Main Features of the Development of Oil Shale Industry in Estonia

Erki Tammiksaar

Oil Shale in the World

Oil shale can be found everywhere world, and, most probably, in terms of quantity, it is the most widespread organic substance that is contained in lithosphere and is suitable for burning, which is evenly distributed all over the world. If the resources of petroleum, natural gas, and coal were to come to an end, oil shale could supply the population of the Earth with energy. However, the heating value of different kinds of oil shale that are available in different parts of the world fluctuates significantly, and, depending on the area of extraction, they also have different chemical composition. This has been the main reason why different kinds of oil shale available in the world have not been researched much, and coal, petroleum, and natural gas are mainly used as the sources of energy instead of oil shale. And still there is one country which is rather an exception in this respect, namely the Republic of Estonia, where oil shale is used as the main source of energy, and the crude oil obtained from oil shale as well as its fractions are sold both on domestic and foreign markets. What are the reasons of this unique development, which denies the worldwide energy generation traditions?

Knowledge about Oil Shale in Estonia until 1916.

Oil shale outcrop area in north-eastern Estonia ranges from half a kilometre to several kilometres, but in nature, it is nowhere found directly on the land surface, it is covered with moraine. Since the moraine layer is not always thick in Northern Estonia, some lumps of oil shale can still be seen on the land surface. The first written data about finding "the burning land" in Kohala manor, the Governorate of Estonia, reached St. Petersburg in the beginning of 1789. This finding sparked the interest of the Free Economic Society in St. Petersburg, which was extremely committed to boosting the well-being of the Russian state. The society sent a question list to Kohala (picture 1) to find out more detailed information about "the burning land or stone". Fabian Reinhold von Ungern-Sternberg, the owner of the manor,

answered the questions and mentioned that the shepherds at the manor were using "the burning stone" at night time to keep themselves warm, but a larger amount of "the burning stone" was obtained from the depth of four metres while digging the well.

Johann Gottlieb Georgi, the chemist of the Free Economic Society, analysed the samples of oil shale sent by Ungern-Sternberg. He presented the results of his research on 28 March 1789. On the basis of the results, it became clear that oil shale can be used in the ovens, because, when being heated, it generates crude oil, and it is possible to produce cement from its ashes. However, in the 18th century, the Russian Empire was underdeveloped in terms of science. Although in the capital of the Empire there was the Academy of Sciences of St. Petersburg, which was prominent in terms of science, there were no universities, except for Moscow, and there were just a few scientific societies. On the territory of Estonia, which was divided between the Governorates of Livonia and Estonia in the Russian Empire, there were no scientific institutions or societies in the 18th century. This is why it is natural that the first available information about oil shale, the heating value of which was low compared to coal, did not deserve much attention in the society in those times.

In the beginning of 1838, on the territory of Kohala manor in the village of Vanamõisa "the burning stone" was discovered again while digging the well. Now Reinhold von Wrangell, the husband of the daughter of Ungern-Sternberg, who had died meanwhile, was sent from St. Petersburg to study oil shale. Mining engineers analysed oil shale in the laboratory of the Academy of Sciences of St. Petersburg and found out that when beaing heated, it generates percentage-wise more combustion gas than coal, and besides, "it seems like it does not contain sulphur at all". In addition to that, oil shale seemed suitable to be used as combustible material and for generating oil. The new natural resource was sent for research to Gregor von Helmersen (picture 2), who was an applied geologist from Livonia. He confirmed the existence of the area of 1.2 km long and 30-40 m wide on the territory of Kohala manor, where the layers of oil shale, mixed with limestone, as thick as 0.5-1 m could be found under sand, earth, and clay. Helmersen found out that "/…/ for the locals, the use of this mineral could be very beneficial", but could not compete with the coal of better quality, delivered from Britain, in St. Petersburg.

After Helmerson´s expedition, the central authorities of Russia did not show any more interest in oil shale. Local manor owners did not use it either. In economic terms, it was easier to use timber rather than oil shale which emitted unpleasant smell when burning. Besides, the availability of oil shale was confirmed only on a very small territory (ca 50 ha). In 1850-1857, the territories of Estonia were wandered far and wide by the paleontologist Friedrich Schmidt (Picture 3). In his research, he also studied the Estonian oil shale, or the reddish bituminous marlstone, which he found during the field works carried out in 1856-1857. The drainage canals that were dug out in the 1850s enabled Schmidt to confirm the existence of oil shale on the territory from Haljala to Kohtla. He mapped the layer of oil shale on his geological map of Estonia (*Brandschiefer*, 1a) (picture 4). Schmidt continued working on his stratigraphical sectional plan in the 1870s.

Especially valuable, both from the point of view of Schmidt himself and of further studies, was the drainage canal near Kukruse manor dug out by Robert von Toll (picture 5) in the middle of the 1860s (Toll´s canal), which was accidentally dug out precisely at the oil shale outcrop area (picture 6). One of the aims of digging out the canal was to drain the territory for laying out a park. It was in this canal that Schmidt, who was staying at the neighbouring manor in Toila, was often studying the organic composition of oil shale (picture 7). In 1879, he decided to name the layer of the oil shale in the surrounding area, on the basis of well-preserved fossils in the oil shale from the walls of Toll´s canal, the *Kukruse layer* (*кукерский ярус*). Schmidt was aware of the value of oil shale as a raw material for chemical industry. At the same time, he had to admit that "„/…/ it would be great to use oil shale as oil fuel or the lubricating oil, but the insignificant thickness of the [Kukruse] layer prevents its use even in the slightest degree".

And still, in the end of the 1860s, oil shale deserved the attention of the relevant branch of industry once again. This time not as a fuel, but as a fertilizer! Namely, in 1869, the German chemist Carl Funk came to the Governorate of Estonia. He received some rocks from Estonia for analysis several years before that, which were very rich in phosphorus (17.4%). Since the price for guano increased significantly due to the warfare in South America between Chile and Spain, Funk decided to launch his fertilizer production in Estonia. However, Funk did not know where exactly in Estonia these rocks originated from. While he was searching for their location, he finally came to Kukruse and got the idea that the oil shale exposed in Toll´s canal

was the rock rich in phosphorus he had been looking for, and he even published an article in Russian about it. The latter evoked a wide response all over the Empire. However, the fact that this was not phosphate rock, but oil shale was established by the chemists of the University of Tartu, headed by the professor Carl Schmidt. They proved that oil shale was a suitable combustible material, in spite of a large amount of ash generated while it is burning, and that it could generate both oil and combustible gas when being heated.

In spite of the results of the tests, no one in the Russian Empire, except for Robert von Toll (he ordered to use oil shale for heating the winery at Kukruse manor for several years starting from 1870), took interest in using the new combustible material in industry/production. The level of industrial development in the Governorate of Estonia did not facilitate the use of oil shale either. In 1857, there indeed was a large industrial Krenholm Manufacturing Company in Narva, but it was using water as a source of energy, just like the cement plant that was established in Kunda in 1870. The trains that were running on the railway line between Tallinn and St. Petersburg, which was opened in 1870, were using coal. So, in the 1870s, the mining engineer Pavel Aleksejev, who had been studying the Estonian oil shale, had to admit that "/…/ the locals [Toll] do understand the importance of oil shale as a combustible material and as a source of gas and oil. However, because of insignificant thickness of oil shale deposits that are available near the surface as well as because of the accidental nature of their discovery, oil shale is nowhere extracted for its own sake".

Aleksejev was right. Oil shale was discovered in different areas of the north-eastern part of the Governorate of Estonia, but the question whether those deposits were a part of a larger uniform field with thicker layer of oil shale remained unanswered.

In the last decade of the 19th century, in addition to Western Europe, the chemical industry started to develop in the Russian Empire, too. Private enterprises were also developing fast. St. Petersburg, the expanding capital of the Empire, needed more and more energy. In 1897, the issue of oil shale extraction in Kukruse area emerged full blown once again. Just like in 1869, in the Russian and even in foreign print media an article was published, which deserved a lot of attention, about a combustible material similar to coal that had been found near Järve community centre and in Toll´s canal. The author of the article was Wilhelm Johanson (picture 8), the handicrafts teacher from Jõhvi Ministry School, the first Estonian

known so far who collected data about the availability of oil shale on the territory of Estonia. The discovery of coal right next to capital of the Empire would mean large profit, because the power demand of St. Petersburg was 90% covered by the coal imported from abroad. The representative of the Yekaterinoslavl/Dnipropetrovsk Krivogorski railways and coal enterprise visited Toll´s canal and took the samples of oil shale from it. A thorough analysis proved that both gas, petrol, paraffin, and aniline dye could be generated from oil shale. On the basis of those studies, Johanson prepared the first and so far the most thorough article in Estonian named *Põlewast kiwist*, which was published in *Postimees* on 14 February 1898. He wrote that oil shale "/…/ contains 65 part of carbon, 9 of oxygen, 7 parts of hydrogen, 1 part of sulphur, amber acid, and other substances, 18 parts of ash. /…/ In addition to that, experts have claimed that paraffin, combustible gas, and kerosene can be generated from it. If there are kerosene substances in the burning stone, it can be assumed that there can be sources of petroleum hidden around here [in Järve]".

Johanson was very optimistic about the future of oil shale, but the Yekaterinoslavl Krivogorski enterprise was not, and the mine was not built. However, there is no doubt that Johanson´s article that was published in the Russian print media in 1897 led to the new oil shale research on the territory of Estonia in 1908 and 1909. The research started in Lüganuse civil parish, Erra rural municipality, and later on it continued in Jõhvi civil parish, Järve rural municipality. The results of the research allowed to prove that there are the layers of oil shale of different thickness around Järve on the territory of about 8-10 square kilometres.

The samples of oil shale were analysed in the chemical laboratory of the Alexander´s Manufacture, belonging to the Nikolaev Railways, established in St. Petersburg. The results of the research were exceptionally good, and the heating value of the organic matter of oil shale even exceeded the corresponding indicator for the coal and amounted to 8,100 kcal/kg. In the laboratory environment, the rock generated 25% of mineral oil, while in the factory environment, its amount did not exceed 18%. According to Vassili Zaitsevski, the process engineer who was analysing the oil shale, on the basis of the results of the research, it can be assumed that "/…/ from the mineral oil that was tested it is possible to obtain petrol successfully, without reducing its quality as a fuel, the demand for which is very high at the moment." The successful results were the reason why in June 1910 Zaitsevski decided to ask for more information about the oil shale from St. Petersburg. The Geological Committee

replied to Zaitsevski in August 1910 that „/…/ The Geological Committee does not know any factories that produce mineral oil from Kukruse oil shale, and, obviously, the issue of profitability and cost-effectiveness of this kind of production as well as of relevant production technologies is still unclear. Similarly unclear is the issue concerning the total thickness of Kukruse layer (which is mixed with limestone) and its chemical composition in different horizontal layers as well as some other exploration and technical issues. Further geological research, no matter how thorough, can hardly provide any new information in this respect."

Since there was very little information about oil shale, the leading Russian applied geology research institution did not lay any hopes for the future with regard to oil shale as a raw material. Secondly, there were no scientists in Russia at the time who would be aware of the achievements of Scotland, Germany, and France in the field of chemical processing of oil shale, which started in the middle of the 19th century. At first sight, such complete unawareness of Russia of the developments in chemical industry in other European countries can seem incomprehensible, but in fact, it is not. Russia did not have chemical industry of its own, and the national heavy industry was based on a well-developed Western European coal technology. Coal was delivered from Donbass, Germany, and Great Britain. This is why it is not at all surprising that the information about the oil shale deposited in the earth interior did not arouse much industrial interest.

Estonian Oil Shale Must Save St. Petersburg from Fuel Crisis

In summer 1914, the First World War started, and things changed. The war complicated the functioning of different spheres of industry and power economy of the Russian Empire, which were mainly based on using coal. The situation aggravated in 1916, especially in St. Petersburg, which was completely dependent on imported coal. The Central War-Industries Committee, the members of which were Russian businessmen, engineers, and scientists, and the Special Council on Fuel, which was subordinate to the Ministry of Trade and Industry, together with the nine local major committees started looking for alternative kinds of fuel both for St. Petersburg and for the whole Empire. On the meeting of the major committee of combustible materials in St. Petersburg one member of the council, R. U. Valentinovich, remembered that oil shale

was found nearby the Baltic railway. Since oil shale was unfamiliar for the members on the major committee, they did not know whether it could help to ease the fuel crisis in St. Petersburg.

In order to clarify the issue, the major committee on combustible materials in St. Petersburg turned to the geological committee with the request to look for articles about oil shale. The archivist and the librarian of the geological committee Nikolai Pogrebov (picture 9) did that. The study of the available literature, conducted by Pogrebov, proved that the previous researchers made their conclusions concerning the thickness of the oil shale layer in Estonia only on the basis of artificial cross sections. Since the wells and drainage canals that had been researched so far were not deep enough and did not go through the layers of oil shale, there was hope that if drilling deeper, the oil shale layer will be much thicker, and its resources were actually much more significant than Schmidt had pessimistically suggested. On the basis of the information obtained by Pogrebov, the major committee on combustible materials in St. Petersburg decided to start the research on site. Pogrebov was assigned as the head of the research, since in the beginning of the 20th century, at the request of the geological committee, he was dealing with geological mapping of ground water reserves in St. Petersburg together with Schmidt.

In the middle of June 1916, the on-site research started. First of all, Toll´s drainage canal at Kukruse manor was excavated. The excavation of Toll´s canal alone enabled Pogrebov to assume that on the territory of ca 40 km² on every square kilometer there were ca 4 million tons of oil shale, which could be extracted through pits. Later on the pits were also built near Järve community centre and Pavandu tavern.

It seemed like the future prospects for oil shale were very good, and the major committee on combustible materials in St. Petersburg opened a separate department for researching oil shale, which was headed by the process engineer of St. Petersburg Technological Institute Aleksei Lomšakov. Additional funding was required, so that it would be possible to extract as much oil shale as was needed for carrying out tests at research institutes and factories in St. Petersburg. The fuel department of the weapons industry committee provided the funding. The promising outlook of oil shale surprised the Russian public, and the prices for the territories in the Governorate of Estonia, on which, presumably, the mines were to be built

in the future, went up straightaway. However, at first, no one rushed to make investments, people rather preferred to wait until further results were obtained.

But it was still some time until the results were ready, because it was very difficult to find labour force for mining oil shale, due to the fact that north-eastern part of Estonia was scarcely populated. At first, oil shale was extracted from the pit that had been built near Järve community centre, and then near Pavandu tavern, where it was decided to build a mine. It was difficult to extract oil shale, since there was not enough labour force, and transporting it on carts to Jõhvi station was too complicated in the Governorate of Estonia, which was proclaimed a war territory. From the second half of June till the beginning of December, 22 wagons with Järve oil shale were sent to Tallinn, Aseri, Port-Kunda, and St. Petersburg. According to different data, there were about 640-690 tons altogether. Now the testing of oil shale started in different laboratories all over the Russian Empire, including the chemical laboratory of the city of Tallinn.

The initial tests were successful, and they proved that oil shale could be used in ovens both at factories and in cement kilns, and also at homes. In the result of retorting, it was also possible to generate gas and raw material. This information was a great relief for the inhabitants of St. Petersburg, who were suffering of fuel hunger. The prices for land plots on the territory of the present-day Kohtla-Järve went up, and in October 1916, the companies that were founded for mining oil shale, e.g. Mutšnik and Co (established legally only on 1 December 1916), started renting the land plots in the areas researched by Pogrebov. Boeckel and Co coal company in Petrograd also entered into a contract with one Kukruse farmer in autumn-winter 1916 (picture 10). Speculations with land plots became a serious problem for the state, since because of them, the mining costs could increase considerably.

The research of oil shale, which started in 1916, provided one more important result. The Russian paleobotanist Mihhail Zalesski proved that the organic matter in the Estonian oil shale originates from algae, which means that it is one of the subspecies of sapropel. This is why the Estonian oil shale needed a more specific name. In 1917, Zalesski wrote in one academic magazine of the Russian Academy Of Sciences: "In its pure form, this rock [oil shale] consist only of algae, does not contain mineral clay or marlstone, which means that the name *Kukruse layer* cannot be used in scientific literature. /…/ [In connection with that],

we suggest naming the oil shale *the kuckersite*. By doing so, we will be able to retain the name that is associated with the place where the most varied examples of the fauna that is typical of it were found, which made F. Schmidt to believe that it was necessary to discern the Kukruse layer".

On 3 January 1917, the oil shale mining plan was presented to the emperor Nikolai II. The plan said: "In addition to using the oil shale as fuel, a whole new industry can be set up in the location where its deposits are found. It is possible that oil shale might be of extreme importance when generating valuable fractions (petrol, oils, and other hydrocarbons) in the result of dry distillation [retorting]. It can provide, although partly, the districts of Petrograd and Tallinn with our own oils and high quality fuels of local origin, and it allows to use the leftovers of excavation processes (limestone and ammonia water) in the production of fertilizers and in other suitable industries. I would like to most humbly inform Your Imperial Majesty about this plan connected with the new fuel of extreme importance, which the oil shale might turn out to be. The plan of investing 1.2 million roubles into renting out the land for mining and hiring 420 workers was attached to the presentation. It was planned to extract 6 million poods (0.098 million tons) of oil shale per year. This is how oil shale turned into the issue of state importance.

The perspective of setting up the oil shale industry in Estonia was bright, however, the military and political situation in Russia in the beginning of 1917 was far from being as bright as that (February Revolution, the emperor leaving the throne, the Russian Provisional Government assuming the office). The Council of Ministers confirmed the allocation of 1.2 million roubles for the commencement of the excavation process on 13 February 1917, and after that, the Russian state purchased 163.4 hectares of land in Järve village and also the lands in Mõisamaa and Käva village (the aim was to obtain so much land that it would be possible to extract 6 poods per year, according to the plan). Later on, 100 tithes (the total of 131.4 ha of land) was leased from the owner of Püssi manor.

Now the mining was supposed to start. In summer 1917, the major committee on combustible materials in St. Petersburg as well as the Ministry of Trade and Industry did their best to start large-scale excavation. The expectations were high. It was planned to extract 35-36 million poods (0.573-0.590 million tons) of oil shale per year. In order to do that, two digging machines were ordered from Tallinn naval harbour. They did arrive to the

location, but no one could assemble them. Even the collectivization of the earth interior in the prospective area of excavation in summer 1917 did not bring any results. So, unfortunately, the hopes did not come true in the scale which had been planned. The major problems were the fact that the excavation area was located on the territory where warfare was held, the lack of labour force in the north-east of Estonia, and labour-intensive preparations for excavation. Altogether, about 500 people were working in the mine near Pavandu tavern, the majority of which were prisoners of war and the people hired for working at the front line (vigilantes). They started the construction of barracks, power station, canteen, repair workshop, narrow-gauge railway (which was completed and stretched up to Kohtla station), and wide-gauge railway, which had to pass through the area of excavation. However, no mass extraction of oil shale started at that time because the Revolution broke out in November 1917, which was followed by the intrusion of German troops into Estonia in February 1918.

In addition to state excavations, some private entrepreneurs were also planning to extract oil shale. In March 1917, four applications were submitted to the Ministry of Trade and Industry for the commencement of excavation operations. The works started in summer 1917 only in Mutšnik´s mine to the north of the state mine (picture 11) and in Pavel Boeckel´s underground mine in Kukruse, three kilometres to the east from Järve. However, the amounts they managed to extract were quite moderate (400-960 tons).

In September 1917, the political and military situation in Russia was already so disastrous that the Ministry of Trade and Industry decided to abandon the idea of further oil shale research. The fact that the launch of the state oil shale mining was dragging on had a bad effect on the research, and the hopes for receiving large amounts of oil shale for St. Petersburg were defeated. However, Lomšakov believed that oil shale was offering great opportunities as a valuable raw material in chemical industry, and he was sure that the research of the oil shale should be continued at any cost. He wrote to the Ministry of Trade and Industry: "The research of geological and [chemical] properties of oil shale and its utilization is /…/ of extreme importance for the districts of Petrograd and Tallinn. And that is regardless of whether we succeed in using oil shale as a fuel right now, at this turning point, or it will only happen after the end of the war. In this case, the issue of using oil shale as a fuel and as a raw material for getting liquid fuel and oil, with using its byproducts, such as its

waste (ash), will be of even greater importance. By that time, the problem [of the extraction of oil shale] will have to be resolved completely. /…/ [Delivering oil shale to St. Petersburg in the current volumes] will allow to temporarily research its application in the industry and to find out which products can be obtained from it [in the result of chemical processing]. All of that serves as the basis for the whole range of measures aiming at setting up the entire oil shale industry, which, actually, is going to help to resolve not only the problems with fuel, but is also going to change the industrial life of the district fundamentally. It will be possible to build a) the plants which produce liquid fuel from oil shale in its different fractions, lubrication oils, possibly also ammonium sulphate and paraffin; b) cement plants which would use oil shale as fuel and its ash as one of the raw materials for producing cement; c) the plants which would use oil shale ash for producing ceramic and chemical products; d) power stations operating on the basis of crushed oil shale fuel, for heating the settlements in the districts, e) electric railways, etc. All of that is going to open up the whole new sphere of activities, and this is why it is extremely important to start processing oil shale as soon as possible. The belief that oil shale is valuable as a raw material in chemical industry, not as a fuel, was very widespread among engineers. It was facilitated by the fact that in 1917, Pogrebov proved in the result of the research that the deposits of oil shale stretched from Vanamõisa and Ubja to Kohtla. The great opportunities offered by oil shale were also supported by the results of the research and tests conducted in the end of 1917 and the beginning of 1918 in St. Petersburg in the Polytechnical Institute etc. It was additionally confirmed by the story of success of one Scottish oil shale company, which Russia heard of. It was decided to apply this experience in the processing of Kukruse oil shale - kuckersite. There were just two problems. Firstly, it was not possible for the Bolshevist Russia, which was involved in the national conflict, to get any technological aid from Scotland for processing oil shale. Secondly, Pavandu mine was under the control of the Germans on Estonian territory. In summer 1918, an attempt was made from Petrograd to reach an agreement with two of the Germans concerning the use of the mine, but without success.

The German geologists, unlike the Russians, were not so sure of the great opportunities offered by oil shale as a raw material for the chemical industry. In 1918, the famous German applied geologist researched the Estonian oil shale. He believed that the extraction of oil shale could not be carried out because of the ground water in the district researched by the

Russians, which is why the extraction would incur too much expenses, because it could not be done on a territory big enough. Whether those expenses were going to be paid off by oil and gas obtained in the result of processing of oil shale, was largely dependent on the prices for petroleum and ammonia after the end of the war. Looking backwards, those were the words of a prophet!

Unlike Beyschlag, the military geologist Hans Gäbert researched oil shale much more thoroughly, and believed that kuckersite was a valuable raw material. He made the first known photos of Pavandu (picture 12) and Mutšnik´s mines in summer 1918. Gäbert acknowledged the existence of ground waters, but, unlike Beyschlag, he believed that, since no leveling was to be done in the future mining districts, the problem should not have been exaggerated.

Setting Up the State Oil Shale Industry

Fortunately, the engineer Märt Raud, who lived in Petrograd and familiarized himself with the issue of oil shale in spring 1918 under the supervision of Pogrebov, was very inspired by a number of research conducted by Russian engineers, and he was a big fan of the idea of establishing the oil shale industry. Similar belief was held by Hendrik Bekker, the oil shale geologist who was working in Toila in 1917. He witnessed the works preceding the construction of Pavandu mine (picture 13). In 1918, he wrote: "The use of the "burning stone" as a fuel. The "burning stone" is a valuable material for chemical processing. It can produce liquid products in the volume of up to 20% of its weight. Different lubrication oils and petrol can be generated from it". The head of the chemical laboratory in Tallinn Henry von Winkler (picture 14) and his assistant Paul Kogerman (picture 15) were also convinced in the bright future perspectives of oil shale as a raw material for chemical industry. They were researching oil shale at the assignment of the main committee.

There were just a few who truly believed in oil shale. Wide Estonian public did not know anything about oil shale and the possibility of it being used, in spite of a number of articles that had been published in the Estonian press in 1917. It was mainly seen as the means for alleviating the fuel crisis in St. Petersburg (this is why the mines were built in the first place!)

The economic importance of oil shale for Estonia was not taken into consideration. This is why it was not surprising at all when in 1909, it was written in the newspaper "Wirulane": "The largest part of the local population [in north-east Estonia] does not know anything about the existence of oil shale. Recently I have told one tenant at Kohtla farm that there is the "burning stone" underneath his garden, but the man did not believe me, until he took the stones home and put them into the oven to see if they were burning". Considering that, the fact that in the beginning of the 20th century one farmer built an oven from the lumps of oil shale, in the result of which, of course, it burned down during the first heating, does not seem weird at all.

Consequently, the success of oil shale in Estonia was largely dependent on supporting it as a new kind of fuel on political level. Fortunately, Märt Raud (picture 16) had some political support. When establishing the oil shale company, he was supported by the first Finance Minister of the Estonian Provisional Government Juhan Kukk, who was hiding himself from the German occupying forces in 1918 in Petrograd in Raud´s apartment. When the Provisional Government took office, the issue of taking over the oil shale mines built by the Russians into state property arose. Märt Raud obtained the power of attorney, and on 25 November 1918, the oil shale mines were taken over from the Germans. Raud became the head of the state oil shale company, which was founded on the same day. At his initiative, on 12 May 1919, oil shale was proclaimed national property, and the search for the possibilities to use the Scottish oil shale processing technologies for processing the Estonian oil shale started. For that purpose, Paul Kogerman was sent to Great Britain, who proved that kuckersite differed from Scottish oil shale in its chemical composition significantly, which made it impossible to use the technology that had already been developed in Estonia.

It was necessary to find or develop other technologies for processing kuckersite. Since, after the end of the war, there was a wide demand for oil products, and the prices at the world market were high, the production of oil was attempted both in Great Britain and in Scotland, using oil stones containing some organic material. It was seen as very promising. Alongside with them, kuckersite was seen as a high quality raw material for chemical industry by some other scientists, and when the state decided to distribute oil shale concessions, there were many applicants and the people who wanted to improve the oil shale retorting technology (pictures 17 and 18). In 1929, Karl Luts (picture 19), the leading Estonian oil shale chemist

and technologist with St. Petersburg background, wrote: "No wonder that the news about the extremely valuable and abundant Estonian oil shale stirred interest among foreign capitalists /…/. In the result of such a keen interest, our mine department was buzzing with applicants in those days. There was not so much to give, compared to the demand. And the undertakers were so different! The former tailor from Narva collected with a huge sum of money, a lady with a couple of reticules of cash set up the oil company, poor state officials, match maker, publisher, etc. Everyone was pushing his or her luck".

In reality, the acquired concessions mainly remained unused. Significant decrease in the world petroleum price in 1921 and later the need for the development of the expensive oil shale retorting technology destroyed any chances for profit-making use of lower quality oil stones. By 1927, for example, the Scottish oil shale industry, which had been extremely profitable directly after the world war, had almost died out and started to process petroleum from Iran in order to survive.

Unlike private entrepreneurs, the newborn Estonian state was acting in a different way. The hopes for getting rich fast were high in 1919 and 1920, since the state was poor. Secondly, it was hoped to transfer the largest Estonian companies from coal to oil shale fuel by using the mines built by the Russians, which would help to save on foreign currency. The state oil shale industry was actively dealing with that (picture 20). In the first years, the volumes of oil shale extracted by the state oil shale industry were quite moderate, and oil shale was not competitive, compared with coal. The salaries of the employees were very low, and the workers at Pavandu mine were mainly using shovels even in 1924 (pictures 21, 22, 23, 24), although the oil shale industry in Kohtla-Järve was fondly referred to as the Estonian Manchester. Two diggers, which had been brought from Tallinn in 1917 (picture 15,16), were only used at Pavandu mine. Horses were used a lot for transporting trolleys. The situation in Kukruse mine was no better. Occupational safety was not a familiar issue. The miners were especially worried about the fact that the management of the mines started to deduct the price of explosives from their salaries. There was a strike in 1924 against that, but the miners lost. The miners working for the state oil shale company assessed their working conditions and salaries in comparison with the private oil shale industries operating on German, Swedish, and British capital as much poorer.

A real headache for the management board of the state oil shale company were the living conditions of the miners. Although some funds were indeed invested in this respect, in 1928, it was admitted that, "from the point of view of human dignity", the living conditions were not at all satisfactory. People were living in extremely poor conditions. 1,500 people were working at the company, but barely 4 m^2 of heated floor surface was allocated for each miner. As years went by, the situation improved a little bit.

Since oil shale was not competitive compared with coal, the Estonian state came to the rescue of its own industry, and the oil shale industry was virtually operating as a nameless department of the Ministry of Trade and Industry until summer 1922. Only after that the state oil shale company, independent from the ministry, was created. In 1921, the state established duties of entry for coal and coke (0.6 kroons per one ton). In 1924, when the prices for petroleum and coal decreased again, the customs duty was increased three times, from 0.7 to 0.9 kroons per ton, so that the oil shale industry could survive. However, the situation in the oil shale industry was aggravated by the fact Estonians are very conservative people, and they preferred to use good old coal, wood, and peat instead of the new kind of fuel. Even at the state railways. Märt Raud, being the head of the state oil shale company, made a lot of effort trying to persuade the state administration to transfer railways to oil shale. It was happening slowly, but sustainably, although in 1924, Raud was forced to admit that "/…/ the final destination of the development of the oil shale industry is the supply of the entire range of Estonian industries and railways with the cheapest local fuel - oil shale, and to satisfy the need for local mineral oil with the oil generated from oil shale. In addition to that, the export had to be significant enough and corresponding to the conditions of foreign market. In order to facilitate it, the trust of even wider range of consumers has to be earned, and their demand for oil shale and its byproducts should be increased by the fact that the goods that they are offered are of high quality, cheap, and easily available. /…/ The state oil shale industry has so far achieved only one fourth of what has been planned according to the action plan".

Establishment of Oil Industry in Kohtla-Järve and Its Development

It was clear that in order to expand the oil shale industry and to improve the situation with the workers, it was first of all necessary to provide added value to the extracted oil shale. Its own oil industry had to be built for that. Raud made his fundamental decision concerning the products of the future oil industry in the beginning of 1919. His idea was mainly based on the fact that the results of the research conducted by the Germans in 1918 proved that it is possible to get high quality lubrication oils from kuckersite. Since the Estonian War of Independence was going in at that moment, lubrication oils were needed in order to provide smooth functioning of the rolling stocks of armored trains. Since the Scottish upright retorts were not suitable for retorting kuckersite, the state oil shale industry started to work on the improvement of the Rolle retort used for retorting the German brown coal. However, the latter allowed to retort only fine oil shale. There was s lot of it generated in the result of chemical reaction between the layers of oil shale, air and water, but it caused the premature "ageing" of oil shale. It significantly diminished the fuel value of oil shale, especially the amount of generated oil. This circumstance as well as the awareness of the fact that the retorting volumes of the Rolle oven were small (5-6 tons per day), and the oven itself was expensive, forced the management board of the state oil shale industry to look for other retort types, in order to retort, for example, lumpy oil shale of higher quality.

Such an opportunity finally came up. In autumn 1919, the representative of the company named Julius Pintsch AG operating in Berlin visited Tallinn. By accident, he met Märt Raud and offered him an opportunity to develop the retort for retorting lumpy oil shale in his company. The trials took place in Germany for longer than it had been planned, but in the first half of 1921, the parts of the trial low-temperature retort with the daily capacity of 40 tons arrived in Kohtla, and on 3 August 1921, the trial oil production was launched (picture 27). The production was so successful (the trial factory provided 18% of raw material instead of 12%) that in the end of August of the same year Julius Pintsch AG made a proposal to develop a new factory producing oil on industrial scale on the basis of the trial factory, but with six upright generators, with the capacity of 200 tons of oil shale per day. The Ministry of Trade and Industry gave its consent to finance the oil plant in the beginning of September 1921.

The cornerstone for the large oil factory was laid when the trial factory was just being commissioned - on 20 June 1922. Since several members of the government and of the party represented in Riigikogu had so far been quite sceptical concerning the prospects of oil shale as a fuel, Märt Raud stressed in his speech the importance of the fact that the members of Riigikogu and the government were present at laying down the cornerstone for the new factory. The building of the large oil factory was completed very fast, but the assembly of the equipment lasted until 23 December 1924 (picture 28). This day can be regarded as the birthday of the production of shale oil on industrial scale. The tests ensuring the smooth operation of the factory lasted until September 1926. Oil yield amounted to 16.4%. The better was the quality of lumpy oil shale (25-125 mm), the more oil yield there was. However, there were still some problems with delivering the best oil shale to the oil factory.

The tests carried out in Kohtla oil shale laboratory built in 1921 (picture 29, 30) (headed by Karl Luts) proved that the raw material obtained at the oil factory after distillation is suitable as ship fuel, and two Estonian military ships started using it. Distilled raw oil, or engine oil, was also suitable for heating locomotives, but since it had to be preheated before being fed to the boiler, the transfer of trains to oil fuel started in 1929 (by 1932, 5 locomotives out of 34 were using oil as fuel). However, there were no other consumers of oil as fuel on the domestic market in Estonia. Bitumen, the byproduct of oil retorting, was used in different ways: softer types were used as roof tar, while harder types were used for producing roofing felt paper. Bitumen was also used for producing "Estobitumen" by adding special mineral substances for coating the roads with asphalt (picture 31). Even different kinds of poison for plants and insects were produced from shale oil.

Another important product of raw oil was phenol, which could be used as impregnation oil. It was proved by the shale oil laboratory of the University of Tartu, built by Paul Kogerman in 1925. The state railways consumed 600-900 tons of impregnation oil per year. However, considering the fact that Kohtla oil factory was capable of producing 10,000-15,000 tons of impregnation oil per year, this amount was still relatively small.

The key to further development of oil industry in Kohtla was, consequently, the production of petrol, for which there was a high demand both in Estonia and abroad. This was the national aim - not to be dependent on the imported petroleum. Before 1928, not much

attention was paid to the production of petrol in Kohtla, because in Pintsch retorts (picture 33,34), petrol could be obtained only from retort gases, not from crude oil. It was because of the structure of the retort. In order to produce petrol from crude oil, it was decided to build a special cracking plant. The question was whether to use the assistance of foreign cracking plants in order to conduct tests while producing petrol from crude oil or to build the factory here, in Estonia, based on the results of the tests conducted in the oil shale laboratory in Kohtla. Since the crude oil generated from oil shale, in terms of its composition, was different from all other known kinds of oils, it was decided to build its own factory.

The cracking plant with the capacity of 35 tons of crude oil per day was designed in Kohtla by the German factory "Friedrich Heckmann". The construction started in autumn 1929, and the assembly of the equipment lasted until the end of 1930. However, the Heckmann company did not get the amount of petrol from crude oil that it had expected. The state oil shale company, headed by Luts, had to rebuild the cracking plant, which was completed in 1932. In the same year, about 450 tons of oil shale petrol were obtained as the produce of the company with the capacity of 30 tons per day. The content of sulphur in it was 0.6%, while the international norm was only 0.1%. The unpleasant odour as well as the colour of oil shale petrol also caused some problems. After being left unattended for several days, the oil shale petrol turned from transparent into cherry-red. While the odour was combatted successfully, the decrease of sulphur in oil shale petrol had more significant consequences. Washing down with sulphuric acid decreased the content of sulphur in oil shale petrol, but also meant a lower octane number and the decrease in the reliability of the engines. In 1938, the amount of sulphur still fluctuated between 0.4-0.7%, but those "sulphur compounds were regarded as completely harmless for engines". In addition to that, about 115 tons of oil shale diesel fuel was obtained at the cracking plant (1932).

Consequently, the issue of oil shale petrol was resolved by means of the oil plant in Kohtla-Järve (picture 35), which, however, was not competitive in comparison with petrol made from petroleum in terms of the price. The same situation was with crude oil. Owing to the commencement of the oil factory in Kohtla, the Republic of Estonia had its own oil industry, which in 1928, provided about 6,600 tons of crude oil, but its saleability was quite limited both in Estonia and at the global market because of the low price for petroleum. Investments into the research of shale oil were urgently needed, in order to obtain new

products from it, but there were no funds for increasing the staff of chemists. At the same time, foreign countries did not want to buy oil shale because of its low fuel value.

Another global economic crisis was a painful blow against the oil shale industry, the culmination point of which in Estonia was in 1931-1934. In order to protect the oil shale industry, in July 1931, the state introduced the customs tariff of 10 kroons per a ton of coal. It made coal very expensive at the Estonian market and facilitated the transfer of Estonian industrial companies to lumpy oil shale and shale oil fuel. Petroleum and oil shale petrol were handled similarly. In July 1932, the customs tariff for petroleum products was raised from 20 kroons to 40 kroons per ton. It meant an increase in the customs duties by about one fourth of petroleum import price, which almost completely devitalized the import of petroleum (in 1932 about 3,000 tons, and in 1933 just 91 tons) to Estonia. For producing oil shale petrol, the state granted the subsidy in 1932 in the amount of 2/3 of the sales price at the domestic market. While the price for imported petrol on the average was 10.3 cents per kilo in those times, the price for oil shale petrol obtained at the state oil shale industry was 36.5 cents. However, oil shale petrol became competitive when the tariff for imported petrol was raised up to 30 cents per one kilo in 1932.

At the same time, Estonia was exporting oil shale petrol. Different agreements between the countries and the subsidies of the Estonian state allowed the country to deal with export. For example: Estonia exported to Latvia 2,300 tons of oil shale petrol without customs taxes, and in return, it purchased sugar for the same amount. Similar contract was entered into with Finland. In addition to that, from 1932, the oil shale industries had the right to purchase duty-free petrol made from petroleum in the volume, in which the oil shale petrol had been exported. Oil shale industries needed petrol made from petroleum in order to mix it with oil shale petrol for improving the properties of the latter and reducing the content of sulphur. On the other hand, the subsidies and protective customs tariffs raised the price of petrol at the domestic Estonian market, and even the state oil shale industry preferred carriages with horses to cars when transporting ash from its two first oil factories!

The development of the oil shale industry is very well characterized by the fluctuations in the number of employees throughout the years. In 1920, when oil shale was becoming more and more popular among the Estonians, 958 people were working at the company, since oil shale

was extracted manually. In 1921, there were twice as many full-time employees. In the following years, the number of employees fluctuated between 1,100 and 1,500, but during the economic crisis, the number of employees was diminishing all the time, and in 1934 it was less than 1,000 people. All of that was caused by low profitability of the oil shale industry, which forced reductions of the people who were not directly required from the point of view of the industry. In summer 1930, even the special saving rules were issued, which had to be "followed unconditionally". However, clause 6 reads as follows: "Not to cut down the price of labour and the salaries of our employees, all of the foremen, cleaners, female gardeners, sauna cleaners, etc., etc., who do not produce anything, but only generate expenses for us, which are not acceptable during depression, should be made redundant without mercy or reassigned to production". The situation at the state oil shale industry got better only in 1936, when 1,800 people were employed by the state oil shale industry, and within the next years, the number of full-time employees reached 2,000 people.

Consequently, it can be said that in the final result, the global economic crisis was quite useful for the development of the oil shale industry. It managed to get rid of dangerous rivals at the Estonian market, such as coal, petroleum, and petrol made from petroleum. At the same time, it was possible to expand the production and to step out of the borders of Estonia with its produce by increasing the production volumes significantly. The low price for petroleum made it impossible. The situation seemed desperate. But there was a limit to the development lying ahead. The head of the factory in Kohtla Karl Luts wrote in 1929: "When is this huge long-expected breakthrough going to happen in the oil industry? Nobody can tell that to the day. In the future, we might have similar development we have had so far, so to say, "at the Estonian scale". But large-scale development will not start happening before a new twist at the oil market takes place, which can be facilitated by the rise in the prices, or if we start to generate a new product from oil shale and oil, which will make its breakthrough to the global market due to its properties and price and will allow us to build and operate new factories. This is the most likely course of events. - And then the great days of the oil shale industry will come. We all believe that they will come. We wish to our land and to our employees that they come the sooner, the better".

Estonian Oil Shale Comes to the World Market

And "the great days" came soon enough, and there was no longer the need to produce any new products from oil shale crude oil. The Estonian oil shale needed Germany, because after Hitler came to power in 1933, the military industry was revived in Germany. Military machines needed fuel. An important part in satisfying the demand of the German military machine for fuel was played by the world leading group of German chemical companies I. G. Farbenindustrie AG. From 1926, the group had been testing the production of synthetic petrol from brown coal with varying success. However, it was expensive, and could not compete with petroleum. But Hitler´s warranties concerning the support of production of synthetic petrol changed the situation, and in 1933, I. G. Farbenindustrie became the only supplier for Wehrmacht of synthetic petrol and diesel fuel. In the end of 1936, Hitler presented the four-year development plan for Germany, with the aim to achieve the independence of imported raw materials, including petroleum, and to get ready for the war with the Soviet Union. It meant the production of much more crude oil from brown coal and its hydrogenation and turning it into fuels. There were no production facilities of sufficient capacity in Germany, and I. G. Farbenindustrie looked at the Estonian oil shale industry, where the crude oil was much cheaper than in Germany.

While the German marine forces were supplied with shale (fuel) oil by AS Kiviõli from 1935, I. G. Farbenindustrie was supplied with crude oil by the state oil shale industry from spring 1937. The need for shale oil started increasing in 1935, what allowed to start the construction of the second oil factory with the upright generator in Kohtla-Järve (with the daily capacity of 320 tons of oil shale, and the annual capacity amounted to 20,000 tons of oil). The factory was completed in 1936, and all of its equipment was manufactured by the Estonian companies, including Pintsch generators, which were named "Kohtla-Järve" because of some minor technical innovations introduced in them. It was mainly making the oil shale industry more profitable that enabled the state oil shale industry to change its organisational structure. From October 1936, the state oil shale industry became the joint-stock company named the First Estonian Oil Shale Industry, which strengthened its position among other Estonian oil shale industries (picture 36).

In 1936, the designing process of the third oil factory with sixteen Pintsch generators started (with the daily capacity of 650 tons of oil shale and 40,000 tons of oil per year). The factory was completed in 1938 (picture 37). The business risk connected with the construction of the third factory was justified by the fact that on 4 March 1937, the agreement was entered into between the First Estonian Oil Shale Factory and I. G. Farbenindustrie, guaranteed by the Republic of Estonia. According to this agreement, the German side gave its consent to guarantee the purchase of the products of the new oil factory until the end of 1940. For the money received from Germany the state had to buy the goods of I. G. Farbenindustrie (especially explosives for the oil shale industry). In addition to that, the contract opened up the credit in the German community bank, which provided an opportunity for building the third oil factory.

The Estonians did not have the slightest idea about the purposes, for which I. G. Farbenindustrie needed crude oil. The contract just provided that the German side would be using crude oil "accordingly in different spheres of application", which were to be determined after the completion of tests and trials in Germany. On the basis of the results of the tests, the German side decided that they needed the "fuel oil" that would be more liquid than the crude oil. It was possible to get the "fuel oil" of the required quality only by mixing the liquid distillate obtained after cracking crude oil with crude oil in the ratio of one to three. According to the assessment of Karl Luts, it was possible to use such "fuel oil" only for heating the steam turbines on the ships. According to his assessment, it was not suitable for diesel engines. Consequently, the belief that was widespread both among the Estonians and the Baltic-Germans that the Estonian oil shale that is heavier than water was used for heating German submarines was just a beautiful fiction. The whole amount of fuel oil was used for heating the German vessels.

Considering very favourable business environment, in June 1939, the state oil shale industry decided to start the designing process of the fourth oil factory with the daily capacity of 860 tons, in order to satisfy the demands for shale oil. I. G. Farbenindustrie was also supposed to purchase these products, and the construction was supposed to be financed by the German community bank. Besides, the Estonian government and Julius Pintsch AG 1940 reached an agreement by the beginning of June 1940 about the construction of a new large natural

gasoline factory in Kohtla, which was supposed to be financed by Pintsch, and in return, it wanted to be provided with 600 tons of petrol free of charge for the duration of six years.

Such large orders allowed to reduce the compensation for the price for oil shale petrol in 1937 from 30 cents to 15 cents. Besides, the compressed air pumps, ventilation, and electricity also reached the state mines. In order to boost the amount of oil produced, a special bonus system was developed for the staff of the oil factory in the second half of the 1930s.

In connection with the fourth factory, the issue of changing the type of generator was raised for the first time. The subject of the discussion was the circumstance that the generators at the first oil factory were operating more smoothly while feeding the oil shale of different sizes than "Kohtla-Järve" generators, which required maintenance too frequently, and it did not allow to use up the oil shale inside the generator completely. It was more expensive. In addition, the Minister Of Economic Affairs made a proposal about considering the construction of the first tunnel oven in Kohtla-Järve. In the end of 1939-the beginning of 1940, there were numerous tests, that were supposed to help choose the generator type. Finally, Pintsch retorts remained, because the company was ready to finance the construction of the factory. Although in Estonia the authorities were changed in summer 1940, the contract entered between the Republic of Estonia and Germany remained valid in the Soviet Union. It allowed to start the construction of the fourth oil shale factory with 20 upright generators already in 1940, and it was completed with the direct participation of the Germans in 1943.

Kohtla-Järve Oil Shale Industry During the Second World War

The Soviet authorities, just like Germany, were very interested in producing mineral fuel from oil shale. After the independence of Estonia was restored, the Russians did not have access to Pavandu oil shale mines. The attempts to start mining operations at Weiman oil shale deposit, discovered in 1918, in order to alleviate the fuel crisis in St. Petersburg (from 1924 - Leningrad) largely failed. The alleviation of oil crisis in Leningrad in 1924 led to the fact that in 1925 the Communist Party proclaimed oil shale as unpromising kind of fuel, from

the perspective of the Soviet Union, and oil shale mines were closed (except for Kashpirsk near Volga). The attitude of the Russians to oil shale was changed by the success of the Estonian oil shale industry in the second half of the 1920s. Owing to the map of oil shale concessions, published by the state oil shale company (1926), in 1927, the Russians investigated oil shale deposits near Polje village on the eastern bank of the Narva River. Then the oil shale deposit in Gdov was discovered. In 1928, the representatives of "Bitumslanets", dealing with the research of the deposit in Gdov, paid a visit to Estonia to familiarize themselves both with the state oil shale company and with the work of private entrepreneurs. The things that they saw exceeded their expectations and once again turned oil shale into a very valuable and promising kind of fuel for the Soviet Union. The construction of trial oil shale factories started both in Kashpirsk (picture 39) and in Leningrad. The lack of engineers and labour force, the low quality of Kashpirsk oil shale and high content of sulphur in crude oil as well as complex geological conditions of the kuckersite deposit in Gdov (ground waters) did not allow to develop oil shale industry as fast as the central government expected. Joining the Soviet Union gave the new hope, since the Russians believed that the Estonian oil shale chemists and engineers would help to solve technical issues arising in Russia while processing oil shale and developing large production.

Large-scale plans were also made in terms of expansion of the Estonian oil shale industry in the beginning of 1941. The plan was to start using 11 mines with the total volume of 11 million tons of oil shale per year by 1945, out of which 7.5 million tons were to be processed and turned into shale oil (1.25 million tons altogether). For example, the volume of oil produced only by the First Estonian Oil Shale Company was supposed to increase from 60,545 tons in 1939 to 250,000 tons in 1945. In 1945, 47,000 people were working in the mines and oil shale companies, which meant that it was necessary to built new dwelling premises for about 140,000 people.

Taking into consideration the general environment in those days, the implementation of unrealistic plans did not even start. The outbreak of the German-Russian war in June 1941 led to a fast retreat of the Russian troops from the territory of Estonia, and oil shale companies were taken over by the Germans. The supervision of operations of the Estonian oil shale companies was taken over by "Baltische Öl GmbH", the Tallinn office of which was headed by the former representative of I. G. Farbenindustrie in Estonia Claus von Kursell

(Picture 40). At the request of the Republic of Estonia, it was supervising the construction of the third and the fourth oil factories in Kohtla-Järve.

The Germans started the reconstruction of the oil shale industry, but the works were not at all active and intensive until spring 1943, when the invasion of the Russians at the Curonian Spit put an end to the dreams of the Germans to reach the petroleum fields of Baku. In order to satisfy the fuel hunger of the German military machine, the Estonian oil shale industry had to be revived. It was mainly achieved through the work of the prisoners of Vaivara system of concentration camps. The plans of the Germans to boost the production of shale oil were very ambitious. In 1943, 107,000 tons of shale oil was produced (Kohtla-Järve share amounted to 52,000 tons), and within the first seven months of 1944, 68,734 tons was produced. In total, 33,000 people were working for the oil shale industry in those times (18,000 of them were the prisoners of war of the Soviet Union).

The British saw certain threat from the Germans in terms of development of the oil shale industry in Estonia, because oil shale provided the Germans with the opportunity to supply their troops with fuel. In October 1942 Ronald Seth, who had been working in Estonia in the end of the 1930s, decided to voluntarily destroy the oil shale industry. He failed. But much more important is the fact that the airforce of the Soviet Union did not demolish the oil shale companies, although it could. The smoothly functioning industry was vitally important, from the point of view of the fact that Leningrad was in desperate need of power sources, since it was clear that the Germans would not stay in Estonia for any longer.

Development of the Oil Shale Industry in Kohtla-Järve and in the Soviet Union

By autumn 1944, the territory of Estonia was once again under the control of the Soviet Union. Initially, there was silence in terms of development of the oil shale industry. According to the plans, which had been made before the war, the production of shale oil was supposed to take place mainly in Estonia, while the gas had to be produced at a large oil shale gas complex in Slantsõ. The oil shale gas was supposed to reach Leningrad through the pipeline. However, large-scale destructions during warfare and the fact that the mines in Slantsõ were filled with ground water changed the situation drastically. The production of

shale oil in Estonia was not of high priority, from the point of view of the Soviet central administration. However, it was of primary importance to supply Leningrad, which survived through the siege, with fuel and power. In the 1920s, the Soviet engineers believed that the low fuel value of oil shale allowed to use it in a profitable way only on large gas industrial complexes, which combine the production of gas, crude oil, cement, and construction materials. It was seen as a possibility to resolve all of the problems with power and electricity supply in Leningrad. Taking into consideration the needs of Leningrad, it was of primary importance to produce household gas from oil shale, not shale oil. And it was this fact that Stalin was relying on, when he passed a resolution on 10 June 1045, which opened the sources of financing for the construction of oil shale companies in Estonia (Kohtla-Järve, Ahtme) and Slantsõ, mainly proceeding from the needs of Leningrad, but also of Estonia (picture 41). Taking into consideration the existing transport corridors and the distance of coal deposit from Leningrad, it was an economically feasible decision, from the point of view of the Soviet Union. Its importance is supported by the fact that the Estonian oil shale companies were transferred under the competence of central administrative board for artificial fuel and gas, which operated within the Council of People´s Commissars of the Soviet Union. In addition to that, the Estonian oil shale industry was supported by the fact that the prices for petroleum at the global market could not hinder the development of the industry under the new circumstances.

In 1944, the First Estonian Oil Shale joint-stock company was renamed into the First Estonian Oil Shale Company in Kohtla-Järve. On 12 April 1949, the oil shale company was named Kohtla-Järve Oil Shale Processing Industrial Complex (named after V. I. Lenin in 1960). It was in the First Estonian Oil Shale Company that the provision of, first of all, Leningrad (1948) and in 1952 also of Tallinn and the of Northern Estonia with oil shale gas started. While during war, the oil shale industry in Kohtla-Järve was mainly restored and expanded by the prisoners of war, after the war, labour force mainly consisted of the German prisoners. However, in the course of the expansion of industry, the labour force was mainly arriving from the interior territories of Russia, because the words *miner, extraction*, and *industry* occupied a special place in the national political rhetoric. They were handled accordingly, in spite of the fact that the people who came to Estonia had very different social background, were mainly women with small children, because men did not come back from war. In 1946, 1,862 people were

working at the oil shale processing factory in Kohtla-Järve (about one third of them were the prisoners of war), i.e. a little bit less than in 1940 in the whole national oil shale industry altogether (including the mines).

The technology of ovens with chambers, which was developed in the Soviet Union in the 1930s, was implemented in Estonia after the war, and in April 1947, the 9-chamber trial device was launched. The central government was in a hurry with the construction, because Leningrad needed Estonian gas. On 5 November 1948, in Kohtla-Järve, the first 46-chamber oil shale gas factory in the Soviet Union was completed with the first oven block (picture 43). At the same time, the oil shale gas was pumped through the recently completed pipeline to Leningrad. It included both the gas purification station and eight compressors with the capacity of 50 atmospheric pressure, produced by the American company Clark, so that the oil shale gas would be clean and reached Leningrad under required pressure. In order to launch the compressors, first electricity had to be switched off in the city, because otherwise there was not enough power. In the press, it was wisely not mentioned that gas compressors were manufactured in the capitalist West. In 1949, the second block of ovens at the gas factory was launched, and in 1951, the third block was launched, too. In spring 1953, the oil shale gas reached Tallinn and at the same time it also reached Kohtla-Järve. And still the household gas, which was used mainly for the purposes of Leningrad industrial companies and private households, within the first years after the completion of the pipeline was not free from hydrogen sulphide and gas petrol. That was achieved later only, as well as the smoothly operating gas plant, because the latter was built in a hurry and with errors in design. It was working until 1987. From 1960, the household gas from oil shale mixed with natural gas was mainly directed to the Estonian consumers, because in those days, Leningrad was only using natural gas.

The production of shale oil as well as adding value to its byproducts in comparison with the oil shale gas has not changed at Kohtla-Järve Oil Shale Processing Industrial Complex. In 1944-1947, the operation of the upright generators of the four oil factories was renewed (gas generator stations), and they managed to produce more shale oil than before the war. Increase in production was connected with the launch into operation of the fourth oil factory, which was not completed before the war. Similarly to the period before the war, the ash from the two first oil factories was initially removed by horses. In 1951, the fifth gas

generator station with twelve generators started producing about 125 tons of shale oil per day. In the end of the 1950s, the technological process at the old oil factories was improved (transfer to generators with cross-current heat exchanger) significantly, which allowed to carry on production successfully. In 1966, the culmination point was achieved. At the industrial complex, 3,556 tons of oil shale was processed into shale oil. This amount could neither be exceeded by the construction of the gas generator station with the capacity of 1,000 tons, built in 1981, nor by the sixth gas generator station which was commissioned in 1986, where two generators with the capacity of 1,000 tons were operating simultaneously (the production was ceased in 1998) (picture 43). In 1986, the construction of the seventh gas generator station started (four ring generators with the capacity of 1,400 tons per day), but it was not completed, since the situation changed.

In addition to upright generators, the oil production from tunnel ovens was attempted at the industrial complex, which were used before the war in Kiviõli and Sillamäe quite successfully. The tunnel ovens built by the Germans during war started operating in 1956. Unlike Pintsch generators, which ceased operation on 1985, the tunnel ovens were stopped in 1968. The reason was the commissioning of the plant for manufacturing nitrogen fertilizers, which, similarly to tunnel ovens, needed a lot of oil shale gas. It was hoped to get it from Pintsch retorts. Finally, the oil shale gas turned out to be too expensive to be used for the production of nitrogen fertilizers (it contained too much sulphur), and natural gas was put into use in the Soviet Union on a larger scale, which was flowing in the direction of Estonia from Leningrad through the pipeline build for oil shale gas.

The victorious march of natural gas in Kohtla-Järve forced to start looking for the new applications of oil shale and retorted oil shale gas. One of the options was to build an oil shale power station in the north-western part of the Soviet Union, which was poor in energy, and where Estonia also belonged. The second option was to develop the chemicals on the basis of oil shale at the factory. Shale oil was actively researched all over the Soviet Union and in different scientific institutions. Furthermore, in the 1930s, it was attempted to develop even further the products developed in the 1930s (e.g. impregnation oils, bitumen). There was also the search for different options for manufacturing synthetic petrol and diesel fuel, but those technologies were not launched into large-scale production. It was simply much easier to process petroleum. At the same time, in cooperation with the Oil Shale

Institute, founded at the Council for National Economy in the ESSR, during Khrushchev Thaw, it was attempted to introduce some new products at Kohtla-Järve Oil Shale Processing Industrial Complex, which was temporarily transferred from the Ministry for Petroleum Industry to the competence of the Council for National Economy of ESSR (1957-1965). In 1962, the natural gasoline pyrolysis equipment was put into operation. It allowed to introduce at the market benzol and toluene as well as resin adhesives (picture 44). The latter were produced on the basis of imported carbamide, formaline, and phenol, i.e. they did not have anything to do with adding further value to shale oil. Kohtla-Järve Oil Shale Processing Industrial Complex was partly turned into the petroleum processing plant. In the 1970s, Kohtla-Järve industrial complex was the largest oil shale chemicals producing company in the world, which was dealing with the development of automatic systems for boosting production, increasing its efficiency, and further development. The industrial complex included the power station working on the basis of oil shale, 23 departments supporting the operation of the industrial complex, and 50 different production departments, all of which were dealing with generating different products from oil shale. At the same time, more and more attention was paid to environment, and the construction of the purification station started. In total, in 1975, 4,322 people were working at the factory, with 3,625 of them working directly in production. In order to satisfy the needs of the employees, the industrial complex accommodated the canteen (for 150 people), the community house (for 600 people), dormitories (for 840 people altogether), the hospital with 50 beds, the kindergarten for 625 children, etc. In 1985, when the large benzoic acid department was completed, 5,386 people were working at the factory. It remained the industrial complex with the largest number of employees in history. From that time on, a slow but continuous decrease in the number of employees at the factory started. Besides, the statistical data proves that in the product range of the oil shale industrial complex, which was the largest in the world, the processing of petroleum started playing more and more crucial part, because the processing of oil shale was not profitable, and the price for fuel oil on the national level was low.

Development of the Oil Shale Industry in the Republic of Estonia and Participation of VKG

The restoration of independence of Estonia, public deterioration of relations between the Estonian and the Russian population, political reforms, and freedom from the economic area of the Soviet Union changed the situation at the industrial complex significantly both as an employer and as a manufacturer. There was a serious economic recession in the whole country, and the industry had to start looking in the direction of new markets. It was a difficult task for the industrial complex, because so far, petroleum and natural gas was obtained from the Russian market at a price that was significantly lower than the price on the global market. The largest share of end products was also exported to the East. However, it was not easy to cope in the new environment. In addition to that, the profitability of the production of shale oil became dependent on the price for petroleum on the global market.

Estonia was poor, but the oil shale industry had to survive at any cost, because the supply of the state with power depended on it. One of the possibilities to do that was to adjust prices on the national level. Such adjustment did not allow the oil shale industry to develop further, because there was not enough money for making investments into production.

In 1993, Kohtla-Järve Oil Shale Chemistry Industrial Group named after V.I. Lenin from 1978 became the National Kiviter Joint-Stock Company, which was under the competence of the Ministry of Economic Affairs (picture 45). The original name "Kiviter" was suggested by Ivar Rooks, the chronicler of the oil shale industry in Kohtla-Järve and the Chief Technology Officer of the company that deserved well of the industrial complex. The name Kiviter, which sounds well in Estonian ([burning]KIVI (stone)+ TER[type of processing]) characterized the operation process of the generator with cross-current heat exchanger, which was developed in Kohtla-Järve after the war. The name itself was derived in Moscow when it was patented in the Soviet times.

Under the conditions of the free market economy, many former subdivisions of Kohtla-Järve industrial group became independent (e.g. the nitrogen fertilizer plant). At the same time, the Ministry of Finance united other production units with Kiviter (e.g. in 1994, it was Eesti Kiviõli). In order to sustain Kiviter and the shale oil industry on a larger scale, the Committee for Oil Shale and Electricity Price operating under the Ministry of Finance, headed by the

academician Ilmar Öpik, was trying to keep the price for oil shale as low as possible. It was also found that the oil industry would be supported by joining with Kohtla-Järve central power station in financial terms.

Kiviter has itself also taken important measures for reducing its production costs and diversifying its range of products under the conditions of market economy. On 12 June 1996, the Estonian state put out the shares of Kiviter to tender, but the first privatization failed. On 12 December 1997, 50% of the shares of Kiviter were privatized. The year 1998 was very difficult for the company, because of the crisis in Russia and the subsequent decrease in the prices for petroleum. The production of oil shale had to be decreased considerably, and the national joint-stock company Eesti Põlevkivi, which was running the mines, had debts. In the end, the company went bankrupt, and instead of Kiviter, the A/S Viru Keemia Grupp (VKG) was established (picture 46).

It was not easy for VKG to start: the production of shale oil was ineffective, and a large number of trained staff left the company after it went bankrupt. Moreover, the company had to work under completely unfamiliar circumstances, i.e. to compete with petroleum products at the global market, and the increasing attempts of other European countries at reducing air pollution also had to be taken into consideration. Consequently, putting production back into operation required considerable investments. From 2001, the investment capacity of VKG has increased, and gradually, all structural units that had belonged to Kiviter before it went bankrupt were put back into operation (except for the sixth gas generator station, which was abandoned and emptied of the equipment containing metal). In 2005, VKG made the first investment in development, and four new generators were installed at the fifth gas generator station.

The year 2005 should be regarded as the beginning of large-scale investments within the group. The company concentrated, just like the former state oil shale company, on the production of shale oil, not power or thermal energy, being 100% sure that bringing additional value to oil shale is of primary importance. In order to achieve that aim, it was necessary to increase the reliability of the equipment used in the oil shale industry, and at the same time to reduce the ecological footprint that appears in the result of the processing of oil shale. The aims for 2005: environmental protection, increased efficiency of processing

oil shale into shale oil, and using the energy generated in the result for the production of power and thermal energy. All of those projects paid off completely. Besides, a lot of time and money was invested at VKG into adding further value to shale oil. The tests carried out in different laboratories proved that it is possible to obtain valuable individual compounds (phenols) with the high level of purification, which are widely used all over the world, from oil shale. It was already in 1981 that the phenol rectification equipment was commissioned, and the trial batches of 5-methylresorcinol were produced there. In the beginning of the 2000s, this project was facilitated once again, and the production of fine chemicals on the basis of shale oil started on a larger scale. In addition to that, the group was planning to join the production of oil shale with the production of cement and construction materials. In autumn 2008, the German engineer Jürgen Hilger started implementing the project. The global economic recession and the explosion of the "bubble" at the real estate market in Estonia put a stop to the project aimed at the construction of the cement plant.

The global economic recession and a sudden drop in the prices for petroleum in the end of the 2000s retarded the development of VKG considerably and made the economic situation very unstable, because from 2007, the group was building its first Petroter plant. The name PETROTER was a sign of respect to the long-term chairman of the management board of VKG Oil Nikolai *Petro*vitš as well as to the engineers who were working together with him and developed the technology of *ther*mal processing of oil shale. In spite of major difficulties, the construction of environmentally-friendly oil production plant Petroter was not ceased not for a single moment, but in order to achieve the aim that had been set, the group sacrificed a number of other environmental and development projects. During crisis, the number of employees at the group diminished significantly, from 1,500 to 1,200 employees.

Concentration on one single aim proved to be successful, and on 21 December 2009, the Petroter plant was opened in the presence of the President of the Republic of Estonia Toomas Hendrik Ilves. It was already in June of the following year that Petroter achieved full capacity, which allowed to build the second and the third Petroter plants in August 2012 and October 2013 respectively.

The increasing shale oil production capacities required to resolve the problems connected with raw material. The national joint-stock company Eesti Energia, which owned the mines

of the former national joint-stock company Eesti Põlevkivi, was not ready to provide the sufficient amount of oil shale for the increasing oil production. It brought VKG to the construction of its own mine at Ojamaa mining field, which was purchased in 2004, and the mining permit was applied for two years later. The construction works at Ojamaa mine started in July 2009, and the production process at the most advanced oil shale mine in Estonia started in August 2012 (the first chamber block was completed). Over 120 million EUR was invested for that purpose. The opening of Ojamaa mine took place on 31 January 2013. In his speech, the President of the Republic of Estonia Toomas Hendrik Ilves thanked all of the VKG employees and stressed that "/…/ nowadays, oil shale is the main source of energy in Estonia, and it is definitely going to remain an important energy source in the visible future. If we learn to value oil shale better and in a more diverse way than before, taking care of the environment at the same time, we will be acting wisely. I am extremely pleased with the fact that VKG is one of the leading companies in this field, and I hope that very soon we will be able to produce our own Estonian diesel fuel from Ojamaa oil shale. Let´s honour the miners and engineers who made their contribution into the opening of the new mine. Thanks to you, the homes in Estonia are warm and bright, and the e-riik is functioning smoothly. Thanks to you, Estonia is one of the countries that is the least dependent on the import of power from the European Union, but this is already the issue of safety and independence of Estonia".

By its 90th anniversary, the oil shale company operating in Kohtla-Järve under the name of VKG has been holding strong positions in terms of economic development, with its own strategy and excellent future prospects. Large-scale investments into industrial development, the environmental protection and social responsibility have boosted the importance of the company not only as the largest employer in Kohtla-Järve, but also within the economic structure of the entire Republic. Today, VKG contributes into the state budget over 40 million EUR per year and about 0.73% into the Estonian GDP. This year the number of employees at VKG exceeded 2,100 people. Over half of them are working in the most important and profitable departments of the group: VKG Oil and VKG Kaevandused (manages Ojamaa mine).

Conclusion

The Estonian oil shale industry has been developing for over 90 years. It would have been a much more challenging process without the technological assistance of Germany and Russia, and without the subsidies of the Republic of Estonia for the development of its national industry both in the 1920s and in the 1990s. The fact that in the Soviet Union the price for petroleum never directly hindered the development of the oil shale industry is of equal importance. On the other hand, if it was not for the Estonians Juhan Kukke, Märt Raud, Karl Luts, Paul Kogerman and many others, who believed in the future of oil shale in Estonia, there would not have been any development in this field at all. The unshakable trust in the future of the oil shale industry and the contribution of the people working in the field of the oil shale industry, from the miners who originated from the troops of Yudenich to the population brought here in the times of the Soviet Union for economic and political reasons, enabled the Estonian oil shale industry to develop. It has never been painless for Estonia, neither from the aspect of environmental, not national policy. But we must not forget that there have always been people behind all of the developments in the field of the oil shale (shale oil) industry, who have facilitated the development of the Estonian economy and the provision of energy security, which is the most important thing. Today, as exemplified by VKG, it seems that the production of oil shale, which started on industrial scale 90 years ago, has definitely paid off, and the group, just like Kohtla-Järve industrial complex in the 1980s, holds the leading role in the field of chemicals on the basis of oil shale on a global scale, and it is the second company in the world in terms of production volumes. This position was achieved within the context of turbulent business environment, which to a large extent depends on political and environmental decisions and on the price for petroleum at the global market. The history of the Estonian oil shale industry is a vivid prove of that.

The article is mainly based on the materials from Tallinn City Archive (the Estonian Knighthood), the Estonian National Archive (Märt Raud, the Ministry of Trade and Industry, the mining department), the Estonian Historical Archive (Hendrik Bekker, Paul Kogerman), the Oil Shale Museum (Karl Luts), the Nordostdeutsches Institute (Otto Petersen), the Geozentrum Archive in Hannover, and the National Russian Historical Archive (the Geology

Committee and the Ministry of Trade and Industry). I would like to thank Julia Piilmann and Õnne Pilvet from VKG, Õnne Song and Ainar Varinurme from the Oil Shale Museum, my father-in-law Jaak Leimann, and the member of the Council of VKG Jens Haug for providing assistance in writing this article.

Reference literature

A/S esimene Eesti põlevkivitööstus endine Riigi Põlevkivitööstus. Tagasivaade tööstuse tegevusele ja saavutustele tööstuse XX aastapäeva puhul 25. 11. 1938. Tallinn: A/Si esimene Eesti Põlevkivitööstuse Kirjastus.

Bekker, Hendrik 1919. Pae seinast ja Kukruse „põlevast kivist". Geoloogiline katkend. – *Sirvilauad*, 1–16.

Beyschlag, Franz, Mühlen von zur, Leo 1918. Die Bodenschätze Estlands. – *Zeitschrift für praktische Geologie*, 26(10): 141–150.

Helmersen, Gregor von 1838. Über den bituminösen Tonschiefer und ein neuentdecktes, brennbares Gestein der Übergangsformation Ehstlands, mit Bemerkungen über einige geologische Erscheinungen neuerer Zeit. – *Bulletin scientifique publié par l'Académie Impériale des Sciences de Saint-Pétersbourg*, 5(4–5): 56–73.

Johannson, Willem 1898. Põlewast kiwast. – *Postimees*, nr. 26, 02. 02. 1898.

Kogerman, Paul 1931. *On the chemistry of the Estonian oil shale "Kukersite"*. Tartu: Mattiesen.

Kogerman, Paul 1948. *Eesti põlevkivi ja selle rahvamajanduslik tähtsus*. Tallinn: Poliitiline Kirjandus.

Luts, Karl 1934. *Der estländische Brennschiefer-Kukersit, seine Chemie, Technologie und Analyse*. Tartu: Mattiesen.

Luts, Karl 1929. Miks areneb meie õlitööstus aeglaselt. – *Eesti Keemikute Seltsi Album seltsi 10 aasta juubeli puhul*. Tallinn, 40–43.

Maasalu Sandra 2012. *Eesti põlevkivi ja Saksamaa – sügis 1941 kuni sügis 1944*. Tartu, Master´s thesis.

M.[ickwitz], A.[ugust von] 1898. Nochmals der sog. „brennende Stein" bei Jewe. – *Revalsche Zeitung*, Nr. 31, 07./19. 02. 1898.

Mühlen von zur, Leo 1921. Die Ölschiefer des europäischen Russlands. – *Osteuropa in Breslau. Quellen und Studien*. Leipzig und Berlin: Teubner, dritte Abtheilung, 4. Heft.

Raud, Märt 1925. *Põlevkivi ja põlevkivi-tööstus Eestis*. [Tallinn]: Riigi Põlevkivi-tööstus.

[Raud, Märt] 1928. *Riigi põlevkivitööstus 1918–1928. Tagasivaade tööstuse tegevusele ja saavutustele tööstuse X aastapäeva puhul 25. XI 1928*. Tallinn: Riigi Põlevkivitööstuse Kirjastus.

Riigi põlewkiwitööstus 25. novembrist 1918 kuni 25. novembrini 1923. Tallinn: Eesti Päevaleht.

Riigi põlevkivitööstus 1918–1933. Andmeid tööstuse tegevuse ja saavutuste üle tööstuse XV aastapäeva puhul 25. XI 1933. Tallinn: Riigi põlevkivitööstuse kirjastus.

Rooks, Ivar. 2004. *Esimesest Eesti põlevkivitööstusest Kiviterini. 1938–1998. Mälestused ja faktid*. Kohtla-Järve: OÜ Mark ja Partnerid.

Schamarin, Alexander 1870. *Chemische Untersuchung des Brandschiefers von Kuckers*. Dorpat: Laakmann.

Schmidt, Friedrich 1858. Untersuchungen über die Silurische Formation von Ehstland, Nord-Livland und Oesel. – *Archiv für die Naturkunde Liv-, Ehst- und Kurlands*, I. Serie, Bd. 2.

Schmidt, Friedrich 1881. Revision der ostbaltischen silurischen Trilobiten nebst geognostischer Übersicht des ostbaltischen Silurgebietes. Abth. I. *Phacopiden, Cheiruriden, Encrinuriden*. – *Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg*, VII. Serie, 30(1).

Schmidt, Friedrich 1882. On the Silurian (and Cambrian) Strata of the Baltic Provinces of Russia, as compared with those of Scandinavia and the British Isles. – *Quarternal Journal of the Geological Society of London*, 38(152): 414–436.

Schröter, Eberhard Johann 1791. Anzeige der Ursachen der Kälte einigen Wohnzimmer und instruktive Anweisungen wie die in St. Petersburg wegen Holzsparung u.s.s. gut befundenen Stubenöfen zu bauen sind. – *Auswahl ökonomischer Abhandlungen, welche die freie ökonomische Gesellschaft in St. Petersburg in deutscher Sprache erhalten hat*, 3: 173–202.

Sepp, Mait; Pae, Taavi; Tammiksaar, Erki, 2013. Kuidas avastati Eesti põlevkivi? Esmamainimisest esmakasutamiseni. In: Järvet, A. (toim.) *Eesti Geograafia Seltsi Aastaraamat*, 38. Tallinn: OÜ Vali Press, 93–118.

Seth, Ronald. 1957. *Langevarjurina Eestis*. Toronto: Estoprint.

Tammiksaar, Erki. 2013. Põlevkivitööstuse algus Eestis – eeldused ja põhjused. Ajalooline sissevaade. — *Akadeemia*, 25(1–2): 15–48; 278–309.

Tammiksaar, Erki. 2014. The birth of the Estonian oil shale industry – links to Russia and Scotland. – *Oil Shale*, 31(2): 195–206.

Tammiksaar, Erki, Pae, Taavi 2012a. Esimene eestlasest põlevkiviuurija – Wilhelm Johanson. – *Eesti Loodus*, 11: 18–23, 25,

[Tammiksaar, Erki, Pae, Taavi] 2012b. Tolli kraav. – *Eesti Loodus*, 11: 24.

Tammiksaar, Erki, Pae, Taavi 2012c. Eestlaste esimesed kogemused põleva kiviga. – *Eesti Loodus*, 12: 22–26.

Varb, Nikolai, Tambet, Ülo. 2008. *90 aastat põlevkivi kaevandamist Eestis*. Tallinn: GeoTrail KS.

Valge, Jaak 1995. Riikliku põlevkivitööstuse majandamistingimused ja -tulemused 1920. ja 1930. aastatel. – *Akadeemia*, 7(8–9): 1712–1740; 1929–1949.

Volkmann, Hans-Erik 1976. Ökonomie und Machtpolitik Lettland und Estland im politisch-ökonomischen Kalkül des Dritten Reiches (1933–1940). – *Geschichte und Gesellschaft*, 2(4): 471–500.

Von einer feuerfangenden Erde aus der Revalschen Stadthalterschaft. – *Auswahl ökonomischer Abhandlungen, welche die freie ökonomische Gesellschaft in St. Petersburg in deutscher Sprache erhalten hat*, 3: 330–331.

Winkler, Henry von 1920. *Über Umfang und Abbauwürdigkeit estländischer Bodenschätze*. Greifswald: Ratsbuchhandlung L. Bamberg.

Winkler, Henry von (Red.) 1930. *Der Estländische Brennschiefer: Untersuchung, Gewinnung und Verwertung*. Reval: Wassermann.

Ülevaade Eesti põlevkivi tööstusest. (Põlevkivi tööstuse juhataja M. Raud õliajamise vabriku hoone nurgakivi panekul). – *Postimees*, 23. juuni 1922, nr. 139.

Wistinghausen, Henning von 1993. *Zwischen Reval und St. Petersburg. Erinnerungen von Estländern aus zwei Jahrhunderten*. Weissenhorn: Konrad Verlag.

Zeidler, Rudolf 1933. *Neue Wege der Verwertung des Ölschiefers und seiner Umwandlung in Öle*. Reval:Kluge.

Алексеев, Павел 1878. О балтийском горючем сланце и сравнении его с Олонецким антрацитом и другими горючими материалами близ С.-Петербурга. – *Записки Императорского Русского технического общества*, 1: 26–39.

Годовые отчеты по испольненным работам, не предусмотренным программой. – *Известия Геологического Комитета*, 37(1): 364–365.

Вальгис, Владимир 1917. Светильный газ из сланцев. – *Бюллетень освед.-стат. Отд. Бюро при Химич. Отд. Петроградского Комитета Военно-технической помощи*, 10: 372–373.

Геккер, Роман 1971. Повесть о Николай Федоровиче Погребове. – *Ученые Геологического Комитета. Очерки по истории геологических знаний*, 13: 60–107.

Залесский, Михайл 1917. О морском сапропелите силурийского возраста, образованном синезеленой водорослью. – *Известия Петербургской Академии наук*, Serie VI, 1: 3–26.

Журнал Присутствия Геологического Комитета заседание 12-го октября 1910 года. – *Известия Геологического Комитета*, 29(9): 200–218.

Материалы для библиографии горючих сланцев. (Иностранная литература по вопросу исследования и применений горючих сланцев). – *Нефтяное и сланцевое хозяйство*, 1(4–8): 154–163.

Кузнецов, Дмитрий Трофимович 1960. Очерки развития сланцевой промышленности Эстонской ССР. Ленинград: Гостоптехиздат.

Левыкин, Виталий Васильевич. 1947. *Горючие сланцы Прибалтики (геология, гидрогеология, условия эксплоатации)*. Ленинград-Москва: Ленгостоптехиздат.

Новый горючий материал в Прибалтийском крае. Торг.-П.Газ. – *Вестник прикладной химии и химической технологии,* 1(5): 308.

О возгараюшей земле из Ревельскаго наместничества. – *Труды Вольного Экономичекого обшество*, 45(15): 350–353.

Обзор деятельности Тепловой Комиссии. In: *Материалы по обзору деятельности особого Совещания по топливу за первый год его существования*. Т. 1 (минеральное топливо). Петроград, 1917, с. 104–109.

Пальчинский, Петр 1926. Прибалтийские горючие сланцы (куккерсит) и их использование в Эстонии и у нас. – *Поверхность и недра*, 4(10–12): 45–51.

Погребов, Николай 1919. Прибалтийские горючие сланцы. In: *Естественныя производительные силы России. Полезныя ископаемыя, составлен Геологическим Комитетом*. Т. IV. № 20, с. 288–323.

Погребов, Николай 1923а. Несколько слов о месторождениях кукерсита в Эстонии. – *Нефтяное и сланцевое хозяйство*, 4(4–5): 685–687.

Погребов, Николай, Кинд, В. А. 1920. Литература по Прибалтийским горючим сланцам. – *Нефтяное и сланцевое хозяйство*, 1(4–8): 152–153.

Протокол заседания Отделения геологии и Минералогии, 08 мая 1910 г. – *Труды Императорского С.-Петербургского Общества Естествоиспытателей*, 49, вып. I, № 5–6: 218–219.

Фокин, Леонид 1913. О строении и продуктах битуминозных горных пород Эстляндии. – *Горный Журнал*, 2(5): 117–142.

Функ, Карл 1869. Открытие залежей гуано в Эстляндии. – *Земледельческая газета*, (35)27: 420–421.

Шмидт, Федор 1879. Взгляд на новейшее состояние наших познаний о силурийской системе С.-Петербургской и Эстляндской губерний и острова Эзеля. – *Труды С.-Петербургского общества естествоиспытателей*, 10: 42–48.

Яцевич, Михайл 1917a. О состоянии работ по разведке и исследованию горючего сланца южн. Побережья Финск. Залива. – *Известия особого Совещания по топливу*, 2: 31.

Яцевич, Михайл 1917b. О переработке горючих сланцев в Шотландии. – *Известия Особого Совещания по топливу*, 3: 84–85.