Peat resources of Canada

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Peat Resources of Canada

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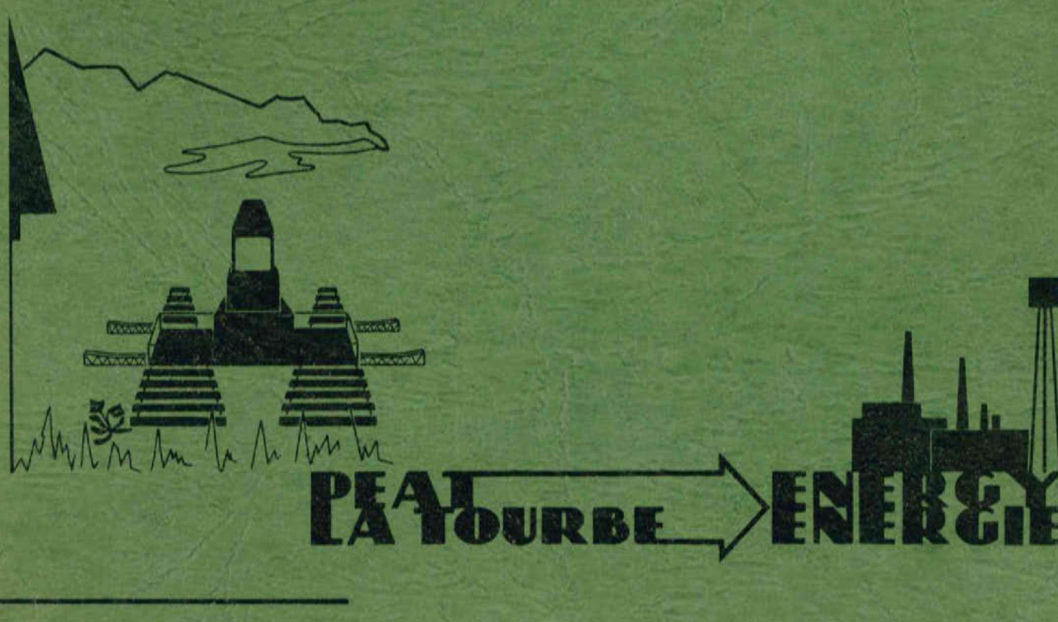
October 1984



Canada

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PEAT RESOURCES OF CANADA

by

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October 1984

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ABSTRACT

There are 111 328 × 10^3 ha of peatlands in Canada, representing 12% of the total land area. Because of the great variation in climate and physiographic situations, a wide range of peatland types occur on these peatlands. Peat materials associated with these peatlands are identified according to their botanical composition. Their physical and chemical characteristics depend on their botanical composition and the region in which they were deposited. There are approximately 3 004 996 × 10^6 m^3 or 335 × 10^9 tonnes of dry peat or 507 × 10^9 tonnes with 50% water content in Canada. The energy value of this peat resource is approximately 6.7 × 10^{21} J. The existing mining techniques are able to handle only the unfrozen, southern peatlands, whose energy equivalent is approximately 2.7 × 10^{21} J, similar to that of the coal resources of Canada.

RÉSUMÉ

Au Canada, il existe une superficie de 111 328 × 10^3 ha de tourbières, ce qui représente 12% de toute la superficie terrestre du pays. En raison des grandes variations que connaissent le climat et les régions naturelles du Canada, ses tourbières présentent un vaste éventail de formes. Les matériaux tourbeux associés à ces tourbières sont identifiés suivant leur composition végétale. Leurs caractéristiques physiques et chimiques dépendent de leur composition végétale et de la région dans laquelle ces matériaux ont été déposés. Au Canada, il existe approximativement 3 004 996 × 10^6 m^3, soit 335 × 10^9 tonnes de tourbe sèche ou 507 × 10^9 tonnes possédant une teneur en eau de 50%. La valeur énergétique de cette ressource en tourbe est d'environ 6,7 × 10^{21} J. Les techniques actuelles d'extraction ne permettent d'exploiter que les tourbières méridionales, non gelées, dont l'équivalent énergétique est approximativement de 2,7 × 10^{21} J, soit à peu près l'équivalent des ressources houillères du Canada.

1.0 INTRODUCTION

Canada's vast land area is divided amongst various physiographic regions, from the high rugged mountains and large central plains to the coastal lowlands. The climate also varies from the cold and dry high arctic to the cool temperate. Marine-modified temperatures and precipitation occur along the southern oceanic areas while marked continentality occurs in the central part of the country.

Peatlands cover 12% of the land area of Canada and are found in almost all geographic regions, although they are less common in the high Arctic and almost completely absent in the Prairies.

A wide range of values is found in the literature for the total area of peatlands in Canada, the largest (170×10^6 ha) being given by Kivinen and Pakarinen (1980), followed by Zoltai (1980) (153×10^6 ha) and the Muskeg Subcommittee of the NRC (1977) (129×10^6 ha). The data concerning peat resources presented in this report are partially based on a study that evaluated Canadian peatland inventories and established the distribution of peatlands based on these inventories (Dendron Resource Surveys Ltd. 1982). In addition to this, the information concerning the distribution of peatlands, based on inventories undertaken by the Canada Soil Survey and other government agencies, was summarized by Tarnocai (1983). It should be noted, however, that the figures presented here are still estimates even though they are based on inventories. Large areas of Canada, especially in the north, have either been covered with only broad level inventories or no inventories are yet available for them.

2.0 PEATLAND TYPES

The wide range of peatland types found in Canada is a result of the great variation in climatic conditions and physiographic situations. A number of classifications were proposed for these Canadian peatlands. Radforth (1955, 1958) stressed the appearance of muskeg patterns, as seen from the air, with ground information being supplied concerning the vegetation and topography. Others emphasized the use of the peatland vegetation (Jeglum et al. 1974) or the peat landform (Tarnocai 1980, Zoltai et al. 1973) for classification.

The approach which is most widely accepted and most commonly used in Canada is a genetically based, hierarchical wetland classification (Tarnocai 1980, Zoltai et al. 1973). This wetland classification includes both peatlands (peat depths greater than 40 cm) and mineral wetlands (peat depths 40 cm or less). In this system of classification peatlands are associated with four peatland classes at the highest level: bogs, fens, swamps, and marshes. A brief description of these classes is as follows:

BOGS: A bog is a peatland which generally has a high water table. This water table is at or near the surface. The bog surface is either raised above or level with the surrounding wetlands, and is virtually unaffected by the nutrient-rich ground waters from the adjacent mineral soils. Hence, the ground water of the bog is generally acid and low in nutrients. The dominant peat materials are undecomposed *Sphagnum* and moderately decomposed woody-moss peat underlain, at times, by moderately to well decomposed sedge peat. The associated soils are Fibrisols, Mesisols, and Organic Cryosols. Bogs may be treed with black spruce or treeless and they are usually covered with *Sphagnum*, feather mosses, and ericaceous shrubs.

FENS: A fen is a peatland with a high water table, usually at or above the surface. The waters are mainly nutrient-rich, minerotrophic waters from adjacent mineral soils. The dominant peat materials are shallow to deep, well to moderately decomposed sedge or woody sedge peat. The associated soils are Mesisols, Humisols, and Organic Cryosols. The vegetation consists dominantly of sedges, grasses, reeds, and brown mosses with some shrub cover and, at times, a scanty tree layer.

SWAMPS: A swamp is a peatland or a mineral wetland with standing or gently flowing water in the form of pools and channels. The water table is usually at or near the surface. There is pronounced water movement from the margins or other mineral sources, hence the waters are nutrient-rich. If peat is present, it is mainly well decomposed woody or amorphous peat underlain, at times, by sedge peat. The associated soils are Mesisols, Humisols, and Gleysols. The vegetation is characterized by a dense tree cover of coniferous or deciduous species and by tall shrubs, herbs, and mosses.

MARSHES: A marsh is a mineral wetland or a peatland which is periodically inundated by standing or slowly moving waters. Surface water levels may fluctuate seasonally, with declining levels exposing drawn-down zones of matted vegetation or mud flats. The waters are nutrient rich. The substratum usually consists of mineral material or moderately to well decomposed peat deposits. The associated soils are Humisols, Mesisols, and Gleysols. Marshes characteristically show a zonal or mosaic surface pattern of vegetation, comprised of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent non-woody plants such as rushes, reeds, reed-grasses, and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish.

On the second level these wetland classes are subdivided according to their landforms. The landform name is based on the surface morphology, the surface pattern, the morphology of the basin in which the wetland developed, or the associated water bodies. The various peat landforms found in Canada are presented, according to the peatland regions, in Table 1, and their geographic distribution is shown in Figure 1. Descriptions of these peatlands are to be found in the works of Tarnocai (1970, 1980) and Zoltai et al. (1973).

3.0 PEAT MATERIALS

As defined in soil science, peat is an organic material having carbon content greater than 17% (Canada Soil Survey Committee 1978). According to the definition used in the fuel peat industry, peat is considered to be an organic material with a maximum ash content of 40% (Monenco Ontario Ltd. 1981).

Table 1. Peatland classification according to the wetland classifications by Tarnocai (1980) and Zoltai et al. (1973)

Peatland Classes			
Bog	Fen	Swamp	Marsh
Peat Landforms			
Palsa	Northern ribbed	Stream	Estuarine high
Peat mound	Atlantic ribbed	Shore	Estuarine low
Mound	Ladder	Peat margin	Coastal high
Domed	Net	Basin	Coastal low
Polygonal peat plateau	Floating	Flat	Floodplain
Lowland polygon	Stream	Floodplain	Channel
Northern plateau	Collapse		Inactive delta
Atlantic plateau	Palsa		
Collapse	Spring		
Floating	Slope		
Shore	Lowland polygon		
Basin	Horizontal		
Flat	Channel		
String			
Blanket			
Bowl			
Slope			
Veneer			

Figure 1. Wetland regions of Canada (Adams et al. 1981) and the peat landforms occurring in these regions.

LEGEND

WETLAND REGION	COMMON PEAT LANDFORMS	WETLAND REGION	COMMON PEAT LANDFORMS
AH: High Arctic	Strongly eroded high center lowland polygons.	BA: Atlantic Boreal	Domed and plateau bogs; horizontal and stream fens.
AM: Mid-Arctic	Low and high center lowland polygons.	PC: Continental Prairie	Devoid of peatlands.
AL: Low Arctic	Low and high center lowland polygons.	PI: Intermountain Prairie	Devoid of peatlands.
SH: High Subarctic	Polygonal peat plateaus; horizontal and shore fens.	TE: Eastern Temperate	Basin, shore and flat swamps; flat and basin bogs; horizontal fens.
SL: Low Subarctic	Peat plateaus; palsas; ribbed and horizontal fens.	TP: Pacific Temperate	Basin and flat bogs; horizontal fens.
SA: Atlantic Subarctic	Slope and basin bogs; ribbed fens.	OA: Atlantic Oceanic	Blanket, domed and basin bogs; horizontal and stream fens.
BH: High Boreal	Peat plateaus; palsas; veneer, collapse, string and flat bogs; ribbed, net, horizontal, collapse, and shore fens.	OP: Pacific Oceanic	Slope, basin and flat bogs; horizontal and stream fens.
BM: Mid-Boreal	Domed, flat, basin and plateau bogs; horizontal and ribbed fens.	Mx: Mountain Complex	Flat and basin bogs; horizontal and ribbed fens.
BL: Low Boreal	Flat and bowl bogs; horizontal fens; basin swamps.		

Peat materials associated with these peatlands are separated according to their botanical composition. Thus, the name of the peat material indicates the most common plant material(s) associated with that specific peat. For example, woody sedge peat is composed dominantly of sedge peat with a subdominant amount of woody peat. A brief description of some common peat materials associated with Canadian peatlands is given below.

SPHAGNUM PEAT: This peat material is usually undecomposed (fibric), light yellowish-brown to pale brown in color, and loose and spongy in consistence with the entire *Sphagnum* plant being readily identifiable. The von Post value is generally H 1 to 3 and the rubbed fiber content is approximately 60%. The material has the lowest pH, ash content, and bulk density (0.07 g/cm^3) of all peat materials.

SEDGE PEAT: This peat material is composed dominantly of sedge (*Carex* spp.) and is generally moderately decomposed and matted. The sedge leaves are readily identifiable with the naked eye. This peat commonly contains large amounts of very fine roots of the above plant species. Sedge peat is extremely acid to neutral (pH 4.5-7.0) and has a von Post value of H 5 to 7. It has a rubbed fiber content of 8 to 30% and a bulk density of 0.11 g/cm^3.

BROWN MOSS SEDGE PEAT: This peat material is composed dominantly of sedges with subdominant amounts of brown mosses of the genera *Drepanocladus*, *Calliergon*, and *Aulacomnium* with both sedge and moss plants being readily identifiable with the naked eye. This peat is usually moderately decomposed to undecomposed (H 5 to 7) and has an unrubbed fiber content of 8 to 30%. It is generally very strongly acid to neutral (pH 5.0-7.0) and has a bulk density of approximately 0.11 g/cm^3.

WOODY SEDGE PEAT: This peat material is composed dominantly of sedge peat with subdominant amounts of woody materials. This peat is usually moderately decomposed (H 4 to 6) with an unrubbed fiber content of 10 to 40% and, in general, sedge and wood fragments are easily identifiable. It is extremely acid to neutral (pH 4.5-7.0) and has an average bulk density of 0.18 g/cm^3.

WOODY PEAT: This peat material is composed dominantly of woody materials derived from both coniferous and deciduous tree species. In general, the wood fragments are easily identifiable in this peat. Woody peat is moderately to well decomposed (H 5 to 8) with an unrubbed fiber content of 5 to 30%. It is strongly to slightly acid (pH 5.0-6.5) and has an average bulk density of 0.15 g/cm^3, although it may reach 0.21 g/cm^3 in material with high wood content.

FEATHER MOSS PEAT: This peat material is composed dominantly of feather mosses (*Hypnum* spp., *Hylocomium* spp., and *Pleurozium* spp.) and occasionally some woody materials derived dominantly from coniferous tree species. This peat is moderately decomposed (H 4 to 7) with an unrubbed fiber content of 10 to 60% and is also extremely to slightly acid (pH 4.5 - 6.5). The bulk density is approximately 0.12 g/cm^3, very similar to that of peats dominated by brown mosses.

SEDIMENTARY PEAT: This peat material is derived from aquatic plant debris (algae, diatoms, aquatic mosses, and other aquatic organic materials). The material is plastic and slightly sticky and is brown to gray in color. It shrinks upon drying to form clods that are very difficult to rewet. This peat is generally well comminuted and has few or no plant fragments recognizable by the naked eye. It is extremely to slightly acid (pH 4.5-6.5) and has a high ash content. The average bulk density is 0.13 g/cm^3, but it may reach 0.17 g/cm^3.

AMORPHOUS PEAT: This peat material is composed of well decomposed plant materials that are unidentifiable by the naked eye. It is generally extremely acid to neutral (pH 4.5-6.9) and has a bulk density of 0.15 g/cm^3. This peat is well decomposed (H 6 to 10) with an unrubbed fiber content 2 to 8%.

4.0 DISTRIBUTION OF PEAT RESOURCES

4.1 Distribution of Peat Resources - by Area

The estimated total areal coverage of peatlands in Canada and in the various provinces and territories is presented in Table 2 and shown in Figure 2. According to this estimate, the total area of peatlands in Canada is 111 328 × 10^3 ha, representing 12% of the land area of Canada. When the various provinces and territories are compared, the Northwest Territories has the largest area of peatlands (25 111 × 10^3 ha), followed by Ontario (22 555 × 10^3 ha) and Manitoba (20 664 × 10^3 ha). The largest concentration of peatlands is found in Manitoba (38% of the land area), followed by Ontario (25% of the land area). Almost one-quarter (23%) of the total Canadian peatlands is found in the Northwest Territories, followed by Ontario (20%) and Manitoba (19%). Approximately 60% of the total Canadian peatlands are perennially frozen.

4.2 Distribution of Peat Resources - by Volume

The total volume of peat (Table 2) in Canada was found to be 3 004 996 × 10^6 m^3 with the greatest volumes being found in Ontario (676 653 × 10^6 m^3), the Northwest Territories (577 553 × 10^6 m^3) and

Table 2. Peat resources of Canada

Provinces and Territories	Peatland areas (ha × 10^3)	Peatland areas: % of land area within designated areas	Peatland areas: % of total Canadian peatlands	Indicated peat volumes ($m^3 \times 10^6$)	Indicated peat volumes (%)	Indicated oven dry weight of peat (tonnes × 10^6)	Indicated weight of peat with 50% water content+ (tonnes × 10^6)	Indicated weight of peat with 50% water content+ (%)	Measured peat (Tibbets and Ismail 1980) (tonnes × 10^6)
Alberta	12 673	20	11	316 822	11	36 118	54 177	11	3
British Columbia	1 289	1	1	38 685	1	4 410	6 615	1	20
Manitoba	20 664	38	19	516 605	17	58 893	88 339	17	103
New Brunswick	120	2	*	4 800	*	466	698	*	103
Newfoundland - Labrador	6 429	17	6	257 160	8	24 945	37 417	8	612
Northwest Territories	25 111	8	23	577 553	19	65 841	98 762	19	-
Nova Scotia	158	3	*	6 320	*	613	920	*	23
Ontario	22 555	25	20	676 653	22	77 138	115 708	23	135
Prince Edward Island	8	1	*	312	*	30	45	*	2
Quebec	11 713	9	11	351 381	12	40 057	60 086	12	64
Saskatchewan	9 309	16	8	232 737	8	26 532	39 798	8	27
Yukon Territory	1 298	3	1	25 968	1	2 960	4 441	1	-
Canada	111 328	12		3 004 996		335 339	507 006		1 092

* less than 1%

+ oven dry weight basis

Manitoba (516 605 × 10^6 m^3). These volumes were calculated using the areal data (Table 2) and the average depth derived from Figure 3. This map was compiled using the Wetland Regions of Canada map (Adams et al. 1981) together with various other surveys and site-specific information.

Tibbets (1983) suggested various categories for estimating the volume of peat, corresponding to the level of confidence in the evaluation. A similar procedure is used in mineral resource evaluation. These categories and their definitions are as follows:

(1) Inferred resources - volume estimates based solely on Telesat data, aerial photographs and topographical maps and based primarily on assumed depth of not more than one metre.

(2) Indicated resources - volume estimated by use of Telesat data, aerial reconnaissance, radar, aerial photographs, topographical maps, and at least one measured depth extrapolated over the entire area.

(3) Measured resources - volume and quality measured and evaluated over the entire deposit by generally recognized sampling and analytical techniques, e.g., the New Brunswick inventory (Keys et al. 1982).

(4) Reserves - measured resources that can be economically exploited - presently, this would pertain only to those peatlands now being used for peat moss production, forestry, and agriculture.

According to these categories the volume estimates given in this paper would be classified under category 2, "Indicated Resources". In reality, however, these volumes are based mainly on reconnaissance and exploratory surveys and thus many actual measurements were made. Insufficient measurements were made, however, to permit them to be classified under category 3, "Measured Resources".

4.3 Distribution of Peat Resources - by Weight

The weight of peat in the various regions of Canada was determined using the calculated volumes (Table 2). The average bulk density values were derived mainly from the work of Mills (1974), which gives mean values for sphagnum peat (0.075 g/cm^3), sedge peat (0.119 g/cm^3), and woody peat (0.149 g/cm^3). Based on these values, a bulk density of 0.097 g/cm^3 was used for the Atlantic provinces, where the peat deposits are composed mainly of sphagnum and sedge peats. For the rest of the country, where peat deposits are composed chiefly of sphagnum, sedge, and woody peat materials, a bulk density of 0.114 g/cm^3 was used for calculations.

The weights of peat in metric tonnes, based on oven dry weight and 50% water content (on a weight basis), are presented in Table 2. The total estimated weight of peat in Canada is 335 × 10^9 tonnes of dry peat or 507 × 10^9 tonnes with 50% water content. On examination of the peat resources in the various regions of Canada, Ontario was found to have the greatest tonnage, 77 × 10^9 tonnes of dry peat or 116 × 10^9 tonnes with 50% water content, followed by the Northwest Territories and Manitoba. Approximately 23% of the total peat tonnage is found in Ontario, followed by the Northwest Territories (19%), Manitoba (17%), Quebec (12%), and Alberta (11%).

Table 2 also contains the tonnages of the "measured" peat resources (category 3) from Tibbetts and Ismail (1980), indicating that a very small fraction of Canada's peat resource has been measured in detail.

5.0 POTENTIAL USES OF PEAT

The utilization of peat depends mainly on the properties and quality of the peat, the climatic conditions of the area where the peatland is situated, and economic factors.

Peat is commonly used in agriculture for growing a variety of crops. There are approximately 280 × 10^3 ha of peatland now being used for agriculture (Agricultural Land Use Tabulation, Canada Land Data System, Environment Canada). These areas are situated mainly in the Atlantic provinces, Quebec and Ontario, and in the Fraser River delta of British Columbia. The main factors controlling the utilization of peatlands for agricultural production are the climate and the type of peat material. The area of peatland that has potential for agriculture is much greater than the area now being used. These regions of high potential are situated in the southern part of Canada.

The use of peatlands for forestry, although not common in Canada, is widespread in Europe. Trials carried out in Newfoundland indicate that the most suitable peatland for afforestation is the slope fen. This peatland is usually the most sheltered, nutrient-rich, and easy to drain (Pollett 1972). The potential of peatlands for forestry in Canada cannot easily be determined from the limited amount of data presently available. The optimum water table level, soil moisture, and nutrient levels depend on the tree species. Regional variations in climate, topography, and geology are also major considerations in site selection and establishment of future plantations.

Peat is also used for horticultural purposes, mainly as a soil enricher. The addition of horticultural peat to a soil increases the organic matter content and the ability to hold water and nutrients and improves aeration. Horticultural peat is used mainly in greenhouses and gardens. It is also used in the production of peat pots and as a seed carrier. In this case, a small package of peat is embedded with seeds for use in home gardens.

Because of its high surface area, porosity, and exchange capacity, peat is often used as a filtration and absorption agent. As a physical filter, peat is effective in removing suspended solids from effluents and in reducing the sludge clogging of traditional filters. Peat materials are also effective in the control of oil spills since they have a high absorbency due to the porous nature of peat. Peat can also be used as a chemical filter since it is very effective in removing heavy metals, color, and toxic materials from industrial effluents.

An important use of peat, and one which dates far into the past, is as a fuel. Peat for fuel can be used either as mined or after upgrading has been carried out. This peat is then fired in furnaces for heating or in boilers to generate the steam needed to drive turbines, thus producing electricity. The mined fuel peat can also be processed into a variety of products including coke, synthetic natural gas, and methanol. Synthetic natural gas can be used as a heating fuel or, in generators, for the production of electric power. Methanol can be used as a feedstock in the chemical industry. A comparison analysis of peat with coals shows that, with increasing age of the deposit, the volatile matter content of these fuels decreases, while fixed carbon content and heating values increase. Peat contains about 60% more volatile matter by weight and has 25% less heating value than lignite (Punwani 1980). Thus, peat is much easier to convert to natural gases and liquids than is coal with its high fixed-carbon content. The coke produced from peat is chemically of a higher quality than coal-based coke. The coke derived from peat can be used as a reducing agent by the chemical and steel industries and as a binder in the production of the iron pellets used by steel mills.

5.1 Peat as a Fuel Resource

The basic characteristics of fuel peat or energy peats are the high degree of humification, high bulk density, relatively low ash content, low content of potential pollutants such as sulphur and mercury, and high calorific value.

According to the U.S. Department of Energy definition of fuel-grade peat, four criteria must be met. The material must be less than 25% ash by weight and must contain 8000 Btu/lb when bone dry. In addition, the peat deposit must be in excess of 5 ft thick and cover an area of 80 contiguous acres in any one square mile (Kopstein 1980).

Table 3 (Monenco Ontario Ltd. 1981), which is based on European data, gives the basic energy values of fuel peat and provides a comparison with various other fuels. Fuel peat has a carbon content of 50-60% (falling between that of wood and lignite) and a hydrogen content of 5.0-6.4% (similar to that of wood and lignite but approximately half as much as heavy fuel oil). The oxygen content of fuel peat is 30-40%, and falls approximately between those of lignite and wood but is much higher than that of bituminous coal or oil. The nitrogen content of fuel peat is 1.0-2.5%, in the same range as that of wood and lignite, and the sulphur content is 0.1-0.2%. The sulphur content of peat is considerably lower than that of coal or oil, making it a very clean fuel. The nitrogen content of Canadian peat is 1-3% and the sulphur content is ~~approximately~~ 0.1-0.5% (Monenco Ontario Ltd. 1981). The ash content of fuel peat is 2-10% (on a dry weight basis), comparable with most coals but higher than wood. The ash content of Canadian peat has a wide range of values and depends on the type of peat material and the region in which it is found. Mills (1974) reported mean ash contents for the various types of peat occurring in Manitoba as: sphagnum peat 7.3%, woody peat 18.3%, feather moss peat 17.3%, and woody sedge peat 15.1%. On the other hand, Tarnocai (1983), in a study of peats occurring in the Ottawa area, found mean ash values as follows: sphagnum peat 4%, brown moss peat 8%, woody sedge peat 19%, feather moss peat 19%, woody peat 16%, and sedimentary peat 39%. The melting point of peat ash is 1100-1200°C, or within the same range as that of coal, thus creating similar slagging properties to coal. The bulk density of fuel peat at 50% moisture content (a common moisture content for milled peat received at the plant) is 300-400 kg/m^3 (Table 3). The bulk density values of Canadian peat, however, are lower. The average bulk density values (based on a moisture content of 50% on an oven dry basis) according to Mills (1974), Tarnocai (1983) and other unpublished data are: sphagnum peat 112 kg/m^3; sedge peat 178 kg/m^3; and woody peat 223 kg/m^3. The calorific values of dry fuel peats vary from 4700-5100 kcal/kg, or within the same range as those of lignite. The average calorific values for the dry peat materials from the Ottawa area are: sphagnum peat 5298 kcal/kg, sedge peat 5181 kcal/kg, woody sedge peat 4777 kcal/kg, feather moss peat 4661 kcal/kg, woody peat 4748 kcal/kg, and sedimentary peat 3436 kcal/kg.

The degree of decomposition is usually indicated by the von Post scale or by the fiber content. Although it is possible to use peat as low as von Post H 3 (greater than 40% rubbed fiber content) for fuel, it is generally recognized that the best peat, technically and economically, for fuel use is the well decomposed, dense peat classified at least H 5 on the von Post scale (Scott and Korpijaakko 1980).

The calorific values for fuel peat vary with the moisture content. The most common operating moisture content is 50% for milled peat and 35%

Table 3. Comparison of the properties of various fuels (Monenco Ontario Ltd.)

Properties of fuels	Heavy fuel oil	Coal (bituminous)	Coal (lignite)	Peat	Wood
C %	83-86	76-87	65-75	50-60	48-50
H %	11.5-12.5	3.5-5.0	4.5-5.5	5.0-6.5	6.0-6.5
O %	1.5-2.5	2.8-11.3	20-30	30-40	38-42
N %	0.2-0.3	0.8-1.2	1-2	1.0-2.5	0.5-2.3
S %	2.0-2.8	1-3	1-3	0.1-0.2	-
Ash content, %	0.3	4-10	6-10	2-10	0.4-0.6
Melting point of ash, C°	-	1100-1300	1100-1300	1100-1200	1350-1450
Volatiles, %	-	10-50	50-60	60-70	75-85
Bulk density, kg/m^3	920-970	720-880	650-780	300-400	320-420
Effective heat value of dry matter, kcal/kg	9900-10000	6800-7900	4800-5800	4700-5100	4400-4600
Operational moisture, %	0.1	3-8	40-60	40-60	30-55
Effective heat value at the lowest operational moisture content, kcal/kg	-	6570-7640	2640-3240	2500-3000	2900-3040
Effective heat value at the highest operational moisture content, kcal/kg	-	6200-7220	1560-1960	1780-1960	1650-1740

for sod peat. The moisture content of milled peat, as mined, may vary from 40 to 60%. Anything over 55%, however, is regarded as unacceptable for long-term use as a fuel. The lower values, in the 40% range, on the other hand, create handling problems and the danger of explosion.

5.2 Peat Mining

Peat is commercially mined, using either dry or wet methods (Aspinall and Hudak 1980, Carncross 1980, and Tomiczek et al. 1980), in almost every country that has significant deposits. The dry methods (milled and sod mining techniques) produce peat containing 35 to 50% moisture content. In the dry mining methods, extensive site preparation in the form of draining and grading has to be carried out before peat production can begin. Since this method of mining requires field drying, it is greatly affected by meteorological factors. Dry mining methods are most commonly used to mine peat and are used almost exclusively to produce peat for fuel and horticultural purposes.

The wet mining method produces peat containing 80 to 98% water, depending on the mining equipment used. This high water content peat slurry is then pumped to the plant for dewatering. The wet mining system requires very little site preparation since the equipment does not travel on the surface of the peatland. This method is used under wet climatic conditions or on peatlands which are difficult to drain.

Climate is one of the main physical factors determining the feasibility of peat mining operations. These climatic variables are temperature, precipitation, the amount of sunshine, and the length of the frost-free period. Other climatic variables, such as evapotranspiration and average annual moisture deficiency, are useful indicators for the suitability of the regional climate for peat mining. Currently, there is no detailed information available which relates climate to peat production rates in Canada. In Finland a system is available which correlates climate, weather, and peat production, not only for planning future operations but also as an aid in daily production planning.

Peat mining, mainly for horticultural peat extraction, is taking place in the southern Canadian peatlands. Present mining techniques are appropriate for unfrozen peat. The perennially frozen peatlands, which cover vast areas of Canada, present a limitation for the existing techniques. On these peatlands not only is the climate unfavorable but the presence of high ice content permafrost creates added problems for the technology and the environment. Mining methods will have to be developed to cope with the permafrost conditions if these peatlands are to be used for extraction.

The development of peat deposits for mining is also dependent on both the available markets and transportation. In Europe it is common to have several peat products produced from the same peat operation, thus utilizing more efficiently the market potential of the area.

6.0 ENERGY VALUE OF THE CANADIAN PEAT RESOURCE

Since a dry tonne of peat has an energy value of approximately 20×10^{9} J (Overend 1981), the total peat resource of Canada has an energy content of 6.7×10^{21} J. The energy value of the Canadian oil resources is 80×10^{18} J, of the natural gas resources 145×10^{18} J, of the coal resources 2.2×10^{21} J, and of the oil sands resources 5.8×10^{21} J (Overend 1983).

The utilization of this peat resource for energy is difficult or impossible with the present harvesting techniques since a large portion of Canada's peatlands are situated in climatically unfavorable northern areas where these techniques do not work economically. If only the conventional unfrozen peatlands (40% of the total peatlands) are considered suitable for harvesting by the present techniques, then the energy equivalent of this peat resource is approximately 2.7×10^{21} J.

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REFERENCES

Adams, G.D., A.N. Boissonneau, H.E. Hirvonen, G.F. Mills, E.T. Oswald, W.W. Pettapiece, C. Tarnocai, E.D. Wells, and S.C. Zoltai. 1981. Wetlands of Canada Maps (Wetland Regions and Distribution of Wetlands). Ecological Land Classification Series, No. 14, Environment Canada, two 1:7,500,000 scale maps.

Aspinall, F., and W. Hudak. 1980. Peat harvesting - state of the art. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., pp. 159-173.

Canada Soil Survey Committee. 1978. The Canadian system of soil classification. Research Branch, Canada Department of Agriculture, Ottawa, Ontario, Publication 1646, 164 p.

Carncross, C.A. 1980. Wet harvesting of peat. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., pp. 175-180.

Dendron Resource Surveys Ltd. 1982. A review of Canadian peatland inventory data. Completed for the Land Resource Research Institute, Canada Department of Agriculture, Ottawa, Ontario, 144 p.

Jeglum, J.K., A.N. Boissonneau, and V.F. Haavisto. 1974. Toward a wetland classification for Ontario. Department of the Environment, Canadian Forestry Service, Information Report 0-X-215, 54 p.

Keys, D., D.E. Gemmell, and R.E. Henderson. 1982. New Brunswick peat - resources, management, and development potential. Proceedings of a Symposium on Peat and Peatlands, National Research Council Canada, Atlantic Research Laboratory, Halifax, Nova Scotia, pp. 222-236.

Kivinen, E., and P. Pakarinen. 1980. Peatland areas and the proportion of virgin peatland in different countries. Proceedings of the 6th International Peat Congress, Duluth, U.S.A., pp. 52-54.

Kopstein, M.J. 1980. DOE peat program. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., pp. 644-646.

Mills, G.F. 1974. Organic soil parent materials. Proceedings of the Canada Soil Survey Committee Organic Soil Mapping Workshop, Winnipeg, Manitoba, pp. 21-43.

Monenco Ontario Ltd. 1981. Evaluation of the potential of peat in Ontario. Ontario Ministry of Natural Resources, Occasional Paper No. 7, 193 p.

Muskeg Subcommittee of the NRC. 1977. Muskeg and the northern environment in Canada. N.W. Radforth and C.O. Brawner, eds., University of Toronto Press, Toronto, Ontario, 399 p.

Overend, R.P. 1981. The peat for energy and chemicals R&D program of N.R.C. Proceedings of the Symposium on Peat: An Awakening Natural Resource, Thunder Bay, Ontario, October 26-28, pp. 251-257.

— 1983. Energy production in the Boreal Forest Zone. In: Resources and Dynamics of the Boreal Zone. Ross Wein, Roderick Riewe, and Ian R. Methven, eds., Association of Canadian Universities for Northern Studies, Ottawa, Ontario, pp. 378-396.

Pollett, F.C. 1972. Nutrient content of peat soils in Newfoundland. Proceedings of the Fourth International Peat Congress, Finland, 3:461-468.

Punwani, D.V. 1980. Peat as an energy alternative: An overview. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., pp. 1-28.

Radforth, N.W. 1955. Organic terrain organization from the air (altitudes less than 1000 feet). Handbook No. 1. Department of National Defense, Ottawa, Ontario, Report DR 95, 55 p.

Radforth, N.W. 1958. Organic terrain organization from the air (altitudes 1000 - 5000 feet). Handbook No. 2. Department of National Defense, Ottawa, Ontario, Report DR 124, 23 p.

Scott, J.B., and E.O. Korpijaakko. 1980. Development of conversion factors for expressing peat resource estimates. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., pp. 37-49.

Tarnocai, C. 1970. Classification of peat landforms in Manitoba. Canada Department of Agriculture, Research Station, Pedology Unit, Winnipeg, Manitoba, 45 p.

— 1980. Canadian wetland registry. Proceedings of a Workshop on Canadian Wetlands, compiled and edited by C.D.A. Rubec and F.C. Pollett, Environment Canada, Ecological Land Classification Series, No. 12, pp. 9-38.

— 1983. Peatland inventory methodology used in soil survey. Proceedings of a Peatland Inventory Methodology Workshop, edited by S.M. Morgan and F.C. Pollett, Land Resource Research Institute, Agriculture Canada and Newfoundland Forest Research Center, Environment Canada, Ottawa, Ontario, pp. 13-22.

Tibbetts, T.E. 1983. The Peat Forum and the peat for energy and chemicals R&D program. Proceedings of a Peatland Inventory Methodology Workshop, Land Resource Research Institute, Agriculture Canada and Newfoundland Forest Research Center, Environment Canada, Ottawa, Ontario, pp. i-iv.

Tibbetts, T.E., and A. Ismail. 1980. A Canadian approach to peat energy. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., pp. 663-677.

Tomiczek, P.W., J.D. Phillips, and W. Hudak. 1980. Potential peat harvesting alternatives. Symposium Papers, Peat as an Energy Alternative, Institute of Gas Technology, Arlington, U.S.A., vol II, pp. 119-133.

Zoltai, S.C. 1980. An outline of the wetland regions of Canada. Proceedings of a Workshop on Canadian Wetlands, compiled and edited by C.D.A. Rubec and F.C. Pollett, Environment Canada, Ecological Land Classification Series, No. 12, pp. 1-8.

Zoltai, S.C., F.C. Pollett, J.K. Jeglum, and G.D. Adams. 1973. Developing a wetland classification for Canada. Proceedings of the Fourth North American Forest Soils Conference, Quebec City, Quebec, pp. 497-511.