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ASSESSMENT OF EXTERNAL COSTS IN OIL SHALE-BASED ELECTRICITY PRODUCTION IN ESTONIA

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In this paper, the authors analyze the nature and structure of external costs in Estonian oil shale-based power plants. The methods for internalizing these costs are also introduced. The external costs discussed here primarily include the expenses related to exhaustion of natural resources and environmental damage in the context of the formation of the oil shale-based electricity production price. The authors calculate these expenses currently and prognosticate various scenarios of oil shale-based electricity production price and external costs until 2010. The scenarios take into consideration possible developments of the legislation that regulates the energy sector, and other energy related factors in the Baltic Sea region and in the European Union in general.

More adequate assessment of the environmental costs is a factor that is increasingly influencing development trends of the energy sector on global scale. This is highly important also in Estonia since planning of further development of oil shale-based energy complex is still very topical.

Introduction

In the planning of the Estonian energy sector development, the future and extent of the ongoing renovation of Narva oil shale-based power plants (Narva PP) is acute on the agenda. Both the national energy sector development plan that was adopted in 1998 [1], and drafts of the new versions and development visions have envisaged reduction of the share of oil shale in the energy balance with increasing of the share of renewable resources and more extensive use of combined production of heat and

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electricity (mostly on the basis of natural gas). An important factor here is environmental restrictions arising from the European Union (EU) energy directives as well as from the Estonian Environment Strategy [2, 3].

According to the present plans of *Eesti Energia AS (Estonian Energy Ltd.) (EE)*, large-scale renovation in Narva PP will continue until 2018. All blocks that presently use pulverized combustion technology will be reconstructed to use circulating fluidized-bed combustion (CFBC) technology. The initial results of the first stage of renovation (test-exploitation of the Estonian PP 8th block) have met the expectations – improvement of the efficiency, reduction of air pollution, etc. However, full-scale renovation of Narva PP requires only during the next 15 years up to 19 billion kroons of investment, and the total amount of expected investments in *EE* is 46 billion kroons [4]. It is assumed that this renovation plan will cover 85% of Estonia's need for electricity. Implementation of such a large investment programme should be discussed as a nationally important decision, which requires weighing of all possible alternatives, energy consumption prognoses, electricity market conditions, etc. Comparisons of various electricity production scenarios play also an increasingly bigger role. An important factor in evaluating these alternatives is so-called external costs internalizing in electricity production.

External costs are defined as costs generated due to the externality of activity or production, which are not fully included in the production price of respective activity or product, and what are not covered by the creator of this impact, but by the environment or society [5]. Therefore, various models are used for taxation of resources or consumption, hence providing a more correct economic feedback on the influence of product or activity on the environment or society under market competition. External costs are primarily environmental costs involved in the exhaustion of natural resources and pollution of the environment.

There are various systems of taxation in the form of resource taxes and pollution charges aiming at internalizing external costs in electricity production from fossil fuels. The EU member states are, as a rule, using taxes that can be classified as energy taxes, which seek to encourage consumers to save energy and make as environment-friendly choices as possible. According to the Council Directive of Restructuring the Community Framework for the Taxation of Energy Products and Electricity (2003/96/EC) [6], this will be the post-accession development also for Estonia.

This paper deals with the experiences of internalizing external costs in oil shale-based electricity production so far, on the basis of both *EE* and government institutions' data and previous works by the authors [7, 8]. We also develop the methods for internalizing the externalities by different scenarios.

Externalities in Power Generation

It is common for economic agents to focus primarily on their operational activities, paying much less attention to developments, which seem to be external from their point of view. Thus, it is understandable that for a long time the only criterion for economic efficiency was keeping company's production costs as low as possible, with minimum discussion about the social and environmental impacts of economic activities. Still, all actions have wider consequences than initially considered, and the extensive economic growth has brought about also large-scale environmental problems.

Partly, those environmental problems have occurred because economic agents have considered those effects, which have not directly influenced their balance sheets as being "external" to them. Reflecting such mindset, the concept of external effects (externalities) has been defined. These external effects can be positive or negative – called external benefits and external costs, respectively. The European Commission has formulated the principle in a following manner: an external cost, also known as externality, arises when the social or economic activities of one group of persons have an impact on another group and when that impact is not fully accounted, or compensated for, by the first group [9].

In power generation, the situation is in principle the same as in other sectors. Price formers have usually focused on keeping the price level low, choosing the cheapest possible sources of energy. However, they have mostly taken into account only production and distribution costs – the choices made therefore have not been the best if to consider all costs. Thus, historically the electricity price has not taken into account the total social costs, which contain, for example, environmental and health costs [10].

It is possible to take into consideration the externalities and thereby correct market failures by changing the price of product or service. Economic theory allows drawing a conclusion in case of competitive markets that distribution of resources is optimal if price is equivalent to marginal cost of the product. Thus, the theory suggests that the suppliers of external environmental costs can be induced to act 'optimally' (i.e. to reduce emissions to an optimal level) by imposing an emission fee on emitters equal to the marginal social damage [12]. Figure 1 describes the phases of internalizing externalities and the related problems.

External costs of power generation can be defined as all technology related costs in power generation paid for not by producer but either by the public or other parties involved. When the damages caused by a particular power generation method have been identified, the policy makers should start internalizing them. The crucial, yet the most complicated, part of the process is the issue of taking the environmental costs into account.

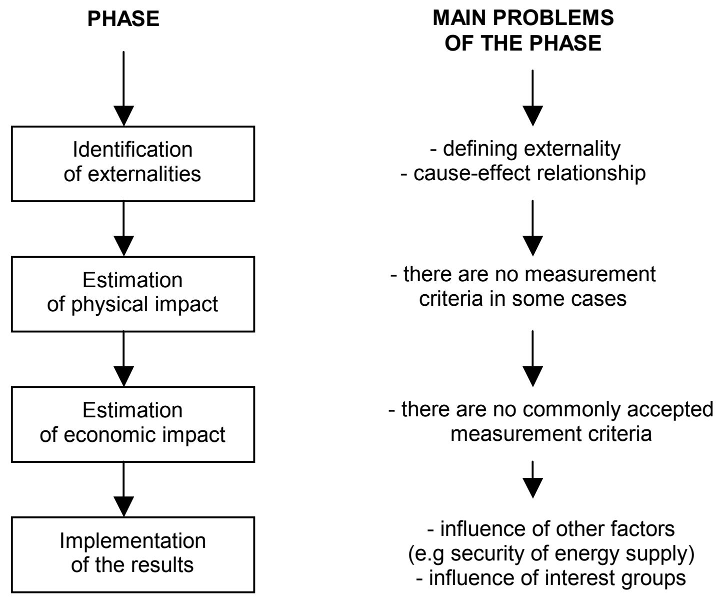

Fig. 1. The phases of internalization of externalities (based on [10, 11])

The internalization of environmental costs and their exact valuation is in any case a disputable process. Attempts to elaborate uniform criteria or sufficiently precise models have not been successful. This has undoubtedly detained attempts to find an optimal solution from the point of view of the society, aggravating the constantly worsening regional and global environmental problems. Fortunately, the lack of common methodology has not prevented working out various approaches trying to address the issue. The following widely recognized methods for internalizing environmental costs can be presented on the basis of what has been done so far [13]:

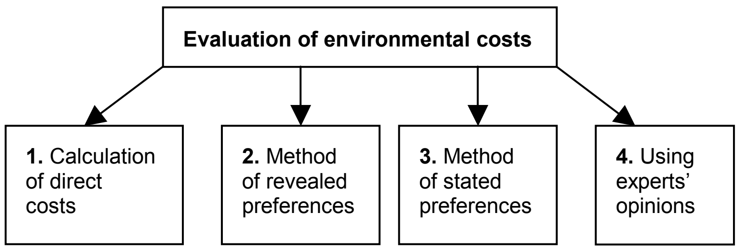

Fig. 2. The main methods for internalizing environmental costs

1. In the case of **calculation of direct costs,** all directly identifiable costs are taken into consideration. A weakness of the method is the risk that most of the environmental expenses are not counted, like the practice so far has been.

2. In the case of **revealed preferences,** individuals' willingness to pay or willingness to accept is measured indirectly, hoping that the persons "reveal" their preferences about non-market goods by market behavior towards related items. Of course, all such indirect valuation methods can be disputed on the basis of non-inclusion of other factors.
3. In the case of **stated preferences,** the preferences of the individuals are measured directly. According to this method, a sample survey is conducted among the target group. The group is asked to estimate the value of natural environment or pollution damages for them. The obvious problem with this method is discrepancies between people's opinions and actual behavior.
4. In the case of **using expert estimates,** the chosen experts make decisions on the basis of scientific analysis (e.g. by combining the above methods) and their own experience.

If we can, notwithstanding the above problems, to take into account the externalities to a more or less extent, the production costs will grow for the enterprises. Usually it means shifting those additional costs over to consumers in the form of a price rise. For the society, an optimal solution does not depend on whether producers or end consumers pay the externalities, as far as it is done sufficiently. The possibility of shifting costs to consumers depends primarily on the competition situation, e.g. it is quite easy for the monopolistic *EE* to do that in the Estonian oil shale-based energy sector.

The environmental policy of the UN member countries (including Estonia) is based on the **sustainable development concept** [14]. The requirement of using sustainable development principle is also stipulated in chapter 53 of the Republic of Estonia Constitution, which says that everyone has a duty to preserve the human and natural environment and to compensate for damage caused to the environment by him or her. Law shall provide the procedure for compensation.

One of the basic documents for implementation of environmental policies of the Republic of Estonia is the Environmental Strategy [3]. The basic principles stated there provide an ample foundation for the implementation of environmental policies in all spheres of life. The goal of the environmental strategy with respect to reducing negative environmental effects of energy production are formulated as follows: "… to reduce negative environmental effects of energy production, to direct energy policies towards energy-efficient technology development programmes, more extensive use of renewable energy resources and reduction of greenhouse gas emissions, **to include all environment-related costs of energy consumption in the energy price**" [3].

The Strategy served as the basis for the first Estonian Environmental Action Plan, which was approved by the Estonian Government in May 1998. This envisaged the environment-related activities towards main goals for the short term (for the years 1998–2000) and longer term (2001–2006). Monitoring of the implementation in practice and results of the activities has been conducted through annual surveys. Different results are born in co-operation between many counterparts, e.g. between local governments and enterprises, non-profit organizations and government institutions [15].

On the basis of the above it may be stated that at least theoretical economic-policy conditions for internalizing environmental costs in Estonian oil shale-based energy sector have been created.

External Costs in Oil Shale-Based Electricity Production Price

Methodological bases for internalizing external costs of oil shale-based electricity production have been worked out in previous investigations by the authors [7, 8, 16]. This article develops the methods further and improves concrete calculation models. The primary concern is the assessment of the principal external cost component in electricity production – environmental costs.

The database for performing a model analysis consists of two different parts. First, national level (as a rule, established by law) information on the regulations (resource and pollution charge rates, the coefficients depending on the location of the power plants and other factors, etc.) serving as the basis for internalizing external costs. Co-ordination of the elaboration (including harmonization with EU respective standards) and implementation of these regulations is the task of the Estonian Ministry of the Environment. The second part of the database is information on concrete economic activities in oil shale-based electricity production. In this case, these are data of the official audited annual reports of *EE* on the performance in Narva PP. These include also particular data on the use of fuels, water consumption, emissions and waste available in the environmental reports of *EE*.

The approach used in Estonia for the establishment of regulation standards relevant for internalizing environmental costs is based mainly on the method of expert estimates (see classification in Fig. 2). The most important elements of information needed for the model analysis below are presented in Table 1 (charge rates for use of oil shale resources and use of water) and Table 2 (air pollution charge rates[*]). They are imposed, as a rule, as a kind of social agreement – a compromise between increasing saving and environment-friendly behavior by enterprises and providing for both their own and national competitiveness in real time. In international practice, movements of environmentalists also play a significant role; their influence in Estonia has been very small so far.

[*] Air pollution charge rates (except for CO_2) are increased 1.2 times for stationary sources of pollution within the administrative units bordering the River Narva if the height of emission of pollutants is up to 100 metres above ground level – hence also for Narva PP.

The regulation standards valid until 2006 [17–20] have been established by law. A draft of the new law on environmental charges, which will establish pollution charge rates for the period 2006–2010, is under elaboration.

Table 1. **Charge Rates for Oil Shale Resources and Use of Water**[*]

	1999	2000	2001	2002	2003	2004	2005
Oil shale resources charge, EEK/t	4.0	4.0	4.8	4.8	4.9	5.1	5.2
Charge for special use of water, sents/m^3:							
Underground water:							
1. Most upper ground level (Q)	20	25	30	33	36	40	44
2. Lowest ground level (E-V)	35	40	45	50	54	60	66
3. Extracted from mines and quarries	3.0	4.0	5.0	5.5	6.0	6.5	7.0
Surface water:							
1. From Tallinn catchment area	20	25	30	30	30	32	33
2. From Tallinn catchment area for cooling	2.5	3.0	3.5	4.0	4.0	5.0	5.0
3. From other areas	10	12	14	15	17	19	20
4. From other areas for cooling in Narva PP	2.0	2.0	2.5	2.5	2.5	2.5	2.5

[*] Sources: 1. Riigi omandisse kuuluvate maavarade kaevandamisõiguse tasu määrad (Mining Charge Rates for State-owned Natural Resources). Regulation No. 342 of 6 November 2001 of the Government of the Republic of Estonia // Riigi Teataja (State Gazette). 2001. Vol. 1, No. 90, 539 (in Estonian).
2. Charge Rates for Special Use of Water in the Case of Water Extraction from Water bodies or Groundwater Aquifers. Regulation No. 160 of 8 May 2001 of the Government of the Republic of Estonia // Riigi Teataja (State Gazette). 2001. Vol. 1, No. 45, 250.

Table 2. **Air Pollution Charge Rates, EEK/t**[*]

		1999	2000	2001	2002	2003	2004	2005
1.	Sulphur dioxide (SO_2)	46.0	55.2	66.2	79.0	95.0	114.0	137.0
2.	Carbon monoxide (CO)	6.6	7.9	9.5	11.0	14.0	16.0	20.0
3.	Nitrogen oxides (NO_x)	105.4	126.4	151.7	182.0	218.0	262.0	315.0
4.	Carbon dioxide (CO_2)		5.0	7.5	7.5	7.5	7.5	11.3
5.	Particulates	46.0	55.2	66.2	79.0	95.0	114.0	137.0
6.	Volatile organic compounds	42.8	51.5	61.9	182.0	218.0	262.0	315.0
7.	Heavy metals	1670.7	1995.5	2413.7	2896.0	3476.0	4171.0	5005.0

[*] Sources: 1. Pollution Charge Act // Riigi Teataja (State Gazette). 1999. Vol. 1, No. 24, 361.
2. Pollution Charge Act Amendment Act // Riigi Teataja (State Gazette). 2001. Vol. 1, No. 102, 667.

Data in Table 1 indicate that the **oil shale resource charge rate** (mining charge rate) will increase 1.3 times in the period 1999–2005. The growth by 2010, compared with 2005, is initially envisaged also to be 1.3 times**.** With respect to the charge for use of **water,** oil shale-based electricity production has been granted a considerable alleviation, both for underground water (used primarily in oil shale mining) and surface water consumption (the latter is used in very large quantities as cooling water in electricity production). In both cases, the charge rate difference from other consumers is nearly 6 times. The cooling water charge rate will not rise by 2010, according to plans, which will relatively increase the advantage still. The mining water charge rate is envisaged to increase 1.6 times, which keeps the proportion with other consumers on the present level.

Data in Table 2 suggest that the **pollution charge rates** for majority of **air pollutants** will increase 20% annually until 2005. The same growth rate has been established for **solid waste** charge rates. The Ministry of the Environment has also planned another 20% increase of air pollution and solid waste charge rates for the period 2006–2010. An exception here is the CO_2 charge rate, which in 2005 will rise from 7.5 to 11.3 EEK/t (growth 1.5 times) [20]. There are no concrete plans so far to raise this charge rate by 2010.

As analysis and prognosis of the traditional cost items of oil shale-based electricity production price (materials, consumables and supplies, operating expenses, personnel expenses, depreciation etc.) have been discussed in detail in previous works, e.g. [7, 16], in this article we present the environmental costs as a general indicator of production price, and, based on the objective of our research, discuss it as thoroughly as possible. The results of calculations are presented in Table 3 – environmental costs of oil shale mining in *AS Eesti Põlevkivi (Estonian Oil Shale Ltd.)* (subsidiary of the *EE*) and electricity production at Narva PP are presented on separate rows. Only oil shale extracted for electricity production, and only electricity production at Narva PP have been considered – the costs related to other production (heat, shale oil, etc) are discounted.

Calculations have been made for the following scenarios:

1. **Base scenario for 2002/2003.** Is based on the data of the economic year of 2002/2003 (01.04.2002 – 31.03.2003) and environmental reports for 2002 [21, 22] of *Eesti Energia AS* (the latest available official data).
2. **Scenario "Water".** A modification of the base scenario, assuming that the rate of general application shall be charged for using both underground and surface water in oil shale mining and electricity production.
3. **Scenario "EC".** A modification of the base scenario where the pollution charge rates for three principal air pollution components (SO_2, NO_x and

particulates) are the average rates for rural areas of old EU member states as calculated in [23]:

SO_2 – 81,120 EEK/t (5200 EUR/t),

NO_x – 65,520 EEK/t (4200 EUR/t),

Particulates – 218,000 EEK/t (14,000 EUR/t).

According to the methods used in [23], these rates are based on the evaluation of total social damage from the emissions of the above pollutants.

With such high pollution charge rates it is obvious that it is a theoretical background scenario, the implementation of which in Estonia is not possible in any realistic perspective. Though according to this study, not all externalities are counted there either, mechanical takeover of these rates for Estonia is not justified, for instance considering the balancing impact of our alkaline solid and oil-shale ash on acid emissions into air, and other local conditions. On the other hand, the CO_2 charge rate is also in many EU countries much higher than the current and short-term planned rates for Estonia (see, for example, [24]). Thus, the above scenario suggests that the internalization of external costs is only in the initial stage and at the same time useful for perceiving future trends.

4. **Scenario "2005".** Forecast of the oil shale-based electricity production price and a detailed forecast of environmental costs for 2005. The electricity output (net output 6550 GWh) has been prognosticated on the basis of both environmental restrictions and results of the first phase of renovation at Narva PP. A rise in efficiency and a reduction of emissions as a result of renovation have been counted [25].

5. **Scenario "2010".** Forecast of the oil shale-based electricity production price and a detailed forecast of environmental costs for 2010. Presented in two versions. The first version presumed that renovation at Narva PP is limited to the 1st phase (2 blocks with total capacity of 430 MW_e). In the event of this version, the net output would be limited to 5300 GWh annually due to the environmental restrictions. Under the second version, another 2 blocks would be renovated by 2010 (with total capacity of 430 MW_e), which enables to produce oil shale-based electricity up to 6900 GWh. The CO_2 pollution charge rate under both versions will be 17 EEK/t (growth 1.5 times compared with 2005).

As you can see from Table 3, the environmental costs in oil shale-based electricity production were approximately 4 sents/kWh according to the **base scenario,** accounting for 11% of the total production price. Whereas 1 sent/kWh from this are environmental costs of mining for oil shale used for electricity production *(AS Eesti Põlevkivi)* and 3 sents/kWh direct environmental costs of oil shale-based electricity production at Narva PP.

Table 3. **Calculation of the Environmental Costs of the Oil Shale-Based Electricity Production at the Narva PP**

	2002/2003			2005	2010	
	Base	Water	EC		I	II
Net production, GWh	7,680	7,680	7,680	6,550	5,300	6,900
Needed amount for oil shale, thousand t	10,305	10,305	10,305	8,900	7,200	9,300
Electricity production price:						
EEK/kWh	0.36	0.38	1.79	0.45	0.53 (0.51)	0.53 (0.51)
EUR/100 kWh	2.30	2.43	11.44	2.88	3.39 (3.26)	3.39 (3.26)
Charges at *AS Eesti Põlevkivi* (for electricity production), thousand EEK						
Oil shale resources	49,464	49,464	49,464	46,280	48,240	62,310
Use of water	7,570	45,421	7,570	8,593	11,199	14,579
Water pollution	5,623	5,623	5,623	7,485	12,721	16,561
Air pollution	93	93	118,124	150	247	247
Waste deposition	5,668	5,668	5,668	6,434	8,384	10,915
Recognition of environmental and mining termination provisions	26,664	26,664	26,664	28,989	33,607	33,607
Total environmental costs	95,082	132,933	213,113	97,931	114,398	138,219
EEK/kWh	0.01	0.02	0.03	0.01	0.02	0.02
Charges at AS Narva PP (for electricity production), thousand EEK						
Water use:						
cooling water	26,716	165,641	26,716	22,925	18,550	24,150
other water	585	585	585	670	895	1,165
Total	27,301	166,226	27,301	23,595	19,445	25,315
Air pollution:						
CO_2	69,581	69,581	69,581	87,782	106,498	137,593
SO_2	5,723	5,723	4,896,792	5,621	9,919	7,702
NO_x	2,123	2,123	637,043	3,095	5,976	7,780
Particulates	2,298	2,298	5,293,596	461	1,040	1,328
Volatile organic compounds	132	132	132	195	391	509
Heavy metals	291	291	291	429	865	1,126
Total	80,148	80,148	10,897,435	97,583	124,689	156,038
Water pollution	393	393	393	130	250	250
Oil shale ash deposition	85,400	85,400	85,400	100,019	123,638 (20,606)	160,963 (26,827)
Total environmental costs	193,242	332,167	11,010,529	221,327	268,022 (164,990)	342,566 (208,430)
EEK/kWh	0.03	0.04	1.43	0.03	0.05 (0.03)	0.05 (0.03)
Total environmental costs of the oil shale-based electricity production:						
Thousand EEK	288,324	465,100	11,223,642	319,258	382,420 (279,388)	480,785 (346,649)
EEK/kWh	0.04	0.06	1.46	0.05	0.07 (0.05)	0.07 (0.05)
EUR/100 kWh	0.24	0.39	9.34	0.31	0.46 (0.34)	0.44 (0.32)

In case the **scenario "Water"** comes true, the environmental costs would rise by 2 sents per kWh (both in oil-shale mining and electricity production by 1 sent/kWh), which would mean for home consumers, for instance, an average price rise by 3 sents/kWh. Thus, the subsidization for water consumption in oil shale-based electricity consumption is not very big, but has a considerable impact still. All environmental costs under this scenario would be 6 sents/kWh (16% of production price).

With **scenario "EC",** environmental costs in the oil shale-based electricity production price would rise to nearly 1.5 EEK/kWh, accounting for the biggest part (approximately 80%) of the production price. As mentioned above, this scenario is a theoretic attempt to establish a "right price" for oil shale-based electricity, considering as completely as possible the externalities of production.

According to the **prognosis for the year 2005,** based on the base scenario, environmental costs in oil shale-based electricity production will increase to 5 sents/kWh (11% of production price). The **prognosis for 2010** under both versions is approximately 7 sents/kWh (13–14% of the production price). It should be mentioned here that the difference in results between two versions in the prognosis for 2010 (in favour of the second version) is surprisingly small – hence the continuing renovation will not exert any significant influence on the environmental costs, neither on their size nor share in oil shale-based electricity production price. At the same time, the influence of direct environmental investments is considerable. The investment plan of EE until 2018 [4] foresees also renovation of the oil shale ash removal system at Narva PP, incl. building of proper ash depositories. Implementation of the project will remarkably reduce the charge for oil shale ash deposition. As a result, the environmental costs can remain at the level of 2005 (the respective data for 2010 are given in brackets in Table 3).

Conclusions

- Internalizing of external costs in electricity production is presently an extremely important issue in Estonia, as planning of the future development of oil shale-based energy production is, in connection with the need to make large-scale investment decisions, more topical on the agenda than ever before. Whereas the methods for internalizing external costs have not been fully developed and the pollution charge rates, which are a fundamental component of these costs, have not been definitely determined. This paper is a contribution to further improvement of the methods for calculating these costs, making an attempt thereby to analyse different potential scenarios for internalizing environmental costs in oil shale-based electricity production.
- Given the analysis results, with the current resource tax and pollution charge rates, the external costs influence the oil shale-based electricity

production price only slightly. However, only the abolishment of the present discount on the water consumption charge for oil-shale mining and electricity production (**scenario “Water”**) would increase the environmental costs in the oil shale-based electricity production price 1.5 times and electricity production price by 2 sents per kWh, compared with the **base scenario “2002/2003”**. If to proceed from the possibility of a considerable rise in air pollution charge rates (**scenario “EC”**), the oil shale-base electricity production price may rise 4–5 times. All these factors must be weighed before making final investment decisions for oil shale-based energy sector development, primarily planning of the volumes of oil shale exploitation and scopes of renovation at power plants.

- Given the above, we cannot ignore in the context of this article the possibility of importing electricity – especially in connection with building a submarine cable between Estonia and Finland. The cable will provide a good technical opportunity for using our oil shale resources more rationally and economically, reducing thus the negative externalities. For example, if our northern neighbours have good conditions for hydroenergy production and electricity price in the Nordic electricity pool will be favorable, we can import it (thus saving oil shale), and vice versa – if Nordic countries have a shortage of electricity, it is reasonable, at the profit-making price, to increase oil shale-based electricity exports. From the aspect of foreign trade, one should take into consideration that the oil shale-based energy production itself is greatly depending on imports – up to one-third of the oil shale mining costs are import-based (equipment, diesel fuel, explosives and their raw materials, etc), and a lot of imported equipment and materials, as well as imported services are used in the renovation of oil shale-fuelled power plants.

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