PRZEGLĄD ELEKTROTECHNICZNY

Ukazuje się od 1919 roku **12'18**

Organ Stowarzyszenia Elektryków Polskich • Wydawnictwo SIGMA-NOT Sp. z o.o.

Svetlana PULKKINEN[1], Juhan VALTIN[1]

Tallinn University of Technology, Republic of Estonia (1)

doi:10.15199/48.2018.12.01

Investments in the shale oil industry under risk and uncertainty

***Abstract**. This paper considers investments in the Estonian shale oil industry, analysing the economic reasonability of the construction of new oil production capacities on the example of a possible new shale oil plant in the Enefit Energiatootmine, the largest energy complex in Estonia. To estimate the profitability of the investments into the project, the methods of the Net Present Value and the Internal Rate of Return were used. Also, the scenario analysis was applied to assess the impact of uncertainty in the further development of the global oil market on the return on the investments.*

Streszczenie.** IW artykule oceniono możliwości wykorzystania złóż palia łupkowgo wydobywanego w Estonii. Do tej oceny użyto takich narzedzi jak Net Present Value I Internal Rate of Return. Uwzględniono także niepewność ogólnego rynku paliw. **Inwestowanie w paliwa łupkowe – ryzyko I niepewności

Keywords: shale oil industry, investments profitability evaluation, scenario analysis, break-even analysis.
Słowa kluczowe: paliwa łupkowe, paliwa łupkowe w energetyce.

Introduction

In the light of European energy policy that intends to limit CO_2 emissions substantially and to promote energy production from renewable energy sources, the emission-intensive power industry in the EU countries faces more and more challenges. One of such countries is Estonia, where 79% of electricity is produced presently from fossil oil shale [1]. Due to the rapid growth of the price of CO_2 emission allowances and increasing competition on the wholesale electricity market caused by Nordic renewable power producers, the old generation units of Estonian condensing oil shale power plants become non-competitive. According to the study in [2], even use of new power generation technologies is economically unreasonable if electricity is produced from oil shale only rather than from fuel mix.

Some countries, the power industry of which is based on the utilization of fossil fuels, tend to modernize existing generation units and implement new power technologies with a high level of efficiency to make the industry more competitive and compliant with the requirements of EU energy legislation [3]. Estonia has another alternative way to keep its oil shale-based power industry – production of shale oil. New generation of oil plants enables production of shale oil, as production of electricity and retort gas. The retort gas, in its turn, is utilized in the power plants located close to the oil plants, which reduces their fuel costs and CO_2 costs. Thus, the production of shale oil maximizes the added value of used oil shale.

Due to the rise of oil and fuel prices along with the growth of energy use around the world in the period from 1999 to 2008, Estonian shale oil producers realized the full business potential of the branch and shifted their focus on the development of oil shale retorting technology and on the construction of new oil plants. However, under the circumstances of economic crisis in 2008 and the world oil market price drop in 2014-2015, the plans had to be revised.

Currently, three Estonian companies are producing shale oil: Enefit Energiatootmine AS, VKG Oil AS and Kiviõli Keemiatööstuse OÜ. In 2016, the total volume of their oil production reached a level of 852,000 tons [4]. At present, the shale oil producers' decisions are targeted to further expansion of fuel production and construction of new capacities. The aim of this paper is to analyse the profitability of investments into the construction of a new shale oil plant under oil market risk and uncertainty. Therefore, different scenarios for the further development of the global oil market were considered.

Expansion of shale oil production capacities

The economic analysis of the project of launch of new oil production capacities will be based on the example of a new shale oil plant construction for Enefit Energiatootmine AS. Presently, it is the owner of the largest energy complex in Estonia, which consists of two condensing oil shale power plants with the total net installed capacity of 1,629 MW_{el} and two oil plants with the total capacity to produce up to 477,000 tons of shale oil per year. The oil plants are based on the Enefit technology that applies a horizontal cylindrical retort, where the shale ash is used as a solid heat carrier. The dried oil shale is mixed with the hot ash carrier, and it is pyrolyzed in the reactor at 500°C [5]. The first oil plant is equipped with the Enefit140 technology, and it has two units. Each unit enables processing up to 140 tons of oil shale per hour. The maximum production capacity of the plant is 220,000 tons of liquid fuel and 60 million Nm^3 of retort gas per year [6].

The second oil plant is based on the Enefit280, improved Enefit technology. The primary modification is replacement of a semi-coke furnace with a circulating fluidized bed (CFB) combustion furnace. The improved technology also incorporates fluid bed ash cooler and waste heat boiler commonly used in coal-fired boilers to convert the waste heat to steam for power generation. The technology allows complete combustion of carbonaceous residue. It has short retorting time and improved energy efficiency thanks to maximum utilization of waste heat [5]. The process diagram of the Enefit280 technology is presented in Fig. 1.

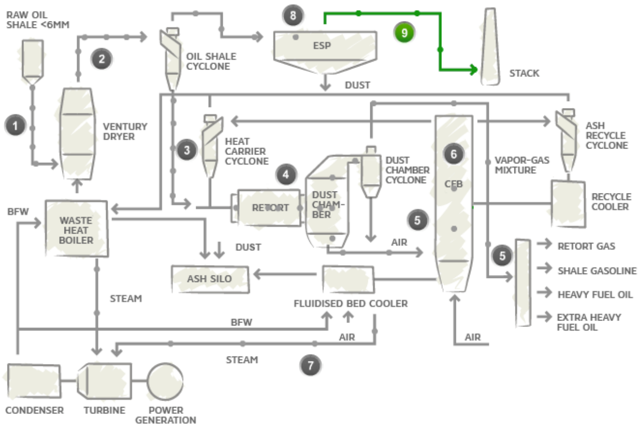

Fig.1. Process diagram of the Enefit280 oil shale retorting technology [7]

The Enefit280 plant can process up to 280 tons of oil shale per hour. It has the capacity to produce up to 257,000 tons of shale oil, 75 million Nm^3 of retort gas and 280 GWh of electricity per year [6, 8].

According to the Strategic Action Plan 2016-2020, a new shale oil plant based on the Enefit280 technology will be built by Enefit Energiatootmine in the future. The timing of the investment decision depends on the market situation and the intention of the owner to extend the combined production of oil, electricity and gas [9]. However, as it has been notified by the company, no large-scale investments are planned until 2020 because of company's large loan load. Therefore, to analyse the economic feasibility of the launch of new oil production capacities, it is assumed that shale oil plant construction will not start before 2021. As the construction is completed in three years, the plant will be taken into operation in 2024. Taking into account that the design lifetime of the current Enefit280 oil plant is 30 years, the new plant is supposed to be operated until 2054.

Investments profitability evaluation criteria

To analyse the economic feasibility of the construction of a new shale oil plant, the profitability of the project investments was evaluated employing the Net Present Value (NPV) and the Internal Rate of Return (IRR) criteria, the most reliable and widely used investments evaluation criteria. The NPV shows the present value of an investment by the discounted sum of all cash flows received from the project. The formula for the NPV can be expressed as:

$$NPV = \sum_{t=J+1}^{T} \frac{C_t}{(1+r)^t} - \sum_{j=0}^{J} \frac{I_j}{(1+r)^j}, \qquad (1)$$

where: t – time of the cash flow (operation period), j – time of the investment, T – total number of the project operation periods, J – total number of the project construction periods, r – discount rate, C_t – net cash flow at time t and I_j – investment at time j.

If the NPV criterion shows a negative value, the investments into the project will be unprofitable, as the net cash flows received from the project will also be negative. If the NPV is positive, the project may be accepted, as investors will receive a return on the investments. However, at decision-making on the basis of the NPV, investors should take into account the weighted average cost of capital, which at best is only an estimate. If the discount rate used in the calculation of the NPV turns out to be smaller than the actual cost of capital, the project will prove unprofitable despite the previously calculated positive NPV.

The IRR shows the efficiency of the project and measures the internal earning rate of an investment. That rate often used in capital budgeting makes the NPV of all cash flows from a particular project equal to zero. If the IRR of a new project exceeds a company's required rate of return, that project is desirable. If the IRR falls below this rate, the project should be rejected.

The NPV and the IRR criteria were calculated for each oil market development scenario and for two discount rates – 5% and 10%.

Scenario analysis

The global oil market is very volatile; therefore, to analyse the expansion of shale oil production capacities under oil market uncertainty, scenario analysis was applied. The price of shale oil tends to follow the price of heavy fuel oil with 1% sulphur content (heavy fuel oil 1%) traded in the market of Northwest Europe. The price dynamics of heavy fuel oil 1% market, in turn, strongly correlates with price movements in the crude oil market that can be seen in Fig. 2 [10, 11].

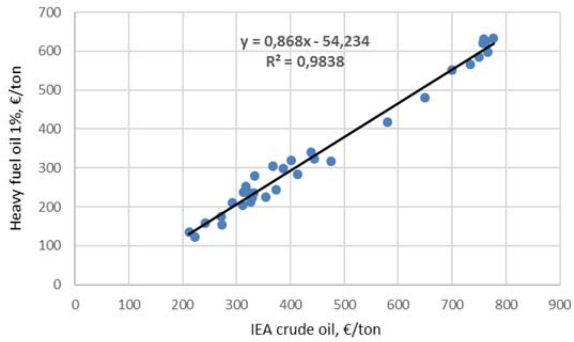

Fig.2. Correlation between average monthly prices of heavy fuel oil 1% and crude oil[1]

Therefore, the scenarios of the development of heavy fuel oil 1% market are based on the scenarios for crude oil market provided by the International Energy Agency (IEA), one of the most credible and competent source. The New Policies Scenario (NPS), the IEA central scenario, reflects both existing energy policies and an assessment of the results likely to stem from the implementation of announced intentions and plans of the governments to develop their energy sectors. The Current Policies Scenario (CPS) is based only on those policies that are in place as of mid-2017; this scenario for the global energy system is a benchmark against which the impact of "new" policies can be measured. The Sustainable Development Scenario (SDS) sets out a pathway to achieve the key energy-related components of the United Nations Sustainable Development agenda: universal access to modern energy by 2030; urgent action to tackle climate change (in line with the Paris Agreement); and measures to improve poor air quality [12].

Table 1. Crude oil price and EU CO_2 price assumptions by scenario

Real terms (€2016)	NPS		CPS		SDS	
	2025	2040	2025	2040	2025	2040
IEA crude oil, €/barrel	75	100	88	123	65	58
IEA crude oil, €/ton[2]	550	735	642	901	477	424
EU CO_2, €/ton[3]	23	43	20	36	57	126

[1] Observed data cover the period 2014 - 2016.

[2,3] Data are presented in euro per ton for the purpose of convenience to compare them with other data given in the paper.

Along with projection of oil prices, the scenarios present the forecast of CO_2 allowance prices that was also used in the analysis of the project. IEA assumptions for crude oil import price as well as for CO_2 price in the EU are shown by scenario in Table 1 [12].

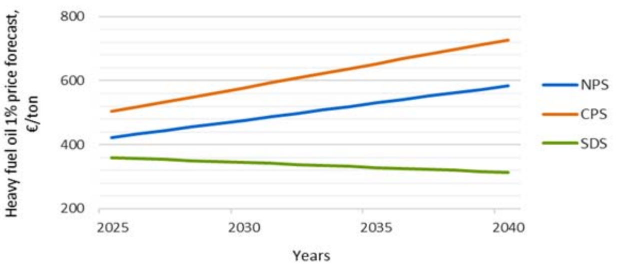

Fig.3. Price forecast for heavy fuel oil 1% by scenario

The price forecast for heavy fuel oil 1% under each scenario was based on IEA crude oil price projection by applying the regression equation presented in Fig.2. The results of the forecast were used for the calculation of the revenue received from the sale of shale oil under each scenario and are shown in Fig. 3.

Break-even analysis

Break-even analysis determines how low an income variable can fall, or how high a cost variable can rise, before the project breaks even at a NPV of zero**Błąd! Nie można odnaleźć źródła odwołania.**. Since production costs generally are fairly predictable, the real concern for investors from the point of view of possibility of losing money is the level of sales revenue [13].

The oil plant project has quite determinable sales volume, therefore the major contributor to revenue uncertainty is uncertainty over the unit selling price. Break-even analysis allows us to determine the selling price, at which the project NPV is just zero.

The general formula for the calculation of the NPV is expressed in equation (1), where C_t, the net cash flow at time t, represents the difference between the cash inflow C_{In_t} and the cash outflow C_{Out_t} at the time t. The cash inflow C_{In_t}, in turn, consists of the revenue received from the sales of project production and the cash outflow C_{Out_t} includes project variable and fixed costs. The revenue of the shale oil plant consists of sales of shale oil and electricity, since retort gas is considered as a free product for electricity generation in the power plants of the energy complex. This is because retort gas is a by-product to be utilized to provide continued shale oil production. Additionally, it is not used in other industries except power production. Assuming that the fuel produced in the oil plant during the operation period t is sold at the same period, equation (1) for the calculation of the NPV of the oil plant project may be expressed as:

$$(2) \quad NPV = \sum_{t=J+1}^{T} \frac{(Q_{Oil_t} * P_{Oil_t} + Q_{El_t} * P_{El_t}) - V_t(Q_{Oil_t} + Q_{El_t} + Q_{RG_t}) - F_t}{(1+r)^t} - \sum_{j=0}^{J} \frac{I_j}{(1+r)^j},$$

where: t – time of the cash flow (operation period), j – time of the investment, T – total number of the project operation periods, J – total number of the project construction periods, r – discount rate, Q_{Oil_t} – volume of shale oil produced at time t, P_{Oil_t} – selling price of one unit of shale oil at time t, Q_{El_t} – volume of electricity produced at time t, P_{El_t} – selling price of one unit of electricity at time t, Q_{RG_t} – volume of retort gas produced at time t, V_t – variable cost of one unit of the oil plant production at time t, F_t – fixed cost at time t and I_j – investment at time j.

As electricity is produced in the shale oil plant in small volume, the main source of revenue for the oil plant project is sales of shale oil. Therefore, the major contributor to revenue uncertainty is uncertainty over the selling price of the unit of shale oil. To determine the oil price at which the project NPV is just zero, it is required to find the break-even selling price of shale oil P^*_{Oil}. This price may be determined by substituting P^*_{Oil} for P_{Oil_t} in equation (2), setting NPV equal to 0, and solving for P^*_{Oil}. Thus, the break-even selling price of shale oil P^*_{Oil} can be calculated by:

$$(3) \quad P^*_{Oil} = \frac{\sum_{j=0}^{J} \frac{I_j}{(1+r)^j} - \sum_{t=J+1}^{T} \frac{Q_{El_t} * P_{El_t}}{(1+r)^t} + \sum_{t=J+1}^{T} \frac{V_t(Q_{Oil_t} + Q_{El_t} + Q_{RG_t}) + F_t}{(1+r)^t}}{\sum_{t=J+1}^{T} \frac{Q_{Oil_t}}{(1+r)^t}}.$$

The break-even analysis assumes that the price P^*_{Oil} is constant through the whole life of the project. The project will have a positive NPV if the forecasted market price exceeds this “cut-off” price. If the decision-makers know that this ”cut-off” price is likely to be reached, then they may decide not to proceed with the project.

The break-even price P^*_{Oil} was calculated for each oil market development scenario and for two discount rates – 5% and 10%.

Data and basic assumptions

To define the NPV and the IRR of the investments of a new shale oil plant, the cash flows received from the project during its lifetime must be calculated. Therefore, some basic assumptions were made to estimate the future revenue and costs of the plant.

As was mentioned above, the revenue will be received from the sale of shale oil and electricity. As return on the investments into the oil plant mainly depends on the revenue received from the sale of shale oil, three different scenarios for further oil market development discussed above are assumed to define the revenue for each case. Since the oil price projection is available until 2040, while the price forecast for fuel oil is needed until 2054, it is supposed that the trend of oil market development will remain unchanged in the future. To estimate the cash inflows from electricity sale, electricity price forecast for the Estonian price area of Nord Pool was used because according to an assumption, electricity produced in the oil plant will be sold on the Nordic power exchange.

To estimate the annual production volume of the oil plant, it is assumed that the oil plant meets European emission standards and, as a result, can operate at full load during its lifetime. Therefore, the data on the maximum annual production of the Enefit280 plant shown in Table 2 were used to calculate the revenue of the new plant, as it is of the same type as those of the Enefit280.

The main production costs for the shale oil plant consist of oil shale purchase costs, environmental costs and operation and maintenance (O&M) costs. The assessment of cash outflows caused by the purchase of oil shale is based on the annual primary fuel consumption and its price growth in the future. Oil shale price projection, in turn, is made on the basis of the price forecast for the major components of oil shale production costs, such as raw materials, electricity, oil shale extraction charge, environmental charges and payroll expenses. According to the Estonian Environmental Charges Act, from 1st of July 2015, oil shale extraction charge rate depends on the price of heavy fuel oil 1% [14]. Therefore, the forecast of the extraction charge was made for each scenario of the fuel oil market development, assuming that the principles of the calculation of the oil shale extraction charge rate will remain unchanged in the future.

The environmental costs of the oil plant include the charge for surface water use as cooling water, the charge for disposal of oil shale ash and the charge for the emission of pollutants, such as CO_2, SO_2, NO_x and fly ash, into the ambient air. As was mentioned above, to calculate CO_2 costs of the plant, IEA forecast of CO_2 allowance price for EU presented by scenario was used [12]. Since the CO_2 price projection is available until 2040, the CO_2 market trends are supposed to remain the same until 2054 when the project will be terminated. Other environmental costs were calculated using the natural resource and pollution charge rates set until the end of 2017 in the Environmental Charges Act of the Republic of Estonia [14]. The growth of the charge rates in the future was estimated on the basis of the projection of the average annual rate of inflation in Estonia presented by the Ministry of Finance [15]. The specific amounts of cooling water, oil shale ash and emissions of the Enefit280 were used to calculate the environmental costs of the new shale oil plant, since the type of the considered oil plant is the same as that of the Enefit280. These data were provided by Enefit Energiatootmine.

To calculate O&M costs, the payroll expenses of the Enefit280 were used, as they account for approximately 50% of the total O&M costs of the oil plant. To estimate the growth of the costs during the project lifetime, the forecast of the average annual rate of inflation was used [15].

To define the investments into the construction of the new plant, investments of the Enefit280 were recalculated for the first year of its construction, using the historical data on the consumer price index in Estonia and the forecast of this indicator [15, 16, 17].

Table 2. General information about a new shale oil plant

Parameter	Value
Investment costs, million euros	304
Construction time, years	3
Design lifetime, years	30
Oil shale processing capacity, tons per hour	280
Installed electrical capacity, MW	35
Annual consumption of oil shale at the maximum capacity, million tons	2.26
Maximum annual production of shale oil, thousand tons	257
Maximum annual production of retort gas, million m^3	75
Maximum annual production of electricity, GWh	280

Information regarding construction time, design lifetime, consumption of oil shale and production capacity for the new oil plan is also gathered on the basis of corresponding data for the Enefit280. General information about the construction project is presented in Table 2 [6, 7, 8, 16].

Results of the investments profitability study

To assess the profitability of the Estonian shale oil industry in the future, the economic feasibility of the construction of new oil production capacities was analysed taking into account the possible scenarios for price dynamics in the global oil market. The analysis of the investments was made by employing the NPV and the IRR methods. The results of the calculation of the NPV and the IRR for each scenario are shown in Table 3.

As can be seen in Table 3, the construction project of a new shale oil plant has the highest NPV and the IRR under the CPS. It means that investments into the shale oil industry will be most profitable if the developments within the global energy system follow an assumption that the implementation of some existing commitments would be sluggish and only the lower level of new policies and measures would be attained in the future. This scenario projects the largest growth of crude oil prices in the global market and the lowest prices of CO_2 allowances in the EU, which provides the highest return on investments into the shale oil production sector in comparison with the NPS and the SDS.

Table 3. Results of the calculation of the project evaluation criteria by scenario

Scenario	Discount rate r, %	NPV, million euros	IRR, %
NPS	5	358	13
	10	77	
CPS	5	699	18
	10	251	
SDS	5	-870	-
	10	-496	

The NPS reflects the policies and measures that are already established as new declared policy intentions. If the energy sectors are developed by their governments according to this scenario, the future energy system will provide quite favourable environment for the expansion of liquid fuel production and for the launch of new capacities to produce shale oil. However, as for the considered project, decision-makers should take into account that the weighted average cost of capital must be lower than 13% to provide the positive NPV for the project under the NPS.

Under the SDS, the construction of new oil production capacities is economically unreasonable, showing strongly negative NPV. It means that investments into the shale oil industry will be totally unprofitable if the SDS relied on the key energy-related aspects of the United Nations Sustainable Development Goals is realized. According to the scenario, extremely high prices of CO_2 allowances in the EU are projected that drastically increase environmental costs for this emission-intensive power industry, making it unfeasible from the economic point of view. The growth of the share of environmental costs from the total operating costs of the shale oil plant can be clearly seen in Fig. 4.

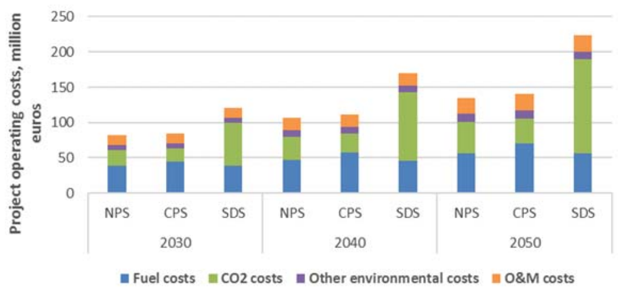

Fig.4. Operating costs of a new shale oil plant by scenario

The results of the calculation of project's NPV were confirmed by the results of the project break-even analysis presented in Table 4.

Table 4. Results of the break-even analysis of the project by scenario

Scenario	Discount rate r, %	Break-even price $P*_{Oil}$, €/barrel	Break-even price $P*_{Oil}$, €/ton
NPS	5	55	405
	10	60	438
CPS	5	57	417
	10	61	447
SDS	5	82	603
	10	83	608

As can be seen in Fig. 3 and in Table 4, the forecasted market price of heavy fuel oil 1% exceeds the "cut-off" selling price of the project only under the NPS and the CPS. It means that investments into the shale oil industry will have a positive NPV if the further development of the energy sectors follows the pathway according to one of these two scenarios.

Conclusion

The aim of this paper was to study the profitability of investments in the Estonian shale oil industry, taking into account different scenarios of further developments in the global oil market. The focus of the analysis was on the economic reasonability of the construction of a new shale oil plant for Enefit Energiatootmine's energy complex, the largest energy complex in Estonia.

The results of the analysis showed that the project of the construction of a new shale oil plant is most profitable under the CPS implementation, which assumes that only the lower level of existing commitments and new political intentions would be attained in the future. This scenario expects very high crude oil prices in the global market and, as a result, high prices of heavy fuel oil 1%, which follow the shale oil price that provides the large return on investments into the project. The low growth of CO_2 allowance prices in the EU that was projected according to the scenario also promotes the profitability of the project.

If the development of the global energy system follows the NPS, which assumes the realization of new declared policies and measures, the investment environment in the shale oil industry becomes less attractive, providing quite moderate IRR for the project. Meanwhile, the NPS is the central scenario of the IEA that is supposed to have a high probability of implementation.

The analysis of investments in the Estonian shale oil industry under risk and uncertainty was focused on the evaluation of the investments profitability under different scenarios for the further development of the oil and CO_2 allowance markets, and on the estimation of the break-even price of the unit of shale oil for each scenario. Although the changes in the price dynamics of oil and CO_2 allowances are ones of the most important factors that influence on return on investments in the shale oil industry, there are a lot of other potential risks that may occur during the implementation and operation phases of a project. Since there are long-term and investment-intensive projects in this branch, such factors as possible fluctuations in capital expenditures, changes in energy policy and legislation should be considered before making any investment decision. Thus, it may be concluded that the risks associated with shale oil production projects should be carefully weighted and included in a discount rate for reliable estimation of the project's profitability to provide return on investments after the project launch.

Authors: *Svetlana Pulkkinen, Physical Market Specialist, Eesti Energia AS, Lelle Str. 22, 11318 Tallinn, E-mail:* svetlana.pulkkinen@mail.ee*; Prof. Juhan Valtin, Tallinn University of Technology, Department of Electrical Power Engineering and Mechatronics, Ehitajate tee 5, 19086 Tallinn, E-mail:* juhan.valtin@ttu.ee.

REFERENCES

[1] Statistics Estonia, Statistical database, Capacity and production of power plants. Available online at: http://pub.stat.ee/px-web.2001/Dialog/varval.asp?ma=FE032&ti=CAPACITY+AND+PRODUCTION+OF+POWER+PLANTS&path=../I_Databas/Economy/07Energy/02Energy_consumption_and_production/01Annual_statistics/&lang=1.

[2] Pulkkinen S., Valtin J., Evaluation of Investments Profitability in Conventional Power Generation Sector in Estonia, Conference Paper, *European Energy Market (EEM) 2016*, http://dx.doi.org/10.1109/EEM.2015.7216768.

[3] Wawrzyńczyk J., Problemy I kierunki innowacyjnych rozwiązań w polskiej energetyce, *Przegląd Elektrotechniczny*, 2017, nr. 11, 14-16.

[4] Viru Keemia Grupp, Yearbook 2016. Available online at: http://www.vkg.ee/eng/company/reporting/yearbooks.

[5] Speight J.G, Shale Oil Production Processes, Gulf Professional Publishing, Elsevier, United Kingdom, Oxford 2012.

[6] Aarna I., Developments in Production of Synthetic Fuels Out of Estonian Oil Shale, *Energy & Environment,* 22(5), 541-552. http://dx.doi.org/10.1260/0958-305X.22.5.541.

[7] Enefit, Enefit shale oil technology. Available online at: https://www.enefit.jo/en/project/production-plant.

[8] Eesti Energia. Annual Report 2012. Available online at: https://www.energia.ee/-doc/8457332/ettevottest/investorile/pdf/annualreport_2012_eng.pdf.

[9] Eesti Energia, Annual Report 2016. Available online at: https://www.energia.ee/-doc/8457332/ettevottest/investorile/pdf/annual_report_2016_eng.pdf.

[10] Platts, The European Fuel Oil Price: Oil Price Assessments. Available: https://www.platts.com/price-assessments/oil/fuel-oil.

[11] International Energy Agency, IEA online data, Monthly data: oil. Available online at: https://www.iea.org/statistics/monthlystatistics/monthlyoilstatistics/.

[12] International Energy Agency, World Energy Outlook 2017, France, Paris 2017.

[13] Dayananda D., Irons R., Harrison S., Herbohn J., Rowland P., Capital Budgeting: Financial Appraisal of Investment Projects, Cambridge University Press, United Kingdom, Cambridge 2002.

[14] Riigikogu, Environmental Charges Act. Available online at: https://www.riigiteataja.ee/en/eli/ee/513012014001/consolide/current.

[15] Ministry of Finance of the Republic of Estonia, Long-term economic forecast up to 2070. Available online at: https://www.rahandusministeerium.ee/et/riigieelarve-ja-majandus/majandusprognoosid.

[16] Eesti Energia. Annual Report 2014. Available online at: https://www.energia.ee/-doc/8457332/ettevottest/investorile/pdf/annual_report_2014_eng.pdf.

[17] Bank of Estonia, Key Economic Indicators. Available online at: http://statistika.eestipank.ee/?lng=en#listMenu/2053/treeMenu/MAJANDUSKOOND.