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WORLD BANK TECHNICAL PAPER NUMBER 41

WTP- 41

Fuel Peat in Developing Countries

Bord na Móna (Irish Peat Development Authority)

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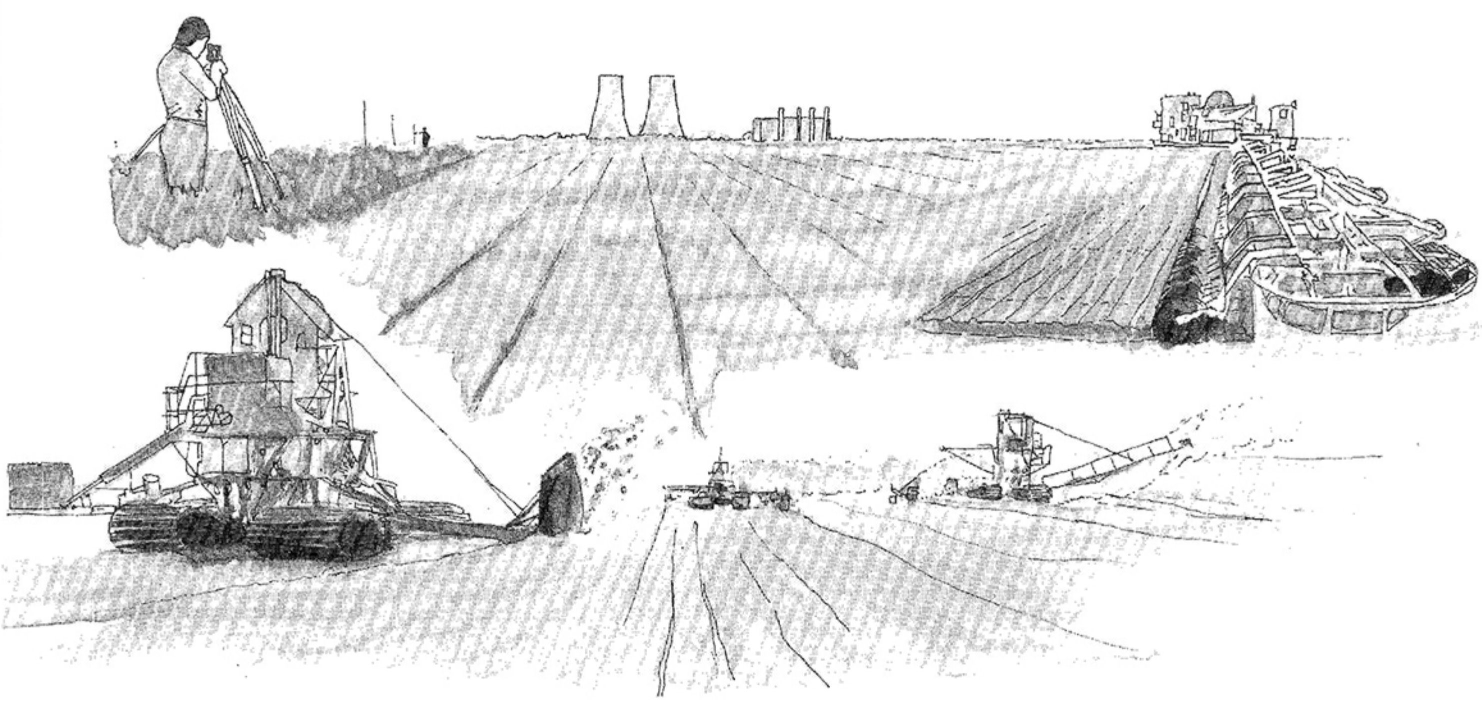

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Bord na Móna (Irish Peat Development Authority, Lower Baggot Street, Dublin 2, Ireland) is a parastatal organization that was established in 1946 to develop Ireland's peat resources.

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ABSTRACT

The study presents a review of fuel peat formation, types, energy content, harvesting, processing, distribution and utilization. It contains basic information on fuel peat production costs in developed countries and assesses the applicability of this technology to developing countries. A major portion of the study reviews the resources and current activities in the developing countries.

Extensive fuel peat reserves exist in developing countries, but much is yet to be done in defining the type, fuel value and reserves. The smaller tractor-attached harvesting equipment is most appropriate for developing countries, and the more advanced peat densification and conversion to high-heat value solids, liquids and gases is either too capital-intensive or not well enough proven for introduction into developing countries at this time. Costs are very site specific, but sod peat production using tractor-operated machinery appears to have the greatest potential for application in developing countries.

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FOREWORD

The World Bank's efforts to assist in the development of fuel peat as a local energy source were hampered by a lack of easily available information on peat resources and activities in developing countries. To overcome this problem and to provide a reference work for policy-makers, the Bank sought a consultant qualified to prepare a paper which would report on peat reserves in developing countries, describe current peat activities in developing countries and assess applicability to developing countries of current peat harvesting, upgrading and utilization technology. Since there exist several good reviews of technology, it was decided to minimize the description of current technology and to include only enough to make the assessment of its applicability understandable.

The Bank staff prepared an outline and a scope of work for a consultant and then requested and evaluated proposals from five qualified candidates. Bord na Mona was selected to prepare the report. During preparation of the report, it became apparent that the results would be more useful if cost data could be included. Bord na Mona agreed to present Irish cost data in the final report.

The resulting paper is intended as guidance both for World Bank staff and authorities responsible for fuel peat in developing countries.

Marianne Haug
Assistant Director, Operations
Industry Department

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GLOSSARY

Ash fusion point - The temperature at which ash converts from a solid into a liquid state. For peat ash this is normally within the range 1100°C to 1400°C - see p5.

Artificial dewatering - The removal of water from peat by means other than by natural solar drying - see p34.

Beneficiation - The upgrading of a peat feedstock to a fuel form with a higher calorific value. The process uses part of the energy content of the original feedstock, e.g. Peat Derived Fuel (PDF) and the Koppelman Process - see p34.

Boreal Zone - The coniferous forest zone of the Northern Hemisphere characterised by cold winter climates. The zone stretches from Northern Canada, across Scandanavia and the USSR to Siberia.

Briquetting - A process which employs artificial drying to reduce the moisture content of peat to around 10% and compresses the dried peat into "briquettes" of 186 x 70x 30-40mm dimension using simple crank extrusion presses - see p32.

Conditioning - The lifting and turning operations carried out to aid solar drying of sod peat prior to harvesting and stockpiling.

Conversion - The changing of solid peat fuel into another energy form, e.g. gasification, liquefaction - see p35 and 39.

Densification - The production of a uniform quality, higher specific energy fuel from a particulate peat feedstock, e.g. briquetting, pelletizing - see p32.

Detrital ooze - An organic mud of algal origin or formed by the almost complete breakdown of aquatic plants. This may underlie lacustrine peat deposits and generally has a higher mineral content than the peat.

"Drowned-valley" mires - Valley peat deposits which have been subjected to a rise in the regional watertable, to such an extent that they can no longer be drained by gravity. Examples occur around Lake Victoria in Uganda and also in Rwanda and Burundi.

Dystric - Peat deposits (Histosols) with a pH of less than 5.5 at least in some part within 20-50cm from the surface, and lacking permafrost within 200cm of the surface - as defined in the FAO/ UNESCO Soil Map of the World [75].

Eutric - Peat deposits (Histosols) with a pH of 5.5. or greater at least in some part within 20-50cm from the surface, and lacking permafrost within 200cm of the surface [75].

Eutrophic - Rich in plant nutrients.

Evapotranspiration - The combined evaporation from the soil/ peatland surface and transpiration, or water vapour loss, from plants.

Flash Drying - The removal of mosture as a stream of small particles (peat) falls through a current of hot gas.

Fluidized Bed - A bed of solid particles which is transformed by the upward passage of a fluid/gas of sufficient velocity to separate, lift and support the particles - see p48.

Histosol - Soils that are predominantly organic, containing at least from 12 to 18% organic carbon, by weight, depending on the clay content of the mineral friction. More commonly called bogs, moors, muskegs, peats or mucks.

Humification - The microbial breakdown or decomposition of plant residues to form amorphous organic matter. The degree of humification in peats is usually measured on a 10-point scale after von Post - see p3.

Hygroscopic - Applied to substances which readily absorb moisture from the atmosphere.

Impulse Radar - Radar systems which send pulses of electromagnetic energy and record the reflected signal. They may be used in peat depth mapping to record the subsurface interface between the peat and the underlying mineral material.

Isopachyte - A line drawn on a map through points where a particular stratum (peat) has the same thickness.

Lacustrine deposits - Deposits which have accumulated in a lake, or former lake, by sedimentation.

Launders - The steel runners on which briquettes are air-cooled en route from the presses to the baling machines or store.

Limnetic, Limnic - Of open water in a pond or lake. Applies to peat formation in deep water by free-floating or deeply rooted plants.

Limnogenic mires - Peat deposits which form alongside rivers and in lakes and depressions under the influence of limnic water - see p2.

Maceration - The mixing and blending of peat in an enclosed chamber by blades or spirals revolving at high speed. This process breaks up the natural layered structure of the peat and forms a uniform mixture which on extrusion and drying yields a more stable product.

Macroscopic remains - Remains of the peat-forming plants which can be easily distinguished and identified without magnification.

Marl - A water-deposited calcareous mud or clay.

Mesotrophic - Of intermediate nutrient status.

Minerotrophic - Peatlands whose vegetation is fed by water originnally derived from mineral soils or rocks, sometimes via lakes or rivers as intermediates - see pl.

Nett Energy Yield - The energy content of a processed or beneficiated fuel as a proportion of the original energy contained in the feedstock fuel.

Oligotrophic - Poor in plant nutrients.

Ombrotrophic - Receiving only an atmospheric water and nutrient supply - see pl.

Paludification - Formation of mire systems over previously forested land, grassland and even bare rock, due to climatic and hydrological changes. Literally "swamping"

Pelletizing (cubing) - Formation of peat pellets by forcing artificially-dried peat through a perforated steel die. Where the holes in the die are circular, the product is a pellet; where they are square the product is a cube.

Pisciculture - The breeding and rearing of fish in captivity. Fish farming.

Profile - A vertical section through a peat deposit exhibiting the constituent layers.

Sapropel - An organic mud deposited under water of neutral or alkaline reaction, and rich in water-plant, algal and animal remains.

Spontaneous combustion - Combustion of peat, particularly stockpiled milled peat, following internal temperature elevation by microbiological and autocatalytic processes - see p57.

Stratigraphy - The sequence of strata or layers, of different plant origin, which comprise a peat deposit.

Taiga - Northern coniferous forest adjacent to the arctic tundra.

Wet Carbonisation - A thermochemical process which improves the artifical dewaterability of peat - see p34.

Windrow - A row of material formed by combining two or more swaths. In sod peat production this refers to an intermediate harvesting stage where the sods are lifted from the spreadground and left in windrows for further drying before final harvesting into stockpiles.

UNITS AND ABBREVIATIONS

Unit	Description	Conversion
°C	Degree Celsius	
m	Metre (length)	1m = 39.37 in
m^2	Square metre (area)	$1m^2$ = 10.76 sq. ft.
m^3	Cubic metre (volume)	$1m^3$ = 35.3 cb.ft.
ha	Hectare (area)	1ha = 1000 m2 2.469 acre
kg	Kilogram (weight)	1kg = 2.205 lb
t	Metric ton (weight)	1t = 1000 kg
kg/m^3	Bulk Density	$1kg/m^3$ = 0.062 lb/cb ft
W	Watt (power)	1kW = 1.34 BHP
MWh	Megawatt hour (energy)	1MWh = 3.6 GJ 3.4×10^6 BTU
J	Joule (energy)	1J = 0.239 cal 1KJ = 0.949 BTU
MJ/kg	Megajoule/kilogram (Calorific value)	1MJ/kg = 430 BTU/lb
toe	Tonne oil equivalent	1 toe = 40.6 GJ
C.V.	Calorific Value	
p.a.	Per annum	
m.c.	Moisture content	
a.c.	Ash content	
PDF	Peat Derived Fuel	
GNP	Gross National Product	

FAC	Fonds d'Aide et de Cooperation (FRANCE)
FAO	Food and Agricultrural Organization of the United Nations
FED	European Development Fund
FINNIDA	Finnish International Development Association
IDA	International Development Association
UNDP	United Nations Development Program
UNESO	United Nations Education and Science Organization
UNIDO	United Nations Industrial Development Organization
USAID	U.S. Agency for International Development
WB	World Bank

INFLATION AND EXCHANGE RATES

IRELAND

Rates of Inflation (Jan to Dec)

Year						
1980	-	18.2% increase				)
1981	-	20.4%	"		)	) 84%
1982	-	17.1%	"	) 29.2%	) 55.6%	)
19B3	-	10.4%	"	)	)	)

Rates of exchange in Dec. 1980 - IR£ = US$ 1.91
Jan. 1984 - IR£ = US$ 1.12

UNITED STATES

Rates of Inflation (Jan to Dec)

1980	-	13.5% increase				)
1981	-	10.4%	"		)	) 42.2%
1982	-	9.7%	"	) 13.5%	) 25.3%	)
1983	-	3.5%	"	)	)	)

Rates of exchange - in June 1980 - US$ = Canada $ 1.15
June 1980 - US$ = IR£ 0.64

FINLAND

Rates of Inflation (Jan to Dec)

1981	-	12% increase			
1982	-	9.3 %	"	)	) 32.8%
1983	-	8.5 %	"	) 18.5%	)

Rates of exchange - in November 1980	- 3.7690	FMK	= 1 US$
January 1984	- 5.8690	FMK	= 1 US$
1984	- 6.573	FMK	= 1 IR£

EXECUTIVE SUMMARY

Peat, an organic material which develops from the incomplete breakdown of wetland vegetation, may occur as a deposit throughout the world anywhere the natural drainage of rainwater is reduced or impeded. Organic matter accumulates when the rate of production exceeds that of degradation, and peat formation rates range up to 1.6 mm per year, depending upon the vegetation type and climatic conditions.

Peatlands (mires) are most extensive in the temperate, boreal and subarctic zones of the Northern Hemisphere. In the tropics and subtropics extensive peatlands are confined to coastal or mountain plateau areas, with lowland mire formation occurring only under the influence of limnic water. Utilisation of peat deposits depends on their inherent properties and qualities and attempts are being made to standardise the various national systems of peat classification.

The organic components of peat, which vary according to the degree of decomposition, are of primary importance in its use as a fuel. The mineral or inorganic ash content and its behavioural characteristics (fusion point) greatly influence peat fuel combustion. In a calorific comparison with other fuels air-dried peat (35% moisture content) has a slightly higher energy content than wood, while processed and beneficiated peat products approach the lower end of the coal spectrum in calorific value.

An understanding of the conditions required for peat formation allows the prediction of the likely occurrence of deposits. Remote sensing provides initial quantification in terms of deposit area, while ground survey is required for complete quantification and quality assessment. The criteria by which an area may be chosen for detailed assessment include the current land use, topography, accessibility, local labour availability and the marketability of the final product.

Climatic conditions have varying degrees of influence on fuel peat production, depending upon whether "wet" or "dry" production techniques are employed, and upon whether solar energy or artificial processing is used to dry the product. Preparation of a deposit for production may take up to seven years depending upon the initial moisture content, the amount of work required on external arterial drainage and the climatic conditions.

Handwinning is the traditional, labour-intensive method of sod peat production. It was superseded in Europe by large bucket-type dredgers ("baggers") which excavate the peat from a vertical face, blend and macerate the peat and extrude and spread it on the adjacent bog surface. More recently smaller machines powered by agricultural tractors have been introduced for the production of sod peat. Milled peat, the primary method of peat exploitation in Europe since the

1950's, produces peat in crumb or powder form. Milled peat production machines can be manufactured either as powered units or attachments for agricultural tractors. Where adequate peatland drainage cannot be achieved even by pumping, wet harvesting techniques, such as the Hydropeat or Slurry Pond methods, may have to be employed. These may be followed by solar or artificial drying.

The environmental impacts of fuel peat production require careful appraisal, especially ecological and hydrological disturbances and the effects of dust, effluents and emissions. Important socioeconomic effects include changes in land use, influences on the local economy, energy substitution, any reduction in the overall cost of energy importation and the long term potential of peatland reclamation.

In developing countries the tractor-attached sod peat production machinery is the most appropriate for small scale deposits supplying local domestic and industrial markets. Milled peat production is more economical and may be used on extensive deposits to produce fuel for larger industrial applications, for power generation, and for beneficiated products.

While sod peat is easily transported and utilised, milled peat benefits from further processing to improve the economics of transportation and to increase its versatility. Densification, by briquetting or pelletizing, produces a clean, uniform fuel with a calorific value of around 18 MJ/kg. Beneficiation by carbonisation prior to densification can produce higher calorific value products, e.g. Peat Derived Fuel (PDF) 20-24 MJ/kg or K-Fuel 25-30 MJ/kg, at the expense of a proportion of the energy content of the original feedstock. Peat may also be converted into other energy forms by gasification or liquefaction.

Peat densification is capital intensive, and although well proven in Europe, it may be too expensive for use in developing countries. Many of the other peat processing technologies are not yet commercially mature, apart from small-scale gasification which may prove attractive for local electricity generation using converted diesel oil power plants.

Milled peat combustion for power generation accounts for the major proportion of peat fuel utilisation in the developed countries. The introduction of fixed and circulating fluidized bed techniques allows the successful utilisation of higher ash content peats and also effectively limits emissions. Industrially, peat is used for the production of energy or process steam, while at the domestic (household) level sod peat or manufactured peat briquettes are used for space and water heating and for cooking. In the developing countries small-scale peat deposits are most suited for use as a local fuel, replacing wood or charcoal, and helping to maintain the level of forest cover. More extensive deposits may be utilised for electric power generation and for industrial application, substituting for imported energy and reducing the foreign exchange requirement.

Peat and peat products are stored both on the production site and at the consumer end, where precautions must be taken to prevent any rise in the moisture content of the peat. Transportation may be by road, rail or waterway, depending upon the existing infrastructure, conditions, and deposit accessibility. The marketing of peat as a fuel may prove difficult in developing countries in which case a complete market analysis and sales strategy will be required to achieve significant market penetration.

In Ireland sod peat used domestically or industrially in 1984 costs per GJ (gross) of energy about US$3.20 while competitive fuels typically cost $4.13 for house coal, $2.10 to $2.90 for industrial coal, $5.40 to $6.10 for anthracite coal, $9.00 for kerosene, and $6.30 for medium weight oil.

The economics of fuel peat production are site specific, but analysis of current Irish capital and operating costs gives an indication of costs in developing countries, providing due cognisance is taken of the criteria applied. Sod peat production utilising tractor-operated machinery appears to have the greatest application in developing countries, since milled peat processing and beneficiation is very expensive, with peat briquettes costing twice as much as sod peat on an energy related base. Peat production skills and training facilities are available in those countries currently utilising their peat deposits as an energy source.

Currently, USSR, Republic of Ireland and Finland are the major users of fuel peat. USSR produces about 80 million tonnes per year, and has around 6,000 MWe of peat-fired generating capacity. Ireland produces about 4.5 million tonnes per year and has about 520 MWe of peat-fired generating capacity. Finland now produces about 3 million tonnes per year but has plans to increase this to about 10 million tonnes by 1990. Peat contributes 15% of Ireland's total energy consumption, 1.5% of USSR's and 2.0% of Finland's.

Peat reserves are listed for the developed countries, developing countries and centrally planned economies. Reserves are quantified in terms of area, within the limits of the criteria applied to defining peatlands, but a knowledge of the deposit depth, moisture content and ash content is required to allow quantification in conventional energy terms. Many of the figures for developing countries are as yet estimates, derived from reconnaissance soil surveys or from remotely sensed data. An indication of the current status of resource survey, peatland utilisation and fuel peat production is given where this information is available.

SECTION I - INTRODUCTION

Peat is an organic material which develops as a result of the incomplete decomposition of wetland vegetation under conditions of excess moisture and oxygen deficiency. It consists of a heterogeneous mixture of partially decomposed plant residues and inorganic minerals which have accumulated in a water-saturated environment. Its colour varies from amber through dark brown to black depending upon the parent plant material, the degree of humification and the presence of inorganic sediment.

PEAT FORMATION

Peat may occur as a sedimentary deposit throughout the world anywhere the natural drainage of rainwater is reduced or impeded. It is most frequently located in deltas and estuarine systems, along river terraces, in lake and former lake basins and in the valleys of mountainous areas with wet and humid climates. Peat is formed by the accumulation of organic matter when the rate of production of this material, by living organisms, exceeds the rate at which it is respired and degraded. This formation is influenced by local geomorphological, climatic and hydrological conditions and by the nutrient status of the water feeding the peat deposit.

The rate of peat formation is exceedingly slow and varies considerably, primarily due to the influence of the macroclimate. Estimates of Eurasian peat formation rates using carbon-14 dating techniques vary between 0.2mm and 1.6mm per year [1], depending upon vegetation type and climatic conditions. For practical purposes peat cannot be considered as a renewable resource.

MIRE TYPES

Mire is a generic term commonly used to describe all types of peat-forming ecosystems, whether swamp, marsh, fen, bog, moor or muskeg [2]. Mires are most extensive in the temperate, boreal and subarctic zones of the Northern Hemisphere and more limited in the cool and humid zones of the Southern Hemisphere. In the tropics and subtropics extensive peatlands are confined to coastal or mountain-plateau areas.

In warm climates evapotranspiration rates are so high that lowland peat vegetation can develop only under the influence of limnic water. In the cooler, temperate zones and the humid mountain areas peat formation is not confined to groundwater fed basins or depressions. Peat formation may occur beyond the physical confines of the depression and above the limits of the groundwater, with the peat acting as a reservoir which is fed by precipitation and retains the water by capillarity [3]. Mires which have only an atmospheric water and nutrient supply are termed ombrotrophic, while those fed by groundwater or flowing surface water are minerotrophic. Depending upon the mineral and nutrient concentration of the feeding water mires may also be termed oligotrphic (nutrient poor), mesotrophic (intermediate), or eutrophic (nutrient rich).

General distribution of the major mire type complexes:

i) Tundra mires - Minerotrophic and shallow (0.5m) mires of the continuous permafrost regions of Alaska, Canada, the Soviet Union and Antarctica.

ii) Palsa mires - Characterised by ombrotrophic peat mounds several metres high with permafrost cores and wet minerotrophic depressions in between. Occur in the zone of discontinuous permafrost in Canada, northern Fennoscandia and the Soviet Union.

iii) Aapa mires - Flat or concave predominantly minerotrophic complexes which often have a distinct string-flark pattern occur within the boreal zone of Fennoscandia and Western Soviet Union with related complexes in North America.

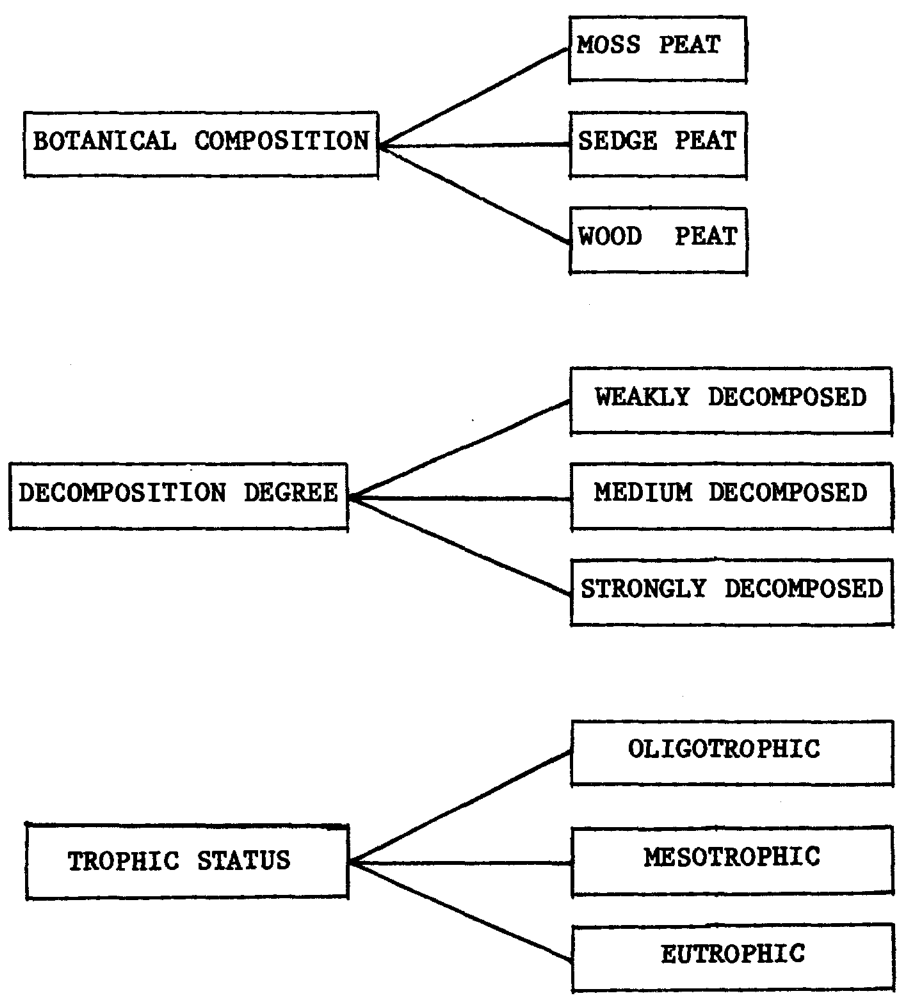
iv) Raised mires - Predominantly ombrotrophic, deep mire complexes with elevated centres. Encountered in Europe, across the Soviet Union, in North Japan and North America. South of this nearly continuous belt they may occur in mountain areas, in the tropical lowlands of Indonesia, Malaysia and Brazil and in the cool-temperate regions of Chile, Argentina and New Zealand.

v) Blanket mires - Mainly ombrotrophic and terrain-covering, these mires occupy relatively narrow coastal areas of Western Europe, the Kamchatka peninsula, Canada, Newfoundland; and in the Southern hemisphere, Southern Chile and South-Western New Zealand.

vi) Southern Limnogenic mires - These include the alluvial swamps and marshes found alongside rivers and the reed and sedge fens which form around lakes or which infill shallow depressions. Examples include the Everglades in Florida, the reed-sedge fens of the Ukraine and the *Papyrus* and *Raphia* swamps in Africa. Limnogenic mires are often strongly minerotrophic and their high ash content can limit their potential utilisation for fuel [70].

PEAT CLASSIFICATION

Peat types vary not only geographically from one area to another but also stratigraphically within a single mire complex, as the result of their formation under successively different climatic conditions and from different plant communities. Historically peat classification was based on observable morphological characteristics such as the surface vegetation, colour, botanical remains, estimated degree of decomposition or fibre content. More recently user-orientated classification criteria have been introduced, which include physical and chemical properties to supplement the visual field observations [2]. Properties specifically related to energy use include calorific value, bulk density, ash content, sulphur content and moisture content. The most widely used criterion for classifying peat is the degree of decomposition or humification. A 10-point humification scale was developed by the Swedish scientist von Post [6] for field mapping of deposits, H1 being completely undecomposed plant remains and H10 an amorphous peat with no discernible plant structure. Many workers find this scale too complex for practical application and modify it to suit their own needs. The proposed International Peat Society classification system [6] is a block system based on decomposition and containing three degrees of decomposition, three levels of base status and three types of plant remains. It attempts to synthesize and simplify the multitude of complex peat classification systems currently in use throughout the world.



UTILISATION

Most peatlands which can be drained may be reclaimed for agriculture or afforestation with suitable nutrient supplementation. Areas with more than one metre depth of peat may have this resource exploited by removing the upper portion prior to reclamation. Effective utilisation of any peat resource is strongly dependent upon its properties and characteristics.

The principal determining factor for peat use is its humification. Weakly humified peats, between H1 and H5 on the von Post scale, are more suitable for use in the agricultural industry than the more highly humified peats, H5 to H10, which are suitable for use as fuel. The horticultural peats have a lower bulk density, a slightly lower calorific value and a high water absorption capacity. Fuel peats in contrast have a higher bulk density, a slightly higher calorific value and do not possess the same water absorption capacity.

SECTION II - PEAT AS A FUEL

In geological terms peat may be regarded as a "young coal", the peat-forming communities of today having many similarities to the giant Pteridophyte swamps of the carboniferous period. However, when considered as a fuel peat exhibits properties which are much closer to those of wood than to those of coal.

ORGANIC COMPONENTS

The organic components of peat, particularly the carbon and hydrogen contents, are of primary significance in its use as a fuel. During decomposition its carbon and nitrogen contents increase while oxygen and hydrogen decrease. This may be illustrated by reference to the degree of decomposition according to the von Post scale.

Table 2.1 Components of different peat grades (% weight in dry solids)

COMPONENT	DEGREE OF DECOMPOSITION	
	Slight H_{1-3}	Medium to High H_{5-9}
Carbon	54-55	56-59
Hydrogen	5.5-6.0	5.3-5.7
Nitrogen	1.0-1.3	1.3-1.5
Oxygen	36-38	34-36

Source: Bord na Mona

ASH CONTENT

Both the type and quantity of inorganic substances found in peat vary considerably and depend upon the prevailing climatic and hydrological conditions during its formation. A proportion of the ash content can be ascribed to the nutrients contained in the plants, but often a greater part consists of substances deposited by wind, groundwater or floods. Ombrotrophic peats, which are formed above the influences of groundwater and receive only airborne and rainfed nutrients, have typically low dry weight ash contents of 1 to 5%. Minerotrophic peats, however, formed under the influence of groundwater and subject to inundation have higher ash contents and grade into organic silts and muds.

Inorganic components are normally closely correlated with adjacent surface geology, the relative proportions of the various minerals having an important influence upon the behavioural characteristics of the peat ash. SiO_3 and Al_2O_3 raise the fusion point of ash while CaO and Fe_2O_3 lower it. In practice the fusion point of peat ash ranges from 1100°C to 1400°C, with a mean value of 1250°C.

SULPHUR CONTENT

The sulphur content of peat is usually very low, within the range 0.1-0.4% dry weight, with around one third of this amount remaining in the ash following combustion. In some minerotrophic formations however, particularly those in former lake basins, higher sulphur levels of up to 4% may occur where sulphide has been produced and deposited by sulphate-reducing bacteria in anaerobic conditions.

CALORIFIC VALUE

The calorific value (C.V.) of peat dry matter is primarily dependent on the peat type, degree of decomposition and ash content. The normal dry matter C.V. range for ash free, medium-decomposed peat from temperate regions is 20-22 MJ/Kg.

Since peat in its natural state normally has a moisture content of over 90% the greatest problem of utilising peat as a fuel is in the reduction of this moisture content to an acceptable level. Different production techniques result in a range of products the heating values of which are normally quoted with reference to their moisture content and bulk density.

Table 2.2 Lower or nett calorific values of fuel peat products.

Product	Moisture Content (%)	Bulk Density kg/m^3	Calorific Value MJ/kg	Usage
Hand cut sod peat	25-40	200-400	11-15	Domestic
Machine sod peat	30-40	300-400	11-14	Domestic, small commercial
Milled peat	40-55	300-400	8-11	Large boilers, Power & Heating Plants.
Peat Briquettes	10-15	700-800	17-18	Domestic, Commercial.
PDF	5-10	750-800	20-24	Domestic Commercial.
K-Fuel	1-5	750-800	25-30	Domestic Commercial

Source: Min. Trade and Industry, Finland [8]; Myreen, Energy Digest [34]

COMPARISON WITH OTHER FUELS

In comparison with other fuels air dried peat has a slightly higher energy content than wood, since it contains a higher proportion of fixed carbon and less volatile material. Processed peat, with a lower moisture content and increased volume weight, approaches the lower end of the coal spectrum in calorific value.

Table 2.3 Average calorific values of different fuels

FUEL	Moisture Content (%)	Bulk Density kg/m^3	Lower or Nett Calorific Value MJ/kg
Milled Peat	45	350	10.5
Wood (Biomass)	30	370	12.5
Machine sod peat	35	350	12.8
Peat Briquettes	15	750	17.0
PDF	10	770	22.0
Coal	9	800	25.0
K-Fuel	5	800	27.0
Anthracite	5	870	29.3
Heavy Fuel Oil	-	950	40.6

Source : Min. Trade and Industry, Finland [7]

CURRENT FUEL USAGE

Peat has been used as a form of energy in many countries for at least 2000 years and on an industrial scale since before World War I. It is often a local fuel, extremely valuable in remote areas which lack other indigenous energy forms.

In the developed countries peat is used for domestic heating and cooking, for commercial and industrial boilers and for large scale power and district heating plants. The largest fuel peat producers are the Soviet Union, Ireland and Finland, with peat playing a significant role in the energy economy, especially in Ireland and in the Moscow/Leningrad region of the RSFSR. Large scale fuel peat production throughout the world increased from 47 million tonnes p.a. in 1950 to around 90 million tonnes p.a. in 1980 [7].

Other developed countries with considerable peat reserves who are actively pursuing the potential of peat as a fuel include the United States, Canada and Sweden, especially as an appropriate fuel in less accessible areas.

Current usage of peat as a fuel in developing countries is extremely limited. China, Rwanda and Burundi are currently producing fuel peat and other countries interested in developing their resources include Brazil, Greece, Indonesia, Jamaica and Senegal. Peat as an energy source may be developed at varying scales in these countries, depending upon local conditions. On a small scale it may replace scarce firewood as the principal source of household energy. On a larger scale it may be used for industrial steam and power generation, substituting for imported fuels and exercising a positive effect upon the national trade balance.

The latest figures for peat production supplied to the International Peat Society relate to 1980 and reflect the relative importance of fuel and horticultural peat in the developed countries.

Table 2.4 World fuel peat and horticultural peat production 1980 (10^3 t/a, 40% moisture content)

Country	Fuel Peat	Horticultural Peat	Total
USSR	80,000	120,000	200,000
Ireland	5,570	380	5,950
Finland	3,100	500	3,600
FRGermany	250	2,000	2,250
China	800	1,300	2,100
USA	0	800	800
Canada	0	490	490
Poland	0	280	280
Sweden	0	270	270
Czechoslovakia	0	270	270
GDR	0	170	170
Great Britain	no data	170	170
France	50	100	150
Denmark	0	110	110
Norway	1	83	84
New Zealand	0	10	10
Others	100	2,900	3,000
TOTAL	c. 90,000	c. 130,000	c. 220,000

Source: Kalmari, Bandung Seminar [7]
United Nations Conf., Nairobi, 1981 [8]

SECTION III - RESOURCE SURVEY

In many developing countries the peat resources are unknown or are at best only partially quantified. An understanding of the conditions required for peat formation allows the prediction of the likely occurrence of peat deposits. This is based on the climatic, topographical and hydrological factors which together with the successional plant communities ultimately govern the incidence and rate of formation. Such predictions, which may be formulated without recourse to groundwork, can be used to prepare a generalised distribution scheme, outlining the probability of occurence rather than the location of exact units, as a preparation for more detailed surveys.

INITIAL QUANTIFICATION

Field operations in peatland resource survey tend to be costly, time consuming and physically demanding on the survey personnel. For these reasons as much information as possible is collected before groundwork commences. Existing soil, terrain, hydrographic and vegetation maps in the scale range 1 : 10,000 to 1 : 250,000 are the most useful for integrated analysis of existing data and for planning further survey.

The spectral characteristics of peatland vegetation communities and the specialised relationship of the plants with the underlying organic strata have long been used as a means of remotely assessing, defining and initially quantifying the type and area of peat deposits. Aerial survey, using the full range of black and white, colour and infra-red photography, has played a significant role in the quantification of the peat resources of many countries.

More recently the multispectral imagery obtained by satellite scanning has been used in peat resource survey. The Macaulay Institute, Scotland and the Ontario Centre for Remote Sensing, Canada have developed methodologies for processing and enhancing the digital information available from the LANDSAT series of earth resource satellites for this purpose [11,13]. Although ground resolution is low in comparison with what can be obtained from aerial photography, space imagery does have the advantage of repetitive coverage and can provide information on features unobtainable by any other means [14]. Increasing interest is also being shown in the use of Synthetic Aperture Radar, which is not limited by cloud cover and may prove to be a useful technique in resource inventory, given the humid climatic conditions under which many peatlands are formed.

RESOURCE ASSESSMENT

Detailed assessment of a peat resource can only be accomplished by ground survey. Working from base lines a team normally conducts close grid topographic and stratigraphic surveys using levelling and sampling equipment [61].

The ground survey team records the surface vegetation, density of tree cover, topographic level, peat depth, peat type based on macroscopic remains, humification, moisture regime, apparent fibre content, incidence of woody remains which may hamper mechanised production operations, presence of marl, detrital ooze or sapropel and the nature of the sub-peat mineral soil. This information is used to prepare working site maps for access, drainage systems, top and bottom contours, isopachytes and also to construct sections and profiles showing stratigraphic sequences and topographic relationships [12].

Recent investigations into the use of impulse radar systems for measuring peat depth and determining the volume of deposits have shown good correlation with manual depth measurement. Results obtained by towing the radar antenna behind an all-terrain vehicle show satisfactory profiling at speeds of 5 km/hr but attempts at airborne measurement have not yet proved successful [15,16].

QUALITY ASSESSMENT

In addition to the extent and depth of a peat deposit it is important to know its quality before decisions are taken on its eventual use. Peat types vary stratigraphically within a deposit, according to the peat-forming vegetation and conditions of deposition, and samples for qualitative analysis should be taken at regular vertical intervals within the profile.

Standard laboratory analysis is used to determine the moisture content, bulk density, ash content, calorific value, absolute fibre content, pH, ash fusion point, nutrient content and permeability of the sampled peat, the results allowing final decisions to be reached on the most effective and economic utilisation of the resource.

SELECTION CRITERIA

Having remotely assessed a peat deposit and obtained some idea of its area and probable energy content, certain criteria must be applied to determine whether or not a more costly detailed assessment of the resource is justified. These criteria include:

- Current land use - if the mire is currently under cultivation in an area where land is of primary importance for food production, then exploitation of the peat for energy may only be justified if reclamation processes will not reduce the productive capacity of the peatland.

- Topography - the topography of the mire should be suitable for production and transport operations, permitting the desired level of mechanisation.

- Accessibility - the deposit should be either accessible by road, rail or waterway, or else be positioned so that access can be provided at a reasonable cost.

- Labour - sufficient local labour should be available for production operations, or if not a study of the economics of either labour transportation or the provision of worker hostels should be undertaken.

- Markets - a suitable market, or the potential for one, should be available for the final product. The market should be within reasonable distance in order to minimize transport costs and be allied to the deposit size and the planned rate of fuel production.

A cursory examination of the mire may be necessary before some of the above criteria can be applied, and if fuel peat production still appears feasible, a more detailed quantitative assessment should be undertaken.

SECTION IV PRODUCTION AND HARVESTING TECHNOLOGY

Manual cutting, the traditional method of producing peat for fuel, has been carried out in various parts of the world for at least 2000 years. Machine production of peat commenced in Europe in the mid 19th century and with many subsequent innovations, modifications and improvements progressed to the highly mechanised technology in use today.

CLIMATIC CONDITIONS

The climatic conditions required for peat production depend upon whether "wet" or "dry" production techniques are employed, and upon whether solar energy or artificial processing is used to dry the product. Conventional "dry" techniques, producing sod or milled peat, rely on gravity or pumped drainage to reduce the moisture content of the in situ peat coupled with passive solar drying of the products. For these processes a reasonable period of minimum rainfall, with temperature and humidity characteristics which provide positive evaporation, is essential. Unstable weather conditions of alternating rain and sun, under which rewetting of semi-dried peat is likely to occur, will tend to favour either the production of sod peat, which forms a moisture resistant outer "skin", or the pneumatic harvesting of milled peat, which lifts only the light, dry particles. When using natural drying, yields will be greatest in regions where the climatic conditions produce maximum evaporation.

Wet methods of peat production, including artificial dewatering, are relatively independent of climate and may proceed throughout the year provided that the peat is not frozen. Climatic conditions are important, however, if solar energy is utilised to dry wet-harvested peat, when evaporation potentials similar to those for conventional milled and sod peat production are required.

PREPARATION

Preparation of the deposit for exploitation must be carefully planned and executed, since it is on this that the success of perhaps 20 to 30 years of production will depend. Although peat is a surface deposit, and rarely requires removal of any overburden, preparatory operations may require from 1 to 7 years before mechanised production and harvesting can commence.

Drainage: Virgin peatland normally has a moisture content of 85 to 95% and it is the progressive reduction of this humidity, to levels at which the production machines may operate, which will govern the period of time required for development. Drainage is normally effected by opening ditches at regular spacings, using low bearing pressure ploughs, disc-ditchers and hydraulic diggers, which connect to main outfalls and eventually lead to the catchment stream and river system. Progressive deepening of the open surface drains gradually removes the water and increases the percentage dry matter content of the deposit.

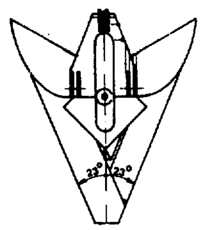
Surface preparation: The "fields" formed by the regularly spaced drains are cleared of vegetation and cambered at the edges to give a slightly convex cross section using specially developed machinery. This cambering increases the surface runoff which effectively removes any incident rainwater.

Timber removal: Peatlands with a natural tree cover must have this cut and removed during preparation. The stumps are grubbed out using a "stump drag" mounted on an excavator which is capable of clearance to a depth of 1.0m. Smaller timber fragments may be pulverised by deep rotary milling to 40cm depth, an operation which also reduces the capillary rise of water and promotes surface drying. The crowns and smaller tree trunks may be used as an underlay during road or rail construction.

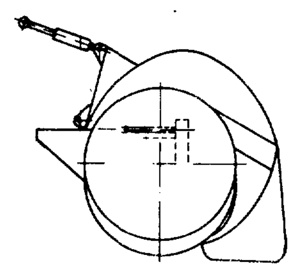
Transport systems: External off-bog systems are required to transport the peat products to the areas of utilisation and also to facilitate workers travelling to and from their places of abode. In large production areas internal systems may be required for worker and machine transport in addition to peat haulage.

Fire precautions: Water reservoirs should be excavated at suitable locations throughout the production area and access provided to nearby streams, rivers or lakes. Suitable firefighting equipment should also be provided.

Building: Facilities for staff and for machine maintenance, either temporary or permanent, will be required on site.

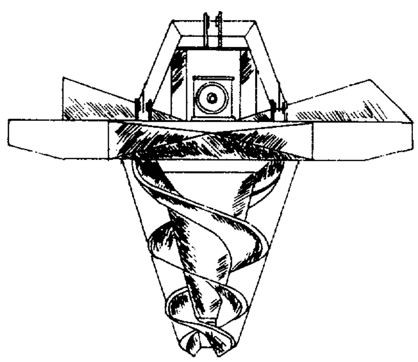


Rear View

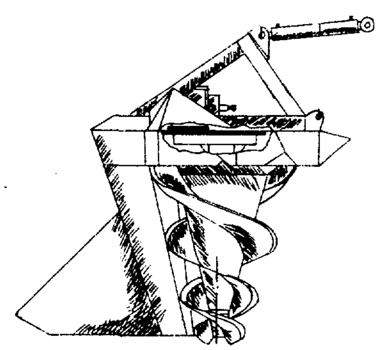


Side View

CUTTER DITCHER

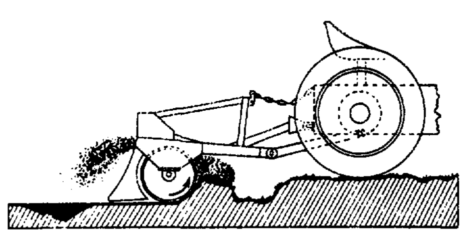


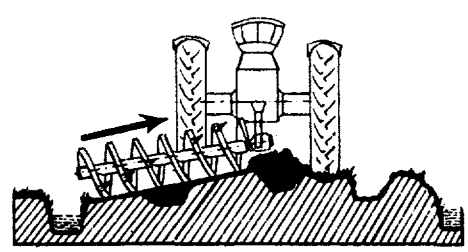
Rear View



Side View

SCREW DITCHER





SCREW LEVELLER

Fig. 4.1 - Bog Preparation Machinery

Source: Suokone Oy; Finland
Herbst Group; Ireland

SOD PEAT PRODUCTION

Handwinning of sod peat is a very old and traditional method of fuel peat production. It is a labour intensive process and results in a relatively low-density fuel which is very weather dependent during harvesting. While still practiced in some regions, especially in Western Ireland and the north of Scotland, this method is now being replaced by newer mechanical methods of production.

Mechanical production of sod peat commenced in the mid 19th century and was further developed during World War I. For over 60 years in Western Europe sod peat production has been carried out using mainly bucket type dredgers, termed "baggers" (German). They are powered by diesel engines or electric motors. They excavate from a vertical face 2-4m high, macerate the peat, extrude and spread it in strings that dry into angular sods on the adjacent bog surface. Starting from deep central drains at 220-250m centres the peat is initially spread and dried on the bog surface and later, as high bog excavation progresses, it is spread and dried on the cutaway. Maximum spread width is 60m and the working area of each machine is around 240 ha. Output in Ireland ranges from 100 to $140m^3$ per hour at 88-91% moisture content. This output eventually yields 11 to 16 tonnes per hour of peat at 35% moisture content, annual output being 25,000 tonnes per machine.

Smaller diesel-powered machines are also being used. These have outputs in Irish climatic conditions of $60m^3$ per hour, which will eventually yield 6-7 tonnes per hour of air dried peat at 35% moisture content. Spread width is up to 22m and the machine working area is approximately 100 ha. The smallest machines are available in a range of sizes capable of producing from 4 tonnes per hour upwards of air-dried peat. Specialised machinery has been developed for windrowing, turning, collecting and stockpiling sod peat [29].

Advantages of using dredger-type machines for sod peat production include their ability to mix and macerate peat from different stratigraphic layers in the bog. This is ideal in the Raised Type bogs of Western Europe where light, fibrous Sphagnum peat from the surface is mixed with the denser, highly humified fen peats below, producing sods with excellent mechanical stability and high calorific value.

Sod peat machines with outputs of 3000 to 6000 tonnes p.a. of air-dried peat at 35% moisture content, which are available as attachments for agricultural tractors, are more suitable for small production operations. With this system the power units may be used for other work outside of the peat production season.

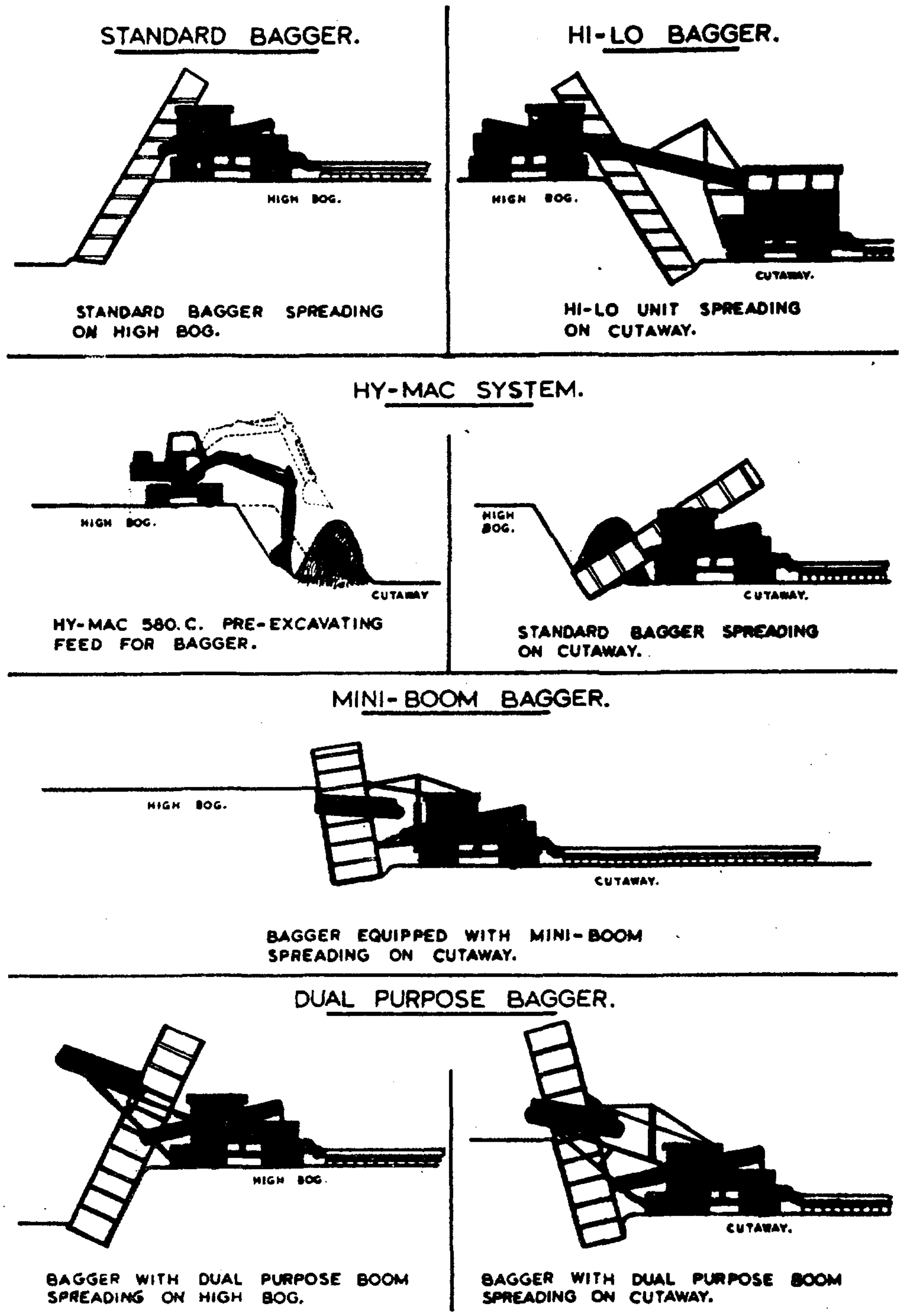


Fig. 4.2 - Bagger Systems of Sod Peat Production

Source: Callanan, 4th IPS Congress, Helsinki [29]

Tractor attached production machinery may be categorised into five basic types:

- Screw: The peat is extracted by a 40-130 mm diameter screw auger which cuts a 400-1000mm deep inclined slit in the bog surface. The peat is macerated and extruded as 60-100 mm diameter cylindrical sods. Capacities normally range from 1 to 3 tonnes per hour of air-dried peat on 40-60 kW farm tractors, although larger machines have also been manufactured. The excavated slit is inclined so that it will close after peat extraction.

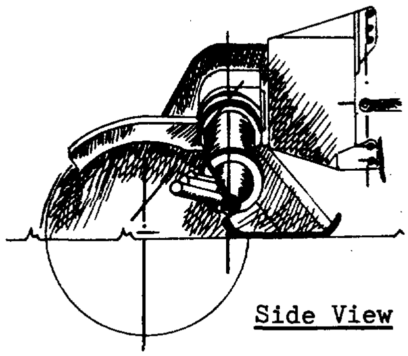
- Disc: Extraction is by a 900-1400 mm diameter toothed disc which cuts an inclined slit 400-600mm deep and 40-70 mm wide. The high revolution rate of the disc allows it to cut through any small timber present. The peat is extruded in sod form and output is from 3 to 5 t/hr of air-dried peat on a 60-80 kW tractor. Again larger capacity machines have been developed [28].

- Chainsaw: The 1000-1700 mm digging blade is equipped with a continuous chain with "spoons" attached which carry the peat into the mixing and extrusion chamber. The peat is extruded through up to ten 100mm diameter outlets and outputs of 5t/hr of air-dried peat on a 60-80 kW tractor can be achieved. Larger machines of this type are being developed.

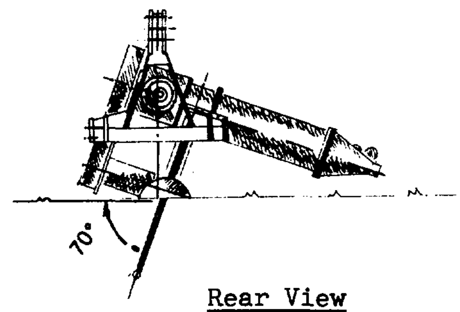
- Surface: The surface sod peat machine has a combined horizontal feeding screw and vertical cutting disc. Peat extraction is from the top 100-300mm, with moisture content regulation by alteration of the cutting depth of the disc. Power requirement is 60-80 KW and output is from 3-4 tonnes per hour of air-dried sod peat.

- Field Press: This tractor-drawn or self propelled extrusion machine is filled by an excavator operating from a face bank. The field press mixes, macerates and extrudes the peat in continuous sod form on an adjacent spread area. Power requirement is lower than for the screw, disc or blade machines at 30-40kW and output is around 3-5 tonnes per hour per extruder [18].

A full range of light, tractor-attached sod conditioning and harvesting equipment, together with drainage and levelling accessories is also available. The size of sod produced may be altered by adjusting the extrusion outlets on the production machines. Small diameter "mini sods" have a greater surface to volume ratio and tend to dry much faster, but mechanical handling is more difficult and the fuel tonnage produced per harvest is reduced. In practice, the optimum sod diameter has been found to range between 80-120mm, depending upon the nature of the spreadground, local climatic conditions, and the desired market.

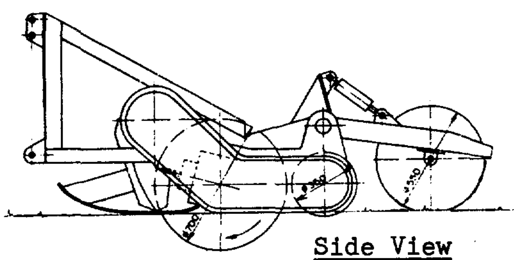


Side View

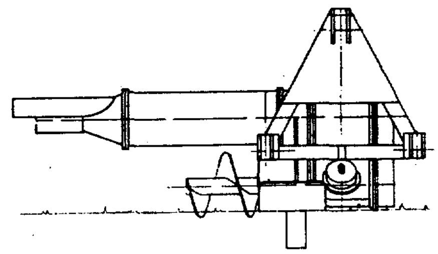


Rear View

DISC TYPE

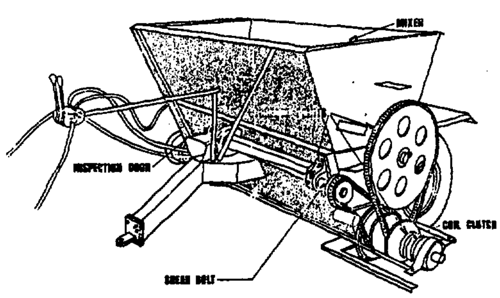


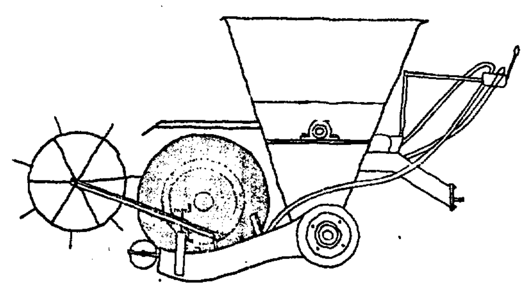
Side View



Rear View

SURFACE TYPE





FIELD PRESS

<u>Fig. 4.3</u> - Tractor-attached Sod Peat Production Machinery

<u>Source:</u> Suokone Oy; Finland
Joe Coyle Ltd; Ireland

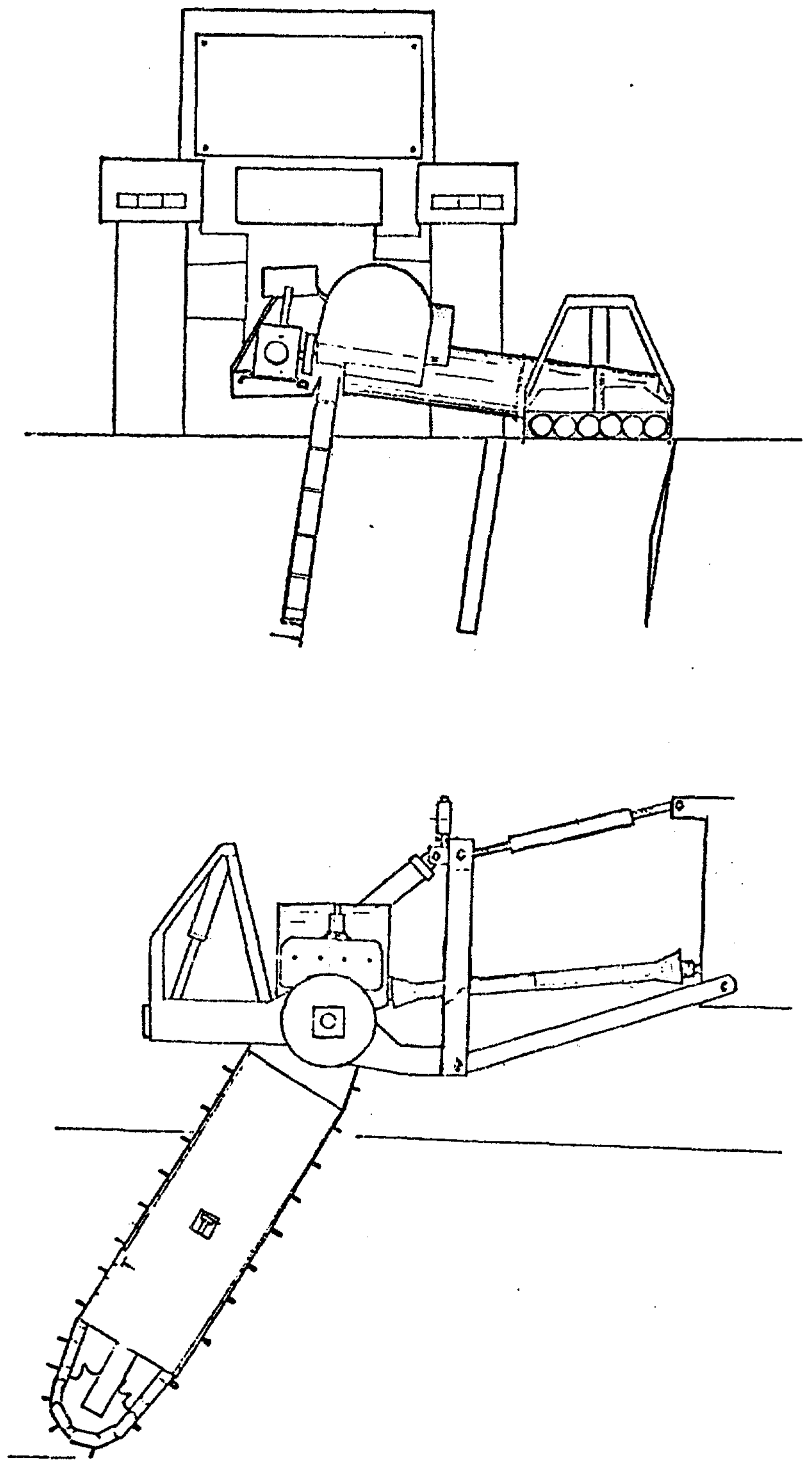


Fig. 4.4 - Chainsaw Type Sod Peat Production Machine

Source: Herbst Group; Ireland

Advantages of these smaller tractor-mounted sod producing machines include their simplicity and ease of manufacture and maintenance, transportability within and between bog units,lower capital investment and the possibility of utilising their power units for other purposes. Disadvantages, with the exception of the field press system, include the relatively shallow depth of cut, the limited composition range of peats from different layers in the maceration mix and the problems caused by buried timber.

MILLED PEAT PRODUCTION

The milled peat method, which produces peat in crumb or powder form, superseded sod peat as the primary method of production in West European countries during the 1950s. Although much more weather dependent than sod peat, and potentially more difficult under oceanic climatic conditions,it is still the most economical method of peat production.

The harvesting cycle is based on 2 or 3 consecutive days of solar drying and in Ireland about 12 harvests, yielding a total of 180 tonnes/ha, are collected during the production season. Finnish conditions allow up to 16 harvests per season and in the Soviet Union 20 harvests may be obtained, producing around 300 tonnes of milled peat per hectare.

Production fields are 15-20m wide and surface milled to depths of 5-20mm. Drying is enhanced by repeated turning of the milled peat using spoon harrows, since a dry surface layer will act as an insulator effectively limiting the drying of the peat below. When the moisture content has decreased to 45% the peat is mechanically collected into field centre ridges and harvested into stockpiles [30]. Alternatively, the dried peat may be picked up pneumatically from the spread. There are three basic harvesting systems.

- Haku system: The dried peat is lifted from the field centre ridge into bog trucks or trailers and brought to large peripheral stockpiles with road or rail access. The peat is piled and compacted by heavy crawler tractors and the stockpiles may be up to 15m high, containing some 10,000-50,000m^3 of milled peat.

- Kaas System: Self-loading hopper trailers or harvesters transport the peat to intermediate stockpiles at the end of 400-800m fields. The peat is piled 6-8m high by scraper elevators and the stockpiles are typically 40-60m long containing 1,000-3,000m^3.

- Peco system: The central ridges are moved laterally from field to field by self-loading harvesters and eventually into stockpiles running parallel to the production fields at 200-400m intervals. Stockpiles are normally 3-4m high and 500 to 3000+m long.

The Peco system is the most economical method of producing milled peat, especially in large production areas, but with smaller stockpiles the losses due to wind erosion and loading are highest. In practice the piles are compacted by rolling during formation and some covered with polythene until required. With the Haku system heavy compaction of the stockpile during building helps reduce self-heating problems and homogenisation of the peat is maximised since the peat in the stockpile is gathered from a relatively large area. Transportation costs are highest for the Peco system since internal transport, either temporary rail or bog dumper, is necessary to bring the peat from the stockpiles to the edge of the bog. With the Kaas or Haku methods the peat is stock-piled along a permanent road or railway [27].

WET HARVESTING

Where adequate drainage of peatlands cannot be achieved even by pumping, wet harvesting techniques may have to be employed. Little site preparation is necessary except for removal of trees and ground vegetation. The peat is then hydraulically or mechanically excavated and pumped to permanent drying fields for harvesting, or process dewatered.

Hydropeat Method

Developed for use in Eastern Europe on bogs with a high timber content which impeded mechanical excavation, this method involves reducing the peat to a slurry containing less than 5% solids using high pressure hoses. This slurry is then pumped to a flat, permeable drying area where the water drains and evaporates leaving a layer of peat which can be marked off into sods or milled. Hydropeat was an important production method in the Soviet Union from the 1920s until the 1940s, when it declined in favour of more economical sod and milled peat methods [31]. It was also used in Ireland for a short period.

Slurry Pond Method

Mechanical excavators or dredgers are floated on a pond within the peat area and used to cut the peat which is then pumped to a dewatering site. The only known commercial operation on which information is available is that of the Western Peat Moss Co. Ltd. at Richmond, B.C., Canada. This operation uses a floating clamshell excavator to excavate the peat which is then separated from timber, roots and debris. The peat slurry is pumped for 4km and dewatered using roller presses and flash drying, the operation producing 32,000 tonnes p.a. of horticult-ural peat at 55% moisture [25]. Locally available natural gas is used for the thermal dewatering.

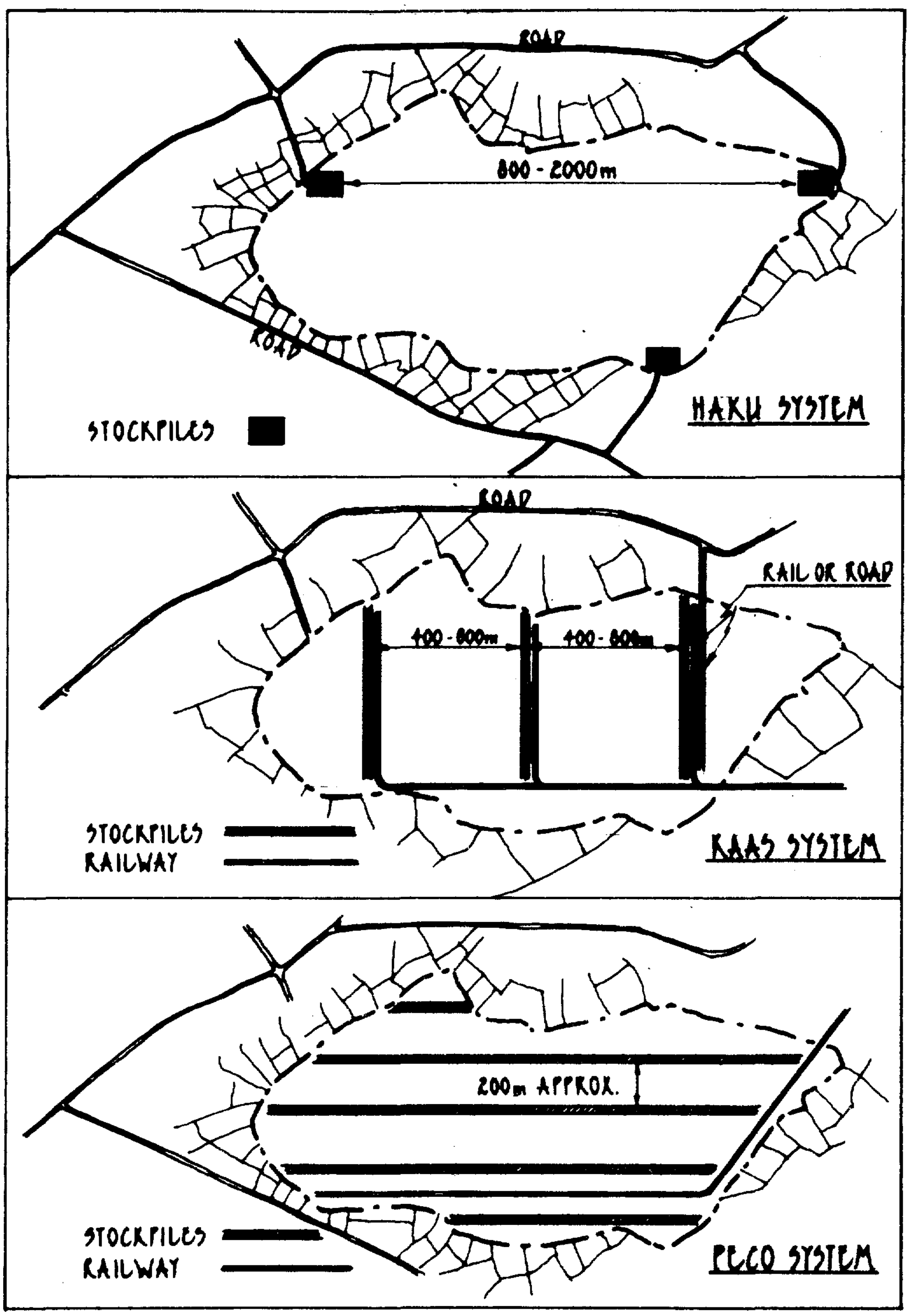


Fig. 4.5 - Plan of Different Production Systems

Source: Bord na Mona, Ireland
Min. Trade and Industry, Finland [8]

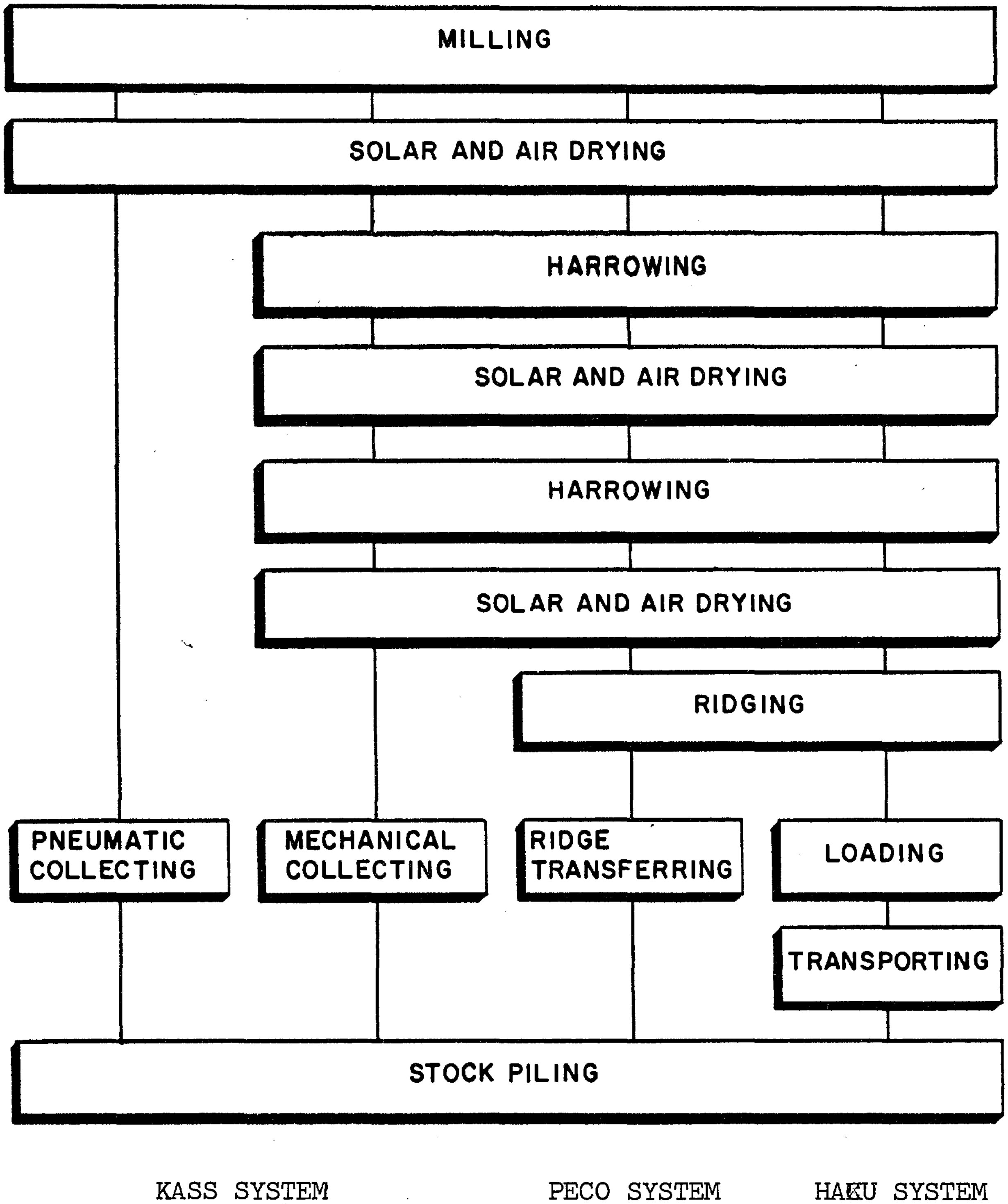


Fig. 4.6 - Operations in Alternative Systems of Milled Peat Production

Source: Burns and Roe, USA, [64]

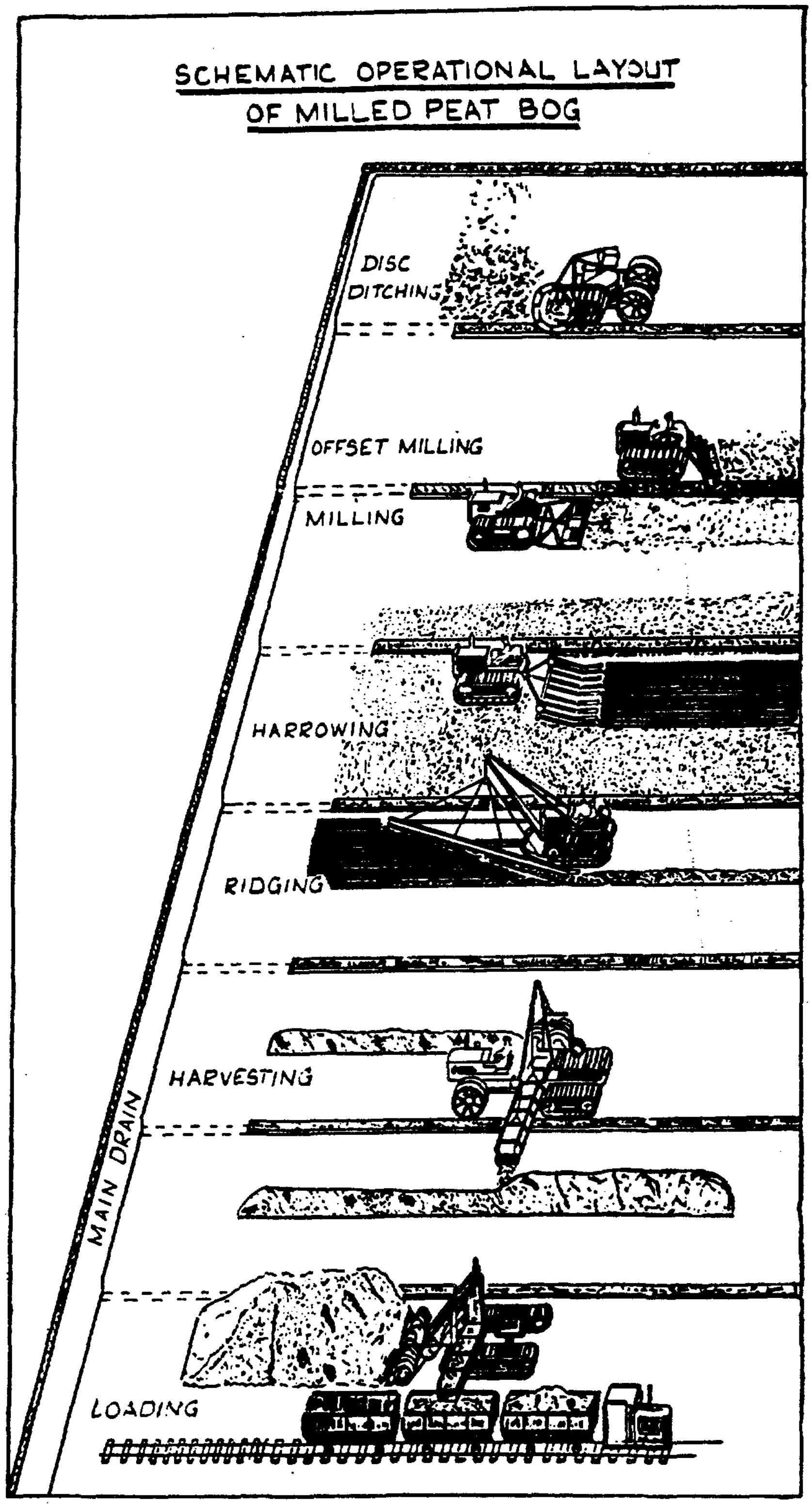
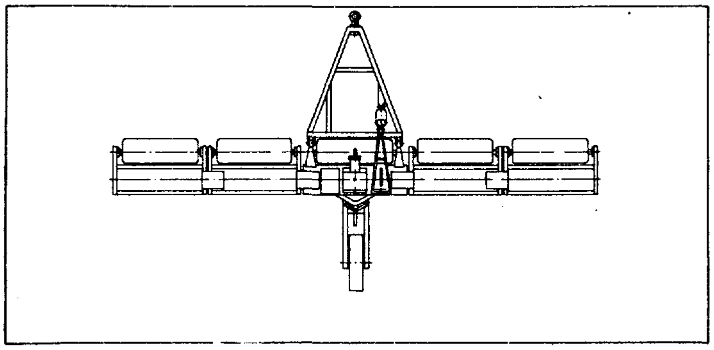
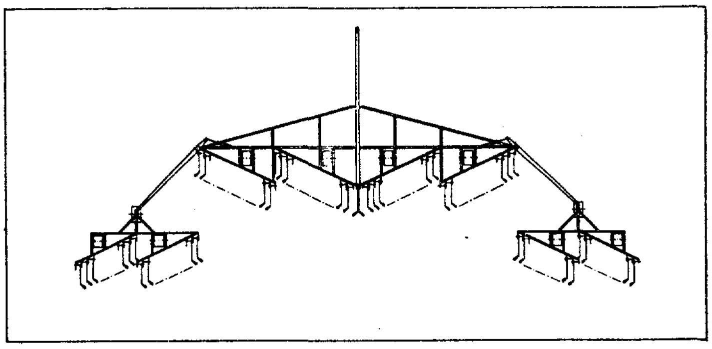


Fig. 4.7 - Peco Milled Peat Harvesting System

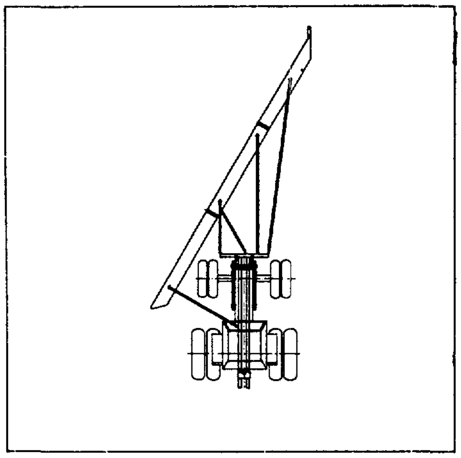
Source: Bord na Mona



MILLER



HARROW



RIDGER

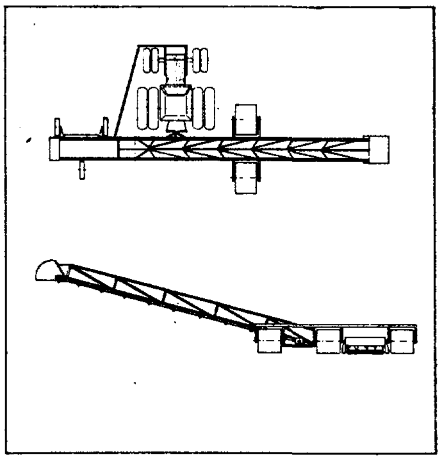


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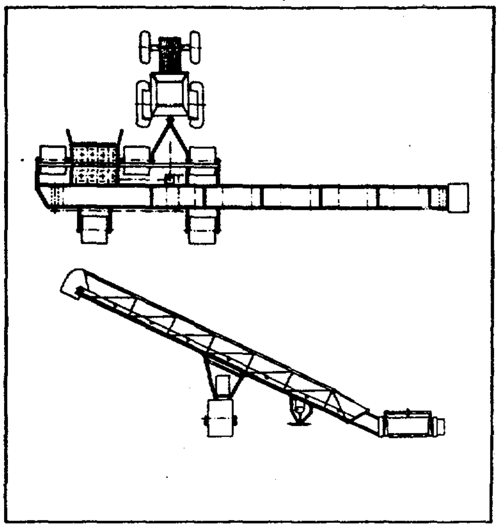
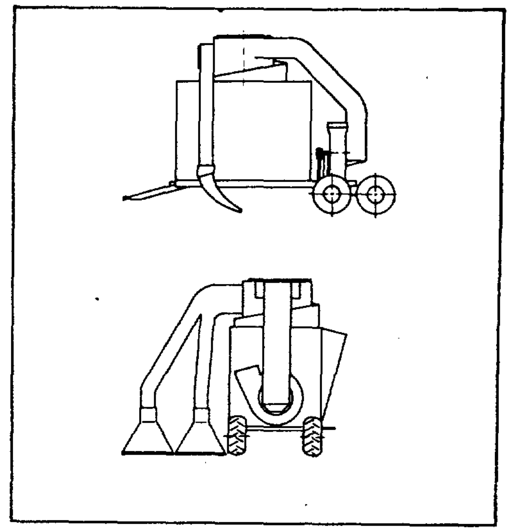
Fig. 4.8 - Tractor-attached Milled Peat Production Machinery

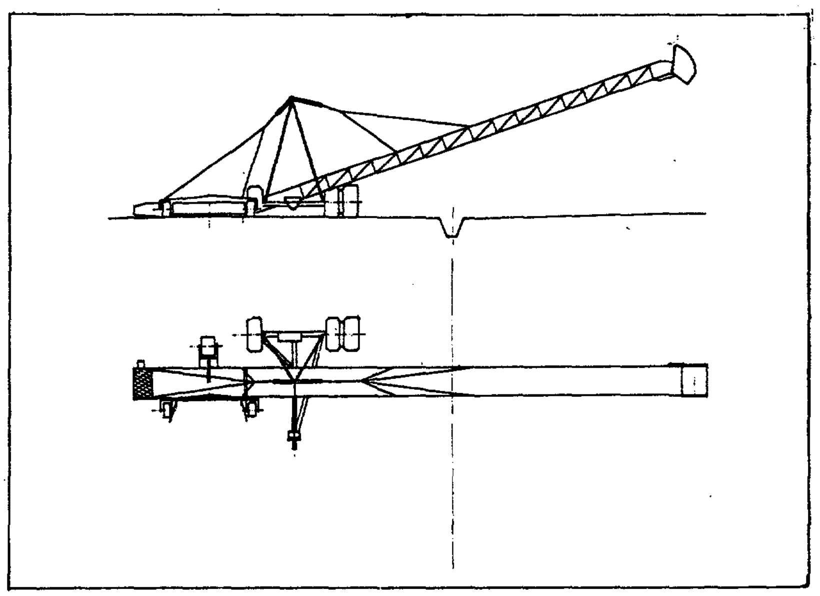
Source: Vapo, Finland



SOD PEAT HARVESTER



PNEUMATIC MILLED PEAT HARVESTER



PECO MILLED PEAT HARVESTER

__Fig. 4.9__ - Peat Harvesting Machinery

__Source:__ Vapo, Finland

Wet harvesting methods have the following advantages:

- They allow the exploitation of deposits which are uneconomic to drain.
- Deposits with a high timber content can be worked.
- Little pre-production preparation is required apart from vegetation clearance.
- The system is unaffected by meterological conditions if artificial dewatering is employed.
- The total peatland area disturbed at any one time is small since this is a one-pass system.

Problems arise, however, with the technical requirements and the economics of wet harvesting systems. Air drying of the peat requires the preparation of extensive, flat, permeable areas and is influenced by meterological factors. Mechanical dewatering is only capable of reducing the peat to a maximum 75% moisture, and considerable energy input is required to dry the peat further so that it may be successfully used as a fuel. Cost information for wet production systems is not available in the literature. However, in European operations hydraulically-produced peat has historically been much more expensive than milled or sod peat. The known operation in Canada produces a high value horticultural product, but operational costs are higher than at other plants producing more than twice the volume using the milled method of production [25]. The economic feasibility of fuel peat production by the wet production method has yet to be established. Commercial scale demonstration tests are underway in the Akanyaru River basin in Northern Burundi [7].

Where solar drying is employed in peat harvesting the rate of production is obviously governed by meterological conditions. The harvesting season is determined by the number of consecutive days with a certain net evaporation per day. In Ireland evaporation is measured using a US Class A open evaporation pan, and from operational experience a total net evaporation of 16-18 mm of water is required for each milled peat harvest. Irish climate conditions normally produce around 5.5 mm of evaporation per day in summer, and thus three consecutive rainfree days are required for each milled peat harvesting cycle. In developing countries, especially those with a more tropical climate where evaporation rates are much higher, the harvesting cycle for milled peat may be reduced to two or even to a single day. The total net evaporation per harvest, however, is likely to remain within this 16-18mm range and thus rates of production are site specific, determined by the local evaporation rates and rainfall pattern.

ENVIRONMENTAL IMPACT

Ecological

Activities associated with peat production can cause serious disruption of wetland ecosystems and, through habitat destruction, may lead to the elimination of plant and animal populations with specialised requirements and limited distributions. Important scientific and educational resources may also be destroyed. The scale of operations in relation to the proportion of the total wetland area being exploited is therefore important [19]. An extensive environmental impact assessment has been conducted as part of the feasibility study on Jamaican peat resources [134].

Hydrological

Conventional peat production systems, which remove the evapotranspirational effects of the existing vegetation and maximize rates of runoff from production fields, reduce the capacity of the peatland ecosystem to store water [20]. Depending upon the size of the operation this may lead to significant changes in the hydrology of the catchment, particularly in the occurrence of flash flooding. Peatland drainage, however, has not been found seriously to degrade downstream systems through changes in the level of water acidity.

Effluents

Drainage water from peatland production areas may carry considerable amounts of suspended solids following periods of heavy rainfall. This peat silt must be trapped and removed in settling ponds to prevent serious pollution of and damage to the ecosystems of the receiving water bodies [24]. These silt traps require regular maintenance with careful disposal of the spoil. Effluent from the wet carbonisation process also requires treatment.

Dust

Dust can pose a problem with the milled peat production method, especially when working highly humified deposits and during windy weather conditions [26].

Land Use

In some countries areas considered as potential sources of peat fuel may already be in use for tree or food crop production. Adequate provision must be made to relocate or compensate the current land users for loss of livelihood, either on a permanent basis, or for the duration of peat exploitation.

Reclamation

Dry harvesting techniques offer the possibility of reclaiming the mined peatlands for agricultural purposes, afforestation or biomass energy crops, provided the drainage systems are maintained [23]. The potential for peatland reclamation may be an important factor in reaching decisions on peat exploitation for fuel in developing countries, in view of the possibilities for increased food production or continuing indigenous energy supply in the post peat production phase. Wet harvested areas and peatlands pumped during exploitation may be reflooded and the open bodies of water developed for pisciculture or for wildlife and recreational purposes [22].

Socio-economic

Exploitation of peatlands brings beneficial socioeconomic impacts to areas which are often remote and underdeveloped. Utilisation of a peat resource for fuel provides employment, develops workforce skills, creates infrastructure and may provide, in the long term, land with a greatly enhanced production capacity.

TECHNOLOGICAL DEVELOPMENT

Research and development is continuous in peat production technology, attempting to increase the efficiency and reliability of the techniques employed and improve the competitiveness of this sector of the energy economy. The fact that countries such as the U.S.A. and Sweden are now actively involved in R & D on peat has given a new impetus in this field. New and simplified machines using standard agricultural tractors as power units are now available. These systems are ideally suited to the small producer and in some circumstances can also be useful in larger operations.

Increasing attention is being paid to the quality of peat produced, within the limitations of deposit characteristics and the prevailing climatic conditions. Efficient utilisation demands homogeneity of product as large variations in the quality of the peat supplied may require considerable investment in blending facilities at the consumption site.

APPLICABILITY

The choice of peat production technology depends upon the climatic conditions, the characteristics of the deposit, the acceptable cost of production and the end use of the fuel produced.

Peat deposits in many developing countries are limnogenic, highly minerotrophic and very humified. Drainage limitations of some coastal, riparian or "drowned valley" deposits would suggest the utilisation of wet harvesting techniques, transporting or pumping the peat to permanent drying fields, or process dewatering. However, the wet transportation of peat obviously adds enormously to the final cost of the fuel even if energy-efficient solar drying is employed.

In process dewatering mechanical pressing can only reduce the moisture content to 75-80%. Wet carbonisation, where the wet peat is preheated under pressure, allows mechanical dewatering to around 50%. A high proportion of the energy content of the peat is however required for process drying. Most such schemes are still theoretical, unproven and production costs are not available.

Highly humified deposits contain little plant fibre and sod peat formed from this source is usually friable. Sod formation is most successful from medium humified peat, or from a mixture of high and low humifications. Peat of low humification, H2-4, if used alone will form light, hygroscopic sods while peat of high humification, H9-10, will form very dry, dense sods with little bonding, which tend to disintegrate with handling. Where a certain proportion of fibrous material is present sod stability is improved by mechanical maceration of the peat before extrusion [21].

Very highly humified deposits, which can have high ash contents, would appear to be most suitable for milled peat production. This is less expensive to produce than sod peat but scale of operation and market outlets are important factors. Milled peat is conventionally used to fuel medium to large size industrial boilers and power utilities or to produce briquettes (or pellets). With small production sites, supplying a domestic market or small boilers of less than 10 MW, sod peat is the most practical form of production [8].

Briquetting is a well proven peat processing technique which requires some artificial drying and sophisticated equipment with a high level of production control. While producing a quality product that is easily transported and particularly suitable for urban, domestic consumption, the process is very capital intensive and requires specialist skills. The skill requirements are not nearly so high for the production of sod peat. At the simplest level this may be produced on a small scale using spades to make drains and hand cut the sods. On a larger scale farm tractors fitted with special low-pressure tyres or tracks can be used for bog drainage and sod production. Turning, windrowing and harvesting of the sods is fully mechanised using a range of relatively inexpensive tractor-attached machines. Areas with a high content of hard timber are best harvested using a Field Press type machine, where the peat is mechanically excavated from a facebank, separated from the stumps and loaded into the hopper for extrusion onto an adjacent drying area.

Deposits with softer, partially decomposed timber may be harvested using the Disc machine which effectively cuts and chips the woody components. The chainsaw machine has the advantage of a deeper cut, allowing mixing of the peat from a greater range of layers, which may prove important for the formation of a good quality sod.

In developing countries sod peat production is the most suitable for supplying fuel for the domestic market, as a substitute for firewood or wood charcoal. It is also the best option for supplying small to medium sized boilers and small power plants.

Milled peat production is more suitable on a larger scale, utilising the fuel to satisfy larger industrial energy demands and for power generation. In certain instances milled peat may be the only feasible production method owing to the highly humified nature of the deposit.

SECTION V - PEAT PROCESSING

Sod peat is an easily transportable fuel with a wide range of local utilisation outlets. Milled peat, however, is a relatively low density fuel, with limited market application, which benefits from further processing to improve the economics of transportation and increase its versatility.

DENSIFICATION

Densification processes produce a uniform quality, high calorific value fuel, suitable for use where storage space is limited and cleanliness is required. The principal densification processes are briquetting and pelletizing.

Briquetting

Peat briquettes are manufactured industrially in the Soviet Union, Ireland and, to a limited extent, Finland. The briquetting process, which was developed by Hodgson in Ireland in 1858, employs artificial drying to reduce the moisture content of air dried milled peat from around 55% to 10% and to briquette the dried product without the use of a binding agent. The milled peat is first blended to homogenize its moisture content, bulk density and ash content, disintegrated with hammer mills, screened and dried. Drying may be direct, using hot flue gases, indirect, using the Peco system, or by rotary drum dryers similar to the type employed in brown coal drying plants. The dried peat is compressed into briquettes with simple crank extrusion presses, cooled on steel launders and either baled or stored loose. Individual briquette dimensions are 186x70x30-40mm and the baled products are used primarily in small domestic heating boilers, cookers, stoves and open fireplaces. Loose briquettes are used for domestic or industrial purposes and smaller one-third size brickeens (62x70x30-40mm) are used in under-feed and other industrial heating and boiler installations [47].

Pelletizing

Feedstock preparation is similar to that for briquetting. Densification employs a hard steel die perforated with an array of holes. The die rotates against inner pressure rollers which force the peat into the die and the pellets are broken off at the required length on extrusion. Peat pellets may be used in suitably designed industrial installations and in domestic boilers with automatic feeding systems, according to Finnish sources, but are not in commercial use elsewhere.

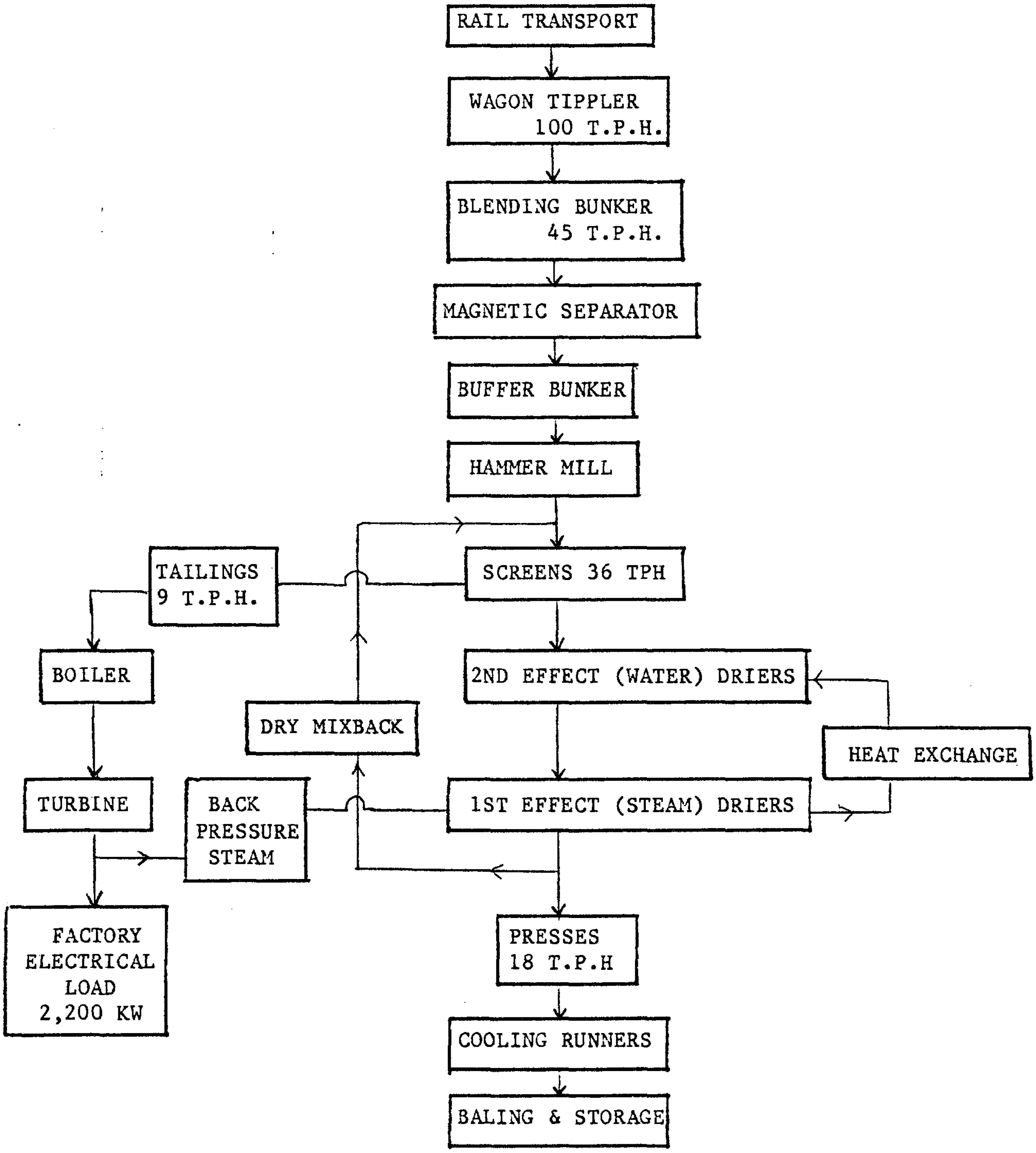


Fig. 5.1 - Irish Briquette Factory Flow Diagram

Source: Bord na Mona

PEAT DEWATERING AND BENEFICIATION

Peat produced by wet harvesting techniques requires artificial dewatering if solar-efficient drying is prevented or severely limited by climatic or local topographic conditions. Dewatering may be used to produce a fuel product, or as an intermediate stage in peat conversion processes.

Mechanical

Mechanical dewatering of raw peat has employed many devices, including roll and belt presses, filter presses, screw presses and screens. Without pretreatment of the peat these processes are only capable of reducing the moisture content to around 75-80%, depending on the peat type, humification and the technique employed. Further drying is required before the product may successfully be utilised as a fuel [39]

Wet Carbonisation

This is a thermochemical process which disrupts the colloidal nature of the peat by breaking down the carboxyl and hydroxyl groups. The wet peat is heated under pressure to temperatures in the range 150-550°C with residence times of up to one hour. This thermal pretreatment removes a fraction of the oxygen, increases the calorific value of the solids and improves their dewaterability. Subsequent mechanical dewatering will further reduce peat moisture content down to 50% [42].

Peat Derived Fuel (PDF)

Essentially a wet carbonization process followed by artificial dewatering [33]. The wet harvested peat undergoes four-stage heating under pressure to 200°C and is then dewatered to 50% moisture in pressure filters. The filter cake is pulverised and further dried in a thermal drier. The process produces a briquette or pellet with 10% or less moisture content and a heating value of 20-24 MJ/kg [34]. Expected nett energy yield is 72%. A new $100m plant is planned for Maine, U.S.A.

Koppelman Process

A high temperature, high pressure beneficiation process originally developed for dewatering and upgrading lignite. The peat is dried to a very low moisture content yielding a final product with a heating value of 25-30 MJ/kg. This high effective calorific value is due to the removal of oxygen from the peat. The fuel may be produced in either pulverised or pelleted form. The energy yield is highly dependent on the consistency of the peat fed to the process and on the degree of closure of the heat exchange circuit. The process is still under investigation and effective energy yield is expected to be around 55% [8]. A new demonstration plant of 25,000 tonnes per year output is now being commissioned in North Carolina, U.S.A.

Carbonisation (Coking)

Peat coke, the firm residue produced by dry distillation of peat, has been manufactured for hundreds of years, with reliable accounts dating back to the beginning of the seventeenth century. High quality, low-ash coke is produced only from well humified peat with an ash content of less than 4%. During the coking process the carbon content of the peat is concentrated from 55% by weight to 90% by weight, yielding a high grade product with a calorific value of 31 MJ/kg. It is less stable mechanically than coke made from coal or lignite, but with low ash, sulphur and phosphorus contents it is highly reactive and ideally suited for use in electrometallurgy and for the manufacture of adsorption cokes and activated carbon.[1/] At present it is used on an industrial scale on both sides of the Northwest German/Dutch border.

Others

Several other methods of peat dewatering are under active investigation and development, mostly on a laboratory or pilot-plant scale. These include :

- Centrifugal dewatering, which removes colloidal material and improves mechanical compression characteristics [43].

- Solvent extraction, which is based on the differential solubility of water in certain solvents at various temperatures [40].

- Carver-Greenfield process, a multiple-effect evaporation process employing a fluidized-bed technique, which was originally developed to remove moisture from municipal sludge [41].

- Wet oxidation - the oxidation of organic materials in an aqueous medium at elevated temperatures and pressures. Partial oxidation enhances the dewaterability of the peat solids. High temperature wet oxidation, however, results in almost complete combustion of of the peat [36].

PEAT CONVERSION

Intensive research into the conversion of peat has been carried out in the United States, Canada, Finland, and Sweden since the mid- 1970s. Based primarily on earlier industrial applications throughout the 20th century, a wide range of processes and techniques have been investigated.

1/ Grumpelt, H., 1983: Development and present state of peat coke production. Recent Technologies in the Use of Peat, ed. G.W. Luttig, E. Schweizerbart'sche Verlagsbuchhandlung (Nagele u. Obermiller), Stuttgart: 167-197.

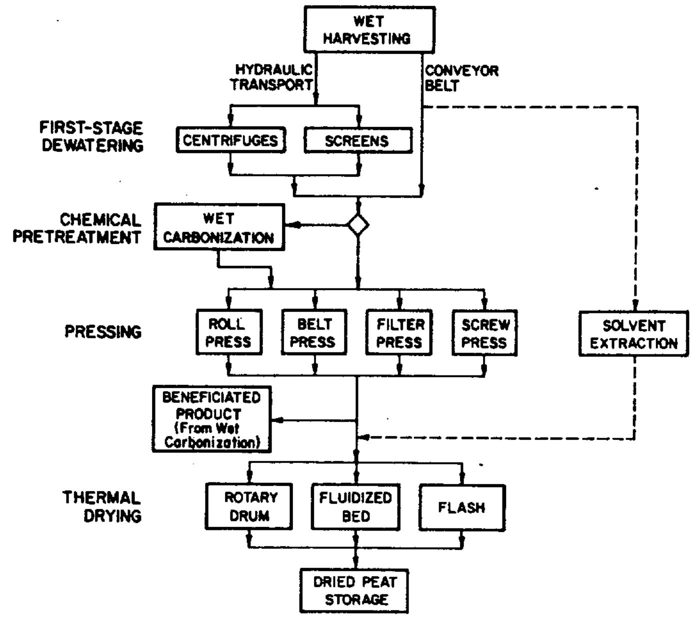


Fig. 5.2 - Alternative Dewatering Methods of Peat

Sources: Tsaros, ITG, USA [39]

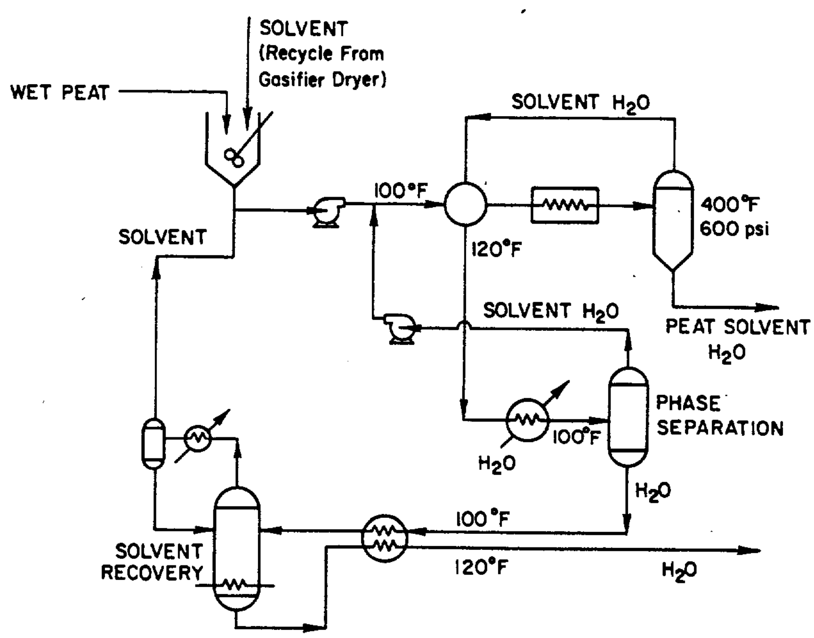


Fig. 5.3 - Solvent Dewatering Flow Diagram

Source: Tsaros, ITG, USA [39]

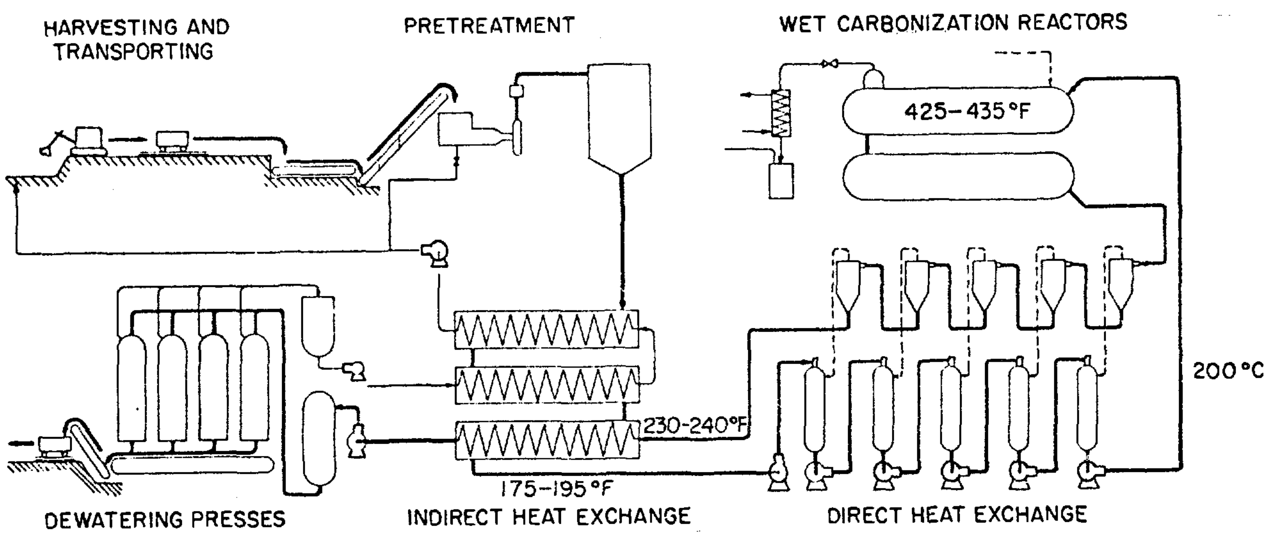


Figure. 5.4 - Swedish Wet-Carbonization Process Flow Diagram

Source: Mensinger, IGT, USA [42]

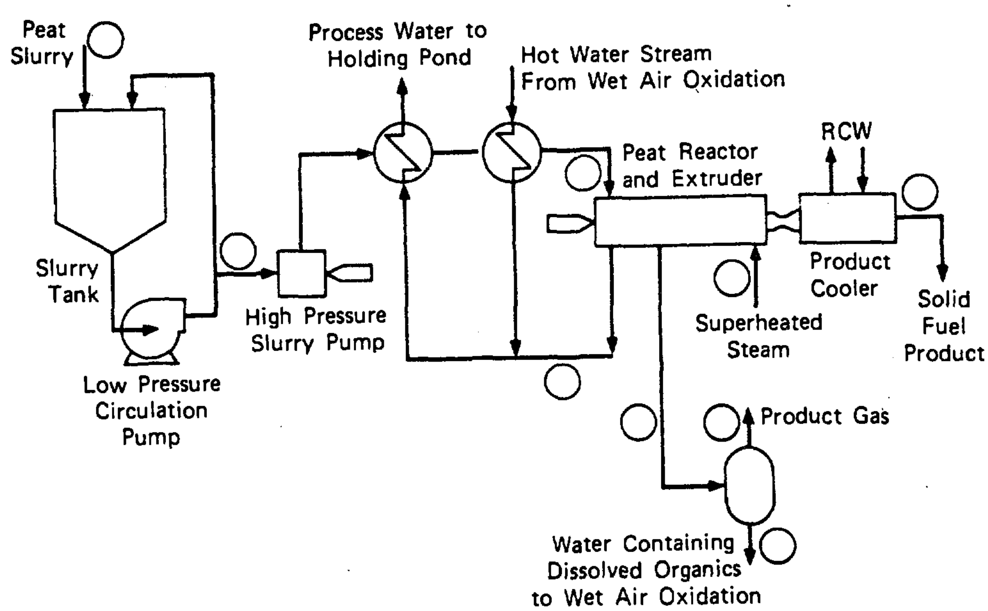


Fig. 5.5 - Koppelman Process Flow Diagram

Source: Mensinger, IGT, USA [42]

Gasification

Thermal gasification processes entail a partial combustion of peat with air, oxygen or steam or with a mixture thereof. There are two basic approaches which yield different calorific value products. When a mixture of air and steam is used as the gasifying agent a low calorific value gas of 4-6 MJ/m^3n is obtained. Pure oxygen or steam or a mixture of both will produce a medium calorific value gas of 10-20 MJ/m^3n. No great difficulties have been experienced with the gasification process and the technical feasibility of producing substitute natural gas (SNG) has been demonstrated on a pilot plant scale by the U.S. Institute of Gas Technology using the PEATGAS process [37].

The production of methanol from peat requires purification of the raw synthesized gas, with removal of H_2S and CO_2, followed by catalytic methanol synthesis at high pressure [45]. A Finnish technical and economic study of possible systems of methanol production from peat concluded that a pressurised entrained bed gasification process had the lowest production costs, but was uneconomical at that time (1980) when compared with the conventional production of methanol from natural gas [44].

Biological conversion processes have been investigated using alkali pretreatment and partial oxidation of the peat followed by anaerobic methane fermentation. Small scale experiments on in-situ methane production have also been conducted in Sweden where methane-rich bog water is pumped to a processing plant, degassed and returned to the bog for re-use [38].

Liquefaction

At present synthetic fuels are manufactured industrially only from coal by Fischer-Tropsch synthesis. The comparatively high oxygen content of peat renders it less suitable for direct liquefaction than coal, but its low sulphur content appears advantageous. Several processes, including hydrogenation, pyrolysis, Fischer-Tropsch synthesis and ethanol production by hydrolysis are currently being studied. Development is still at the laboratory stage and commercial application remains futuristic [8].

APPLICABILITY:

While some peat processing technologies have not yet progressed beyond the theoretical or laboratory scale stage, even those processes which are well proven and industrially and commercially operative in the developed countries require careful examination and economic appraisal before being considered suitable for developing countries.

Briquetting

The best developed and most widely used peat processing technology, briquetting produces a clean low moisture content fuel which can greatly increase the market application of milled peat. The product is easily transported and is well suited to the urban domestic market and to small industrial applications. The production process, however, is likely to be too capital intensive for application in many developing countries. Capital investment, which is of the order of US$ 30 million (1984) for a plant with an output of 150,000 tonnes/year, adds considerably to the market price of the fuel.

Pelletizing

Peat pelletizing is a comparatively recent process developed and used in Finland. This has restricted usage, however, as it requires a special type of burner and consequently production is only on a small scale.

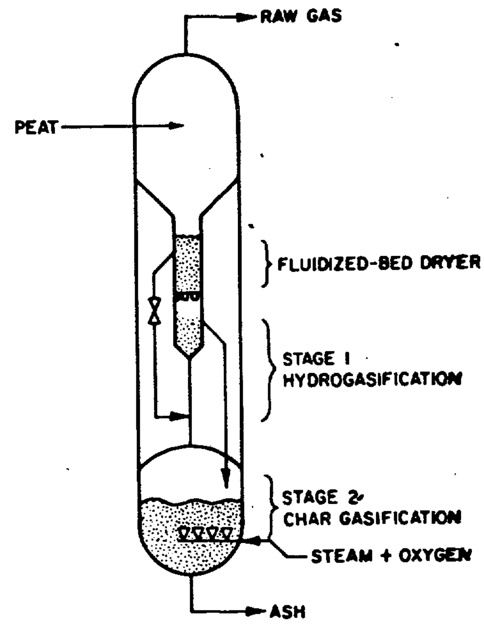
Dewatering and Beneficiation

Most of the processes in this field have not been developed beyond the conceptual to pilot plant stage. While recognising that wet harvesting of peat may be the only technically feasible method of extraction in some developing countries, the costs of dewatering and processing are likely to be prohibitively high. The only known application of wet harvesting and artificial drying is by the Western Peat Moss Co. Ltd. Canada, who produce a high-value horticultural product using a fairly conventional thermal flash drying technique - see section IV.

The historical development of wet carbonisation methods spans many years and a wide range of operations, all of which have proved to be commercially unsuccessful. It is used as first stage processing in the production of high calorific value peat derived fuel (PDF), but this process has not yet been taken beyond the pilot plant scale.

Conversion

Although gas has been successfully produced from peat for over 200 years, most notably in Germany during wartime [46] and the technology has been amply demonstrated, no commercial peat gasification or liquefaction plants are operating anywhere in the world. A 1982 feasibility study of large scale substitute natural gas production from peat concluded that the process was not commercially viable at that specific site and in competition with other energy forms at that time [35].



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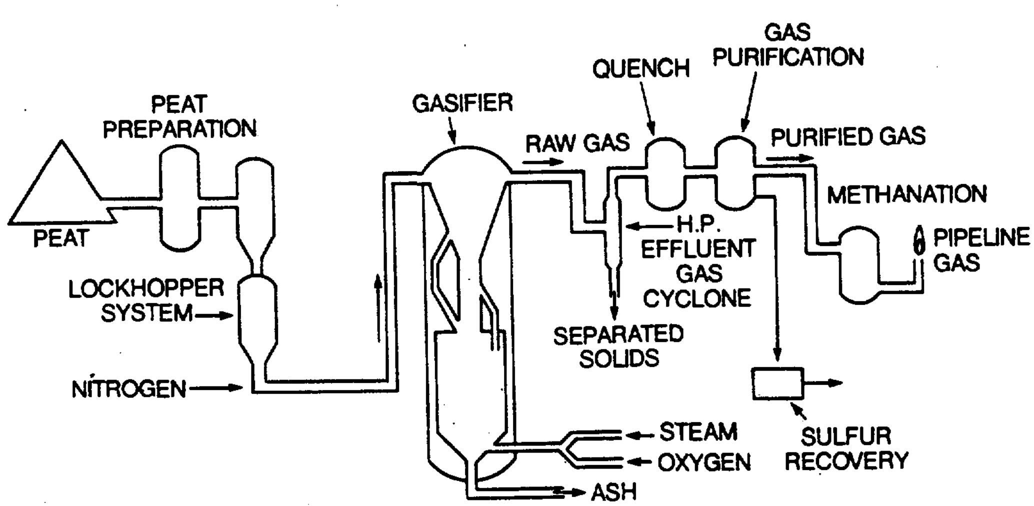


Fig. 5.6 - PEATGAS Process Flow Diagram

Source: Punwani and Biljetina, USA
"Peat as an Energy Alternative II"
ITG Symposium, Arlington, Va. DSC 1981

Smaller peat gasification facilites, using a fixed bed, may prove attractive in developing countries under certain circumstances, e.g. for local electricity generation using diesel power plants and in oil-fired boilers which cannot be converted to firing with solid fuels [8]. A pilot demonstration plant comprising a gasifier close coupled to a boiler (5MWt) has recently been installed in the town of Kankaanpaa in Finland. This system has the principal apparent advantage that it is capable of utilising peats with a relatively high ash content, without the formation of clinker. Consequently, it is claimed that the system is amenable to a higher degree of automation than more conventional boilers. Small plants of this type are being marketed in Ireland.

SECTION VI - UTILISATION

PEAT ECONOMICS AND THE POLICY FRAMEWORK

The potential for utilization of peat as a fuel depends on a wide range of factors, amongst which the most significant are:

- the extent and location of peat reserves;

- the competitiveness of peat with alternative fuels;

- the national energy policy framework, including energy pricing policies.

The extent and location of reserves has a major impact on the potential for peat utilization. Being a bulky, low value per unit weight commodity, peat cannot be transported economically for any significant distance without prior processing. Sod peat is thus used as a domestic and small-scale industry fuel in the vicinity of the deposit, and hence, is mainly a rural fuel. Milled peat, after processing into briquettes, has a geographically wide market area and may also serve as a cooking, heating and industrial fuel in urban areas. However, as most major peat deposits are in remote areas, the major potential use of sod or milled peat is for on-site power generation and transmission to load centers.

In all cases, the viability of peat as an energy source will depend on its economic competitiveness in relation to other available fuels - its opportunity cost. As a fuel for power generation the total economic costs of peat use must be compared with the costs of generation using other available sources such as hydro power, geothermal energy, oil, gas, coal and nuclear. Capital and environmental costs of peat fired power generation will be substantially higher than for other forms of thermal power generation. Amongst these costs are:

- fuel handling

- ash disposal

- large boiler size required for a given power unit size and consequent higher capital cost

- lower thermal efficiency of boilers

- land use as represented by the loss of valuable agricultural land or water resource effects

- reclamation costs

The economic evaluation of peat for power generation must take explicit account of all these factors. In addition, the question of the resource rent, or depletion allowance, must be considered. This is distinct from any royalties that may be charged by the state for the right to exploit the peat deposit, which are a purely financial transfer from one national entity to another. The resource rent measures the cost to the economy of consuming the resource today rather than in the future when the resource is depleted, in terms of the substitute fuel at that time. For deposits supplying domestic and small industrial markets, where the reserve lifetime is likely to be very long (over 30 years), the resource rent will be insignificant. For power generation use, resource rent considerations can be significant where depletion can be expected to occur at the end of power plant lifetime or where the alternative fuels are much more costly than peat, e.g., in a land-locked region without other indigenous energy resources.

In addition to favorable economics, peat development in developing nations requires the support of national energy and pricing policies. As a domestic and small industry fuel, peat is often competing with energy sources such as firewood, charcoal and kerosene. Given the growing scarcity and increasing economic cost of firewood in many nations, sod peat or milled peat briquettes have the potential to alleviate this problem. Pricing of peat and the financial incentives, such as tax breaks, exceptions from import duties, and credit lines, offered to peat producers are important policy tools for encouraging peat use. In setting peat prices the interrelationship with other fuel prices must be taken into account. For example, kerosene is often priced below cost as a means of providing a subsidy to low income groups; firewood collection often has low personal opportunity cost in rural areas (despite high environmental costs) with high disguised unemployment, whereas the purchase of peat requires a cash outlay. Set against this aspect are the potential employment generation aspects of peat production, particularly manually produced sod peat.

Development of peat reserves for electricity generation requires a commitment to long range planning and the development of expertise for the assessment of reserves and evaluation of alternative harvesting technologies. Extensive exploration should be undertaken to define peat parameters before initiating power plant design. This applies particularly to peat heating value where variability, if not compensated for by adequate mixing facilities, can be a major problem in maintaining steady operation of the power station. Special emphasis should be given to the feasibility and design stages of peat development and government policy, in those countries lacking the requisite expertise, should be to enable and encourage the agency responsible for peat development (often the power utility) to have access to latest technological developments through cooperative arrangements and use of consultancy services.

MAJOR CONSUMING COUNTRIES

The potential for the utilisation of peat as a fuel depends not only on the extent of a country's peat resources but also on its competitiveness against other fuels. This in turn is very dependent on local conditions, including the level of government support, tax structures and interest rates, labour and material costs and deposit location(s) in relation to major population centres.

Soviet Union

By far, the USSR is the world's largest producer of peat for fuel with current annual production of 80-90 million tonnes p.a. Of this, 98% is produced as milled peat primarily for power generation in 47 state electric generating stations or 32 combined heat and power industrial plants. Total installed peat generating capacity is around 6000 MWe, with a maximum single station size of 732 MWe. Five million tonnes of peat briquettes are also produced. Overall, peat contributes less than 1.5% of total Soviet energy consumption, but plays a significant role in the energy supply of the western, European part of the country.

Republic of Ireland

Ireland is the second largest producer of fuel peat, with 4.0 million tonnes of milled peat and 0.6 million tonnes of sod peat produced annually by Bord na Mona (parastatal sector) and up to 1.0 million tonnes of sod peat produced by private enterprise. Milled peat is used for electric power generation and to manufacture 0.5 million tonnes/year of briquettes for domestic and industrial consumption. Installed peat generating capacity is 420 MWe for milled peat and 97 MWe for sod peat. Major sod peat utilisation is in industrial heat and steam production and for domestic heating and cooking. Peat contributes some 14% of Ireland's electrically generated power and 15% of the country's total energy consumption.

Finland

Although fuel peat production can vary considerably according to climatic conditions during the production season, Finland is rapidly developing its peat resources. 3.1 million tonnes were produced in 1980 and targeted production is 8-10 million tonnes p.a. by 1990. Over 90% is produced as milled peat and used for power generation in condensing stations, combined heat and power plants and in industrial installations. Briquette manufacture is around 80,000 tonnes p.a. which, together with sod peat, supplies the smaller-scale industrial and domestic markets. Overall contribution is around 2% of Finnish energy requirements.

Others

The Middle European countries have long traditions of peat production and utilisation for fuel dating back to the 18th and 19th centuries. Peat was still of considerable importance for power generation -0.8 million tonnes p.a. - in the Federal Republic of Germany in the early 1960s, but has gradually decreased to the recent figure of 0.25 million tonnes p.a. most of which is now sold to the Netherlands for activated carbon manufacture. No production of peat for fuel was reported from Poland, Czechoslovakia or the GDR in the late 1970's. A small amount of peat is used for fuel in Great Britain, particularly by the whiskey distilleries in Scotland [74].

POWER GENERATION

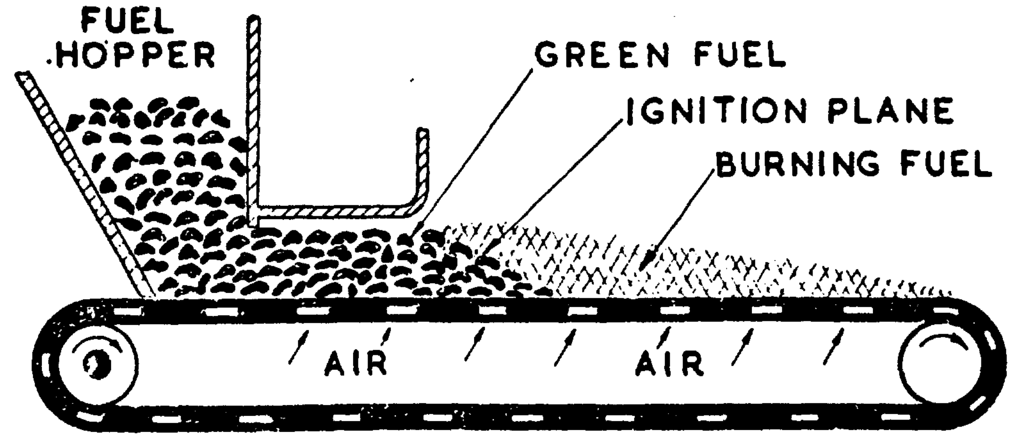
The primary use of fuel peat in the developed countries is for electrical power generation, both in condensing plants and in co-generating plants producing heat and power. Milled peat is the major fuel form, its economics being positive in comparison with heavy fuel oil and competitive with imported coal under certain circumstances [8]. The generating plants are normally located close to the deposits, minimizing transportation distance and costs, and ideally provide base load power. The largest single boiler units have outputs close to 200 MWe and several of these may be grouped to form condensing power blocks with total output of over 600 MWe. Maximum size is limited by the area of adjacent peatland required to supply the fuel and by transportation costs. Under Irish conditions, with a milled peat yield of 185 tonnes per nett hectare p.a., a total gross area of 3600 hectares is required to supply a single 45 MWe generating unit [52].

In milled peat fired plants the peat is first pulverised, dried with hot flue gases and burned in suspension [51]. Owing to the low density of peat the boiler size is comparatively large, the physical dimensions of a 40 MWe milled peat boiler being approximately the same as a 120MWe oil-fired unit. The variable quality of the fuel, its corrosive nature and the explosive susceptibility of dry peat, all lead to higher capital and operating costs, in comparison with other fuels, which must be compensated for by considerably lower fuel costs. In practice peat has been found to be most competitive in the 60-200 MWe power range [8].

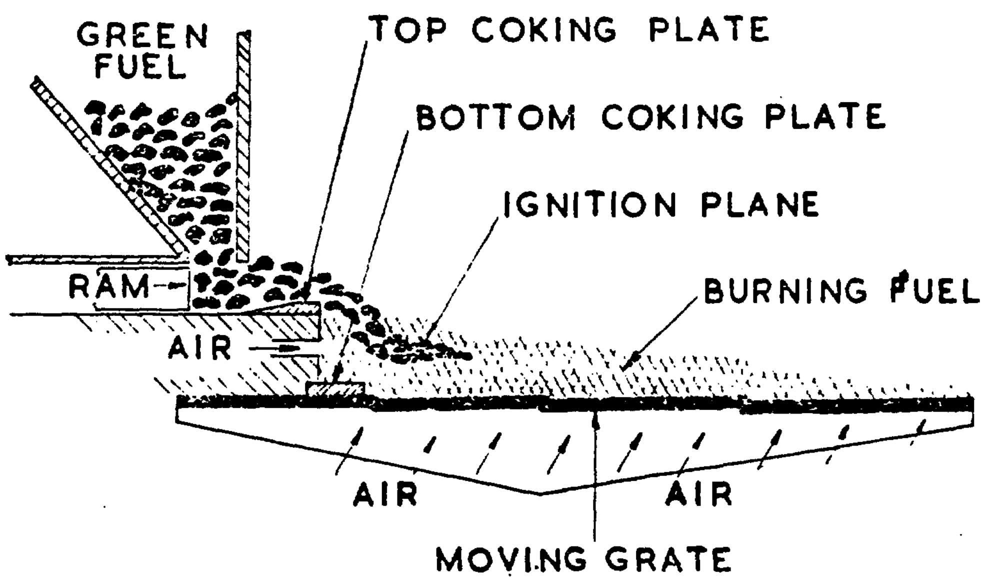
On a smaller scale, power may be generated using sod peat. The peat is grate-fired and Irish experience would suggest that the largest practical unit size is around 20 MWe [52].

Emissions

Considered from a combustion and emission point of view peat is very similar to wood. It usually contains very low levels of sulphur and is thus environmentally more acceptable than coal or oil. Solid particle removal processes are technically similar to those employed on coal-fired units. In large pulverised peat fired boilers the ash is very fine and electrostatic precipitators are used to reduce emissions and dustfall in the plant vicinity. Wet scrubbers are a reasonable-cost alternative which also provide good fire safety. In smaller plants mechanical separators may prove sufficient and the very smallest industrial and domestic units usually run without flue gas treatment, as local impacts do not justify the cost of filter equipment.



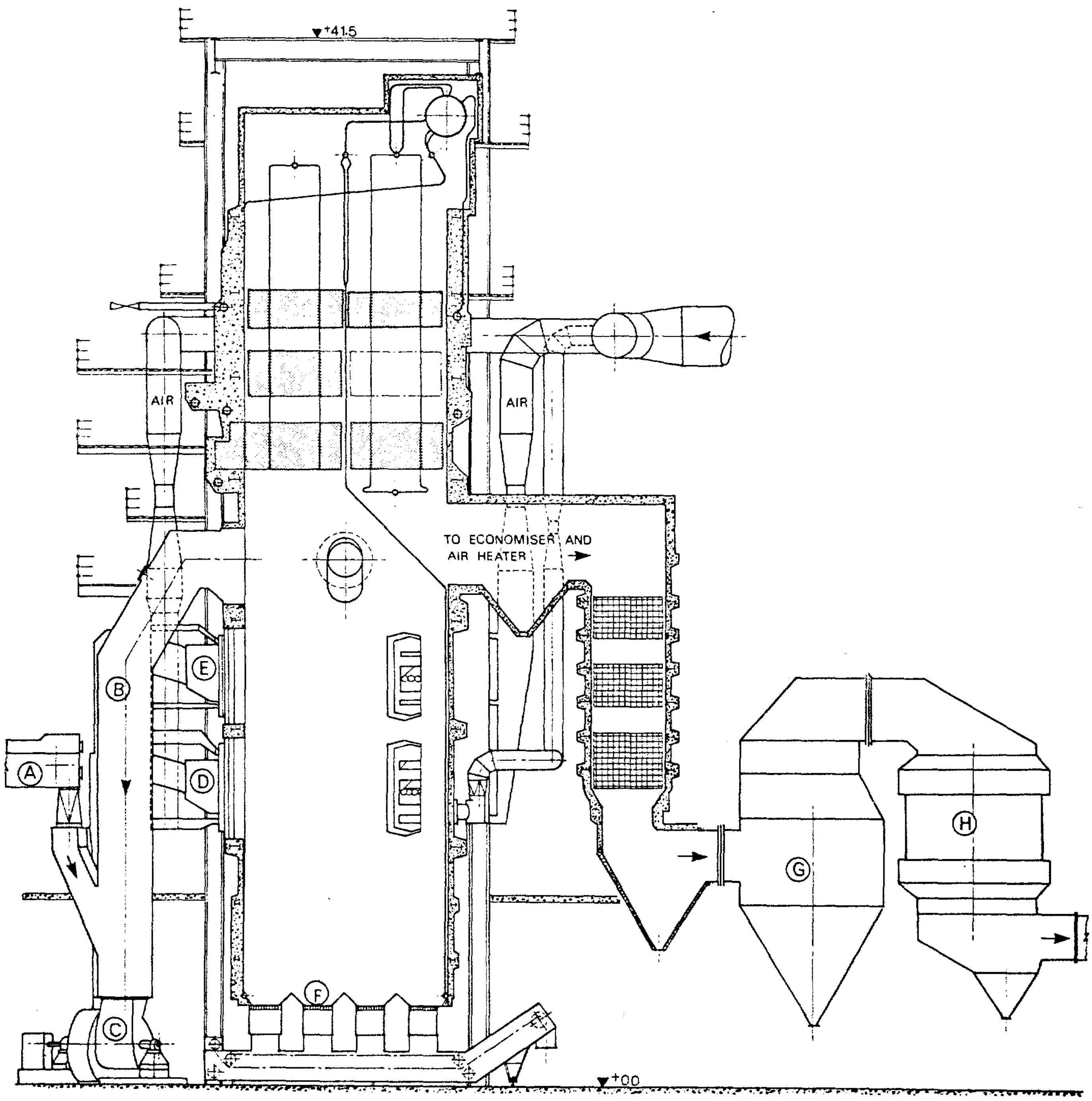
TRAVELLING GRATE STOKER



COKING STOKER

Fig. 6.1 - Sod Peat Combustion on Moving Grates

Source: Bord na Mona, Ireland



A : Peat feeder
B : Hot gas duct
C : Pulverising mill
D : Main peat burner
E : Vapour burner
F : Burn-off grates
G : Dust collector
H : Airheater

Fig. 6.2 - Cross-section of Milled Peat Boiler

Source: Brophy, Amer. Soc. Mech. Eng., USA [51]

With pulverised peat firing the furnace temperatures are comparatively low, yielding and emitting moderate concentrations of nitrogen oxides (NOx). The formation of polycyclic aromatic hydrocarbons (PAH) has not been detected. In grate-fired installations, however, the furnace temperature fluctuates considerably, producing peaks of unburned gases and moderate levels of NOx. In fluidized bed systems complete combustion occurs at modest reactor temperature, limiting NOx emission. Here the level of PAH formation is unknown [8].

FLUIDIZED BED COMBUSTION

Fluidized beds have been used for many years in the petrochemical and pyrometallurgical industries, but the concept of their utilisation for steam generation is relatively new. In principle, an air stream passing through a bed of solid particles, consisting of sand, ash and fuel, transforms it into a state in which it behaves like a boiling liquid. The fuel is dried and burned in the air flowing through the bed.

Second generation fluidized bed systems are characterised by a circulating bed. A high air velocity is used to circulate the bed and fuel through the combustion chamber and into a cyclone collector. The hot gases are separated from the bed and ash and the solids recycled back into the combustion chamber [56].

Advantages of fluidized bed systems include stable, efficient combustion in spite of wide variations in the particle size, moisture content, ash content and effective calorific value of the fuel feedstock. This flexibility allows combinations of sod peat, milled peat, briquettes, coal, wood biomass or municipal waste to be fired in the same unit. At 800-900 C the combustion temperature is below ash fusion temperature and softening does not occur, regardless of the ash content of the feedstock. This low operating temperature minimizes emissions, particularly NOx, and eliminates the need for flue gas scrubbing equipment. If high sulphur fuels are used the sulphur may be retained as calcium sulphate by the addition of limestone to the bed [49]. No supporting fuel oil is required for combustion control. The principal disadvantage of the fluidized bed combustion system is its relatively long start-up time.

Fluidized bed combustion has a history of progressive development over the last ten years. Developing from the conventional fluid bed furnace (1st generation) pilot plant tests were carried out on a circulating bed (2nd generation) in 1977. The first commercial circulating installations were commissioned in Finland in 1979:

- a 15 MW unit burning peat and wood waste retrofitted to an existing boiler.
- a 7 MW district heating plant burning peat and wood chips.

The largest circulating bed unit built to date is a twin cyclone 65 MW steam boiler which was commissioned in 1981 and burns peat, wood waste and coal [56]. Each unit is designed specifically for the individual customer, incorporating any design improvements or modifications gained from operating experience. Fluidized bed combustion of peat may be regarded as being on the verge of commercial maturity.

The first commercial circulating bed units are as yet only 5 years old, and obviously will have to be monitored over a much longer period to prove their long-term efficiency, durability and cost-effectiveness. Bord na Mona regard the technology as sufficiently established for the combustion of peat and plan to install an 18 MW circulating fluidized bed boiler in a new briquette factory under construction. A combined fixed bubbling bed and circulating bed 35 MW unit, which will burn sod peat and coal, is currently being installed by an agricultural co-operative in Southern Ireland [48].

INDUSTRIAL UTILISATION

Peat may be used as an energy source for industrial heat or steam generation. Pulverised peat firing, grate firing or fluidized bed combustion may all be considered, depending on energy requirements, peat quality and peat harvesting techniques. With grate-firing of sod peat the grate design, air supply and stoking system employed are all extremely important in achieving efficient, controlled combustion [54,57]. Owing to the handling equipment required and increased boiler size, peat-fired steam or heating plant in the 1-30 MW capacity range costs from 3 to 5 times its oil-fired equivalent. Otherwise plant capital investment is more or less similar to that for coal. Peat is most competitive where steam or heat is required all the year round, and economics improve as plant size increases [8].

Peat has a long history of use in industrial processes, especially during wartime. Peat coke production dates back to the late 18th century in Germany when it was used for metallurgical purposes. Peat coke is still favoured by the metallurgical industry for its high reactivity and chemical purity. It is produced only from peats with very low sulphur and phosphorus levels and ash contents not exceeding 3-4%. Other industrial uses of peat include kiln firing of bricks and clay, cement burning and glass melting. Peat fibre occupies a small but potentially expanding market for use in filter beds for chemicals and in air purification systems.

DOMESTIC UTILISATION

As a low density, bulky fuel, peat is most suited to small-scale domestic utilisation in the immediate area surrounding the production site. Hand-harvested sods, machine produced sods or peat briquettes are all used for domestic space heating, water heating and cooking purposes. Use in an open fire, even where fitted with a back boiler,

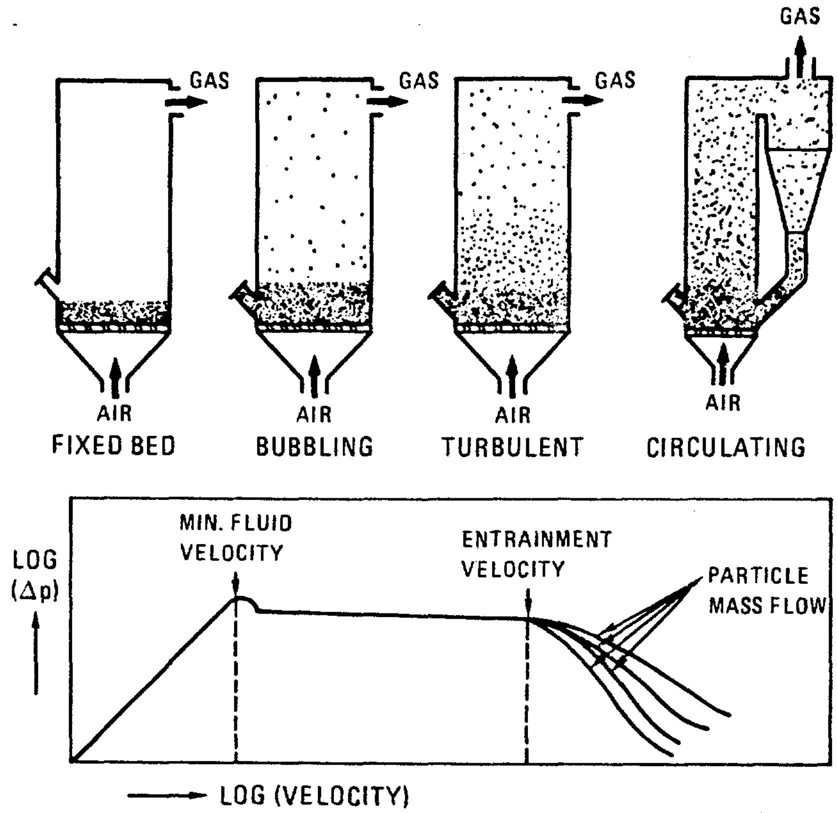


Fig. 6.3 - Pressure Drop Versus Gas Velocity in a Fluidized Bed.

Source: Yip, 6th IPS Congress [56]

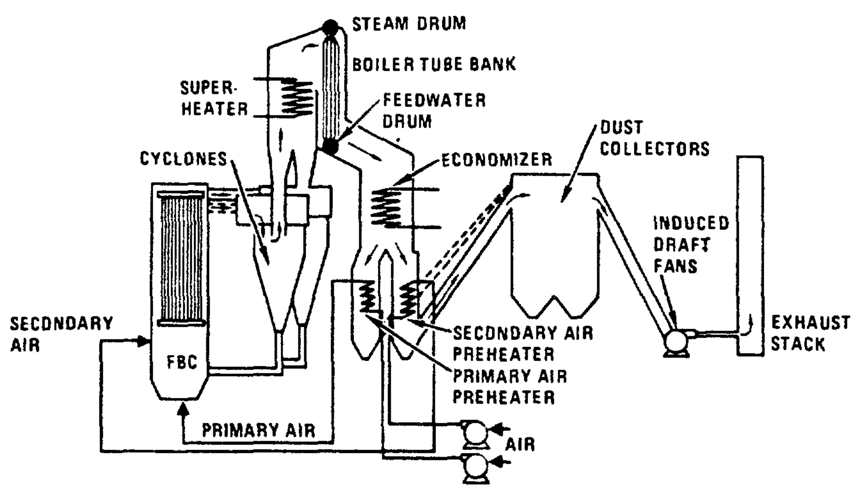


Fig. 6.4 - Schematic Layout of a Fluidized Bed Boiler

Source: Yip, 6th IPS Congress [56]

leads to incomplete combustion and a high proportion of the energy being lost. It is much more efficient to enclose the furnace and control the access of combustion air.

Most stoves designed to burn solid fuels are capable of burning peat, although inefficient and faulty combustion may cause chimney tar deposits. These difficulties may be overcome through firebox design and by correct proportioning of primary and secondary air supplies. Cooking ranges and domestic hot water boilers should be designed for convected rather than contact heat transfer. Where peat is used for space heating with a closed stove, the provision of internal flues increases the overall efficiency of the system [58].
For small domestic stoves and boilers in the 10-500 kW range peat is especially competitive with light fuel oil, although exact economy depends on labour costs, since daily stoking and ash removal are required. The conversion of existing oil-fired boilers of this output range is extremely difficult and may be more expensive than installing new peat-fired appliances.

A wide range of cookers, stoves and domestic boilers is currently available on the European market. Most of these units have multifuel potential and will burn peat successfully with due allowance for differences in fuel calorific value. Three or four stove designs have evolved in Ireland which include the facility to burn sod peat or briquettes. Indeed, over 20% of all non-electric household energy in Ireland is supplied from peat. Recognising the inefficiency of open fires, the most recent trend has been towards the use of enclosed appliances, especially those with glass fronts. Use of peat fuel in these appliances leaves opaque tarry deposits on the glass, although this is gradually being overcome through better selection of glass type and by improved air passage design. British stove manufacturers are currently designing bituminous coal burners for use in "clean air areas", which feature almost total combustion of the coal within the chamber, and these will problably be equally advantageous for burning peat fuel.

While European stove design is becoming more sophisticated, the units are also relatively expensive and most are unlikely to be suitable for installation in individual households in developing countries. A simpler and much less expensive approach to stove design [53] needs to be taken to provide appliances suitable for household heating or cooking in these countries - e.g. the simple peat stove (imbabura) designed and manufactured from waste metal in Burundi under the USAID Alternative Energy peat development programme [82] - see Figs. 6.5 and 6.6.

OTHER USES

Apart from its use as a fuel, harvested peat may have other potential uses in the developing countries:

Horticulture: The actual tonnage of peat currently used for this purpose greatly exceeds that consumed as fuel in the developed countries - see Table 2.4. The principal uses are as a soil-conditioner and as a compost base in the protected cropping industry.

Peat Wax: Produced commercially only at one plant in the Soviet Union. Used as a mould release agent in foundries and as a lubricating agent on polyurethane surfaces.

Peat coke: Used for metallurgical purposes and as a decolorising and deodorising agent.

Activated Carbon: Used for water purification, the removal of organic impurities from starch and sugars, colour removal and gas and vapour adsorption.

Wastewater Treatment: Absorption of oils following spills, the removal of hazardous and undesirable chemicals from wastes and the adsorption of dyes from textile effluents.

Microbiological Products: Sugar released from peat by hydrolysis for the production of alcohol by fermentation. Alternatively the peat may be used as a substrate for the production of high protein yeasts suitable for human and animal diet supplementation.

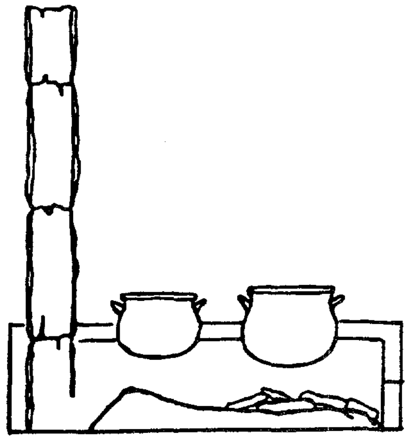
Healthcare: Based on the B-vitamin content of peat, the principal medicinal product is Torfot. It is mostly used for the treatment of opthalmic diseases and also for anaemia, hepatitis and various dermatological and neurological disorders [55].

Balneology: Therapeutic peat bathing at special spas is a well-established practice in Central and Eastern Europe. Effects are thermophysical, based on the bathing temperature and the physiologically-active substances contained in the peat.

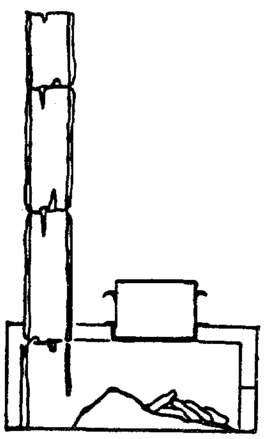
APPLICABILITY

Fuel utilisation of peat in developing countries ultimately depends on the quality of the peat, the volume of the deposits and their distribution in relation to the major population centres. Owing to its high volume : heat ratio, peat is generally regarded as a local fuel, long-distance transportation adding considerably to the final energy cost.

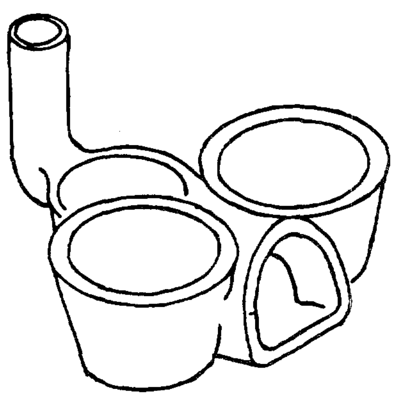
Small-scale deposits are most suitable for use as a local rural fuel, replacing wood or charcoal and thus helping to maintain the level of forest cover. Although more expensive than milling, sod peat would be the preferred method of production, as the briquetting of milled peat is likely to yield a prohibitively expensive product. Local utilisation of sod peat includes domestic heating and cooking and smaller industrial heat and steam generation.



New efficient wood-burning stove - Upper Volta



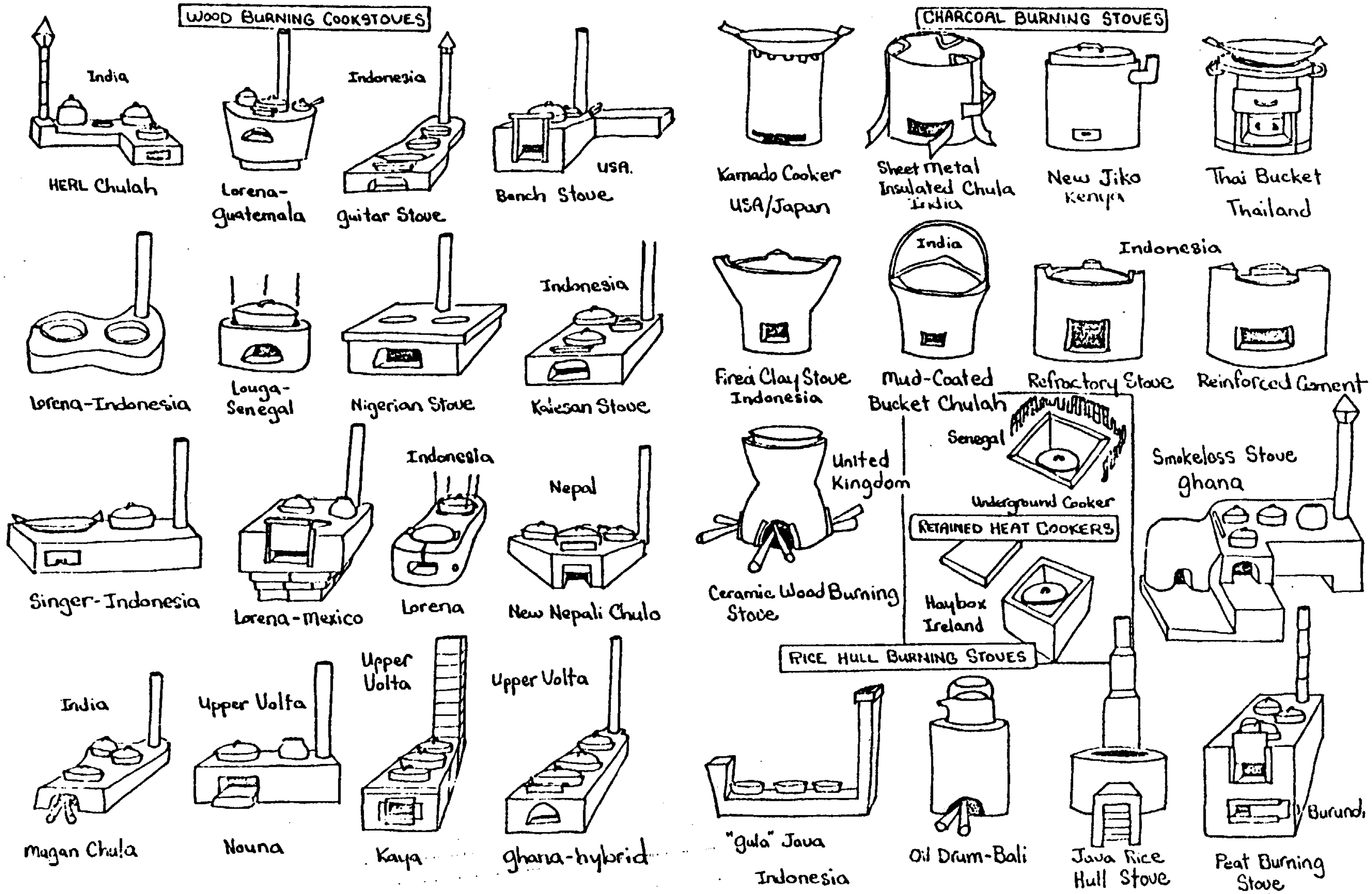
New peat stove with insert for flat-bottomed pot - USAID Burundi.



New portable stove-
ILO project, Ivory Coast.

<u>Fig. 6.5</u> - Improved Stove Designs for Burning Wood and Peat

<u>Source:</u> Commission of European Communities [170]



<u>Fig. 6.6</u> - Cookstoves for Various Fuels

<u>Source:</u> Cookstove News, USA [53]

Extensive deposits may be used for electrical power generation, industrial applications and briquette production. Milled peat, the most economical method of production, can be used with either pulverised fuel or fluidized bed combustion. Plant capacity will be determined by the size of the deposit, the planned annual output and supply duration, combined with the necessary provision for servicing and amortisation of capital. The economic constraints of the briquetting process may be increased by inferior quality, high ash content peat.

The main domestic provision of energy for heating and cooking in developing countries is via the open fire, normally fuelled by wood, and/or charcoal used in a simple stove. Sod peat may be substituted, although much better economy will be achieved if it is burned in a small stove fitted with a flue. This also eliminates any problem which may be caused by smoke from the peat - Fig. 6.5. The greater heat generated from peat fires has been found to cause distortion of the light cooking pots used on charcoal fires, and utensils normally used on wood fires are recommended.

On a larger industrial scale sod peat may be considered for use in existing coal or wood-fired boilers. From a combustion point of view peat is very similar to wood and furnace modification costs should be be minimal. Operational problems which may be encountered include those arising from variations in the peat quality, from moisture and humic acid corrosion of the fuel handling equipment necessitating the replacement of ordinary steel with stainless steel, and from physical wear of the handling plant if the peat has a high mineral content. Conversion of existing oil-fired plant is more difficult. One possibility is by installing a solid fuel fore-furnace and ducting the hot flue gases into the old boiler. A significant reduction in boiler output would have to be accepted, and a better long-term solution may be complete replacement with proven equipment.

The greatest single problem likely to be encountered with peat utilisation as a fuel in developing countries relates to ash content. While the exact peat ash melting point depends on the elemental constitution of the mineral fraction, the high natural ash contents of most minerotrophic peats are likely to render them unsuitable for conventional grate firing. From Irish experience ash contents up to the order of 4% do not present any problem with grate firing. Above this level problems with ash melting, clinker formation and sealing of the grate increase in a linear relation to the percentage ash content of the peat. The attempted use of high-ash peats in grate-fired boilers in Burundi has demonstrated the unsuitability of these appliances for burning this type of fuel [81].

While pulverised firing in suspension is still technically possible, the best means of utilising these high-ash peats, on an intermediate and large scale, will be by fluidized bed combustion. At 800-900 C the combustion temperature is well below ash fusion point - see section II - and excess ash may be continuously removed from the bed. A pilot plant designed in Finland for sewage sludge disposal proved capable of handling up to 45% ash content in the feedstock. While the fluidized bed system can cope with variations in the fuel quality, these are best reduced by utilising bunker and blending facilities to maximise homogenisation before combustion. The wide range of acceptable feedstocks also allows the development of multifuel systems, which may be particularly significant in the overall utilisation of indigenous fuels in developing countries.

SECTION VII - DISTRIBUTION AND MARKETING

STORAGE

With a relatively low calorific value per unit volume, storage of unprocessed peat occupies a considerable amount of space. In practice both sod peat and milled peat are stored on site in stockpiles until required, as investment in storage facilities at the consumer end tends to be relatively high. Stockpile size, shape and position vary according to the production method and the transportation network-see Fig. 4.5.

Ideally stockpiles are designed to minimize surface to volume ratio and limit, as far as possible, increases in the moisture content of the harvested peat. Correctly macerated and dried sod peat forms a semi-impermeable outer skin which is fairly resistant to rewetting under light rainfall. Where long-term storage on site is forseen, or rainfall incidence is high, the sods may be protected by covering with polythene film.

Aside from any moisture content increase through precipitation, milled peat in stockpiles is also susceptible to spontaneous combustion. This originates as a microbiological process, with activity of the natural peat microflora progressively raising the temperature in the stockpile to around 70 C. The process then becomes autocatalytic, with strongly exothermic chemical reactions causing rapid increases in temperature and leading to combustion. Highly minerotrophic peats are much more susceptible to self-ignition than ombrotrophic peats and it is thought that iron and other minerals present in the peat act as catalysts in the thermochemical process. Spontaneous combustion may be checked by repeatedly rolling and compacting the peat during stockpile formation and/or by covering the piles with heavy gauge polythene film, which also effectively prevents rewetting.

Fuel peat is usually stored in only relatively small amounts by the consumer. At the domestic level up to one year's supply of sod peat or briquettes may be stored under a simple shelter capable of deflecting rain. Commercial and industrial boiler installations require storage bins or hoppers with capacity for a few days supply and designed to prevent bridging or arching of the fuel at the discharge outlet. In handling and conveying peat, screw conveyors are suitable for moving milled peat over short distances, while belt systems are used for longer distances and for transporting sod peat. Dischargers may be screw feed, scraper chain or hydraulic rod systems, depending on fuel type and silo design [62]. At larger capacity power stations and peat processing plants substantial bunker facilities are required for blending and homogenizing peat quality prior to utilisation.

TRANSPORT

Transportation of peat requires specialised machinery and ideally is carried on throughout the year, allowing maximum utilisation of the equipment and economic return on investment. Road, rail and water should all be considered when investigating the most economical means of transporting fuel peat from the production site to the consumer. Rail is the preferred system of peat transportation in the major peat-producing countries. In the Soviet Union peat is transported from production areas to adjacent power plants using diesel locomotives and self-discharging cars on narrow gauge - 750mm - track. For transportation over greater distances the peat is reloaded onto mainline trains [63].

Bord na Mona in Ireland also use narrow gauge track - 914mm - to transport harvested peat over short distances to power stations, briquette factories and tipheads. The systems are comprised of permanent distributive tracks, with temporary lines which are laid alongside stockpiles for loading and moved up to 12 times each year [61]. Sod peat for domestic and commercial utilisation is road transported by lorry and tractor-trailer from tipheads. Peat briquettes are also distributed by road.

Narrow gauge rail is not used for carrying peat in Finland. Around 70% of the peat produced is transported by road and the remainder by mainline rail. On the road tractors and dumpers are used over short distances and high-sided, 70-80m^3 trucks for longer hauls. The estimated capacity of a truck with a delivery distance of 70 km is 78,000m^3 p.a. For mainline rail transport the peat is first carried by tractor-trailer or lorry from the production area to a loading yard and then reloaded into 150m^3 wagons for distribution countrywide [60].

For over a hundred years in Ireland peat transportation by canal was used to supply urban centres with fuel from the peatland areas. Similarly in the Netherlands and in Germany the canal network was historically used to distribute peat fuel. Although no longer employed in the developed countries, barge transportation of peat may be a viable option in developing countries with estuarine or floodplain deposits, provided adequate handling facilities are installed.

MARKETING

The greatest problems ecountered in the commercial development and marketing of fuel peat relate to the costs of distributing a relatively low density fuel, continuity of supply with consistent quality and consumer preference and acceptability. Market sectors to be considered are large-scale power generation, commercial/industrial enterprises and domestic consumers, and pricing structures should reflect the relative importance of the sector and the competing fuels.

With peat utilisation for power generation capital investment is the over-riding consideration and a long term market view must be taken. The base price for peat fuel is determined by production costs and is independent of world energy costs. Evaluation of local peatlands for power generation should consider both the social and economic benefits, compared to alternative local and imported fuels and the development of any local hydroelectric potential.

Commercial and industrial customers require an efficient and reliable distribution system and advice on suitable handling and combustion equipment. To a certain degree fuel production may be geared towards and adapted to customer requirements, e.g. fuel sizing. Guarantees of continuity of supply and fuel quality are necessary before enterprises are likely to invest in conversion to peat fuel.

The domestic market is perhaps the most conservative, and in an open market considerable publicity will be required to achieve significant penetration. This should emphasise peat in comparison with other fuels, highlighting any cost and heating advantages. Advice is also required in the utilisation of peat as a domestic fuel, especially in promoting the use of suitable appliances. Minimising transportation and distribution costs must be the prime objective in reaching the domestic consumer. The development of distribution channels to achieve this objective may necessitate the creation of a system that is specifically directed to peat fuel, and unencumbered by distribution practices in existence for other fuels.

Sales of sod peat and/or loose briquettes to domestic consumers, for instance, benefit from the delivery of full loads, of suitable size, direct from the bog or factory to the household without any intermediate handling. In Ireland 75% of sod peat sales occur within 30km of production sites [59]. Baled briquettes can be distributed most economically through high volume, low overhead, self service outlets.

PROBLEMS IN DEVELOPING COUNTRIES

By their very nature peatlands tend to be wet, inhospitable wastelands which do not have any sizeable human settlements. Accessibility is poor and considerable initial investment may be required in roads, railways, bridges, etc., to allow development of the deposit and facilitate transportation of the fuel. The lack of foreign exchange is a serious problem in almost all developing countries. Consequently, the foreign exchange requirement to cover the initial capital investment must be weighed carefully against the future reduction in foreign exchange required for imported fuels.

Peat is a relatively bulky fuel and expensive to transport in small amounts. Major consumers, such as power generating stations, should be located adjacent to the peat deposits, minimizing transportation distance and cost. Local distribution of small loads may be economical, especially if collected by the consumers. Transportation to major population centres requires good road/rail links of maximum carrying capacity servicing distribution depots.

The marketing of peat is a major problem in developing countries. A comprehensive assessment of existing and potential markets and distribution channels must form part of any initial feasibility study on fuel peat production. This should include a systematic survey of potential customers, with estimated costs for the modification of existing utilities or the installation of new equipment for the combustion of fuel peat.

Aside from the need for peat to be competitive with other indigenous or imported fuels, an innate conservatism and traditional fuel bias will have to be overcome. Wood and charcoal are the primary sources of energy in many developing countries. Charcoal production is a very energy-inefficient process, with around 7kg of wood required to produce each kilo of product. Urban populations are the main consumers of charcoal and, if the utilisation of peat as a alternative fuel aims to conserve forest cover, it is towards these consumers that peat fuel promotion should be directed. Satisfactory results will not be obtained by using peat in existing charcoal burners. The design and local manufacture of acceptable, domestic, fixed and portable stoves may be a prerequisite for significant market penetration by peat fuel. On-site carbonisation of the peat is possible, leading to a reduction in the transportation costs and greater market acceptance of the fuel. These factors, however, need to be set against the process costs and the overall energy loss. A low ash raw material is also required to produce good quality, mechanically stable peat charcoal.

Other potential customers for peat fuel, who at present are more likely to consume firewood than processed charcoal, are rural domestic hearths or grate fires, commercial brickmakers, bakers and institutions such as schools, missions and hospitals. Selling fuel peat to a rural population used to gathering free firewood will be extremely difficult. Commercial and institutional customers who pay for their current fuel may accept a reasonably priced alternative.

SECTION VIII ECONOMICS OF FUEL PEAT PRODUCTION

This section describes the major cost elements and design choices to be made in considering the development of peat as a fuel source. In addition, current data on Irish peat production and transportation costs are given and compared with those in Finland and other countries. Land reclamation costs and training requirements are also examined.

ECONOMIC ANALYSIS AND CHOICE OF TECHNIQUE

As outlined in Section VI, the potential for viable utilization of peat deposits depends to a great extent on the economics of deposit development and peat production in relation to alternative fuels. A comprehensive analysis must include consideration of costs related to all stages of development, with factor inputs costed at their economic (opportunity) costs and the resource rent (depletion premium) explicitly considered.[2/]

The major cost components to be considered in the analysis of a peat project are the following:

- Land use and reclamation: if the mire is currently used for agricultural production, then the value of this production foregone during the peat extraction period is a cost to the project. To this cost should be added the cost of reclaiming exploited peatland to make it agriculturally productive. Any costs of population resettlement should also be included. In most cases, extensive agricultural use of peatlands will preclude the large scale development of peat as an energy source as the cost of foregone agricultural produce will be positive.

- Peatland preparation: this phase of peat deposit development, during which drainage channels are cut, the surface is cleared of vegetation, timber is removed and transport systems and infrastructural facilities installed, can last from one to seven years (see Section IV). As in the later production phase, there are choices to be made between techniques with different degrees of capital and labor intensity, choices which will depend on technical considerations and the relative economic costs of the options. Peat production in Europe originally developed using manual cutting of drainage channels, clearing of the surface and cutting the peat. These options are still open to developing countries where the opportunity cost of labor is low. Different degrees of capital intensity may be considered. Bog clearing may be done manually with simple implements, manually with power tools, or using large machinery. Likewise peat cutting can be done manually with a shovel, with an implement attached to a farm tractor, or with specialized equipment that gives high output per manhour of labor.

2/ "Economic Analysis of Projects", L. Squire and H. van der Tak, Johns Hopkins, University Press, 1975.

In analyzing the economics of each alternative, care must be taken to price labor at its opportunity cost, which may differ from the wage rate, and to exclude all import duties, sales taxes or subsidies to local manufacturers from the cost estimates of equipment. Foreign currency costs should also be shadow priced appropriately if there is evidence that the existing exchange rate undervalues foreign exchange. Attention should be paid to the time phasing of costs since, given the relatively long preparation period, this phasing will have an important influence on overall project economies. The objective should be to achieve a phased development that is tailored to long-term production needs and does not give rise to early peaks in the labor force, which is then not required during the long drainage phase to production.

- Production Phase: as in the bog phase, there are a variety of technologies with different capital and labor requirements for the harvesting of peat. Peat production for local use as a domestic and heating fuel using largely manual methods can be feasible alternative where labor costs are low. As a fuel for power generation, harvesting will require some degree of mechanization, though even here the question of appropriate design should be fully explored using appropriate prices for labor, capital and foreign exchange.

- Resource Rent:[3/] use of a depletable resource over a certain period of time eliminates the possibility that the same resource could be used at another time in the future. The economic costs associated with this aspect of resource use is called the resource rent, or depletion allowance (see Section VI). For large peat deposits, where the reserve lifetime exceeds 40 years under all scenarios of possible use of the peat, the present value of the future loss of benefits, and hence the resource rent, will be negligible. However, for a reserve that is only sufficient, for example, to supply one power station during its economic life, and where the alternative fuels for power generation in the future are more costly than peat, the resource rent will be significant and should be taken into consideration in the economic analysis of the project. The magnitude of the resource rent will be dependent primarily on the size of peat reserves to their projected use, the projected future costs of alternative substitute fuels, the cost of developing peat resources and the opportunity cost of capital in the country in question.

3/ "Economic Theory and Exhaustible Resources", P.S. Dasgupta and G.M. Heal, Cambridge University Press, London, 1979.

TYPICAL EUROPEAN PRODUCTION COSTS

General

Costs have been established in European countries which use conventional natural drying techniques for the production of fuel peat in sod and milled (crumb) form, with beneficiation by briquetting which necessitates additional thermal drying. The Irish costs referred to are based on operational experience over many years and cover the complete cycle of deposit exploitation, i.e. investigation, development, production and cutaway bog reclamation. These costs are made up of actual production costs and current capital costs and are not comparable with fuel peat market prices in Ireland (ref. Tables 8.11 and 8.12), as the capital interest and repayment increment in the market price is not current and has been the subject of inflationary trends for a number of years. Owing to variations in international exchange rates these costings can only convey an order of magnitude; however, when they are taken in conjunction with estimates of the personnel required, it should be possible to establish meaningful guidelines.

As the exploitation of a peat deposit is site specific, like all mining operations, the costings will vary with each deposit. Variations in Western European deposits are not excessive, but in developing countries the economics of fuel peat production may be very different. One important factor is the output per worker in developing countries, which can be low by American and European standards, but which will most probably be reflected in the pay structure.

Criteria

The following criteria apply to the Irish production costs:

- Average depth (thickness) of undrained deposit - 5.5m
- Average moisture content of undrained deposit - 93.5%
- Anhydrous ash content - 2.4%
- Average depth of drained deposit left for reclamation - 0.5m
- Production areas are 80% of total areas.
- Production losses are 7.5% of total fuel content.
- Duration of preparatory work 4 to 5 years on average.
- 20 million B.T.U. (20 GJ) per tonne-anhydrous and ash free.
- Bog surface free of timber
- Containing only small amounts of buried timber.
- Irish climatic conditions.

Variations which may be expected to occur in developing countries include:-

- The depth (thickness) of the unmodified peat (by drainage etc) will vary considerably, perhaps from 2 m to 30 m.

- The moisture content of the unmodified peat will vary from 85% to 95%. These variations in depth and moisture content can have a significant impact on the costings. Reducing the moisture content of a bog by drainage from 95% to 90% means that 50% of the initial moisture must be removed and this could take up to 7 years, whereas a bog of 85% to 90% moisture content could be brought into production within 1 to 2 years. Capital drainage costs in the latter case would be minimal provided gravity drainage was possible.

- Ash contents will frequently be much higher, reaching 50% in some instances and thereby increasing production and transport costs based on energy values. Marketing will also be more difficult and costly and specialised burning equipment may have to be installed at extra cost.

- Agricultural productivity from reclaimed cut-over bog areas may be greater, thereby reducing the cost of restoration in relation to subsequent productivity.

- Deposits in river valleys or estuaries which cannot be drained by conventional means will usually be more costly in terms of both capital and production expenditure.

- Growing timber will increase bog preparation costs although it is not expected that all bogs in developing countries will have this problem.

- Climatic conditions should in most cases have a favourable impact on production costs.

- The presence of buried timber in the deposit will cause production costs to increase and if excessive could make exploitation impractical.

- Most Irish bogs are located in the flat midlands, where road services are reasonably good, and are on average within about 65 km of their market. Irish transport costs quoted are on this basis, but it is anticipated that conditions will be less favourable in the majority of peatland areas in developing countries, leading to higher transport costs. Most of the cost factors, except wages, are expected to be higher, and in locations where all the conditions which affect transportation are adverse, it is possible that road transport costs could be in excess of US$ 25 per tonne.

IRISH PRODUCTION COSTS

Typical costings and personnel requirements for the exploitation of a deposit in Ireland, using conventional production methodologies, are outlined in Tables 8.1. to 8.10. In these costings a conversion rate of US$1.12 to the IR£ is used, and giga joules and 10^6 BTU are regarded as equivalent.

Table 8.1 - Sod and milled peat production costs in Ireland, January 1984

	Milled Peat (800,000 tpa) Production Unit	Sod Peat (200,000 tpa) Production Unit
	US$ per tonne	US$ per tonne
Production costs, including overheads	5.43	15.3
Transport costs (on site railways)	3.20	5.6
Administrative costs (marketing, R+D etc.)	1.20	1.73
Total	9.83	22.63
Cost per 10^6 BTU at 9.3×10^6 BTU/tonne	1.06	-
Cost per 10^6 BTU at 13.3×10^6 BTU/tonne	-	1.70

Source: Bord na Mona

Table 8.2 - Bog development costs in Ireland for sod and milled peat, January 1984.

	Milled Peat (800,000 tpa) Production Unit	Sod Peat (200,000 tpa) Production Unit
	US$ per productive ha	US$ per productive ha
Resource assessment (studies and survey)	125	150
Bog and site preparation (incl. buildings)	1,950	1,925
Plant and machinery	1,450	850
Railways (incl. loco, rolling stock etc.)	1,575	925
Acquisition of bog	1,000	1,025
Capital work overheads	1,050	750
Total	7,150	5,625

Source: Bord na Mona

Table 8.3 Capital repayment and interest charges for sod & milled peat (At an interest rate of 15% and repayment period of 15 years).

	Milled peat 800,000 t.p.a. Production Unit	Sod peat 200,000 t.p.a. Production Unit
Capital expenditure per productive ha.	US$ 7150	US$ 5625
Output in tonnes per annum per productive ha.	161.	93.75
Capital outlay per tonne/annum	US$ 44.4	US$ 60.00
Annual interest and capital repayments per tonne (x 0.171)	US$ 7.6	US$ 10.26
Cost of interest and capital repayments per 10^6 BTU	US$ 0.82	US$ 0.77

Source: Bord na Mona

Table 8.4 Irish sod and milled peat ex-works costs per 10^6 BTU, January, 1984.

	Milled peat 800,000 t.p.a. Production Unit	Sod peat 200,000 t.p.a. Production Unit
	US$ per 10^6 BTU	US$ per 10^6 BTU
Capital costs.	0.82	0.77
Production, bog transport and administration costs.	1.06	1.70
Total	1.88	2.47

Source: Bord na Mona

Table 8.5 1984 Personnel requirements and labour costs for a sod peat production unit in Ireland.

PERSONNEL	Annual Output 165,000 Tonnes	Annual Output 30,000 Tonnes
Administration	20	7
Skilled	45	12
Supervisors	11	2
Others	126	50
Total Average	202	71
Total Permanent	176	61
Total Peak	221	76

LABOUR COSTS	IR	IR
Wages & Labour Overheads	1,980,000	668,000
% of Operational Expenditure	72%	73%
% of Nett Sales Revenue	42%	77%

Source: Bord na Mona

Table 8.6 1984 Personnel requirements and labour costs for a milled peat production unit in Ireland.

PERSONNEL	Annual Output 1,000,000 Tonnes	Annual Output 400,000 Tonnes
Administration	36	17
Skilled	95	47
Supervisors	32	16
Others	236	118
Total Average	464	230
Total Permanent	399	198
Total Peak	580	290

LABOUR COSTS	IR	IR
Wages & Labour Overheads	5,650,000	2,775,000
% of Operational Expenditure	74%	75%
% of Net Sales Revenue	38%	41%

Source: Bord na Mona

Table 8.7 Briquetting capital costs in Ireland, January 1984 (Interest rate of 15% and repayment period of 15 years)

	US$
Capital cost of a 150,000 tonnes per annum briquette factory.	29,000,000
Capital outlay per tonne per annum	193
Annual interest and capital repayments tonne (multiply by 0.171)	33
Cost of interest and capital repayments per 10^6 BTU	1.8

Source: Bord na Mona

Table 8.8 Briquette plant operating costs January 1984.

Operating Costs per Tonne	US$
Production, storage and loading	5.2
Workshops	3.7
General overheads	5.6
Power	0.3
Miscellaneous	0.5
Milled peat at 55% moisture content (input-output ration 2.4)	41.8
Total operating cost per tonne	57.1
Operating cost per 10^6 BTU	3.2
Operating cost per 10^6 BTU (excluding feedstock)	0.86

Source: Bord na Mona

Table 8.9 Cost of briquettes per 10^6 BTU, January, 1984

	US$
Capital costs	1.8
Operating costs (including cost of feedstock)	3.2
Total (including feedstock)	5.0
Capital costs	1.8
Operating costs (excluding costs of feedstock)	0.86
Total (excluding feedstock)	2.66

Source: Bord na Mona

Table 8.10 Personnel requirements and labour costs for a briquette factory in Ireland.

PERSONNEL	Annual Output 150,000 Tonnes
Administration	13
Skilled	28
Supervisors	5
Others	77
Total Average	123
Total Permanent	123
Total Peak	125

LABOUR COSTS	IR£
Wages & Labour Overheads	£ 1,409,000
% of Operational Expenditure	28%
% of Nett Sales Revenue	23%

Source: Bord na Mona

Sod Peat and Milled Peat

It will be seen from the sod and milled peat costings that, based on heat value, the cost of sod peat is approximately 30% greater than that of milled peat. The sod peat is produced by the dredger type machines (see page 15) and some reduction in this cost could be made by using tractor-drawn cutting attachments if the quality of peat in the deposit proved suitable. Milled peat is of course limited in application to pulverised fuel burning or briquette (pellet) production, whereas sod peat has a much wider range of outlets. The prices of peat products as shown in Tables 8.11 and 8.12 do not reflect up-to-date capital charges which would increase the sod peat cost for 10^6 BTU to US$3.66. Even at this price the Irish energy-related costs indicate that sod peat is the cheapest fuel on the domestic and industrial market with the exception of industrial coal.

It is anticipated that bogs in developing countries will generally be suitable for the use of tractor-operated cutting attachments, some of which are now in use in Burundi. The sod peat method should therefore have greater application in these countries in cases where the direct burning of milled peat is not considered practical. The beneficiation of milled peat requires sophisticated plant and equipment which should be avoided in developing countries if the simpler sod peat system can be operated successfully to produce a satisfacory fuel product.

Briquettes

The cost of briquettes in Ireland, on an energy related base, is double that of sod peat. The briquettes are, however, in every other respect a more attractive fuel, but at the ex-works price of US$ 5 per 10^6 BTU, sales would be limited to a section of the domestic market where the facilities associated with the use of peat briquettes (i.e. packaging, cleanliness etc.) would outweigh the energy related price disadvantage. The actual delivered prices shown in Tables 8.11 and 8.12 are competitive, but do not reflect current capital outlay and services charges for either the feedstock or the briquetting operation. All of these costs are based on a capital repayment period of 15 years at 15% interest and do not take cognisance of the fact that the life of the bog could be 35 years, which is normal in Ireland, or that alternatively a greater annual output per hectare could be achieved under the better natural drying conditions which can be expected in tropical regions. The feasibility of providing new briquetting capacity in Ireland is therefore dependent on market acceptability rather than the economic fuel related values, unless an inflation factor is taken into account and capital costs levelised over the expected plant and bog life.

Under Irish conditions a reasonable plant and bog life is 35 years, and if a 6% annual inflation rate is assumed, the levelised factors over 35 years are revenue 3.37 and costs 2.2. At an initial ex-works

Table 8.11 Delivered costs of domestic fuels in Ireland, January 1984

Fuel	Type	Unit of Supply	Average Price per Unit US$	Gross Calorific Value BTU/lb (MJ/kg)	Delivered Cost US$ per GJ (10^6 BTU)
Peat	Machine turf (sod peat)	Tonne	45.69	6192 (14.4)	3.16
	Briquettes (loose)	Tonne	71.84	8299 (19.3)	3.72
	Briquettes (80 bales/tonne)	Bale	.98	8299 (19.3)	4.08
Coal	House Coal	Tonne	122.85	12814 (29.8)	4.13
	Continental Antracite Peas	Tonne	196.94	13803 (32.1)	6.14
	Standard Antracite	Tonne	168.69	13502 (31.4)	5.37
Oil	Kerosene	Litre	0.3282	19952 (46.4)	8.96

Source: Bord na Mona

Table 8.12 Delivered costs of commercial/industrial fuels in Ireland, January 1984.

Fuel	Type	Unit of Supply	Average Price per Unit US$	Gross Calorific Value BTU/lb (MJ/kg)	Delivered Cost US$ per GJ (10^6 BTU)
Peat	Machine turf (sod peat)	Tonne	46.09	6192 (14.4)	3.20
	Crushed machine turf	Tonne	50.47	6192 (14.4)	3.50
	Brickeens (small briquettes)	Tonne	69.72	8299 (19.3)	3.61
Coal	Smalls	Tonne	66.11		2.36
	Fines	Tonne	56.09	11997 (27.9)	2.12
	Singles	Tonne	79.14		2.84
Oil	Gas oil 35 sec.	Litre	0.2955	18447 (42.9)	7.77
	Medium Oil	Litre	0.2569		6.30

Source: Bord na Mona

price of US$ 3.4 per 10^6 BTU, briquette production would prove marginally profitable in the long term, even when making allowances for carrying costs or overdraft interest. Aside from possible lower feedstock production costs, owing to more favourable climatic conditions, labour costs, etc., the availability of interest free loans and grants and the prevailing taxation policies will have enormous influences on the feasibility of briquette production in developing countries.

COMPARISONS WITH PRODUCTION COSTS ELSEWHERE

Finland

Finnish costs for fuel peat production by conventional techniques are available for 1980 [8]. Using a 1980 capital base, and adjustments to account for Finnish and Irish inflation (See Appendix II), these Finnish costs are compared with those currently applying in Ireland in Table 8.13.

Table 8.13. Comparison of ex-works costs per 10^6 BTU (1984)

PRODUCT	Ex-works Cost per 10^6 BTU (IR£)	
	IRELAND	FINLAND
Milled Peat	1.42	1.30
Sod Peat	1.94	1.90
Briquettes	3.50	3.50

Source: Min. Trade and Industry, Finland [8]
Bord na Mona

Others

Comparisons of Irish fuel peat production costs were made with various actual and estimated published costings:

- Finnish costs given in May 1980 have similar ratios for the three peat products [65].
- An estimated Canadian price of US$1.90 per 10^6 BTU for milled peat including a 20km transport distance, is comparable at $ 1.7 for peat production and $ 0.2 for transport [66].
- The estimates quoted at US$ 0.75 and $1.05 per 10^6 BTU appear to be optimistic for the production of milled peat [10].

- The January 1981 estimate of US$1.42 for milled peat appears relatively low, especially as this includes a 40km (round trip) transport cost compared with 16km (round trip) included in the Irish costs. However, this estimate is for Carolina, where there are 125 harvesting days per annum and natural drying permits moisture content reduction to 35%. The size of the operation also allows for economies of scale [64].

- The published ex-works cost of milled peat for power generation is US$ 21.5 per tonne in 1981, or IR£ 1.3 per 10^6 BTU [52]. When adjusted for Irish inflation this gives IR£ 1.68 or US$ 1.88 per 10^6 BTU, which is the current Irish cost given for milled peat - Table 8.4.

Non-Conventional Production Techniques.

Wet harvesting of moss peat is operated in Canada at a production cost of 3.5 to 4 times the cost of conventionally produced milled peat [68]. The operational size is quite small and economies of scale are possible both in the harvesting and subsequent drying processes.

There are many estimated costs in the recent literature on fuel peat production by unconventional techniques. Broadly they approximate to 50% moisture content, artificially-dewatered peat costing the same as conventional milled peat, and products which have been subjected to beneficiation costing the same as briquettes on an energy related basis [39,40,42,43,44]. Production costs for these systems will not be established on an operational basis for some years.

EXTERNAL TRANSPORT COSTS.

The Irish road transport costs in table 8.14 are based on experience over one-way distances of 16 and 64km. The trucks in use are 14 wheel articulated units, 12m long, $60m^3$ capacity and carrying a pay load of 20 tonnes. They operate on two shifts for 6 days per week. The vechicle life is taken at 5 years with no residual value. The operational costs per tonne for a 64 km (one-way) journey on a percentage basis are as follows:-

Drivers wages (overheads, bonus etc. included)	30.0%
Fuel costs	33.0%
Capital servicing	14.0%
Maintenance	16.5%
Miscellaneous	6.5%

Finnish transportation costs for December 1980 are given as 1 cent per 10^6 BTU per 1.4 km [67]. This is equivalent to the Irish cost for an 80km single journey distance. Finnish milled peat transportation costs for journeys of 100km are given as US$0.8 per 10^6 BTU in 1980 [8]. When corrected to 1984 costs (US$0.73 per 10^6 BTU) this remains high in relation to the Irish costs shown in table 8.14. However, these may not be exactly comparable as Irish costs are based on a very well organised transport system with uniform daily deliveries to the consumer.

The estimated 1980 American milled peat transport cost per 10^6 BTU for a 40km journey (single distance) is equivalent to US$ 0.32 in January 1984 [64]. This figure compares favourably with the Irish cost for 1984 of US$ 0.29 for a 32km journey. Synthesised costings for road, rail and waterway transportation, derived from a combination of published costs [64] and Irish road transport costs, are illustrated in Fig. 8.1.

Table 8.14 - Road transport costs in Ireland, January, 1984

Transport Distance in miles (kms) (one-way distance)	Cost per tonne in US$	Cost per tonne/ mile (km) in US cents
40 (64)	4.5	11.25 (7.0)
20 (32)	2.9	14.5 (9.1)
10 (16)	1.8	18.0 (11.2)
5 (8)	1.1	22.0 (13.8)

Peat @ 50% M.C. and 1.25% Ash

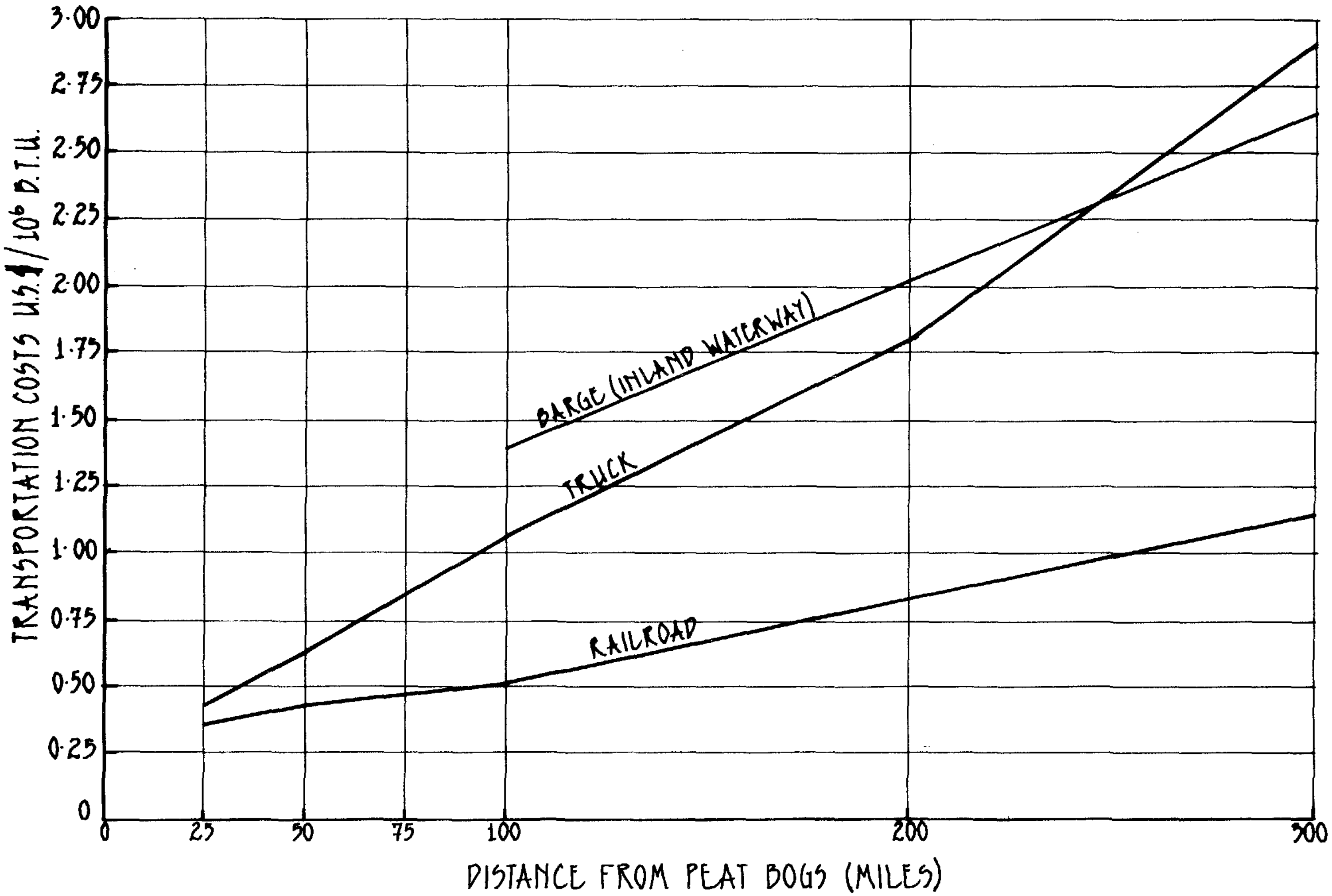
Transport Distance in miles (kms) (one-way distance)	Cost per 10^6 BTU in US$	Cost per 10^6 BTU/ mile (km) in US cents
40 (64)	0.45	1.13 (0.70)
20 (32)	0.29	1.45 (0.91)
10 (16)	0.18	1.80 (1.12)
5 (8)	0.11	2.20 (1.38)

Peat @ 35% M.C. and 1.6% Ash

Transport Distance in miles (kms) (one-way distance)	Cost per 10^6 BTU in US$	Cost per 10^6 BTU/ mile (km) in US cents
40 (64)	0.35	0.87 (0.55)
20 (32)	0.22	1.10 (0.69)
10 (16)	0.14	1.40 (0.88)
5 (8)	0.09	1.80 (1.13)

Price of diesel oil in Ireland = US$1.7 per US gallon.

Source: Bord na Mona



<u>Fig. 8.1</u> - Off-site Peat Transportation Costs - US$/$10^6$ BTU

<u>Source</u>: Burns and Roe, [64]
Bord na Mona

RECLAMATION

The reclamation cost for mined-out areas following fuel peat production is extremely site specific, depending on the degree of restoration, the level of inputs, the amount of supplementary drainage required and the level of infrastructural development. An indication of current Irish peatland reclamation costs is given in table 8.15.

Table 8.15 Irish reclamation costs, January 1984

Land use	Preparatory Technique	Cost IR£/ha
Grassland	Surface cultivation	600
Grassland	Deep ploughing	1000
Cereals	Surface cultivation	750
Vegetables	Surface cultivation	750
Forestry	Direct planting	700
Biomass-energy	Surface cultivation	2500

Source: Bord na Mona

These costs include lime addition, major and minor nutrient addition and incorporation, seed bed preparation and sowing/planting. They do not include any supplementary drainage which may be necessary following peat exploitation, or infrastructural development. Drainage costs may range up to IR£1000 per ha, and the provision of an infrastructure in terms of roads, power, water supply and buildings may add an additional IR£1000 per ha, depending upon the scale and nature of the enterprise.

Experience of peatland reclamation for agriculture has shown grassland to be the most successful land use under Irish climatic conditions. Deep ploughing, where residual peat layers are mixed with the underlying mineral soil, is superior to surface cultivation. Vegetables may be grown successfully on the deeper fen peats while cereals tend to suffer minor-element deficiencies, giving poor grain development and low yields. Forestry plantations of coniferous species have fast growth rates and high yields on cutover peatlands, while research on short rotation forestry (biomass) would indicate that the development of fast-growing, broad-leaved species can be limited by the acidity of the residual peat [23].

Peatland reclamation costs in developing countries will obviously depend upon the desired land use, the amount of supplementary drainage needed, the degree of cultivation required and the level of nutrients added. From our experience of peatland reclamation for intensive food crop production in Senegal, where rehabilitation involved the restoration of a fertile medium on sand-backfilled excavated peatland areas, the highest costs involved were for the neutralisation of the acidic peat residues and for the provision of an adequate water supply to facilitate crop production throughout the year.

SKILLS AND TRAINING

Skill requirements for the assessment, exploitation and subsequent reclamation of a peat deposit include:

- Peatland scientist - resource classification and qualitative assessment; potential utilisation.
- Hydrological - effects of peatland drainage on catchment hydrology and other land use.
- Ecological - effects of drainage and exploitation on environment.
- Surveying - quantitative assessment; topographic mapping; peat stratigraphy.
- Civil Engineering - peatland drainage; internal and external transport systems.
- Mechanical Engineering - machine fabrication and maintenance .
- Operational - peat production; transportation; peat processing.
- Marketing - marketing of peat as a fuel.
- Technological (fuel) - peat utilisation; combustion; plant and appliances.
- Agricultural/ Pedological - cutover peatland potential; land use planning; reclamation.

All of these skills are available in the developed countries currently exploiting their peat deposits for fuel; some are available in countries which previously utilised peat as a fuel and others may be found throughout the world. The Soviet Union, Ireland and Finland, actively engaged in fuel peat production, can offer the complete range of conventional production skills. Countries which have used peat for fuel more extensively in the recent past include FRG, GDR, Poland and Denmark. Other countries currently investigating the potential use of their peat resources, e.g. Canada, U.S.A., Sweden, can offer resource assessment skills including those connected with the newer utilisation technologies. Finally, some of the less specific skills, such as civil and mechanical engineering, may be found more widely within both the developed and developing countries.

Training facilities may be offered by those countries engaged in fuel peat production, and to a certain degree by those which have a history of peat exploitation or are involved in resource assessment. Training may be through personnel visiting the peat producing countries, or through the provision of skilled staff for "in country" training. Operational training of course can only be offered by those countries currently involved in the exploitation of their peat deposits for fuel.

SECTION IX - WORLD RESERVES

When compiling information on world peatland reserves consideration must be given to the defining criteria employed. Some variation exists internationally in the minimum values of the peat layer thickness utilised when defining peatlands. In Germany the limit value is only 20 cm, while in Ireland a 45cm defining limit applies on undrained peatland and 30 cm on drained areas. According to the Canadian Soil Classification System, the thickness criteria of peatland is 60cm for weakly decomposed deposits and 40 cm for medium and well decomposed peats.

Attempts have been made to standardise the thickness criterion. The International Society of Soil Science-Sub-Commission for Peat Soils - formulated the following definition at a congress held in Zurich, 1936:

> "For land to be designated as peatland, the depth of the peat layer, excluding the thickness of the plant layer, must be at least 20cm on drained and 30 cm on undrained land" [77].

This 30cm limit applies in Nordic countries and has been used in recent statistics of the International Peat Society [72]. In the FAO/UNESCO Soil Map of the World, however, peatlands (Histosols) are defined as having an organic horizon of greater than 40 cm, with a 60cm limit applying in the case of Sphagnum moss [75]. Organic deposits with potential for fuel peat production have a minimum depth requirement of 1.0m. Workable reserves are therefore likely to be considerably smaller than the total area defined as peatlands.

Estimates of the total area of peatlands in the world have changed considerably during the past decades. As recently as the 3rd International Peat Congress (1969) the world reserves were estimated at 150 million ha. The current figure is around 420 million ha and, taking into account the many areas for which accurate information is still unavailable, this total is eventually expected to approach 500 million ha [72].

Remotely sensed data has contributed enormously to our knowledge of global peat reserves. Considering the absence of even reconnaissance soil surveys for many developing countries, it is likely to play an increasing role in the future. The criteria used in peatland definition, however, require the exercise of caution in the interpretation of this data, with definition based on ground observations rather than on extrapolation. This is especially true in relation to the organic content of the substrate. Peat is normally defined as having an organic content in excess of 50%, while values over 20% would constitute an organic soil. Vegetation type alone cannot be used as an indicator of substrate organic content, hydrological regime or decomposition rate [69].

Peatland reserves are most frequently quoted on an area basis, since initial quantification normally arises through soil survey programmes or from remote assessment. Even where deposit depths and total peat volumes are known, it is still not possible to quantify the reserves in energy terms, since the energy content of in situ peat depends on its moisture and ash contents.

However, the organic component of peat deposits has a fairly constant anhydrous, ash-free calorific value (20-22 MJ/kg - see Section II), and if the total quantity of organic material is known then the peat reserve may be equated with standard energy units.

Example: Deposit area - 100 ha   Average Depth - 4.0m
Average moisture content - 90% by wt.
Average ash content - 10% by wt.

Volume of deposit = 4.0 x 104 x 100 = 4×10^6 m^3

Assuming a specific gravity of 1.00:

Weight of deposit = 4.0×10^6 tonnes.

@ 90% m.c. : Wt. of Solids = 4.0×10^5 tonnes

@ 10% a.c. : Wt of Organics = 3.6×10^5 tonnes

Assuming an ash-free, anhydrous calorific value of 22 MJ/kg = 22 GJ/Tonne

Total energy content of the deposit = $3.6 \times 10^5 \times 22 = 7.92 \times 10^6$ GJ.

1 Tonne Oil Equivalent = 40.6 GJ

Therefore our peatland reserve contains:

$$\frac{7.92 \times 10^6}{40.6} = 1.95 \times 10^5 \text{ TOE}$$

DEVELOPED COUNTRIES

The current utilisation of peat resources by the developed countries bears little relation to the extent of their deposits. Only the Soviet Union, Ireland and Finland utilise peat for fuel to any notable extent, while many of the developed countries produce horticultural peat, mostly for national comsumption - table 2.4. The most recent reserve estimates for peatlands in the developed countries, exceeding the 30cm depth limit, were returned to the International Peat Society in 1980.

Table 9.1 Areas of peatland in developed countries (peat depth exceeding 30cm)

Country	Area (ha)
Canada	150 000 000
U.S.A. : Alaska	49 400 000
U.S.A. : S of 49 N	10 240 000
Finland	10 400 000
Sweden	7 000 000
Norway	3 000 000
Great Britain	1 580 000
Ireland	1 180 000
FRG	1 110 000
Iceland	1 000 000
Netherlands	280 000
Japan	250 000
New Zealand	150 000
Denmark	120 000
Italy	120 000
France	90 000
Switzerland	55 000
Austria	22 000
Belgium	18 000
Australia (Queensland)	15 000
Luxembourg	200

Sources: Kivenen, Acad Sci. Finland [70]
Kivenen, 6th IPS Cong [72]
Goodwillie, Council of Europe [73]

Canada

The total area of wetland has been estimated at 170 million ha and Canadian peatlands probably cover 150 million ha. Exploitable resources are about 56 million ha, or 102 x 10^9 tonnes of peat at 40% moisture content [72].

United States

Peatland areas of the contiguous states - south of 49°N - total 10.24 million ha, with estimated reserves of 60x10^9 tonnes at 35% moisture content. In Alaska, tundra bog soils cover 38.0 million ha while deep peats (Histosols) occupy 11.4 million ha [70].

Iceland

While peatland covers 1.0 million ha, or 9.7% of the country, individual bogs are small, owing to the irregular relief. It has been estimated that units greater than 100 ha cover only 20,000 ha and those greater than 10 ha occupy 75,000 ha. Most of the larger deposits are found in the south west, near Reykjavik. Peat depth varies from 0.3-6.0 m, with occasional deep pockets containing up to 10m, and the estimated area with an average thickness of 2.5m is 300,000 ha [157].

Ash content of Icelandic peat is generally high, owing to the frequent volcanic eruptions which occurred during the period of peatland formation, and also to the deposition of aeolian dust (loess) [156]. Values of 20-40% are common, and significant quantities of peat with an ash content below 10% are found only on Snaefellsnes peninsula in the west.

With a humid climate and the short Icelandic summer air-drying alone could not be relied on for sucessful large-scale fuel peat production. A combination of solar and artificial drying of the peat would prolong the production season, and recent proposals include the use of geothermal heat for fuel peat drying in the Akranes region [154].

Netherlands

Practically all of the 280,000 ha of peatlands have been reclaimed to grasslands and many of the remaining uncut areas are protected as nature reserves. In addition, there are 170,000 ha of peat deposits covered with marine and fluviatile sediments [70].

Japan

Over 200,000 ha of peatlands occur on the northern island of Hokkaido, with 37,000 ha on Honshu and 3,500 ha on Kyushu [118]. The majority of these peatlands are distributed on the alluvial floodplains of the largest rivers and contain relatively high levels of mineral materials, as the result of repeated flooding and from the deposition of volcanic ash. Average peat thickness is 3-5m and total peat reserves on Hokkaido are estimated to be 62.5 million tonnes. The peatland areas are utilised mainly for rice cultivation in paddy fields and for grassland farming [117].

New Zealand

Peatland covers 150,000 ha on the two main islands, with a total estimated volume of 300 million m^3. While peat is not harvested for fuel in New Zealand a small amount is mined in the Waikato Basin for horticultural use. A high proportion of the peatland is used for agriculture, with upland sheep grazing on the blanket peats and dairy farming on the lowland mires [167].

Australia

Reserves have been quantified for the northern state of Queensland, which has at least 15,000 ha of peatland. The Soil Map of the World lists 133,000 ha of Histosols in Australia, including the south-eastern coastal swamps and the valley bogs of the Eastern Highlands [75]. Tasmania is also known to possess lowland swamps and mires with cushion bogs occurring in the uplands [69].

DEVELOPING COUNTRIES - AFRICA

While various types of swamps are extremely abundant in Africa, true peatlands are comparatively rare. The total area of African tropical swamp has been estimated at 34 million ha, including over 10,000 individual swamp units [78]. The principal swamp complexes are shown in Fig. 9.1. below. Since very few of these areas have been surveyed, difficulties arise in assessing whether they are likely to contain deposits of peat, or are merely inundated and waterlogged depressions.

Low temperatures and consistently high water-tables create the best conditions for peat accumulation, while high temperatures and fluctuating water-tables, characteristic of many of these swamp areas, do not provide satisfactory conditions for peat formation. Even where peat accumulates under swamp vegetation it is often of poor quality, containing a very high level of inorganic material. This may be derived from aeolian dust, waterborne silt and clay, or from the natural mineral content of the peat-forming plants.

With evaporation potential consistently exceeding rainfall below 2000m altitude, true peat formation is confined to certain wet highland and mountain areas - Fig. 9.2. The total area of true peatland is very small, the main centres of peat formation being:

- The Highlands of Rwanda and Burundi.
- Kigezi Region of southwestern Uganda and the adjacent highland areas of Zaire.
- Aberdare Range and Cherangani Hills - the "Kenya Highlands" - in western Kenya.
- The Ethiopian Plateau.
- Drakensberg Range of South Africa / Lesotho.
- Ruwenzori Range of Uganda/Zaire.
- Kipengere Range in southern Tanzania.
- Nyika Plateau and Mulanje in Malawi.
- Mt Elgon in Kenya.

Peat deposits are also found under some of the swamp forests while coastal margrove swamps can accumulate substantial deposits of peat, e.g. along the Mozambique coast.

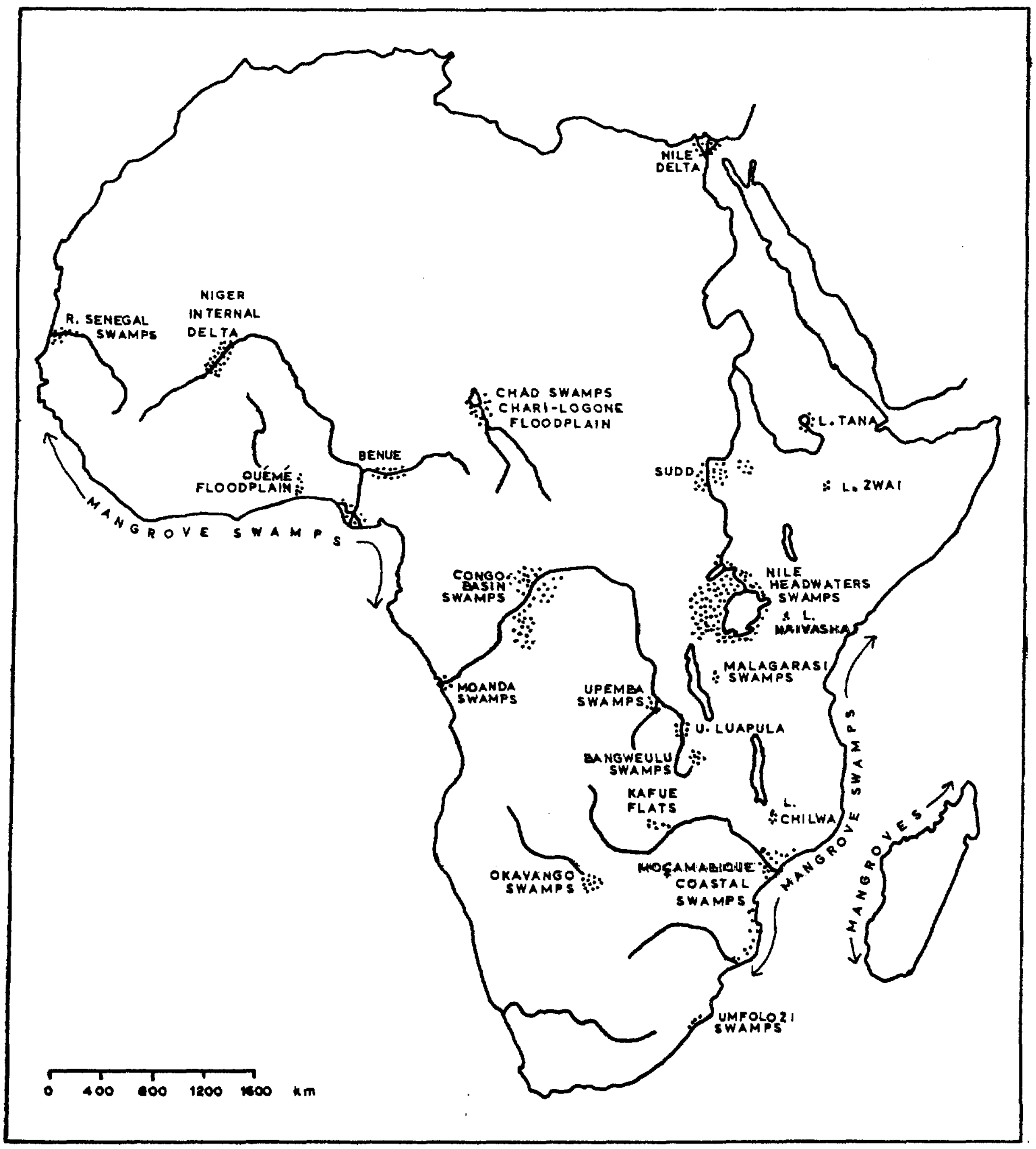
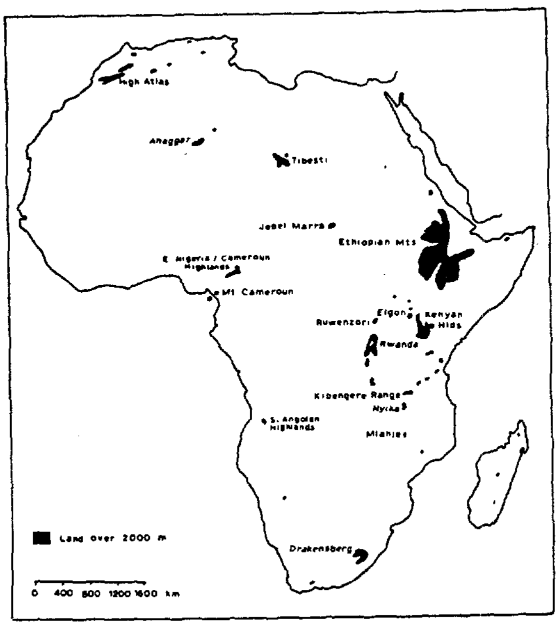
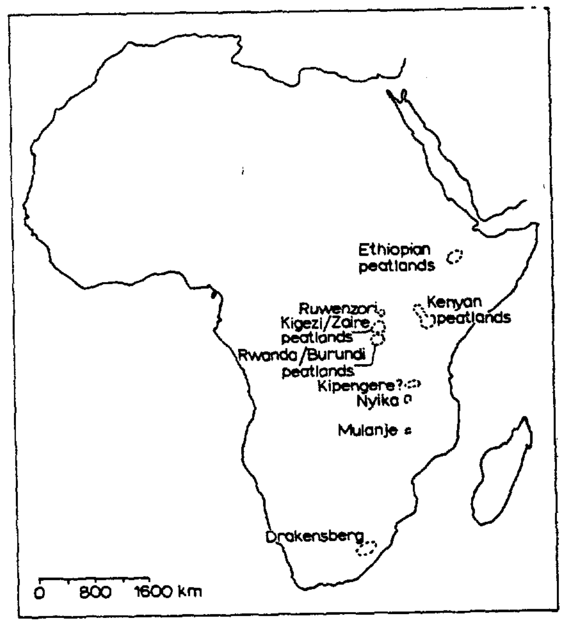


Fig. 9.1. The principal swamp complexes of Africa.

Source: K. Thompson and A. Hamilton, Chap. 11, Ecosystems of the World [69]



Land > 2000m



Main Peatland Areas

Fig. 9.2 - Land in Africa above 2000m in altitude and the distribution of main peatland areas.

Source: K. Thompson and A. Hamilton, Chap. 11 Ecosystems of the World [69]

Angola

Extensive peat deposits are known to occur in the valley of the River Cuanza, south east of Catate and about 50 km from Luanda. Initial survey has revealed that in some areas the peat is a surface deposit, while in others it may be covered by up to 10m of alluvium. Precise information on the extent of the deposit and the peat quality are not yet available [Source: Ministry of Energy, Luanda].

Burundi

Burundi, a small, land-locked country between Zaire and Tanzania, has one of the world's highest population densities. The 1979 census gave a return of 4.1 million, with a density of 150 inhabitants/km^2. The principal domestic fuels are wood and charcoal, with an estimated wood consumption of 2.0 million m^3 p.a. Only 3% of the dry land surface, or 90,000 ha, is covered by forest and the deforestation rate is one of the highest in Africa. The Government has commenced an ambitious reforestation programme with bilateral and multilateral aid. In 1977 they also created the Office National de la Tourbe (ONATOUR), a parastatal agency under the jurisdiction of the Ministry of Public Works, Energy and Mines, to survey, extract, commercialise and popularise the use of peat as a fuel [84].

Peatland Survey - The first studies of the peat reserves of Burundi and Rwanda were conducted by the Belgian botanist Paul Deuse between 1958 and 1964. He estimated the total reserves of the two countries at 3×10^9 m^3 with 1.5×10^9 m^3 located in the "Grand Marais" along the valley of the Akanyaru River which separates Rwanda and Burundi [93].

A more detailed inventory of peat deposits in Burundi was carried out in 1974 by Ruston Technical Services International for UNIDO. The total reserves were estimated at around 14,000 ha containing 200 million tonnes of peat with a residual moisture content of 30%. Of this total, 85% was located in the north of the country in the marshes along the Burundian bank of the river Akanyaru and its tributaries. The remaining 30 million tonnes were contained in numerous small valley bogs scattered throughout the country at higher altitude [86].

A Bord na Mona (Ireland) team surveyed some of these smaller valley bogs which may be readily drained in 1979. Ash contents were found to be relatively high, especially in the upper metre where the peatland had been cultivated, and also along the edges of the deposits, owing to the washdown of mineral material from the adjacent slopes. Ash content was also found to increase with depth and a 30% ash content limit was adopted as the production criterion when assessing the deposits for fuel [85].

Of the nine sites surveyed only three were considered suitable for fuel peat production:

- Kishubi Bog — 14km south east of Matana. Nett production area 27 ha, with estimated reserves of 70,000 tonnes at 30% moisture content.

- Gitanga Bog — 20 km east of Matana. Nett production area 89 ha containing 178,000 tonnes @ 30% m.c.

- Nyacijima Bog — 8 km north of Ngozi. Nett production area 70 ha with reserves of 70,000 tonnes @ 30% m.c.

Nyamuswaga Bog, near Ngozi, is currently - 1984 - under survey by a Bord na Mona team and a parallel hydraulic study is being conducted to assess the effects of drainage on the hydrology and ecology of the catchment.

Parts of the extensive peat deposit along the Akanyaru River in the north have been studied by Outokumpu Oy from Finland, financed by UNDP. The surface of this vast swamp area is covered by 3-4m high Papyrus vegetation and peat depth can be as great as 30m. Ash content is lower than in the smaller, valley bogs, averaging 10% [8]. As the river level is much higher than the bottom of the deposit, conventional drainage techniques cannot be used for fuel peat production.

In a follow-up study funded by the Finnish Government, IDA, UNDP, and the Burundian Government, Ekono Oy (Finland) are assessing the possibility of utilising peat from this deposit to generate steam, power and reduction gases for the Musongati nickel project. A pilot production scheme on 16 ha, which will test the feasibility of wet harvesting the peat by dredging and pumping the slurry to levelled drying areas, should have been completed by the end of 1983 [7], but the project is now continuing into 1984.

Peat Production - Peat production in Burundi commenced in 1977, on the establishment of ONATOUR, with 50 tonnes being produced by hand. This rose to 4000 tonnes in 1980 and manual production on three peatland areas Kashiro (Ijenda), Kuruyange (Gisozi) and Kishubi (Matana) - Fig. 9.3. continued until 1981 [84]. However, manual mixing and maceration of the peat had produced too brittle an end product and in 1982 three types of machines were introduced for mechanical production:

- Semi-automatic machine - hand-fed machine, which macerates and extrudes the peat along a conveyor from which the sods can be removed and spread to dry.

- Lilliput Bagger - small, fully-automatic, sod-producing

- Tractor-mounted chainsaw type machine (see Fig. 4.4) - extrudes the peat in continuous, cylindrical sod form.

These machines are still being assessed on the different production areas, especially in relation to the variable fibre content of the deposits [83]. Fuel peat production in Burundi is expected to increase to 30,000 tonnes p.a. by 1985.

Peat Utilisation - In August 1978 an Alternative Energy : Peat I Project commenced, with US$490,000 provided by USAID to assist ONATOUR in developing Burundi's peat reserves for non-industrial energy use. Initially, peat was seen as an alternative to the firewood used for rural cooking and heating. Later, given the inefficiencies of the charcoal conversion process, attention focused on the consumers of charcoal, who are mostly urban householders. The follow-on project, Alternative Energy: Peat II, was authorised in August 1980 and provides ONATOUR with US$ 8.0 million over 5 years to further develop peat production and marketing.

Great difficulties have been encountered in achieving any significant market penetration with peat fuel in Burundi. To date the programme has had little impact on slowing down the rate of deforestation. In the January to October period in 1982 domestic and artisanal customers purchased only 2% of ONATOUR's total sales.

Urban domestic sales will be limited until a suitable combustion appliance becomes available, as peat cannot be used in existing charcoal burners. A peat stove - imbabura- has been designed, but it requires further modification before being produced by project-trained stovesmiths. The retail price structure for peat needs to be examined to ensure that it is more economical than charcoal for the urban householder [82].

Congo

Some 290,000 ha of dystric Histosols - peat deposits with pH 5.5 - are located in the north of the country in the valleys of the Rivers Motaba and Ibengo, tributaries of the River Oubangui. A further 5.6 million ha of quaternary alluvial and lacustrine deposits have peats associated with Humic Gleysols underlying swamp forests and marshes to the east of the Oubangui River. The potential for fuel production has not yet been assessed [75].

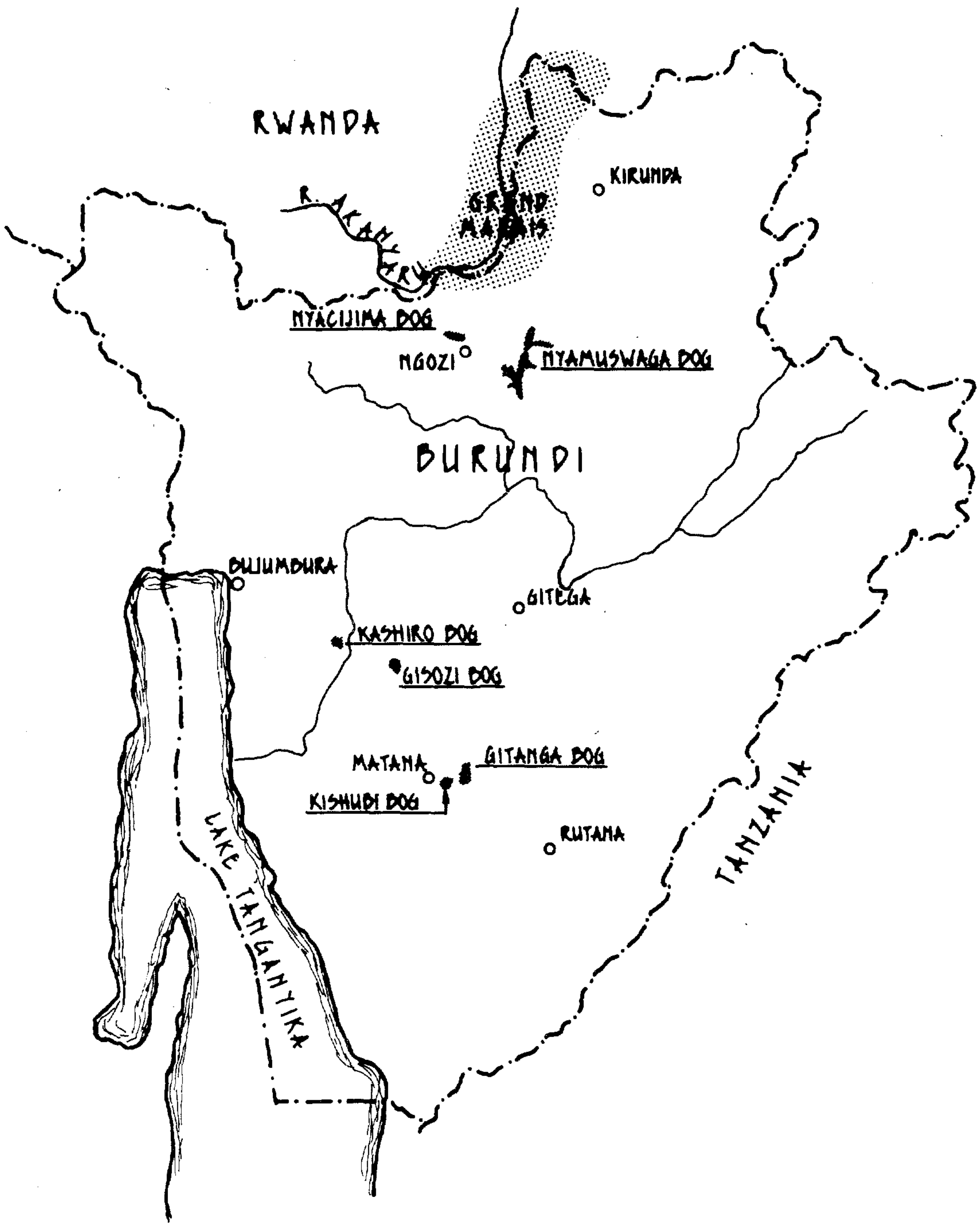


Fig. 9.3 - Exploitable Peat Bogs in Burundi - Irish Survey 1980

Source: Bord na Mona [85]

Guinea

Histosols are associated with 525,000 ha of lagoonal deposits and delta soils along the Guinea coast [75]. Three types of peat have been defined:

- Saline mangrove peat - formed by Rhizophora spp. on present fluvial-marine deposits.
- Intermediate Raphia peat - formed on desalined marine sediments and alluvium.
- Continental Raphia peat - formed on alluvial deposits in river valleys.

All of the peats are fairly shallow, are regularly inundated and have ash contents ranging from 30% to 53% [87]. Extensive survey work would be required to determine whether or not any areas contain deposits suitable for peat fuel production.

Lesotho

Only around 20% of the country is lowland, lying between 1700m and 2000m altitude, the remainder being formed by the Maluti Mountains, the Drakensberg Range and their accompanying foothills and valleys. The lowlands contain numerous small, marshy areas of reed beds on shallow deposits of peat sometimes used locally as a fuel [89]. The mountains and valleys contain many small areas of peat, known as sponges, which form around springs on the gentler slopes and in the valley heads.

A survey of Lesotho's peat resources was conducted under the Irish Bilateral Aid Programme in January 1976. This concluded that the unit areas of peatland were too small - 0.2 - 2.0 ha, and too shallow - maximum depth 2.0m - for industrial development and could make no real contribution to the energy requirements of the country. Many of the deposits contain interstitial layers of mineral materials, which have been washed down from the surrounding slopes, and peat ash contents range from 27% to 67%. As the peat areas contain much more luxuriant vegetation than the adjacent, eroding slopes, it was recommended that their current utilisation for agriculture should continue. [88].

Liberia

Peat deposits are found in valley-bottom swamps in Liberia. While a detailed soil map of Liberia has not yet been prepared, the estimated area of the deposit is 40,000 ha. The peats are shallow, with depth rarely exceeding 0.5m, and the swamps are covered by tree species tolerant of the hydomorphic conditions, e.g. Raphia, Loeserna. The quality of the peat and the feasibility of utilising the deposits for fuel are unknown. [Source: CEE Office, Monrovia].

Malawi

Although the peat resources of Malawi have not been seriously studied, upland deposits are known to occur on the Nyika Plateau in the north and on Mulange to the south [69]. The Soil Map of the World also records 91,000 ha of lowland Histosols on recent alluvial deposits along the valley of the River Shire, southwest of Blantyre [75].

Mozambique

Extensive swamp, marshland and seasonally-flooded areas occur in river valleys, estuaries and along the coast. Specific formations, known as "Machongos" are associated with depressions between old coastal dunes. Some of these contain relatively pure peats while others, which have been subjected to repeated flooding, contain mixed peat and alluvium with ash contents ranging from 20% to 50% [90].

Mozambique is currently facing a serious domestic energy problem, owing to the heavy use of firewood and charcoal, which has led to largescale deforestation around urban centres. UNDP, who are actively engaged in aiding the Government to develop alternative energy sources for domestic use, e.g. hydroelectric power and coal/semi-coke, have not yet investigated the potential of peat [Source: UNDP Office, Maputo].

Rwanda

Like its southern neighbour, Burundi, Rwanda is a small, densely populated, land-locked country with similar energy problems. The traditional fuels of the rural population are wood and agricultural residues, with wood charcoal preferred by urban householders. Only 6% of the dry land area remains forested, with a considerable proportion of these remaining forests legally protected and therefore unavailable as firewood. Reforestation schemes are in progress, financed by external agencies. However, these schemes are in direct competition with land utilisation for food and for cash crops. Since Rwanda possesses considerable reserves of peat, the potential exists for partial fuel substitution in small industries, rural institutions and eventually in urban households. It is unlikely that the rural householders, who traditionally gather all their fuel for free, would purchase fuel peat [91].

The exact extent of Rwanda's peat reserves still remains unknown. In his study of peat deposits in Rwanda and Burundi, Paul Deuse had estimated the total reserves at $3 \times 10^9 m^3$, with perhaps more than 50% in Rwanda, in view of the estimated 500 million m^3 located in the Rugezi valley alone [93]. Later studies, however, have shown Deuse's estimates, sometimes based on surface indications, to be optimistic. A survey of selected peatland areas, conducted for UNIDO in 1978 by a Bord na Mona engineer, demonstrated that some *Papyrus* marshes, previously thought to contain considerable volumes of peat, actually consisted of a 0.5m vegetation mat floating on water, with only a thin layer of deposited peat - 0.7m - lying on the bottom [92]. The most recent estimate of peatland reserves by the Ministry of Natural Resources is 80,000 ha, with a depth range of 3 to 20 m and an average depth of 11m [Source: Kigali].

Hand cutting of peat on Kiguhu Bog, near Ruhengeri, was already in progress before the UNIDO survey. The peat was used to dry Pyrethrum flowers at an adjacent plant. Cyabaralika Marais, also near Ruhengeri, was surveyed and the removal of a lava barrier commenced in November 1978 to facilitate drainage. Gishoma Bog, south of Cyangugu, and Nyanza Bog, south of Gitarama, were found to contain deposits mostly in excess of 20% ash content. - Fig. 9.4. Gishoma had been used during the colonial period to supply peat to a cement plant in Zaire. Exploitation ceased when the plant closed in the early 1960s.

The UNIDO survey also investigated Busoro Bog, 80 km south of Kigali, in the Akanyaru River basin. This is a "drowned valley" type of mire, covered by 1.0m of water during the rainy season and with the watertable dropping to only 0.3m below the surface in the dry season. 800 ha were surveyed and revealed peat depths of up to 10m, although only the top 4m were deemed to be useful for fuel, owing to an increase in the ash content with depth. The area was selected for pilot exploitation, by hand excavation from trenches and transportation of the peat in buckets to adjacent lower hill slopes for maceration, sod formation and drying. Manual sod peat production at Busoro commenced in 1980 and a semi-automatic macerating machine was introduced in 1981 [92].

A joint UNDP/WB energy assessment mission to Rwanda in April and May 1981 included the peat reserves in its analysis of the energy options. Peat production was in operation at Kiguhu Bog, supplying the Pyrethrum processing plant, at Cyabaralika Bog, supplying fuel for a 10,000 tonnes p.a. capacity cement plant near Ruhengeri, and on a pilot basis at Busoro Bog. They recommended that the extensive reserves in the Rugezi Basin, east of Ruhengeri, should be investigated. A hydrological survey of the area will also be required to determine whether or not peat extraction could adversely affect Lakes Bulera and Ruhondo where the Ntaruka (11 MW) and Mukungwa (12 MW) hydroelectric power plants are situated.

The most extensive, and unquantified, reserves are found in the Akanyaru River Basin in south central Rwanda. The assessment mission recommended that investment in exploitation should await the results of pilot production tests carried out on the Burundian side of the river by Finnish consultants in conjunction with the Musongati nickel project. Production should probably commence in the south east, if significant, exploitable reserves are located in that sector, as construction of the proposed Rusumo Falls dam will flood those deposits [91].

Peat resource exploration and peatland development in Rwanda is at present under the auspices of the Ministry of Natural Resources. Current production is geared towards specific industrial customers and market development is poor. Production bogs are too far from Kigali to supply the capital with peat fuel at a competitive price. Only a few tonnes of sod peat have been sold from Busoro Bog and with around 1000 tonnes in stock the assisting agency, the Irish Government, is reluctant to increase production. Pilot prodution of briquettes made from air-dried Papyrus is currently under research. If successful, the extensive swamps which lie within 40 km of Kigali may be capable of supplying the capital with a source of renewable energy, without recourse to drainage [21].

Senegal

Peat deposits are found in the Niayes region of Senegal, which stretches along the coast from Dakar to St. Louis. This area is characterised by series of stable dunes and inter-dune depressions lying behind the more active shoreline. Following 25 years of cumulative rainfall deficit, and a general lowering of the water-table, the shallow lakes which occuppied many of these depressions have disappeared, revealing peat deposited under lacustrine conditions. Peat depths vary between 1.0 and 10m, with an average depth 3.4m. Ash contents range from 10% to 75% and the deposits are scattered over several hundred small, 1-10 ha units with a mean area of 5.7 ha [96].

The Government of Senegal have set up the Compagnie des Tourbieres du Senegal (CTS), under the Ministry of Industrial and Craft Development, to develop these peat deposits within their programme for diversification of the country's energy sources. The central Niayes zone, covering over 40km between Mboro and Loumpoul (Fig. 9.5) contains the highest concentration of peat deposits and appears to be the most promising for industrial exploitation. The designated use of this central zone is for the thermal generation of electricity, while the less concentrated deposits to the north and south may be used to produce an alternative domestic fuel, to help conserve the country's dwindling forest reserve.

The scattered nature of the peatland areas, their relatively small unit size, and the drainage problems created by the general level of the dune water-table mean that peat extraction and drying methods may differ significantly from those used in the established peat-producing countries. The Government also wish to ensure that peat extraction does not damage important market-gardening activities in this area through saline intrusion, and that reclamation of the peatland areas will permit further agricultural development of the region.

Various consultants and funding agencies have been associated with the background studies of the Niayes peatlands conducted to date. France, through FAC, has financed the quantitative and qualitative assessment of the reserves and a study of possible exploitation methods. The

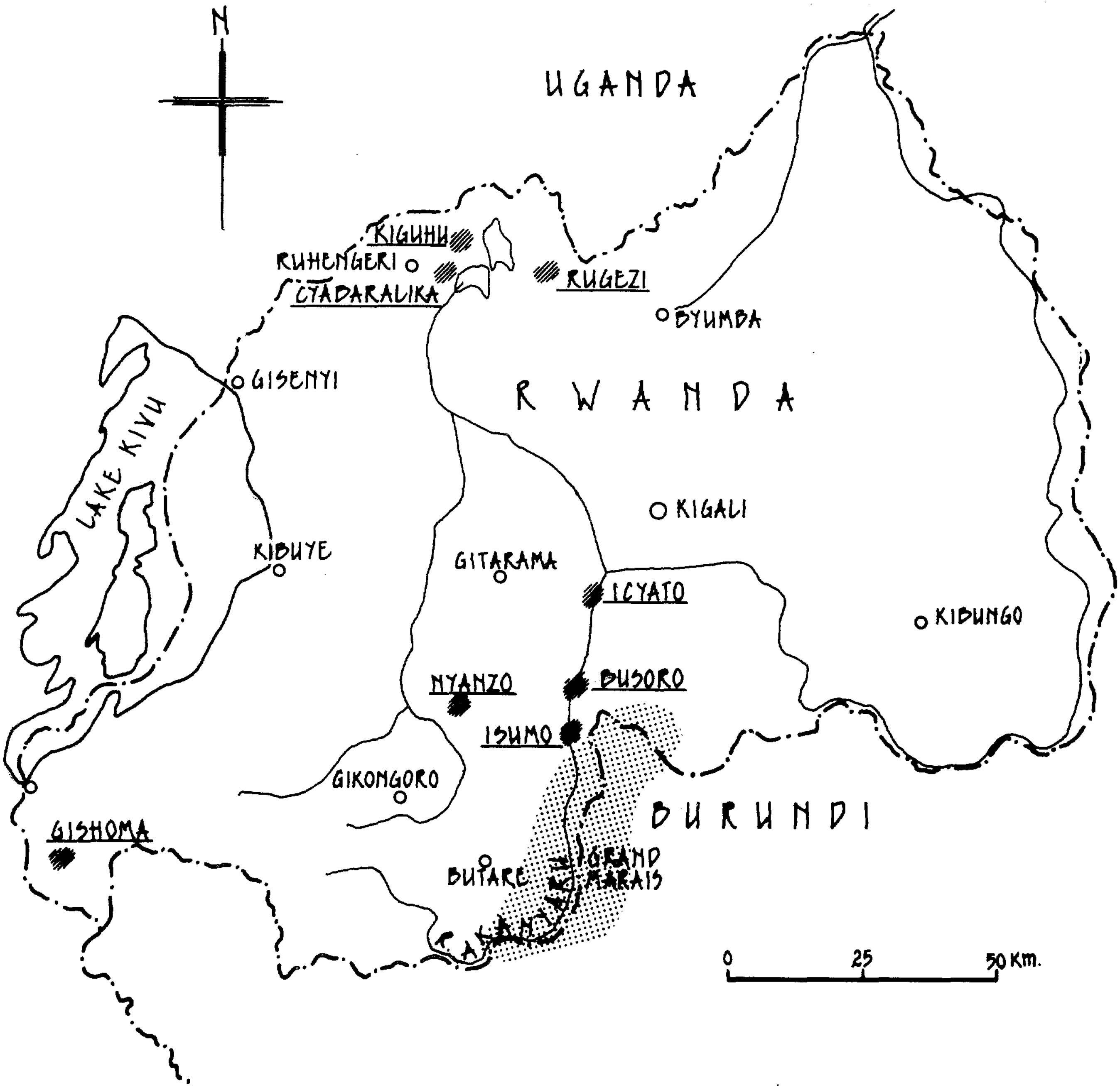


Fig. 9.4 - Peatland areas in Rwanda assessed during UNIDO survey 1978

Source: Bord na Mona, UNIDO Report [92]

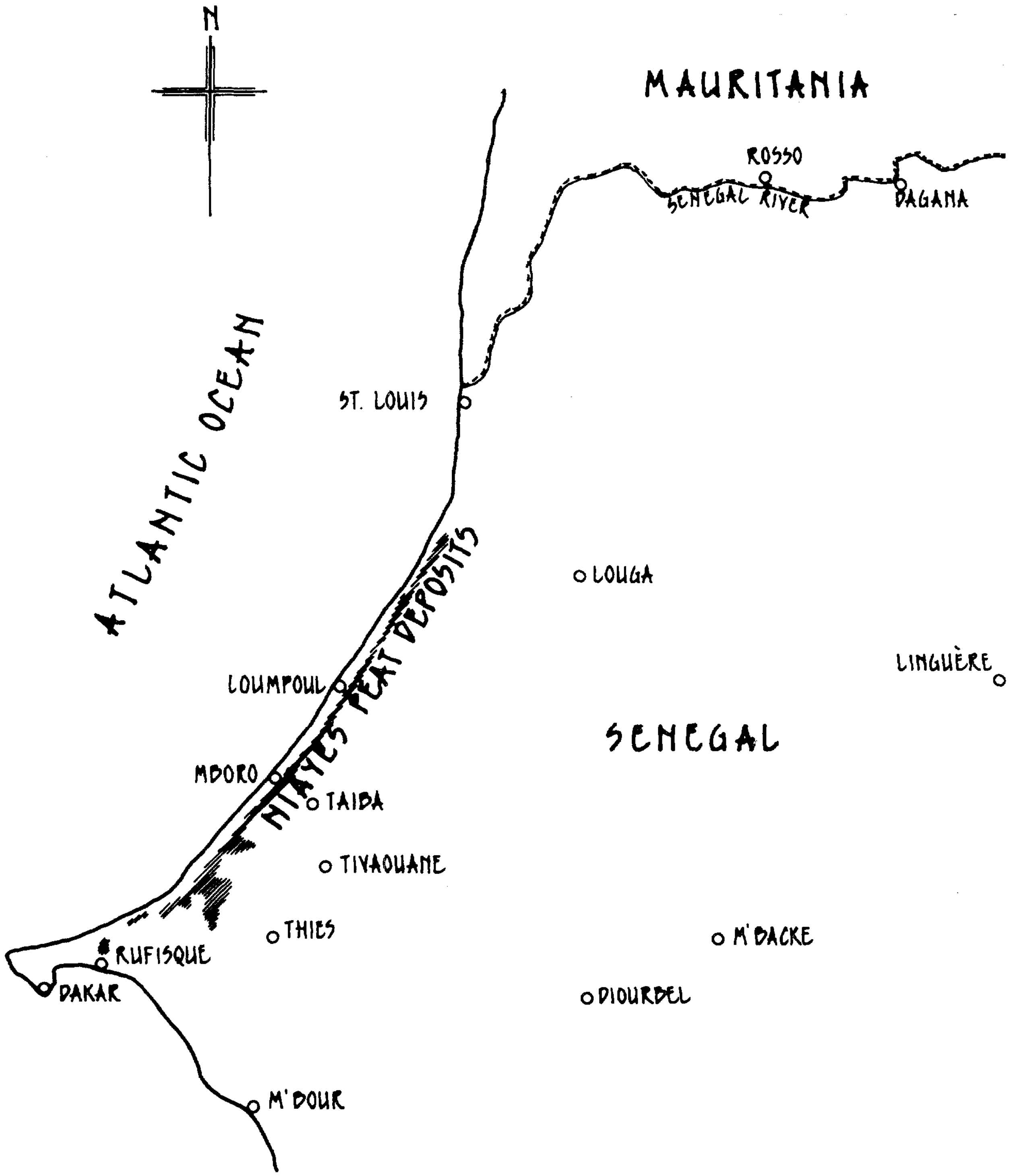


Fig. 9.5 - Location of Niayes Peat Deposits, Senegal

Source: Bord na Mona
Compagnie des Tourbieres du Senegal

Federal Republic of Germany has financed a feasibility study of electric power generation from the reserves. The United Nations, as part of a study on domestic energy utilisation, have financed a study of production techniques for peat briquettes for domestic consumption. Canada has financed a preliminary survey of peat deposits in the southern Casamance Region and also in the east of the country. Finland has financed the overall co-ordination of the various investigatory studies [94].

A pilot peat extraction project, funded by the European Development Fund (FED), was carried out in summer 1983. Bord na Mona acted as consultants to this project, which investigated peat extraction by successive trenches with immediate backfilling of dune sand, and rates of drying following dispersal or extrusion of the peat. Studies were also conducted to determine the behaviour of the sand aquifer during peat extraction and to investigate crop behaviour on reconstituted soils after reclamation of the site.

Reports from all of the background studies on the Niayes peat deposits and their utilisation were due to be presented to the Senegalese Government at the beginning of 1984, at which stage decisions would be taken on the effective utilisation of this energy resource.

Uganda

Together with Rwanda and Burundi, Uganda must be considered as one of the central African states with substantial peat deposits, as yet unexploited for fuel. Total peatland reserves are estimated to occupy 1.42 million ha. [70]. *Papyrus* swamp covers up to 30% of the area of some parts of the country, totalling some 2,500 square miles of permanent swamp lying mainly in littoral regions north and west of Lake Victoria. Additionally, there are considerable swamps in the mountainous and volcanic-crater District of Kigezi bordering the Western Rift Valley, and in the shallow valley country between Lakes Albert, Victoria and Kyoga. Large parts of the swamp areas do not necessarily contain peat, but many of the known peat deposits are swamp-formed.

Temporary wet-season swamps form on alkaline soil in Northern Uganda, but no peat is formed under these conditions. High temperature, the seasonal character of rainfall, and high evaporation ensure that *Sphagnum* bogs in Uganda are not "raised" or "domed" as in more temperate climates, but are in contact with low-acidity groundwater [98]. In certain of the Ruwenzori highland areas peat depth exceeds 10m. *Sphagnum* moss peatland of this type is very rare in Africa [69]. Peat depths in the *Papyrus* swamps around Kampala, at 60-90 cms, are uneconomic for fuel production. In the volcanic craters and *Papyrus* valley swamps of the western highlands, however, depths can vary from 10m to 16m. Agricultural exploitation of the peat bogs in Kigezi District and elsewhere, mainly for vegetable production, is substantial and increasing, and the immediacy of food requirements impedes their conversion to fuel production. There is no evidence at present of the exploitation of peatlands for fuel in Uganda, and while the volume of peat deposits per se would suggest possibilities for economic fuel exploitation, the food-versus-energy priority problem is likely to impede the development of peat for fuel. Peat quality is fair to good, with 10% to 35% ash content throughout the profile.

Overall there is potential for fuel use of peat in Uganda, particularly where peat depths and ash content are favourable, as in some of the valley and volcanic mountain bogs in the Southwest. Agricultural exploitation poses a major impediment, however. There is little evidence of scientific assessment of peat for fuel use in the country, and no evidence of foreign funding agencies supporting projects either to assess or to develop fuel utilisation of peat. Technical data on peat quality in Uganda is extremely difficult to acquire, but extrapolation from neighbouring areas of similar geology and topography suggests that ash contents will be high. The calorific value of organics in southwest Uganda can also be assumed, from experience in both Zaire and Burundi, to be very similar to those of temperate regions.

Zaire

Peat deposits, which are not currently exploited for fuel, are located in mountainous areas of Bukavu in eastern Zaire, immediately west of Lake Kivu. This is an extension of the Virunga volcanic range shared with Kigezi District in Uganda. Individual bogs are small (50 to 1,000 hectares), with peat depths varying from 1m to over 15m in the volcanic craters at between 1600m and 2200m altitude. Ash content varies from 9% to 65%, and bogs with the higher ash contents are of doubtful value for exploitation as fuel, except with fluidized bed combustion. In-situ moisture contents between 86% and 95% have been established, and the calorific value of the organic matter is similar to that of peat from temperate regions [100].

While some of the bogs in the Bukavu region contain viable peat deposits, it must be emphasised that these bogs are small and are located at high altitudes in mountainous country. Roads are very inadequate, presenting transport problems both for moving men and equipment into the bogs and for transporting peat products out. Drainage will be required and labour availability in the sparsely - populated mountain areas is also problematical.

Limited studies have been made of the feasibility of peat fuel utilisation in the Bukavu region [100,101]. A clear prima facie case exists for a broad technical assessment of the potential. There is little evidence of any involvement of foreign development aid agencies or of the Government of Zaire in attempting to develop the bogs on any appreciable scale.

Others

The FAO/UNESCO Soil Map of the World also includes the following Histosols for Africa. While these peatlands, by definition, have an organic horizon of greater than 40cm depth, the exploitable reserve is likely to be considerably less than the area given.

Ivory Coast	: 32,000 ha	On recent alluvial deposits along the River Agneby, near Abidjan.
Madagascar	: 197,000 ha	On quaternary alluvial and lacustrine deposits around Lake Alaotra.
Zambia	: 1,106,000 ha	On quaternary lacustrine deposits around Lake Bangweulu and in the Lukanga swamp.

Histosols are also associated with Orthic Ferrasols in Cameroon and Gabon and with Humic Gleysols in Cameroon, Kenya, Sudan and Tanzania [75].

<u>Fig. 9.6.</u> - Peat Deposits in East Zaire

<u>Source</u>: Bord na Mona [101]

DEVELOPING COUNTRIES - ASIA

Bangladesh

Bangladesh peat deposits are located primarily, but not exclusively, in the Ganges Delta area. The Government agency with responsibility for peat development is the Bangladesh Mineral Exploration and Development Corporation (BMEDC). They estimate current utilisation of the peat areas as 20% virgin or untouched; 60% agriculture and horticulture, and 20% pisciculture. A Canadian/Irish and one Dutch survey of peat resources were carried out between 1958 and 1962; BMEDC carried out a further survey in 1979-80.

There are limited peat deposits, believed to be commercially non-viable, in the Sylhet region in north-eastern Bangladesh. The main deposits are located in the delta and the major problems in this low-lying and waterlogged area are:

- the peat deposits lie under an overburden of alluvial silt varying from 8cm to 1.5 m in depth, are therefore not obvious from visual observation, and the bogs can be located only through surface geological boring.

- summer monsoon floods, which raise the water level 2m to 4m above the level of the land, necessitate the construction of dykes to a minimum height of 5m before peat production could begin.

The peat area is estimated at 60,000 hectares in total, with an average depth of 1.5m in a depth range of 0.3m-4m. The deposits are highly decomposed, between H7 and H9 on the von Post Scale, have a high ash content and are relatively shallow. The anhydrous calorific value of the Ganges delta peat is 17.5 MJ/kg at about 24% ash content, and moisture contents for the undrained deposits range from 85-89% [103]. The fuel quality of peat in Bangladesh is reasonably good. The drainage problem in the delta, however, would be a major consideration in any feasibility assessment.

Peoples' Republic of China

China has a long history of developing and utilising peat. Surface peatland is estimated at 3,477,000 hectares, buried peatland at 682,000 hectares. Peat reserves are estimated at 27 billion tonnes (80% surface, 20% buried). Surface peat is distributed in the north-eastern mountains and in the southwestern plateaux, the Changvai mountains, the Sanjiang Plain, the Ruoergai Plateau and the Altay mountains in Xinjiang. Buried peat is distributed mainly along the east coast, in the middle/lower Yangtse Basin and in the Yunnan-Kweichow Pleateau [106].

Most virgin peat in China has medium decomposition levels, high ash and humic acid content, abundant nitrogen and a small bitumen content. Many of the plant residues are similar to those found in Europe. The decomposition degree of exposed peat is between 10% and 20% (H4-5), while that of moss peat is less than 10% (H3-4). The figure for buried peat is between 30% and 50% (H6-7) [104].

Peat is used as a domestic fuel and as an additive to raw animal effluent in the generation of methane gas. The humic acids are used in industry, in medicine and in agriculture. Extensive peatlands in some areas have been transformed into farmlands growing rice, soyabean and wheat, and also into forest and pasture lands.

Calorific value varies greatly between the regions, but the organic C.V. in general is similar to that of most European bogs, i.e. averaging 20.9 MJ/kg and ranging between 16.7 MJ/kg and 23.9 MJ/kg. An average analysis of an hydrous organics would be:

carbon	57.15%
hydrogen	5.25%
nitrogen	2.10%
oxygen and sulphur	35.5%

Current fuel peat production is around 800,000 tonnes p.a. and the potential for increased production in the Peoples' Republic of China appears very good, if demanded by the domestic and industrial sectors.

Fiji

Fiji possesses peat deposits totalling 4000 ha, located mainly along the southeast coast of Viti Levu. The principal deposits are along the Rewa River, northeast of Suva and close to Nausori [107]. Peat depth ranges up to 5.0m and ash contents are up to 55%. The peat is poorly decomposed, fibrous and derived mainly from ferns, reeds and sedges on river flood plains behind the coastal mangrove swamps. When drained, the peats are used for low-grade pasture and cultivation of sago palm. Development of the reserves for fuel would require further investigation [Source: Ministry of Agriculture and Fisheries, Fiji].

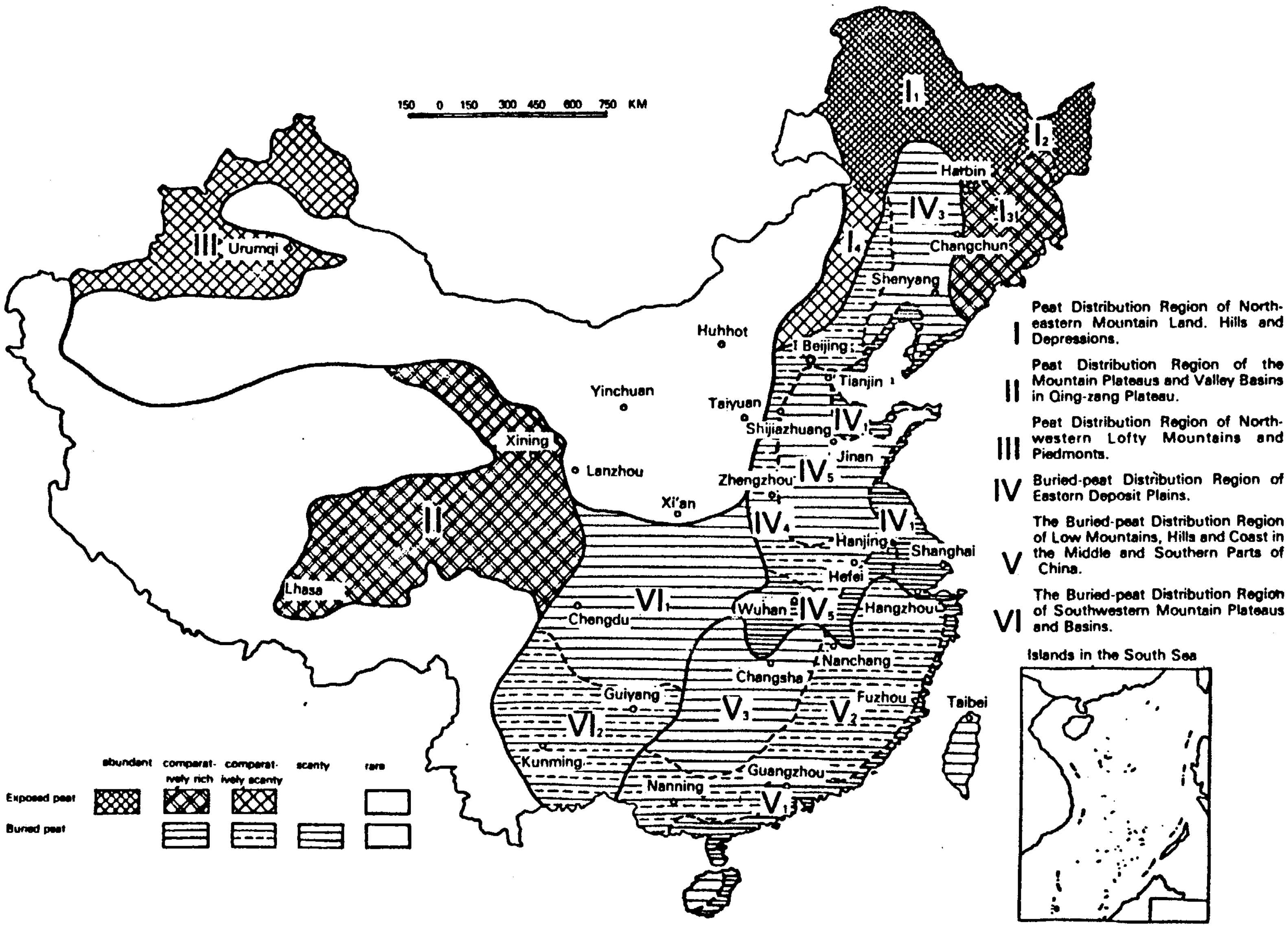


Fig. 9.7 - Peat Distribution in China

Source: Chai, 6th IPS Congress [106]

Indonesia

Indonesia must rank highly in any classification of developing countries based on their potential for utilising peat for fuel purposes. Ash contents are low, peat depths are often suitable for commercial exploitation and very large reserves exist.

The major deposits are in Sumatra, Kalimantan and Irian Jaya (West Irian). Estimated peat deposits are:

Sumatra	6.8 million ha	- most of the North-East coast and extending well inland
Kalimantan	6.4 " "	- major deposits on the West and South coasts; other deposits on the East coast and North-East coast immediately south of the Sabah border.
Irian Jaya	3.6 " "	- the extensive flat coastal region of southern Irian Jaya, plus pockets in the central highland areas and West and North coasts.
Java	25,000 ha	- On the South coast, near Tjilatjap.
Total:	17 million ha	

Source: Young, Bandung Conf. [110]

The Indonesian peatlands are known to contain very deep deposits similar to the raised peat bogs of the temperate latitudes. Depth varies from 5m to 15m, and some bogs have a high timber content. Much shallow peat also exists, with depths below 1m, and this land can be used for agricultural purposes. Its availability dovetails well with land requirements for the Government's family transmigration policies.

Ash contents vary, but are mainly between 3% and 30%, and are favourable for fuel exploitation. Moisture contents vary between 83% and 95%; calorific values range from 18.8 MJ/kg to 23.0 MJ/kg. Sulphur content is low. Analysis of peat from a small area in Kilimantan gave the following composition:

volatiles	62%
ash	3%
fixed carbons	35%

Indonesian peat is mostly lowland and coastal, the Sumatra deposits extending sufficiently far inland to cover one fifth of the island. Systematic surveys of the Indonesian peat deposits, including a major series of studies undertaken by the Soil Research Institute at Bogor have to date concentrated on the agricultural potential of the reclaimed peat swamps. Relatively little attention has been paid to their energy potential, but the chemical and physical data available suggests that Indonesia's lowland peats are very similar, in terms of energy potential, to temperate latitudes peat [110].

It should be emphasised that the estimate of peat area in Indonesia given above (17 million ha) refers to those soils containing more than 65% organic material by weight to a depth of 1m or more. In the lowlands, two peat types may be distinguished, topogenous peat or marsh peat, which has been deposited below the groundwater table and is always covered by water, and ombrogenous peat, which is dome-shaped or convex, rising above the groundwater level. While depths may extend to 15 meters, figures between 3m and 7m are more common [109].

In evaluating peat fuel potential in Indonesia, the largest constraint may be found to be competition from agricultural utilisation of the peatlands. A potential asset in resolving this problem, however, may be the fact that very thick peat deposits lacking plant nutrients, and with relatively low ash contents, are the least favourable for agriculture [111].

Considerable work is underway, in part aid-funded, on agricultural utilisation of the peatlands [114, 115]. Study of possible energy utilization lags far behind. Indonesia has a relatively high GNP growth rate, and a comparatively cheap oil policy for domestic consumption.

Oil demand in Indonesia exceeds the increase rate of oil production and the country could be an oil importer by the end of this century. Decreased oil revenues could affect the Government's social and development objectives. To avert this, oil, gas and coal exploration and development have been expanded, as has the use of hydroelectric and geothermal sources.

The Government is also anxious to develop other energy forms [108]. An assessment of possible fuel peat production in Indonesia is at present being made in a study funded by the Dutch Government.

Israel

The main peat area, covering some 5,000 ha, is in the Huleh Valley in the north. Peat depth is in the range 1-12m. The area has been extensively drained to produce highly fertile agricultural land growing corn, sorghum, cotton, peanuts and vegetables. Research into fertiliser use of peat has been carried out, but the major utilisation is likely to remain agricultural. No fuel utilisation of the resource is envisaged [77].

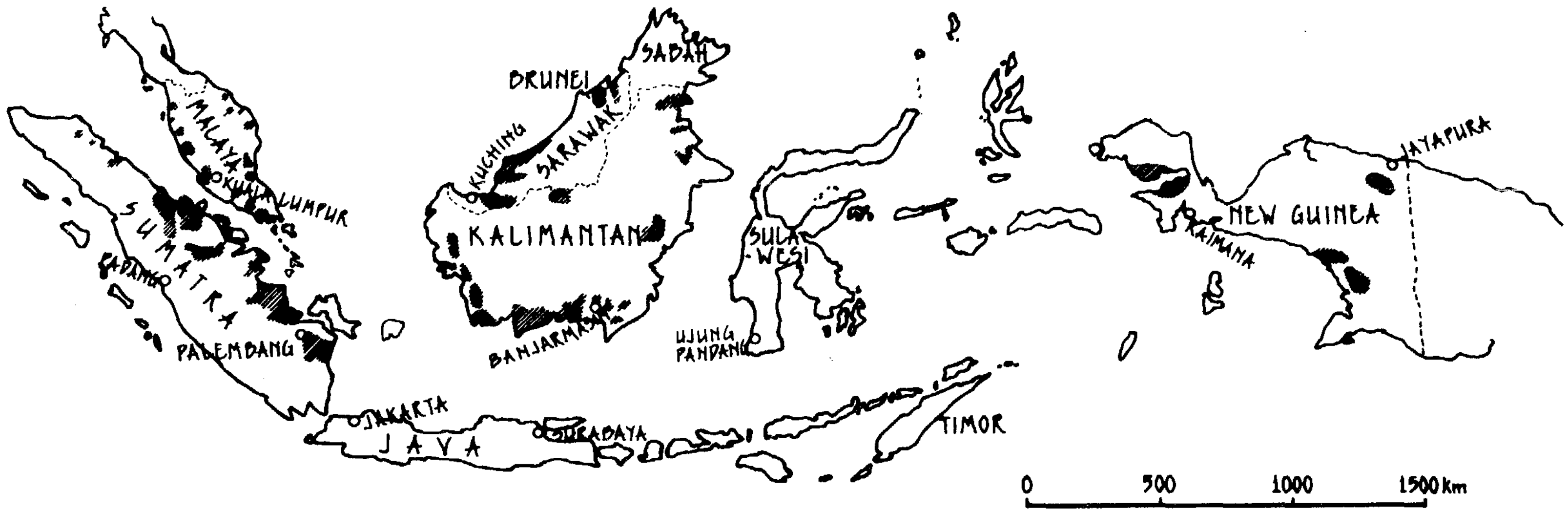


Fig. 9.8 - Peat deposits in Malaysia and Indonesia

Source: Bord na Mona
J. Anderson, Chap. 4, Ecosystems of the World [69]

Malaysia

Malaysia contains extensive peat deposits, covering between 2.25 and 2.5 million hectares. The most recent data for peninsular Malaysia (Malaya) suggests 800,000 ha of peatland with 1.45 m ha for Sarawak, representing about 12% of the land area of the State, and a further 10,000 ha occuring in Brunei [69].

The peatlands in peninsular Malaysia are a discontinuous series of deposits stretching North-South along both the East and West coasts, and extending a considerable distance inland, particularly in the South. In Sarawak, the peat is found in both coastal and inland areas of the South-West where depths of up to 17m have been recorded. Mineral content is extremely low, loss on ignition usually exceeding 90%. The peat is essentially woody, being formed from the debris of former forests, and acid, with a common pH range of 3.0 to 4.5. Ash content is usually less than 5% and over large areas it may be less than 1% or 2% [69].

Except where they have been cleared and drained for agriculture, the peat swamps are covered by forest. No open sedge or grass swamps occur. The peatlands are typically convex, analogous to the raised or "domed" bogs of the temperate regions. Maximum heights of the domed surface above the river flood level of 9.1m have been recorded. The greatest depth of peat (31m) occurs in a swamp at the apex of the Rejang Delta in Sarawak [121].

The agricultural potential of the peat swamps is currently the subject of much investigation in Malaysia (as in Indonesia). Areas of shallow peat, mainly less than 1m in depth, have already been largely utilised for forms of settled and shifting agriculture. Research is now being directed at the possible use of the deeper peats. The natural forests on the peat have also been exploited for timber [119]. The major crop presently being cultivated on Malaysian peatland is pineapple [122].

Very little research into possible fuel utilisation of Malaysian peat appears to have been undertaken. Clearly, agricultural competition would be a disincentive. On the other hand, the physical properties of Malaysian peat, its known depths and extent, suggest at minimum a prima facie case for fuel utilisation, subject to detailed assessment of particular deposits in either Sarawak or peninsular Malaysia.

Papua New Guinea

95% of Papua New Guinea's land area is under tropical rain forest, which is used as a source of firewood. Some peat exists in the Waghi valley, a proportion of which has been drained and is being sucessfully cultivated for arabica coffee. [127]. Peaty soils, some quite shallow, exist throughout the highlands. There is little evidence to suggest the possible viability of peat as a fuel source.

The main present energy sources are imported oil (665,000 tonnes) and imported natural gas (3,200 tonnes). [Source: Dept of Primary Industry, Boroko].

Philippines

The relative paucity of peat deposits in the Philippines suggests that detailed study of their fuel use potential will prove considerably less rewarding than in either Indonesia or Malaysia.

The Bureau of Energy Development of the Ministry of Energy estimates a total peat area of only 6,000 ha with an average depth of 5.3m in a depth range of 0.5-12m. The peat areas appear to be virgin and untouched.

Sri Lanka

The largest known deposit of peat in the island is the Muthurajawela swamp immediately North of Colombo on the west coast. It covers about 2,200 hectares, with an average depth of 4m and a maximum observed depth of 6.5m. Moisture content is 80-90%, ash content range 10-30%, sulphur content 1-9%, nitrogen content less than 1%, fixed carbons 26-37% and volatiles 43-56%. It seems likely that in addition to Muthurajawela, smaller peat deposits exist inland, mainly in the West [128].

Detailed assessment would be required to establish the fuel potential of Muthurajawela but, prima facie, the problems posed by drainage and high sulphur content are substantial. The average sulphur content in Sri Lanka is about 5%, in contrast to usual values of less than 1% elsewhere in the world,and this would be a major factor in determining peat utilisation [130]. Technopromexport (USSR) prepared a report on Muthurajawela in 1961 which was not encouraging in relation to fuel peat exploitation [132].

Others

The following areas of Histosols, with depths in excess of 40cm, are shown on the FAO/UNESCO Soil Map of the World.

India	32,000 ha	- On the West coast of India, south of Alleppey.
Democratic Peoples Republic of Korea	136,000 ha	- One large deposit Northwest of Kilchu, with several smaller peatland areas Northwest of Hamhung, near the Changjin Reservoir.
Thailand	68,000 ha	- On the Malay Peninsula, just North of Kota Bharu.
Vietnam	183,000 ha	- In the South of the country, just North of Quan Long.

DEVELOPING COUNTRIES - CENTRAL AMERICA AND CARIBBEAN

Jamaica

Jamaica is one of the relatively few developing countries with peat deposits in which the possibilities of fuel utilisation have not only been technically and completely assessed, but are at present under very active consideration. A Peat Resources Utilisation Project is under way within the Petroleum Corporation of Jamaica. Electricity could be generated from peat in Jamaica by 1988.

The peat area is estimated at 21,000 ha. There are small (and in fuel terms probably insignificant) deposits in St. Thomas, St. Catherine, Clarendon, Manchester and Westmoreland. The two major deposits, on which current activity is concentrated, are at Negril in the Hanover district, virtually on the Western tip of the island, and Black River in the St. Elizabeth district, on the Southwest coast [Fig. 9.9].

Both morasses have been extensively surveyed; expertise from Ireland, Sweden, Finland and the United States has been and is being used in connection with a possible project to use peat fuel for electricity generation.

Total available peat resources at Black River and Negril are estimated at 20 million tonnes dry weight. Black River Lower Morass covers 6,000 ha, containing a Holocene fluviatile/estuarine sedimentary sequence in which non-peat materials are largely confined to the present course of the Black River. Associated peat swamps occur along tributary watercourses. Depths exceeding 10m have been probed by some 1,200 auger soundings. Ash content ranges between 10% and 25%. Negril, 2,300 ha in extent, is a coastal swamp. Again, detailed auger surveys have been carried out, recording peat depths of up to 16m, with an average of 5m. The probable usable peat reserves at Negril are about 16 million tonnes at 35% moisture. Pilot extraction programmes in 1978 produced peat which was shipped to Ireland for combustion tests, the results of which were generally satisfactory [133].

The Peat Resources Utilisation Project commenced in 1976 with resource identification by the Ministry of Mining and Energy and a pre-feasibility study by Ewbank Engineers of Ireland (1978). A resource evaluation study was then commissioned by the Petroleum Corporation of Jamaica. This is being followed over the period 1982-84 by environmental, hydrological and engineering feasibility studies. The Environmental Feasibility studies are being carried out in conjunction with a team of wetland specialists from the University of Lund in Sweden, under grants from the Swedish Commission for Technical Co-operation [134]. The Hydrological Feasibility studies involve consultants from the Swedish Meteorological and Hydrological Institute. The Engineering Feasibility studies are being carried out in conjunction with a firm of consulting engineers (J.P. Energy Oy) from Finlnd, under a grant from the Government of Finland (FINNIDA). In addition, the suitability of the local peat as a horticultural medium is being assessed by the Botany Department of the University of the West Indies.

Some US$ 3.0m will have been spent by the time the feasibility studies are completed in March 1984. This comprises US$ 1m equivalent in foreign exchange largely through Swedish and Finnish grants, and US$2m equivalent in local currency through the Petroleum Corporation of Jamaica and Government of Jamaica. The schedule of final reports on the various feasibility studies is as follows:

-	Environmental Report	September 1983
-	Wetland Utilisation Report	December 1983
-	Hydrological Report	February 1984
-	Engineering Report	March 1984

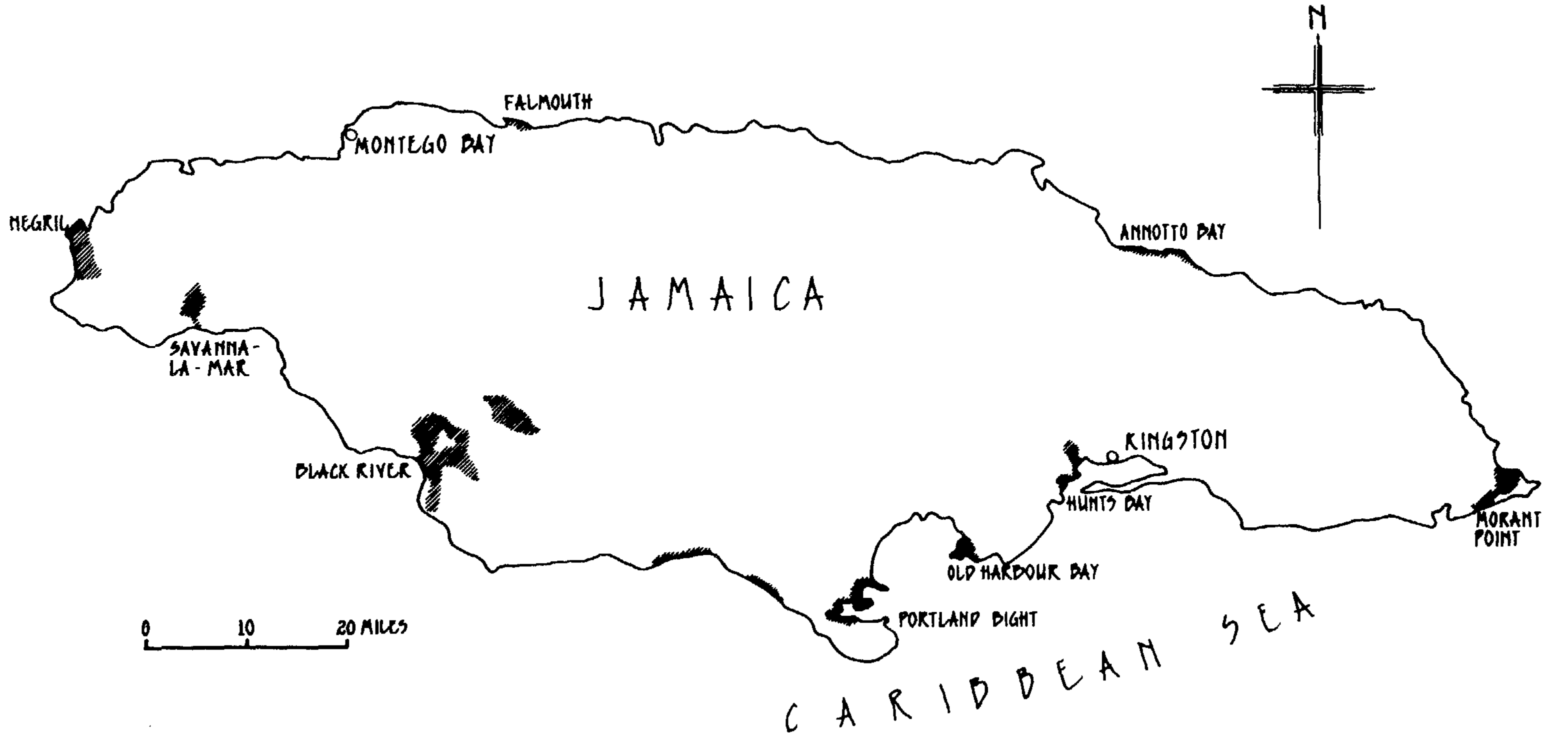
The trend of conclusions emerging to date suggests that use of Jamaican peat as a fuel for electrical power production would be feasible both technically and economically. The peat available in the two deposits would appear to guarantee sufficient material to fuel an 80 MW power plant for at least 30 years. As base load, this capacity could provide between 30% and 40% of the present day demand on the island's electricity utility. The extraction and drying procedures would almost certainly involve moving cut peat by barge to upland drying sites before feeding it to the power plant. These have already been tried successfully on a pilot scale. Preliminary estimates suggest that, even using barge transport, peat could be delivered to the power plant at less than three quarters the cost of equivalent fuel oil [Source: Petroleum Corporation of Jamaica].

Puerto Rico

There are more than 10,000 ha of organic soils in Puerto Rico, confined to the coastal lowlands of the island. Most of these areas remain untilled, mainly because of very poor natural drainage complicated at times by the presence of harmful alkali salts in the profile. Given the island's pressing need for more agricultural land, agriculture would be very likely to take precedence over fuel use on any organic soils reclaimed. The characteristics of the peats would furthermore suggest agricultural rather than fuel utilisation [136].

Trinidad and Togago

Peat reserves in the country are extremely limited, with no known peat deposits occurring in Tobago. In Trinidad, there are some 36,500 ha of swamp alluvium, of which 1,000 ha are peat. These are located on the West coast, Southeast of Port-of-Spain, and at San Rafael in the centre of the island. 85% of the peat area is untouched,



<u>Fig. 9.9</u> - Distribution of Peat Deposits in Jamaica

<u>Source:</u> Bord na Mona
Jamaican Petroleum Corporation

the remainder being divided between agriculture and forestry. The peats are of low calorific value, below 10 MJ/Kg, and are not considered economically exploitable other than for agriculture. A large proportion of the existing peat is saline [Source: Ministry of Agriculture, Trinidad and Tobago].

Others

According to the Soil Map of the World, Histosols have a limited distribution in Central America. They occur as associates of Andosols on the higher elevations of volcanic mountains, and also in a narrow strip along the Eastern coastline running South from British Honduras. These coastal deposits, which are mainly organic residues from mangrove forests, sometimes mixed with coastal alluvium, are also found in Cuba [75].

British Honduras	68,000 ha
Honduras	453,000 ha
El Salvador	9,000 ha
Nicaragua	371,000 ha
Costa Rica	37,000 ha
Panama	787,000 ha
Cuba	767,000 ha

DEVELOPING COUNTRIES - SOUTH AMERICA

Bolivia

It is estimated that 900 ha. of peatlands exist in Bolivia, distributed between Toloco (400 ha) Chuquiaguillo (100 ha) and a series of smaller bogs around the Caluyo River and Laguna Paco Khota. These reserves are very small and exploitation for energy purposes does not appear feasible [Source: UNDP, La Paz].

Brazil

Peat reserves in Brazil are fairly extensive and from preliminary satellite data may amount to over 1.5 million ha, containing an estimated 4 x 10^9 m^3 of peat. Systematic ground survey commenced in 1980 and to date 114,000 ha have been investigated.

Ash contents appear to be higher than in the temperate regions (19-24% in the Marau-Camamu coastal basin; 16% in Baixada de Campos; 15% at Jacarepagua near Rio de Janeiro; 10-20% at Recife-Jaboatao in Pernambuco; 14% at Pindamonhangaba). Fixed carbons in those bogs which have had even a preliminary survey (a minority) range from 8.1% to 50%. Volatiles range from 35% to 65%. Calorific value varies between 16.9 MJ/kg and 27.6 MJ/kg. Depth estimates range from 0.3m

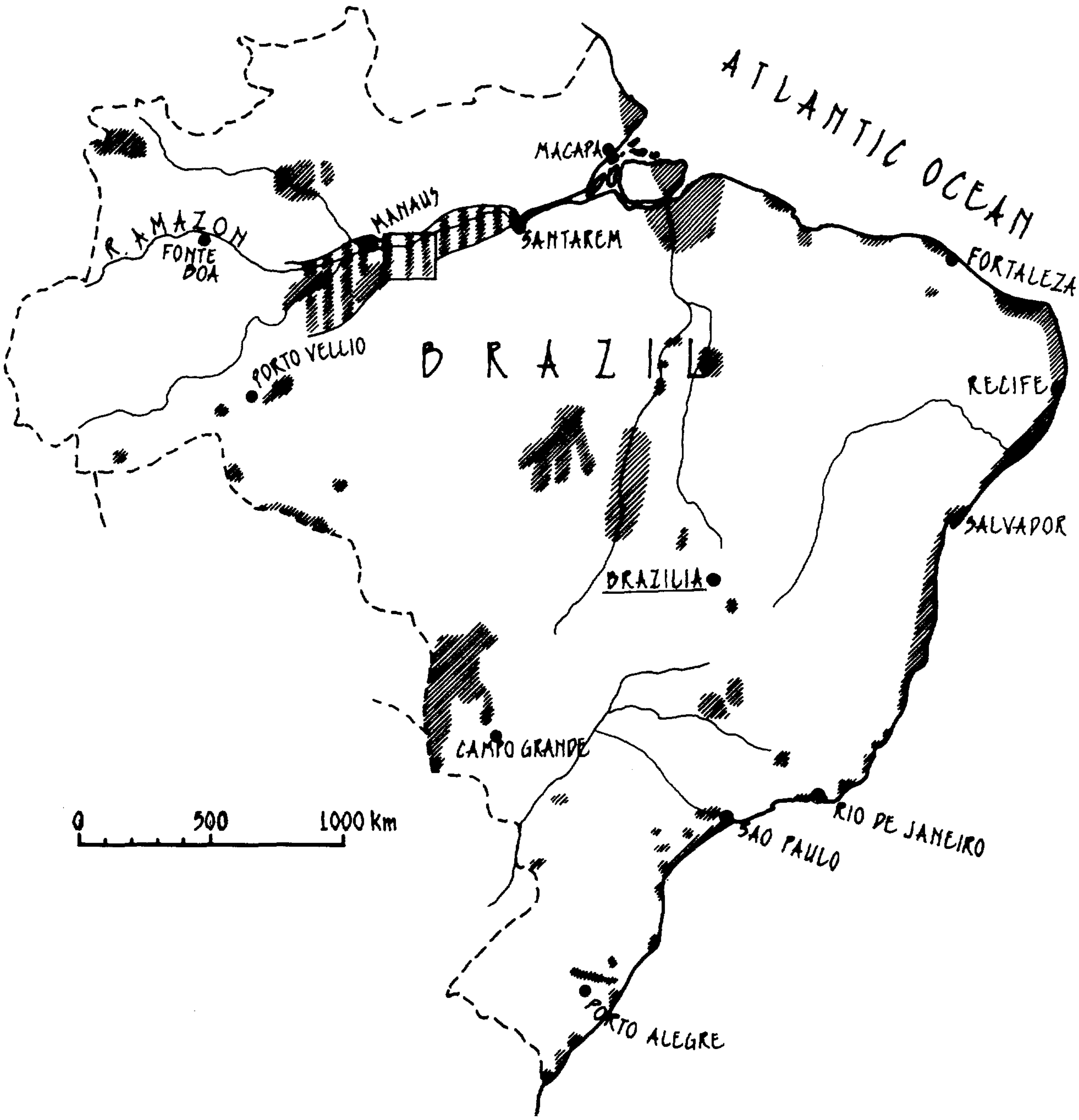


Fig. 9.10 - Peat Deposits in Brazil

Source: Bord na Mona
Companhia de Pesquisa de Recursos Minerais, Brazil

to 13m, while estimates of average depth range from 1.35m to 3m. It appears that most of the peatlands are untouched, even for agricultural purposes [137].

There are 66 separate areas of deposits containing some 358 bogs - Fig. 9.10. The National Department of Mineral Production (DNPM) of the Ministry of Mines and Energy consider that the most important peat areas lie along the North-East and South-East coasts. A national peat inventory sponsored by DNPM is being undertaken by the Mineral Resources Research Company (CPRM). Technical assessment of the peatland deposits is now being undertaken on a much greater scale than heretofore [139]. An initial survey and characterisation of several deposits has recently been completed for CPRM by the Canadian consultants Relatorio Goodwin.

Colombia

Histosols occupy 339,000 ha in Colombia, primarily swamplands in river valleys and on alluvial floodplains, and moorlands at higher altitudes [75]. Deposits in the Valle de Sibundoy in the Province of Putumayo and in San Miguel de Sema in the Department de Boyaca have been studied by Drs. Alonso Lopez and Abdon Cortes and published in "Organic Soils of Colombia" by the Agustin Codazzi Institute of Geography [Source: Banco de la Republica, Bogota].

Guyana

Peatlands occupy 813,880 ha in Guyana, with a depth range of 0.4 to 9.0m and an average depth of 0.7m. They are mainly shallow marsh and swamp forest deposits on coastal alluvium. Approximately 20% of these areas are currently used for agriculture and no studies have been conducted to date to determine the suitability of the deposits for fuel production. [Source: Ministry of Agriculture, Georgetown].

Uruguay

Several peat deposits are known to exist. The most important is near Laguna Negra, in the South-East. The deposit covers more than 2500 ha with an average depth of 2.5m. Analysis of dry peat samples from this bog shows:

Ash content	12.5%
Volatiles	63.4%
Fixed carbons	24%
Calorific value	19.5 MJ/kg kg

[143].

This analysis suggests that Laguna Negra peat is similar to peat found in the temperate zones and indicates a deposit suitable for fuel peat exploitation.

Venezuela

Peat reserves in Venezuela are estimated to occupy 1 million ha., with depths ranging up to 10m and averaging 4m. The peats are primarily coastal and delta deposits - fig 9.11 - and to date some 10% have been reclaimed for agriculture and forestry. The resource is not used for fuel, although 50,000 tonnes of horticultural peat are produced annually by private enterprise. A more detailed survey of the reserves is currently under way. [Source: Geological Survey, Caracas]

Others

According to the Soil Map of the World, Histosols are found throughout South America in the valleys and floodplains of the major rivers. Extensive coastal deposits are also found in Guyana, Surinam and French Guiana, where they are cultivated to a certain degree for bananas and coffee, following artificial drainage and liming. Extensive areas of moorland are found on the Falkland Islands while Tierra de Fuego and the offshore islands of Southern Chile contain "Magellanic Moorland" and tundra type peatland constantly swept by gale force winds [75].

Surinam :	113,000 ha	- Swamp deposits on recent alluvium.
French Guiana :	162,000 ha	- Herbaceous aquatic swamp on fluvio-marine alluvium.
Chile :	1,047,000 ha	- Peatland on rock and glacial deposits.
Falkland Is. :	1,151,000 ha	- Peatland deposits on rock.

Although they are not recorded in the Soil Map of the World, Argentina is also estimated to possess 45,000 ha of peatlands [72].

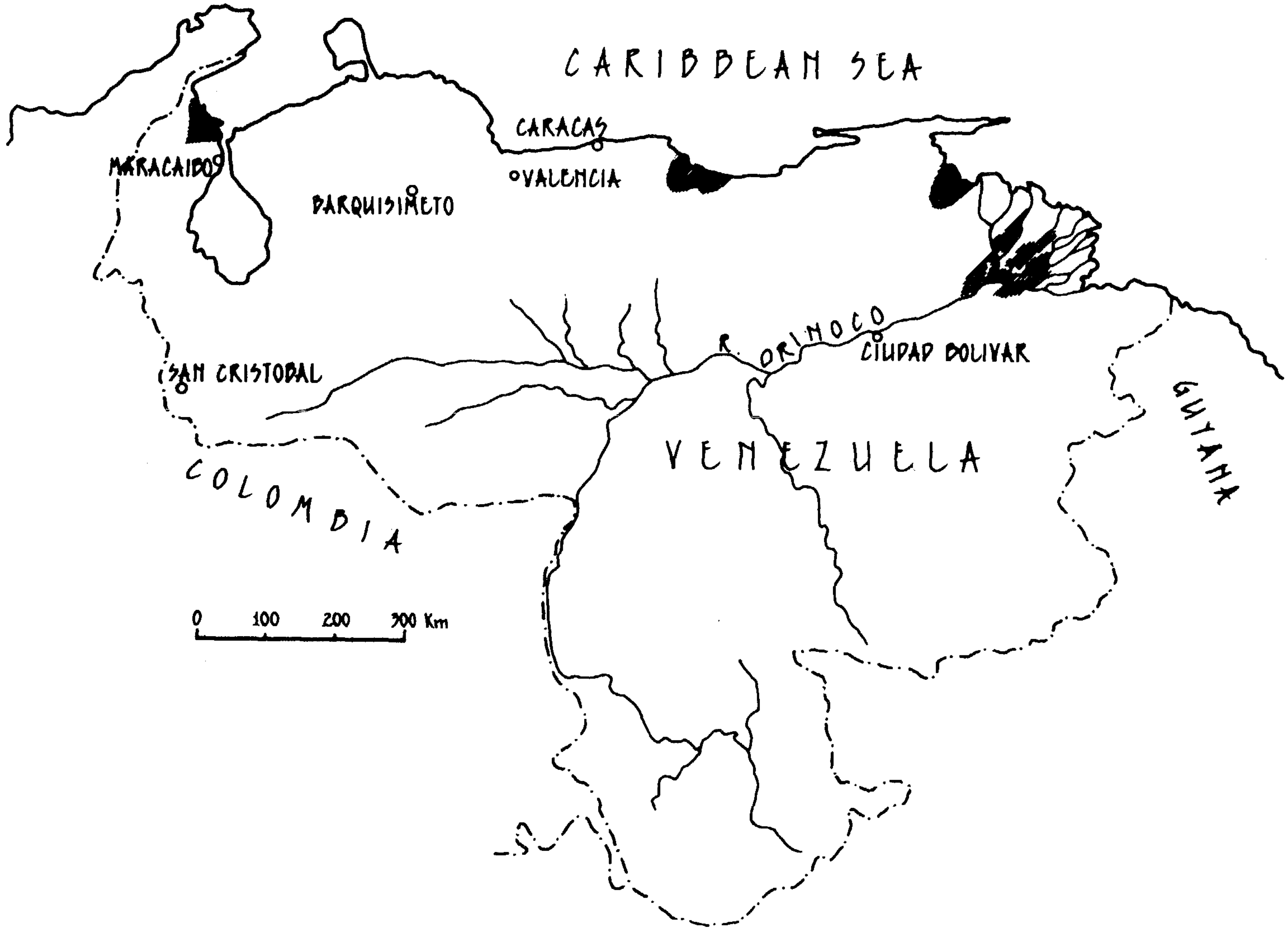


Fig. 9.11 - Peat Deposits in Venezuela

Source: Bord na Mona
Geological Survey of Venezuela

DEVELOPING COUNTRIES - EUROPE

Greece

Greece is one of the very few European countries with a promising peat fuel potential as yet unexploited. The major deposit is at Philippi in Eastern Macedonia,- Fig 9.12 - and is characterised by an unusual depth of 190m. Studies carried out since 1964 on behalf of the Greek Public Power Corporation have established the fuel potential of the deposit. Estimated volume is 4×10^9 m^3 [150].

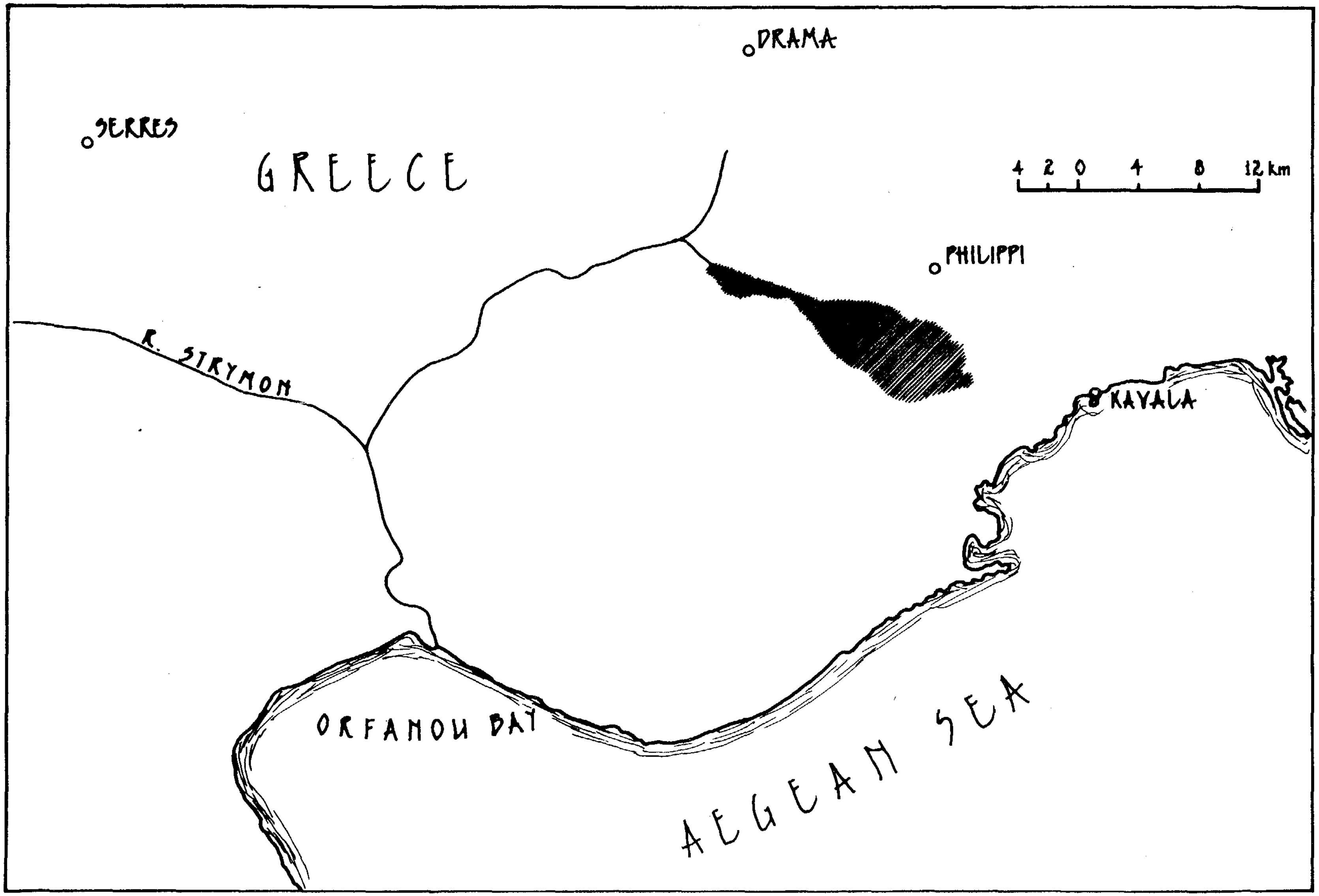
Preliminary studies were initiated in 1968 by Fichtner, a West German firm of consulting engineers. This was followed in 1970 by a main study carried out by Energomachexport (USSR). There are back-up flooding problems, but drainage and embankments, it is believed, will provide the solutions.

The surface, covering about 5000 ha, is almost level, at an elevation of about 44m above sea level. The deposit divides broadly into two parts. The upper stratum corresponding to a depth of 60m, is free of major layers of mineral matter. The lower strata are heavily contaminated with mineral layers, some of which are several meters thick. Ash content at about 30% is high, but fluidised bed burning should solve this problem. Moisture content of the top 30m is rarely over 85% and is often as low as 75%. Reserves in the upper part of the deposit correspond to about 500 million tonnes of peat fuel, with a gross calorific value of 16.7 MJ/kg.

The Philippi deposit, being strongly decomposed and heavily contaminated with mineral soil, is not particularly suitable for use as horticultural peat. Moreover,the high ash content makes it unsuitable as a material for coking. With the climate providing practically ideal air-drying conditions, fuel potential is high [150].

Spain

Spanish peat deposits occupy some 6,000 ha, of which 4,500 ha remain undrained. The major peatland area is formed by minerotrophic mires in the delta of the Guadalquivir River, South of Seville. Smaller heathland-type deposits occur as the result of local drainage inhibition in the Cantabrian Mountains and in the Pyrenees. Certain areas are protected as wildlife refuges by the State, and considering the limited extent of the deposits they are unlikely to be developed for fuel [73].



<u>Fig. 9.12</u> - Peat Resources in North-East Greece

<u>Source</u>: Bord na Mona
Melidonis, (149)

TABLE 9.2 Areas of peatland in developing countries

Country	Area (ha)	Remarks/Source
AFRICA		
Angola	-	Not quantified
Burundi	14 000	Ref [86]
Congo	290 000	FAO/UNESCO [75]
Guinea	525 000	FAO/UNESCO [75]
Ivory Coast	32 000	FAO/UNESCO [75]
Lesotho	-	Not quantified
Liberia	40 000	Estimate
Madagascar	197 000	FAO/UNESCO [75]
Malawi	91 000	FAO/UNESCO [75]
Mozambique	-	Not quantified
Rwanda	80 000	Min. Natural Resource
Senegal	1 500	Estimate
Uganda	1 420 00	Ref [70]
Zaire	-	Not quantified
Zambia	1 106 000	FAO/UNESCO [75]
ASIA		
Bangladesh	60 000	Estimate
China	4 200 000	Estimate
Fiji	4 000	Min. Agriculture
Indonesia	17 000 000	Ref [110]
India	32 000	FAO/UNESCO [75]
Israel	5 000	Ref [77]
Korea (DPR)	136 000	FAO/UNESCO [75]
Malaysia	2 500 000	Estimate
Papua New Guinea	-	Not quantified
Philippines	6 000	Min. Energy
Sri Lanka	2 500	Estimate
Thailand	68 000	FAO/UNESCO [75]
Vietnam	183 000	FAO/UNESCO [75]

Country	Area (ha)	Remarks/Source
CENTRAL AMERICA AND CARIBBEAN		
British Honduras	68 000	FAO/UNESCO [75]
Costa Rica	37 000	FAO/UNESCO [75]
Cuba	767 000	FAO/UNESCO [75]
El Salvador	9 000	FAO/UNESCO [75]
Honduras	453 000	FAO/UNESCO [75]
Jamaica	21 000	Min. Mining & Energy
Nicaragua	371 000	FAO/UNESCO [75]
Panama	787 000	FAO/UNESCO [75]
Puerto Rico	10 000	Estimate
Trinidad and Tobago	1 000	Min. Agriculture
SOUTH AMERICA		
Argentina	45 000	Estimate
Bolivia	900	Estimate
Brazil	1 500 000	Estimate
Chile	1 047 000	FAO/UNESCO [75]
Colombia	339 000	FAO/UNESCO [75]
Falkland Is.	1 151 000	FAO/UNESCO [75]
French Guiana	162 000	FAO/UNESCO [75]
Guyana	813 880	Min. Agriculture
Surinam	113 000	FAO/UNESCO [75]
Uruguay	3 000	Estimate
Venezuela	1 000 000	Estimate
EUROPE		
Greece	5 000	Ref [150]
Spain	6 000	Ref [73]

Source: Bord na Mona
Others as indicated

Most of the areas shown in Table 9.2 are estimates. Some are derived from remote sensing, others from soil survey with extrapolation according to vegetation pattern. The FAO/UNESCO Soil Map of the World, which was compiled from the most recent resource data available for each individual country, delineates organic deposits greater than 40 cm in depth [75]. No qualification of their of ash content is included, and deposits with sufficient depth for fuel peat production are likely to be considerably less than the areas shown in the table above.

CENTRALLY PLANNED ECONOMIES

Czechoslovakia

Peat bogs in Czechoslovakia cover a smaller area than in neighbouring countries. The most recent figures suggest 30,750 ha, of which 26,778 ha or 87% are in the Czech Socialist Republic and approximately 4,000 ha or 13% are in Slovakia. 8,822 ha are fen, 10,504 ha are intermediate or transitional types and 11,434 ha are raised bog. Here a peat deposit is considered to be a bog when it covers a minimum area of 0.5 ha with a peat layer at least 50cm. thick when undrained or 30 cm when drained [146].

In the Czech Socialist Republic peat production is mainly for horticulutral use while in Slovakia about 95% of peat output is used for the production of commercial composts. Total production for the country in 1977 was 403,000 tonnes [144]. Fuel utilisation of peat in Czechoslovakia is an unlikely prospect.

German Democratic Republic

Peat deposits in the GDR cover about 489000 ha of which 99% are lowmoor or fen. Fuel peat winning gradually decreased with the progressive expansion of brown coal briquetting, and was almost completely discontinued in 1960. Agriculture rather than fuel utilisation is the priority, including harvesting of moss peat for horticultural use. Older Sphagnum peat is excavated at one plant, which produces sod peat for further chemico-thermal refinement to activated carbon [147].

Hungary

Total peatland area is estimated at 30,000 ha, with a depth range between 0.3m and 3.0m and an average depth of 1.5m. About 40% of this area is used for agriculture, 10% is conserved for environmental purposes and the remainder is untouched. Almost 1 million m^3 of horticultural peat is produced annually at 50 sites (15 large bogs, 25 small and 10 discontinuously working). Peat is not currently produced as a fuel and agricultural and forestry utilisation of the limited reserves appear to have priority [151].

Poland

Poland has substantial peat deposits, and a long history of fuel peat utilisation. Production for fuel use, however, declined rapidly after post-war rehabilitation of the coal industry. Between 1920 and 1956 fuel peat production per annum lay in the range 1.2-1.8 million tonnes. From 1956 onward production declined rapidly, reaching 500,000 tonnes in 1961 and continuing to decline thereafter [163].

The country has about 1,300,000 ha of peatland, 82% of which have been developed, mainly for grassland agriculture. The bogs are scattered throughout the country, with a lower frequency in the far South - Fig 9.13. In all, 5% of the land area is peatland, containing an estimated minimum of 18 x 10^9 m^3 of peat. Fens account for 89% of the peatland area, the remaining 11% consisting of transitional and raised bogs. The peatlands often form large complexes, for example in the Biebrza Valley (100,000 ha) and in the Notec Valley (50,000 ha). Ash content averages 15% of dry matter, with pH in the range 5.5-6.5 on average [158].

Devastation of Poland's coal mines during World War II resulted in a rapid increase in demand for peat fuel, chiefly the fen peats because of their abundance and widespread distribution throughout the country. No significant volume of peat is now produced for fuel. This is likely to remain the case for as long as coal supplies remain plentiful. While the fuel potential of the peat resource remains, actual utilisation is currently restricted to agriculture and the production of horticultural peats [162].

Romania

Romania has 436 individual peat bogs, with a total area of just over 7,000 ha containing 83 million m^3 of peat. The largest concentration of deposits is in the Carpathian Mountains. There is no fuel utilisation at present and, in view of the very limited peatland area and its location, it is difficult to envisage economic use of peat for this purpose [77].

Soviet Union

Mire, swamp and paludified forest areas in the Soviet Union cover a total of 245 million ha. The mean depth of peat varies from north to south, being 0.3m near the Siberian arctic circle, 3-4m in the northern taiga zone, 8-9m maximum in the heartland raised mires, but decreasing again to 1-3m in the southern eutrophic fens. The best available estimate for peatlands exceeding 30 cm in peat depth is 150 million ha, corresponding to 6-7% of the territory. Utilisable peat resources are estimated at 166 x 10^9 tonnes of peat at 40% moisture content [70].

Others

According to figures published by Schneider[4/] and quoted in reference [70], Yugoslavia possess 100,000 ha of peatlands while Bulgaria contains an estimated 1,000 ha.

4/ Schneider, S. (1976). Verteilung der Moore auf der Erde. In: Moore - und Torfkunde, ed. by K. Gottlich. pp. 27-30. Stuttgart.

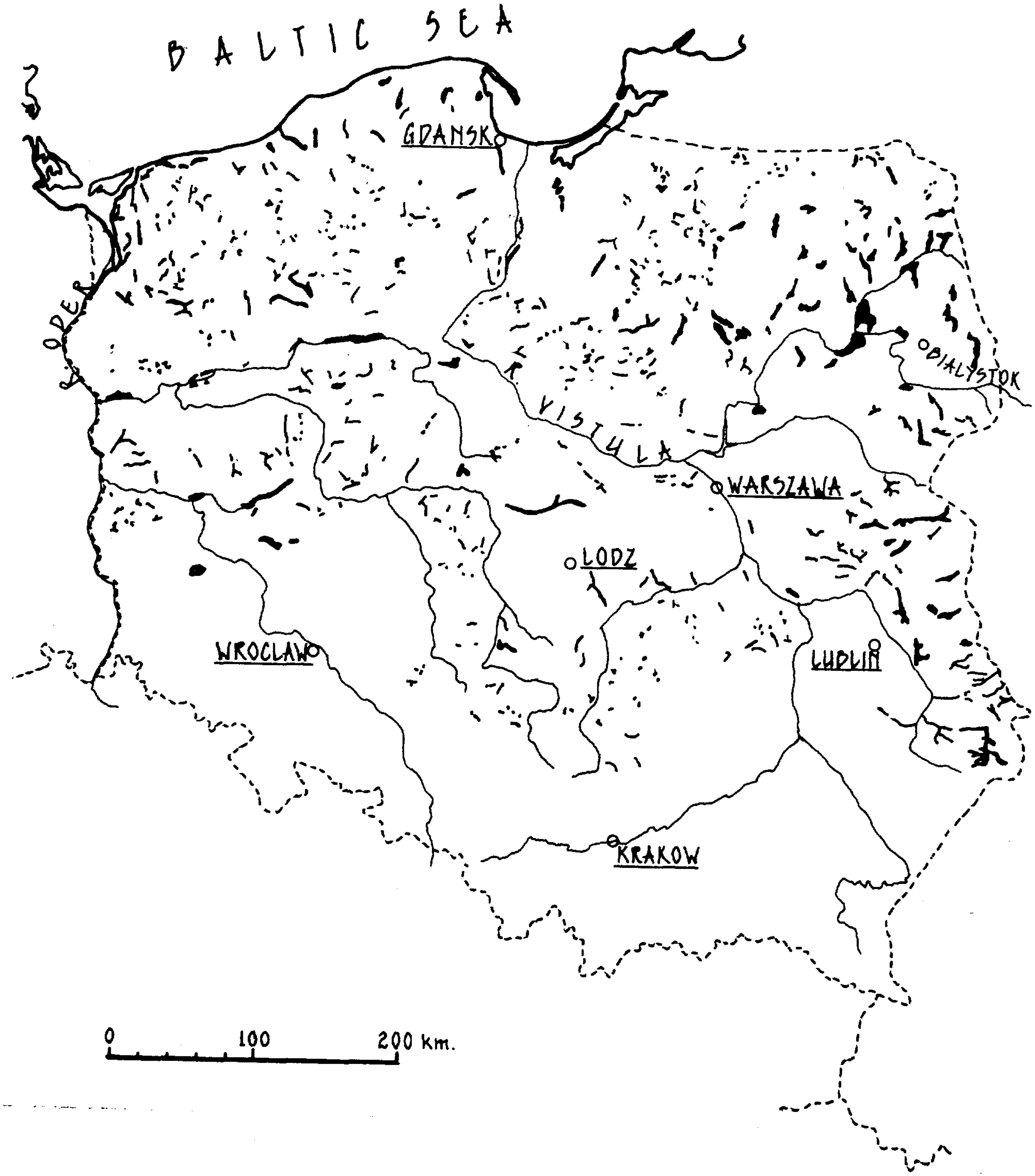


Fig. 9.13 - Peat Deposits in Poland

Source: Bord na Mona
5th IPS Congress [162]

TABLE 9.3. Areas of peatland in centrally planned economies.

Country	Area (ha)	Remarks/Source
Bulgaria	1 000	Ref [70]
Czechoslovakia	30 750	Ref [146]
GDR	489 000	Ref [147]
Hungary	30 000	Estimate
Poland	1 300 000	Ref [158]
Romania	7 000	Ref [77]
Soviet Union	150 000 000	Estimate
Yugoslavia	100 000	Ref [70]

Source: Bord na Mona
Others as indicated

SECTION X - CONCLUSIONS

In the case of developing countries, the following conditions should be considered in all feasibility studies of peatland exploitation for peat fuel production:

- In localities where food is in short supply due to the scarcity of agricultural land, development of cultivated peatland for fuel production would be undesirable. Exploitation in these localities should be confined to areas which are not under cultivation, and to those areas where it is considered that existing cultivation may be improved by the removal of some or all of the peat (for example Senegal). Plans for development should include possible proposals for the reclamation of the cut over bog, preferably for agricultural purposes.

- The hydrological and other environmental effects resulting from peatland exploitation, should be carefully examined prior to the commencement of development operations, in order to avoid irreversible damage.

- The effects of peat exploitation should not be detrimental to the quality of life in the region.

- It should be established by pre-feasibility study that the quality and constituents of the deposit are suitable for fuel peat production.

- A suitable market should be available for the form of energy proposed i.e. solid fuel, carbonised peat, etc.

- Because of the bulk density of peat, it is relatively costly to transport. Markets therefore should be reasonably close to the peat deposits. In Ireland transport distances of over 40 miles are considered undesirable for fuel peat which has not received beneficiation treatment. Assessment of acceptable transport distances will be greatly influenced by topographical and economic factors.

- The quantity of peat in deposits should be capable of supplying the selected markets for about 25 years. The production rate can be planned to correspond to the period of repayment of investment capital.

- The deposit should be deep enough to permit exploitation by established techniques or modifications thereof. Deposits of less than one metre are normally not considered suitable for exploitation; a depth of over two metres would be most desirable.

- If the deposit requires draining, the possible use of gravity or pumped drainage systems, should be examined.

- Unless wet production and harvesting techniques are employed, the climatic conditions should be suitable for drying the peat to an acceptable level, in such a period of time as would permit a desirable annual yield per hectare. (The annual yield would probably be not less than 150 tonnes per hectare, and the moisture content of the product not more than 50%).

- The deposit should be accessible by road or waterway and the topography suitable for both production and transport operations.

- Deposits which contain substantial amounts of buried timber may prove uneconomic to develop by conventional methods. In such cases the pumped method of exploitation may be feasible.

Fuel peat production, using natural drying, employs a combination of opencast mining and agricultural harvesting techniques. Peat deposits like ore bodies will vary considerably; therefore, in order to assess the economic feasibility of exploitation, each deposit would need to be examined individually in relation to the above.

The main difference in characteristics between deposits in the temperate and equatorial zones can be classed as follows:-

- Higher ash contents are more prevalent in equatorial zones. Many such deposits would be considered unsuitable for burning by conventional means. However,with the development of fluidised bed burning, the level of acceptability of ash content has been raised considerably. This type of burning should have a greater application in developing countries. High ash content does of course increase costs; it also reduces the thermal value of the peat, limits the available markets, and makes the peat unsuitable for carbonisation or briquetting.

- Peat deposits on river banks (Marais of Rwanda and Burundi) and estuarine deposits (Jamaica and Brazil) are impractical to drain, and consequently require either modified conventional or unconventional techniques. These techniques would be required to transport the peat to higher ground by barge, by land transport units, or by pumping the peat as a slurry. Environmental aspects of the hydrological impact of this type of operation are important. Drying grounds for the peat are conventionally on bog which is agriculturally unproductive, whereas in this system the drying grounds might not be on the bog, and interference with much needed agricultural productivity may result. This would entail an assessment of the relative importance of agriculture as against energy.

- Climatic conditions in the tropics can give peat yields, by natural drying, which are up to ten times greater than in those obtainable in the temperate zones. Consequently economic constraints are considerably reduced, making deposits economically viable, which in the temperate zones would be deemed to be uneconomic.

There will of course be many other variations in the deposits of developing countries, but economics will be the main factor in any feasibility study. Many peat production techniques have been tried since the early part of this century and found to be uneconomic, i.e. gasification, wet carbonisation, pressure and thermal de-watering. Recently, especially in the U.S.A. these techniques have again been examined, particularly gasification, with the application of modern high technology, but as yet no definite full-scale production plant, illustrating their economic viability, is in operation.

In our assessment of these newer techniques, fluidised bed combustion is expected to have the greatest impact in developing countries. Artificial de-watering methods, pressure, thermal and chemical, would we think, have only limited application, if any at all. Beneficiation by briquetting, where natural drying reduces the moisture content to 15%, could have some application. However, not enough is yet known of the economics of beneficiation by wet carbonisation, or by the Koppelman and P.D.F. processes, to assess their potential influence. From past experience we would be sceptical that they could make a major contribution, mainly for economic reasons.

Conversion to gas and liquid products is both sophisticated and costly. It is doubtful if this form of production would have much application in developing countries, except for producer gas which can be used in converted diesel engines and which may be applied to convert diesel-electric plant to gas-electric plant in remote areas.

There are units on the market for the conversion of oil-fed boilers to solid fuel boilers. If proved reliable and economic, these could play an important role in the development of fuel peat production and peat marketing in developing countries. The information regarding these units is as yet not reliable enough to draw positive conclusions, but we are of the opinion that it is an area which should be closely observed, and a thorough investigation of operational units would perhaps be justified.

Of the potential markets for fuel peat in developing countries it is our opinion that the industrial market would be the fastest and simplest to establish, especially with fluidised bed combustion. From this base it would be possible to expand into the domestic market. Electricity generation is of course the easiest market, but then electric power is not always the primary requirement.

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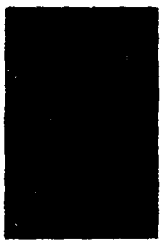

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