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Editor's Page

Implications of the possible exit from oil shale for Estonian electricity sector

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1. Introduction

Estonia recently celebrated the 100th anniversary of its oil shale industry. This event gave the industry an opportunity to present achievements made in both the technology and economics of oil shale mining and end use. While the companies presented remarkable success stories about the reduction of air emissions and gains in the overall efficiency of both power and oil production, there were others who voiced concerns about the sustainability of the sector. This was at the end of 2016, today, more than three years later, these concerns are expressed even louder.

During the last 100 years approx. 1 billion tonnes of oil shale has been used, theoretically, there is still more than 4 billion tonnes of oil shale left, but out of this only around 1 billion tonnes can be classified as active reserves [1]. Taking today's yearly regulatory limit for oil shale mining (20 million tonnes) [2] as a basis for calculating the theoretical lifetime of oil shale industry, we see there are enough active reserves for at least 50 years, combined with the passive reserves oil shale will suffice for at least two centuries. For many this is too long a time and they are advocating for a quicker exit from oil shale.

The successful exit from oil shale would mean that by 2030 there would be no oil shale use by the energy sector in Estonia. In other words, no production of electricity, heat, or oil from oil shale. No new investments, no jobs, and no more environmental impact post 2030. It is clear that this kind of radical transformation would have major consequences in at least three dimensions:

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1) socioeconomic, 2) environmental, and 3) energy security. It is the job of politicians to weigh all these effects and pick the best course to set our sights on. However, it is the job of the scientific community to provide adequate information on which policymakers could act.

The job of both policymakers and researchers is complicated due to the fact that energy policy is a multi-dimensional issue, and hence, the regulations governing it come from many different fields. First there is the General Principles of Climate Policy until 2050 [3] approved by the Estonian parliament on 5 April 2017. Then there are national development plans for oil shale [4], long-term energy policy [1] and climate change adoption [5]. These are Estonian national policy documents. In addition, there are international agreements like the Paris Climate Agreement or the European roadmap for greenhouse gas emissions reduction.

The mentioned policy documents are no doubt impactful and need to be considered, but the most important one, and the one used as a reference for business-as-usual, is the Estonian National Development Plan of the Energy Sector until 2030 (ENMAK). ENMAK outlines the following future for Estonia [1]:

- energy intensity of economy will decline by 66% from the year 2012 to the year 2030
- energy independence will be reached by 2030
- share of imported electricity will remain at 0% until 2030
- energy market will remain open, non-subsidized, and market-based
- there will be enough electricity production assets in Estonia to fulfil the N-1-1 criterion
- renewable electricity production will cover at least 50% of inland electricity consumption
- share of renewable energy in heating will be at least 80%

In the following analysis these axioms are taken as something Estonia must accomplish and are hence not up for debate.

When examining the future, it is always useful to first see where one is coming from. Looking back on the historical use of oil shale in Estonia, it can be seen that the use of oil shale has steadily grown since 2005, except for the two low-oil-price periods: first in 2009 and then again in 2015 (Fig. 1). It should be noted that in this paper, oil shale use figures refer to tonnes of oil shale used, not tonnes of oil shale mined.

It is clear that all radical transformations disturb the *status quo*, the question is how much.

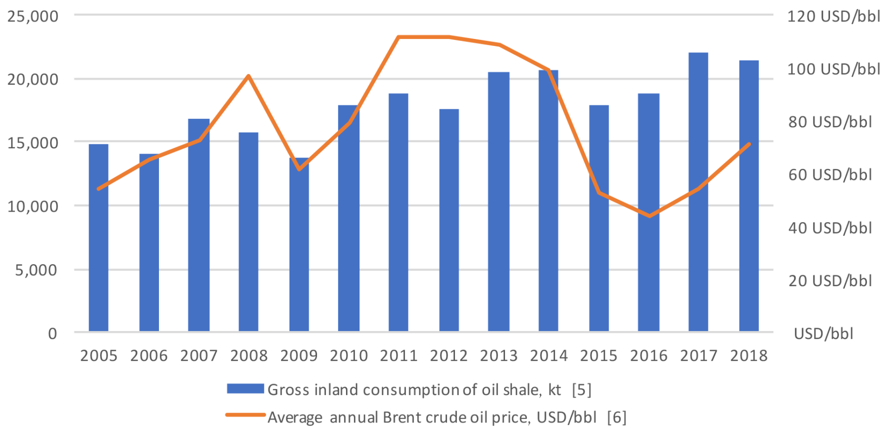

Fig. 1. Oil shale use in Estonia [6, 7].

2. Socioeconomics

The first category to look at is socioeconomics. The socioeconomic effects include the impact on employment, governmental revenues, and the overall economy of Estonia. Historical analysis shows that oil shale industry has generated a lot of income for both the government and the economy. Eesti Energia, the biggest company using oil shale in Estonia, pointed out in their last annual statement that in 2018 the company generated almost 900 million euros of economic value, out of this 130 million euros was paid as taxes to the state and 115 million was paid out to employees [8]. The same holds true for other companies working in the sector. This of course includes other businesses of Eesti Energia as well, like the grid services or the renewables business. Still, the majority of Eesti Energia's income was generated from the oil shale business, in 2018 the share of electricity and liquid fuels was more than 60% of the company's total sales revenue, this equates to more than half a billion euros [8].

Companies operating in the sector have jointly published yearbooks of Estonian oil shale industry. Covering all the most important aspects of the industry, these yearbooks represent the best publicly available source of information about the sector and give a unique insight into the industry-related socioeconomic impact since 2014 when the first yearbook was issued.

Concerning the impact on economy and state treasury, the data published in the yearbooks reveal that prior to 2015 the companies had annual sales revenues from oil shale-related business in the amount of more than 900 million euros, of which more than 30% was paid to the state (Fig. 2) [9]. As the oil price fell, so did the sales revenues and, as a result, also the profits and income to the state treasury. Despite the low oil price, oil shale industry

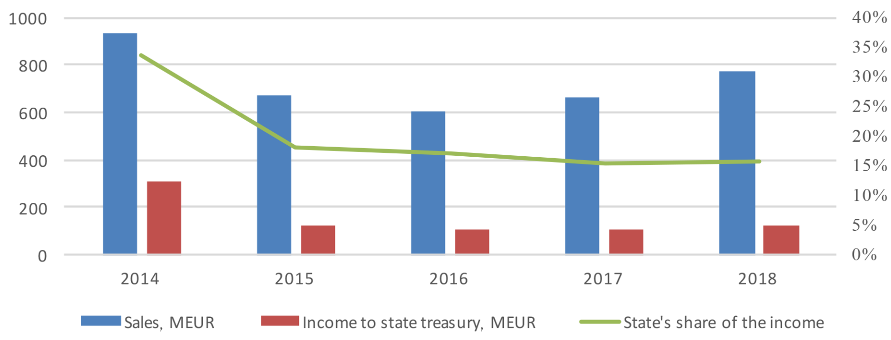

Fig. 2. Economic impact of oil shale industry [9].

still generated more than 600 million euros of annual sales revenues, out of this each year more than 15% was paid to the state. For comparison, the total Estonian state budget in 2014 was 8 billion euros, which means that the oil shale industry's contribution to the state budget was almost 4%. By 2017 the state budget had grown to 9.48 billion euros, indicating that the oil shale industry's contribution had fallen to 1%.

Additionally, the industry generates the spillover effect on the economy by creating jobs servicing the companies and the people working in the industry. The issue was analysed in more depth four years ago by Ernst & Young. Then the analysis showed that the oil shale industry generated approx. 4% of Estonian GDP and employed about 2% of Estonian workforce [10]. Even more important for Estonia is the fact that oil shale industry is largely a regional phenomenon. Most of the people employed are working in the northeastern

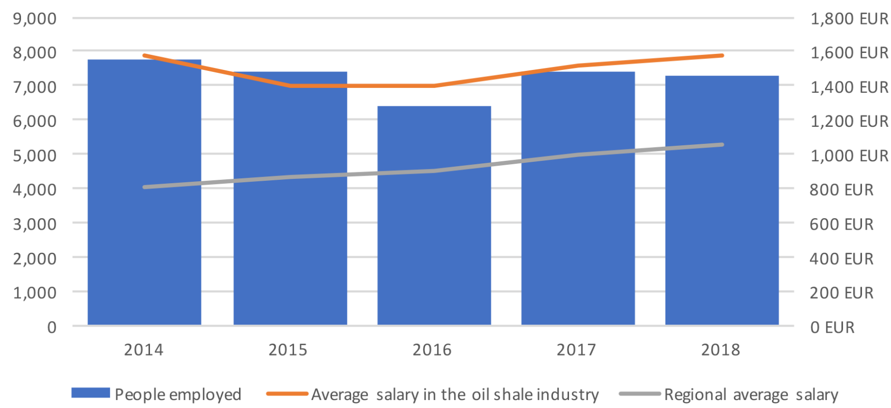

Fig. 3. Socioeconomic impact of oil shale industry [9, 11].

part of Estonia and while the average salary in the oil shale industry exceeded the national average by 20%, it exceeded this region's average by more than 50% (Fig. 3) [9, 11].

Speaking of oil shale industry, one of the most commonly overlooked aspects is allocation of CO_2 quotas. If there were no oil shale industry, the Estonian government would have almost no income from the sale of free CO_2 quotas allocated to Estonia by the European Commission. This is due to the fact that the country-by-country quotas depend on the actual CO_2 emissions in each country in 2005 [12]. We do not know what the allocation of quotas in the next period 2021–2030 will be, but we do know that with no oil shale industry operating in Estonia, the allocated quota will be lower.

These are just some of the positive aspects of the oil shale industry, others include income from the export of electricity, oil, and know-how. It is very important that domestic oil shale energy supply guarantees stability both in terms of market price and energy security for large energy-intensive consumers. It is exactly this stability that has made several big industrial players bring their production next to the oil shale-based power plants.

As regards the export of know-how, then Estonian scientists and engineers have participated in the development of new technologies available for oil and power production from oil shale. A good example of know-how export is the 2.1 billion USD power plant project in Jordan, the world's largest single investment into oil shale-based energy and the biggest foreign direct investment in Jordan. The state-of-the-art circulating fluidized bed boilers used in the project are developed with the help of scientists from Tallinn University of Technology. The same scientists have helped to develop and refine shale oil pyrolysis technologies like Enefit280 which is considered to be the most efficient and environmentally friendliest technology for producing shale oil.

The authors interviewed senior project managers from Eesti Energia to have information about the achievements made in developing the technology for producing shale oil. The following aspects were brought out as most important. First, Eesti Energia confirmed their Enefit280 plant has exceeded the design parameters and is currently working with 10% higher efficiency than planned (12.3% planned oil yield vs 13.6% actual oil yield, oil yield here refers to tonnes of oil produced from one ton of oil shale). Secondly, it was pointed out that the plant has high availability, which is currently around 90%. These two factors combined resulted in record production numbers. For example, the 90-day production volume in 2019 exceeded 66 thousand tonnes of shale oil. Eesti Energia also confirmed there is a lot of interest from countries with oil shale resources in acquiring the technology for shale oil production purposes.

3. Environment

Stopping the use of oil shale is, at least for proponents of the idea, mainly an environmental issue. And while it is true that the oil shale industry has relatively high CO_2 emissions, it is also true that the industry is adhering to all environmental rules and regulations. However, Estonia is part of the European Union and therefore needs to fulfil the targets commonly agreed by the member states.

The environmental aspects of Estonian energy sector are covered also in ENMAK [1]. ENMAK mandates Estonia to meet all European targets related to climate policy and sets some national targets as well. For example, according to ENMAK, Estonia will need to reduce the CO_2 emissions from energy sector by 70% by 2030 (compared to 1990), the share of renewable energy in the final energy consumption must be higher than 50%, and the share of renewables in electricity consumption must be more than 50%.

In 2016 the total oil shale use across all sectors was 18.84 Mt [6], which contributed 67.5% of national primary energy supply. In 2016 the total emissions of greenhouse gases (GHGs) were 16.9 Mt CO_2 eq and without land use, land-use change and forestry or the change in CO_2 emissions resulting from human effects on land use (LULUCF) were 19.6 Mt CO_2 eq [13]. A major contributor to GHG emissions was energy sector, which accounted for 17.5 Mt (89.1% of total emissions) (Fig. 4), followed by agriculture with 1.3 Mt (6.8%), industrial processes with 0.5 Mt (2.5%) and waste with 0.3 kt (1.6%). Within energy sector the main contributors to GHG emissions were energy industries with 13.8 Mt (70.3% of national total) and transport sector with 2.4 Mt (12.1%). Oil shale was not used in transport sector.

Going even deeper into energy industries, oil shale is mainly used for public electricity and heat production where oil shale related GHG emissions in 2016 were 11.3 Mt, accounting for 90.6% of the sectoral emissions. GHG emissions from the manufacture of solid fuels and other energy industry, including shale oil production, were 1.3 Mt and accounted for 100% of the sectoral emissions. Oil shale contribution to emissions in other sectors was just over 0.1 Mt. Altogether, the use of oil shale resulted in 12.8 Mt of CO_2 eq. So, we could say that oil shale was responsible for 64.9% of total GHG emissions in Estonia or 72.9% of energy related emissions in 2016.

We can lower the CO_2 content of power production by using oil shale more efficiently, in the combined production of oil and power as is already applied in Enefit280 process. This process first extracts oil from the shale and power is then produced from the residues of oil production. Estonia has taken the aim for 2030 to emit less than 10.5 Mt of CO_2 eq from energy sector. This means that GHG emissions in energy sector need to be lowered by 7 Mt of CO_2 eq (i.e. by 40%) compared to 2016. That can be achieved by further replacing the direct firing of oil shale for power production with the co-production of oil and electricity, and by replacing oil shale with biomass.

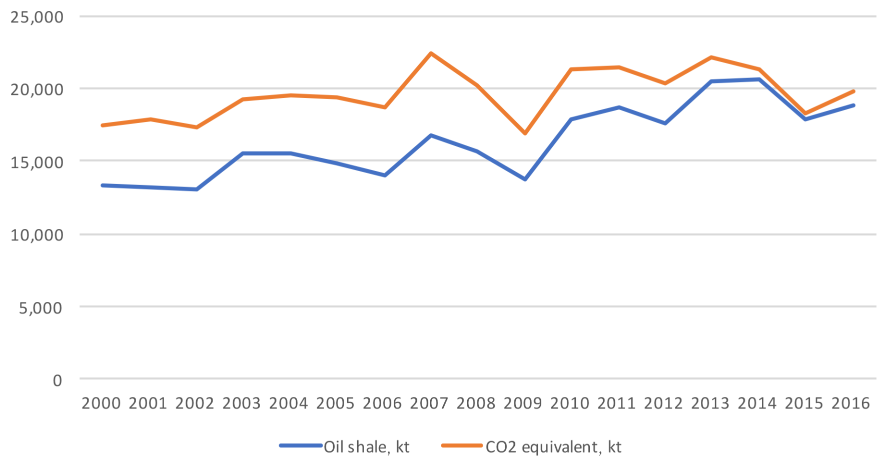

Fig. 4. Greenhouse gas emissions and oil shale use in Estonia, kt [6, 14].

Another important factor is the amount of renewables in the system and their share in the end consumption of electricity. Electricity consumption (with losses) was 8.4 TWh in 2016. Renewable electricity (RE) generation was 1400 GWh and the share of renewable energy was 15.1%. This mainly came from biomass and renewable waste from cogeneration of heat and power (CHP) 681 GWh and wind 589 GWh. Forecast for the electricity consumption in 2030 is 10 TWh. As ENMAK targets to achieve the share of renewable energy of 30%, then renewables must contribute 3 TWh. This means that the generation of RE must more than double. Most of the renewables today are unfortunately intermittent and need supporting assets for balancing the energy system during times when there is no wind or sun. Today the power plants using oil shale are effectively used for this purpose. Should these plants be shut down, the need for new balancing assets will arise.

4. Energy security

The final aspect to look at is energy security. In Estonia the majority of electricity is produced in oil shale-based power plants. The total available production capacity from oil shale is approx. 2000 MW of electricity (Table 1) [15]. Most of the capacity was put into operation in 1959 and 1973, while the newest unit, Auvere Elektrijaam, started production in 2015.

Now we see that the power generation from oil shale is decreasing, unfortunately this means that the total available generating capacity in Estonia is declining as well. This puts Estonia in a rather tricky situation

Table 1. Oil shale-based power plants in Estonia [15]

Power plant	Installed net capacity, MW
Eesti Elektrijaam	1355*
Balti Elektrijaam	322*
Auvere Elektrijaam	274
Enefit	10
Põhja SEJ	78
Sillamäe SEJ	16
Total	2055

* In total, ten energy blocks and four units are equipped with $DeSO_x$ SDA devices and two units are equipped with fluidized bed boilers, altogether 1058 MW. Four blocks out of ten with a capacity of 619 MW have limited allowed production hours – 17,500 hours during 2016–2023.

when it comes to energy security. One view is that as Estonia is part of the Nordic power market, then all the necessary electricity can be bought from the market. However, this viewpoint does not take into account the fact that most of Estonia's neighbouring countries are in electricity deficit themselves (Table 2). During 2016–2018 the Baltic states' (Estonia, Latvia, Lithuania) electricity market total production volume was 58.8 TWh, while market consumption was 77.2 TWh. On average Baltic states were in deficit with 713 MW. It is clear that removing oil shale-based power plants from the market would put the whole region in a worse position when it comes to energy security.

Table 2. Electricity balance of Estonia's neighbouring countries in 2017, TWh

	Finland	Sweden	Denmark	Latvia	Lithuania	Poland
Production	63.3	158.5	28.0	7.3	2.5	152.1
Consumption	83.4	138.1	32.4	7.2	10.4	168.1

5. Conclusions

Energy policy is a multi-dimensional issue and needs to be examined as such. This paper scanned different aspects of a potential transformation of Estonian long-term energy policy and found many arguments that support re-examination of which path to take. This article confirms that the issue needs a more in-depth analysis and the authors plan to take the three categories into focus in their upcoming research.

In the environmental dimension the authors found that stopping the use of oil shale would reduce CO_2 emissions, but further work is needed on other environmental concerns. From socioeconomic analysis it is clear that the state would lose an important source of revenue and the region would suffer from loss of jobs, but again the exact degree of impact needs to be examined in more detail. The same is true for energy security. It was found that stopping the use of oil shale would have a negative impact on the region as a whole because most of Estonia's neighbours are in deficit. From the research it became clear that Estonia needs a domestic energy industry which would be capable of providing flexible energy production that is competitive on the regional market – exactly what the oil shale sector is offering.

All in all, it can be said that the transformation of Estonian energy industry is already ongoing, now only the pace needs to be set. For best results, the issue needs more thorough research. Today the proponents of oil shale exit are mainly environmental groups and green lobby organizations looking for bigger subsidies for their industry. For the former it is almost a religious issue, the latter on the other hand are merely doing their job and are trying to keep the bread on the table, letting their employers feel happy.

Everyone is entitled to their own opinion, but when it comes to issues with impacts as high as oil shale exit could potentially have, then one cannot rely only on religious beliefs or concerns voiced by lobby groups. These kinds of decisions need to be based on thorough research and all the facts need to be on the table. Later, after all the facts have been considered, Estonian long-term energy policy will still need to be a political decision. It is the job of the scientific community to make sure that policymakers have had the chance to see all the facts and that they understand the consequences of both decisions. This applies not only to Estonia and Estonian policymakers, but also to all countries going through an energy transition. Energy transitions need to be analysed thoroughly, minimally from the three aspects covered in this article, but most probably on an even wider scale. Oil shale might be Estonia-specific, but the discussion is not, and this is where the scientific community must be the one to carry out similar analyses to give policymakers right tools for choosing the right path.

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