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USAGE OF ESTONIAN OIL SHALE

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Estonian oil shale has been used for 90 years mainly for electricity and oil generation with the ash being used for cement and light brick production. The oil shale usage has always been related to available mining and processing technology, and vice versa, with external influences of worldwide petroleum prices. The same situation is true today, when new technology is being applied in power generation units, in oil generators and in oil shale extracting processes.

Introduction

There are two oil shale types in Estonia – Dictyonema argillite (claystone) and kukersite. The organic content of Dictyonema argillite is low, varying from 10 to 20%, and it contains up to 9% pyrite.

The argillite in north-eastern Estonia contains heavy metals on a small scale: uranium up to 300 g/t, molybdenum up to 600 g/t and vanadium up to 1200 g/t. From 1949 to 1952, 60 tonnes of uranium were produced in Sillamäe [1, 2]. However, metal content of ore is an order of magnitude less than the content of corresponding ores.

The argillite of north-western Estonia contains less metals and up to 17% organic matter. Attempts to put this kind of Dictyonema argillite to use ended with no success because of its low organic matter and high sulphur content.

The main Estonian oil shale type is kukersite, which is the sedimentary rock of Kukruse stage. It belongs to the lowest Upper Ordovician formation. Kukersite deposits form the Baltic basin of Estonia where Estonian deposits and Tapa occurrences belong (Fig. 1). In Russia there are Leningrad deposits as well as Veimarn and Chudovo-Babino occurrences [3].

The useful component of oil shale is kerogen, the main harmful admixture is pyrite and the useless, or noncombustible, matter (i.e. ballast) consists of lime and clay minerals. There are a total of fifty oil shale layers

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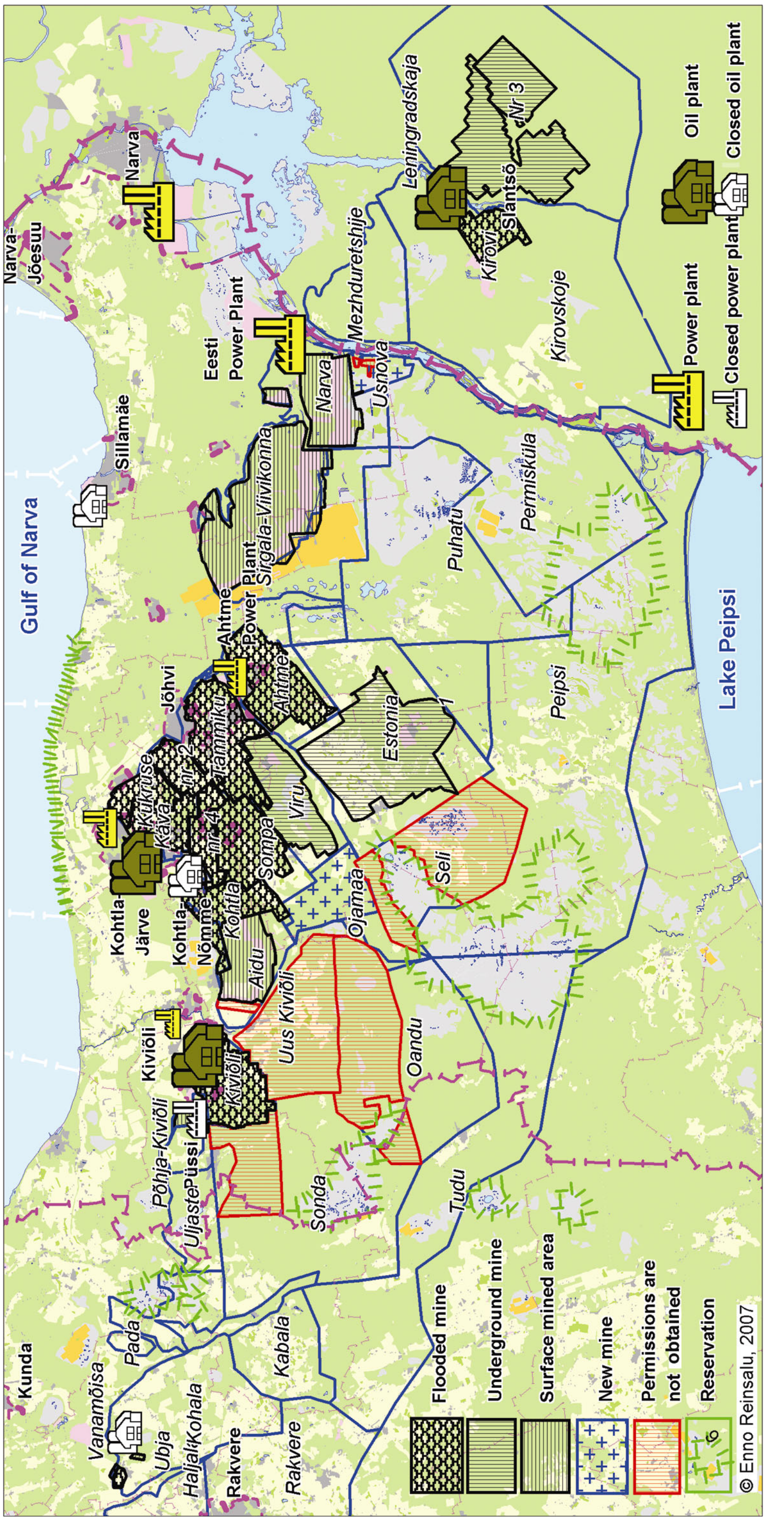

Fig. 1. Estonian and Leningrad oil shale deposits.

in northern Estonia. The lowest layers of Kukruse stage are the most interesting from the mining standpoint. The complex of layers A-F, the thickest in north-eastern Estonia, is called the mineable bed. The mineable bed forms the primary part of the Estonia oil shale deposit. The northern part of the deposit was broken and swept off in ice ages. That is why the layers are thickest on the outcrop. The thickness of the mineable bed in the deposit ranges from 2.5 to 3 m. Run-of-mine (ROM) general production varies from 4.2 to 5.5 t/m^2. At the present moment the cut-off grade is energy productivity, which should be not less than 35 GJ/m^2 [4].

The lowest layers of Kukruse stage are the most interesting from a mining perspective. They are designated with capital letters A-H in Estonia (see Fig. 2). Layers A-F are situated in proximity to each other, being separated by thin limestone interlayers (the latter ones are marked E/F-A/B or have names: D/E – "Roosa paas" (Pink flagstone), C/D – "Valge paas" (White flagstone), A/B – "Sinine paas" (Blue limestone). Some oil shale layers are divided into sublayers (Fig. 2). The lower part of layer F is indicated as F_1, while the upper one is marked F_2. The upper part of layer A in the central and western part of the Estonia deposit is differentiated by A/A'.

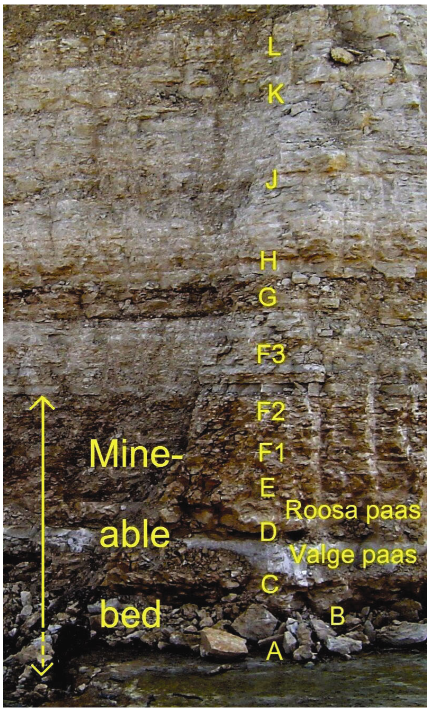

Fig. 2. Upper part of mineable bed and overlying rock in Põhja-Kiviõli opencast.

The upper bed, which is about half a meter thick and consists of two oil shale layers G and H and a limestone interlayer G/H, rests on the mineable bed. General production from the upper bed is approximately 1 t/m^2 and its energy content is 6.5 GJ/m^2. According to present economic considerations, the upper bed is not mineable, because of an intercomplex layer that is about 1 meter thick and which is between the upper bed and the mineable bed. Extraction of the intercomplex would lower ROM calorific value. That is why the upper bed is not extracted in underground mining [4, 5]. It would be possible in surface mining, when using high-selection extraction. Since layers G and H are not considered mineable, they have not been investigated much geologically. These layers contain little concretions, that is why their calorific value in the deposit is homogeneous, and the mineability of the upper bed depends on the thickness of oil shale layers H and G [6–9]. The mineable and upper beds are the thickest in the central part of the Estonia deposit, to the south of the towns of Jõhvi and Kohtla-Järve. The greater part of this reserve is already extracted.

The higher oil shale layers (marked I – P) are thin, with low (less than 20%) or sometimes average (20–30%) organic matter content. These oil shale layers are separated from each other with thick limestone layers. The upper layers are thickest in the western part of the Estonia deposit, to the south of the town of Rakvere (Fig. 1). The layers situated even higher than layer P are marked with Roman numerals I–VII. Layer III, with average organic matter content, is rich in concretions and has a thickness of 1.6 m. It forms the Tapa oil shale occurrence. This oil shale bedding is at a depth of 60 to 170 m under Pandivere uplands. Pursuant to mining conditions existing in the former Soviet Union, the oil shale was mineable in this area, but now it is not.

Layers A, B and E of the mineable bed are the richest in organic matter, while A’ and F are the poorest. As for organic matter content, layer H in the upper bed can be compared to layer B, and layer G – to layer D. Limestone interlayers B/C and C/D are kerogenic limestone, while A/B and D/E are clay-like limestone. Kerogen content of oil shale can be up to 60%. Such oil shale can be found as pure seams in the best oil shale layers A, B and E (Table 1).

Oil shale reserve calculations are done according to layers, though only layers A, D and evidently H consist of pure oil shale. Other layers contain, on a bigger or smaller scale, limestone concretions with kerogen content averaging 8%. The quality of oil shale layers varies indirectly depending on the abundance of concretions – the more concretions, the lower is the energy content of the layer.

The quality of oil shale is evaluated according to several characteristics. The main index in Estonia and Russia is calorific value (Q, MJ/kg) which shows the thermal energy obtained from burning a mass unit. This correlates with kerogen content. However, oil (tar) yield (T, %) is more widely known in the world. It is defined in a lab using a Fischer retort, and the oil amount obtained from a mass unit in the process of low temperature carbonization of oil shale is correlated to it. All quality characteristics are defined for dry oil shale – that is why moisture content is another important index for the quality of the product. The moisture content of commercial oil shale can vary from 8 to 14%. Working calorific value is used for calculations in sales deals, which unites the calorific value of dry oil shale and the moisture content of commercial oil shale into one parameter. The third quality index is grain size, which classifies oil shale in millimeters.

Table 1. **Main parameters of oil shale mineable bed**

Matter	Index of layers	Calorific value, *Q*		Kerogen content, *K*		Volume weight of non-combustible matter, d_m	Constant c according to units *Q* or *K*:			Volume weight, *d*
		kcal/kg	GJ/t	t / t	%	t/m^3	kg/kcal	t/GJ	t/1	t/m^3
Oil shale, pure, without concretions	F_2	1600	6.7	0.19	19	2.55	0.000304	0.07262	2.56	1.72
	F_1	2750	11.5	0.33	33	2.43	0.0002	0.0533	1.88	1.51
	E	4200	17.5	0.50	50	2.41	0.0002	0.0499	1.76	1.28
	D	2264	9.4	0.27	27	2.16	0.0002	0.0389	1.37	1.59
	C	3400	14.2	0.40	40	2.42	0.0002	0.0523	1.84	1.38
	B	4600	19.2	0.54	54	2.40	0.0002	0.0492	1.73	1.22
	A'	1792	7.5	0.21	21	1.70	0.0001	0.0251	0.88	1.42
	A	3628	15.1	0.43	43	2.16	0.0002	0.0389	1.37	1.37
Limestone concretion in layers	F, E, C, B	700	2.9	0.08	8	2.38	0.0002	0.0456	1.61	2.10
Interlayers, kerogenic limestone	E/F, D/E, B/C, A/A'									
Interlayer - flagstone "Valge paas"	C/D	150	0.6	0.02	2	2.53	0.0002	0.0504	1.77	2.45
Interlayer - flagstone "Sinine paas"	A/B	300	1.3	0.04	4	2.38	0.0002	0.0456	1.61	2.25

Composition of oil shale

Oil shale consists of three components:

- Organic matter or kerogen
- Calcareous material (lime minerals) manifested as calcite and, on a lesser scale, dolomite
- Terragenous matter, or clay minerals, which consists of quartz, hydromica, feldspars et al.

The higher is the content of kerogen, the lower is the content of carbon dioxide and ash (Fig. 3) [10]. The calorific value and oil yield of oil shale are proportional to kerogen content. As kerogen's calorific value is 35±3 MJ/kg, so oil shale calorific value formula is

$$Q = 35\,K,\ \text{MJ/kg}$$

where K is kerogen fraction (100% = 1), and its oil yield formula is

$$T = 65.5\,K = 1.86\,Q\ \%.$$

When doing energy productivity calculations, one has to be aware that the calcareous components of fuel and oil raw material absorb heat in the process of decomposition, thus the actual calorific value of oil shale as ROM is lower than calculated. Dry volume weight of oil shale depends on the ratio of kerogen, lime and clay minerals and can be calculated as follows [10]:

$$d = d_m / (c\,Q + 1)\ \text{t/m}^3$$

where Q – calorific value of oil shale with concretions or ROM, d_m – volume weight of noncombustible part, i.e. clay and lime minerals in oil shale.

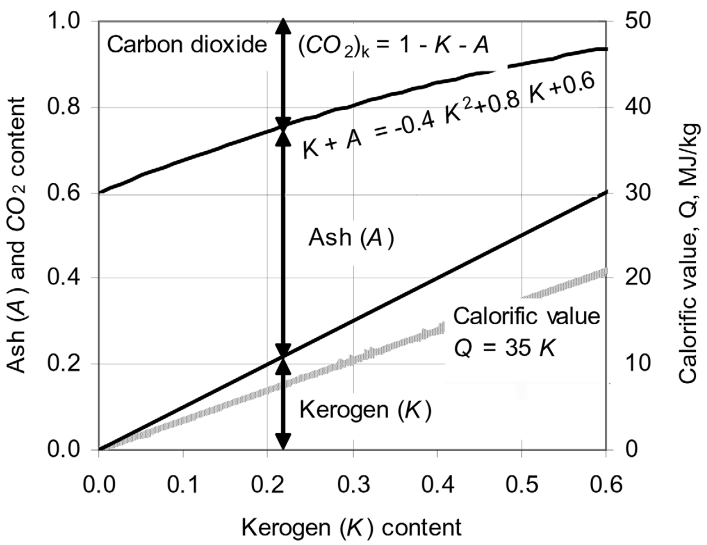

Fig. 3. Dependence between oil shale components and organic matter (kerogen) content.

Table 2. **Ojamaa mining field ROM quality sheet**

Block: Ojamaa 1
Layers: A…F_{lower}

Geological data						Run-off-mine, dry									Run-off-mine, natural					
Layer, seam		Extrac-tion rate	Thickness natural, m	Thickness extraxt., m	heigth, m	Calorific value, kcal/kg	Calorific value, MJ/kg GJ/t	Fischer oli, %	Org. matter, %	Volum weight, t/m^3	Mass product., t/m^2	Oil product., t/m^2	Org. product., t/m^2	Energy product., GJ/m^2	Moisture content, %	Calorific value, kcal/kg	Calorific value, MJ/kg GJ/t	Volum weight, t/m^3	Mass product., t/m^2	Energy product., GJ/m^2
Topsoil		0	0	0.00			0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.000	1.3	0	0.00	2.39	0.00	0.000
Morain		0	2	0.00			0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.000	1.3	0	0.00	2.39	0.00	0.000
Rock		0	25.00	0.00			0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.000	1.3	0	0.00	2.39	0.00	0.000
Upper	H	0	*0.20*	0.00		*2000*	8.4	15.0	22.5	1.74	0.00	0.00	0.00	0.00	10.2	*1589*	6.65	1.94	0.00	0.00
bed (not	H/G	0	*0.20*	0.00		*0*	0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.00	1.3	0	0.00	2.39	0.00	0.00
mineable)	G	0	*0.15*	0.00		*4500*	18.8	33.8	50.6	1.34	0.00	0.00	0.00	0.00	9.9	*3716*	15.56	1.49	0.00	0.00
	G/F_3	0	*0.10*	0.00		*0*	0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.00	1.3	0	0.00	2.39	0.00	0.00
	F_3	0	*0.3*	0.00		*1100*	4.6	8.3	12.4	1.97	0.00	0.00	0.00	0.00	7.2	*876*	3.67	2.13	0.00	0.00
Inter-	F_3/F_{1-2}	0	0.13	0.00		*600*	2.5	4.5	6.7	2.14	0.00	0.00	0.00	0.00	4.8	*600*	2.51	2.24	0.00	0.00
bed	F_{1-2}	0	0.18	0.00		*1100*	4.6	8.3	12.4	1.97	0.00	0.00	0.00	0.00	7.2	*876*	3.67	2.13	0.00	0.00
	Draw roof	0	0.17	0.00		*600*	2.5	4.5	6.7	2.14	0.00	0.00	0.00	0.00	4.8	*600*	2.51	2.24	0.00	0.00
	F_{upper}	0	0.23	0.00		1197	5.0	9.0	13.4	1.95	0.00	0.00	0.00	0.00	7.6	954	4.00	2.11	0.00	0.00
	F_{lower}	1	0.38	0.38	2.6	2340	9.8	17.6	26.3	1.67	0.63	0.11	0.17	6.20	10.9	1857	7.78	1.87	0.71	5.52
	F/E	1	0.00	0.00	2.2	0	0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.00	1.3	0	0.00	2.39	0.00	0.00
	E	1	0.44	0.44	2.2	2896	12.1	21.7	32.5	1.56	0.69	0.15	0.22	8.32	11.6	2302	9.64	1.76	0.78	7.48
	E/D	1	0.00	0.00	1.8	0	0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.00	1.3	0	0.00	2.39	0.00	0.00
Mine-	D	1	0.00	0.00	1.8	0	0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.00	1.3	0	0.00	2.39	0.00	0.00
able	D/C	1	0.20	0.20	1.8	596	2.5	4.5	6.7	2.14	0.43	0.02	0.03	1.07	4.8	596	2.49	2.24	0.45	1.12
bed	C	1	0.57	0.57	1.6	2926	12.2	22.0	32.9	1.56	0.89	0.19	0.29	10.86	11.6	2327	9.74	1.76	1.00	9.76
	C/B	1	0.11	0.11	1.0	778	3.3	5.8	8.7	2.08	0.23	0.01	0.02	0.74	5.7	778	3.26	2.20	0.24	0.79
	B	1	0.54	0.54	0.9	4340	18.2	32.6	48.8	1.36	0.73	0.24	0.36	13.31	10.3	3562	14.91	1.51	0.82	12.18
	B/A	1	0.14	0.14	0.4	365	1.5	2.7	4.1	2.22	0.31	0.01	0.01	0.47	3.5	365	1.53	2.30	0.32	0.49
	A'	1	0.09	0.09	0.2	1927	8.1	14.5	21.7	1.76	0.16	0.02	0.03	1.27	10.0	1532	6.41	1.95	0.18	1.13
	A'/A	1	0.02	0.02	0.2	602	2.5	4.5	6.8	2.13	0.04	0.00	0.00	0.11	4.8	602	2.52	2.24	0.04	0.11
	A	1	0.13	0.13	0.1	3610	15.1	27.1	40.6	1.45	0.19	0.05	0.08	2.85	11.5	2900	12.14	1.64	0.21	2.58
Bottom		0	1.00	0.00	0.0	0	0.0	0.0	0.0	2.36	0.00	0.00	0.00	0.00	1.3	0	0.00	2.39	0.00	0.00
Sum/ average			5.28	2.62	2.62	2515	10.5	18.9	28.3	1.64	4.29	0.81	1.21	45.20	9.6	2070	8.66	1.81	4.75	41.17
				m	m	kcal/kg	MJ/kg	%	%	t/m^3	t/m^2	t/m^2	t/m^2	GJ/m^2	%	kcal/kg	MJ/kg	t/m^3	t/m^2	GJ/m^2

italic - extrapolated geological data

The density of oil shale varies from 1.22 to 1.72 t/m^3, and interlayer densities, accompanying oil shale, vary from 2.1 to 2.45 t/m^3. Moisture adds weight to commercial oil shale because it fills the pores both in the rock and in the dust on the rock surface and even between them. That is why the density of natural oil shale increases with the occurrence of moisture.

Calculations of reserves for the Ojamaa mining field blocks are presented in Table 2, based on these rules and quality data of all layers and interlayers.

Oil shale mining

Industrial use of Estonian oil shale began after World War I. Two mining areas – Kohtla-Järve and Ubja-Vanamõisa – were developed in three years in Virumaa County. The oil shale in Kohtla area was better and a bigger oil shale industry center formed there. There are over twenty mining areas in Estonia, including opencasts and underground mines, where oil shale was, or has been, extracted. Currently six mines and opencasts are in operation (Table 3).

Mining technology

Surface mining technology used in the Aidu and Narva opencast mines, operated by *AS Eesti Põlevkivi*, developed after World War II when stripping with relatively big bucket (10–35 m^3) excavators, mainly draglines, started to be used. Both the overburden and the bed are at first broken up by blasting. Stripping is done with smaller excavators in opencasts with thin overburden using front end loaders and hydraulic excavators. The overburden is transported with front end loaders and trucks.

Bulk extraction of all beds (layers A-F) is performed only in the Aidu opencast where a separation plant is in operation. The Narva opencast uses selective extraction in three layers of seams. The upper (layers E-F) and the lower (layers B-C) seams are extracted as ROM, the middle seam (interlayers C/D-E/F) is shoved or dozed into the mined-out area. If the bed is broken mechanically, with ripper dozers, the oil shale can be extracted selectively and more completely taking layers A and D into ROM, which were lost in partial selective extraction. Highly selective extraction was started in 2006 in Põhja-Kiviõli opencast of *Kiviõli keemiatööstus*, using milling cutter surface miner from the German Company *Wirtgen*. And in 2007, the Narva opencast mine of *Eesti Põlevkivi* started highly selective extraction as well [9].

ROM was loaded into vehicles with front shovel excavators till the end of the 90s. In the 90s front end loaders were put into use. ROM is transported with trucks of up to 40 tonne payload capacity. It is delivered to consumers by railway, highway trucks and dump trucks. The surface mining is finished by reclamation of the mined out area.

Table 3. **Oil shale mines in Estonia in year 2007**

Enterprise, Mine	Approximate annual output, Mt	Started
AS Eesti Põlevkivi (state owned mining company):		
Viru mine with separating plant	2	1964
Narva opencast	5	1970
Estonia mine with separating plant	5	1972
Aidu opencast with separating plant	2	1974
OÜ VKG Aidu Oil Ojamaa mine	Preparation phase	2006
AS Kiviõli Keemiatööstus Põhja-Kiviõli open cast	1	2003
AS Kunda Nordic Tsement Ubja open cast	0.3	2005
Total	15–16	

Underground mining technology evolved in the 60's when room and pillar mining was put to use. The main characteristics are as follows:

- Blocks of rooms, formed by a number of small (up to 10 m long) working faces
- The roof and the mined out land are supported with pillars of unextracted oil shale (averaging 25% of the reserve)
- The ground does not subside
- The direct immediate roof of the rooms is anchored to the upper rock layers.

Longwall mining has also been used, where the bed was mined with a coal cutting shearer-loader [11]. The roof was temporarily supported by hydraulic support. When mining with the shearer, layers A-C were extracted, so in reality it was selective extraction. This mining method was more productive but much more capital-intensive and the changes in land surface were noticeable. These were the reasons for abandoning longwall mining in the 90's.

Separating oil shale

Oil shale ROM dressing was put into use and it has been used up to now mainly for the benefit of the shale oil processing industry. The present day technology of oil processing (vertical retort) can use only oil shale lumps of size 25–125 mm, because the processed raw material must have sufficient gas permeability to ensure the separation process in the retort. Oil shale is separated in dressing plants out of big ROM (>25 mm) pieces. This takes place in heavy medium where pieces of limestone interlayer lumps and concretions of ROM sink, and oil shale floats on the surface (Fig. 4.). The fine oil shale, sifted out of ROM before dressing separation, goes to power plants. The limestone separated from ROM, i.e. waste, which is approximately 40% of ROM ore, is suitable for production of low-quality crushed aggregate used in building construction, but most of it goes into waste dumps as this market is too small.

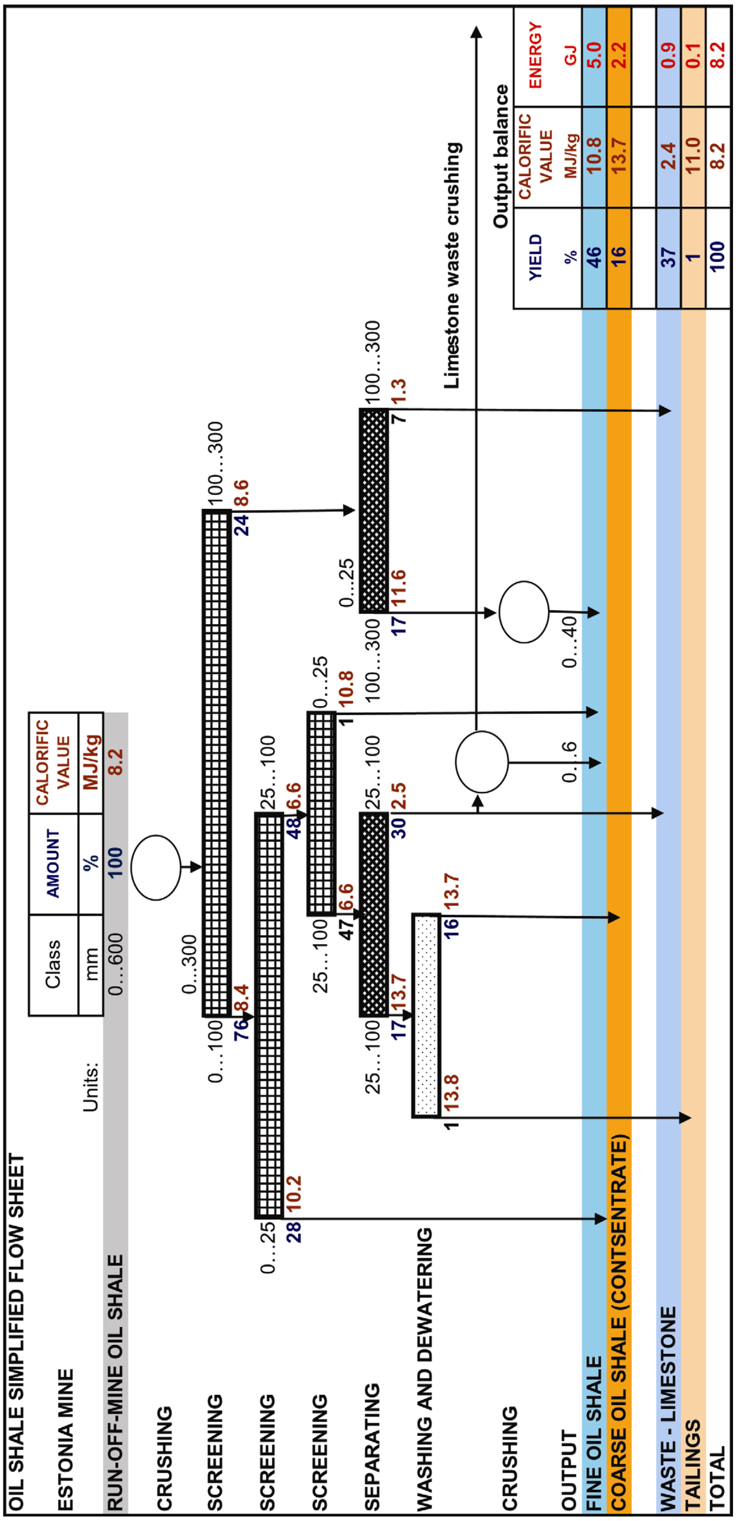

Fig. 4. Oil shale separation sheet, Estonia mine.

Oil shale processing

Oil production

In the early years oil shale was used as a solid fuel for steam locomotives and heat plants. The development of the oil shale industry started due to changes in the conventional petroleum industry. Until World War II the main uses of oil shale were for the oil and chemical industries, processing 60% of mined oil shale. Oil gave 8% of Estonia's export income [12, 13]. After WW II the conventional petroleum industry developed. At the end of the last century the importance of oil production decreased since oil prices were low and oil production in Russia increased. In the seventies the interest for oil had increased for a while in connection with the Arab oil embargo. The same reason has developed today for oil shale processing interest in Estonia [14–16], due to the recent rise in international oil prices.

Several oil and gas production technologies have been developed, tested and used (Table 4).

The main product of the chamber retort was gas. The produced oil was a by-product. Although it was a valuable chemical product, the yield of oil was low. The low yield of oil from fusion-retort was caused by the low organic content of oil shale in the mining area of Vanamõisa. The simplest and most proven units are vertical generators where processing is carried out with an internal energy source of blowing hot gas from the generation chamber. At the same time, vertical generators have the lowest yield of oil.

Table 4. **Oil production technologies in Estonia**

Process, name versions	User	Years	Processed mill tonnes	Average oil yield, %
Pintsch's generator or Vertical retort or Kiviter process	First Estonian oil shale Industry, *Eesti Esimene põlevkivitööstus* (in Estonian) ⇒ *VKG – Viru Keemia Grupp*	1921…	80.3	16
	A/Ü Kiviõli ⇒ *Kiviõli Keemiatööstuse OÜ*	1953…	14.0	
Horizontal retort or Fusion retort	Vanamõisa Oil Plant	1923–1931	0.004	16
Davidson's retort	Kohtla Oil Plant	1931–1961	1.4	19
Tunnel oven	Kohtla-Järve Oil Shale Processing Plant	1955–1968	2.7	21
	A/Ü Kiviõli	1929–1975	14.4	
	Sillamäe Oil Plant	1928–1941	0.8	
Chamber retort	Kohtla-Järve Oil Shale Processing Plant	1947–1987	55.9	5
Solid heat carrier (SHC) or Galoter process	*Kiviõli Keemiatööstuse OÜ*	1953–1981 2006…	2.2	13
	Eesti Power Plant	1980…	7.7	
Amount		since 2002	179.3	13

The Davidson and Fusion-retort and tunnel oven and chamber retorts that used external heating produced higher yield, but required more repair, handling and workload. In SHC generators, oil shale is heated by the ash/mineral residue from heating. At first SHC units required too much service and repair and had short equipment lifetimes. The reason was mainly low construction quality, low quality of fabrication materials and low levels of automation. Today most of these disadvantages have been corrected. Units that were more commonly used – vertical retorts and tunnel and chamber retorts – required material that is called lump oil shale. This material provided enough permeability for gas movement. Pelletized fine oil shale was tested in generators in Sillamäe but these tests were not successful.

Oil shale separation is costly. For that reason lump oil shale has been sold to oil production plants at a cost that is below its actual production cost. The oil industry has been subsidized by the power industry [17, 18]. This guaranteed that the oil production industry did not vanish already 40 years ago. Already at that time it was a goal to find technology that would be capable of using unprocessed oil shale. The most successful approach has been the SHC unit. Due to the fact that this technology is complicated, the development has not been totally successful enough in the beginning of the free market economy period. An important obstacle for SHC development has been the attitude of academic society in Estonia.

Tests of underground oil extraction were performed in the Kiviõli mine in a block measuring 25 × 75 m. The better-quality oil shale was brought to the surface but low-quality oil shale was set into piles and ignited. Air was pumped into and gas out of the mine. The oil shale bed was only 12 m deep, and most of the gas came out from cracks in the ground. Water flowed into the mine from side pillars and from the surface; this absorbed heat. This method did not prove itself because of the work load, low yield and environmental impact. The last test block was prepared but not ignited and was abandoned in the sixties.

Power production

Estonian heating and power stations started to use oil shale in the 1920's. The first oil shale power plant with a capacity of 3.7 MW was built in Püssi. After WW II Tallinn and Kohtla-Järve power plants were renovated. Ahtme power plant was started in 1951. New plants were equipped with powder units that were capable of burning fine oil shale. During this period the development of the oil shale industry was driven by Russian interests in north-eastern Estonia. Two large power plants were constructed close to Narva, both capable of burning oil shale with high mineral content. For supplying these power plants, the Viivikonna surface mine was reconstructed and the Sirgala and Narva surface mines were opened. For the same reason the Viru and Estonia mines were opened, the Aidu surface mine was opened, and the Tammiku and Ahtme mines were reconstructed. Separation plants were built in the new and reconstructed mines and in the Aidu surface mine that allowed finishing handmining techniques and handsorting and started high production levels for power plants and oil factories.

Oil shale development decreased when the nuclear power industry developed. Until the accident at the Tshernobyl Nuclear Power Plant, it had been planned to shut down the large Estonian power plants by the end of the millennium. Only the Püssi plant was actually closed.

Oil shale-based construction materials

The first building material industry segment that started using oil shale was the cement industry. The content of oil shale ash is similar (clay minerals) to the raw material of cement. The feedstock for Portland cement that was made from oil shale ash came from flyash that had been collected in electrostatic flue gas cleaners at the power plants. Light brick products from flyash and sand heated in autoclaves became popular. The waste rock from oil shale separation units has constantly been used as a building material. Due to the low resistance to freezing and the occurrence of micro-fractures from blasting this aggregate is suitable only for road or construction site ballast material. Lately (since 2006) oil shale wasterock has become beneficial due to road construction activity and limitations to limestone mining, crushing and sorting. The main method of beneficiation is crushing the softer part of oil shale, i.e. organic material, and screening it out.

Conclusions

The future of oil shale mining is closely related to the past and current situation in Estonian deposits and international oil prices. Mining and processing technology has been continuously developed but further development is required for meeting environmental and economic requirements.

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