



**ESTONIAN
OIL SHALE INDUSTRY
YEARBOOK 2019**

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**ESTONIAN OIL SHALE
INDUSTRY YEARBOOK
2019**

Statements from heads of companies and organizations in the oil shale industry . . .	6
The role of the oil shale industry in the economy.	9
Operational framework in Estonia 2019.	13
Mining	19
Liquid fuels	25
Electricity	31
Heat	35
Fine chemicals and by-products	39
Oil shale industry and environment	45
Science-based industry	53
Contribution to education and the community.	61

Year 2019 in the Estonian oil shale industry:

Revenue to the Treasury

121

million EUR

Total investment

70

million EUR

Investments in the environment

21

million EUR

Jobs for

6530

people

Sales revenue

725

million EUR

Year 2018 in the Estonian oil shale industry:

Revenue to the Treasury

122

million EUR

Total investment

116

million EUR

Investments in the environment

55

million EUR

Jobs for

7303

people

Sales revenue

772

million EUR

Year 2017 in the Estonian oil shale industry:

Revenue to the Treasury*

104

million EUR

Total investment

70

million EUR

Investments in the environment

31

million EUR

Jobs for

7387

people

Sales revenue

663

million EUR

Year 2016 in the Estonian oil shale industry:

Revenue to the Treasury

103

million EUR

Total investment

63

million EUR

Investments in the environment

26

million EUR

Jobs for

6400

people

Sales revenue

606

million EUR

Year 2015 in the Estonian oil shale industry:

Revenue to the Treasury

120

million EUR

Total investment

199

million EUR

Investments in the environment

82

million EUR

Jobs for

7411

people

Sales revenue

669

million EUR

Year 2014 in the Estonian oil shale industry:

Revenue to the Treasury

174

million EUR

Total investment

266

million EUR

Investments in the environment

42

million EUR

Jobs for

6683

people

Sales revenue

933

million EUR

* Includes the adjusted total of KKT's resource and pollution charges

** Eesti Energia's calculation of jobs is based on new grounds from 2017, also taking into account the company's Central Services and Enefit Solutions

Statements from heads of companies and organizations in the oil shale industry



Hando Sutter

Chairman of the Management
Board of Eesti Energia

The focus is on the development of liquid fuels and the circular economy

The year 2019 was controversial for the oil shale sector. A record low amount of electricity was produced from our main mineral resource. As a result, Estonia became the fastest carbon footprint reducer in Europe, and we are well ahead of our climate goals. It is pleasing that the production of shale oil reached the highest level in history.

To ensure sustainability, we are following the strategy of switching from direct oil shale combustion to cogeneration of oil, gas and electricity, which will be confirmed by the construction of a new oil plant to be completed by 2024. Supported by this, Eesti Energia's annual oil production will grow by more than 700,000 tons per year. At the same time, our technology enables the recycling of waste tyres and po-

tentially waste plastics as well during shale oil production, thus enabling environmental issues to be addressed in the circular economy. There is already cross-border interest in this, which has given us the opportunity to become a partner for Turkish and Israeli companies.

As global demand for oil products is going to grow in the long run, oil production from oil shale will remain competitive for the next 20 years. This is a sign that we must continue to work with universities and keep an eye on technological developments, be it capturing carbon at a reasonable cost or something else. Estonian research can make a significant contribution to the preservation of our industry and to increasing its competitiveness.



Ahti Asmann

Chairman of the Management
Board of Viru Keemia Grupp

Openness and development make a solid foundation during challenging times

The year 2019 caused mixed feelings. The increase in demand for the relatively low-sulphur shale oil from Estonia due to the introduction of the Sulphur Directive for marine fuels was positive. The business was complicated by the usual volatility of the petroleum market, rising CO₂ prices, and the great uncertainty about the future of shale oil production caused by the European Green Deal in the last hour of the year. Some uncertainty is inevitable in business, but ambitious climate goals, combined with a lack of knowledge about how to achieve them, have made it very difficult to predict and mitigate the risks arising from environmental policies. We hope that 2020 will bring a clear balanced national climate strategy with intermediate stages until 2050, which, in addition to environmental ambitions, will take into account the economic and socio-economic aspects at national level.

For Viru Keemia Grupp, 2019 was a year of developing stable production activities - we continued to cooperate with the community to maintain the quality of the living environment, and development work with research institutions in search of new and environmentally friendly solutions. The work done on various development projects provides a basis for confirming that over the next ten years we will be able to reduce our CO₂ emissions by 20-40% compared to today.

At the time of completing this yearbook, the world is quietly exiting from two crises - COVID-19 and the drastic fall in oil prices of the current century. The real consequences are likely to be greater than we might think, but our group's values - openness, commitment and development - are a strong foundation in times of uncertainty.



Priit Orumaa

Chairman of the Management Board of Kiviõli Keemiatööstus

Increasing reliability and efficiency during revolutionary times

The year 2019 was revolutionary for the oil shale industry, but difficult - rising CO₂ quota prices, stricter environmental requirements and unstable situation in the petroleum markets affected everyone. Quick ways need to be found to expand the range of raw materials in order to survive in ever-changing circumstances. We conducted several successful experiments to find suitable waste as raw material for SHC oil. The future of Kiviõli Keemiatööstus largely depends on how quickly we can obtain the necessary environmental permits from the authorities for such changes.

We were engaged in increasing the efficiency and reliability of our production. Changes in the SHC staff resulted in a longer operating period of the equipment than before, a larger and higher-quality oil production volume. Overhauls of several generators on the generator unit also increased the reliability of the installation. As a result of the changes and repairs, we achieved the largest oil production volume of recent years.

Of new environmental projects, we started preparations for the transfer of the thermal power plant to natural gas and for the construction of a new heavy oil purification unit. In order to increase the long-term security of supply of the company's raw materials, we submitted an application for a geological exploration permit for the Uljaste exploration area, focusing mainly on the environment.

We continue to contribute to our employees - we have created Alexela's common values and we try to follow them together in our daily activities. Our efforts show a desire to preserve and value Estonia's important mineral resource, to continue to create and develop new and modern jobs and working conditions, without forgetting that our plant has survived the storms of the economy and provided employment to the people of the region for almost a hundred years.



Kalle Pirk

Head of the Oil Shale Competence Centre at TalTech Virumaa College

The oil shale sector is moving in the winds of change and innovation

The year 2019 can be briefly summed up with the title of the XI Oil Shale Conference - Winds of Change. The European Green Deal introduced at the end of the year is one of the important factors in shaping the future of the Estonian oil shale industry. Certainly, in the context of this deal, the main issue cannot be to set a deadline for the cessation of the use of oil shale. The wider role of the oil shale sector in supporting change and sustainable development in the conditions of new and emerging regulations are more important. Innovation, the search for new solutions and their implementation is nothing new for oil shale companies, researchers in the field and companies in other sectors. The focus is on various directions - reducing the CO₂ footprint, improving the quality of shale oil, enhancing the value of kerogen, the possibilities of using oil shale ash, etc.

One of the outputs of the research on the capture and use of CO₂ for the purpose of reducing emissions is the possibility to plan the use of both residual heat and CO₂ in the

construction of the Auvere agropark. In the production of liquid fuels, the suitability of adding waste tyres to the shale oil production process has already been proven. Based on the utility model registered in 2019, the by-products of the oil shale industry (ash, waste rock) are suitable additives for the processing of various plastic waste into liquid fuels. This discovery by Tallinn University of Technology researchers allows the oil shale industry to participate even more in the processes of the circular economy.

The know-how in the field of oil shale acquired in Estonia is also applied abroad - the specialists of the Virumaa College of TalTech participated in the launch of an accredited laboratory dealing with product quality control in the world's largest oil shale quarry in Jordan. We can state that research and development activities in the oil shale sector continue, companies from other industries are involved in it, and the know-how is still in demand elsewhere in the world.



Year 2019 in the Estonian oil shale industry:

Revenue to the Treasury

121

million EUR

Total investment

70

million EUR

Investments in the environment

21

million EUR

Jobs for

6530

people

Sales revenue

725

million EUR

Compared to 2018:

Oil shale
production

+5,8%

Export of fine chemical and
phenol products

+18%

Oil shale industry
CO₂ emissions

-39%

Oil shale mining

-24%



THE ROLE OF THE OIL SHALE INDUSTRY IN THE ECONOMY

THE ESTONIAN OIL SHALE INDUSTRY IN FIGURES IN 2019:

	Sales revenue (millions of EUR)	Average number of employees	Oil shale mined (thousands of tonnes)*	Tax footprint (millions of EUR)**
Companies related to Eesti Energia's oil shale industry	391 718 192	4 069	7 457 572	76 591 000
Viru Keemia Grupp	256 762 706	1 710	3 520 549	32 520 391
Kiviõli Keemiatööstus	34 941 212	581	1 084 058	7 639 244
Kunda Nordic Tsement	41 859 782	170	65 000	4 257 210
TOTAL	725 281 892	6 530	12 127 179	121 007 845

* Includes the company's central services

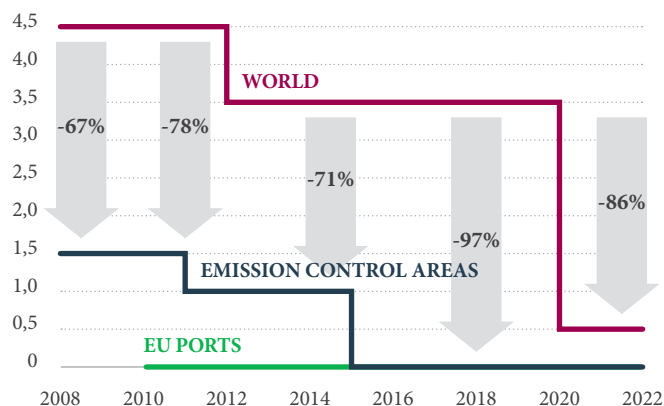
** Workforce taxes, resource and pollution charges, corporate income tax, customs duty, land tax

Estonian revenue from the oil shale industry

In the year 2019, full of change, the Estonian oil shale industry was able to evolve and produce a record amount of shale oil, supply the country with electricity produced from oil shale, participate in the circular economy with its by-products, develop science, contribute to the environment and the community.

In 2019, the contributions of Eesti Energia (EE), Viru Keemia Grupp (VKG), Kiviõli Keemiatööstus (KKT) and Kunda Nordic Tsement (KNT) to the Treasury totalled over EUR 121 million, which is similar to 2018. The state received the largest tax revenue from oil shale industry companies from the salaries of 6,530 people - a total of 42 million euros - and 70 million euros from environmental charges. The average monthly salary of employees related to the oil shale industry in 2019 was EUR 1,663.

CHANGES IN THE SULPHUR LIMIT 2008-2022



Oil shale products for export

According to Statistics Estonia, goods worth 14.4 billion euros were exported from Estonia in 2019, equal to the previous year. Estonian shale oil exports help to balance the import market of transport fuels, as 99% of the produced shale oil is sold to other countries. In 2019, the three companies in our oil shale industry again produced more than one million tons of shale oil, a total of 1.17 million tons. The total volume of annual oil production increased by 5.8% or by 64 thousand tons compared to the previous year.

Rising CO₂ quota prices and low electricity prices have accelerated the changes in the oil shale sector. The main factors influencing the price of electricity in the Nord Pool market in 2019 were the large amount of cheap Norwegian hydropower and electricity produced in third countries, the price of which does not take into account quota fees. The electricity price of 55.76 euros per MWh at the beginning of 2019 dropped to 29.05 euros per MWh by the end of the year.

Since 2013, Estonia has been the country in Europe with the lowest dependence on energy imports, largely due to oil shale energy. Due to the changed carbon tax policy, Estonian electricity exports in 2019 were 2.7 TWh, which was 54% less than in the previous year. At the same time, electricity imports increased by a third in 2019, reaching 4.7 TWh, which was 36% higher than in 2018. In 2019, nearly 4.9 TWh of electricity was produced in Estonia from oil shale and oil shale gas, i.e. 65% of the electricity produced in the whole country.

In 2019, VKG produced more than 1,500 tons of fine chemical and phenolic products and exported for 2.6 million euros, which is 18% more than in 2018.

More than 70 million in innovation and research

Several developments in new technologies, and projects to increase production efficiency and environmental sustainability were implemented in 2019. Companies alone invested more than 70 million euros in innovation and development in 2019, of which 21 million were investments in the environment. In addition to universities and research and development funding, the companies invested 6.5 million euros in research activities, which makes 37% more than last year.



It is possible to achieve the smoothest possible shale transition through the cooperation of entrepreneurs and higher education institutions. Science, education, and innovation are at the core of the questions about the future of oil shale power engineering. Ida-Virumaa has excellent conditions for making a significant contribution to the shale transition, as three higher education institutions and a Vocational Education Centre are located here.



Mare Roosileht
Director of Virumaa College,
Tallinn University of Technology





OPERATIONAL FRAMEWORK IN ESTONIA 2019

Exemption of oil shale ash from hazardous waste

The classification of oil shale ash as hazardous was due to the content of lime (free CaO) and crystalline quartz (SiO₂) exceeding the limits. The study of hazardousness of oil shale ash conducted by researchers from Tallinn University of Technology and University of Tartu in 2019 (supported by the Environmental Investments Centre) proved that oil shale ash does not differ negatively from coal ash. Based on the calculation results taking into account the content of heavy metals, the team of researchers concluded that oil shale ash was not hazardous for the environment. As a result of the survey, the hazardous waste codes for oil shale bottom ash and oil shale fly ash were removed from the waste list, and the hazardousness of these waste products no longer needs to be separately assessed.

Although many products made from oil shale ash have been standardised in previous years, the exemption of oil shale ash from the list of hazardous waste allows for more efficient and greater use of it as a building material, in cement and concrete production, in agriculture, in the production of other construction materials and plastics, and in road construction. The exclusion of oil shale ash from hazardous waste improves Estonia's position in the hazardous waste statistics of the European Union, as in other member states the ash generated during the combustion of fossil fuels was not included in the list of hazardous waste.

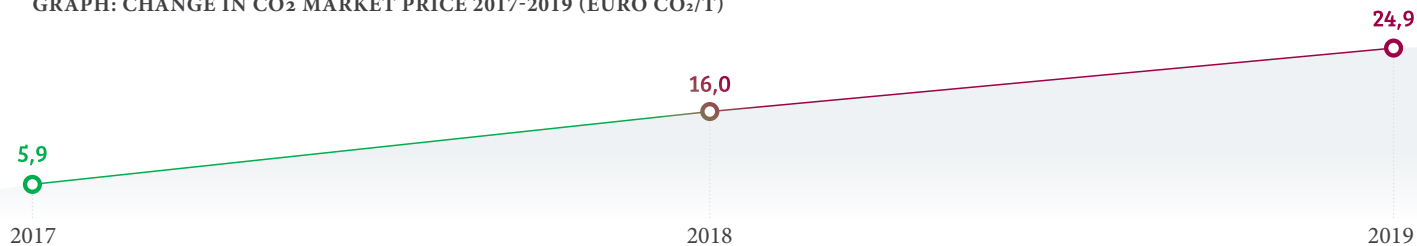
Greenhouse gas emissions have fallen

The greenhouse gas emission allowance trading scheme is a tool for reducing emissions in the European Union. This is a political agreement between the member states to combat global warming. The number of CO₂ units in the market is constantly declining, leading to an increase in the price of a unit of carbon dioxide.

From 2021, the total amount of greenhouse gas units will be reduced by 2.2% per year instead of the previous 1.74%. The European Union aims to reduce CO₂ emissions in the sectors covered by the EU emissions trading system by 43% by 2030 compared to the levels of 2005. In addition to the fact that the number of units in the market is going

to decline faster, fewer and fewer free units will be allocated to the sectors in the carbon leakage list each year, and it is possible that free allocation of emission allowances will end after 2030. Rising prices will encourage companies to invest in more efficient production and reduced greenhouse gas emissions. At the beginning of 2019, the average price of emission rights for a tonne of CO₂ was less than 10 euros, but from February about 20 euros per tonne. The average market price was 24.7 euros CO₂/t on average in 2019, while a year earlier it was only 15.6 euros CO₂/t. The highest price of the year was recorded on 29 July - EUR 29.10 per tonne.

GRAPH: CHANGE IN CO₂ MARKET PRICE 2017-2019 (EURO CO₂/T)

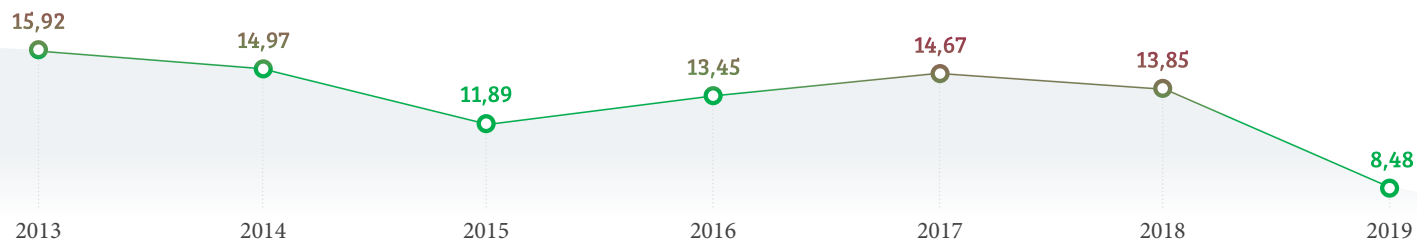


Source: Environmental Board

Estonia's share of greenhouse gas emissions is very small on a global scale. Among the European Union member states, Estonia's share of greenhouse gas emissions is approximately 0.5 percent. In 2019, CO₂ emissions from Estonian installations included in the European Union greenhouse gas emission allowance trading system decreased by 38.7% compared to the previous year. The CO₂ emissions of four

companies in the oil shale industry were 8.1 million tons, which means a reduction almost 40% in a year. Compared to 2013, CO₂ emissions in Estonia have been reduced by 46.7% in the 48 companies belonging to the trading system. With this, Estonia has achieved the goals of 2030 in advance.

GRAPH: CO₂ EMISSIONS FROM ESTONIAN INSTALLATIONS BELONGING TO THE EUROPEAN UNION GREENHOUSE GAS EMISSIONS TRADING SCHEME 2013-2019 (IN MILLION TONNES)



Source: Environmental Board

Limitation of the sulphur content of marine fuels

At the end of 2016, the International Maritime Organisation approved the MARPOL (International Convention for the Prevention of Pollution from Ships) regulation amendment, which limits the sulphur content of marine fuels used in the world's oceans. From the beginning of 2020, the level of sulphur in marine fuels must not exceed 0.5% instead of the former 3.5%. Approximately 99% of shale oil production is sold to major players in the global fuel market, who use shale oil as a component in the production of marine fuel. The average sulphur content of shale oil produced in Estonia is 0.8%, which is why it is considered a low sulphur fuel oil (LSFO 1%S) based on its sulphur content.

Charge rates for oil shale mining rights

At the end of 2018, changes in the charge rates for the right to extract state-owned mineral resources came into force. The regulation established charge rates for the right to mine oil shale for an indefinite period. If the price of heavy fuel oil with 1% sulphur content is below the world market average by 241 up to above it by 650 euros/ton (as quoted in Rotterdam), the charge rate for oil shale mining rights is 0.275–10.00 euros/ton, respectively. Until 31 December 2018, the charge rate for oil shale mining rights for heavy fuel oil with a sulphur content of 1% priced below by 241 to above by 431 euros/ton on average was 0.275–2.21 euros/ton. The average price of heavy fuel oil in 2019 ranged from EUR 336 to 361 and the charge rate for mining rights was 1.255–1.78 euros per tonne.

Changes in mining rules

From the beginning of 2019, several amendments to the Earth's Crust Act entered into force. The list of activities permitted under a mining permit was extended and these activities must be written down in the mining or reclamation project. It is no longer necessary to submit a separate report on land damaged and reclaimed by mining, but it is submitted as part of the mining volume report. For a natural person who owns the immovable or a natural person who has the right to use that immovable, the requirement to request the consent of the Environmental Board for the transportation of the mineral resources taken from the immovable and rock and sediment not registered as mineral resources between immovables belonging to self was abolished. The rights and obligations in connection with the use and transfer of the overburden and the ore have been specified and simplified - in the future it is not necessary to apply for a separate permit, but the related information must be presented in the mining volume report. In the spring of 2019, the Ministry of the Environment opened the KOTKAS information system which includes the application for and processing of environmental permits, declaration of environmental charges and submission of annual reports.

Approximately 99% of shale oil production is sold to major players in the global fuel market, who use shale oil as a component in the production of marine fuel.



Climate-neutral Europe 2050

The European Commission's long-term strategic vision "A Clean Planet for all" is to reduce greenhouse gas emissions in the EU to zero over the next 30 years. Up to € 290 billion in investments per year is needed to reach this target. According to the Commission's plans, electricity from renewable sources must ensure more than half of all energy needs by 2050, at least twice as much as at present. The European Green Deal agenda foresees a number of initiatives, including the drafting of a climate law and climate package, the development of a carbon border adjustment mechanism in Europe's foreign trade to prevent carbon leakage, and development of the circular economy. According to the European Union's current targets, it is planned to reduce greenhouse gas emissions by 40% by 2030 compared to 1990 levels, with a possible ambition of increasing it up to 55%.

In principle, the Estonian government supports the climate-neutrality target across the European Union by 2050, if it is supported by adequate transitional measures and takes into account the differences and different baselines of Member States and sectors.

Estonian National Energy and Climate Plan 2030

The main goal of the National Energy and Climate Plan 2030, approved by the government in December 2019, is to reduce Estonia's greenhouse gas emissions by 80% by 2050 (incl. 70% by 2030). In addition, the desire is to reduce greenhouse gas emissions in the transport, small-scale power, agriculture, waste management, forestry and industrial sectors by 13% by 2030 compared to 2005, i.e. in 2030 the emissions may be 5.5 million tonnes of CO₂ eq. In 2020, annual national emission levels for the sectors covered by the regulation on shared obligations for activities exempted from quota trading for the period 2021-2030 will be approved.





MINING



In Estonia, there are two main oil shale deposits in the north-east of the country. In the so-called Estonian deposit between Rakvere and Narva, oil shale is mined in both mines and quarries. The thickness of the productive layer there is up to 2.9 metres. According to current knowledge, oil shale in the so-called Tapa deposit between Ambla and Väike-Maarja is of lower quality and lies deeper in the earth's crust.

The Estonian oil shale industry has mined approximately one billion tons of oil shale in more than a hundred years. There is the same amount of un-mined active oil shale that can be mined without restrictions in the local 4.8 billion ton oil shale reserve.

Less oil shale for electricity production

Four companies mine oil shale in Estonia: Eesti Energia, Viru Keemia Grupp, Kiviõli Keemiatööstus and Kunda Nordic Tsement. In 2019, a total of 12.1 million tons of oil shale was mined, being the smallest volume during the last 30 years. Compared to 2018, the mining volume of oil shale decreased by almost a quarter. 20 million tons of oil shale is allowed to be mined in Estonia per year, of which EE may use 15.01 million tons, VKG 2.77 million tons, KKT 1.98 million tons and KNT 0.2 million tons of geological reserves. EE and KKT mined half of their permitted volumes in 2019, VKG exercised its right to mine more at the expense of previous years, i.e. 127% of its annual volume.

The decrease in the oil shale mining volume of Eesti Energia was related to the situation in the electricity market and the company's strategic direction to reduce electricity production from oil shale and increase the production of liquid fuels and renewable energy. The high price level of the CO₂ quota inhibited the competitiveness of electricity produced from oil shale in 2019, but according to the decision of the Government of the Republic of Estonia as the owner of Eesti Energia, electricity production capability from oil shale must be maintained, ensuring the production of electricity at the level of the Estonian average consumption - 1,000 MW - until 2023.

OIL SHALE MINING 2013–2019

Company	Permitted annual rate, in thous.	Actual mining volumes (in thous. of tons)*, use of annual rate (%)												2013-2019 average %		
		2013		2014		2015		2016		2017		2018			2019	
Eesti Energia	15 010	11 830	79%	11 614	77%	11 083	74%	9 732	65%	11 157	74%	11 296	75%	7 458	50%	70%
Viru Keemia Grupp	2 772	2 344	85%	2 483	90%	2 637	95%	1 791	65%	3 239	116%	3 487	126%	3 520	127%	96%
Kiviõli Keemiatööstus	1 980	755	38%	1 058	53%	1 350	68%	1 581	80%	1 164	80%	1 088	55%	1 084	55%	62%
AS Kunda Nordic Tsement	238	98	41%	113	47%	116	49%	0	0%	74	31%	74	31%	65	27%	33%
TOTAL	20 000	15 027	75%	15 268	76%	15 186	76%	13 104	66%	15 634	80%	15 945	80%	12 127	60%	75%

** Data for 2014-2016 are adjusted on the basis of consolidated balances for natural resources

Towards efficiency

The oil shale industry currently uses more efficient and cleaner technology than it used to. To do this, companies are constantly investing tens of millions of euros to modernise existing equipment and adopt innovative, more environmentally friendly solutions. The key words are automation, data digitalisation, and decision-making based on the analysis of the data obtained.

In 2019, KKT continued blasting the overburden in the Põhja-Kiviõli II Quarry, instead of mechanical breaking. The latter was due to the growing volume of the overburden and the consequent need to find alternative solutions that would speed up the mining process and help ensure the same volume of oil shale output as before.

A raise boring rig was acquired for Eesti Energia's Estonia Mine in order to pass through the ventilation shafts of the mine in a faster and safer way. While previously it took 6-9 months to tunnel one shaft, the shaft borer will do all the work in 2-3 weeks. This is a portable machine that can be easily transported from one place to another and, if necessary, used in other mining units. The new tunnelling process is much safer. It is necessary to bore 2-3 shafts per year in the mine. The device is the first of its kind in the Baltics.



The raise boring rig works as follows: at first a hole is drilled from the ground surface into the underground part. Then an extension is attached to the cage, which the cage begins to pull back up. The diameter of the resulting bore hole is 3.1 meters.

A smarter industry

To check the condition of the closed chamber blocks of the Estonia mine of Enefit Kaevandused, the robotic crawler vehicle Multiscope was involved, which is used to perform 3D metering works underground and in places that are closed or inaccessible to people. Smart and innovative solutions are used to achieve production efficiencies that have a minimal impact on the environment and help avoid occupational safety risks.

In cooperation with Tallinn University of Technology, the RTK-GNSS latest technology drones, which do not require ground signs for orientation, were tested for mapping the volumes of quarries and oil shale warehouses. Using drones saves time and makes mine survey oper-

ations more efficient, as a drone does a day's work in 30 minutes. A legal act is being prepared on the conditions for the use of drones in mine survey operations.

VKG has developed a data communication network for high-speed data transmission and communication in the underground mine. Together with a German IT company, the digitalisation and systematisation of data from mining machines and the introduction of monitoring software have been initiated. Management software is implemented to save administration time and speed up data exchange between employees who directly manage work processes.

Estonia's newest oil shale mine is 10 years old

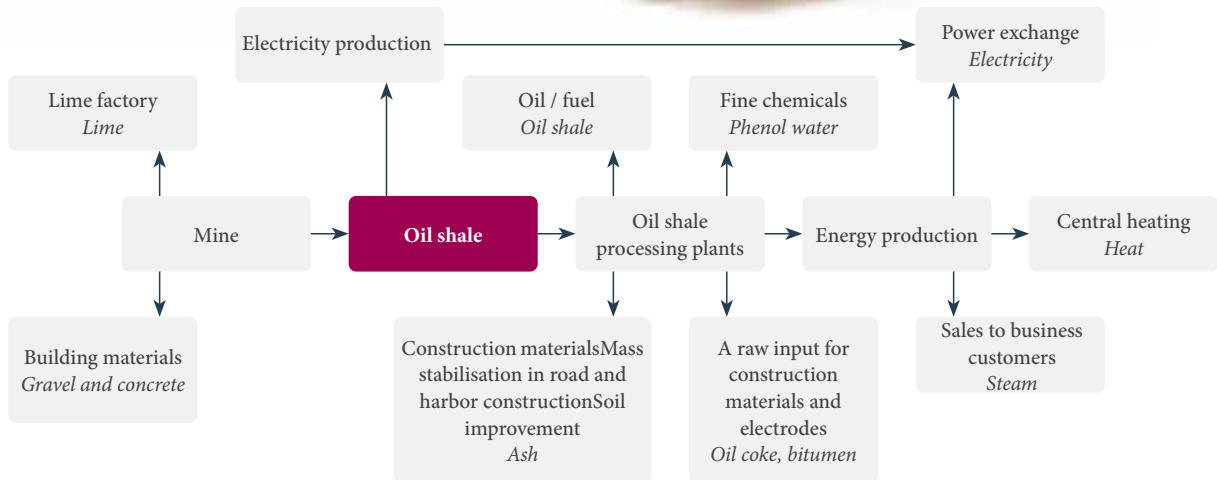
In November 2009, the first blasting was carried out at the Ojamaa mine of VKG. In ten years, 8.6 km² have been mined and approximately 22 million tons of geological reserves of oil shale have been extracted from the ground. The mine uses a total of 30 km of conveyors, of which 14 km are surface conveyors and 16 km are underground conveyors. The construction of the Ojamaa mine cost 120 million euros and it employs more than 500 people.

Permission to found a new mine

The Environmental Board granted AS Enefit Kaevandused a permit for 30 years to mine up to 6 million tons of oil shale per year in the Uus-Kiviõli mine located at Alutaguse and Lügänuuse rural municipalities. Mining will start in 2025 at the earliest in co-operation with VKG, and mining operators are required to recycle 40 percent of the waste rock generated during enrichment of oil shale. A shared mining permit agreement between the two companies saves the environment by making the most of the existing infrastructure. The application for a mining permit was submitted already in 2005.



OIL SHALE VALUE CHAIN





The background features a repeating pattern of light gray hexagons on a white background. A vertical blue bar is positioned on the left side, containing a blurred image of a mechanical component, possibly a valve or a part of a fuel system.

LIQUID FUELS



The advantage of oil generated in dry oil shale distillation over heavy fuel oil is its low sulphur content and good flowability for its density, so it does not need to be heated. Shale oil is used as a raw material for the chemical industry and as impregnation oil, for heating boilers and industrial furnaces, and as an additive to marine fuels. Currently, Estonia is one of the largest producers of shale oil in the world and the Estonian oil shale sector has the best knowledge of shale oil production in the world. The average sulphur content of shale oil by Estonian producers is 0.8%, which meets the criteria for a low sulphur fuel.

LIQUID FUEL OUTPUT OF THE ESTONIAN OIL SHALE INDUSTRY 2014–2019 (THOUS. TONS)

	2014	2015	2016	2017	2018	2019
Eesti Energia	265	337	318	395	410	442
Viru Keemia Grupp	433	506	451	536	607	637
Kiviõli Keemiatööstus	62	72	83	89	92	94
TOTAL	760	915	852	1 020	1 109	1 173

Source: Oil shale companies

A record year for shale oil

In 2019, the Estonian oil shale industries again produced more than a million tons of shale oil. The total volume of annual oil production increased by 64 thousand tons compared to the previous year, reaching 1.17 million tons, which is 5.8% more than a year earlier. About 99% of the output continued to be sold abroad, mainly to the Netherlands and Belgium, as well as Sweden, Malta and Denmark.

In 2019, VKG processed oil shale in three Petroter plants and three shale oil plants operating on Kiviter technology. Due to oil shale defi-

cit, one factory remained preserved. VKG processed 5 million tons of oil shale during the year, which resulted in 659 thousand tons of shale oil products, being almost 6% more than a year ago. The reason for the increase in production was the 4.5% increase in the working hours of the three Petroter oil plants - 944 days - and the four-month longer working period of the additional Kiviter plant launched in June 2018. The average net oil shale processing efficiency indicator of the three Petroter oil plants reached 87.5% last year. In 2019, the first Petroter plant celebrated its 10th operating anniversary.

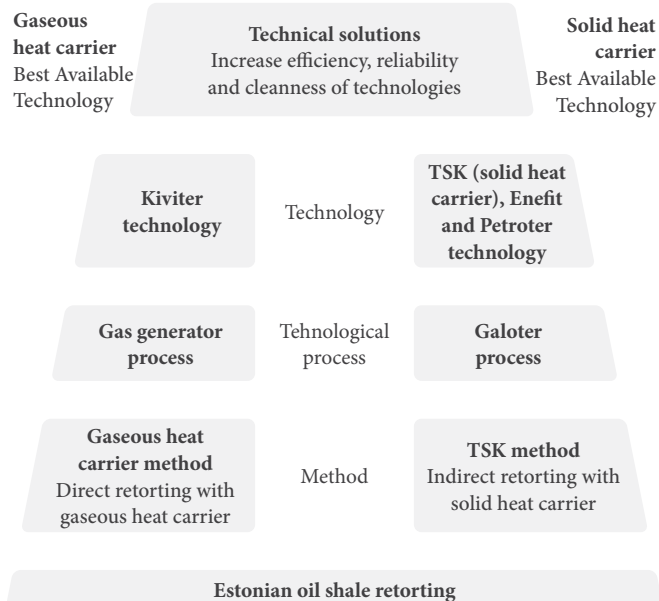
Eesti Energia set an all-time record in the production of shale oil at its Enefit140 and Enefit280 oil plants - 442 thousand tons. The output increased mainly due to improved reliability and yields of the Enefit 280 oil plant. The solid heat carrier technology of the new plant enables to produce liquid fuels and thermal energy, some of which is returned to production and some of which is converted into superheated water vapour. The Enefit280 plant has a steam turbine that converts steam heat into electricity. The remnants of oil shale processing are only ash with a high mineral content, which is practically free of organic impurities.

The volume of oil production in Kiviõli Keemiatööstus was affected by the overhaul of gas generators, which resulted in increased reliability, and the renewal of the engineering-technical staff of the TSK equipment, which also contributed to positive changes in reliability. The measures introduced at both plants to improve reliability helped to increase the production of shale oil and to achieve the highest annual oil production volume in the last five years - 93.7 thousand tons.

Two technologies are used for the production of shale oil in Estonia:

- 1 Older vertical retorts with gas heat carrier (GHC) (e.g. Kiviter technology)
- 2 Newer horizontal retorts with solid heat carrier (SHC) (e.g. Petroter and Enefit technology) with low CO₂ emissions and extremely high energy efficiency

EQUIPMENT USED FOR THE PRODUCTION OF SHALE OIL IN ESTONIA (AF-CONSULTING)



Source: AF-Consulting

Variable price of crude oil

The price of crude oil in 2019 was affected by global and political tensions, as well as the uncertain outlook for the future of the economy. The price of Brent crude oil was the lowest at the beginning of the year at \$ 54, but rose steadily to \$ 74.57 a barrel in April. From May, the price of crude oil in the markets was volatile between \$ 56 and \$ 75 per barrel. At the end of the year, the price remained at \$ 66. The security was provided to Estonian shale oil producers by a stronger dollar and increased demand for low-sulphur fuel oils. Compared to 2018, the expected price increase in the crude oil markets to \$ 80 did

not happen. The average Brent crude oil price of the year was \$ 64.15 per barrel, which is 11% lower than the 2018 average.

In the fuel oil market, the average price of 1% fuel oil was 3% higher than the 2018 price of 349 €/t. The price of fuel oils was affected by both the strengthening of the dollar and the increase in the demand and price of fuel oils with lower sulphur content at the end of the year.

MARKET CONDITIONS

		January	February	March	April	May	June	July	August	September	October	November	December
1% Fuel Oil FOB NWE (\$/t)	\$/t	353	389	404	413	411	393	407	362	361	376	377	426
Brent oil	\$/bbl	60,13	63,61	65,91	71,34	71,68	63,04	64,17	59,45	62,21	59,61	62,62	64,98

Oil from tyres and plastic waste

Approximately 12,000 tons of waste tyres are generated annually in Estonia and over three million in Europe. The Environmental Board issued a complex permit to Eesti Energia, which allows to replace up to 10% of oil shale in oil production with tyre chips. Oil shale will initially be replaced by about 300 tons of tyres per month with a maximum capability of up to 260,000 tons per year. The use of tyres in oil production solves an important environmental problem, diversifies the use of alternative energy sources, promotes the circular economy and saves the environment.

Tests carried out at the Enefit oil plant in 2017 confirmed that the quality of oil produced by the combined use of oil shale and tyre chips

was equivalent and the environmental impact did not increase. Eesti Energia has taken the direction to start developing the use of waste plastics in oil production at Enefit oil plants together with oil shale and tyre chips. Using the latter would make it possible to process at least 80,000 tonnes of waste a year into a new, environmentally friendly and valuable product, reduce CO₂ emissions from production and improve the quality of liquid fuels. In cooperation with the Oil Shale Competence Centre at TalTech Virumaa College, laboratory tests are carried out, followed by tests on a pilot device and in the oil plant, obtaining the necessary environmental permits and preparing for production. The planned start of production will be in 2024.

Plans for the construction of a shale oil pre-refinery

On the one hand, the need to improve the quality of shale oil is brought about by stricter environmental requirements, especially with regard to the permitted sulphur content, on the other hand, the use of shale oil is mainly limited to marine fuel additives or fuel oil. The pre-refinery would allow the sulphur content of the oil to be reduced to less than 0.1% and to enhance the value of shale oil as a low-environmental-impact motor fuel component and a standard low-sulphur marine fuel. The plans to build the plant are based on the assumption that global demand for liquid fuels will increase until 2040.

VKG and EE therefore decided to sign a memorandum of cooperation at the beginning of 2019 to initiate a feasibility study for the pre-refinery. The volume of liquid fuels reprocessed in the refinery is estimated to be about 1.5 million tonnes per year, which indicates the possibility of reprocessing the entire annual shale oil production of Estonia. The plant would employ nearly 100 people in Ida-Virumaa and secure already existing jobs there. Reaching the market with a final product would significantly strengthen the global competitiveness of shale oil and increase the added value created. On the basis of the feasibility study, it became clear that, in the near future, shale oil will be of sufficient quality and value even without pre-refining.

Refining

Refining - the final purification of a product from unnecessary or harmful impurities. Refining uses hydrogen to remove undesirable compounds (sulphur, metals, oxygen and nitrogen) from crude oil and the hydrogen-enriched product will have better properties. The process is carried out in reactors using catalysts, high temperature and pressure.





ELECTRICITY

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The biggest changes in the Estonian oil shale industry in 2019 took place in the production of electricity from oil shale. The reason for the change was the almost 4-fold increase in the market price of CO₂ and the 1.5-fold increase in the amount of cheap and quota-free electricity from third countries, compared to the previous year. In 2019, 7.6 terawatt-hours (TWh) of electricity was produced in Estonia, which is 40% less than in the previous year. The lion's share of the electricity produced came from oil shale companies which produced almost 4.9 TWh from oil shale and oil shale gas. In 2019, electricity production from renewable sources increased to 1.9 TWh, which is 33% more than in 2018.

Less electricity directly from oil shale

Due to the change in the market situation, Eesti Energia reduced the production of electricity from oil shale and conserved four units and the first fuel feed at Eesti Power Plant until the end of 2019. Electricity production directly from oil shale decreased by more than 54% compared to a year ago - to the level of 3.7 TWh per year. The reduction in production volumes led to changes in work organisation, affecting around 1,300 employees. By the decision of the Government of the Republic of Estonia, electricity production capability will be maintained until 2023 in the amount of 1,000 MW, the average consumption of Estonia.

This meant the need to keep at least two units equipped with desulphurisation equipment (deSOx) on standby in addition to three fluidized bed units. The operation of the Narva power plants was reorganised so that the plants increased their capacity to work at peak loads

at hours with higher electricity prices and at lower loads at hours with lower prices. At the end of June 2019, Eesti Energia did not produce a single megawatt-hour of electricity from oil shale during an eight-hour period, being the first time in the company's history. All the electricity generated for the power network during this period came from renewable or alternative sources.

Auvere Power Plant, completed at the end of 2018, produced almost 300 gigawatt-hours less electricity in 2019 than planned due to a heat exchanger leak. In addition to oil shale, up to 50 percent of biomass (wood chips), 20 percent of peat and up to 10 percent of oil shale gas can be used at Auvere. The plant can produce 2.2 terawatt-hours of electricity per year, which can cover more than 25 percent of Estonia's consumption.

More environmentally friendly oil shale gas

In 2019, Eesti Energia, VKG and KKT produced a total of 973 GWh of electricity from oil shale gas, making approximately 20% of the total volume of electricity production of the companies. In 2018, the share of electricity produced from oil shale gas was 10%.

From 2018, Enefit Energiatootmine started using more oil shale gas generated in the course of shale oil production at Eesti Power Plant. The high calorific value gas released as a by-product of oil production can be used as a raw material in one energy unit to the extent of up to 50% next to oil shale. Thanks to the innovations, the environmental impact of electricity production will be reduced and production will become more flexible.

For energy production, VKG Energia uses only the heat released in the production processes of oil shale gas and shale oil. Depending on the type of turbine, electricity is generated in either cogeneration or condensation mode. In 2019, 1 TWh of energy was produced at VKG's Põhja Thermal Power Plant, of which 474 GWh was electricity and the rest thermal energy and steam sold to large consumers.



Circular economy also offers environmental solutions to other industries, such as using wood waste for renewable energy production.

Replacing oil shale with biomass

In April, after the renovation of the biofuel conveyor belt at Balti Power Plant, the share of biomass in the oil shale energy production unit was increased to almost 25%. The use of biofuel instead of oil shale reduces the purchase of CO₂ quotas, improves the efficiency and competitiveness of the plants. In the autumn, a biomass treatment and crushing complex was opened in the territory of Balti Power Plant, further increasing the amount of biomass used in electricity production. The three newer energy production units of the Narva power plants can use up to 50% of biomass and produce renewable energy from it.

ELECTRICITY PRODUCTION OF OIL SHALE COMPANIES IN ESTONIA 2014–2019 (GWh, %)

	2014	2015	2016	2017	2018	2019
Eesti Energia	9 343	7 312	8 695	9 363	8 658	4 352
<i>of which oil shale electricity</i>	<i>9 003</i>	<i>6 745</i>	<i>8 203</i>	<i>8 741</i>	<i>8 074</i>	<i>3 691</i>
Viru Keemia Grupp	217	311	352	416	466	474
Kiviõli Keemiatööstus	39	41	44	51	52	47
TOTAL POWER OUTPUT	9 599	7 664	9 091	9 830	9 176	4 873
<i>of which oil shale electricity</i>	<i>9 259</i>	<i>7 097</i>	<i>8 212</i>	<i>8 747</i>	<i>8 081</i>	<i>3 695</i>

Source: Oil shale companies





HEAT

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Most of the thermal energy consumed is produced in environmentally friendly combined heat and power plants. According to the Estonian Competition Authority, in 2019 the average limit price of heat excluding VAT for final consumers in Estonia was 63.82 euros per MWh. All companies producing thermal energy from oil shale sold heat at a lower price than the Estonian average. The cheapest communal heating can still be used by consumers who use thermal energy produced as a by-product of the oil shale industry. In 2019, the residents of Narva got the cheapest heating - 35.33 EUR/MWh - and the most expensive heat was sold in Harku - 86.96 EUR/MWh.

For the last five years, heat production from oil shale has been 1.4 TWh - about a third of Estonia's district heating consumption. The total annual heat consumption in Estonia is below 6.3 TWh, of which 70% (4.4 TWh) in 2018 was district heating.

Cheaper heat from oil shale

In 2019, nearly 60,000 residents of Narva received the cheapest thermal energy for district heating in Estonia by purchasing heat produced from oil shale and biomass at EE's Balti Power Plant, provided by AS Narva Soojusvõrk. A total of 692 objects are heated through the Narva heating network and the total capacity of consumers reaches 333 MW. In addition, nearby industrial consumers are supplied with 15-atmospheric steam.

VKG Soojus has been supplying consumers in the Kohtla-Järve and Ahtme-Jõhvi areas with thermal energy since 2018, with a tariff of 52.66 €/MWh. The VKG subsidiary produces heat in an environmentally friendly manner, primarily by using waste gas generated during

oil shale processing. VKG sells the heat and steam generated in the oil shale industry to industrial companies in Ida-Virumaa and consumers in the region, but electricity produced in cogeneration they sell all over Estonia. Despite the fact that the district heating pipeline network is one of the longest in Estonia (VKG Soojuse's network is 161 km long, while the entire Tartu city network is 176 km) and the number of losses is therefore higher, still the price of district heating has been kept well below the Estonian average.

Residents and companies of the town of Kiviõli consumed thermal energy from the combined heat and power production of KKT through Kiviõli Soojus for 50.03 €/MWh.

10 kilometres of new district heating pipelines

In 2019, VKG Soojus continued the extensive renovation project of the depreciated main route of the heating pipeline. The renovation of the ten-kilometre-long heating pipeline cost a total of 4.4 million euros, a third of which was covered by the Estonian Environmental Investment Centre.

The Estonian Power and Heat Association recognised VKG Soojus' distribution network with the energy-efficient district heating system label "Efficient district heating". The label certifies and recognises the

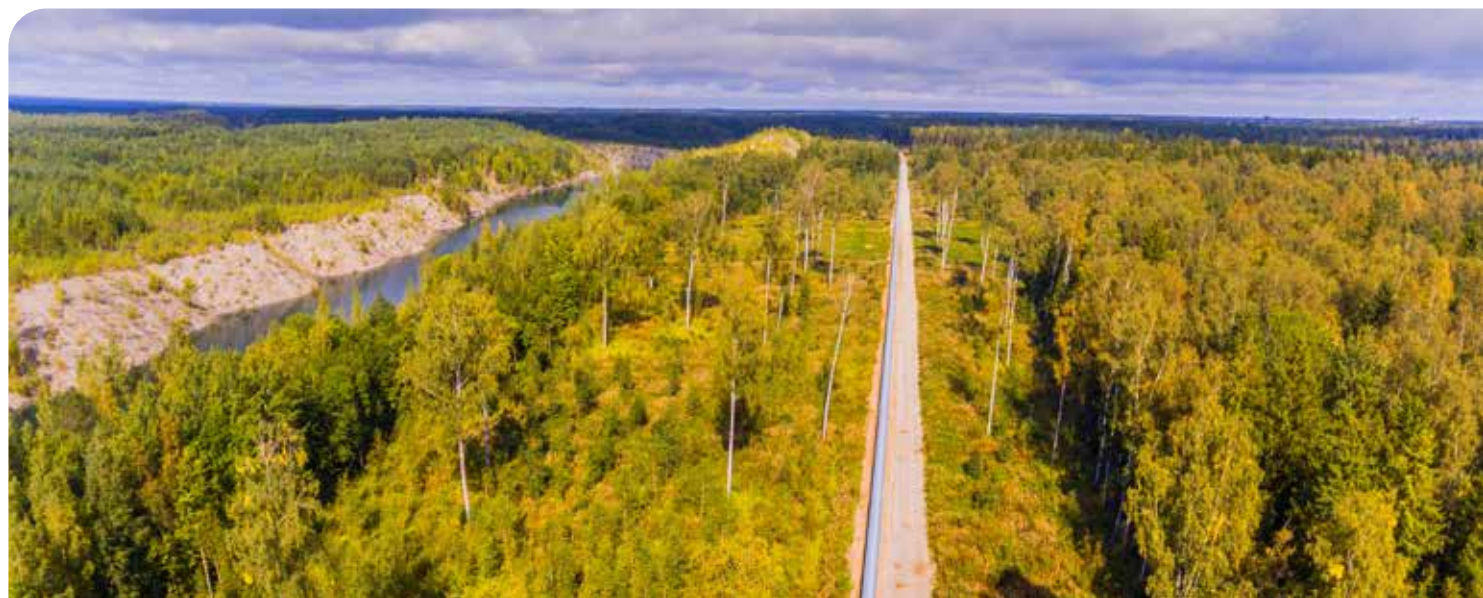
efficiency of the district heating system, i.e. the significant share of renewable energy and cogenerated heat in the district heating system. VKG Soojus deals with the transmission and sale of thermal energy in the Ahtme-Jõhvi area and in Kohtla-Järve. The company supplies heat to an area with more than 30,000 inhabitants.

VKG Energia sells thermal energy for industrial processes nearby Kohtla-Järve, Ida-Virumaal, both as steam and hot water for heating buildings.


HEAT PRODUCTION AND HEAT CONSUMPTION OF OIL SHALE COMPANIES IN ESTONIA 2015–2019 (GWH)

	2015	2016	2017	2018	2019
Narva Power Plants of Eesti Energia	614	596	564	582	584
Viru Keemia Grupp	532	506	452	454	452
Kiviõli Keemiatööstus	108	123	125	139	144
TOTAL	1 254	1 225	1 141	1 175	1 180

Source: EE, VKG, KKT, KNT







**FINE CHEMICALS
AND BY-PRODUCTS**

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Phenolic water formed during the thermal processing of oil shale contains large amounts of organic and inorganic compounds in the form of salts, resins and various other organic substances, including phenols. VKG continues to be the largest company in Estonia, separating valuable chemicals from the phenolic water released during oil production at Kiviter plants. In 2019, VKG produced a total of 1,520 tons of fine chemical and phenolic products. Kiviõli Keemiatööstus produced a total of 294 tons of fine chemicals in 2019.

The valorisation of oil shale generates approximately 20 million tons of by-products in Estonia each year: waste rock from the processing and enrichment of oil shale, and ash from oil and electricity production. For many years, oil shale companies have been committed to finding new applications for waste rock and ash as potential second-round production inputs. This reduces the sector's impact on the environment and is also economically beneficial.

The circular economy creates new prospects

The classic linear production model in the economy is being replaced by the model of the circular economy, focusing on products and services the creation of which generates minimum waste. The circular economy is a solution for the rational use of resources in the oil shale industry. Companies are developing several projects to adopt the principles of the circular economy.

VKG is developing oil shale chemicals as a branch, because they see definite potential and sustainability in it in the future as well. Fine chemicals are synthesised from phenols which are a by-product of

shale oil production. The production of high value-added fine chemicals is part of the circular economy and extends the value chain of oil production. The main concern of the oil shale chemical industry is still high research, development and marketing costs. Companies also have significant costs due to the European Union's obligation under the so-called REACH Regulation to register chemical substances.

The sales geography of fine chemicals is expanding

VKG manufactures and markets in the European Union more than 40 different chemicals produced from oil shale. After a registration process of almost five years, VKG received the right to sell its oil shale chemical product Honeyol™ in the United States market from mid 2019. Honeyol™ has two major applications in the new market: the production of rubber resins in the tyre industry and the production of adhesive resins for the timber industry. It is one of the best alternatives

to the common chemical resorcinol which is very widely used in the US market, so Honeyol™ has great potential in that market. Already during the registration process, several large American customers have shown interest in the Honeyol™ produced in Kohtla-Järve.

EXPORTS OF FINE OIL SHALE CHEMICALS AND PHENOLS 2014-2019 (IN EUROS)

Product group	2014	2015	2016	2017	2018	2019
Fine chemicals	719 168	1 034 909	730 309	968 059	2 767 446	3 058 440
Total oil shale phenols	41 849	39 596	6 212	4 411	0	9 503
TOTAL	761 017	1 074 505	736 521	972 470	2 767 446	3 067 943

Source: Statistics Estonia

Valuable phenols

The output of oil shale phenols includes alkylresorcinol fractions, high-purity fine chemical resorcinols and synthetic products of the adhesive resin type. These products are sold to both domestic customers in Estonia and foreign ones. VKG exported oil shale chemicals produced in 2019 for EUR 2.6 million, being 18 percent more than a year ago. The main markets where the products were sold were Great Britain, India, Italy, Belgium and the United States.

Alkylresorcinol fractions are widely used in the manufacture of moulds and as adhesive resins in the rubber, plywood and petroleum industries. In Estonia, mainly Honeyol 80, Honeyol and Rezol phenols are produced, which end up, for example, in Lexus and Toyota car parts and are used for making tyres with high wear resistance.

High-purity fine chemicals from oil shale (2-methylresorcinol, 5-methylresorcinol anhydrides and 5-methylresorcinol monohydrates) are used by the pharmaceutical, cosmetic and electronics industries. Products with the purity level of more than 99% are also found in pharmaceuticals and hair dyes, and they are used for making liquid crystals for LCD monitors. Fine chemicals of high purity are expensive - the price of one kilogram can reach tens of euros. The adhesive resin type SF-281 synthetic products are intended for use in the tyre or foundry industry.

As a development, VKG is exploring the possibilities of obtaining adhesive resins for the wood processing and rubber technical products industry on the basis of Honeyol, and of granulating Honeyol 80.



A pilot batch of granules from oil-shale ash was made in the laboratory of the Institute of Chemistry and Biophysics (KBFI). Thus, it was proved that shale ash can be granulated in accordance with the requirements of the agricultural sector.

Waste rock

Waste rock mainly consists of limestone and contains a small amount of oil shale. In 2019, 6 million tons of waste rock was generated in the oil shale industry, of which more than half or 3.6 million tons were reused. Limestone is suited for the construction of roads, large squares, dams as well as other massive projects, and is also good for repairing forest roads. The biggest challenge in waste rock recycling is its large quantity.

36 percent or 1.3 million tons of Eesti Energia's waste rock reached the circular economy. Limestone formed as a by-product of oil shale mining is suitable as a filling material in the construction of railways and roads, according to a study commissioned from Tallinn University of Technology. The study concluded that the use of limestone in the construction of the Rail Baltic railway line will alleviate the environmental damage that would result from the opening of new quarries. The Environmental Board granted Enefit Kaevandused the right to reuse waste rock in the amount of up to 3 million tons for the construction of the foundation structure of a solar power plant to be built on the territory of the Estonia Mine.

In 2019, VKG recycled as a filling material as much as 92 percent of its 2.3 million tons of waste rock generated in mining.

Oil shale ash

Ash waste is mainly generated in the boilers of oil shale power plants. Some of the ash from combustion is carried along with the gas stream and the rest is deposited at the bottom of the hearth. The latter is called bottom ash, and the ash carried away from the hearth by the gas stream is fly ash. Bottom ash makes up 30–40% of the ash flow and fly ash 60–70% of the ash flow mass. Fly ash is used as a raw material.

In 2019, 6.5 million tons of ash was generated in the oil shale industry, of which Eesti Energia recycled only 1.8% - 120,000 tons - in construction and agriculture. Compared to previous years, almost 60% or 4.1 million tons less ash was generated in Eesti Energia's boilers. VKG uses a new technology for depositing ash mainly produced in oil production - the ash is deposited moistened and compacted so that a waterproof layer is formed, and this layer is in turn covered with semi-coke. VKG generated 1.9 million tons of ash in 2019.

Fly ash is released from oil shale during the production of electricity in the flue gas cleaning process. To catch the high-calcium-content fly ash, power plants' fly ash passages have special filters that collect tiny particles of ash.

Bottom ash is formed in the hearth chamber and removed from the bottom of the hearth. The bottom ash has a variable grain size, it has no reuse at the moment and is sent in full to the ash fields.

SOLID BY-PRODUCTS OF THE OIL SHALE INDUSTRY (THOUS. TONS) AND THEIR USE AS PRODUCTS (%)

	2014	2015	2016	2017	2018	2019
Oil shale ash	8 554	7 296	8 973	9 323	9 387	6 499
%	4,0	2,1	1,4	1,6	1,9	1,8
Waste rock	8 083	11 973	10 312	6 261	6 461	5 970
%	32,8	29,1	34,9	55,8	52,9	57,1

Source: Oil shale companies

Green light for the plastics industry

The exemption of oil shale ash from hazardous waste promotes the circular economy in industry. In addition, the new original Estonian standard EVS 940:2019 “Burnt shale for productions of plastics. Specification and conformity criteria” enables to start using oil shale ash in the plastics industry. Standardisation allows ash to be officially used as a product, thus increasing the amount of ash used.



“The use of standardised oil shale ash in the production of plastics is a very important step in terms of the use of oil shale ash and the development of the plastics industry as a whole. This is the first step on a global scale. From here, the company will be able to export the resulting product without having to answer too many questions about the quality of the product.”



Ivar Viira

CEO of Ati Profiil OÜ and Chairman of the Estonian Plastics Association

Ash as a successful soil improver

The results of tests performed on conventional and organic fields with Eesti Energia’s soil treatment Enefix made of oil shale ash in 2018 showed a positive effect on both yield and soil pH neutralisation. A study commissioned from Tallinn University of Technology and TTK University of Applied Sciences confirmed that oil shale ash is suitable for stabilising large peat areas.

The results of the research have led to an increase in the demand for burnt oil shale as a product. Thus, cooperation is ongoing with a Lithuanian fertiliser manufacturer; ash is used in other industries for neutralising acidic waste; oil shale ash mixed with other fertilisers gave good results in one of the largest tomato and cucumber farms in Sicily.

In order to develop a soil improver made from ash, cooperation takes place with the crop cluster and research institutions for the development of prototypes of multi-functional organic fertilisers and for the creation of technology and recipes for agricultural ash granules.





OIL SHALE INDUSTRY AND ENVIRONMENT

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The oil shale industry has an impact on the environment, but the magnitude of it has fallen sharply over the last 10-15 years. In order to reduce the environmental impact, oil shale companies make large investments in various measures every year and develop more environmentally friendly technologies in cooperation with universities. Compared to 2018, the environmental load arising from the oil shale industry has decreased by almost 40 percent, primarily due to a reduction in electricity produced from oil shale.

In the European Union, CO₂ emissions from the energy sector decreased by 12 percent in 2019. The decrease was due to increased use of renewable energy sources and the transition from coal to gas. The total CO₂ emission of the Estonian state decreased by almost 40% with the year as Eesti Energia's electricity production decreased.

Nearly 70 million euros for the environment

In 2019, oil shale companies paid more than 70 million euros in environmental charges to the state, of which more than half were resource fees for oil shale mining and water. Pollution charges for refuse, emissions, and waste disposal related to the mining and processing of “the brown gold” amounted to nearly 30 million euros, being almost 10 million less than last year. At the same time, companies invested a third of their total annual investment - 22 million euros - in projects reducing environmental impact.

In 2019, the Estonian Association for Environmental Management issued Green Office Certificates to Eesti Energia Õlitööstus and Enefit Kaevandused logistics office buildings. The office in Auvere was the first administrative building in Ida-Virumaa to receive such a certificate.

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One option for the transition to a low-carbon economy is afforestation of abandoned mining areas. Planted trees grow well, their thorns and leaves are larger than in non-fertilized areas, the species richness of the ground vegetation increases over time.



Katri Ots

Senior scientist, Estonian University of Life Sciences

DIRECT AND INDIRECT ENVIRONMENTAL INVESTMENTS OF ESTONIAN OIL SHALE COMPANIES 2013–2019 (MILLION EUROS)

	2013	2014	2015	2016	2017	2018	2019
Eesti Energia	69,8	28,5	27,4	9,4	16,2	40,8**	10,9
Viru Keemia Grupp	3,9	8,9	53,5*	14,4	12,1	9,4	8,4
Kiviõli Keemiatööstus	8	5,2	0	0,4	0,8	4,2	1,8
Kunda Nordic Tsement	0,2	0,2	0,9	1,9	1,4	0,5	0,4
TOTAL	81,9	42,8	81,8	26,1	30,5	54,9	21,5

* Includes indirect environmental investments related to the expansion of production volumes and the construction of the Petroter III shale oil plant

** Includes investments in the development of Auvere Power Plant. 328.4 million euros were invested in the Auvere Power Plant in 2013-2018.

Estonia's climate ambition

The analysis of the possibilities for increasing Estonia's climate ambition, completed in 2019 at the Stockholm Environmental Institute's Tallinn Centre, concludes that reaching a climate-neutral Estonia by 2050, where anthropogenic greenhouse gas emissions are balanced by removals, is possible with the contribution of everyone - private, public and non-profit sectors. The ambitious forecast stipulates that the target will be met, if Estonia invests 17 billion euros in the next thirty years. The study states that until 2040, global demand for shale oil is going to increase and it will not be possible to reduce emissions to zero. Climate neutrality presupposes an emission-binding land use and forestry sector as well as the introduction of technologies capturing and using carbon.

Landscape recovery

Oil shale mining changes the ground. The terrain, hydrogeological situation, soil, flora, but also fauna are impacted. An integral part of oil shale mining is the recovery of former quarry areas in order to recreate a usable landscape. Industrial landscapes are being technically rehabilitated, post-mining surface is being levelled, new landforms are being created and new forests are being planted with biological landscaping. Oil shale companies have planted trees on a total of 14,000 hectares in half a century. High forests with diverse vegetation have now grown on the former industrial areas, being home to many animal species.

In 2019, Eesti Energia and Kunda Nordic Tsement afforested more than 9 hectares of quarry areas. The oil shale company of Kunda made an inventory of quarry mammals and their habitats in 2019, which will be the basis for compiling a quarry biodiversity plan. After the inventory, it was learned that the landscape of the Ubja oil shale quarry is well suited for wild goats, rodents and hares.

Collapses will be eliminated

While the impact of opencast mining on the surrounding environment is immediate, then the impact of underground mining may be felt decades later. In 2018, researchers from Tallinn University of Technology compiled a survey of the collapses in oil shale mining areas on sinkholes, depressions and sunken shafts in the areas of former oil shale mines. The work of the researchers provides clarity about the collapses of old airshafts at Ida-Virumaa underground mining sites in 2019. National authorities are dealing with the elimination and remediation of the sinkholes.

Water in the oil shale industry

When oil shale is mined, water is pumped out of the cavities, sent to sediment pools for cleaning from suspended solids and then released back to nature. The water pumped out during mining comes from groundwater and rainwater, which account for 80% in quarries and almost 50% in underground mines. Drainage volumes are directly related to precipitation.

In 2019, the four companies pumped a total of 162 million cubic metres of water out of quarries and mines during oil shale mining - over 30% more than in the previous year. The companies paid 20.26 euros for pumping water out of quarries and 56.51 euros from mines for every 1,000 m³. The rates for the special use of water and their increase for each year were set in a regulation by the Government of the Republic of Estonia for 2016–2025. In total, oil shale companies paid 8.2 million euros in fees for the special use of water in 2019, which is 32% more than a year earlier.

Clean catchment area of the Purtse River

Large-scale cleaning of the Purtse River catchment area in Ida-Virumaa began at the beginning of 2019. The pollution was caused to the area by the Kohtla-Järve and Kiviõli oil shale processing plants in 1930–1980. In the first year of the largest residual pollution elimination project in Estonia, nearly 40 thousand cubic metres of contaminated soil was dugged out and a 5.6-kilometre section of the river was cleaned by removing a half-metre-thick layer of mud contaminated with oil residues at the bottom. After this, the river water was returned to the cleaned Vahitsepa main ditch and the cleaned sections of the Kohtla River. In addition, 3.4 kilometres of the Kohtla River flows in a new clean riverbed built during the cleaning work and now adopted by nature.

During the 2019 cleaning works, a 14-hectare phenolic bog was made safe to a large extent. In the coming years, a pumping station and pressure pipeline will be built to pump the polluted water out from the phenolic bog to the percolation trench of the semi-coke landfill and from there to the purification unit. In the summer of 2020, the cleaning of a 1.4-kilometre section of the Purtse River will begin. The cleaning of the residual pollution was commissioned by the Ministry of the Environment. The cost of the works which will last until the end of 2022, is 21 million euros, co-financed by the Cohesion Fund, the Environmental Investment Centre and the Estonian state.



Air emissions

In the name of cleaner air, oil shale companies have been moving towards more efficient and cleaner energy production for years, investing in new technologies and supplementing older production equipment with modern cleaning units. Air emissions have decreased over the years despite a steady increase in production volumes. There was also a significant reduction in air emissions in 2019 due to a decrease in electricity production from oil shale.

Compared to the previous year, SO₂ emissions decreased by more than 40%, NO₂ emissions by 46% and particulate emissions by 40%. Over the last five years, the corresponding figures have decreased by more than 60%. The efforts of the industry are confirmed by studies, according to which the air in Estonia and Ida-Virumaa is one of the cleanest in Europe.

AIR EMISSIONS FROM THE OIL SHALE INDUSTRY (THOUS. TONS)

	2014	2015	2016	2017	2018	2019
SO ₂	38,6	29,6	27,7	31,0	26,5	15,7
NO ₂	9,7	6,4	7,0	7,7	7,1	3,8
Particulate matter	8,8	3,6	2,6	2,7	2,3	1,4
CO ₂	14 600	11 159	12 862	14 327	13 290	8 100
Oil shale mined	15 258	15 187	13 104	15 633	15 944	12 127
Shale oil produced	760	915	852	1 020	1 109	1 173

KNT data includes all air emissions from the company, most of which are from the combustion of waste fuels.

Air quality monitored

The ambient air is under constant watch in Estonia by several monitoring stations. Monitoring stations in Ida-Virumaa measure pollutants in the air of Narva, Kiviõli, Sillamäe, Kohtla-Järve and Sinimäe. The permanent ambient air quality monitoring station established by Eesti Energia and the Environmental Investment Centre in 2017 measures the amounts of sulphur dioxide, benzene and hydrogen sulphide in ambient air. In addition, the station provides valuable information for controlling air quality by measuring wind direction, speed, humidity and temperature.





Improving urban air quality

VKG has implemented several projects to improve the air quality of Kohtla-Järve in order to reduce the company's environmental impact, ensure a sustainable development of the industry and improve the environment of local residents. In 2019, an odour management plan concluded between VKG and the Environmental Board aimed at reducing unpleasant odours was completed. The investment amount for the implementation of the five measures provided for in the plan exceeded 1 million euros. Thanks to the measures of the plan taken in 2018 and 2019, two sources of odour have completely disappeared and unpleasant odors from the VKG production area are reducing by 12% as planned. The closure of the Lõuna thermal power plant a few

years ago also significantly reduced the ambient air load. Since then, cogeneration of electricity and heat from shale gas has taken place at the Põhja thermal power plant which is equipped with new efficient sulphur capture equipment.

Kiviõli Keemiatööstus' major investment in a new electrostatic precipitator for the TSK unit will reduce the dust content in the flue gas from the oil production equipment, as well as the emission of particulate matter and fragrances. With the investment, the air in the Kiviõli area will become cleaner.





SCIENCE-BASED INDUSTRY



The fuel crisis that arose during the World War I made oil shale mining and exploration topical. Under the leadership of Paul Kogerman, the oilstone research laboratory established at the University of Tartu in 1925 began to use various internationally known methods for studying fuels. With his research, Kogerman laid the foundation for further research into the practical use of oil shale products. The comprehensive research started by Kogerman was continued in the Institute of Chemistry of Tallinn University of Technology established in 1947, and in other research institutions.

With more than 100 years of history of oil shale mining and industry, Estonian oil shale education and research are at the top of the world. The know-how accumulated over a century is in global demand and is exported to other oil shale countries around the world, from the United States and Jordan to Russia, Myanmar and Turkey.

Oil shale has been studied on site and in depth in the Estonian oil shale industry area in Ida-Virumaa since 1958 when the Oil Shale Scientific Research Institute (later Oil Shale Institute) was established in Kohtla-Järve. Laboratory of Fuel Technology of Oil Shale Competence Centre with an international reach can be considered the driver of the continuity of diverse research activities in the oil shale city.

Standardisation in the field of oil shale

The Oil Shale Competence Centre at TalTech Virumaa College coordinates the activities of the Technical Committee for the Processing of Oil Shale and Oil Shale Products (EVS/TK 57) established at the Estonian Centre for Standardisation. The existence of standards applied to oil shale simplifies and supports the daily activities and development work of laboratories.

With the help of the Technical Committee EVS/TK 57, nine standards have been published: one of them is an original Estonian standard, some are new revisions of original Estonian standards, some are international ISO standards adopted as reprints. In 2019, a total of two standards mentioned below were prepared and published.

EVS-ISO 334:2019 Solid mineral fuels. Determination of total sulphur. Eschka method.

Modified edition of ISO 587:2010. Updates were added that extend the scope of the standard to oil shale and its thermal treatment products, taking into account the specific properties of oil shale and its products. The water extraction method was added as an alternative, as well as some important specifications for performing analyses.

EVS 940:2019 Burnt shale for productions of plastics. Specification and conformity criteria.

A new original Estonian standard, the preparation of which was proposed by Eesti Energia. The standard applies to thermally treated oil shale or a mixture thereof in which the share of oil shale is at least 70%. Burnt oil shale is considered in the standard as a product that is used in the plastics industry as a filling material for one of the constituents of plastics. This, in turn, made it necessary in the industry to set requirements for the filling material, its production control organisation and for the procedure for demonstrating conformity.

STANDARDS UNDER DEVELOPMENT:

- **EVS 652:1994** Shale oils. Method for determination of sediment content and ash.
- **EVS 943:2020** Synthetic fuels - Fuels (class F) - Estonian shale oil specification.
- **EVS-ISO 29541:2015** Solid mineral fuels. Determination of total carbon, hydrogen and nitrogen content. Instrumental method.
- **EVS 669:1996** Kukersite oil shale. Determination of ash.
- **EVS 670:1998** Trade oil shale.



When using oil shale, it is necessary to study and apply technologies for producing refined oil without CO₂ emissions. As well as other new and old technologies for direct conversion of oil shale. The shale chemical industry should be based directly on oil shale, not on its residues such as resorcins.



Margus Lopp

professor academician of Tallinn University of Technology



Biotreatment and co-pyrolysis

The latest developments in the processing of metal ores and residues are developed through biotreatment. Researchers from the research and development company BiotaTec OÜ try to add value to ores or residues by taking advantage of the natural life processes of certain microorganisms. In the laboratory, various communities are attracted to adapt to ores so that the content of organic sulphur and metals in oil shale, for example, decreases during the cooperation of microorganisms and their natural life processes, or in the case of so-called “poor” ores and waste, metals become soluble in water. One of the best results achieved in cooperation with the researchers of TalTech’s Oil Shale Competence Centre was a reduction in the organic sulphur content of kukersite by approximately 55%.

Oil shale ash survey

The study of hazardousness of oil shale ash conducted by researchers from Tallinn University of Technology and University of Tartu in 2019 proved that oil shale ash did not differ negatively from coal ash. As a result of the study, the exclusion of oil shale ash from the list of hazardous waste allows the ash to be used more efficiently and in bigger quantities than before as a building material, in the production of cement and concrete, in agriculture, in the production of other construction materials and plastic products, and in road construction, instead of landfilling it.

“Raw materials or residues can be upgraded by exploiting the natural activity of certain microorganisms. In the laboratory, we “tempt” different microbial communities to adapt to raw materials in such a way that, through the cooperation of microorganisms and natural life activities, for example, organic sulfur and metals in oil shale are reduced or metals become water-soluble. Studies showed that it is possible to reduce the content of organic sulfur in kukersite by about 55%.



Sirli Sipp Kulli

Member of the board of BiotaTec OÜ

National support for research and development activities

The state's contribution to the growth of the knowledge intensity of the Estonian economy is implemented through the smart specialisation support measure. From 2014, companies can co-operate with Estonian research institutions by commissioning the necessary applied research or product development projects from universities and research institutions. By the end of 2018, more than 10 million euros worth of applied research had been carried out.

Through the national research and development support program RITA established at the Estonian Research Council in 2017, the government aims to receive recommendations for making science-based decisions and to implement them in solving the socio-economic challenges facing society. Among the supported research are surveys of various types of mineral resources in order to identify more expedient and innovative possibilities of using crustal resources in Estonia and to provide input to the state for planning future developments.

Three large-scale studies have been taking place from 2017, running until 2021 through the RITA program:

1. The study of a consortium led by the University of Tartu (UT, TalTech, Geological Survey of Estonia) "Critical Technological, Geological, Environmental, Socio-Economical Problems of Valourising the Estonian High Priority Mineral Resources (Oil Shale, Phosphorite, Peat, Metal Ores) and Possible Solutions";
2. The study led by Tallinn University of Technology together with the University of Tartu "Climate Change Mitigation with CCS and CCU Technologies";
3. The study led by Tallinn University of Technology "Innovative Gasification, Pyrolysis, and Combustion Technologies for Oil Shale".

Business and research

Companies in the oil shale industry are constantly investing in innovation to reduce their environmental impact, increase production volumes through technical updates and new technologies, ensure the sustainable development of the oil shale industry, and improve the living environment of local residents.

In 2019, the companies invested 6.5 million euros in research and development related to the oil shale industry, being 2.4 million euros more than in the previous year.

Through the smart specialisation support measure, VKG started developmental research into the possibilities of obtaining adhesive resins for the timber processing industry and the rubber technical products industry on the basis of Honeyol, and granulating Honeyol 80. As a further development, co-operation is established with Tallinn University of Technology as well as Finnish and Russian companies in order to build a pilot device for resin synthesis.

In co-operation with the Estonian University of Life Sciences, Eesti Energia started examining lime fertilisers - they performed tests with fluidised bed boiler ash and the competing lime fertilisers. As a result of the work, it was confirmed that oil shale ash was one of the best field liming materials that can be used in the Baltic Sea region. Smart specialisation applied research looks for ways to raise the efficiency of mine survey operations, studies the impact of oil shale sulphur content on the final product, and helps reduce the CO₂ footprint of oil production.



Knowledge for export

An agreement for the export of Eesti Energia's oil shale processing knowledge and experience was signed in 2019 with the Turkish state-owned companies Turkish Petroleum and Turkish Coal Enterprises. The aim of the research group advised by the Estonian oil shale industry company is to conduct a geological survey and analyse the properties and quality of local oil shale. Turkish oil shale differs from Estonian oil shale - it is characterised by low sulphur content and light composition of shale oil.

Recognition for development work

In 2019, VKG won the Smart Industrialist award granted by the Estonian Association of Engineers and Enterprise Estonia in the category of large enterprises for interfacing several automated systems and streamlining its business processes. The award is given to Estonia's most innovative industrial companies that have invested in the industrial revolution over the past year and set a good example with digitalisation and automation.

Important research in the field of oil shale

RESEARCH AND DEVELOPMENT	CONDUCTED BY	FINANCED BY
Underground Enrichment of Oil Shale Ore and Storage of Tailings in the Developed Area	Tallinn University of Technology	Environmental Investment Centre.
New Technological Platform for Oil Shale Kerogen Valorisation: Partial Oxidation to Dicarboxylic Acids and Further Conversion to Valuable Dicarboxylic Acid Derivatives	OÜ Kerogeen (research partner: Tallinn University of Technology)	European Regional Development Fund (NUTIKAS)
Technical Platform for the Conversion of Oil Shale Kerogen to Dicarboxylic Acids	OÜ Kerogeen (research partner: Tallinn University of Technology)	European Regional Development Fund (NUTIKAS)
Database of Estonian Subsoil Publications (Phase I)	Tallinn University of Technology	Environmental Investment Centre.
Effect of Activation Conditions in the Production of Porous Carbon from Oil Shale	Tallinn University of Technology	Estonian Research Council (Personal research start-up grant)
Research on Oil Shale Technologies at Enefit Energiatootmine AS	Tallinn University of Technology	Eesti Energia AS
Zoning of Bogs in the Oil Shale Area	University of Tartu	Environmental Investment Centre.
New Sulphur-Tolerant Electrodes for Reversible Solid Oxide Cells	University of Tartu	Estonian Research Council (Personal research start-up grant)
Stabilisation of Soil Containing Humic Substances in Road Embankments by means of Oil Shale Ash	Estonian University of Life Sciences	Environmental Investment Centre.
Development of Deep Impregnation Technology for Multifunctional (Fire, Rot and Insect) Protection of Wood on the basis of Oil Shale Ash, Peat Humates and Nanosilicate	Estonian University of Life Sciences	Environmental Investment Centre.
Water Pollution Related to Oil Shale Mining in the framework of Climate Change - Bioaccumulation and Bioavailability of Toxic Pollutants in Food Chains of Water Bodies	Estonian University of Life Sciences	Estonian University of Life Sciences
Recycling of Fermented Residue and Oil Shale Ash - Preparation of Granulation Pilot Plant	Institute of Chemical and Biological Physics	Environmental Investment Centre
Use of Granulated Oil Shale Ash in Organic Farming	Institute of Chemical and Biological Physics	Environmental Investment Centre
Follow-up and Maintenance of Kiviõli Industrial Waste and Semi-Coke Landfill 2019–2020	Ministry of the Environment	Environmental Investment Centre
Applied Study of the Possibilities of Streamlining Mine Survey Operations by Remote Monitoring Methods	Eesti Energia AS (research partner: Tallinn University of Technology)	European Regional Development Fund (NUTIKAS)
Applied Research for the Reduction of the CO ₂ Footprint of Shale Oil Production	Eesti Energia AS (research partner: Tallinn University of Technology)	European Regional Development Fund (NUTIKAS)
Influence of the Sulphur Content of Oil Shale on the Properties of the Final Product	Eesti Energia AS (research partner: University of Tartu)	European Regional Development Fund (NUTIKAS)
Applied Research on Optimising the Properties of Oil Shale Alkyl Resorcinol Adhesive Resins	VKG Oil AS (research partner: Tallinn University of Technology)	European Regional Development Fund (NUTIKAS)
Applied Research of the Possibilities of Adding Value and Recycling the Oil Shale Ash of R-S OSA Service OÜ	R-S OSA Service OÜ (research partner: Tallinn University of Technology)	European Regional Development Fund (NUTIKAS)





CONTRIBUTION TO EDUCATION AND THE COMMUNITY

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Tallinn University of Technology, University of Tartu, Estonian University of Life Sciences, regional colleges, other higher education institutions and vocational education centres take care of the future players in the oil shale industry. One of the missions of oil shale companies is to help arouse young people's interest in science and energy, in order to ensure the sustainability and development of the industry in the future.

Noticing talent

VKG has recognised the outstanding students of Tallinn University of Technology with scholarships for 16 years, encouraging the acquisition of professions necessary for the group. In 2019, through the Development Fund of Tallinn University of Technology, VKG provided scholarships to students of specialties related to technology, chemistry and energy in applied higher education, bachelor's and master's studies at TalTech and Virumaa College.

Kiviõli Keemiatööstus supports outstanding students of chemical and environmental protection technology or fuel technology with scholarships. The 2019 grantee was a student of fuel technology at TalTech Virumaa College.

In co-operation with the Association of Local Authorities of Ida-Virumaa, for the fifth year in a row, Eesti Energia, through the Talented

Youth Fund, issued scholarships to 35 brilliant young people in the total amount of 8,800 euros to support the extracurricular activities from science to sports of young Ida-Virumaa people aged 7-19. The aim of the energy fund is to recognise the young people of Ida-Virumaa and contribute to their development.

In cooperation with the Ida-Virumaa Vocational Education Centre and Enefit Kaevandused, 29 miners received their level 5 certificates as mining workers. The company has been investing in youth studies for ten years in a row to popularise the mining profession and secure the future. Kiviõli Keemiatööstus trains specialists important to the company through in-service training and workplace-based learning.

High school students to know the industry

For the fourth year in a row, several experts from VKG, Eesti Energia and Eastman have been offering the elective program “STEM” covering science, technology, engineering and mathematics to the 11th grade students of Jõhvi State Gymnasium. The course consists of lectures and study visits to companies. Interest in the elective program is growing every year.

On job-shadowing day, VKG opened its doors to seven high school students who could take part in the workday of various professionals. The undertaking aims to give young people a better idea of the oil shale industry and its professions. As part of the “Bring to Work” venture, Eesti Energia brought nearly 100 young people to the company to introduce them the work of their parents or grandparents. Kiviõli Keemiatööstus introduced the oil shale industry to primary and secondary school students as well as to TalTech’s students of mineral resources.

Contribution to the community

For years, oil shale companies have been engaged in enriching the livelihood of Ida-Virumaa and preserving local traditions, contributing to county’s maintenance work or participating in blood donation. VKG has been cooperating with Ida-Viru Central Hospital for several years. The company decided to support the maternity ward of the hospital with a Christmas gift of 5,000 euros instead of giving hundreds of corporate gifts, and VKG employees donated a total of 58 litres of blood over the year.

Support to sports activities

The Narva Energy Run, which has become the largest sports event in Ida-Virumaa, encourages people to engage in fitness sports and aims to increase the importance of Ida-Virumaa in the Estonian cultural and sports landscape. The event has been held annually from 2017.

Kiviõli Keemiatööstus cherishes to support young athletes in the city of Kiviõli. The company supports the young Irbis footballers in Kiviõli and the young running talent Luna-Aleksandra Lagoda. According to the agreement concluded with Lüganuse Municipality, the oil shale company will supply free crushed stone for the construction of a new football field with artificial grass.

Thank-you events for miners and chemists

One of the oldest and most anticipated family events in Ida-Virumaa for the recognition of employees in the oil shale industry and the appreciation of their work is Miners’ Day, organised by Eesti Energia and VKG. The community party has a cultural program and miners are recognised. Chemists’ Day organised by VKG was celebrated in 2019 with a thank-you event in the company’s territory instead of the traditional folk festival.



Recognised responsibility

Oil shale industry companies feel responsible for the surrounding environment. As responsible companies, the focus is not only on financial indicators, but also on the company's environmental and social impact, i.e. footprint. As industrial enterprises, they aim to minimise their negative impact and increase their positive contribution to the social environment, the community, the work environment, the natural environment and the market environment.

The Responsible Business Forum recognised Viru Keemia Grupp with a silver level certificate in 2019, and Eesti Energia was recognised with a gold level quality label in 2018. The label is issued to the company for two years. The label is awarded to companies that have participated in the evaluation of responsible business in Estonia and that consider sustainable development of the company important and contribute strategically to the development of the social and natural environment. The label has been issued since 2007.

Corporate social responsibility (CSR) is the natural and voluntary integration of company's economic, environmental and social dimensions into the day-to-day operations, management and business strategy of the company.

Viru Geopark

In 2019, the development strategy of Viru Geopark was prepared at the request of the Association of Local Authorities of Ida-Virumaa. The area of the park covers Ida-Virumaa as a whole but also Viru-Nigula Municipality in Lääne-Virumaa. The basis for the creation of the geopark are the distributional centres of oil shale and other important mineral resources - phosphorite and blue clay - in Estonia. The mission of the park is to value and exhibit the natural and industrial heritage of the region and to develop geotourism products.

The geopark is an initiative created at the initiative of the local community in an area rich in natural and cultural heritage, the main goal of which is to create opportunities for the local community to earn economic income by offering geotourism products and services. The goals of the geopark in a broader sense are the preservation and exhibition of natural geological monuments, cultural heritage objects and wildlife in the park area for the development of geotourism and nature education.



VKG photo competition "You are beautiful, Virumaa!", 2011 Author: Karel Kravik.

The Oil Shale Museum reopened its doors

Three years after moving from Kukruse to Kohtla-Järve, the Oil Shale Museum opened its doors once again. The new exposition introduces the history of the Estonian oil shale industry from the first mention of kukersite to the present day. The museum was founded in 1966 and has remained a unique museum of this field in the world. The Oil Shale Museum has undertaken to collect, preserve, research and mediate material reflecting the oil shale industry as well as the historical heritage and present of the surrounding area for educational, scientific and experiential purposes.

