The history, present status and future prospects of the Russian fuel peat industry

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SUMMARY

The purpose of this article is to review the history of the Russian fuel peat industry, analyse the prospects for its further development, and draw attention to its significant technical and economic potential. Russian peat resources represent more than 30 % of the global total. Peat production peaked during 1960–1980, when the volume of peat extraction was two orders of magnitude higher than it is now. The key factors that prevented further development of the Russian fuel peat industry were an inadequate regulatory framework for peat processing and the inability of peat extraction enterprises to overcome the energy supply monopoly of the coal, oil and gas industries. At present, the peat industry of the Russian Federation is in decline and its potential has been lost. Most of the power plants that previously operated on peat have been converted to coal and other fuels and, as a result, the occurrence of peatland fires has increased greatly. A case is made for revival of the industry to exploit peat as a local energy resource, employing modern processing techniques that can achieve full utilisation of the peat whilst reducing air pollution and generating little waste.

KEY WORDS: energy resources, local fuel, peat stocks, pyrolysis, Russian regions

INTRODUCTION

The main objectives of the modern Russian fuel and energy industries are to provide energy, to ensure energy efficiency for enterprise, and to ensure the effectiveness of the energy supply system in remote regions - in particular the Arctic, the Far East and Siberia (Didenko & Kunze 2015). These industries are based on geographically concentrated deposits of oil, gas and coal which means it is often necessary to transport these fuels over long distances.

The adequacy of the electricity supply is expressed by the so-called RIA rating (quantity of electricity produced ÷ quantity of electricity consumed) (RIA 2012) and varies considerably between different Russian regions. In 2012, Tver was the highest-ranked region with a rating of 458 %; whereas Khabarovsk, Kirov, Vologda and Yaroslavl regions, as well as the Republic of Karelia, had energy deficits.

Russia's primary energy source for generating electricity is natural gas, and many regional power stations require access to the main gas pipeline. Domestic gas consumption in 2014 amounted to 454.4 billion cubic metres, which was 68.6 % of the quantity produced that year (Ministry of Energy 2016). However, these figures give no insights about the needs of regions with local energy sources. According to the Federal Statistics Service, despite the enormous gas potential of Russia, a significant number of regions do not have gas supplies (Table 1). An illustrative example is provided by Yaroslavl Region, whose main energy source is natural gas although this fuel is not produced there. The gasification level in rural areas of Yaroslavl Region is 18–20 %, whereas in the region as a whole it is 67 % (United Russia 2015). A similar situation occurs in other regions of Russia because of the low diversification of fuel and energy balances.

These problems could be addressed by developing local energy industries, which currently contribute a minor fraction of the energy balances of the regions. Various alternative and local energy sources are available, but many have significant drawbacks such as high level of impact on the environment (oil, coal, shale), rapidly increasing cost (gas), low efficiency of power plants (the majority of renewables), and high risk of disastrous accidents (nuclear energy). Peat is widely distributed and, although Russia's peat reserves are among the largest in the world (Didenko *et al.* 2015), less than 0.1 % of Russia's energy is currently derived from peat (Sarkisyan 2011). Moreover, according to the "Energy strategy of Russia until 2030" (Ministry of Energy 2009), by 2017 the cost of generating one tonne of gas fuel equivalent from natural gas will exceed the cost of generating it using fuel peat.

Unlike coal, oil and gas, peat is still being formed at the earth's surface, albeit extremely slowly in relation to human timescales. The rate of peat formation across the whole of Russia is estimated at

Table 1. Results from a questionnaire survey about the lack of natural gas in Russian Federal Regions (RUSSTAT 2014).

	Federal Region				All of Russia
	North-West	Ural	Siberia	Far East	
Percentage of responding households indicating that they do not use natural gas	39.7	43.6	93.8	79.0	36
Percentage of these respondents stating that they do not use natural gas due to lack of infrastructure	61.6	62.7	84.4	96.4	74

around 250 million tonnes *per* year (ROSTORF & BioEnergo 2014). This is two orders of magnitude greater than the current annual rate of fuel peat extraction within Federation territory. However, for peat and carbon balancing purposes, the whole of the new peat formation in a year is not available for accounting against newly extracted and burned fuel peat because at least part of it is already compensating for peat oxidation and greenhouse gas emissions from previously abandoned (partially depleted) peat extraction sites and other degraded peatlands. The question of peat renewability is complex, and further discussion of this aspect is beyond the scope of the present review.

With these points in mind, this article considers the potential of peat as an alternative to coal, oil and gas, for utilisation as an energy source in Russia.

WORLD PEAT RESOURCES AND PEAT EXTRACTION DYNAMICS

The sizes of peat reserves are expressed in terms of the "dry weight" of peat (water content 40–50 %), whereas the water content at the point of extraction is 90 %. Although estimates vary significantly, it can be stated that the peat reserves of Russia amount to more than 30 % of the global total (Table 2). Other countries contributing substantially to the world's peat reserves are Indonesia (15.84 %), the United States of America (USA) (7.3 %), Canada and Finland (both 7.07 %). The countries that produce peat (i.e. they have peat extraction industries) are Finland (25.08 % of world production), Ireland (14.05 %), Sweden (12.04 %), Germany (10.03 %) and Belarus (10.03 %). More than 80 % of the world's peat extraction takes place in Europe (Apuhtin & Plakitkina 2011) and less than 5 % in North America (USA and Canada).

World peat production decreased from 155 million tonnes in 1992 to 29.9 million tonnes (less than one fifth) in 2014 (USGS 2016). This was mostly due to changes in the countries of the former Soviet Union between 1992 and 1997, when the volume of peat extracted in Russia decreased by 85.3 million tonnes (97.15 %) and in Belarus by 10.05 million tonnes (97.1 %). Changes in annual peat production between 1997 and 2010 varied considerably between different countries (Figure 1). The greatest relative growth in production was observed in Belarus (866.7 %; from 300,000 to 2,600,000 tonnes *per* year). The most significant decline, from 2,500 tonnes to 1,300 tonnes *per* year, occurred in Russia. On average, world production fell by 11.54 % (2 million tonnes) and more than half of this decline happened during the period 2009–2010 due to the effects of the global financial crisis.

In contrast, the global volume of peat production has increased significantly over the last four years due to two main factors, namely the rising price of primary energy resources (oil, gas, coal, *etc*.) and the desire of countries to move towards becoming independent of foreign energy sources (energy security). During this period world peat production increased by 30 % (6.9 million tonnes), more than one-third of which was contributed by Sweden (2.32 million tonnes). This increase creates both technical and economic possibilities for development of the Russian peat industry and its seamless incorporation into the national economy.

In some settlements in Belarus, boiler plants have been upgraded into mini cogeneration plants (mini CP) that process local energy resources including peat (Markov 2012). This allows imported coal, oil, natural gas, *etc*. to be phased out. In Finland, peat is the only indigenous energy resource and provides 7 % of primary energy production as well as more than 15 % of heat production.

It is worth noting from the research literature the experience of the USA, Germany, Sweden, Finland, Ireland, *etc*. in the development of alternative uses of peat including the production of synthetic gas and hydrocarbons, in addition to traditional uses. An industrial facility with capacity to produce 30,000 tonnes of coke *per* year, using diced peat as the raw material, was constructed in the Seinäjoki district of Finland in 1976 (Shlyamin 2010). In Sweden, research relating to methanol production based on

Table 2. The global distribution of peat reserves by country. Sources: [1]Institute of the Peat Industry 2015, [2]USGS 2016, [3]Peat Resources Limited 2015, [4]WEC 2013.

Country	Total reserves, (billion tonnes)[1]	Total area of peatland (million ha)[3]	Total area of peatland (million ha)[4]	Peat extraction in 2009 (thousand tonnes)[4]	Peat extraction in 2014 (thousand tonnes)[2]
Russia	175.6	150.0	139.00	1,287	1,500
Indonesia	78.5	26.0	20.69	*	*
USA	36.3	40.0	62.50	*	510
Canada	35.0	170.0	111.30	*	1,100
Finland	35.0	10.0	8.90	4,770	7,500
China	27.0	3.5	5.30	*	*
Malaysia	11.8	*	2.50	*	*
Sweden	11.2	7.0	6.60	701	3,600
Germany	7.3	*	1.30	*	3,000
Poland	6.0	*	1.25	*	760
Ireland	5.8	1.2	1.18	3,089	4,200
United Kingdom	5.7	*	2.75	20	*
Belarus	*	*	2.35	2,944	3,000
Other	49.7	12.3	34.08	713	4,730
Total	495.4 (12.0)[2]	420	397.35	13,524	29,900

* included in data for ‘other countries’.

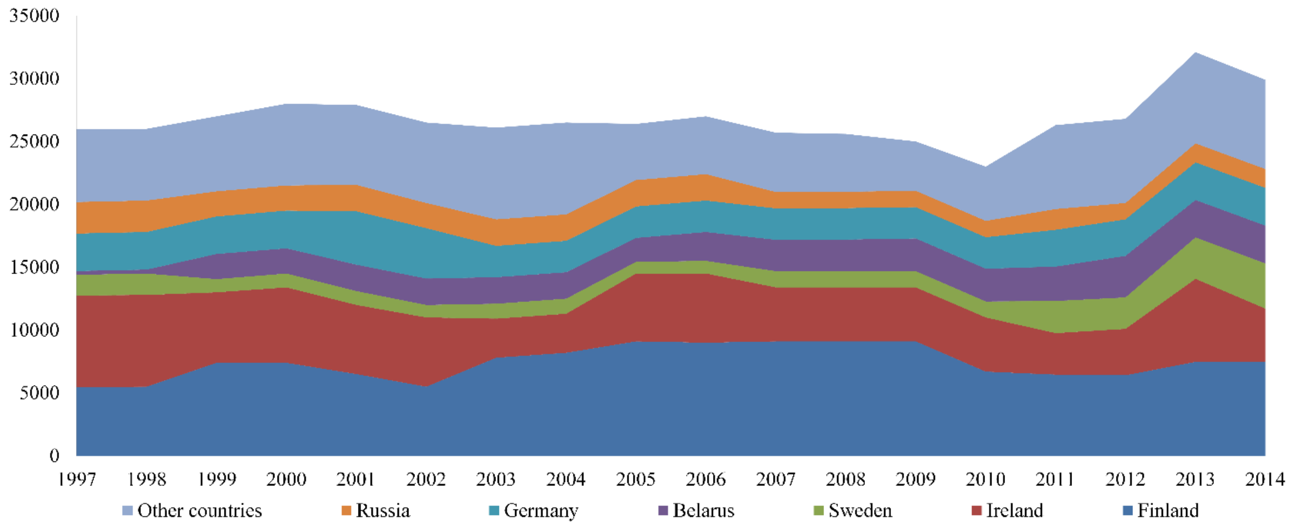

Figure 1. Global progress of peat extraction (units: thousand tonnes), 1997–2014. Source: USGS (2016).

peat gasification indicates that the methanol produced from two million tonnes of peat could replace 15 % of the country's gasoline consumption (Shtern 2009). One of the objectives of a long-term research programme on peat gasification in the USA is to develop *in-situ* peat bio-gasification to produce a substitute for natural gas.

In Russia, peat extraction started during the early 20th century (Figure 2). The first significant rise in the volume of peat extraction (up to 32 million tonnes) was observed in 1929–1939. During World War II, when energy resources could not be transported freely, peat was used to locally meet both industrial and domestic energy needs. After the War there was a sharp rise in the extraction of peat for local energy. At that time there were 220 peat production enterprises with a total workforce of 96,000 staff working in 37 regions (Kulagin 2010), and the enterprises of the Ministry of Fuel Industry of Russia alone extracted more than 50 million tonnes. From the late 1980s there was a decline in peat extraction which lasted until 2013. This was mainly due to intensive development of the oil, gas and coal industries, as well as the demise of the Russian agricultural industry. In contrast to oil, gas and coal, peat has hardly changed in price since 1992 because peat extraction is regulated by the State (Misnikov *et al.* 2011). Indeed, the peat industry is totally controlled by the State for strategic reasons. The "VAPO" state company has an 82 % share of the peat market, "Turveruukki" has a 7 % share, and several hundred small private companies account for the remainder (Motilkov 2001). Nowadays, Russia uses up to 500,000 tonnes of peat for energy production and the share of peat in the fuel balance of Russia's regions is 0.5 %. This does not reflect the potential of the industry that was evident in Soviet times, when the maximum annual production was more than 175 million tonnes.

COMPARATIVE ANALYSIS OF ENERGY RESOURCES

Peat furnishes Russia's second largest fuel reserve, which amounts to 68.3 billion tonnes of fuel equivalent (t.f.e.). The first position is held by the coal reserve of 97 billion t.f.e. Other important fuel reserves are oil (31 billion t.f.e.), gas (22 billion t.f.e.) and wood (14.4 billion t.f.e.). The effectiveness and potential use of peat can be estimated by comparing its cost and quality characteristics with those of the other primary energy resources (Table 3).

Despite its relatively low power characteristics, peat is becoming economically competitive when logistics costs are taken into account. Up to 80 % of the cost of coal may consist of transportation costs (Apuhtin & Plakitkina 2011). For example, while the cost of a tonne of coal in Tver region is 3,800 roubles (RUR), calculations show that the costs of milled peat extraction (without transportation) amount to about 250 RUR tonne^{-1}, and those for lump peat to 550 RUR tonne^{-1} (Timofeev & Shahmatov 2011). In addition, peat processing is environmentally friendly in that the waste (ash) can be used to manufacture, for example, mineral fertilisers (Kanareikin 2012).

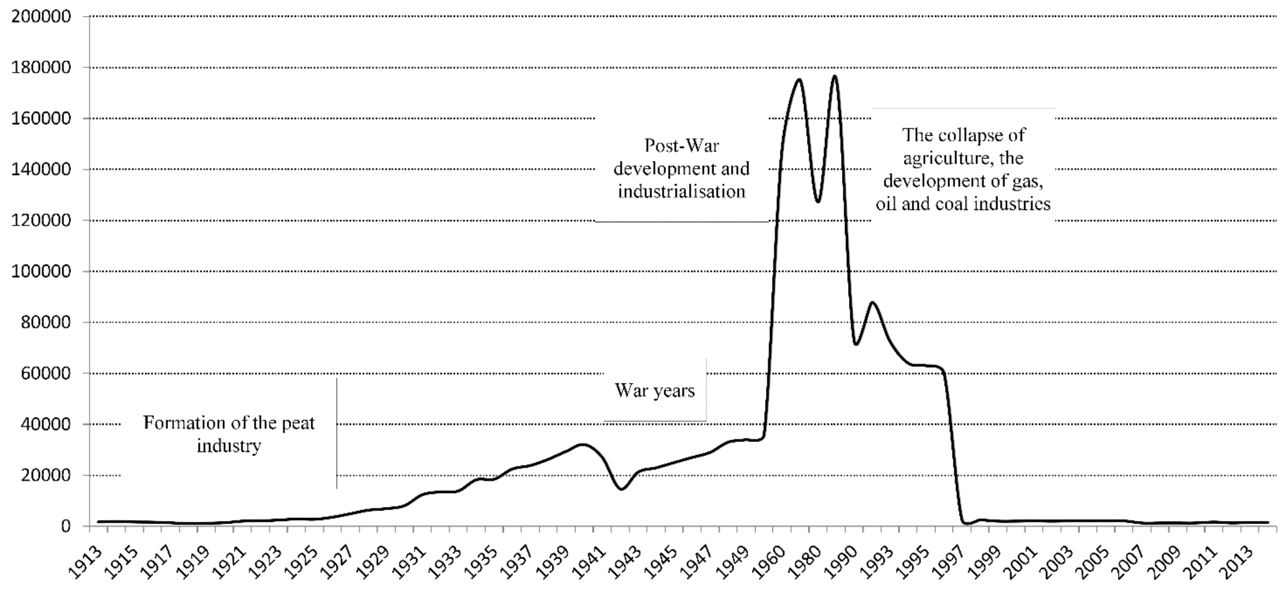

Figure 2. The dynamics of peat extraction in Russia during the period 1913–2014. Units: thousand tonnes. Sources: Markov (2012) and USGS (2016).

Projects implemented at a number of boiler plants in the remote regions of Russia, to convert them from coal and oil to peat fuel, lead to the following conclusions (Table 4):

1. The use of peat increases the efficiency of boiler plants by 2–3 times.
2. The economic advantage achieved by the conversion varies with geographical location.
3. When peat fuel replaces coal, shale and oil, emissions of air pollutants (oxides of sulphur) will be reduced by 4–24 times (for coal, depending on the ash content and the coal basin), 9 times (for shale) or 6 times (for oil).

On the other hand, some studies indicate that it is inappropriate to use peat as an energy resource under modern conditions. For example, the study of Bernatonis *et al.* (2011) based on data from Tomsk region shows that the use of peat is not economically justified (Table 5). However, a number of questions arise regarding the assumptions of this assessment. For instance, the calorific value of peat is slightly low (Table 3). If the calorific value of peat is taken to be 2650 Kcal kg^{-1}, the cost of power generation will decrease to 345 RUR Kcal^{-1}. Secondly, while it would be possible to manufacture peat products with higher calorific value (for example, factory production of peat fuel agglomerates or peat pellets), only traditional use of peat is considered. Also, given the interest of the regional authorities in the development of local industry, such projects can be implemented through the mechanism of public-private partnerships. Thus, the apparent inefficiency of peat use in Tomsk region is a controversial issue that requires more detailed study.

Table 3. Energy characteristics of different fuels (authors' own data).

Fuel	Combustion heat MJ kg^{-1} (MJ m^{-3})	Fuel value Gcal kg^{-1} (Gcal m^{-3})	Energy production kWh kg^{-1}
Peat	10.84–12.57	2.15–3.12	3.40
Coal	20.00–23.00	4.96–6.45	6.97
Brown coal	12.18–15.41	2.50–4.18	3.96
Standard fuel	29.30	7.00	8.14
Natural gas	33.40–36.90	8.00	9.30
Oil	41.80	10.55	11.60
Fuel oil	38.61–43.50	9.70	11.63

Table 4. The effect of using peat in thermal energy production (ROSTORF & BioEnergo 2014).

Location of boilerhouse (village)	Capacity (MW)	Fuel		Coefficient of efficiency (%)		Savings after one heating season (RUR)
		before	after	before	after	
Tyurmerovka	0.20	coal	peat	33	91	1,270,000
Bolotskiy	0.16	coal	peat	30	90	1,171,000
Andeevo	3.00	fuel oil	peat	40	87	11,547,000
Kondryaevo	0.56	coal	peat	30	89	1,311,000
Golovino	1.40	coal and fuel oil	peat	35	87	3,175,000
Sojm	0.30	coal	peat	30	84	565,000
Likino	3.30	fuel oil	peat	40	90	22,395,000

Table 5. Comparison of the efficiencies of different energy resources in the production of thermal energy (Bernatonis *et al.* 2011).

Indicator	Peat	Kuzbas coal	Wood
Extraction (RUR t^{-1})	425	850	-
Loading (RUR t^{-1})	55	500	410
Transport (RUR t^{-1})	195		
Drying (RUR t^{-1})	50	-	80
Processing (RUR t^{-1})	25	-	
Total (RUR t^{-1})	750	1350	490
Fuel value (Kcal kg^{-1})	1680	4800	2000
Boiler: coefficient of efficiency (%)	82	82	82
Price of 1 Gcal (RUR)	**544**	**343**	**299**

Using modern technologies, fertile soils, fertilisers, insulation and packaging materials, coal, graphite *etc*. may be manufactured from peat. However, at the present stage of development, a key component of peat use should be deep processing following, in particular, the production of thermal and electric energy.

CURRENT PROBLEMS OF THE RUSSIAN PEAT INDUSTRY

The current situation of the Russian peat industry is characterised by complex problems that began to emerge during the late 1980s. Firstly, the development of peat deposits is not specifically catered for by legislation or other legal instruments. Peat extraction is regulated by the law "On mineral resources" as well as the Water, Land and Forest Codes, whose provisions differ in some cases. The Water Code of the Russian Federation defines bogs as water objects, which means that peat extraction should be authorised by a water licence. In the Forest Code, bogs are defined as forest lands whose diversion to peat extraction requires their transfer into the category of non-forest lands of the forest fund, at significant financial cost. The law "On mineral resources" places peat on the same footing as mineral resources, and peat extraction is equated to mining. Furthermore, peat deposits are classified as dangerous industrial facilities. The potential for problems can be illustrated by the following example. Due to inconsistencies between the texts of the Forest Code, the Water Code and the law "On mineral resources", land charges in Shatura District increased 900 times in the early 2000s. Local peat became uncompetitive compared to coal imported using subsidised transport, with the result that the Shaturaskaya GRES company abandoned their peat works. As a consequence, the peatland was left without water management and in the hot summer of 2010 this led to a major fire (Markov 2012).

Overall, the accumulation of taxes and regulatory requirements makes the development of peat deposits unprofitable (Kanareikin 2012). Payments to government at all levels amount to around 20 % of the prime cost for peat (700–875 RUR *per* fuel equivalent), whereas they are only 5 % of the prime cost for coal (280–350 RUR *per* fuel equivalent) (Cherepovitsyn & Tsvetkov 2016). However, in some regions of Russia including Smolensk, Lipetsk, Kostroma, Tver, Kirov, Yaroslavl and Pskov, attempts are being made to implement special legislative regulation of public relations in the field of peat extraction and development of the industry as a whole (Hludeneva 2013).

Peat extraction in Vladimir Region will be increased ten-fold and reach 180,000 tonnes $year^{-1}$ when 56 boiler plants with an overall capacity of 61.6 MW have been converted to peat fuel, and a new coal-fired boiler plant in Sverdlovsk Region will replace two old ones that run on oil. According to the calculations of "Ural Peat Company", based on peat costing 1,300 RUR $tonne^{-1}$ and coal 3,300 RUR $tonne^{-1}$, the savings should amount to seven million roubles for one heating season (Kanareikin 2012). However, as evidenced by the dynamics of peat production in Russia (Figure 2), these actions are insufficient to support the development of peat industry, and thus to stimulate the conversion of local boiler plants from coal and liquid fuel to peat, in these regions.

Apart from prospecting for peat deposits and developing them for extraction, a re-developed peat industry must be supported by enterprises producing modern equipment for peat extraction and processing (Misnikov *et al*. 2011). Also, the peat industry is now experiencing a shortage of highly qualified scientific, technical and engineering personnel, for whom training is almost unavailable nowadays due to lack of business demand (Markov 2012). Finally, in the absence of demand for fuel peat from both large and small power plants, mechanisms for organising and promoting peat production are lacking and this leads to financial instability of peat enterprises in Russia (Apuhtin & Plakitkina 2011). As a consequence, peat suppliers are unable to capitalise on the competitive advantages of peat over coal and oil (namely lower price, transport costs and SO_2 emissions). The root problem is that coal and oil are sold by large national companies exercising aggressive marketing policies, who also have some "political weight".

EXISTING RESEARCH ON DEVELOPMENT OF THE RUSSIAN PEAT INDUSTRY

Although the Russian peat industry is in a state of collapse today, significant scientific and technological potential for the utilisation of peat was developed in the USSR between 1950 and 1980. A significant study on the efficiency of peat deposit development was undertaken by Tver State Technical University, the East European Institute of Peat Development, the All-Russian Scientific Research Institute of Peat Industry and NPO Russian Peat and Bioenergy Community (Kopenkina 2015). According to Tver State Technical University, the number of scientific papers devoted to the development of peat industry decreased 20 times (from 43 to 2 *per* year) between 1972 and 2012. Most of these publications address technical aspects of peat production.

The Soviet Union previously accumulated considerable experience in deep peat processing. In 1930–1950 a number of enterprises (e.g. Uralmash, Uralvagonzavod and Pervouralsk New Pipe Plant) worked on peat gas, and several research institutions developed methods for obtaining gas from peat. These studies showed a high intensity of gasification processes and the possibility of obtaining gas with a calorific value of 6.3–17.6 MJ m^{-3}, which is equivalent to the heat generated by peat combustion. Deep peat processing was studied by the Energy Institute of the Russian Academy of Sciences, the Energy Institute of the Academy of Sciences of Belarus, and the G.M. Krzhizhanovsky Power Engineering Institute of the all-Russian Peat Industry Research Institute. The focus was on technical and economic substantiation of the application of deep peat processing technologies, and the final stage of the work would have been the construction of an industrial plant with a capacity of 5,000 tonnes day^{-1}. However, in the late 1980s all work in this field was terminated on the basis that the strategic importance of peat was low.

The effectiveness of deep peat processing has not been studied in Russia during the last 15 years, whereas it is still regarded as an important topic and widely studied in Sweden, Finland, Germany, the USA, *etc*. However, under current conditions, legal regulation of the peat industry may be an even more important research topic. The problem of finding ways to rehabilitate peat industry in Russia also remains unresolved. This might require the development and implementation of organisational and economic support mechanisms for companies carrying out peat extraction and deep peat processing within public-private partnerships.

Insofar as the urgency of the task of establishing rational usage of Russia’s peat will only increase in the future, it seems appropriate now to resume the studies of thermal peat processing in the context of modern technology, as well as to investigate how an organisational-economic support mechanism for peat enterprises might be developed.

PROSPECTS FOR PEAT INDUSTRY DEVELOPMENT

The "Energy Strategy of Russia for the period till 2030", which was adopted by the government of the Russian Federation on 13 November 2009, mentions the need for development of local energy resources and of peat in particular. However, it sets out a need to increase the share of peat in the regional fuel and energy balances from 1 % to only 8–10 %, which is a fairly modest figure given the study on energy adequacy of the Russian regions mentioned previously (Table 6).

Despite the small number of scientific papers on the development of the peat industry in recent years, there are several expert forecasts. According to the chief researcher of the Energy Research Institute (Voskoboinik 2015) it is possible to distinguish three scenarios for peat industry development in Russia: conservative, innovative and forced (Table 7). Volumes of peat extraction are proposed on the basis of the needs of individual sectors of the economy for

Table 6. Regional comparison of electricity deficit (million kWh, source RIA 2012) and peat reserves (million tonnes).

Region of Russia	Electricity deficit	Peat reserves
Tomsk Region	3637	31008.7
Vologda Region	6285	5455.7
Karelia Republic	3658	2347.5
Khabarovsk Region	1881	1212.3
Kirovsk Region	3239	953.6
Yaroslavl Region	4099	369.5

Table 7. Scenarios for development of the Russian peat industry: estimates of production capacity according to (a) Voskoboinik 2015 and (b) the present study. Units: thousands of tonnes.

Year	Scenarios					
	conservative		innovative		forced	
	(a)	(b)	(a)	(b)	(a)	(b)
2015	1949	2728.6	1982	2737	1955	2737
2020	2324	3253.6	3200	4480	6801	9521.4
2025	2484	3477.6	4751	5744.2	10672	14940.8
2030	2688	3763.2	5266	7372.4	14219	19906.6
2035	2770	3878	6272	8780.8	19184	26857.6

raw materials. The key differences that distinguish the scenarios are:

1. consumption (as volume) of peat and peat products for generating electricity and heat derived through processing by thermal power plants;
2. the needs of utility boiler plants for peat;
3. the needs of the agricultural sector for peat;
4. the rate of renewal of the industrial base of peat industry enterprises; and
5. the regulatory and legal conditions on peat extraction.

Although the methodology of the forecast is sound, there are some controversial provisions. First, up to 100,000 tonnes of peat (5–10 % of the volume produced) is exported annually at the present time, mainly from the regions of Kaliningrad and Leningrad and Primorsky Krai. It is logical to assume that the share of exports will remain at least at the same level. In the case that conditions for development of peat extraction companies are created in the absence of production facilities for processing (conservative and, partly, innovative scenarios), with an increase in the production volume the fraction exported should reach 30–40 %. Secondly, the level of peat extraction should grow faster than recommended by the forecast, as a number of facilities can switch to using peat products very rapidly, provided that the market they create is supplied. Thirdly, the needs of the Russian economy for peat are estimated on the basis of traditional applications only, without considering the prospect of deep processing to synthesise gas, synthetic oil, methanol *etc*.

Markov (2012) defined three stages of peat industry development, with two options for the first one, as summarised below.

First stage (the period from now until 2030)

Option 1: partial use of peat in existing power plants (Table 8).

Option 2: the development of a system of small power facilities by creating a number of mini CP. It is proposed that 71 mini CP with a total capacity of 565 MW will be built by 2030 within seventeen named regions. The total production volume required to supply these CPs is estimated at 5.65 million tonnes year^{-1}. In terms of peat extraction, this period of development occupies an intermediate position between the conservative and innovative scenarios of Voskoboinik (2015); and in terms of the level of peat use in the energy sector its position is between the innovative and forced scenarios. Different approaches show the potential for peat diversification as a raw material for various industries.

Table 8. Existing regional power plants that are suitable for fuelling with peat. PE = peat enterprise.

Region	Potential peat consumption (tonnes)	Peat supplier
Smolenskaya	≤ 500,000	Svitskoe PE
Pskovskaya	≤ 500,000	Polistovskoe PE
Cherepoveckaya	≤ 500,000	Ulomskoe PE
Shaturskaya	≤ 500,000	PEs from Moscow, Vladimir and Ryazan Regions

Second stage (the period 2030–2050)
Involvement in the production of the remaining power facilities, of which there are about 146 according to Markov (2012). Specific production volumes are not given, but the potential development of Siberia and the Far East is mentioned. The need for complex exploration work to identify and assess reserves is recognised.

Third stage (the period 2050–2100)
It is expected that the management system of the industry will be re-organised at regional and federal levels. At this stage, the development of alternative uses of peat use is proposed. Special attention is paid to research in the field of peat gasification. This has obvious significance for the energy sector because, in addition to thermal energy from the heat treatment, it will be possible to generate electricity during processing of the synthesised gas. Processing peat to produce active charcoals for water filtration (according to the technology of OAO ENIN named after G.M. Krzhizhanovsky) is also considered, as is the use of peat as a component of ameliorants to restore land and for fertilisers.

Despite the long-term and fairly comprehensive nature of this plan, there are some controversial points within it. For example, the industry should be restructured earlier than the second half of the 21st century. The foundations of legal regulation are being laid today, and the projections for the first period will be difficult to achieve without this. Because exploration is accompanied by development of the peat industry, peatlands must be under the control of extracting companies from the outset to allow assessment of their impact on the environment, as well as to implement measures to prevent fires in times of drought (Kozlov *et al.* 2015). Also, attention must be paid to the issues of deep peat processing during the period up to 2030. These issues are already under scrutiny throughout the rest of the world as they are key ones for ensuring and improving the competitiveness of peat extraction and peat processing enterprises in comparison with oil, gas and coal industry enterprises.

The development of deep peat processing introduces the possibility of creating complex peat enterprises which could be analogous with the vertically integrated oil companies (VIOCs) although functioning across smaller geographical areas. Advantages of this organisational structure include full utilisation of the peat, low waste production, reduced air pollution, increased use of the potential of the peat in comparison with single-stage specialised processing, and an increase in economic efficiency (Lázár *et al.* 2012). There may also be significant effects in terms of job creation; development of mechanical engineering, rural areas, science and education; improved forest fire protection; replenishment of budgets at all levels; *etc*.

Analysis of modern developments in the field of peat processing shows that the most effective one, from an economic point of view, is fast pyrolysis. In addition to generating heat energy, it is possible to produce several by-products during this process (Tcvetkov & Strizhenok 2016). The data presented in Table 9 show that the products are competitive on price. The main problem of implementation would be to identify markets for the products.

CONCLUSION

Russia has significant peat reserves, which exceed the total reserves of oil and gas. Practice in both the Soviet Union and the rest of the world evidence the possibilities for integrating peat industry into the national economy through diversification of regional fuel and energy balances, as well as through the generation of raw materials for other industries by deep processing of peat.

Despite differences in the approaches and methods of predictive assessments, scientists agree that the volumes of peat demand and consumption will continue to grow in the coming years. This is reflected at state level in the "Energy Strategy of Russia for the period till 2030". Regional strategies for development of the peat industry have also been elaborated.

Table 9. Value indicators of the final by-products of fast pyrolysis of peat.

Product	Units	Annual production	Cost excluding logistics expenses (USD)	Sales price (USD)	Return on margin (%)
Synthetic oil	tonnes	3,000	28.3	37.62	32.8
Synthesis gas	cubic metres	7,920,000	16.1	30.10	87.0
Thermal energy	Gigacalories	37,200	5.7	12.04	110.8

In modern times the peat industry is faced by a complex of obstacles amongst which legal, infrastructural and market problems can be distinguished. Prospects for realising the potential of the industry are dependent on the effectiveness of the measures that are taken to address these problems. Considerations that should be taken into account in determining what these measures should be include the following:

1. The most pressing current problem for modern Russian industry is inadequate energy supply. This problem can be solved by using local energy resources, which include peat.
2. In Russia there are many small settlements that are inefficiently provided with electrical and thermal energy by large boiler plants and CPs. There are also tens of thousands of small municipal boiler houses, the majority of which run on imported coal and oil. This situation greatly increases the cost of thermal energy for both the population and the utilities sector.
3. With the tightening of environmental standards, the competitiveness of peat as a local energy source will increase in comparison with oil, shale, coal, *etc*.
4. Deep peat processing makes it possible to create new raw materials that could support the development of a number of other industries, providing a new angle on the competitiveness of peat as an energy resource.

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