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FUTURE OF OIL SHALE MINING TECHNOLOGY IN ESTONIA

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In the future, oil shale mining conditions will worsen and environmental taxes will be increased. Higher calorific value and more homogeneous material are required for more effective usage of boilers and generator units in power stations and oil plants. The solution for the mining industry is related to the optimal usage of mineral and technological resources, utilizing the best available techniques and modelling and visualization of mining impacts for explaining the changes in technology to the influenced parties. The main challenges for technologies in the future are related to the mining in environmentally or socially sensitive areas. One of the solutions could be utilizing selective mining and backfilling. Related tests have shown good results and show a promising future for sustainable oil shale mining.

Introduction

The modelling and planning of mining fields are based on measurements and analyses of the deposit which are gathered in parallel with industrial tests that provide initial data. For this purpose sampling tests of oil shale and limestone have been carried out from 2005 to 2007 in Estonia. The tests have been performed in *Väo Paas*, *Paekivitoodete tehas* and Aru Lõuna limestone quarries and Põhja Kiviõli, KNC Ubja and Narva oil shale surface mines and in Estonian underground mines. Similar previous tests have been executed in all Estonian oil shale mines. Backfilling and stability tests are in the planning stage for future implementation at underground mines.

Mining of non-traditional fuels in flat-laying deposits is well developed in Estonia, and the BAT (*Best Available Technology*) developed here could be used for future deposits elsewhere. Due to environmental restrictions, social pressure and deeper bedding of oil shale in potential mining fields, testing of high-productive, environmentally friendly mining is needed for

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successful continuation of an independent energy supply (oil shale) for Estonia [1]. New flexible and powerful mining technology will guarantee securing independence for the Estonian energy sector until the establishment of secure renewable energy production takes place.

Purpose of the study

The main purpose of the research is analysing the BAT and establishing criteria for selecting, planning and design of mining technology. The requirement for using a more effective extraction method is related to the worsening of mining conditions for oil shale and the increase in environmental taxes. Higher quality (calorific value, moisture, grain size) and courser material is required for more effective usage of boilers and generator units in power stations and oil plants [2]. The goals are

* to map possibilities for utilising BAT,
* to create criteria, methods, and bases for planning for choosing BAT for Estonian and similar mineral resources,
* to decrease the impact of mining on the environment,
* to improve mining environment, and
* to decrease the opposition of society to use of the minerals industry for the economy.

Additional goals include

* finding and selecting the criteria and bases for BAT,
* decreasing losses of minerals and
* lowering the impact on the environment from surface and underground oil shale mining. In general the objective is to optimize usage of mineral resources in the economy, and to establish sustainable development of mining, land usage, resource and subsurface usage.

Hypothesis

Coordinating criteria and methodology allows for decreasing expenses both in mining and planning. The experiences, gained in this field, can be used for other similar deposits elsewhere. It is possible to extract minerals in populated areas with suitable technology and at an acceptable cost. The criteria for solving the problems include minimum influence and cost, minimum influence to the environment and social sphere, minimum waste and residue production and maximum benefit for society, economy, education and country.

Methods

The main methods for the research include installation of sensors, gathering data and defining mining conditions, converting received data and using them for modelling. The methods also include testing of application, cooperation, range of usability and suitability of mine planning and software, laboratory and fieldworks for application of mining measurements equipment for modelling.

Analyses of Estonian energy systems have shown that increasing the fuel quality in power stations could improve the issues of high CO_2 emissions and at the same time increase effectiveness of power or oil generator units [2]. This goal can be achieved by decreasing CO_2, ash and water pollution. To avoid a potential problem of non-utilizable waste in stockpiles of mine areas, selective mining leaves the low-grade ore in mined-out underground or surface areas [3].

Selection of future technology

The selection of technology depends directly on economic considerations, but if economic issues are set aside, then BAT criteria have to be used (Fig. 1).

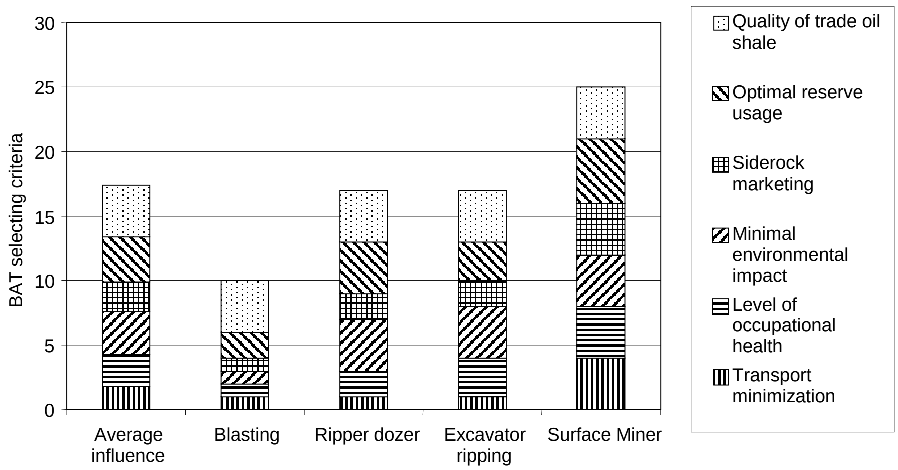

Fig. 1. Selecting mining technology for testing by BAT criteria.

Mechanical extracting

Given the condition of continually decreasing mining conditions, the main ways of increasing output material quality are selective mining (Fig. 1) or more effective processing after mining. The tests of mechanical mining have shown that selective mining with ripper-dozers have proved themselves, but in order to decrease losses, higher accuracy of cutting samples is needed [4]. This has been tested with high selective cutting with surface miners.

A surface miner breaks, crushes and loads material in one operation. The size of particles of the extracted rock depends on milling depth and operating speed. Usually it does not exceed 200 mm [5]. Two types of surface miners have been tested in Estonian mines, with centrally located and rear located cutting drum (Fig. 2 and Fig. 3).

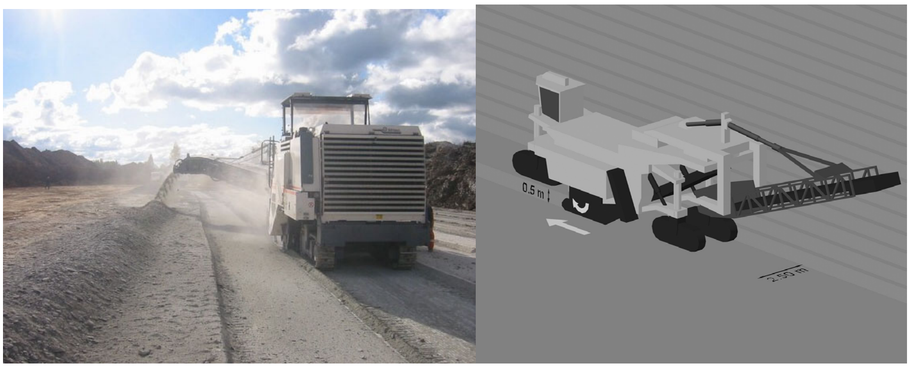

Fig. 2. High-selective surface mining with centrally located cutting drum.

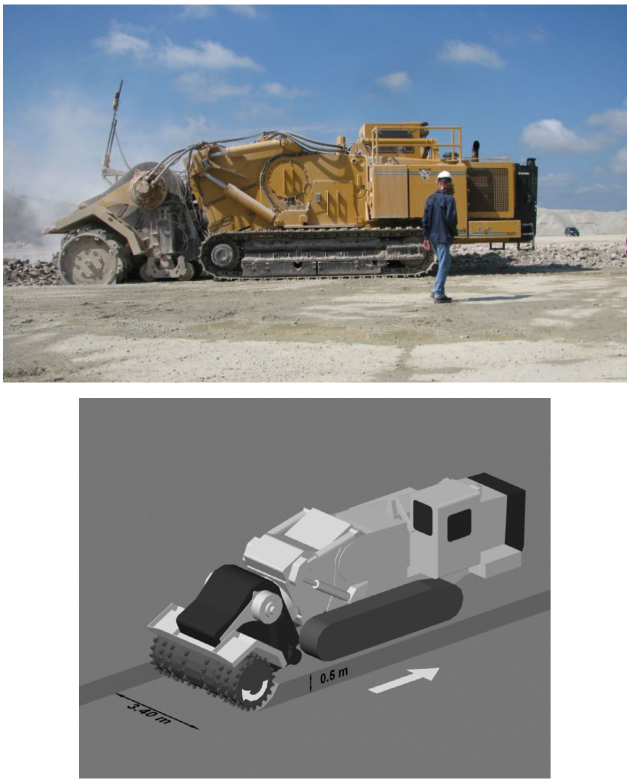

Fig. 3. High-selective surface mining with rear located cutting drum.

Testing of limestone and oil shale cutting in surface mines

Recent tests have shown that the decision for changing or improving extracting technology depends on usability of the equipment. Usability has been tested by measuring the production parameters. The main factors influencing production are: rock strength, cutting depth, and operator skills. Real productivity and effectiveness cannot be evaluated during short tests but with actual working conditions that depend on organizational conditions.

Mechanical cutting is accepted if the quality of the product and productivity of the machine is satisfactory. Generalized initial productivity chart of surface miner in various types of ore bodies shows a dependence on the material being mined and it mainly differs by resistivity to cutting, compressive strength and seam thickness (Fig. 4).

According to the tests, actual cutting time varies from 35 to 75% from total surface miners working time (Fig. 5) [6]. This percentage is highly

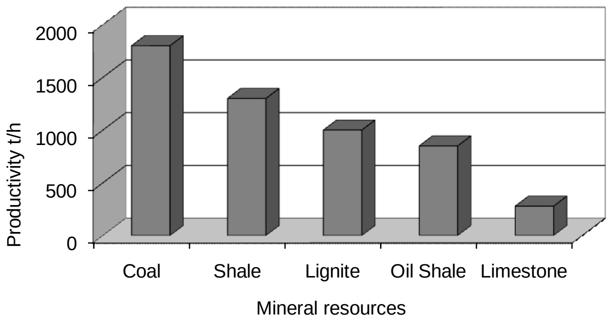

Fig. 4. Generalized initial productivity chart of surface miner, depending on cut material.

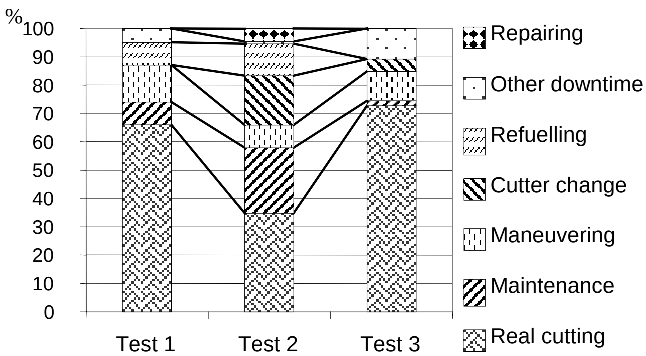

Fig. 5. Initial results of the surface milling tests in oil shale and limestone deposits.

dependent on organizational conditions, testing period and preparation and operational skills as well as suitability of the cutting drum and cutting tools.

As the result of initial tests – the minimum criteria for Estonian oil shale surface milling are: cutting depth 500 mm; machine weight 100 t; power 1000 hp; hard rock specific cutting tools and selectivity 5 cm.

Conventional underground mining

In spite of the shallow depth of oil shale bedding, underground mining has spread instead of surface mining. Currently room-and-pillar mining with drill and blast technology is used. Roof supporting is done with bolts. Total mining production is 14 Mt/y, including 7 Mt/y from underground mines. Total raw material production from underground mines is 12 Mt/y. Tests are made for opening two new mines, with total production up to 10 Mt/y. Room dimensions in oil shale mines could be up to 15 m in comparison with conventional coal mining with 5 m dimensions.

Development of oil shale underground continuous mining technology

The strategic aim of the development of oil shale underground continuous mining technology is to expand mining technology in stratified conditions by testing continuous mining systems in Estonian oil shale deposits [7]. This method improves coal mining possibilities due to enhancing cutting, supporting and face transport from high productive short-wall face. The main problems to solve are unstable roof, dilution of side rock and abrasive and hard parts of side rock inside or between usable seams.

The project stages include selective mining research for mining machinery development. In addition, it results in increasing oil yield, decreasing CO_2 pollution, decreasing ash amount, decreasing oil shale losses, avoiding vibration caused by blasting, avoiding ground surface subsidence (in the case of longwall mining), increasing drifting and extracting productivity compared with current room-and-pillar mining and increasing safety of mining operations. The final aim of the research is to use BAT for underground mining in difficult conditions of coal and oil-shale deposits.

The main problem to be solved is to selectively cut oil shale (15 MPa) and hard limestone (up to 100 MPa). The oil shale seam consists of up to 50% limestone layers and concretions. Other tasks are roof support at the face, stability of the main roof, roof bolting, selection of pillar parameters, backfilling with rock or residues (ash) from power plants or oil production, water stopping and pumping in problematic environment (30 m^3/t of produced oil shale expected).

The planned research project is based on the Sustainable Development Act and directs the development of the Estonian fuel and energy sector until the year 2015. This document defines the current situation in the sector, presents issues set out in the EU accession treaty, predicts developments in energy consumption, and states the strategic development objectives for the energy sector, the development principles and the extent of the necessary investments. The plan describes the problems that require further analysis and the functions of the state relating to supervision and regulation. Estonia's oil-shale industry is at the beginning of introducing modern mechanized continuous miner systems, which will increase productivity and safety in underground mines.

Previous experience of short-wall continuous mining

A longitudinal cutting head type was first introduced by Alo Adamson and Viktor Andrejev from the Estonian Branch of Skotchinsky Institute of Mining Engineering (Kohtla-Järve, Estonia) in the former Soviet Union, by modifying the Hungarian F2 road headers and in the 1970's in Estonia by modifying the Russian coal road header 4PP-3. Evaluation of breakability was performed by a method developed by Skotchinsky Institute of Mining Engineering (Moscow, Russia). For this purpose over a hundred tests were performed by cutting oil shale and limestone. Evaluations were made for using coal-mining equipment for mining oil shale. Comparative evaluations were made by the experimental cutting of oil shale in both directions – along and across the bedding, including also mining scale experiments with cutting heads rotating around horizontal (transverse heads) and vertical axes (longitudinal heads). In both cases the efficiency was estimated by measuring the power requirement for cutting. The feasibility of breaking oil shale by cutting across the bedding using cutting drums on the horizontal axis of rotation was shown. The research also showed that the existing coal shearers proved to have a low endurance for mining oil shale. Therefore, the problem arose of developing special types of shearers or modifying the existing coal shearers for mining oil shale [8].

It was further stated that the better pick penetration of the longitudinal machines allows excavation of harder strata and at higher rates with lower pick wear for an equivalent-sized transverse machine. It was reported that with the longitudinal cutting heads the formation of dust per unit of time decreases due to the lower peripheral speed. The change in the magnitude of the resultant boom force reaction during a transition from arcing to lifting is relatively high for the transverse heads, depending on cutting head design. Specific energy for cutting across the bedding with longitudinal heads is 1.3–1.35 times lower which practically corresponds to the difference in stratification factor.

The results of these tests were used in a large body of fundamental research into rock and coal cutting in Great Britain during the 1970's and early 1980's at the Great Britain Mining Research and Development Establishment.

Three decades ago a progressive mining method with continuous miner, which is most suitable for the case of high-strength limestone layers in oil-shale bed, did not exist in oil-shale mines of the former USSR and in Estonia. Therefore, up to now, oil shale mining with blasting has been used as a basic mining method in Estonia minefields while a continuous miner was tested for drifting only. With regard to cutting, the installed power of coal shearers and continuous miners has increased since the original tests. The market has changed and a range of powerful mining equipment from manufacturers like *DOSCO, EIMCO, EICKHOFF*, etc. is now available.

Estonia has 30 years of experience in cutting oil shale with longwall shearers which were not capable of cutting the hardest limestone layer inside of the seam. Currently mechanical short-wall mining is in the planning stage being in close relation with backfilling options (Fig. 6).

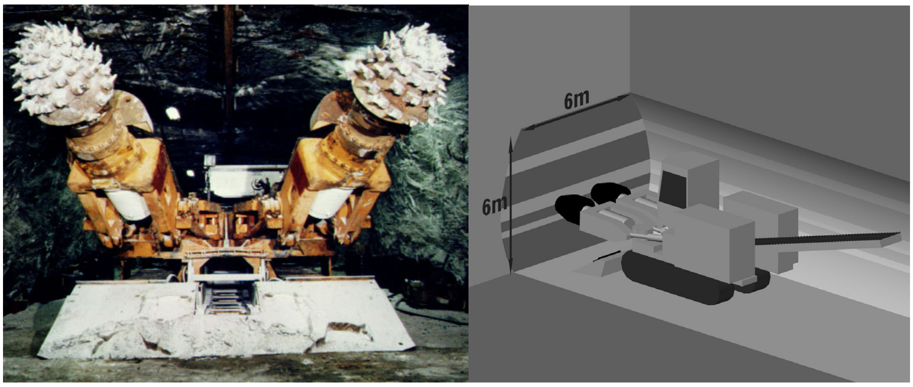

Fig. 6. Double-drum continuous miner for mechanical – selective room and pillar mining.

Backfilling

Previous experience with backfilling of oil shale mines and phosphorite mines allows one to consider that there is the possibility of using ash from powerplants, oil shale separation waste rock and/or limestone – as siderock from selective mining for perfoming backfilling [1, 9]. Selfhardening concrete could be used as a backfilling material for making artificial pillars in the case of room-and-pillar mining (Fig. 7). This allows for a decrease in the size of current oil shale pillars and an attendant decrease in the amount of deposited ash in the ash deposit.

The question of using advanced technology is directly dependent on mining conditions that have to be suited together by criteria and successful tests.

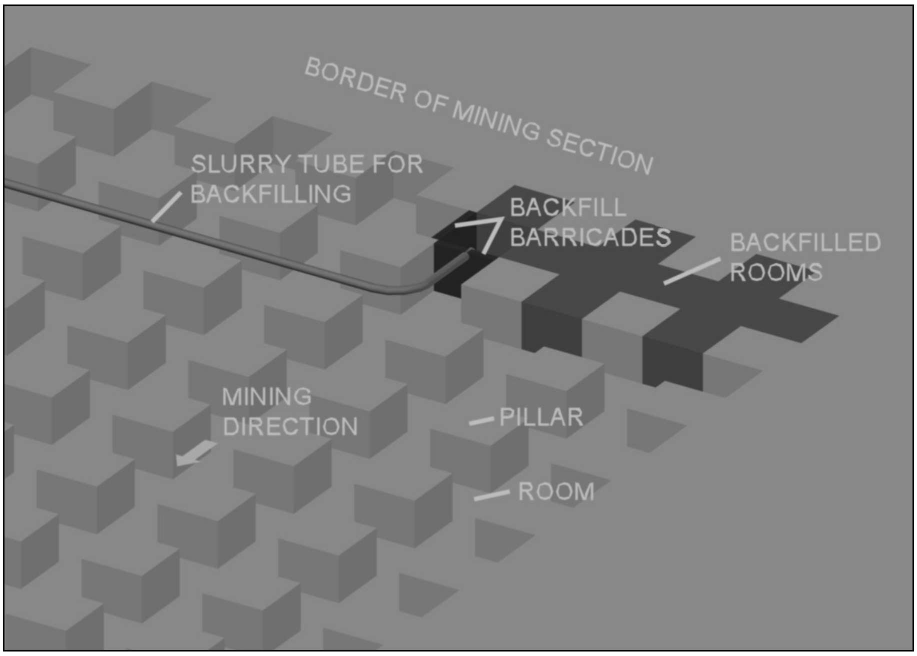

Fig. 7. Principal layout of backfilling in underground mines with concrete made from power plant ash and from waste rock aggregate.

Conclusions

The main reason for developing oil shale mining technology is to decrease CO_2 emissions from furnaces and to offset the continuing decline of mining conditions and increase of oil price as side product for Estonian electricity production. BAT analyses showed that one of the solutions for increasing oil shale quality (calorific value as well as grain distribution) is selective mining. Tests have shown that mechanical cutting is possible, and the size distribution and increasing oil shale quality are possible. In addition to better quality of the product that is related to the higher yield and less dilution, the opposition of society to the mining industry decreases due to its lower impact on the surroundings. The results of the test can be used for redistricting of mining regions and for creating criteria for resource usage and mining impact evaluation.

Acknowledgements

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REFERENCES

1. Emissions from power plants. European directive 2001/81/EU.
2. *Reinsalu, E., Valgma, I.* Oil shale resources for oil production // Oil Shale. 2007. Vol. 24, No. 1. P. 9–14.
3. *Reinsalu, E.* Relationship between crude mineral cost and quality // Miner. Resour. Eng. 2000. Vol. 9, No. 2. P. 205–213.
4. *Kattel, T.* Modern mining without blasting operations // Mining Machinery and Equipment / Proc. of Estonian Mining Conference 2003. I. Valgma (ed.). Tallinn: Mining Department of Tallinn University of Technology, 2003. P. 13–14.
5. *Kattel, T.* Design of a new oil shale surface mine // Oil Shale. 2003. Vol. 20, No. 4. P. 511–514.
6. *Nikitin, O., Väli, E.* The surface miner sustainable technology introduction for oil shale mining in Estonia // Proc. of the 6th International conference “Environment.Technology.Resources", Rezekne, June 20–22, 2007. P. 45–52.
7. *Valgma, I., Nikitin, O., Lohk, M.*, 2006. Oil Shale Mining Development in Estonia // Proceedings of Taiex Workshop on EU Legislation as it Affects Mining. Tallinn: TUT, Department of Mining, 2006. P. 103–113.
8. *Valgma, I., Karu, V., Viil, A., Lohk, M.* Oil Shale Mining Developments in Estonia as the Bases for Sustainable Power Industry // Proc. of Doctoral School of Power Engineering and Geotechnology. Tallinn: Tallinn University of Technology, 2007. P. 96–103.
9. *Jurkevitš, G., Adamson, A., Gaitšuk, V., Paldra, V.* Increasing effectiveness of underground mining of oil shale // Transactions of Tallinn Technical University. 1990. Vol. 660. P. 10–17.
10. *Adamson, A., Hints, H., Tomberg, T.* Rock pressure regulation with the help of filling up the excavated areas in the Rakvere Phosphorite Deposits // Transactions of Tallinn Technical University. 1988. Vol. 660, P. 10–17.

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