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Assessment of the economic regulation of network industries: oil shale value chain in Estonia

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Abstract. *Naturally monopolistic network industries are subject to economic regulation to achieve an optimal use of infrastructure and avoid the abuse of monopolistic power. In theory, such intervention leads to a higher allocative and productive efficiency in the industry. Relatively little is known about the results the economic regulation gives in practice and whether it achieves the objectives set. Literature states that due to the context-specific nature of regulatory framework, ex post analysis and practical experiments are necessary to be performed to study the impact of economic regulation on the performance of industries. In this paper, analysis of the impact of economic regulation on the oil shale value chain in Estonia is performed and the results are provided. Based on relevant policy documents, regulatory objectives and targets are identified and indicators compiled to monitor the results. The discussion is presented and recommendations for further research are given.*

Keywords: *oil shale value chain, economic regulation, network industries, ex post analysis.*

1. Introduction

Network utilities like railways, district heating, water and sewage, electricity transmission and distribution produce services that are important intermediate inputs for the overall economy and largely non-discretionary to consumers and the society as a whole. Such industries are all associated with capital intensive infrastructure and sunk costs that create a substantial barrier to new entry. Moreover, due to the naturally monopolistic character of production technology, legal monopolies are established to avoid unnecessary duplication of utility infrastructure. Thus, a framework of economic regulation needs to be established to provide approriate incentives for the industry and balance a spectrum of interest pursued by different stakeholders. For example, exploitation of monopoly market power by a network utility must be prohibited. On the other hand, important considerations like sustainability of operations, affordability of service, safety of supply, etc., must be ensured.

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The concept of economic regulation and its implications for the productive and allocative efficiency in an industry have been extensively discussed in theoretical literature, however, empirical studies on the subject are rare. The latter can be attributed to the context-specific nature and variety of regulatory systems across industries and countries. Therefore, theoretical models often fail to convey the actual regulatory dynamic between stakeholders and the impact of regulation cannot be meaningfully predicted ex ante and should rather be evaluated ex post. As put by Jacobs [1], the most important aspect for the quality of government decisions is not the precision of calculations but asking right questions, understanding real-world impacts and exploring assumptions. Even though the European Union (EU) has been labelled "a regulatory state", it is more advanced in initiating regulations than measuring regulatory performance [2].

The objective of this paper is to assess the impact of economic regulation on the Estonian oil shale sector. Oil shale related industries have been the cornerstone of Estonia's energy independence and contribute an important share to the national economy. The competitiveness of the sector, however, is undermined by the EU's climate policies. The oil shale sector in Estonia presents a value chain of industries that are subject to varying economic regulations enforced by multiple regulators. Although the value chain involves industries with monopolistic and competitive market structures, firm inter-linkages between these industries create vertically integrated industrial conglomerates that have network utility characteristics.

There are only few analyses of the economic regulation of network utilities in Estonia. Eerma [3] discusses sector-specific regulation in selected industries, Uukkivi et al. [4] propose a comprehensive framework of the economic regulation of five network utility sectors in Estonia, and Ots [5] analyses price regulation practices from a regulator's perspective in the energy sector. More recently, Uukkivi and Koppel [6] present a sector-specific study on the results of the economic regulation of railway infrastructure management. With regard to the oil shale sector, there are few academic works that address regulatory issues of industries within the Estonian oil shale value chain. Kearns [7] provides commentaries on the trends in oil shale utilisation in Estonia: electricity generation, shale oil production, and heating. Kallemets [8] discusses the sustainability potential of Estonian shale oil production until 2030 and regulatory developments both at the national and EU level. Additionally, the National Audit Office of Estonia conducted an assessment of the effectiveness of implementation of strategic policies in the Estonian oil shale sector [9] and the Ministry of the Environment of Estonia published the first progress report on the implementation of the National Development Plan (NDP) for the Use of Oil Shale 2016–2030 for the years 2016 and 2017 [10].

The paper is structured as follows. First, an overview of theoretical literature is presented and the methodology used in the paper is described. Secondly, a summary of the institutional setup and framework of the economic regulation of oil shale value chain in Estonia is provided, objectives to be achieved are set and indicators to monitor the outcome of the regulation are compiled. Then a discussion is presented and conclusions are provided.

2. Overview of theoretical literature

Porter [11] puts forward a concept of value chain to distunguish different stages of the supply process as well as the support services within a company which are necessary to deliver a product to the market. In a similar manner, the term value system proposed by the reseacher describes the set of activities between inter-industry linkages and includes suppliers who provide inputs (raw materials, purchased services, etc.) to the firm's value chain. Both concepts are used to address strategies in terms of relationships between relevant counterparts, including firms, regulators and the government [11]. In this sense, the value chain and the value system are similar to what has also been labelled as "industrial complex" formed around the core firm [12]. This paper treats the terms as synonyms.

Transaction cost economics explains the economizing, organizational and contractual aspects associated with the value chain phenomenon whereas transactions involving assets with specific physical, human or location characteristics are of relevance to the topic of this paper. As argued by Williamson [13], large investments in asset-specific transactions lead to non-marketability issues and substantially increase governance costs of parties involved in the transaction. According to the author, a greater vertical integration of the value chain is therefore seen as a way to optimize governance costs when it is not possible to benefit from the economies of scale on the market.

There are specific industries, the so-called natural monopolies, where competition leads to a wasteful duplication of resources. In such cases economic regulation is needed to restrict entry but also to avoid exploitation of monopoly power by the incumbent that does not face the competitive pressure. More specifically, regulation is designed to improve the unregulated performance and address market failures and achieve optimal outcomes for society. Economic regulation therefore addresses a variety of objectives like asymmetry of information, market power, investment and operating efficiency, tariff structures and levels, viability of the regulated firm, etc. [14, 15].

The most widely accepted definition of natural monopoly in contemporary academic discourse stems from the seminal works of Baumol [16] and Baumol et al. [17]. According to this definition, a natural monopoly is presented in an industry with declining average costs per single product and cost subadditivity of multiple products. In such cases, the production technology of the industry is usually associated with some combination of economies of scale, economies of scope and economies of density, which makes it most efficient to have a single definite produce for the whole market [18].

Joskow [18] argues that besides economies of significant scale and scope, sunk costs in an industry are the most important linkage between behavioral parameters and economic performance problems thought to arise from unregulated natural monopolies. According to the investigator, most of the industries regulated based on natural monopoly arguments have a large fraction of their total costs as sunk capital costs which create potential opportunities for a strategic behavior of monopoly pricing or discouraging entry by the incumbent The literature discusses several other considerations of the natural monopoly approach, for example, technological complexity of operations [19] and societal importance of the industry [20]. It is important to note, however, that industry characteristics may change over time. For example, innovations in technology can disrupt capital intensive naturally monopolistic production infrastructure or political priorities may require the economic regulation of inherently competitive industry. Joskow [18] therefore stresses that there is no definite distinction between "naturally monopolistic" and "competitive" industries, while in reality, the judgement depends on what is considered a relevant product market and what are substitute products in a particular environment.

Regulated infrastructure monopoly may be vertically integrated with network services that are inherently competitive and do not have the properties of a natural monopoly properties. For example, vertical integration between complementary services used to be the mainstream approach with network industries in telecommunications, railways, electricity, etc., where the process of production and distribution of the product were organised by the same entity or concern. Vertical integration between regulated and non-regulated industries upstream or downstream within a value chain may also be the case. As a vertically integrated monopoly will have a rationale to utilise differentiated regulation across industries for strategic gain, the regulatory framework must be designed accordingly. Knieps [21, 22] summarizes that subparts of a production chain characterized by a natural monopoly in combination with sunk costs lead to network-specific market power and can be exploited for monopolistic charges or inadequate access conditions. Therefore, if the network infrastructure is a monopoly (i.e. there is a "monopoly bottleneck"), non-discriminatory access to service providers has to be solved by the regulatory access regime. Competitive subparts can be regulated ex post under the general competition law.

3. Methodology

The empirical analysis performed in this paper is based on the process tracing approach and addresses the design, implementation and outcomes of the regulatory framework of industries in Estonian oil shale sector. The paper refers to regulation as a combination of both legislative domain (composition of the rules) and executive domain (enforcement of the rules). Although not directly enforcable, legally mandated strategy documents are considered an inherent part of regulation. This is because such strategies trigger future legislative intervention and guide on the discretion of regulatory authorities when they enforce compulsory regulation. The period of interest for the study is set from 2008 to 2018. Such a timeframe allows inclusion of two subsequent strategy periods in the analysis. Moreover, the period is sufficiently long for regulated companies to adjust capital investment programs in order to cope with regulation.

The authors define the system of the oil shale value chain in Estonia, address the composition of vertically linked industries and discuss the natural monopoly parameters of the combined system. All industries included in the value chain are mapped for operational performance and trends, mutual interdependencies, stakeholding company groups, regulatory institutions and instrumental economic regulation provisions.

Regulations under review in this paper have been in force for a relatively long period of time, therefore the main reference to ex post evaluation is provided by the problem definition that these regulations should solve. Although elected politicians, bureaucrats and economists often have different views on what a "good regulation" is, as stated by Radaelli and De Francesco [23], the direction of a policy is always guided by regulatory objectives. As put by Coglianese [24], regulatory objectives also define the selection of indicators for evaluation because defining something as a problem cannot be accomplished without reference to value choices. In the absence of a specific problem, the discussion of indicators for regulatory evaluation will be abstract.

In order to identify regulatory objectives across the oil shale value chain, the authors trace the legislation of associated industries and applicable strategic plans in the oil shale and energy policy domain. The objectives are summarized and matched with the corresponding indicators on the industry or company level. The actual values of regulatory indicators are benchmarked against targets and outcomes are discussed with reference to the regulatory activities and interventions. The discussion concludes with recommendations for further research.

It is important to note that this paper has no intention to make a normative case for regulatory objectives or regulatory indicators for the oil shale value chain but to analyse what incentives are set for regulated companies and whether the regulatory framework achieves the objectives. As put by Arndt et al. [25], regulatory effectiveness is based on the extent to which a regulatory system pursues its underlying objectives on policy, efficiency and governance. While the implementation of the measures aims to meet wider public policy objectives with a positive impact on the economy and society, the indicators themselves do not necessarily assess the achievement of such objectives.

4. Economic regulation of oil shale value chain in Estonia

4.1. Mapping of the oil shale value chain

Extensive use of oil shale is the unique and defining quality of the Estonian energy system [7]. In 2017, about 76% of electricity and 8% of heat produced in Estonia was based on oil shale [26]. Although Estonian oil shale deposits are insignificant compared to the world resources, even “small” deposits can be huge related to the country’s energy needs and Estonia is among the few countries where oil shale is in commercial use [27]. Oil shale serves as a raw material for a number of industries in Estonia which account for about 4–6% of its GDP and about 2.5% of total employment [28]. Due to the concentration of deposits, oil shale is particularly important for the economy and livelihoods of eastern Estonia.

The oil shale sector in Estonia presents an ecosystem of vertically linked industries that form the oil shale value chain (Fig. 1). For the purpose of this paper, the authors differentiate between the following industries within the oil shale value chain: mining of oil shale, utilisation of oil shale for electricity and shale oil, and cogeneration of heat. Oil shale utilisation for cement production in Estonia is marginal and is therefore left outside the scope of this paper. Horizontal supporting functions like transport and logistics, construction, warehousing, cleanup, etc., are considered as an inherent part of each industrial phase.

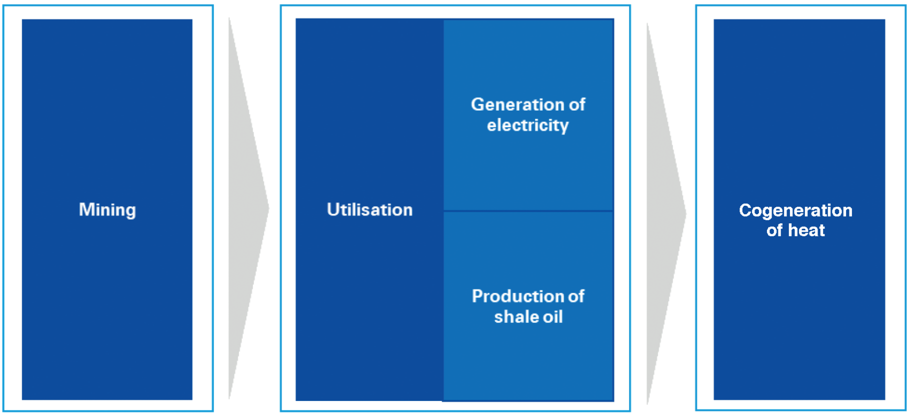

Fig. 1. Oil shale value chain in Estonia.

The properties of Estonian oil shale deposits largely define industry links within the value chain. First, the mineral utilisation involves a high amount of ballast, making the export of oil shale uneconomical due to the low energy value of the stock. The utilisation technology is proprietary and there is no competition between oil shale utilisation alternatives but with substitute products on the marketplace (e.g. eletricity, oil and heat from oil shale are substitutes for similar products from other resources). The physical limit of oil shale value chain is legally set by the maximum volume of the mineral that is available. Similarly, the volume of economic operations of the companies is limited by the access to the mineral as the supply needs to be secured in downstream industries. For those reasons, access to the oil shale mineral effectively presents a monopolistic bottleneck across the whole oil shale value chain regardless of the production technology.

Oil shale mining operations and processing facilities must be located within a logistically efficient range as the trading in the mineral between vertically integrated groups is marginal. Therefore, a natural monopoly's arguments for economies of scope, economies of scale and economies of density apply to utility scale oil shale energy production due to the geographical irreversibility of infrastructure and subadditivity within the value chain. Competitition or contestability within the value chain is not a viable option. Oil shale mining and utilisation require capital intensive infrastructure with an asset life span over several decades and specific parametres for each mining-utilisation complex. Therefore, investments in both the physical and human capital related to oil shale mining and utilisation are to a high degree sunk with no practical alternative uses.

The asset-specificity of location, and physical and human assets in oil shale related industries has led to a high degree of consolidation of the oil shale value chain. As a result, practically all of the oil shale in Estonia is mined and processed by three groups of companies: Eesti Energia AS, Viru Keemia Grupp and Alexela Grupp (Table 1). All these companies are vertically integrated and provide support services mostly within the concern companies.

Table 1. Corporate groups in Estonian oil shale sector

Parent company	Mining	Electricity/ shale oil production	Cogenerated district heating
Eesti Energia AS	Enefit Kaevandused AS	Enefit Energiatootmine AS	Enefit Energiatootmine AS/ Narva Soojusvõrk
Viru Keemia Grupp	VKG Kaevandused OÜ	VKG Oil AS, VKG Energia OÜ	VKG Soojus AS
Alexela Grupp	Kiviõli Keemiatööstuse OÜ	Kiviõli Keemiatööstuse OÜ	Kiviõli Keemiatööstuse OÜ

Compiled by authors.

4.2. Oil shale mining

Access to Estonian oil shale resource is economically regulated through a scheme of mining licences. Mining licenses are issued by the Estonian Environmental Board and effectively create a legal monopoly on a particular deposit for a period of up to 30 years. The long mining permit validity period allows the complete mining of the resource and recouping of sunk investments in capital intensive infrastructure.

The National Development Plan for the Utilization of Oil Shale 2008–2015 introduced the maximum mining limit of 20 million tonnes of oil shale reserves per annum that was later also incorporated into the law [29]. Annual mining allowances per license are set by a decree of the Minister of the Environment.

The government collects revenue and incentivises the achievement of regulatory objectives through a combination of resource fees and environmental charges. There is no universal price regulation for third parties besides general ex post competition rules as most of the mineral for utilisation is provided by affiliated miners within the vertically integrated groups. Resource fees are set by a governmental decree, the rationale of which has changed during the recent years. Formerly, the mining companies were charged a fixed tonnage rate irrespective of the market conditions but from 2016 onwards, a fluctuating rate has been applied based on the world market price for fuel oil with a sulfur content of 1%. Due to the fluctuations in downstream demand, a

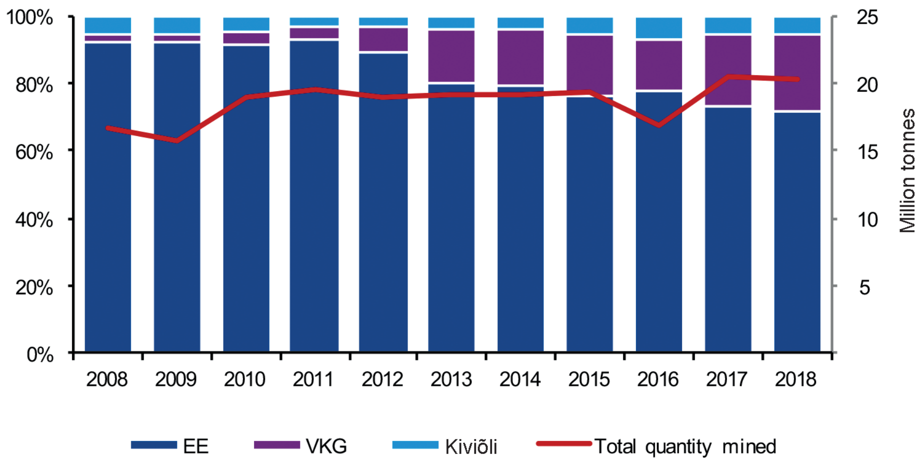

Fig. 2. Oil shale mining volumes in Estonia 2008–2018, million tonnes. Compiled by authors, data from [30]. (Abbreviations: EE – Eesti Energia, VKG – Viru Keemia Grupp, Kiviõli – Kiviõli Keemiatööstus.)

compensation mechanism was introduced in 2015 that allows a retrospective mining of unused quota. Also, the trading in the annual mining allowance is possible within the 20 million tonne maximum mining limit.

With regard to the economic operators, Eesti Energia is the biggest miner of oil shale in Estonia, accounting for more than 90% of the mining volume in 2008 and 71% in 2018. In 2018, Viru Keemia Grupp peaked at 22% and Kiviõli Keemiatööstus mined around 7% of the total volume (Fig. 2).

4.3. Oil shale utilisation

Oil shale in Estonia is mostly utilised to generate electricity and produce shale oil (Fig. 3). Both products compete on the marketplace with a number of substitutes from other energetic sources. It is important to note that the economics of oil shale electricity and shale oil is sensitive to the regulation of the oil shale value chain. The production technology is viable only with large scale operations, therefore mining activities must be coordinated with the utilisation. Oil shale utilisation is also subject to a set of environmental charges that are imposed by the Estonian Environmental Board and are aimed to incentivise efficient and innovative production practices.

Most of oil shale electricity is generated in Eesti Energia's Eesti and Balti power plants, also Auvere Power Plant can be operated on oil shale. The volume of shale oil production in Estonia is sensitive to changes of crude oil prices in the world market. All of the vertically integrated groups that operate in the oil shale value chain produce shale oil and have developed proprietary technological solutions.

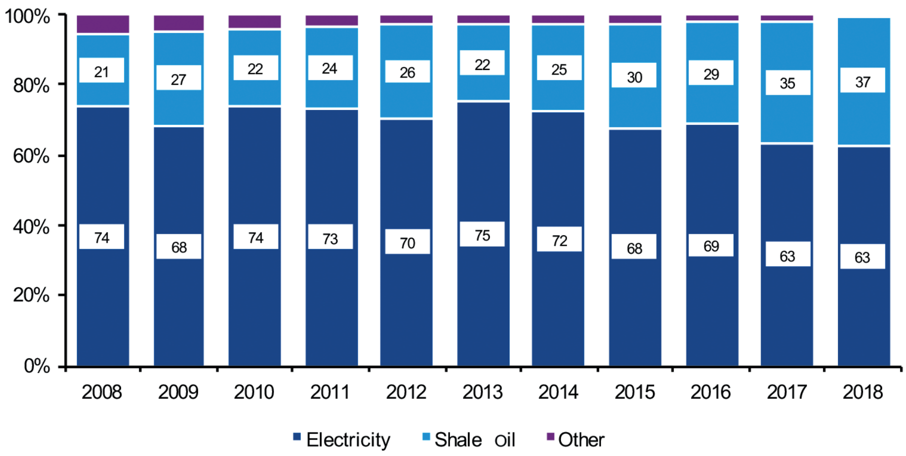

Fig. 3. Utilisation of mined oil shale in Estonia 2008–2018. Compiled by authors, data from [26, 31].

In total, about 70% of oil shale mined in Estonia was consumed for electricity generation during the period 2008–2018, the respective figure for shale oil production was around 25% [26, 31]. The shift of the EU's policy towards the use of renewables and the "cap-and-trade" principle-based emissions trading scheme have been posing a major regulatory threat to oil shale electricity. For example, the price of carbon dioxide emission quota increased threefold in 2018 [32], which has drastically undermined the competitiveness of oil shale electricity and favoured shale oil production as according to the emissions trading scheme, the latter is classified as less carbon dioxide intensive [33]. The domestic energy policy foresees a gradual decline of oil shale electricity portfolio and a strong impetus to utilise the mineral for the production of shale oil of higher value added [34]. The strategy of the state-owned Eesti Energia is in line with the mentioned objectives.

Both oil shale utilisation methods allow co-production of heat that requires capital investment in the associated production and distribution infrastructure. The commercialisation of heating, however, must take place in the vicinity of production facilities due to the absence of viable technologies for heat storage and transport. Heat is distributed to residential areas through district heating networks in the vicinity of production facilities in Narva, Kohtla-Järve, Jõhvi and Kiviõli and subsidiary companies have been established in the vertically integrated groups to manage the operations. District heating is a typical network utility domain that is subject to ex ante economic regulation relating to access to market and setting of tariffs by the Estonian Competition Authority.

5. Discussion

5.1. Regulatory objectives of the oil shale value chain in Estonia

In order to identify regulatory objectives of the oil shale sector value chain in Estonia, the authors traced the most important legislative acts and strategic policy documents of the oil shale domain. The Earth's Crust Act, the National Development Plan for the Utilization of Oil Shale 2008–2015 (NDP 2008–2015), the National Development Plan for the Use of Oil Shale 2016–2030 (NDP 2016–2030) and the National Development Plan of the Energy Sector until 2030 (EMDP 2030) were studied for this purpose. While certain overarching regulatory principles can be drawn from the Earth Crust's Act and EMDP 2030, NDP 2008–2015 and NDP 2016–2030 set very concrete policy objectives that can be scrutinized in practice. The results are summarized in Table 2.

Table 2. Regulatory objectives and indicators of the oil shale value chain in Estonia

	NDP 2008–2015	NDP 2016–2030
Objectives	1. Securing sufficient reserves of oil shale energy and safeguarding Estonia's energetic independence 2. Increasing the efficiency and reducing the environmental impact of oil shale mining 3. Increasing the efficiency and reducing the environmental impact of oil shale utilisation	1. Increasing the efficiency and reducing the environmental impact of oil shale mining 2. Increasing the efficiency and reducing the environmental impact of oil shale utilisation 3. Developing education and research activities in the field
Indicators and targets	Mostly activity based indicators and no numerical targets	Mostly outcome based indicators and detailed numerical targets

Compiled by authors, data from [35, 36].

NDP 2008–2015 stipulates 12 different measures in order to achieve the objectives [35]. NDP 2016–2030 sets three strategic objectives with eight respective measures for the oil shale sector but with somewhat different composition. The strategic objectives are: increasing the efficiency and reducing the environmental impact of oil shale mining; increasing the efficiency and reducing the environmental impact of oil shale utilisation; developing education and research activities in the field of oil shale [36]. NDP 2008–2015 and NDP 2016–2030 stress the importance of oil shale as a strategic resource of national importance but the composition of objectives has changed. The objective to secure energy independence through oil shale energy was dropped from the current strategy and replaced with initiatives on education and research activities in the sector. This change was necessary because consumers are free to choose between alternatives in an open energy market and oil shale based energy cannot have any preference. As a result, increasing the efficiency and reducing the environmental impact of the oil shale value chain have been the overarching objectives of the regulatory policy throughout several strategy cycles.

5.2. Regulatory indicators and outcomes of the regulatory framework

Regulatory indicators provide reference to the status of regulatory objectives compared to targets and reflect on the outcomes of policy implementation. Implementation of NDPs is supported by regular progress reports to be submitted to the government for approval. While NDP 2008–2015 was of general character and contained no numerical targets, NDP 2016–2030 sets specific values for every indicator to be achieved and requires updating the target levels every five years.

Compiled by the authors, the summary of regulatory oil shale mining and utilisation indicators is presented in Table 3. The indicators listed in the table are matched with target and actual values for the period 2008–2018 and are numbered for easier reference in the discussion. The average indicator values are calculated because the respective annual figures may fluctuate substantially due to exogenous factors. It should be noted that although conceptually elaborate, the calculated oil shale utilisation indicators (indicators 4–5, 7–9) are highly dependent on the consistent approach towards and format of input data and calculation methodology. Target values for calculated indicators in NDP 2016–2030 are based on an expert opinion commissioned by the Ministry of the Environment of Estonia but there is no common data series or calculation methodology. Moreover, the NDP 2016–2030 progress report retrospectively revises base indicator values by up to 40%. The authors are therefore unable to calculate or verify oil shale utilisation efficiency indicator values and refer directly to the data from the NDP 2016–2030 progress report for the period 2013–2017.

NDP 2016–2030 sets three indicators (indicators 1–3) to monitor the efficiency and environmental impact of oil shale mining in Estonia. The underground mining loss, waste rock recovery and pumped-out water volume indicators are a function of mining technology and mining intensity combined with geological and environmental conditions at mining locations. The values are aggregated from measurable parameters that are reported by the companies. The set of indicators reflecting on the regulatory objective of increasing the efficiency and reducing the environmental impact of oil shale utilisation is more complex. This set consists of six indicators, of which only one (indicator 6) is measurable based on the data reported by the companies. Other indicators are calculated aggregates which reflect technological efficiency ratios of shale oil (indicator 4) and oil shale electricity (indicator 5) production and economic efficiency ratios of oil shale value chain per various key parametres (indicators 7–9). Economic efficiency ratios are also descriptive of energy products pricing conditions on the marketplace.

The analysis of the data shows that in the years 2008–2018, the underground mining loss was mostly above the target level, 29.2%, averaging 30.4%. Considering that during the same period, the underground oil shale mining accounted for 2/3 of total mining volume and has been increasing especially in recent years, extended mining loss has led to substantial inefficiencies in and negative environmental impact of mining. This problem has been repeatedly acknowledged in various progress reports and explanatories, yet the research pipeline does not indicate mature projects on the domain. As capital investments in new technologies have prolonged incubation periods, it is unlikely that substantial progress will be achieved in this measure during the NDP 2016–2030 period.

Table 3. Economic regulation indicators of oil shale value chain in Estonia

Category	Indicator	Base value	Target value	Actual value
Mining efficiency and environmental impact	1. Percentage of the underground mining loss from oil shale reserves already mined and rendered unfit for use, %	29.2	Up to 29.2 (2020)	32.2 (2008); 29 (2018); 30.4 (2008–2018 avg)
	2. Recovery of waste rock, %	40	Not less than 40 (2020)	17 (2008); 57 (2018); 50 (2008–2018 avg)
	3. Volume of water pumped out for each tonne of oil shale reserve extracted from the Earth's crust, m^3	15 m^3	14 m^3 (2020)	8.91 (2008); 5.74 (2018); 6.9 (2008–2018 avg)
Utilisation efficiency and environmental impact	4. Energy efficiency of shale oil production, %	76	Over 76 (2020)	76 (2013); 78 (2017); 78.2 (2013–2017 avg)
	5. CO_2-specific emissions emitted in relation to total electricity and thermal energy in the case of cogeneration, tCO2/GWhe+th	1186	Below 1186 (2020)	1186 (2013); 1204 (2017); 1210 (2013–2017 avg)
	6. Percentage of recovered oil shale ash from the total formation, %	4.5	At least 4.5 (2020)	4.7 (2008); 1.92 (2018); 3.7 (2008–2018 avg)
	7. Indicator of economic efficiency of producing energy from oil shale, €/t per trade oil shale	34.55 (adjusted to 24.37)	No degradation of value (2020)	24.37 (2013); 25.13 (2017); 24.87 (2013–2017 avg)
	8. Value added created by producing energy from oil shale in relation to the oil shale reserve mined and made unusable, €/t	29.78 (adjusted to 19.61)	No degradation of value (2020)	19.61 (2013); 16.37 (2017); 17.83 (2013–2017 avg)
	9. Value added created by producing energy from oil shale in relation to th e deposited waste, €/t	71.04 (adjusted to 43.17)	No degradation of value (2020)	43.17 (2013); 32.76 (2017); 38.06 (2013–2017 avg)

Compiled and calculated by authors, data from [10, 30, 35–37].

The target for recovery of mining waste rock (40%) was exceeded in 2018 (57%) and the average achieved during 2008–2018 (50%), whereas the oil shale ash recovery has underperformed the target in both comparisons. It must be noted that the yearly values for both indicators fluctuate substantially as the recovery depends both on mining and utilisation volumes as well as on recycled water pipeline projects within the logistical range. As the waste to mineral ratio in the mining and utilisation process is largely fixed, better prospects of recovery are associated either with utilising the material in the construction industry (Rail Baltic railway, etc.) or with the regulatory redefinition of the recycling criteria. The indicator of pumped-out water volume per mined oil shale tonne was in positive territory both in 2018 and during 2008–2018. The lack of a coherent methodology, however, presents problems as alternative approaches to data series handling lead to unreliable calculation results.

The summary of oil shale utilisation performance indicators is ambiguous. The technological efficiency of shale oil production has somewhat increased but that of electricity production decreased due to recent major production facility upgrades or lack thereof. The growth of oil and electricity market prices over the recent years has caused the indicator of aggregated net sales per trade shale oil to exceed the target whereas the same measure per used oil shale reserves and deposited waste falls short due to the use of lower energy value mineral.

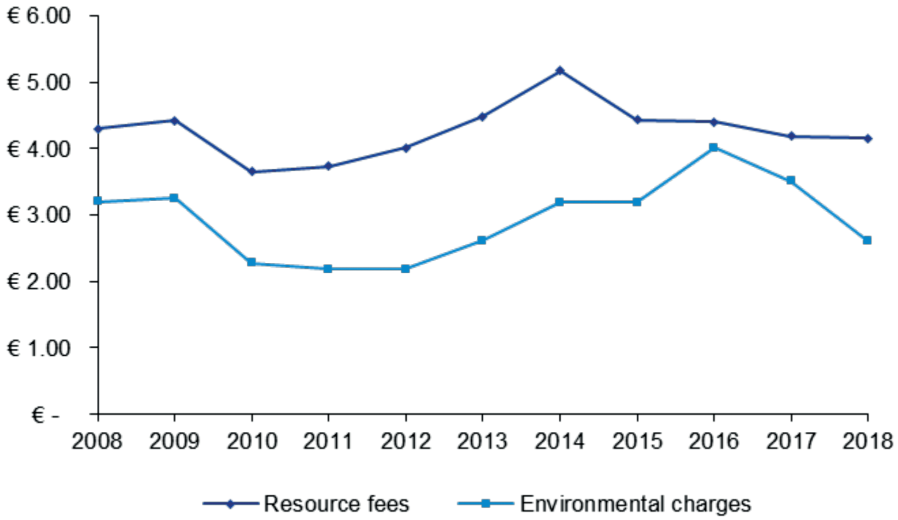

Fig. 4. Resource fees and environmental charges of oil shale value chain in Estonia 2008–2018, €/mined oil shale tonne, inflation adjusted. Compiled by authors, data from [38].

The authors note that the economic regulation of the oil shale value chain in Estonia is differentiated between industries without uniform technical or operational requirements. Incentives to abide by the regulatory objectives are set in two ways. First, the state sponsors a pipeline of applied research related to oil shale industries and disseminates the know-how. Second, there is a system of resource and environmental charges to increase the efficiency of the oil shale industry and mitigate its environmental impact (Fig. 4). The companies are charged for mined oil shale and mining loss, used and contaminated water, air pollution and deposited waste generated by oil shale operations. It is therefore rational to assume that any investment in technological upgrades is weighed against the level of charges that would be saved by making such invesment.

Based on the charges paid by the oil shale industries, the authors calculated the inflation adjusted level of annual resource and environmental charges per mined oil shale tonne for the period 2008–2018. This level presents input that is available for value adding operations in downstream industries.

The analysis shows the inflation adjusted level of resource fees to have been relatively stable over the period 2008–2018, averaging 4.3 €/tonne. During the whole period, environmental charges accounted for about 2/3 of total charges. This appears to support the conclusion that either operational measures fall short to impact on regulatory indicators that have had no sustained improvement over the period, or it was economically more beneficial to pay charges rather than invest in technological upgrades. In such case, the tariff system effectively amounts to an implicit taxation regime. Introduction of composite regulatory indicators [39] would be warranted for additional clarity how sectoral trend and company level performance contribute to the outcomes.

6. Conclusions

The objective of this paper is to present an ex post analysis of the impact of economic regulation of the oil shale value chain in Estonia. Oil shale value chain is a system of vertically linked industries with competitive and monopolistic market structures and varying regulatory regimes and regulators. Fixed investments have a high degree of asset-specificity with regard to physical and human assets and location. The combined value chain in Estonia has natural monopoly characteristics of economies of scope, economies of scale and economies of density, and is dominated by three concerns of integrated companies.

The industries in the oil shale value chain were mapped for operational performance and trends, regulatory institutions and provisions of economic regulation. Legislative acts and policy documents were studied for regulatory objectives and regulatory indicators. The analysis demonstrates that the regulatory framework of oil shale value chain in Estonia over several strategy cycles has aimed to increase the efficiency of oil shale mining and utilisation and reduce its environmental impact.

The implementation of regulatory oil shale mining and utilisation policies in Estonia is monitored by annual progress reports which are submitted to the government for approval. A set of indicators is established to survey the status of regulatory objectives. However, there has been a significant time lag between observation of indicators and the authorities' regulatory reaction to the findings. The empirical analysis of regulatory indicators and targets shows the impact of economic regulation during the period 2008–2018 to have been ambivalent. In oil shale mining, underground mining loss was continously in excess of the target but objectives of waste rock and pumped-out water recovery in relation to oil shale mining were met. In oil shale utilisation, targets to increase the energy and economic efficiency of oil shale-based production were reached. The calculated CO_2 emissions, oil shale ash recovery and oil shale utilisation added value remained below the target levels.

Analysis of the design of regulatory indicators leads to the following conclusions. First, there is no common methodology for collecting data and calculating indicator values. Furthermore, the base values of several indicators have been revised but cannot be scrutinized or replicated as the revisions are based solely on expert opinions. Second, the application of many regulatory indicators is limited due to geological and hydrological conditions, regulatory discretion or macroeconomic trends that are beyond the control of companies. For example, the legal waste recycle and pipeline classification applied to infrastructure construction projects significantly influences the values of relevant indicators. Third, regulatory indicators are calculated on an aggregate level for the combined oil shale value chain and the performance of individual companies that mine and utilise oil shale is not measured or benchmarked. The impact of companies' technological upgrades or operational performance on achieving regulatory objectives is therefore unclear.

Incentives for companies to comply with regulatory objectives are mostly provided by a system of resource tariffs and environmental charges. It is shown that combined inflation adjusted charges paid by the oil shale value chain were relatively stable in 2008–2018, however, this did not lead to a sustained improvement of regulatory indicators.

Composite regulatory indicators of oil shale value chain industries, which aggregate sectoral and company level performance, monitor parameters the economic operators can affect and allow benchmarking, will require further research. Also, access to oil shale mineral that presents a monopolistic bottleneck for the whole value chain is based on legacy market conditions. The economic regulation of oil shale mining and the tariff system of oil shale value chain industries merit further study to enable using the mineral in operations that generate higher value added.

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