAL	AS RECEIVED (2%)	13,200
ANTHRACITE COAL	AS RECEIVED (4%)	13,100

Table 4.
COMPARATIVE CALORIFIC VALUES

An important point to be noted is that the calorific value of air-dried peat is about the same as that of lignite, of the order of 7,000 BTU per pound, or slightly over half of the heating value of the higher-ranked coals.

SOVIET UNION

The U.S.S.R., which possesses about 60 percent of the world's peat resources, was the first country in the world to use fuel peat on an industrial scale. In pre-revolutionary days most of the peat was harvested manually. After the Revolution, however, emphasis was placed on mechanized harvesting methods and production rates increased rapidly. In 1928, fuel peat production in the U.S.S.R. amounted to 5.85 million tons; production soared to 15 million tons by 1932, an *increase of 156 percent*. The production rate increased until 1940, when a total of 32 million tons was produced. During the war years the production rate slacked off, but after the war the rate again increased, reaching 45 million tons in 1950, 54 million tons in 1960, and 70 million tons in 1975. It is estimated that the production will reach 80 million tons by 1980.

The Soviet fuel peat industry was actually initiated with the so-called GOELRO electrification plan adopted by the Soviet government in 1920. In this plan the construction of 20 power plants, including five power stations running solely on peat and supplying about 10 percent of the nation's electric energy, was foreseen. These power plants were to be constructed close to the peat deposits that would provide them with fuel, which at that time was supplied in the form of sod peat. As anticipated in the GOELRO plan, five power plants operating on peat were built, the first one coming on line in 1922.

In 1931 the first district power plant working solely on milled peat was put into operation. This successful shift to milled peat for electric generation stations in turn provided the impetus for a rapid development in milled peat harvesting technology in the Soviet Union. Since the development of milled peat production, several power plants previously using sod peat have been converted to milled peat consumption. The Kirov plant near Leningrad, for example, was converted to milled peat in 1958 and at that time had a total output capacity of 300 megawatts.

At the present time 80 million tons of peat are consumed by 76 power stations in the U.S.S.R., which have a total output capacity of about 4000 megawatts. Fuel peat is also used by a number of industrial boiler houses and municipal electric power plants. The Shaturskaja electric power station is at the present time the biggest peat powered plant in the Soviet Union, having an output capacity of about 730 megawatts of electric power. Several new power plants, with an output of 600 megawatts each, have recently been constructed in several regions of the U.S.S.R., and there are plans to increase total national capacity to 6300 megawatts.

Leningrad power station No. 15 was constructed in 1956 and now produces 25 megawatts of steam for heating and 150 megawatts of electric power to the new suburbs of Leningrad. The steam output of the plant heats 2575 houses and provides 1600 houses with hot water. The peat is obtained from a bog located 84 miles southwest of Leningrad, near the town of Pskov. The peat is transported from the bogs using a narrow-gauge railway system. From this system it is transferred to a standard-gauge railway and shipped to a storage area, which has a capacity of 100,000 tons, located about 3 miles from the power plant.

The peat supplied to the plant has a sulfur content of between 0.54 and 0.68 percent and an ash content of between 8 and 14 percent. The moisture content varies with the weather. In 1975, which was a dry year throughout Europe, the plant obtained peat having a 45 percent moisture content. In 1974, a very wet year, the moisture content of the peat averaged around 60 percent.

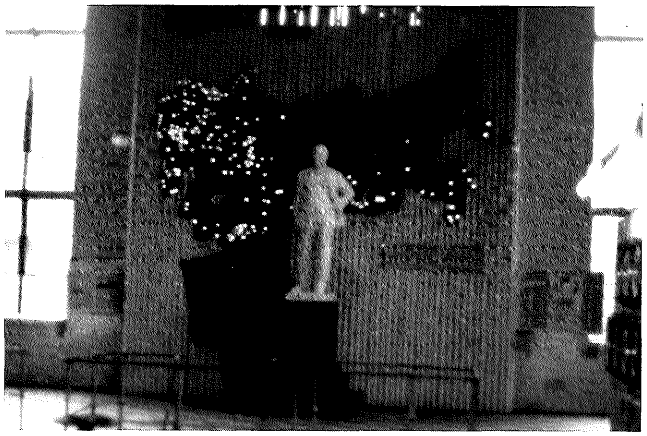


Figure 4.2
DISPLAY AT POWER PLANT

Because of an abundant supply of natural gas during the summer, peat is burned only during the winter months. Soviet technicians estimate that they obtain three units of energy output for every unit of energy input in their peat harvesting and combustion operations.

The Soviet Union has also carried out peat gasification to obtain low BTU gas. These gasification plants, which were first constructed to provide town gas in remote areas of Siberia, were essentially small-scale pilot projects. The one at the Torfyanaya Opytnaya Stantsiya, near Kalinin, supplied low BTU gas (230 BTU per cubic foot) to a town of 1300 in 1958. Now, with the more abundant supplies of natural gas and LNG, peat gasification has been deemphasized. According to Dr. Vladymyr Kortchunov, Head of the peat Thermal Processing Laboratory, the production of low BTU gas from peat is currently profitable only "in those areas where there are no other resources of fuel" and where the conditions are such that peat can be cheaply dried by solar energy.

IRELAND

In Ireland, peat has been used as a domestic heating and cooking fuel for more than a thousand years. It was cut by hand with "slanes," dried, and stored for winter use. Such peat cutting was carried out, and is still common, as a normal adjunct to farming, although modern peat briquetting operations now supply much of the domestic fuel peat in Ireland. In 1946, when Bord na Mona was established, the indigenous fuel peat activities in Ireland were nationalized and geared to power plant consumption. Since then, fuel peat production has increased steadily. At the present time fuel peat production in Ireland amounts to about 3.5 million tons annually. The rate of production is expected to increase to more than 5 million tons annually by 1980.

BRIQUETTING

Peat briquetting, which is currently carried out in Ireland, Sweden, and the U.S.S.R., is a process by which milled peat is screened, dried, and compressed into small briquettes to be used for both boiler firing and domestic heating. In the course of the briquetting operation, the moisture content of the peat is reduced from about 55 percent to 10 percent, which is about one-third to one-fourth the moisture content of air-dried sod peat. In Ireland, which has three briquetting facilities, the annual production of briquettes exceeds 350,000 tons and consumes over 850,000 tons of raw peat. The briquettes are sold loose or in bails weighing 28 pounds each.

The peat briquetting industry commenced in Ireland in 1935 when a steam drying system was developed by the Irish Peat Fuel Company. This system was later applied to briquette production in both Sweden and the Soviet Union. Soviet technicians have also developed a hot-gas drying system which has a lower capital cost but is thermally less efficient than the steam drying system. Some peat drying systems also use rotary drum dryers similar to those employed in German brown coal drying plants.

Because the briquetting process demands a homogeneous feed stock and because milled peat is variable in moisture content, bulk density, and fiber concentrations, the raw milled peat must be blended, milled, and screened to obtain maximum efficiency in the drying and pressing operations. When the milled peat is delivered to the briquetting factory, it is spread in thin layers in a blending bunker, alternate layers having differing characteristics. Technicians monitor the arriving shipments and instruct blender operators to alternate the layers in such a way as to achieve a homogeneous mix.

Figure 4.3
LULLYMORE BRIQUETTE PLANT

The blended peat is removed from the bunker by a spiral screw loader and is conveyed to a hammer mill by way of a buffer bunker which regulates the flow in the mill. The mill reduces the particle size of the peat to less than 10 mm and prepares the peat for screening, where oversized and fibrous particles are removed. The tailings from this screening process are fed to a 2400 kilowatt back-pressure boiler system which supplies steam to the peat drying circuit.

The screened peat is eventually fed to the base of the first of five vertical tube dryers through which the peat is pneumatically conveyed. The peat first passes through two hot water dryers (150°F) and then through three steam dryers (212°F). In each case the peat is blown through the dryer by a large fan. From the dryers the peat particles, now having a moisture content of near 10 percent, pass into a "prepacker" and from there to the briquette presses. The drying process produces vapor containing heavy concentrations of very find dust and cyclonic separation is necessary to prevent environmental problems. Small amounts of dust nevertheless escape into the atmosphere and settle on the fields in the neighborhood of the briquetting factories.

The briquette presses are mostly double ram presses patterned after the preses used by the German brown coal industry. The particle size of the peat entering the presses used by than 4 mm. Considerable effort must be expended to control the consistency of the peat from batch to batch. The absence of such control would cause problems in both the drying circuit and the presses. The briquettes leave the presses at a temperature of 212°F and enter cooling slides which extend about 250 feet. Even when packaged, however, the core temperature of the briquettes is about 170°F. About 80 percent of the briquettes are baled, and the remaining 20 percent are packed loose.

Figure 4.4
BRIQUETTES

Figure 4.5
BRIQUETTES ON TRUCK

POWER GENERATION

SOD PEAT COMBUSTION

In the 1940's the Irish made a policy decision to expand their fuel peat industry--despite the fact that oil could be obtained more cheaply--because they believed the additional costs could be more than compensated for by an improvement in the balance of payments, increased employment, and the assurance of a secure fuel supply. With these benefits in mind, the Electricity Supply Board planned the construction of several peat-fired electrical generating plants. In addition to development of their own technology, the Irish relied heavily on experience in other European countries.

The first two generating plants built in Ireland, which operated on sod peat, were constructed in Portarlington (25 megawatts) in 1950 and Allenwood (40 megawatts) in 1952. The boilers in these plants had a pre-drying shaft leading from the bunker to the grate; an open-work water-cooled firedoor which allowed radient heat to reach the fuel before it entered the furnace and which controlled the fuel bed height between a minimum of 12 inches and a maximum of 30 inches; front and rear refractory arches with provisions for admitting preheated secondary air to create turbulence and control steam profiles; and twin variable-speed chaingrate stokers with primary air control by dampers in undergrate zones. Because some combustion problems were experienced with the boilers at both Portarlington and Allenwood, the boiler at the Lanesboro plant (20 megawatts), constructed in 1958, was radically redesigned to give a much larger flame path between the grate and the first bank of convection tubes. These boilers are similar to the sod peat fired boilers operated by the G. A. Serlachius paper mills in Finland.

MILLED PEAT COMBUSTION

Experience in operating sod peat boilers led to the conclusion that the maximum feasible size for such a boiler was 20 megawatts. That fact, combined with the high production costs of sod peat, caused Bord na Mona to examine the use of boilers fired by milled peat, and in 1953 a decision was made to design all future plants for milled peat consumption. The Irish, who had no experience with such technology, modeled their equipment after that used by the German brown coal industry, appropriately modified to meet the special characteristics of milled peat. The first milled peat generating plant, which employed three prototype boilers, was built at Ferbane (60 megawatts) in 1957. Experience with these boilers led to the formulation of standard processes which were applied to all subsequent plants. The peat is drawn from the bunkers by four conveyors and fed to mills through verticle ducts. Hot furnace gas (about 900°C) is drawn into each mill to dry the peat to less than 25 percent moisture content and to preheat it in preparation for combustion. To achieve this drying and preheating, and still maintain a mill outlet temperature below 200; cold air must also be added. Cool flue gas was originally recirculated to regulate mill temperature but that procedure was abandoned because it caused corrosion and deposit problems. Each mill feeds four "corner burners" which are also provided with auxiliary oil burners for both starting and stabilizing the peat combustion process. This oil stabilization is especially important when the quality of the peat fuel is poor.

The milled peat generating plants have proved themselves to be reliable, the only persistent problem being the variability of the bulk density and moisture content of the peat delivered to the plant. The moisture content of the peat frequently fluctuates between 40 and 65 percent, and in any one day it is quite possible the mills will receive peat from both extremes of this spread. Because handling procedures are such that little mixing of different batches occurs in the bunkers, and because moisture content influences the amount of fuel passing through the mills and the amount of air needed to maintain load, it is very difficult to achieve a consistently high thermal efficiency in the system. The impact of such variability on thermal efficiency is not as seriously impaired by variability in the raw fuel. Irish technicians are now considering the installation of "blending bunkers" to ensure more homogeneity in the peat fed to the mills. Such blending bunkers were proposed when the first milled peat generating plants were being designed, but the capital outlay required to install them was not considered worth the savings in efficiency they promised to produce. Now it appears that such bunkers would have been worth the price.

The three 30 megawatt units built at Ferbane were followed by two 20 megawatt units at Rhode in 1960 and two at Bellacorick in 1962. A 30 megawatt unit was added to the Ferbane plant in 1964 and a 40 megawatt unit was completed in 1965 at Rhode. Similar 40 megawatt units were constructed at Shannonbridge and Lanesboro in 1966 and 1967, respectively. All in all, the Irish Electricity Supply Board presently operates seven peat-fired electrical generating

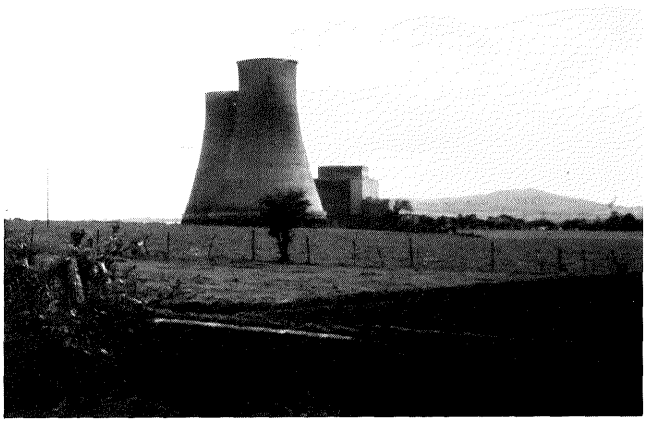


Figure 4.6
POWER PLANT

plants having a total output capacity of almost 400 megawatts.

Peat Fired Power Stations in Ireland (1975)

Portarlington, County Laois	37.5 MW
Allenwood, County Kildare	40 MW
Ferbane, County Offaly	90 MW
Rhode, County Offaly	80 MW
Shannonbridge, County Offaly	40 MW
Lanesboro, County Longford	60 MW
Bellacorrick, County Mayo	40 MW

Another 200 megawatts in capacity will ultimately be added to the current output. A 40 megawatt expansion of the Shannonbridge facility will be completed in 1976. Another 40 megawatts will be added to Shannonbridge in 1982, another 40 megawatts to Lanesboro by 1983, and another 80 megawatts will be installed at a plant which is yet to be built.

SUMMARY OF IRISH EXPERIENCE

Irish technicians believe that the last 25 years of experience prove conclusively that peat-fired electrical generation is a sound and practical enterprise. According to J. F. Lang, Chief Generation Engineer with the Irish Electrical Supply Board, "the major technical problems have been solved" and the reliability of the peat-fired plants "is on a par with that obtained on conventional fossil-fueled plants." It has also happended that, while electricity produced from oil has been cheaper per megawatt-hour for most of this 25-year period (principally because the price of imported oil declined between 1952 and 1972), the cost per megawatt hour of peat generated electricity since the oil price increases of 1973 has fallen below that of competing oil production. If the electricity produced by peat-fired generating plants in 1974 had been produced by oil purchased at 1974 prices, the extra cost would have amounted to almost 11 million dollars.

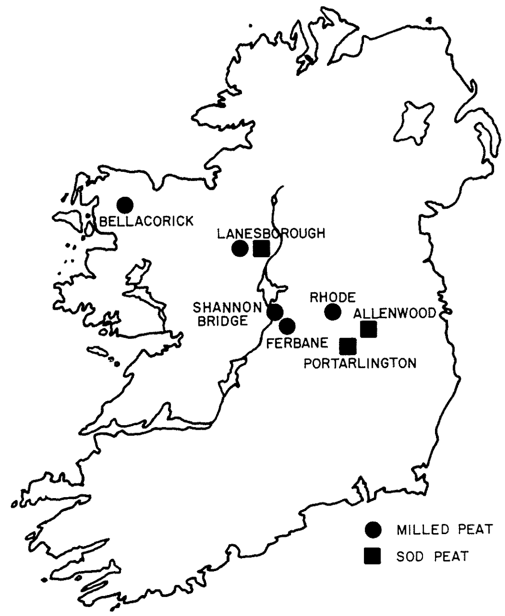


Figure 4.7
POWER PLANT LOCATIONS

The Irish see other advantages, as well, in the use of peat fuel for electrical generation. The supply of peat is more secure than the supply of imported oil; the use of peat contributes to the national balance of payments; and the peat industry, as a whole, provides considerable local employment and promotes local industries. It is estimated that the peat program in Ireland has saved over 125 million dollars on the balance of payments since 1952, and that these savings will accelerate in the future. Since the peat program was initiated, moreover, a considerable improvement in local economic health has occurred in the Midlands area of Ireland, where most of the peat industry is concentrated and where employment was low and out-migration high prior to the development of the peat industry. At the present time more than 6,000 people are employed directly in peat production and electrical generation in Ireland.

It has been shown by a Bord na Mona cost-benefit study that when allowance is made for the benefit to local employment and for the reduction in the national balance of payments, a net favorable benefit can be achieved by the use of peat even if the cost per megawatt-hour of electricity generated by a peat-fired plant were *twice* the cost of electricity generated by an oil-fired plant. This fact, added to the prospect of increasing the thermal efficiency of peat-fired plants by 6 percent, indicates that the peat industry will fare very well in Ireland.

FINLAND

Much of the research related to alternative energy sources in Finland has been directed toward peat development because the 17 million acres of peatland in the country constitute Finland's only energy alternative to imported fuel. Peat combustion, as an alternative to the combustion of imported oil and coal, has become especially attractive in the northern and eastern parts of Finland where the price of imported fuel is higher than it is in the south. Although peat has been used as a fuel in Finland since the 1940's, no large power plants were constructed until 1972 when rising oil prices spurred Finland's interest in developing its own energy resources. Finland now has one peat-fired district heating/power plant in Kuopio, built in 1972, and six more plants are either in construction or planning. As a result of this decision to develop a peat-fired district heating/power industry, the amount of peat harvested in Finland will need to be increased from its present annual level of .5 million tons to about 3 million tons by 1980.

BOILER OPERATIONS

In the late 1940's sod peat was used to fuel heating plants in a number of public buildings in Finland. The peat was sometimes burned in boilers initially constructed for the combustion of wood waste. With the increased importation of foreign fuel, however, such peat firing diminished to almost nothing. In the late 1960's milled peat combustion replaced sod peat combustion in the few heating plants which still burned peat--two small (less than 10 megawatt) plants at Ähtäri and Haapavesi, and the small boiler operations at the Niinisalo garrison and Pelso prison. But such plants actually consumed very little peat and contributed very little to the national effort to make heat and power production more efficient and reduce dependence on imported fuel. The only other sod peat burning operation in Finland is at the G. A. Serlachius paper mills in Mäntta where sod peat has been burned since the 1940's to produce process steam. The Serlachius mills are currently planning to increase peat combustion at their plants 2 to 3 times and intend to build a new peat handling terminal.

DISTRICT HEATING

BACKGROUND

In the 1950's the Finnish government, with an eye to the increasing need for energy and an acute awareness of Finland's meager energy resources, initiated an investigation into the types of energy which could best satisfy the country's needs and into the means by which such energy could be supplied efficiently. As a result of these feasibility studies, it was decided that the government would promote the construction of district heating/power plants, that is, power plants which both generate electrical power and supply hot water for a municipal heating system. During the last ten years, a number of district heating/power plants have been planned or constructed by municipalities or municipality-owned electricity works in Finland, and the construction of these power plants has inevitably been connected to the district heating activities of the municipalities. In a country with a climate like Finland's, where a relatively high quantity of energy is needed for the heating of buildings, the district heating system has been found to have a number of advantages.

In an electrical generating plant not all the thermal energy of the fuel can be turned into electricity. A large quantity of heat remains in the steam flowing through the turbines, which are operated in a "condensing" mode to achieve the most efficient turbine operation. Even in large condensing generating plants this heat loss accounts for about 60 percent of the energy value of the fuel. This excess steam, which must be condensed in cooling towers before it can be discharged, is not only evidence of the thermal inefficiency of the operation but represents a source of potential thermal pollution. In a district heating/power plant operating in a "back-pressure" mode, the steam flowing through the turbines is used to heat water in a district heating network. A large portion of the heat in the steam can thereby be recovered. Since in an average district heating/power plant only about 20 percent of the flow-through heat is lost, it is possible to reduce thermal loss to 1/3 the loss in a condensing plant. If, moreover, one compares fuel consumption in a district heating/power plant to the fuel that would be consumed by an electrical generating plant *plus* that consumed individually by all the home furnaces required to heat the houses which could be served by a district heating network, the savings amount to more than 35 percent. The cost of purchasing fuel falls about 50 percent because the light fuel oil used in home furnaces can be replaced by the much cheaper heavy fuel oil which can be combusted in the district heating/power plant.

electricity. In a district heating/power operation, on the other hand, the heat not "used" by the turbines is used to supply heat to the district heating network and is paid for by the district heat consumers. This reduces the cost of electricity generated and sold to electrical consumers. The district heating/power concept also allows for the use of less expensive fuels (such as peat), reduces fuel transportation costs, almost eliminates transmission costs, and promises to produce a cleaner environment. Since, moreover, the fluctuations in heating demand and electricity consumption follow the same curve, the electricity generated in conjunction with district heat is available precisely when it is needed most.

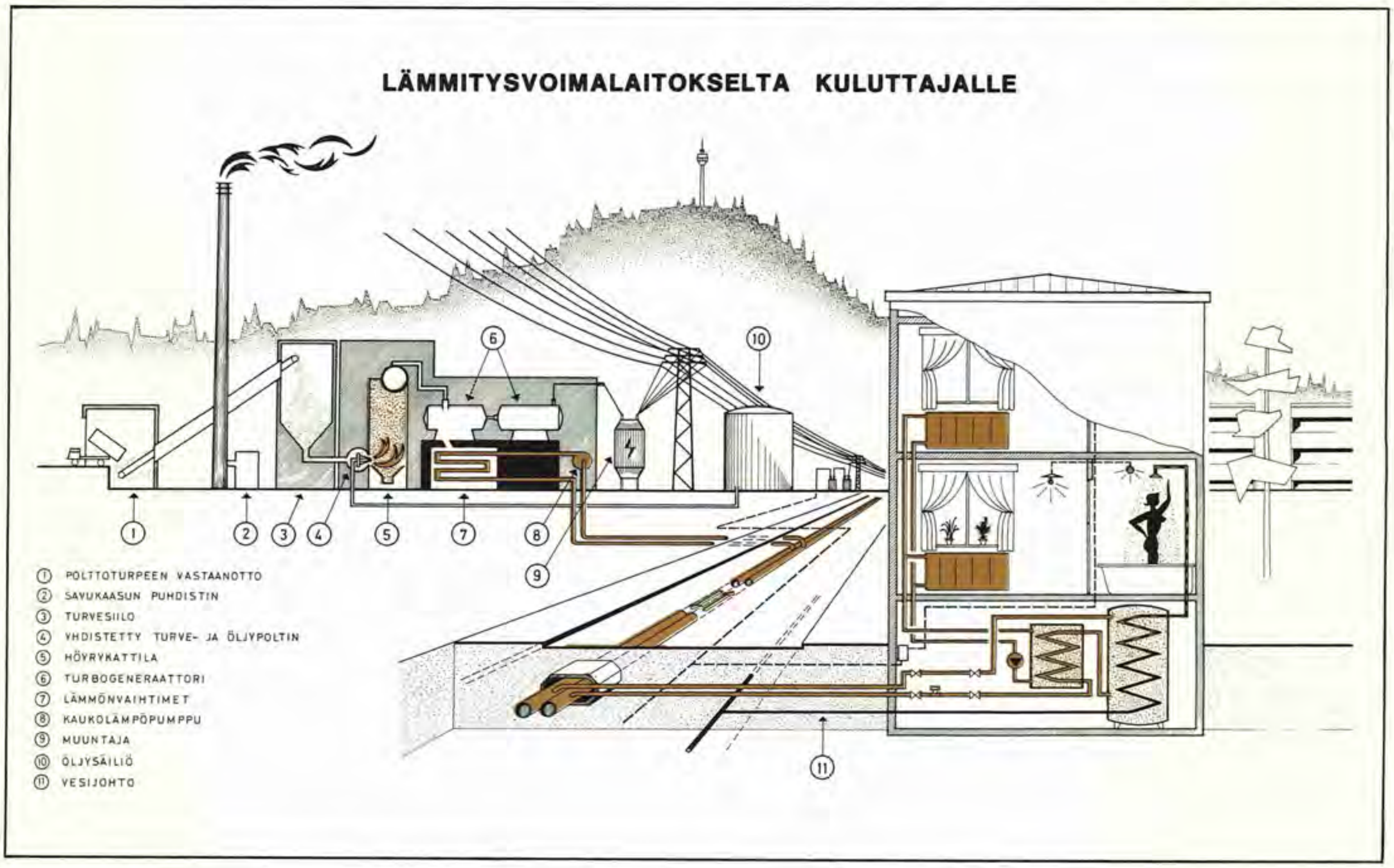


Figure 4.8
DISTRICT HEATING CONCEPT

The district heating/power operation is also advantageous to those who purchase only electricity from the plant. In a conventional electrical generating operation, all the fuel costs must be included in the price of

District heating was first introduced in Finland with the construction of simple heating plants in Helsinki (1952) and Tapiola (1953). Soon the potential for combined district heating and electrical generation was recognized, and studies to pursue this potential were initiated. The introduction of district heating in any locality is now normally associated with the heating of new residential areas, sometimes including entire sections of towns. In most cases the aim has also been to begin the generation of back-pressure electricity as soon as possible. Six such district heating/power plants are now being planned or built. Their combined output capacity will be 300 megawatts of electricity and 600 megawatts of district heat--and they will consume 6 million cubic meters of peat annually.

KUOPIO SYSTEM

In 1958 a district heating operation was proposed in the town of Kuopio where the new Puijonlaakso housing development provided a sufficiently large heating load (700,000 m^3 of building volume) to warrant district heating. A plan was drawn up, construction was started, and in 1963, Kuopio became the eighth municipality in Finland to have district heat and back-pressure electrical generation with completion of the Niirala plant. In 1967, plans were prepared for the Haapaniemi district heating/power plant which was to supply heat to other sections of Kuopio. The plans called for 13 megawatts of back-pressure capacity, and construction was to start in early 1968. But the late 1960's was a time of surplus generating capacity in Finland, so construction of the plant was delayed until 1971. When in 1971 a revised plan for the plant was drawn up, the plant's capacity was raised to 30 megawatts of back-pressure power (40 megawatts condensing power) and 60 megawatts of district heat. The revised plan also called for adapting the plant to burn milled peat.

In the early 1960's the Finnish State Power Company (Imatran Voima Oy) had also looked into the possibility of building a large peat-fired district heating/power plant in Kuopio, but the plan fell through because the price of imported oil declined dramatically during the decade. The Kuopio Electricity Works nevertheless asked the Finnish Peat Industries to examine the feasibility of harvesting fuel peat from bogs at Kiurvvesi, Rantalampi, and Hankivuori. A more detailed study was then made of the Rastunsuo bog at Rantalampi, which was nearest Kuopio, and when the decision was made in 1969 to construct the Haapeniemi district heating/power plant to operate on peat as well as oil, it was also decided that the Rastunsuo bog, which lies about 47 miles from Kuopio, would be developed to supply milled peat to the plant.

Construction of the Haapaniemi plant, which is situated about one mile from the center of Kuopio on the shores of Lake Kallavesi, was started in early 1971 and completed in April 1972. During the busiest construction phase as many as 250 workers were employed at the site. District heat was first released to the Kuopio heating network in April 1972, and electrical generation was synchronized to the network in May of that same year. The plant went into full commercial production in September 1972.

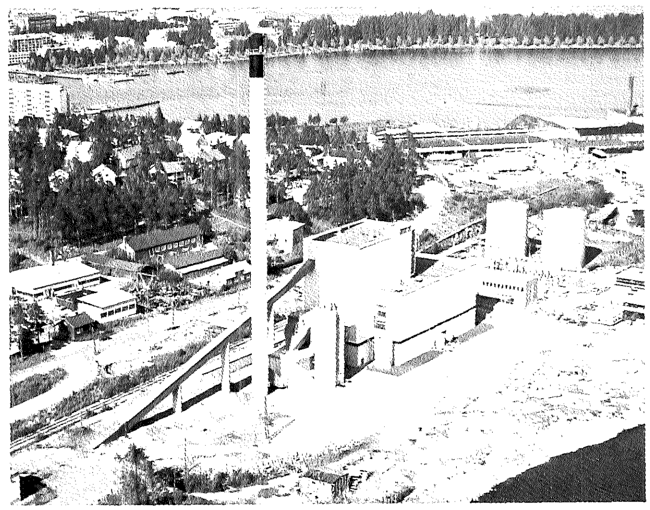


Figure 4.9
KUOPIO PLANT

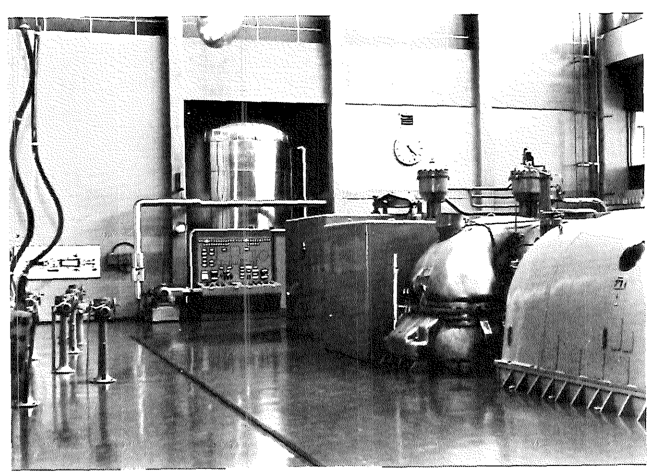


Figure 4.10
PLANT INTERIOR

TAMPERE SYSTEM

District heating was started in Tampere in 1964 with the construction of a small boiler plant. Then toward the end of the 1960's plans were prepared for the construction of a combined district heating/power plant at Naistenlahti, just outside Tampere. The plans called for 60 megawatts of electrical generation capacity and 120 megawatts of heating capacity, and construction of the plant, which was designed to burn heavy oil, was completed in 1971.

Shortly after the Naistenlahti plant was completed, a second plant was planned for the same location and the possibility of designing it to burn peat was examined. The possibility of using peat as a fuel for the first plant had already been considered and dismissed because fuel oil promised to be more economical. With this second plant fuel peat was again considered but, as in the case of the first plant, oil promised to be more economical. In 1973, however, after the sharp rise in imported oil prices, the Tempere Electricity Works again examined the feasibility of constructing a peat-fired district heating/power plant, and it was found that even if oil prices fell somewhat from the 1973 levels, a peat-fired plant would remain competitive with an oil burning one.

On the basis of this examination, the city of Tampere decided in early May, 1975 to construct a peat-fired district heating/power plant having an electrical generating capacity of 60 megawatts and district heating capacity of 120 megawatts. The construction of the plant will be completed in 1977. It will consume 1 million cubic meters of milled peat annually.

CONSTRUCTION COSTS

At the present time, construction costs for a peat-fired district heating plant are around \$800,000/megawatt for a 30 megawatt plant, and \$600,000/megawatt for a 60 megawatt plant. These costs of building a peat-fired plant are about one-third higher than those of an oil burning plant, most of the extra costs going into the boiler and boiler room, the peat handling terminal, and the peat conveyor. The costs of building a 50 megawatt peat-fired district heating/power plant are compared with the costs of building an oil-fired one in Table 5.

A peat-fired plant also will incur increased annual costs due to the following factors:

- *Increased personnel requirements*
- *Increased repair costs*
- *Increased ash transportation expenses*

	OIL		PEAT	
COMPONENT	MILLION DOLLARS	PERCENT	MILLION DOLLARS	PERCENT
BOILER	4.44	17	7.57	22
TURBINE	6.01	23	6.01	17
CONSTRUCTION, ROADS	6.01	23	9.14	26
MACHINERY	7.84	30	10.19	29
PLANNING, MISCELLANEOUS	1.83	7	2.09	6
TOTAL	26.13	100	35.00	100

Table 5. CONSTRUCTION COSTS

Thus, the decision to use peat as an energy source depends on several factors. Construction costs and operating costs are definitely higher for a peat-fired plant. However, because of the higher costs for other imported fuels (due largely to the transportation charges) Finland has made the decision to use peat.

SCOTLAND (WESTFIELD CENTRE)

For over a century the British gas industry depended on coal carbonization as a source of both low BTU town gas and coke. The Westfield Gas Works, situated on the border between Fife and Kinross-shire in Scotland, was built in the late 1950's to supply town gas and was one of the last surviving plants of this type when it ceased to produce gas in June 1974 due to the sudden availability of natural gas from the North Sea.

The plant, which has a current replacement value of about 60 million dollars, occupies a 45-acre site adjacent to an opencast mine that supplies low swelling non-caking bituminous coal for the gasification process. The mine occupies an area of about 250 acres, and altogether an area of approximately 1,000 acres is required for overburden dumping, coal preparation plant, and buildings. The plant has rail service and is 30 miles from Port of Leith, which can handle ocean-going ships carrying coal.

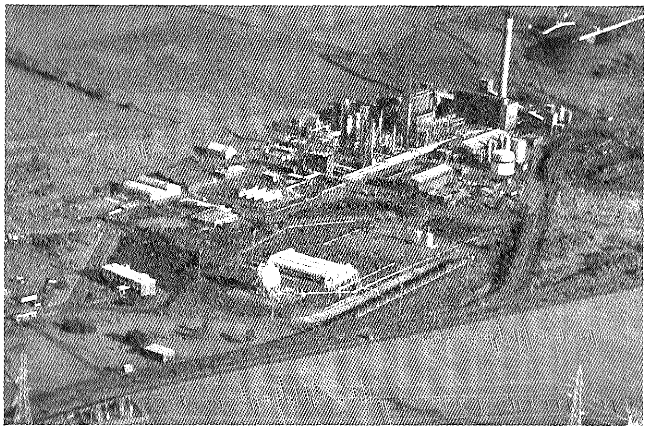


Figure 4.11
WESTFIELD PLANT

In the early 1960's the British Gas Corporation initiated a research program to develop a commercially viable process for the production of high BTU gas from oil and coal. To further this research, the British Gas Corporation founded the Westfield Development Centre at the Westfield Gas Works and there built one of its two Lurgi gasification systems. During 1973 and 1974, while still manufacturing town gas, the Westfield plant was used by the BGC in collaboration with the Continental Oil Company (acting as principal for seventeen other U.S. companies) to demonstrate the purification and methanation of raw gas produced from the high pressure gasification of coal. The project was successfully completed in September 1974 and represented the first commercial demonstration of the production of synthetic natural gas (SNG) from coal.

The Westfield Works was designed to produce 36 million cubic feet of product gas at a pressure of 25 psig using Lurgi gasifiers with LPG enrichment. Toward the end of its town gas days natural gas was used for enrichment. The major component of the plant consists of four Lurgi gasifiers with associated wash towers, waste heat boilers and precoolers. The gasifiers are 9.25 feet internal diameter and operated at 370 psig. Only three were required to produce the design output of the plant and one gasifier is now converted to slagging operations. Other components consist of three coal fired boilers, two oxygen plants, two water gas shift plants, three benzene adsorption plants, two Benfield plants, and two Bischoff towers capable of reducing residual hydrogen sulfide from the gas leaving the Benfield plant from 200 ppm to less than 0.1 ppm; also two gas drying plants, one Rectisol plant, one methane synthesis plant, 700 tons of butane storage and 600 tons of propane storage, 350 tons of methane storage, and various other facilities including plants for effluent disposal, laboratory, workshop, and stores.

The Lurgi gasifier is a steel vessel about 19 feet high and having an outside diameter of 10 feet. Coal enters through a lock hopper at the top of the gasifier. Inside the gasifier, which operates at high pressure and into which both steam and oxygen must be fed, a rotating grate continually cuts through the softening mass of coal to prevent the formation of a gas-tight layer which many produce at elevated pressures. The ash residue from the gasification operation, which enters a lock hopper at the bottom of the gasifier after gasification is completed, has an ultimate flow temperature of 1400°C.

Because the Lurgi process requires the consumption of large quantities of high pressure steam, the British Gas Corporation has considered constructing a process steam plant which could use local fuel. Oxygen is another major component in the gasification process and must be available at all times, especially if the gas produced supplies a public utility. At Westfield liquid oxygen is vaporized and fed to the gasifier at 350 pounds/square inch. The gas from the gasifier is cooled from 450°C to about 196°C and the heat gained from this cooling is used to produce low pressure steam for use in the purification process. The gas is crude and must be purified by removal of benzene, carbon dioxide, and hydrogen sulfide. Finally, the gas must be standardized to correspond to the requirements of the distribution system.

During 1973 and 1974, a series of tests was carried out to determine whether several U.S. coals (Illinois 5, Illinois 6, Pittsburgh 8, and Rosebud) could be successfully gasified in a Lurgi gasifier modified for use in a slagging operation. Removal of the ash in a molten slag form enables the production of up to four times the volume of gas produced in conventional systems of the same size, where ash is removed as a dry solid. The tests were successful using both graded and run-of-mine samples and demonstrated that a wide range of coals is suitable for gasification by the Lurgi process. In two record runs of seven days each, as much as 25 million standard cubic feet of gas were produced. This medium BTU gas is suited to further conversion to a pipeline quality product. The results were instrumental in the decision to maintain the Westfield site in operation as a development center.

In response to several questions pertaining to the gasification of peat, Dr. Bennis Hebden, Program Directed at Westfield, made the following comments:

1. "...Lurgi has run trials on peat. It is possible to gasify peat in the Lurgi Gasifier. We have not run these trials at Westfield. It is not an easy feedstock for gasification. It has moisture that has to be removed before you can gasify it. Both a Lurgi and a slagging gasifier could gasify peat. What you would gain by going to slagging gasification with peat would be a higher output. But really we have no experience with peat..."

2. "Three problems exist with peat. First, how do you get the reaction to go. Second, how do you get the water out in an economical manner. Third, how strong is the peat to enable you to get the high output. The ash content must also be low for an efficient process, say one percent.

3. "You might use low BTU gas production from peat for ore processing. I think it's extractable sort of stuff by our processes. You might consider going just to the low BTU industrial gas and not go to the high BTU gas for residential use which changes your capital costs considerably."

4. "I would suggest that you convert your peat to a producer gas rather than methane, because converting the product of gasification to methane involves a lot of process steps. You have to react hydrogen and the CO which gives out a lot of heat and in all these steps, you inevitably lose heat somewhere because it is a relatively low grade heat and you can't recover it all. This compounds the inefficiencies."

ENERGY COSTS

Peat has become an economically attractive fuel in Finland, Ireland, and the U.S.S.R. In all three countries, as Table 6 indicates, peat was very competitive with fossil fuels in 1975.

FUEL	SOVIET UNION	FINLAND	IRELAND
	Dollars per Million BTU		
COAL	1.00*	1.80	--
OIL	.92	2.34	5.41**
NATURAL GAS	.89	2.60	--
PEAT	.57	1.15	3.07**

*Estimated
**1974 Figures

Table 6.
ENERGY COSTS

It should also be noted that European technicans have somewhat different estimates of the overall energy efficiency of fuel peat operations. Soviet engineers estimate that they obtain three units of energy output for every unit of energy input. Finnish engineers, on the other hand, estimate that they obtain 250 units of energy output for every unit of energy input. Between these extremes are the Irish and Swedish engineers who estimate that they obtain roughly 100 units of energy output for every unit of energy input.

5. RECLAMATION

OVERVIEW

Reclamation of peatlands is a common practice in all European countries where peat has been extracted for fuel and horticultural purposes. Many of the peatlands in Scotland, Germany, Finland, the U.S.S.R., and Ireland have been dramatically transformed into productive land for crop and tree production, or reclaimed to recreational uses, fish production, and wildlife habitat areas. In all European peat producing countries there are now laws pertaining to the depth of peat which must be left in place by harvesting operations and laws pertaining to the use of harvested peatlands. Many of these countries also support research on the suitability of reclamation crops, land preparation techniques, water control practices, and fertilizer requirements, and through such research attempt to establish general management guidelines for reclaimed peatlands.

Although the European reclamation efforts on peatlands have provided much useful information that would assist in the development of peatland reclamation policies for Minnesota, they either have been on a relatively small scale or have not been completely developed. The only large-scale and completely preplanned reclamation efforts in the world are those carried out by the German Brown Coal Industry. The brown coal (lignite) mining and reclamation operations are characterized by planning of the entire process before the land is disturbed. Although the brown coal mining operations are completely unlike peat harvesting procedures (large amounts of overburden must be removed because the brown-coal seams are often several hundred feet beneath the surface, in contrast to peat deposits which have little or no overburden and are of the order of 10 feet in depth), many aspects of the reclamation technology can be related to reclamation of harvested peatland areas in Minnesota if intensive harvesting becomes a reality.

Research in peat reclamation practices has normally been carried out by agricultural research institutes such as the Macaulay Institute for Soil Research in Aberdeen, Scotland. In Scotland, which probably has some of the oldest reclaimed peatlands in Europe, there are many areas where all of the peat has been removed, and these areas now constitute some of the most productive agricultural lands in the country. The Institute has developed reclamation practices for harvested and burnt-over peatlands, outlined proper drainage techniques, established fertilizer and lime requirements, and has examined the most suitable cultural practices for reclaimed peatlands.

The Peat Institute in Bremen, Germany has been one of the leaders in peat reclamation research. The large developed bogs in northern Germany, located mostly on an extensive glacial sand plain extending northward to the North Sea and westward into Holland, have been used for the production of fuel and horticultural peat for many years. Research at the Bremen Institute and elsewhere has led to the reclamation of these harvested peatlands for vegetable, tree, and forage production. Early efforts at reclamation included mixing the underlying sandy soil with peat to improve soil productivity, and more recent reclamation practices have included growing crops on the shallow peat layer left after harvesting. As a result of reclamation research, the German government now requires peat producers to leave at least 18 inches of peat at the bottom of a harvested bog.

FINLAND

In Finland, reclaimed peatlands are placed primarily in tree production. Because the forest products industry in Finland is the country's chief export industry, the use of reclaimed peatlands for forestry contributes in an important way to the national economy. The Finnish forest industry, in recognition of this fact, has established numerous research stations around the country. The Forestry Research Institute has studied bog drainage and hydrology, peat growth rates, vegetative growth rates under various management practices, and some environmental implications of peatland forestry. The Institute also has a very active peat survey team which includes soil scientists, foresters, geologists, and agricultural engineers. The survey team is presently completing a survey of the country's fuel peat resources. Finland has more than 17 million acres of peatland, of which almost 10 million acres are in forestry (Scotch pine, Norway pine, spruce, aspen, birch) and over 600,000 acres in crop production, primarily vegetables, fruits, and forage. In some places in Finland harvested peat bogs are also used *in situ* to treat municipal wastes. There were 20 such treatment systems active in 1975. The Finnish government, like the German and Soviet governments, requires that peat producers leave at least 18 inches of peat on harvested bogs.

SOVIET UNION

In the U.S.S.R., harvested peatlands are reclaimed primarily to agricultural production, although some areas are being reforested. All bogs less than 5 feet in depth are reserved exclusively for either agriculture or forestry. About 2 million acres of peatland are currently being used for agricultural purposes in the Soviet Union. Much of this land has been reclaimed following peat harvesting. One important reclamation problem studied by Soviet researchers has been peatland drainage. As Dr. Kortchunov of the Peat Research Institute explained: "It was not long ago that we at the Institute thought it was absolutely necessary to just drain the area, but now the problem is to regulate the moisture content in the peat... The ditch system then performs two functions: first it lowers the ground water for [harvesting] the peat, and then it is used to supply the area with water so it can be further used in agriculture."

IRELAND

A considerable portion of Ireland's 3.5 million acres of peatland has been converted to grass and crop production as the deep peat has been cut away for domestic fuel over the centuries.

Since Bord na Mona was established in 1946, moreover, 130,000 acres of peatland have come under production, requiring a more careful and systematic examination of reclamation practices and potential. The responsibility for carrying out such research rests primarily with Bord na Mona and the Irish Department of Agriculture (Lullymore Agricultural Research Institute). Since about 1960, the Department of Agriculture has carried out numerous experiments pertaining to the suitability of vegetable, grass, and tree varieties for peatland culture, and has also studied beef cattle production on harvested bogs. Because agriculture is vital to Ireland's economy and because the country needs to bring as much land as possible into cultivation, the government requires that all harvested peat bogs be reclaimed and put to agricultural use. On poorer types of peat, which would not be suitable for cash cropping, tree and grass production could be established after harvesting. In the last 10 years a forest area of approximately 20,000 acres has been established on harvested raised bogs in the Irish Midlands. In many ways Irish reclamation efforts can be considered exemplary of peat reclamation techniques in Europe.

Figure 5.1
HOUSING AREA

A bog in Ireland will usually be worked about 35 years before it is turned over to reclamation. This means that at the present rate of harvesting, Bord na Mona's larger bogs will be worked out in about 25 years. Already a small bog at Lyrecrumpane, County Kerry, has been completely harvested and turned over to the Department of Lands for reclamation. In 1972, portions of another harvested bog near Clonsast, County Offaly, were placed under cultivation. To date, Bord na Mona has

Figure 5.2
MIXED CROPS

Figure 5.3
VEGETABLES

developed more than 500 acres of harvested peatland for grass production and produced from that grassland over 100 tons of beef (live-weight gain) and 25 tons of mutton (live-weight gain). Research in reclamation practices has also been carried out at the Lullymore Agricultural Research Institute, County Kildare, where experiments have been conducted in matching reclamation practices to peat subsoil conditions in an effort to identify harvesting techniques which will not inhibit cultivation of a harvested bog. Since harvested bogs will have been partially drained and levelled, and will be left with between 18 inches and 5 feet of peat, they will possess valuable potential for agricultural crops, grassland, forestry, and recreational areas.

Previous experience has shown that on both milled and sod peat production areas, grass and beef output equals that on good mineral upland soils. While researchers have encountered some water ponding and drainage problems, and some difficulties with soil acidity and plant nutrition, they believe all these can be overcome with proper management and cultural practices.

Although reclamation practices will vary somewhat from location to location, there are some general principles which must be applied:

1. *Drainage System.*

   An adequate drainage system must be developed after peat removal. Ditch spacing varies with the amount of rainfall in a particular area, although ditches on reclaimed bogs are usually spaced not more than 1000 feet and not less than 300 feet. Because harvested areas are frequently left in an "over drained" condition, ditches are sometimes back-filled in order to provide sufficient moisture for crop production.

2. *Grading Land.*

   Most reclaimed areas need levelling and some should be cambered between ditches to allow surface runoff of rain water.

3. *Crop Production Practices.*

   a) An initial fertilizer treatment is needed to correct for phosphorus and potassium deficiencies.

   b) Lime is needed on peats if pH is below 5.0.

   c) Application of proper minor elements such as copper, manganese, and boron is needed for certain vegetable and grass crops.

   d) Preparation of a desirable seed bed by disking and rototilling is necessary.

   e) Use of proper weed control chemicals for specific crops is required.

According to Andy Cole, Lullymore Agricultural Research Institute, most well decomposed (fen) peat is "a wide range soil," is especially good for growing vegetables, and should not be harvested thoughtlessly: "There is no problem about moving all the raised part of the raised bog. I think when one gets to the fen peat below...there would be a question as to how much of it to leave and where to leave it and so on. There would tend to be a conflict between the energy user and the agricultural user."

The Department of Lands, which has recently started to place greater emphasis on recreational opportunities, has turned to harvested peat areas as potential sites for artificial lakes for water skiing, sailing, canoeing, fishing, and hunting. These lakes would be linked to the river system in the Midland district. Other harvested areas could be used for the establishment of wildlife habitats. Such areas are now being planned next to forested tracts by the Forest and Wildlife Service of the Department of Lands. Peat reclamation requires sophisticated management practices, and because most peatlands have more than one potential use, there will always exist a certain competition among potential uses.

GERMANY (BROWN COAL)

The Rhineland coalfield in North Rhine Westphalia, contains over 55 million tons of brown coal (or lignite), making the region one of Europe's most important energy centers. The lignite is extracted from huge open-pit mines resulting in large areas of disturbed land. The German reclamation approach is characterized by planning and carrying out the mining processes as one continuum for early planning to final restoration of land and its succeeding use. Since the coal field is located in a populated region with settlements dating back to Roman times, whole villages lying in the path of the mining operations sometimes had to be evacuated and relocated. Even before mining begins, detailed concepts must be worked out for the new landscape which will follow. The topography, the water drainage system, lakes and forest, and the intended land-use pattern are designed and specified in advance. Early, detailed planning makes it possible to coordinate mining and concurrent land reclamation activities. The comprehensive approach permits treating the overall problem as a whole rather than dealing with separate aspects on a piecemeal basis.

On March 1, 1966, a special team appointed by President Johnson traveled to West Germany to learn about German conservation methods and to study air and water pollution control programs. The findings of the study team with regard to strip-mine land restoration are as follows:

The German practice of restoring their strip mined areas to productive use contrasts sharply with common practice in the United States. Restoration of 'stripped land' *is considered in Germany part of the cost of doing business. Mining firms are required by law to formulate plans for restoring the landscape before the first spade of land is turned... The Rhineland brown coal area developed an exemplary problem for exploitation of the resource, restoration of the landscape, and reconstruction of the social, economic, and cultural life of communities formerly located on mine sites. It involves cooperation of the state and mine operators, with consultation with representatives of all affected local citizens. The goal is to exploit the deposits at economic cost but, through planning and exercise of government initiative, to leave the neighborhood a better place than before the mining started. ... By contrast, the work of mine restoration in the United States is in its infancy. ... A thorough understanding of the German approach to mine restoration would be helpful for those who are now attempting to find solutions to the problem in this country.**

The largest solid lignite deposit in Western Europe, covering 970 square miles and containing 60 billion short tons of brown coal, is located in the Federal Republic of Germany in the triangle between Cologne, Duesseldorf, and Aachen. The lignite seam averages a thickness of 160 feet, occasionally branching out into as many as five separate seams. With modern machinery about 13 million short tons of brown coal can be mined, in places to a depth of 1,650 feet. During the last two decades, moreover, mining technology has been characterized by two developments: growing annual production rates--from 66 million to 105 million short tons between 1950 and 1972--and a shifting from the conventional flat open mines to deep open mines.

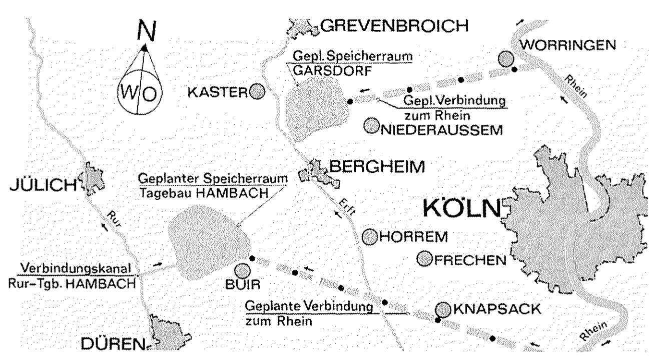


Figure 5.4
BROWN COAL AREA

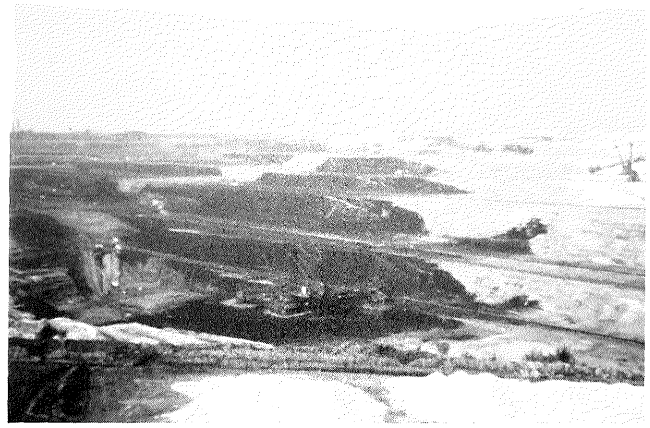


Figure 5.5
MINING AREA

In the Rhineland, brown coal mining has to cope with a number of complicated factors:

1. The open cast mines are in the vicinity of various cities which are situated in the agricultural district where wheat and sugar beets are mainly grown.

2. Railways, highways and rivers are in the mining area.

3. The brown coal district in the Rhineland has a population of one million inhabitants, excluding the populations of Cologne, Duesseldorf and Aachen. The population density of 1070 inhabitants per square mile makes the region into one of the most densely populated parts in Europe.

To make the open-cast mining process economical, the Germans developed large machinery to remove the overburden, mine the brown coal, and replace the overburden in the areas to be

---
*E. A. Nephew, *Surface Mining and Land Reclamation in Germany*, Oak Ridge National Laboratory, ORNL-NSF-EP-16, May 1972.

reclaimed. These machines are over 600 feet long and have capacities of about 130,000 cubic yards of material per day. A new machine having a capacity of 260,000 cubic yards per day has recently been constructed.

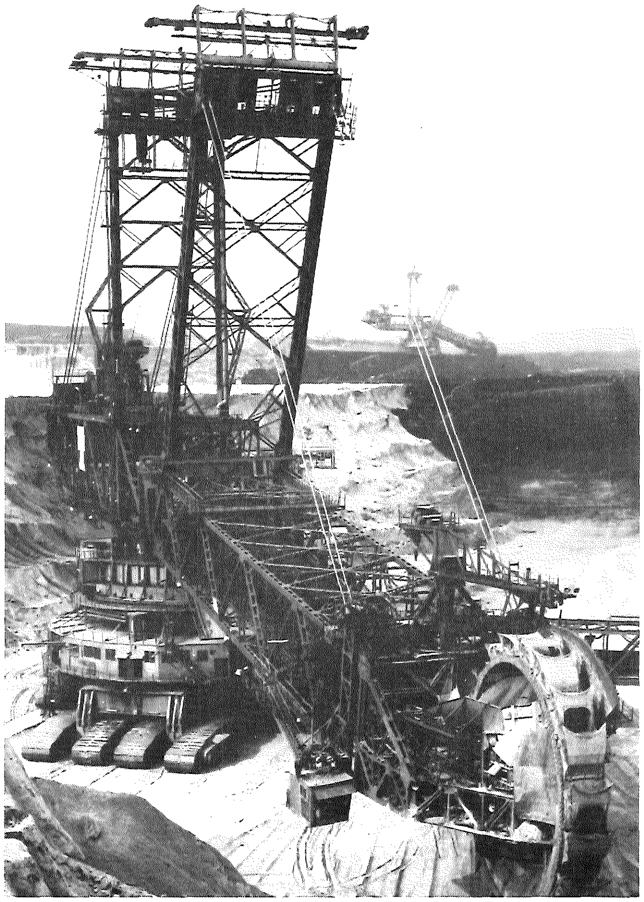


Figure 5.6
BUCKET WHEEL EXCAVATOR

Open cast mining in such a district brings about very particular problems such as land reclamation and the resettling of communities, both of which are required because of the demand for land. Various problems had to be evaluated and an appropriate resolution of conflicting interests had to be found. This necessitated a well-in-advance information program directed toward the people living in the area and, for that reason, an information center was set up. Almost 50,000 people visit the center annually.

Areas have been reclaimed for forestry, agriculture, recreation, and housing. Much can be learned from the German experience.

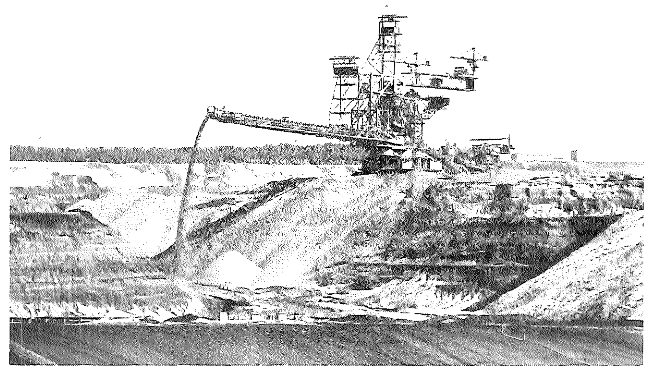


Figure 5.7
RECLAIMING OPERATION

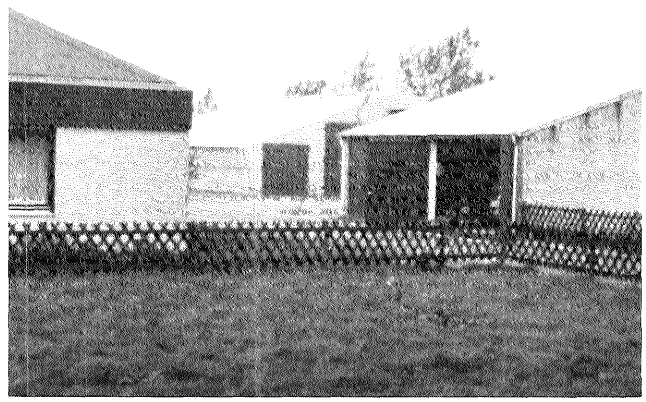


Figure 5.8
FARMING

Figure 5.9
HOUSING

NOTES

NOTES

NOTES

NOTES