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Development of Resource Regime of Oil Shale Industry: A Case of Estonia

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Declaration:
Hereby I declare that this doctoral thesis, my original investigation and achievement, submitted for the doctoral degree at Tallinn University of Technology has not been submitted for doctoral or equivalent academic degree elsewhere.

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KALEV KALLEMETS

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Other publications of the author related to the doctoral thesis:

- Kallemets, K.; Heffron, R. (2012). Estonia: The Prospects of Nuclear Energy. *Journal of Energy and Power Engineering*. Volume 6. Number 4 April 2012. David Publishing Company, El Monte 2012.
- Marko Viiding, Kalev Kallemets, Peeter Pikk. (2013). Electricity Cost as a Driver of Competitiveness in Northern Europe: *The Case of Estonia. Transition Studies Review*. February 2013, Volume 19, Issue 3, pp 367–381.
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Author’s contribution to the publications

Contribution to the articles in this thesis are as follows:

I Single author

II Single author

III Lead author

Introduction

In the modern era, the development of steam engine, transportation, large-scale manufacturing, processing, lighting, heating and cooling have quickly improved living standards of the ever-increasing number of people to historically unknown levels (Pinker, 2018). The scale of demand and corresponding production has made the energy industry a leading force in the global economy along with a high degree of political influence. Every nation needs to decide how to balance its energy supplies with sustainability goals and economic development, and how to utilize natural resources for maximum economic impact.

The problem with oil shale mining in Estonia is similar to that of other solid fuels or depletable minerals like coal in Poland (Kowalska, 2015), phosphates in Jordan (Al Rawashdeh, Maxwell, 2013), metals in Finland (Tuusjärvi et al., 2014), or gold in California (Rawls, 1999). Similarities include volatility of revenues, environmental impact, eventual depletion of economic reserves and related socio-economic changes. Estonian oil shale has unique characteristics as a dominating source of power supply, versatility of the resource for multiple applications and concerns related to energy and national security. While previous studies have addressed breakeven production costs (Kleinberg et al., 2018), taxation (IMF, 2016), revenue management (van der Ploeg, Venables, 2011), R&D expenditure (Sagar, van der Zwaan, 2006), resource curse for developing nations (Sachs, Warner, 2001), there is a need for a comprehensive, evidence-based resource regime approach for the lifecycle of a nationally major resource. Current thesis intends to fill in this research gap***.***

The concept of resource regime was developed by Young (Young, 1986) to define ”social institutions that serve to order the actions of those interested in the use of various natural resources“. Resource regime covers items like taxation, exploration and mineral rights licencing, revenue management (revenue sharing and resource fund management) and enabling environment (open data, rule of law, control of corruption, skills, research and development, etc). This concept is being empirically studied annually since 2013 by the Natural Resource Governance Institute based on 14 indicators for 89 jurisdictions under name of Resource Governance Index (NRGI, 2017). Since 2016, the resource regime in Estonia has been undergoing significant changes, but the subject has not been studied based on the theoretical concepts of resource economics.

So far, there is a lack of resource-specific academic literature regarding natural resources about economic impact and mechanisms how to improve or sustain positive economic effects of a major natural resource. Based on the literature review of papers published between 2014-2017, only a few articles (Kowalska, 2015; Ebert, La Menza, 2015, Ramirez Cendero, 2014) published in Journal Resource Policy have covered the economics and mineral policy of a major natural resource that is of national importance. Current thesis aims to fill this research gap.

Main objectives of this thesis are to fill the gaps in research by developing a model for resource regime along with a method of adaptation for achieving economic sustainability. The model developed is based on the empirical data of the economic impact of Estonia’s oil shale industry. Economic sustainability is hereby defined following the Brundtland Report: “Sustainable development is the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (World Commission on Environment and Development, 1987). According to this report, the key concept enabling broader economic view of natural resources is through mining and processing conversion of minerals into capital assets that can be allocated to enable future generations to meet their own needs. Thus, without economic production by current generation, provision of goods for future generations will be compromised. Therefore, it needs to be determined whether current production is economical and what its economic impacts are.

The research questions of this thesis are:

- What are the economic impacts of the oil shale sector in Estonia? (Addressed in Articles I and II.)
- What factors influence the future economic impact of the oil shale sector in Estonia? (Addressed in Articles II and III.)
- Is the oil shale sector economically sustainable in the long term? (Addressed in Articles II and III.)
- What resource regime supports the economic sustainability of oil shale industry? (Addressed in Articles I, II and III.)

Key theoretical basis of current work is insight developed from seminal work of Harold Hotelling, (Hotelling, 1931) which states socially and economically the most profitable extraction path of a non-renewable resource. This so-called Hotellings rule implies ability to convert natural resources through extraction and processing to other forms of capital such as know-how, social capital and equity. This thesis contributes to a better understanding of a resource regime through constructing a resource regime model based on solutions to research questions. Currently, in case of Estonian oil shale, that model is evolving from a simple state-led model to a more modern model that needs to be adapted to market conditions, social and ecological demands through better resource revenue allocation and research funding. This model helps to visualize and understand the interactions between individual elements of the resource regime. Based on extensive review of relevant literature, the author believes that this circular model of interconnected effects supporting sustainability of resource regime is the most novel approach.

The method of adaptation for a resource regime developed in the thesis (section 3.7.) is the first to separate individual elements and improve the understanding of how each element of the model affects the others. Second, to identify the main factors limiting economic sustainability and third, to the identify the potential to reallocate revenue flows or amend regulations to improve economic sustainability.

Several factors and empirical cases are studied in Article I, which concludes that Estonia’s current resource revenue system is not optimal and puts forward ways of improving this element of the resource regime. Estonian government uses a complicated system of environmental fees and resource revenues, which affects the oil shale sector. Based on Hotelling’s rule (Hotelling, 1931) it is clear that the return on resource revenue impacts directly the way exhaustible natural resources are utilized. Currently, resource income flows are not allocated to increase the definable return on these revenues.

The competitiveness of shale oil in terms of taxation is the key issue of the resource regime and it is the subject of Article II and as a relevant element of the modern resource regime model. Global crude oil prices started to increase in 2004 beyond 60 USD/barrel, increasing interest in shale oil production and between the years 2006–2016, companies within the industry invested a total of 3 billion euros. Following a dramatic oil price fall from 110 USD/bbl in 2014 to 28USD/bbl in early 2016, shale oil production became unprofitable, which led to job losses and government policy change of resource revenues to the ad valorem system.

Research and development funding of Estonian oil shale is compared to that of Canada's Alberta oil sands in Article III. The article concludes that a substantial increase of private and public R&D funding is necessary for Estonia to meet the International Energy Agency's average. Both the power generation and shale oil production face unique, yet similar challenges in terms of European and global environmental regulations and product competition. The environmental footprint of the industry must be reduced, while increasing its economic value added. Substantial positive externalities and the economic footprint of the energy industry are the key reasons for public involvement in innovation. A significant R&D funding is a crucial element in the modern resource regime model for the oil shale industry.

Estonia has enjoyed a significant economic benefit from its oil shale industry and continues to do so to this day. However, much more has to be done by the state and the industry to enable its economic sustainability in the long run and to diversify both the country's energy supply and the regional economy of Ida-Viru County. In the development of the industry, public revenue has not been a major consideration. The main conclusion of the current thesis is that, given the challenge of adaptation to environmental requirements and economic situation, revenue allocation needs to be changed to meet current demands. This thesis provides calculated revenues from the industry as both the output and the source of R&D funding, and demonstrates their relevance for the regional socio-economic development given the decline of oil shale power generation.

The thesis is structured in three parts: literature overview, results of research, followed by discussion and conclusion. The literature overview provides an introduction to Estonian oil shale and the theory of resource regimes. The main body of evidence based on published papers is presented in the Results of Research section. This section also provides one of the main new findings of the modern resource regime model.

Abbreviations

Bbl	barrels of oil
CAD	Canadian Dollar
CO_2	carbon dioxide
EE	AS Eesti Energia
EU	European Union
EUA	European Union Allowance Certificates for Offsetting CO_2 Emissions
EU-ETS	European Union Emissions Trading Scheme
GWh, MWh, kWh	energy units
HFO	heavy fuel oil
IOC	international oil company
Kcal/kg	kilocalories per kilogram
KKT	OÜ Kiviõli Keemiatööstus
Mln	million
MWe	megawatts of electrical capacity
PIF	permanent income fund
PP	power plant
R&D	Research and Development
SDF	State Development Fund
SO_2	sulphur dioxide
T	ton
Tbbl	terabarrels
VKG	AS Viru Keemia Grupp

1 Literature review

1.1 Oil shale utilization

The global oil shale resources are estimated at 2,8 trillion barrels crude oil equivalent, 1,5 trillion barrels of which is US Green River formation (WEC, 2013). This potential has been exploited globally on a relatively minor scale, with the exception of Estonia, where it represents a major energy supply of the country. Oil shale pyrolysis was developed in France, where in 1832a method for producing lighting oil was realized. Both France and Scotland started significant oil shale industries in the 19th century, but closed them down in 1957 and 1962, respectively (Francu et al., 2007).

Estonian oil shale *kukersite* is a low-grade fuel with approximately 33% of kerogenous organic content, Fischer Assay oil yield is 30 to 47% with a mean calorific value of 3600 kcal/kg (Soesoo et al., 2007). Estonia's active oil shale reserves total approximately 950 million tons as of the end of 2015, the reserves under protected areas amount to another 1,1 billion tons in the Estonian basin.

Oil shale mining started in Estonia in 1916 and peaked in 1980 at 31 million tons per annum. Between the years of 2005–2015, annual mining quantities of geological reserves did not exceed 15 million tons. Estonian oil shale represents a unique case globally because its main utilization since the 1960s has been power generation due to the country being part of the North-Western Soviet power supply system. However, due to the increase in oil prices since 2004, several new investments have been made in oil production, utilizing previously untapped fine oil shale that forms the majority of the mined oil shale. Also, much attention has been devoted to maximizing energy efficiency through coproduction of oil and electricity along with heat for district heating. Therefore, energy efficiencies of new capacities are above 80% for Petroter and Enefit 280 units.

Table 1. *Oil shale consumption in millions of tons.*

Oil shale utilization\Year	2009	2010	2011	2012	2013	2014	2015
Power generation	9.3	13.7	13.9	12.7	15	14.3	10.5
Heat production	0.6	0.6	0.4	0.4	0.5	0.5	0.4
Shale oil production	3.6	4.2	4.5	4.8	5	5.7	6.7
Cement production	0.1	0.2	0.2	0.2	0.2	0.2	0.1
Total consumption	**13.6**	**18.7**	**19**	**18.1**	**20.7**	**20.7**	**17.7**

Source: Final Report on Execution of National Oil Shale Utilization Development Plan 2008-2015.

Estonia's oil shale industry consists mainly of three enterprises. The largest is 100% Estonian government owned Eesti Energia AS (EE) that utilizes 11 mln t of oil shale per year for power generation to produce 10 TWh of electricity. In addition EE produces 200 000 t of oil per year from 1,7 mln t of oil shale. In 2013, the turnover of the company was 822 mln euros (Eesti Energia, 2015). The second largest company is the privately owned Viru Keemia Grupp AS (VKG) that processes and produces 370 000 t of oil annually. In 2013 their turnover was 220 mln euros (VKG 2014). The third largest company is also privately owned Kiviõli Keemiatööstus OÜ (KKT) that processes 0,6 mln t of oil shale, produces 60 000 t of oil and has a turnover of 35 mln eur. In 2016, the total

Estonian oil industry production was around 23 000 barrels per day or 915 000 tons per year (see Table 1 for oil shale processing data over 2007–2015).

Most of the presently operating mines and production units in the industry are the heritage from the Soviet period that have undergone many renovations and technology improvements in the last 15 years. In 1997–1998, the oil industry went bankrupt and was on the verge of shutdown due to the drastic drop in world oil prices. However, the industry bounced back thanks to the increasing oil prices from 2004 to 2016, which brought about large investments in the industry to replace the aging capacities with new more efficient ones.

1.2 Research on resource regime

Relevant to the theoretical understanding of resource economics is the term "resource curse" as studied and defined by Alan Gelb in his seminal book "Oil Windfalls: Blessing or Curse" (Gelb, 1988). The book describes countries with rich natural resources such as Venezuela, Nigeria and Iraq as being unable to use that wealth to boost their economies as they all have lower economic growth than countries with few natural resources such as South-Korea, Taiwan and Japan. Sachs and Warner's empirical work confirmed adverse effects of resource dependence, where major revenue streams lead to currency depreciation, crowding out other sectors of the economy, fiscal dependence, conflicts, corruption and political power monopolisation (Sachs, Warner, 2001). Such examples include Cameroon, Iraq, Libya, Venezuela, Mexico (Rey, 2010).

Studies by Gylfason (Gylfason, 2001; Gylfason, 2005) look at how resource dependence affects savings, investment and human capital formation. These studies tend to focus on developing nations, but there are plenty of developed nations with mineral endowment and Estonia can be considered among them. Experience of successful resource rich jurisdictions such as the Canadian province of Alberta, US state of New Mexico, Norway, as well as developing nations such as Botswana and Morocco prove that resource curse is not inevitable. Badeeb et al. (2015) demonstrate in their comprehensive literature survey that there is no academic consensus on the inevitability of resource curse, but a fair consensus of the importance of good governance.

The theoretical question that can be asked based on empirical evidence is whether there is a resource curse in oil shale or is it a blessing for Estonia. A relevant comparison here are not Sub-Saharan oil-rich states, but regional states like Latvia, Lithuania, Finland and Poland. There is no evidence that high mineral resource endowment has been a drag on the economic development of Finland or Poland compared to the economies of Latvia and Lithuania, which are far poorer in terms of their mineral resources. The opposite is true given that resource-based companies have been key industries in these nations for decades (Tuusjärvi et al., 2014) despite reduction of employment due to advances in automisation. For example, Polish coal mining employment decreased from 388 000 in 1990 to 107 000 in 2013 (Kowalska, 2015). This thesis provides some comparative evidence regarding Baltic countries.

Using a triple difference model with instrumental variables to control endogenous factors that can be correlated with shale development in drilling counties, Brown (2014) found that communities situated near oil and gas shale booms experience positive income and employment effects, although the employment effects are mainly concentrated within the mining sector. Douglas and Walker (2012) found that annual income growth per capita between 1970 and 2009 was about 0.3–0.4% less in core Appalachian counties that never had coal production compared to counties with coal industry. These studies do not consider private and public revenues from coal mining as inputs into regional economy diversification.

Shao, et al. (2014) developed a conceptual model validated with a mathematical model, indicating that the rate of return on education investment and government behavior play a crucial role in promoting the formation of the virtuous circle of economic development. Indeed, Shao allocates real significance to natural resource revenues as capital to be accumulated, rather than to be consumed. However, education and know-how are not the only form of capital. Living conditions, social norms, diversity of economy, good governance, open competition are also assets that enable or discourage sustainable economic development (Collier, 2008). Similarly, developing countries without notable natural resources, such as Armenia, Moldova, Albania, experience similar challenges with governance and poor development. Thus, abundance of resources does not determine the degree of development, instead it is more likely to be determined by the quality of governance.

Venables (2016) argues that there are four main determinants separating resource winners from losers: discovery, development, rent capture, and the management of revenues. Underlying these, Venables also claims that there are two common causes for the countries' heterogeneity of experience with resource endowments. The first is the technical difficulty of handling resource revenues that are risky, volatile, and time-limited. The second is that governments have commonly been unable to resist short-run spending pressures to commit to long-run investment and growth strategies. More optimistically, Venables notes that recent decades have seen significant improvements in terms of governance in resource-rich countries.

The simplest depletable resource models are those applicable to the competitive owner of a resource stock, where the owner chooses the time path for its extraction. Hotelling's rule states that socially and economically the most profitable extraction path of a non-renewable resource is the one where the price of the resource, determined by the marginal net revenue from the sale of the resource, increases at the rate of interest (Hotelling, 1931). The key term here is net revenue, which is affected not only by the net revenue of the producer, but by the social level at which different revenue streams are being allocated and utilized. Other factors of expected net revenue are technological progress, environmental externalities, excise taxes, price expectations, role of national security, and interest rate (Sweeney, 1992).

These theoretical concepts have contributed significantly to the author's thinking of resource regime of oil shale, especially in shaping the view that natural resources can be converted through mining and processing to monetary resources, which in turn can be converted to human capital, environmental improvement, research & development, social development and other goods. However, if these revenues are simply spent through annual state budget, there is no obvious accounting of the conversion process. A second revelation is the effect of externalities of research and development which is hard to quantify. However, it is obvious through theory and studies that multiplier effects are likely to be substantial.

1.3 Economic impacts of energy sources utilization

Economic impact analysis typically estimates changes of economic activity in a particular professional field or region (Weisbrod, 1997). Most regular economic impact indicators are jobs, business output (sales), value added, effect on GDP and fiscal contributions. Studies measure three major channels of impact: direct, indirect and induced impacts. Direct impacts are the changes in business activity occurring as a direct consequence of public or private business decisions or public policies and programs. Indirect impact is measured as a business growth/decline resulting from changes in sales for suppliers to the directly-affected businesses. Induced impact is defined as further shifts in spending on food, clothing, shelter and other consumer goods and services, as a consequence of the change in workers income and payroll of directly and indirectly affected businesses.

Utilization of a particular energy resource has several positive impacts. If the resource is competitive, it supplies necessary goods and reduces prices for customers in some markets. Secondly, it creates employment and net revenues to the related industry, thereby providing fiscal effects to the state. Third, it creates an industry that supplies and constructs various buildings, equipment for the energy industry. The absence of an energy resource creates import dependencies and monetary cost for national economy.

Utilization of an energy resource for various needs in the transportation, heating or power sector creates new opportunities that would not exist otherwise. In Estonia, oil shale was the dominant fuel for electricity generation for the needs of the capital city of Tallinn from 1924 to 1949. The first oil shale-based power plant (PP) in the then Soviet Union was completed in Kohtla-Järve in 1949. Next, in 1951, Ahtme PP was completed, and in 1959, the Balti PP was put into operation. The latter reached a nominal capacity of 1400 MW within a few years. Finally, the Eesti PP achieved a capacity of 1600 MW in 1973 (Bachmann et al., 2014).

In 2015, Estonia was the most energy independent nation in the European Union, largely due to oil shale (Eurostat, 2016). If no oil shale would have been available in Estonia, it is likely that the history or electrification in the Soviet Union-occupied Estonia would have been similar to Latvia's or Lithuania's, where electricity production is mainly based on natural gas. According to Elering, Lithuania is one of the most energy dependent nations in the region with annual costs for imported electricity and natural gas for power generation reaching approximately 300 million euros (7,45 TWh imports in 2016) and 750 million euros, respectively. Lithuanian natural gas imports in 2014 were 8,4TWh per million residents compared to 3,8 TWh per million residents in Estonia (EC, 2014).

Oil shale power generation has enabled Estonia to enjoy lower power prices compared to Latvia's and Lithuania's regulated market prices over the period of 2010–2016. As Estonia has been a significant supplier of electricity to Latvia and Lithuania (2 TWh in 2016), it is certain that with the missing power supplies from Estonia, power prices in Latvia and Lithuania would have been even higher. Therefore, even neighboring countries have gained from oil shale power generation in Estonia. Comparing regulated and market power prices in Estonia and Lithuania in reference to Estonian annual average power consumption 7,3 TWh, the economic gain for Estonian consumers over the last seven years has been 417 million euros (see Table 2).

Table 2. *Estonian and Lithuanian regulated and market power prices.*

Country\Year	2010	2011	2012	2013	2014	2015	2016
Estonia, €/MWh	30.7	43.4	39.2	43.1	37.6	31.1	33.1
Lithuania, €/MWh	46.6	45.2	46.2	48.9	50.1	41.9	36.5
Difference, €/MWh	15.9	1.8	7	5.8	12.5	10.8	3.4
Mln €	**116.1**	**13.1**	**51.1**	**42.3**	**91.3**	**78.8**	**24.8**

Source: Nord Pool, Elering.

The skill and competence in handling solid fuels has contributed into Estonia becoming the most successful Eastern-European country in the utilization of biomass for the co-production of heat and electricity. Related investments have been funded, by the government, through the Environmental Investment Center (EIC) which receives over 70% of its revenues from environmental fees related to oil shale processing (see Tables 7 and 8). As the switch-over to biomass has been taking place from either natural gas or heavy fuel oil, consumers have seen a decrease of the district heating price, according to the Estonian Competition Authority.

Having solid fuel power generation capacities also creates potential for large-scale renewable energy generation. In 2011–2012, a feed-in-tariff that supported 0,65TWh of renewable energy production was implemented. The new 300 MW fluidized bed combustion boiler in Auvere is able to use up to 50% of wooden biomass as fuel together with oil shale. In 2017, there were expectations that the European Union renewable energy statistics trade will enable Member States that do not fulfill their national renewable energy targets to purchase renewable energy form Estonia. EE expected to produce up to 2,5TWh of renewable energy in oil shale power plants by using renewable biomass and generating additional revenues to the amount of 66 million euros.

Years 2006–2015 saw major investments by the oil shale companies totalling 3,2 billion euros, according to the company's annual reports. In 2002–2004, two 215 MWe power blocks at Narva Power Plants were refurbished and in later years, new shale oil production units Petroter, Enefit 280 and UTT-500 were completed. The industry has been a substantial source of construction orders and employed people in Estonian civil and metal construction industries, by including many large domestic companies in the field such as Merko, Nordecon, Maru, Technobalt, ABB, Remeks Keskus, Estanc, etc. Analysis carried out by PricewaterhouseCoopers (PwC) of VKG's Petroter unit construction revealed that the project contributed 40 million euros to Estonia's GDP and the state tax revenue during the investment period amounted to 15 million euros (PwC, 2011).

These detailed direct and indirect economic impacts are the reason why it is important for the state to develop a resource regime that is economically sustainable.

2 Research Setting and Results

2.1 Research plan

Methodology of this thesis is applying key theoretical concepts of resource regimes such as resource funds and research expenditure, to the empirical comparison of the resource regime of Estonia with those of other developed nations (Canada, USA, Norway), in terms of fossil fuel resources. The thesis focuses on Estonia's specific natural resource – oil shale, and draws empirical comparisons with similar resources in other countries. Furthermore, the thesis follows a traditional measurement of direct and indirect economic impacts and utilizes the industry standard full cycle breakeven cost calculation in estimating oil production competitiveness.

Some researchers might find the profitability of resource industry as insignificant from the perspective of sustainable development. As discussed earlier in Introduction, the long-term sustainability, i.e. provision of resources for future generations, is impossible without a short-term economic sustainability. Therefore, the author finds it important that fair taxation is considered a relevant component of the resource regime system.

Economic impact on sustainability of resource regime taxation system needs to be understood and measured. Therefore, gathering empirical data is necessary to achieve numerically relevant conclusions. Additionally, the academic work on resource regimes discussing reasons of resource curse, resource revenue allocation, research and development policy, and industrial change is also relevant, as are the empirical studies conducted by Natural Resource Governance Institute.

The main research questions addressed in this thesis are the following:
1) What are the empirical economic impacts of the oil shale sector in Estonia? Data and explanations are provided in sections 3.3, 3.4 and 3.5.
2) What factors influence the future economic impact of the oil shale sector in Estonia? The issue is addressed in sections 3.1, 3.2, 3.3 and 3.6.
3) Is the oil shale sector economically sustainable in the long term? The problem is addressed in sections 3.3 and 3.6.
4) What resource regime supports the economic sustainability of oil shale industry? The issue is addressed in sections 3.6, 3.7 and 3.8 as the development based on data presented in the above sections.

2.2 Competitiveness of Estonian oil shale in oil production

Shale oil is a somewhat unique product, which is mostly used as heavy fuel oil or bunker fuel. However, it is fair to say that most global crude oils from particular deposits are unique, in terms of individual American Petroleum Institute gravity, sulphur content and molecular characteristics. Ultimately, oil derived from oil shale is a particular sort of crude oil competing on the market with crude oil as a product and as an investment opportunity. The direct pricing benchmark for shale oil is the heavy fuel oil with 1% sulphur content priced at Rotterdam. Thus, the same economic analysis applies to shale oil as to other conventional and unconventional crude oils.

The conventional oil project full cycle cost consists of the following:

1. Property Acquisition Costs;
2. Exploration Costs;
3. Development Costs;
4. Production Costs;
5. Transportation Costs;
6. Production Taxes;
7. Return on Capital.

In long term, the oil and gas industry must incur certain costs in order to find, develop and produce petroleum products. This full set of costs that the industry needs to incur in order to sustain or grow production is known as “Full Cycle costs”. If crude oil or natural gas prices are generally persisting above these Full Cycle costs, the industry has an incentive to sustain investment and activity in the sector. However, if the margin between Full Cycle costs and prices is squeezed for prolonged periods, the industry finds that investment is not sustainable and capital spending, production and reserve replacement will begin to fall off as a result. This will eventually lead to a decline in production or even shutdown.

The abrupt fall of oil prices in the second half of 2014 and the leveling at 60–65USD/bbl thereafter led to a 25% reduction (approximately 100 bn USD) in new capital expenditure or project delays into new oil upstream capacity, particularly in Canadian oil sands, according to a consultancy firm Rystad Energy (Nysveen, 2015). It is relevant to note that breakeven prices are not constant through time even for particular oil plays. Recent examples is a reduction of breakeven costs in US shale oil plays through increased productivity of wells, higher selectivity in drilling and other methods (Energy Information Agency, 2015)

Most of the mines and production units in the industry in Estonia are the heritage from the Soviet period. The oil industry almost went bankrupt and was on the verge of ending in 1997–1998 due to the fall of world oil prices, but the subsequent increase in prices has been accompanied by steady investments to replace the aging capacities and add new, more efficient ones. Most active investor has been VKG, which completed two new Petroter oil shale processing units in 2010 and2014. VKG also opened a new Ojamaa underground oil shale mine in 2013 and they are currently constructing a third Petroter unit. Thus, 59% of oil was produced in new units in the year 2016. EE is equally active, having invested in 2016 in a new 300 MWe circulating fluid bed power generation unit and a new oil production unit Enefit 280. The latter is able to process 2 mln t of oil shale and produce 5000 barrels of kerogen oil per day.

The oil shale sector faces many industry and EU specific risks. These are the following:

1. EU climate policy

The European Union Council has endorsed the objective of reducing Europe's greenhouse gas emissions by 80-95% compared to the 1990 levels by the year 2050 as part of efforts by developed countries to reduce their emissions to a similar degree. The EU's key tool is the European Union Emissions Trading System (EU ETS) which was launched in 2005. The EU ETS is now in its third phase, running from 2013 to 2020. Since 2009, the European Emission Allowances (EUA) price has been lower than expected due to economic depression and renewable energy push. As of 2018, uncertainty remains regarding the future of CO_2 prices.

2. National taxation.

Estonia has a complicated environmental charges system with a relatively high level of costs to the industry (Ernst&Young, 2014). A portion of the charges are related to environmental effects such as charge on SOx, NOx and particle emissions, processing water disposal, disposal of mining water, depositing of mining waste (lime stone), semi-coke and oil shale ash. The rest is traditional resource revenue (mining fee) based on each ton of the geological reserve extracted.

In international resource taxation comparison, all taxes borne by producer related to production are compared to earnings of mining operation, resulting in Average Government Take (Agalliu, 2011) or Average Effective Tax Rate (IMF, 2012). The Estonian Mining Industry Association ordered a similar analysis from Ernst&Young, which found that compared to international mining Total Tax Rate (TTR) of 39% (PwC 2010), the Estonian rate for oil shale processing in 2011 was 62% (Ernst&Young, 2016). In 2014, the TTR for VKG was around 68% at oil prices of 105 USD/bbl. For comparison, Alberta oil sands Average Government Take in 2011 was 67%.

In June 2016, Estonian government, as a response to the very low oil prices, conceded that the fixed rate mining fee with annually increasing rates was unfounded and decided to adopt ad valorem mining fees that depend on the heavy fuel oil price quoted in Rotterdam. This amendment reduced the costs to oil shale industry in times of market turmoil. However, according to Table 3,environmental fees as share of the production cost actually increased from 2013 and the cost of environmental fees to the industry relative to oil price was in 2017 almost 50% higher than in 2013.

Table 3. *Mining fees and environmental charges in Estonia in 2013 and 2017.*

Kind of fee\Year	2013 rates	2013 rate cost per t of oil	2017 rates	2017 rate cost per t of oil
Mining fee	1.39 €/t	11.1 €/t	0.59€/t	4.7 €/t
Mining waste depositing fee	1.09 €/t	3.1 €/t	1.31 €/t	3.7 €/t
Mine water disposal fee	49.7 €/1000 m^3	0.76 €/t	53.25€/1000m^3	0.8 €/t
Oil shale ash depositing	2.07 €/t	5 €/t	2.98 €/t	6.6 €/t
SO2 in atmospheric emissions	86.08 €/t	4.7 €/t	145.46 €/t	6.8 €/t
NO2 in atmospheric emissions	101.1 €/t		122.32 €/t	
Particles in emissions	86.5 €/t		146 €/t	
Total environ. fees		24.7 €/t		22.6 €/t
Average oil price		432 €/t		271€/t
Per cent of oil price		**5.7%**		**8.3%**

Source: Environmental Taxation Law; the author's calculations.

3. Heavy fuel oil product risk

There is great difference between the pricing of crude oil and that of heavy fuel oil with 1% sulphur content, which is the actual pricing reference for oil produced from oil shale.

The difference is called crack spread and has varied in the period of 01.01.2013–31.01.2014 from 71.8 to 163 USD/t. For example, when Brent crude price was at 790 USD/t, the price of heavy fuel oil was at 626 USD/t, therefore high oil prices do not necessarily result in higher revenues for oil shale oil producers. An option to reduce that risk is to upgrade shale oil into diesel fuel through dedicated refinery or partial upgrading.

With a total capacity of 23 000 barrels of oil per day, Estonian shale oil producers are undiversified minor oil businesses exposed to the high risks of volatile oil prices among other factors. Given significant unavoidable capital expenditure to replace production capacities, build new oil shale mines, as well as to comply with EU ETS, the competitiveness of shale oil production will be low in the coming decades, barring any regulatory changes to reduce government take and innovation in increasing the value added of shale oil production. In the low-price scenario of 200 €/t for HFO, a fairly quick fade-out of the industry will be likely. At a price of around 320 €/t the industry may be sustainable and heavy fuel oil prices at 450 €/t would lead to substantial capacity increasing investments, according to EY (EY, 2016).

Clearly, world oil prices are the most relevant factor influencing the economic sustainability of the sector, but since Estonia has a negligent effect on global oil supply and demand, resource regime has to focus on factors it can directly control. The previous section responded to research question two on factors that influence future economic impact of the industry.

2.3 Competitiveness of Estonian oil shale in power generation

Power supply in Estonia has been mainly based on oil shale since the 1950s and that trend is likely to continue for the next decade. Since the launch of a 350 MW Estlink1 interconnector to Finland in late 2006, power generation has been highly dependent on power prices and demand. Table 4 shows the correlation between Estonian market power prices and oil shale power generation. Power prices in Finnish and Baltic power markets are largely dependent on hydropower generation (rainfall, snowmelt) in Sweden, Finland and Latvia, as well as power demand depending on weather conditions.

Table 4. *Estonian market power prices and oil shale power generation.*

Year	2011	2012	2013	2014	2015	2016
Market power prices, €/MWh	43.4	39.2	43.1	37.6	31.1	33.1
Oil shale power generation, TWh	9.6	8.5	10	9	7.3	8.7

Source: Nord Pool; Annual Book of Oil Shale 2014 & 2015; Eesti Energia Annual Reports, Announcements.

Strategically, the competitiveness of oil shale power generation has been influenced by two main policy factors: environmental fees and CO_2 emission cost (see Table 5). During the period between 2012-2015, environmental fees were somewhat higher than emission unit cost, but if EUA unit prices are above 15€/t, the CO_2 emission cost will begin dominate. The weight of the CO2 emission cost can be partially offset with trading strategies, such as purchasing emissions units ahead at lower cost, forward deals or using previously accumulated CO_2 emission units.

Table 5. *Cost components of EE power generation.*

Cost component		2012	2013	2014	2015
Average power price,	€/MWh	39.3	43.1	37.6	31.1
Power generation,	GWh	9201	10278	9343	7312
CO_2 emission unit price,	€/t	8.2	5.5	7.1	8.4
Cost in production,	million euros	6.5	56.7	65.6	12.6
Power sales revenue,	million euros	361.6	443.0	351.3	227.4
CO_2 emission cost share,	% of revenue	2%	13%	19%	6%
Environmental fees of power generation,	million euros	41.2	44,8	49,3	47,5
Environmental fees of power generation,	% of revenue	11%	10%	14%	21%

Source: Eesti Energia Annual Reports 2011–2016.

In the long term, oil shale power generation will decline as the 619 MWe boiler units will be closed in succession by the year 2023, followed by the closure of other older boiler units in 2030 and 2035, leaving just the 300 MW new CFB power generation unit at Auvere PP in operation as the post-2035 capacity. Shutting any capacities in the Baltic region will likely increase power prices, which is favorable for the remaining oil shale capacities to generate power near full capacity. One option regarding the CO_2 cost is converting fossil fuel-based power plants to those using biomass instead. This process is taking place in the United Kingdom, Belgium and Denmark. The new Auvere CFB will be able to use up to 50% biomass as fuel.

2.4 Oil shale revenues

In order to overcome the resource curse, British authorities established the Kuwait Investment Authority in 1953, the first of what is known today as Sovereign Wealth Fund (SWF). In 2015, a total of 68 national or state SWFs managed assets with a market value of 7.2 trillion USD. 56% of SWFs receive their revenue from oil and gas, 10% from metal ores or minerals and many are non-commodity funds like Temasek of Singapore. The main logic for oil and gas revenue funds was the relatively large scale of revenue stream that was achievable quickly from a particular deposit (Davis et al., 2001). Tsani (2012) provides an extensive overview of the pro and con debate on resource funds (RF). Arguments for RFs are:

1. insulate price volatility and exchange rate pressures;
2. improve fiscal discipline as tools of self-constraint upon fiscal actors;
3. serve revenue saving and intergenerational fairness goals;
4. funds insulate natural resource revenues against rent-seeking and corruption;
5. capital allocation to non-resource sector;
6. environment restoration can be viewed as capital investment.

Taxation of the oil shale sector occurs by means of environmental charges that are levied as mining and environmental fees. The latter consists of different fees such as for mining water disposal, mining waste and in the processing phase on atmospheric emissions, waste water disposal and depositing of oil shale ash (see Table 6).

Table 6. *Distribution and total of environmental fees paid by oil shale industry, per cent.*

Year\Kind of fee	Mining fee	Environmental fee	Total
2013	26.5	36.9	63.4
2014	27.9	44.8	72.7
2015	17.4	44.4	61.8
2016	10.5	48	58.5

Source: Final Report on Execution of National Oil Shale Utilization Development Plan 2008–2015. Ministry of the Environment.

Fee revenues paid by oil shale industry are distributed, based on the Environmental Taxation Law, between the municipalities located in the oil shale mining area, the state general budget and the foundation Environmental Investment Centre. The latter in turn re-distributes the revenues for nationwide environmental projects, including waste and water management, renewable energy and environmental awareness, often as a co-financier of the respective projects together with the European Union Structural Funds. Over the years, the principles of revenue distribution have changed (see Table 7).

Table 7. *Distribution of mining fee revenue receivers.*

Revenue receiver\Year	2015	2016	2017	2018
Municipalities	16%	21%	17%	17%
State general budget	50%	35%	53%	54%
EIC	34%	44%	30%	29%

Source: Ministry of the Environment, author's calculations.

When developing the most suitable resource revenue model for Estonia, four parameters were selected based on the literature and case studies introduced in the previous section:

a) Size of public revenue stream relative to GDP. This means that if the size of revenue stream is large relative to GDP, it suggests higher savings in international assets to avoid the Dutch disease.

b) Period of revenue stream. This means that if the revenue stream is short-term (few decades), it suggests a higher saving ratio in liquid assets to ensure intergenerational equity and lower the risk of short-term rent seeking.

c) Economic development level of the country. This means that if the country's economic development relative to the region's is lower, it suggests a higher investment in assets contributing to the domestic economic development, and vice versa.

d) Institutional development. This means that if the institutional development of the country is rapid enough and ensures transparency, it is less likely that investments in domestic assets would encourage rent-seeking and corruption.

Table 8 provides comparative data on resource revenue streams, development level of jurisdictions and proposes a suitable resource revenue model. Due to the relatively small and long revenue stream from oil shale and other minerals, lower relative development level and sufficient institutional development, Estonia should continue fiscal expenditure while adding the Sovereign Development Fund as a point of revenue allocation. This is even more relevant if the planned ad valorem oil shale royalty is introduced to increase fiscal variability.

Table 8. *Resource fund factors in different jurisdictions.*

	Alaska oil	Wyoming oil, gas, coal	Alberta oil sands, oil, gas	New Mexico oil, gas	Estonia oil shale, etc. (2015)
Revenue stream, % GDP	$ 3 bn, 6.7%	$ 1 bn, 3.6%	$5 bn, 2.7%	$1.6 bn, 2%	€182 mln, 1%
Period of revenue stream	50 years	50–100 years	100+ years	50–100 years	100+ years
Development level, GDP per capita in region	$45 665, 110% US average	$ 47 898, 115% US average	$ 49 562, 159% Canada average	$ 34 133, 82% US average	$ 20 700, 67% EU average (2011, PPS terms)
Institutional development WB GI score[1] TI CPI score[2]	High 73	High 73	High 84	High 73	High 64
Suitable model	Fiscal with PIF	Fiscal with PIF	Fiscal with PIF	Mixed PIF/fiscal/SDF	Mixed fiscal/SDF

Source: Alaska Permanent Fund Corporation, Wyoming Department of Revenue, New Mexico Taxation and Revenue Department, Alberta Heritage Saving Trust Fund, Rahandusministeerium.
[1]– World Bank Governance Index; [2]– Transparency International Corruption Perception Index.

As a 100% shareholder of EE, a major oil shale miner that is involved in power generation, power distribution and oil shale oil production, the state of Estonia also receives significant revenues from oil shale processing. EE mines and processes roughly 80% of the country's oil shale. From 2005 to 2016, EE contributed between 50 and 90 million euros annually to the state budget through dividends. The state budget received a total of 650 million euros was the direct state general budget revenue from dividends and additional 130 million euros from associated taxes through this period.

2.5 Emission revenues

The oil shale power generation revenues from the emissions permits trading under The Kyoto Protocol have been quite significant for Estonia. Under Annex I of the Kyoto Protocol, Parties made use of the International Emissions Trading system. Under the Protocol, for the 5-year compliance period from 2008 to 2012, nations that emitted less than their quota could sell the assigned amount units (AAU; each AAU representing an allowance to emit one metric ton of CO_2 to nations that exceeded their quotas. Kyoto emissions trading system used 1990 emissions as a benchmark for the goal of a 30% emissions reduction. Because Estonia started to reduce its oil shale power generation substantially in 1990 due to the economic meltdown of the Soviet Union, the CO_2 emissions decreased well below 30% of the 1990 levels very quickly from 40 million t CO_2 equivalent in 1990 to 20 million t in 2005. This led to a considerable number of unused AAUs (NAO, 2009).

Estonia has been very successful in selling the unused Kyoto emissions rights and investing the obtained funds through the Green Investment Scheme. The country has concluded 22 transactions for the sales of AAUs with the proceeds totaling 392 million euros. The proceeds from earlier transactions have been invested in the renovation of over 500 state and municipal buildings, hundreds of apartment and private houses, 15 boiler houses and over 100 km of district heating networks, as well as in the establishment of three wind farms and 6 combined heat and power plants, over 500 electric cars, and other environmentally friendly undertakings (EIC, 2012). Not only have these investments improved the service quality with new vehicles, but, most importantly, these have led to a significant reduction of heating costs for thousands of consumers.

Since 2005, the European Union operates the Emissions Trading System based on EU Directive 2009/29/EC, which concerns 46 Estonian facilities with an energetic capacity of over 20 MW. In 2017, ETS was still in Phase III where the majority of European Emissions Allowances (EUA) were allocated for free. However, from year to year, this number has been decreasing, meaning that companies have to either cut emissions or purchase EUAs on the market. In 2006, EE received considerable revenue from the sale of emissions units to the amount of about 100 million euros, but, according to the company's annual reports of 2007–2015, a total of 337 million euros was spent on the purchase of emissions units even when price emission units during that period were at 12€ per ton of CO_2. For example, in 2015, EE reported that 83,7 million euros was spent on EUAs at an average price of 7,8 €/t.

In 2012, 10,3 million emissions units were allocated to EE facilitate an investment into an energy efficient 300 MW FBC production capacity unit, with permission from the European Commission. This move was criticized by environmentalists in Estonia as a government subsidy to the fossil fuel industry. Such a support mechanism for a new efficient power generation capacity is not unique in the European Union, considering that the new 300 MW CFB plant will be using up to 50% biomass. In 2015, EE sold emissions permits to the amount of 83,7 million euros at an average price of 8 €/t (EE, 2015). For the period of 2013–2020, of the state is projecting revenues of 290 million euros from the greenhouse gas emissions allowances trading scheme of the EU (Directive 2003/87/EC).

2.6 Economic effect of competitive energy costs

The share of oil shale industry in Estonian GDP amounted to 19.5% in 2009, which was a slight drop from the pre- economic crisis level of 21%. At the same time, the industry used 35% of Estonia's total electricity production, being by far the largest consumer group (Estonian Statistical Office, 2010). Higher electricity consumption can be explained for historical reasons – Estonian electricity production is 90% based on oil shale and it has substantially lower production costs (and, hence, lower regulated retail sales prices) compared to other Baltic countries. In 2010, according to the prior-agreement with the European Commission, Estonia had to open its electricity market to free competition for all users whose yearly electricity consumption exceeded 2 GWh. Since Estonia is interconnected to Finland and therefore to the Nord Pool Spot power exchange, as well as to Russia and via Latvia to Lithuania and Belarus, the changes in 2010 meant that all Estonian-based large-scale consumers had to switch to market-based pricing. The increasing capacity of interconnectors to Finland from 350 MW to 1000 MW in 2014 to has played a significant role in the harmonization of electricity prices with Finland, as seen from Table 9.

Table 9. *Average annual Finland and Baltic Nord Pool electricity prices, €/MWh.*

Year\Country	Finland	Estonia	Latvia	Lithuania
2016	32.45	33.06	36.09	36.54
2015	29.66	31.08	41.92	41.85
2014	36.02	37.61	50.13	50.12
2013	41.16	43.14	48.93	
2012	36.64	39.2		
2011	49.3	43.35		

Source: Nord Pool.

Another benefit of oil shale is the low-cost process heat from power generation and oil production that is utilized for the district heating of four main cities of Ida-Viru County. In 2015, oil shale companies produced a total of 1 244 GWh of heat for the county's district heating (in comparison, Estonia's total heat production was 7 789 GWh). In December 2016, maximum district heating prices ascertained by the Competition Authority were 28.6 €/MWh for oil shale-based heat producers and 36.9 €/MWh for other heat producers that used either biomass or natural gas. Thus, the combined economic gain for consumers in Ida-Viru County in 2016 even at low natural gas prices was around 10 million euros.

2.7 Research and development potential of oil shale

Seminal works by Arrow (1962) and Nelson (1959) have pointed out the need for public support for entrepreneurs due to the lack of demand for certainty and return on investments, which leads to suboptimal levels of investment and, hence, societal loss. This gap between the private and social returns is the principal argument for government intervention in innovative activity. Innovation in the energy sector has led to an improved energy supply (making difficult-to-manage resources economically accessible), lower costs and prices to consumer, lower environmental impact, higher safety (especially relevant in nuclear energy) and security of supply. On larger scale, these elements cannot be captured as private rent, but factors benefitting society as a whole, which justifies public funding of related R&D.

One of the best unconventional oil resource analogues to oil shale are Canadian oil sands. These are either loose sands or partially consolidated sandstone containing a naturally occurring mixture of sand, clay, and water, saturated with a dense and extremely viscous form of petroleum technically referred to as bitumen. Athabasca-Wabiskaw oil sands located in the Canadian province of Alberta cover over 140 000 square kilometers and contain approximately 1.75 Tbbl (280 × 109 m^3) of crude bitumen. About 10% of the oil in place is estimated to be recoverable with current technologies and market prices by the government of Alberta . This recoverable quantity still amounts to 75% of the total North American petroleum reserves. Only 3% of the oil sands area containing about 20% of recoverable oil can be produced by surface mining, so the remaining 80% will have to be produced using in-situ wells.

Canadian public research and development financing totaled 9,5 billion CAD in 2013, yet its total R&D funding has fallen from 2,1% of GDP in 2000 to 1,6% in 2014 (OECD, 2016). Total government energy sector research funding was estimated at $941.9 million for 2014–2015 (CAD 439 million federal and CAD 503 million provincial and state-owned enterprises), down from CAD 1,34 billion in 2013–2014, according to the IEA. IEA (2016) suggests increasing public R&D funding for energy projects. Canadian R&D funding ecosystem is very robust, providing support in all stages from basic research to applied, demonstration, commercialization and market development.

Comparatively in Estonia, from 2009 to 2015 Estonian oil shale companies spent a total of 25,9 million euros on research and development, which contributed to 434,6 million euros worth of innovation led investments in physical capital in the whole value chain of oil shale mining and processing by three companies (see Table 10). Total investment by the industry during the period of 2009–2015 was 428,8 million euros for VKG, 60 million euros for KKT, and 1 100 million euros for EE, with a total of 1 589 million euros.

Table 10. *Estonian oil shale companies R&D expenditure and innovation led investments, million euros.*

R&D expenditure and investments\Year	2009	2010	2011	2012	2013	2014	2015
Total R&D expenditure	0.44	8.8	2	3.4	4.4	5.2	1.8
R&D led investments	39	27	3	119	109	90	48

Data source: gathered by the author from companies.

In 2012–2013, the oil shale sector R&D expenditure amounted for 15–20% of total Estonian R&D expenditure, although it is worth noting that substantial innovative technology investments (such as part of cost of Enefit 260 and Petroter oil shale processing units) were listed as R&D expenditure. Public funding to energy and oil shale related research has been relatively low. According to the International Energy Agency, the share of energy-related research in 2014 in total R&D was around 4% on average in IEA member countries, down from 11% in 1981. Japan was leading with 12% in 2014, but in the EU, this share was much lower, averaging 9% in Finland, 1.6% in Estonia, and 3% across EU (see Table 11).

Table 11. *International Energy Agency member countries R&D spending in 2014.*

Country\R&D spending	Energy related research in total R&D funding, %	Public energy RD&D budget per 1000 units of GDP
IEA average	4	0.4
Finland	9	1
Canada	7.2	0.7
Estonia	1.6	0.12

Source: IEA 2015.

The ratio of public energy RD&D budget per unit of GDP varies greatly within EU, ranging from less than 0.1 in Portugal and Spain to over 1 per thousand in Finland, with an EU average of 0.4. Among fossil fuel producers the respective ratios are: USA 0.35; Canada 0.7; Norway 0.86 and Poland 0.23. Estonia with 0.12 stands out with one of the lowest public energy RD&D budgets per unit of GDP. Comparative data for Canadian oil sands and Estonian oil shale industry are presented in Tables 12 and 13 where a difference in the order of a whole magnitude can be observed.

Table 12. *Summary of economic impacts of unconventional hydrocarbons in Canada and Estonia for the year 2014.*

Impact factor\Country	Canada (oil sands)	Estonia (oil shale)
Oil production, bbl/d	2 300 000	60 000*
Sales revenue	40 000 million euros	933 million euros
Investment	22 700 million euros	263 million euros
Public energy R&D	650 million euros	3.2 million euros
Private R&D	606 million euros	5.2 million euros
Direct employment	105 000	6 683
Indirect employment	127 000	17 372
Government revenue	4 800 million euros	174 million euros

Data sources: Statistics Canada 2015; Alberta Economic Development and Trade 2017; CAPP 2017.
* – 60 000 bbl/d would be oil production if all mined oil shale would be processed to oil. All numbers include oil, heat and power production sales revenue, R&D, employment, government revenue data.

Table 13 also shows that Estonia’s investment ratio is lower, which can be explained by the highly active investment period of Canadian oil sands of the period and the presence of legacy capacity in Estonian oil shale. The difference in R&D effort is evident in both the private and public sectors. A substantially larger need for direct employment in the oil shale sector compared to oil sands is an expected result and it is caused by the difference in production mechanisms, with oil shale requiring much more labor-intensive mining operations. The data from Table 13 shows somewhat unexpectedly a higher direct government revenue from oil shale. This is due to the fact that Estonia’s biggest oil shale producer (EE) is 100% owned by the government so the state receives additional revenue from dividends.

Table 13. *Comparison of economic impacts of unconventional hydrocarbons in Canada and Estonia per millions of barrels produced for the year 2014.*

Impact factor\Country	Canada (oil sands)	Estonia (oil shale)
Sales revenue	47.6	42.4
Investment	27.0	12
Public energy R&D	0.8	0.15
Private R&D	0.7	0.24
Direct employment	125	303
Indirect employment	151	789
Government revenue	5.7	7.9

Source: author's calculations based on table 12.

Compared to other policy options such as taxation, mineral resource allocation, environmental regulation, R&D has the highest economic effect for unconventional hydrocarbon development. After the ratification of the Paris Agreement, very high regard must be given to the reduction of greenhouse gas emissions in unconventional hydrocarbon production. Meeting the Paris Agreement targets requires further reductions in oil shale mining cost, transportation and higher value added through upgrading and utilization of all possible waste and potential synergies such as more effective heat utilization, mining waste as aggregate, mining cavities as pumping hydropower stations, adjacent territories of industries for industrial parks, waste hills for wind and solar power generation areas etc. Each of these elements requires relevant studies, research and development.

2.8 Initial state-led model versus modern resource regime model

Until the early 2000s, oil shale industry was developed mostly by state policies, state demand or impulse to industrialize and develop power generation. Economics and revenues earned were treated as public good, internalized as "other revenue" in the state budget and were not subject to discussion. Research and development as well as regional development were funded by the state irrespective of the revenue from utilization of oil shale. This "initial state-led model" is presented in Figure 1.

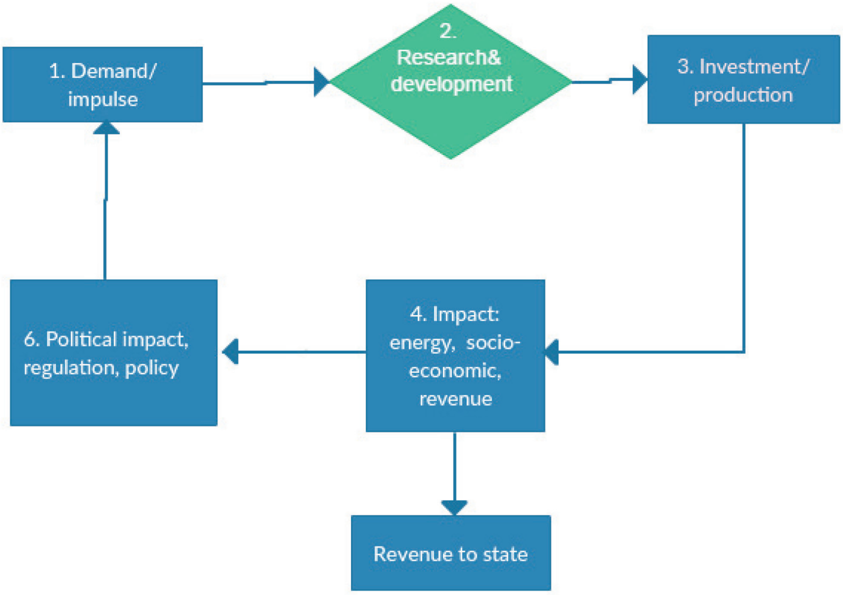

Figure 1. *Initial state-led model of oil shale industry.*
Source: author.

However, this simple state-led model is not sustainable as it does not provide society with sufficient benefits to justify its presence as some alternatives for employment and energy production are developed. Also, there is a perception among communities that negative externalities have not been covered by industry highlighting the issue of visibility regarding benefits from oil shale industry. This has resulted in formal proposals by Estonian environmentalists to abruptly close the industry through so-called PÕXIT.

Thus, this simple model is under pressure and is already changing due to increased demands of competitive oil market and environmental challenges. The author proposes the following method to improve the resource regime model:

a) develop detailed data and understanding of the economic sustainability and potential of a natural resource;

b) identify the main factors limiting the economic sustainability of the natural resource (such as regulation, taxation, R&D, resource revenue allocation);

c) identify the potential to reallocate revenue flows or amend regulation to improve the economic sustainability of the natural resource and economic development of a region or nation.

This method can be applied to other resources. However, the two key insights are highly relevant – in order to maintain an industry that provides positive economic impact rather than strangling it with too much taxation, the government needs to understand the underlying value added and find optimal, competitive taxation solutions. And second, it is possible to convert natural capital to other forms of capital (social, human, investment assets) to benefit from extraction of natural resources over long term, recognizing the eventual end of revenue stream from oil shale.

By applying the aforementioned method, the author proposes a new, modern resource regime model for the oil shale industry presented in Figure 3. According to the new modern resource regime model, public revenues need to be utilized to maintain a positive revenue flow through R&D, regional employment and to reduce negative externalities (blocks 4 and 2 in Figure 3). Revenue to the state will be recognized alongside other economic effects such as effect on power and heat prices, (block 5 in Figure 3) which leads to political impact and policy adaptation (block 6 in Figure 3). An alternative to adaption, continuing cannibalization of oil shale industry by the state budget, would likely lead to results observed in Poland where the state has been pressed to offer state support in order to maintain social stability (Kowalska, 2015).

Block 1 (demand/impulse) is described in section 3.2. and Article II, which state that the key driver for oil shale industry has been the need for a power supply. Block 2 (Research & development) is addressed in section 3.6. and Article III. Block 3 (investment/production) of Figures 1 and 2 is covered in section 3.1. and Article II on investments and full cycle breakeven cost. Revenues to the state of block 4 (Revenue to state) are subjects in sections 3.3. and 3.4.; and Article I. Same subject of block 5 (Impact) is covered in this section and Article III; and block 6 (Political impact, regulation) is addressed in section 3.8. and Article I.

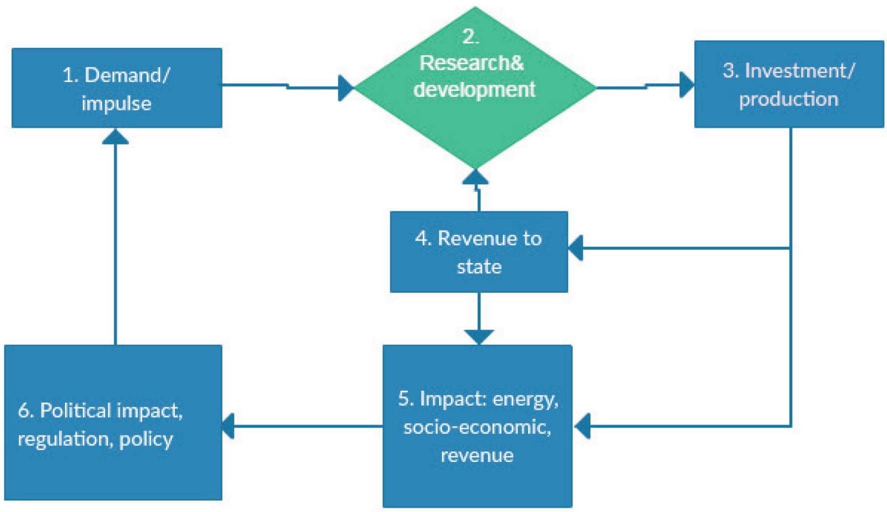

Figure 2. *Modern resource regime model for oil shale industry.*
Source: author supported by the study results summarized in Table 14.

In this model, revenues from the oil shale industry are vital for the state as they can be used as a source of funding for R&D, thus it would be rational for the state to try and maintain the industry. Also, a very relevant factor in the "Market, revenue and research model" presented in Figure 3 is the quality of revenue management, i.e. how revenue is utilized to enhance positive effects of regional development and energy diversification. Given the size of revenue withdrawn and consumed for other public purposes each year, ca 100–150 million euros or even 20% of these funds would a) substantially improve R&D and social development; and b) support economic sustainability of the sector.

It is highly encouraging that partly due to the author's efforts, several practical steps have been taken in public policy. In November 2018, the Minister of State Administration signed an act on Ida-Virumaa program that will see 23,8 million euros over four years allocated to economic diversification and development of Ida-Virumaa. In October 2018, several members of Parliament made a formal proposal to create a Minerals revenue investment fund for allocation of revenues from minerals extraction to environmental and industrial research and development.

2.9 Estonian resource regime compared internationally

Resource regime areas have been empirically studied by the Natural Resource Governance Institute (NRGI, USA) which was founded in 2013 and has annually published the Resource Governance Index (RGI, 2017) since its inception. RGI measures are based on 3 areas and 14 indicators in 89 jurisdictions. RGI is compiled based on expert assessments of 150 experts from 81 countries. For example, the best performing jurisdictions are those of Norway, Chile, UK, province of Alberta, USA (Mexican Gulf area). On the opposite end of the spectrum we find Turkmenistan, Sudan, Congo and Zimbabwe.

The main areas of evaluation are value realization (includes licensing, taxation, local impact and state-owned companies); revenue management (revenue sharing and resource fund management) and enabling environment (open data, rule of law, control of corruption, etc). However, it does not include elements of public research and development activity, which are very relevant in Canadian, Finnish, Australian and Estonian mineral policies to ensure sustainable mineral sector and resource potential management. This element is missing although the Institutes own ”Natural Resource Charter“ precept number 3 ”Build and maintain a good understanding of the resource base“ details: ”Government officials must build a thorough understanding of their country's resource base — both the quantum of resource and its geographic distribution. The quantum of the resource base informs key decisions on the rate of exploitation and potential future revenues. Information on the geographic location guides the establishment of property rights and exploration licenses within the country and future social and environmental impacts.“

Based on empirical research on the challenges of the oil shale sector presented above, the author suggests some ways to optimize Estonian resource regime (see Table 14 and Figure 2). First, it is essential to achieve a higher legal certainty about oil shale mining allowance distribution and to have a long-term solution to taxation based on the internationally competitive *ad valorem* effective tax rate. Particularly urgent is a review of environmental fees that have been rising annually for over 10 years and are becoming a substantial fixed cost burden on the oil shale industry.

Second, it is necessary to improve revenue distribution to the main areas affected by the oil shale industry, i.e. Ida-Viru County. It is highly unfair that a region bearing environmental, social and economic structure burdens related to the oil shale industry receives no revenues from it to mitigate problems in these respective fields. This in turn arouses resentment and opposition among the people of the county against oil shale development in the region. The author considers it fair that at least 20% of oil shale industry revenues should be allocated for regional development.

Third, it is important to increase the financing of public energy and mineral (including oil shale related) research and exploration to improve both the economic and environmental sustainability of the oil shale sector. These suggestions coincide with those presented in “General principles of Earth's crust policy until 2050”, which was adopted by Estonian Parliament in June 2017.

Table 14. Resource regimes in Alberta, Russia, USA, Estonia current and Estonia estimated.

Resource regime\Country	Canada, Alberta	Russia	US, Gulf states	Estonia (current)	Estonia (suggested)
Mineral ownership**	Province	State	Private	State	State
Legal certainty*	High	Moderate	High	Moderate	High
Corporate ownership**	Private	Mostly state	Private	State/private	Private, state share
Mineral taxation**	Moderate	High to moderate	Low	High	Moderate
R&D (total)**	High	Low	High	Low	High
Public mineral exploration*	Active	Moderate	Moderate	Passive	Active
Revenue management**	Fiscal/SDF /PIF	Fiscal/SDF	Fiscal/PIF	Fiscal	Fiscal/SDF
Environmental standards*	High	Low to moderate	Moderate	High	High
Stakeholder engagement*	High	Low	High	High	High
Resource Governance score***	75/100	45/100	74/100	Not graded	

* – The author's estimates based on literature; ** – data provided in articles.
*** – Source: Resource Governance Index.

Fourth, with some contribution in the process by the author, the government decided in February 2018 to launch the Ida-Viru program, which foresees a funding of 23,8 million euros for the socio-economic development of the region over 4 years (Estonian Government, 2018). In the spring of 2018, discussions were held on the possibilities of funding the program with revenues from the oil shale industry to secure program's long-term success. These steps are closely in line with the European Commission's goals and activities set in "Coal Regions in Transition Platform" goals and activities (European Commission, 2017). In 2016, the Ministry of Environment initiated innovative studies to monetize externalities of oil shale industry and prepare a review of environmental fees however these efforts have been discontinued as of this day. At the same time, a scientific review of environmental fees, which are one of the highest in the world, is long overdue.

Several policy changes based on the current research are in process as of early 2018 with a contribution by the author in his working positions. First, oil shale resource fees became dependent on heavy fuel oil price from June 2016 by the amendment to the Environmental Tax Law and the Decision of the Government of the Republic of Estonia on resource fee rates (Riigi Teataja, 2017). Second, Estonian government decided in to adopt further amendments to the resource fee system in November 2017, such as separating oil shale based on use for oil production and power generation. (Estonian Government, 2017) Third, with the Decree of the Minister of Economic Affairs and Infrastructure of 13th April 2017, a new government agency, the Geological Survey of Estonia, was established to increase the funding of mineral resources and geological research and development.

3 Discussion and conclusions

The main objective of this thesis was to develop a model for resource regime and method of its adaptation to achieve economic sustainability based on empirical data and understanding of economic impact of the oil shale industry. The author finds that all four research questions have been solved.

Based on detailed understanding of factors that influence the future economic impact of Estonia's oil shale sector, it is possible to develop a new resource regime model. Also, it was possible to develop a method how to adapt a resource regime to changes in economic environment. Only a few academic articles on resource policy of past several years have dealt with the resource regime of a particular commodity in an empirical fashion and it is difficult to find a resource regime model based on empirical data. The National Resource Governance Institute (NRGI) develops discussion papers on Improving Resource Governance of 11 individual countries, covering the whole resources spectrum based on Natural Resource Charter Benchmarking Framework. Compared to NRGI discussion papers, this thesis studies a mature industry in an industrially developed country with strong institutions. The majority of problems in developing nations are related to weak rule of law, weak democracy, problems with enforcement etc.

The author is on the opinion that a nationally vital natural resource industry will be sustainable in the long term only if is it is open to studies and subject to adaptation. However, it should be noted that historically, some natural resources like copper or gold have been used permanently in their many forms, while other resources such as coal or sperm whale oil have had relatively short periods of dominance.

Estonia's economic and usable reserves of oil shale are estimated at 1 312 million tons, which would last until the year 2080 at an annual mining rate of 15 million tons. Yet, as stated by Saudi Arabia's oil minister "Stone age did not end because of lack of rock", neither will the lack of oil shale or oil be the reason for ending the fossil fuel era. Also, the decline of Polish and US coal industries proves that reserves are not the problem, rather organization, management and policy are the key to a sustainable resource industry (Betz, et al. 2015).

The strongest push for reduction of oil shale utilization comes from power generation, where, according to the Estonian Energy Development Plan until 2030 (Ministry of Economic Affairs and Communications, 2017), the share of renewable energy should form 50% of consumption by 2030. This is in line with "General Principles of Climate Policy until 2050", which adopts the EU's commitment to cut CO2 emissions by 2050 by 80% compared to the 1990 levels. In practice, this would mean a near-total phase out of oil shale power generation by the year 2050.

There are also uncertainties about shale oil production due to the factors discussed in Article III. Indeed, in 2018, crude oil demand and supply balance attracts buyers with relatively low prices of 70 USD/bbl compared to the 2007–2014 prices averaging 90 USD/bbl. The IEA World Energy Outlook 2016 projects only a tepid growth for EVs, with the EV stock rising from 1,3 million in 2015 to a cumulative total of 150 million by 2040. That would only displace 1,3 million barrels of oil per day (mb/d). IEA sees oil demand rise by 13.5 mb/d between 2016 and 2040, from 94.1 mb/d to 107.7 mb/d (IEA, 2016). Thus, while there might be more challenging market conditions, due to their high energy density, relatively low cost, existing global infrastructure and demand, liquid fossil fuels will likely remain a leading global transport fuel in the first half of 21st century.

Therefore, shale oil too will likely be produced until economic or environmentally suitable oil shale reserves are exhausted. A key challenge for shale oil is to be competitive and on par with regular crude oil suitable for refining into higher value petroleum products.

A theoretical contribution of the current thesis is the development of a model based on the 3-point methodology adaptation consisting of: data gathering and understanding; impact factor identification and revenue flow reallocation and identification of potential regulation improvement. With these steps it should be possible to describe an impact cycle for a nationally relevant natural resource and to see how resilient it is to changes in its economic and regulative environment. Such a comprehensive model has not been developed before to the best knowledge of the author, but it is very helpful in understating resource regime as a comprehensive interdependent system, not a simplistic “dig-get money-and-forget” plundering of mineral wealth. Classic cases of resource curse such as phosphate mining from island of Nauru, tree felling of Easter Islands, and the hunting of Atlantic whales near their extinction should be unforgettable reminders of poor understanding of natural resource management.

As a practical input, the author has been contributing over the period of 2014–2018 to national energy policy discussions at several official meetings and conferences, the results of these research contributions are presented in Articles I, II and III. As a researcher, member of parliament and public official, the author has contributed personally to energy policy analysis and formulation, especially with regards to the reform of mining fees of energetic resources (including oil shale). The degree of harmonisation of minerals policy at EU level is quite low, despite the Raw Materials Initiative launched by the Commission in 2008. As a national delegate of the Geological Survey of Estonia, the author has recommended, together with directors of other European national geological surveys, to establish a regulatory policy expert group. Another initiative by the author is the approved cooperation project with the US Geological Survey to assist Ukraine, a major European mineral resource country, to develop its modern national Minerals Strategy that would follow concepts developed in this thesis.

It is highly advisable that academic studies continue to provide empirically comparative and numerical data for the most economically successful and socially sustainable resource regime models. The key finding of this thesis is that the development of a nationally significant resource can form an economically and socially sustainable cycle of market demand, research & development, investment, revenue management and policy improvement impulses. The latter must be fed by studies and research. Further research will be necessary, especially on the resource revenue allocation in the public sector, and on the optimal revenue allocation balance between central and regional levels.

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Acknowledgements

…but the wretched race of man he purposed to annihilate and create another in its stead. This plan was frustrated by Prometheus, who, in compassion on their feebleness, showed them the use of fire, which he had stolen in their behoof…

Aeschylus, Prometheus Bound

"And God said, "Let there be light," and there was light.[4] *God saw that the light was good"* (Genesis 1, 3-4).

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Abstract

Development of Resource Regime of Oil Shale Industry: A Case of Estonia

The author researches the resource regime of Estonian oil shale industry to provide empirical data on the economic impact of oil shale industry, develop a model for resource regime and its method of adaptation to achieve economic sustainability. So far, on the topic of natural resources, there is lack of resource specific academic literature about economic impact and mechanisms, how to improve or sustain these effects, especially in developed nations. According to the authors review of published papers on economics and mineral policy, only a few papers cover the topic from a perspective of a specific major national natural resource. None of the articles attempted to develop a holistic resource regime model. This thesis aims to fill this research gap.

The problem with oil shale mining in Estonia is somewhat similar to those of other solid fuels or exhaustible minerals, like coal in Poland, phosphates in Jordan, metals in Finland or gold in California. Similarities include volatility of revenues, environmental impact, eventual depletion of economic reserves and related socio-economic challenges. Estonian oil shale has unique characteristics as a dominating source of power supply, versatility of the resource for multiple applications and concerns related to energy and national security. Research in resource economics has been focused on resource curse, resource revenue allocation and management and social impact, however no research has been conducted involving oil shales. Most research on Estonian oil shale focuses on its chemical and mineral properties, processing technologies and environmental impact. Comparative resource regimes have not been addressed in the available literature on European mineral policies.

Estonian government applies a complicated system of environmental fees and resource revenue, which affects the oil shale sector. The question is how well these revenues are managed. From Hotelling's rule it is clear that that the return on resource revenue has a direct impact on the utilization of exhaustible natural wealth. If the return is low, resource should be left to future generations, if higher, then future generations will benefit from wise wealth management of their parents. Several factors and empirical cases are studied in Article 1 to suggest that Estonia should allocate its resource revenues to development rather than a permanent income fund, similarly to Norway.

With the onset of dramatic oil price fall in 2014 from 110 USD/bbl to 28USD/bbl in early 2016, shale oil production became unprofitable, which leading to job losses and government policy change on resource revenues to the ad valorem system covered in Article 2.

Both power generation and shale oil face unique, yet similar challenges within European and global environmental regulation and product competition. Estonian oil shale as a resource, is not fundamentally different compared with lignite in Germany, or as a unconventional oil source compared with Canadian oil sands. The environmental footprint of oil shale has to be reduced and its economic value added increased in order to enable sustainable production. Substantial positive externalities and economic footprint of energy industry are key reasons for public involvement in innovation. Research and development funding of Estonian oil shale compared to Alberta oil sands is studied in Article 3, which concludes that a substantial increase of private and public R&D funding is necessary in Estonia to meet the International Energy Agency's averages.

Research questions of this thesis are:

- What are the empirical economic impacts of the oil shale sector in Estonia?
- What factors influence the future economic impact of the oil shale sector in Estonia?
- Is the oil shale sector economically sustainable in the long term?
- What resource regime supports the sustainability of oil shale industry?

This thesis is contributing to a better understanding of a resource regime through constructing a resource regime model based on the answers to the established research questions. Currently that model, in case of Estonian oil shale is evolving from a simple state-led model to a modern model that needs to be adapted to market conditions, social and ecological demands through a better resource revenue allocation and research funding. The model helps to visualize and understand interactions between the individual elements of the resource regime. The method of adaptation of a resource regime is to first separate the regime into individual elements and improve the understanding of how all the elements are interconnected. Second, to identify the main factors limiting economic sustainability and third, to identify potential for reallocating revenue flows or amending regulation to improve economic sustainability.

The key finding of this thesis is that the development of a nationally significant resource can form an economically and socially sustainable cycle of market demand, research & development, investment, revenue management and policy improvement impulses. The latter must be fed by studies and research. Further research is necessary, especially regarding the resource revenue allocation in the public sector and an optimal revenue allocation balance between central and regional levels.

Lühikokkuvõte

Põlevkivitööstuse ressursipoliitika arendamine Eesti näitel

Käesolevas dissertatsioonis uurib autor Eesti põlevkivitööstuse ressursipoliitikat ja selle arendamise võimalusi. Toetudes empiirilistele andmetele ning analüüsides majanduslikke mõjusid ja mõjufaktoreid, arendab autor ressursipoliitika mudeli ning näitab, kuidas seda kohandada, tagamaks sektori majandusliku jätkusuutlikkuse. Senises loodusressursside alases akadeemilises kirjanduses on puudulikult kajastatud konkreetse ressursi kasutuse majanduslike mõjude ja mõjufaktorite mõõtmist ning analüüsitud mehhanismide kogumit, mis aitaks majanduslikke mõjusid suurendada või säilitada, seda eriti arenenud riikide puhul. Valdav osa ressursikasutuse ökonoomika teadusuuringutest käsitleb arenguriikide väljakutseid ja probleeme loodusressursside kasutamisel. Vaadeldud akadeemilistest artiklitest ei olnud võimalik leida terviklikku ressursipoliitika mudelit. Käesolev töö täidab seda uurimislünka.

Eesti põlevkivi kasutamise väljakutse on mõnevõrra sarnane teiste riikidega probleemidega, nagu Poola kivisüsi, California kuld 19. sajandil, fosfaadid Jordaanias ning naftaliivad Albertas, kus üks maavara on domineeriva majandusliku kaaluga ning on selge, et maavaravaru kasutamine ei ole igavene. Väljakutseks on ressursitulude volatiilsus ja tõhus kasutus, keskkonnamõju, majanduslikku väärtust omavate tarbevarude lõppemine ning sellega kaasnevad sotsiaal-majanduslikud mõjud. Eesti põlevkivi omapära on tema mitmekesine kasutamine nii elektri kui ka õli tootmiseks, aga samuti keemiatööstuse toorainena. Kuigi Eesti põlevkivi on põhjalikult uuritud nii geoloogilisest, tööstustehnilisest, keskkonnaalasest ja energiamajanduse aspektist, on selle ressursi majanduslik käsitlus Eestis olnud vähene. Ressursiökonoomika kui teadusharu, mis tagab loodusressursside kasutamise jätkusuutlikkuse ja nendest saadava maksimaalse majandusliku hüve, on Eestis samuti algusjärgus.

Eesti valitsus rakendab keerukat keskkonnatasude ja ressursitasude süsteemi, mis otseselt mõjutab põlevkivitööstust. Oluline küsimus on, kui hästi neid tulusid kasutatakse. Hotellingu reeglist on selge, et nende ressursitulude kasutamise tootlus mõjutab otseselt lõppeva loodusressursi kasutamise põhjendatust. Kui tootlikus on madal, peaks ressurss jääma tulevastele põlvkondadele, kui kõrgem, siis tulevased põlvkonnad saavad kasu antud ressursi kasutamisest teenitud tulude targast haldamisest.

Käesolev dissertatsioon on koostatud artiklite kogumikuna. Artiklis 1 uuritakse mitmeid faktoreid ja empiirilisi juhtumeid, mis osutavad, et Eesti peaks enda ressursitulusid eraldama pigem arendusse kui Norra sarnasse püsitulufondi või eelarve kaudu äratarbimisse, mis on tänane valdav tulukasutus.

2014 aastal käivitunud dramaatilise hinnalangusega hinnalt 110 USD/barrel hinnale 28USD/barrel 2016 aasta alguseks muutus põlevkiviõli tootmine kahjumlikuks, mis viis koondamisteni. See omakorda põhjendas artiklis 2 käsitletud valitsuse ressursitulu poliitika muutmise vajadust seniselt tonnipõhiselt fikseeritud ressursitasu mudelilt toodetavast tulust sõltuvale mudelile, tagades sektori suurema jätkusuutlikkuse.

Nii elektri kui põlevkiviõli tootmisel on omapärased, kuid samas sarnased väljakutsed, arvestades Euroopa Liidu ja globaalset keskkonnaregulatsiooni ning tootekonkurentsi. Eesti põlevkivi ei ole ressursina põhimõtteliselt erinev Saksa pruunsöest või mittekonventsionaalse naftatoormena kasutatavatest Kanada naftaliivadest. Igal juhul tuleb alandada keskkonnajalajälge ning tõsta toodete lisandväärtust tagamaks

jätkusuutlikku tootmist. Olulised positiivsed välismõjud ning energiatööstuse majanduslik mõju on peamised põhjused avaliku sektori panustamiseks selle tööstusharu innovatsiooni. Näiteks just avalik rahastus võimaldas Kanadas arendada tehnoloogia, mis võimaldab kasutada 80% Alberta naftaliivade ressursist, mis avakaevandamiseks oleks liiga sügaval, in situ meetodil. Artiklis 3 analüüsitakse Eesti põlevkivitööstuse teadus ja arendustegevuse (T&A) rahastust võrreldes Alberta naftaliivadega, jõudes järelduseni, et isegi Rahvusvahelise energiaagentuuri liikmete keskmise taseme saavutamiseks peaks Eesti era- ja avalik sektor energiavaldkonna T&A rahastust tõstma vähemalt 3 kordselt. Kanada ja Soome energeetika T&A rahastus tasemed on aga veelgi kõrgemad.

Käesoleva dissertatsiooni uurimisküsimused on:

- Millised on Eesti põlevkivisektori empiirilised majanduslikud mõjud?
- Millised faktorid ja kuidas mõjutavad Eesti põlevkivisektori majanduslikke mõjusid?
- Kas põlevkivisektor on pikas perspektiivis jätkusuutlik?
- Milline ressursipoliitika toetab põlevkivisektori majanduslikku jätkusuutlikkust?

Käesolev dissertatsioon panustab ressursipoliitika parandamisse ja täiustamisse tõstatatud uurimisküsimustele vastamise kaudu. Töö otseseks tulemuseks on ressursipoliitika mudel. Uue mudeli kohaselt peab Eesti põlevkivikompleks suunduma lihtsast riigi juhitud mudelist kaasaegsesse mudelisse, mis peab kohanema turutingimuste, sotsiaalsete ja keskkonna nõuetega, kasutades paremat ressursitulu jaotust ning suuremat T&A rahastust. Mudel visualiseerib ja võimaldab mõista eri ressursipoliitika elemente ja nende vahelisi seoseid. Ressusipoliitika kohandamise metoodika on esmalt jaotada ressursipoliitika üksikuteks osadeks ja kujundada teadmine nende omavahelistest seostest. Teiseks tuleb määrata peamised faktorid, mis piiravad majanduslikku jätkusuutlikkust ning kolmandaks, määrata potentsiaal, kuidas tuluvooge või regulatsioone muutes parandada majanduslikku jätkusuutlikust.

Antud dissertatsiooni peamine uudsus seisneb tõendamises, et riiklikult olulise ressursi arendamine võib moodustada majanduslikult ja sotsiaalselt jätkusuutliku ringi turu nõudlusest, teadus ja arendusest, investeeringutest, tulu haldusest ja poliitika arendamisest. Viimane peaks kujunema uurimis- ja teadustöö abil.

Alates maavarade kasutamise algusest on ressursside kasutamise oskustele ja kapitalile tuginedes olnud võimalik kasutusele võtta järjest jätkusuutlikumaid ja teadmismahukamaid ressursse ning vähendada ka ressursikasutust tõstmaks inimeste heaolu. Eesti põlevkivipoliitika vajab täiendavat uurimist optimaalse tulujaotuse osas keskvalitsuse ja kohaliku omavalitsuse vahel ning keskvalitsuse tasemel valdkondlik tulujaotuse osas, eriti T&A valdkonnas.

Käesoleva töö autori seisukoht antud uurimistöö jooksul analüüsitud andmete ja teabe põhjal on, et elektri tootmine põlevkivist lõppeb lähema 30 aasta jooksul kliimapoliitika tõttu ning arvestades konkurentsi, kütuste hindu, õlitootmise omahindu ja tootmisvõimuste vananemist ka põlevkiviõli tootmiskogused pigem vähenevad kui kasvavad. Kui see nii kujuneb, siis on nii elektritootmise kui Ida-Virumaa sotsiaal-majandusliku arengu seisukohalt põhjendatud adekvaatselt suunata uuringuid ja ressursse mõlema väljakutsega tegelemiseks.

Appendix

Article I

Kallemets, Kalev (2015). Resource revenue model for a developed country: case of Estonia. Estonian Discussions on Economic Policy, Vol. 23, No. 2, pp. 36–48.

RESOURCE REVENUE MODEL FOR A DEVELOPED COUNTRY: CASE OF ESTONIA

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Abstract

The main objective of this paper is to find appropriate parameters for a resource revenue fund model in the industrial part of the World, with Estonia as an example. Based on literature review and case studies of resource revenue funds, four parameters are suggested: the period of resource revenue flow, the magnitude of the revenue flow relative to GDP, relative development level of the country and institutional development level. Additionally, four resource revenue fund models are characterized: fiscal, mixed, Permanent Income Fund and Sovereign Development Fund.

Analysis shows that for a country where the main natural resource is oil shale (as is the case in Estonia), the most suitable resource revenue fund model would be a blend of fiscal modelling and Sovereign Development Fund.

Keywords: natural resource revenue, natural resource funds, oil shale, mining regulation

JEL classification numbers: Q320

Introduction

Despite technological progress, mankind still needs and extracts annually a large variety of natural resources in large scale. Exploitation of exhaustible natural resources depends on the revenue to the society and effectiveness in using that revenue stream. There are several models for public resource revenue collection, revenue fund management and revenue distribution. While most research focus regarding resource revenue has been on developing nations with hydrocarbons revenues, there are substantial mineral resources also in industrial countries, and effectiveness of revenue allocation deserves equal attention there.

Elaboration of Estonian case shows that suitability of a particular resource fund model depends on several characteristics. A suitable and effective resource fund model can positively transform the economy in addition to being just an additional revenue stream. The purpose of this paper is to identify the most suitable parameters of a resource fund model in an industrial setting.

A methodology is developed and applied to case studies in order to draw motivated conclusions. The paper aims to address the following questions: What is the theoretical argumentation of resource funds? What are the main models of resource revenue allocation? What is the empirical experience of resource revenue funds in industrial

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countries? What is the most suitable resource fund model for Estonia given its main resource and development level?

1. Literature overview

The majority of literature on resource revenue deals with hydrocarbons revenue in developing countries. This is objectively understandable as hydrocarbons represent the largest wealth pool and are of major global economic significance. Much of the discussion has been on "resource curse" where major revenue streams lead to a currency appreciation, crowding out of other sectors of the economy, fiscal dependence, conflicts, corruption and political power monopolisation. (Sachs, Warner, 2001). Examples include Cameroon, Iraq, Libya, Venezuela, Mexico (Rey, 2011).

To overcome this resource curse already in 1953 British authorities established Kuwait Investment Authority that is the first of what is today called Sovereign Wealth Fund (SWF). In 2015 total of 68 national or state SWFs manage assets with a market value of 7.2 trillion USD. (Sovereign Wealth Institute) 56% of SWFs receive their revenue from oil and gas, some 10% from metal ores or minerals and many are non-commodity funds like Singapore Temasek or China Investment Corporation. The main logic for oil and gas revenue funds was the immense relative scale of revenue stream that was achievable from particular deposit fairly quickly (Davies, et al 2001). It was the Dutch experience with Groningen gas field that coined the term Dutch disease for currency appreciation and relative expensiveness of other exported products.

Tsani (2012) provides an extensive overview of the pro and con debate on resource funds (RF). Arguments for RFs are: (Tsani , 2012; Baena et al., 2012):

1. Insulate price volatility and exchange rate pressures;
2. improve fiscal discipline as tools of self-constraint upon fiscal actors;
3. serve revenue saving and intergenerational fairness goals;
4. funds can insulate natural resource revenues against rent-seeking, politicized use and corruption, enforcing the conditions of proper management of resource endowments;
5. capital allocation to non-resource sector;
6. Environment restoration can be viewed as capital investment.

The theoretical framework for resource funds is the Permanent Income Hypothesis (PIH) postulated by Milton Friedman in 1957 on an unrelated subject. Applied to resource revenues PIH would mean that states should view windfall revenue as a source of funds that can be levelled for a longer period to attain permanent income. By definition, expenses made out of a PIH oil revenue fund would be stable and would avoid boom and bust cycle (Segura, 2006). To achieve permanent income stream and not to inflate national economy further than private revenue streams from hydrocarbon development would, RF should diversify its assets globally and by asset classes according to Modern Portfolio Theory. Classical example of PIH application would be Government Pension Fund of Norway with current assets valuation of 719 billion USD.

Several analysts have argued that the permanent income rule is optimal only under special circumstances that do not apply to most developing countries (Collier and Venables, 2008; Van der Ploeg and Venables, 2009) or for revenues streams other than hydrocarbons. Most developing countries, however, are characterized by restricted access to world capital markets, capital scarcity, and potentially high rates of return on domestic investment, especially if the government is able to efficiently supply public infrastructure and to improve the investment climate to raise returns on private investment. Under these circumstances, a more optimal strategy would be to devote a larger portion of resource revenues to high-return public domestic investments, leading to higher growth and, ultimately, a higher economic impact than under the permanent income strategy (Segal, 2012).

Much of the research has focused on developing nations with its apparent institutional problems, which have been present before discovery or exploitation of significant mineral resources. Revenue funds in Kuwait, Iran, Oman, Venezuela, Papua New Guinea, and Nauru are claimed to be institutional failures (Stevens, 2003). The main reason for this failure has been government mismanagement of fund resources. Baena et al (2012) concludes that following practices are essential for getting the management of a fund right: accountability, transparency in decision-making and information access, corporate governance, and clear and sustainable regulations. Also Leong, Mohaddes (2011) argue that "there are levels of institutional quality above which resource abundance becomes growth enhancing".

Thus, literature suggests intensity and period of revenue stream, economic development level and institutional quality are important factors influencing resource revenue utilization.

2. Resource fund models

Overview of resource fund models introduces some empirical examples around the world and their motivations showing how different models have been set up. Levels and means of taxation of natural resources vary across the world (see Otto et al, 2006). In case of oil, mostly ad valorem royalties are being used and effective rate of taxation (defined by World Bank and IMF as direct taxes related to production in relation to profit) is on average 60-70% (IMF 2012). In case of more labour intensive and less profitable iron ore the average effective rate of taxation is around 40-60% and for copper ore 45% (Otto et al, 2006). The main befit to society is employment, especially in remote rural areas where employment opportunities are otherwise scarce. This argumentation is key for low taxation of mining in Sweden and Finland with 0,02% of the ore value.

Wide varieties of resource revenue models are being used. Apparently, different models have developed in particular economic and political context. Most resource revenue models fall under one of these four categories: fiscal, savings fund, mixed model or the latest trend: sovereign development fund.

1) Fiscal model
All resource revenues flow into general government budget in United Kingdom, Denmark, Ireland, Australia, USA at federal level and Canadian provinces except for Alberta. Fiscal model serves its purpose for reallocating resource revenues to the population, but there is no saving nor insulation from price volatility.

Baena et al (2012) describe "Investments in the public sector and in infrastructure are usually lavish at period of high commodity prices, encouraging rent-seeking and policy inefficiency. As windfall revenues diminish, governments turn to foreign markets for further sources of revenues, acquiring as a result an unsustainable level of debt".

2) Mixed model
Under mixed model most of the resource revenue is retained by the government budget and often part of the funds is allocated to the region of resource extraction. Peru is an example of mixed model where both mining royalties and even more significantly 50% of the corporate income tax of the mining companies is redistributed at regional level (see figure 1). In 2007 Peruvian government received total of 2 billion USD from corporate income tax from mining sector. Since 1999 10% of concession fees and privatisation revenues are diverted to Fiscal Stability Fund that has accumulated 7 billion USD by 2012.

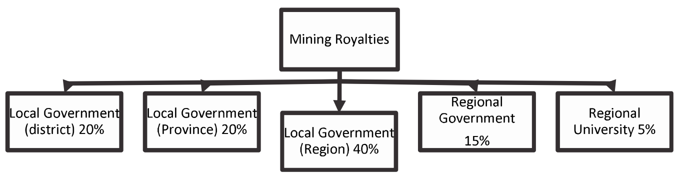

Figure 1. Mining revenue allocation on regional level in Peru. Instituto de Ingenieros de Minas del Perú (2011)

Until 2012 Australia had only decentralized revenue model where royalties were earned only by provinces. Several resource rich US states like North-Dakota, Wyoming and New Mexico allocate funds to state budgets and into permanent income funds. Indonesia is allocating since 1999 80% of its royalties to mining regions. In Ghana its 20% of revenues are directed to mining regions (ICMM, 2009).

3) Savings funds; Sovereign Wealth Funds
More than half of capital in 68 known global Sovereign Wealth Funds (SWF) are based on natural resource revenue. Investments of SWFs have raised some concerns due their size and potential political motivation. These concerns led to establishment of Santiago principles for best practices on SWF transparency and management developed by SWFs together with IMF and signed so far by 25 nations. Main natural resource of SWFs is oil and gas. Unique characteristic of oil and gas revenue is that the revenue stream can grow within few years several times creating a problem of efficient use of funds and its overheating effect on the economy even if there would be no rent seeking by officials and politicians. (Davies, et al., 2011). Substantial savings funds not generated by oil or gas are maintained by Chile, Peru, Botswana, Mongolia and US

state of Wyoming. Lücke (2010) shows how well established institutions can help to sustain public support for long-term savings of resource revenues.

4) Sovereign development fund (SDF)

Javier Santiso (2008) of OECD marked that several Sovereign Wealth Funds have evolved policies where substantial part of their portfolio is invested into domestic assets so that "they are key engines of development finance within their homelands, some very explicitly involved in national strategies of industrial diversification". Further he cites Malaysia's Khazanah, Kazakhstan's Kazyna, Mubadala from Abu Dhabi or Istithmar from Dubai and more conventional SWFs like Temasek Holdings of Singapore and Kuwait Investment Authority that have clear domestic and regional development related investment policies. Santiso argues that, "because of their mandates and objectives SDFs tend to look for secure investments and long-term returns."

3. Developed countries resource funds

A closer look at several resource funds in industrial countries is used for conclusions on most suitable factors of a resource model in a country with strong institutions. The countries to be reviewed were chosen based on data availability, research and variety of different settings. Funds presented are also some of the oldest in World, with the first established in the early 1970s. Thus, these funds have gone through a noteworthy learning curve and have established what may be called best practice. A thorough overview of active resource funds and their fund governance is available at the National Resource Governance Institute.

Alaska Permanent Fund was created in 1976. Since 1980 APF is managed by Alaska Permanent Fund Corporation (APFC). Assets worth $49.9 billion on June 2015 are distributed between stocks 36%, bonds 20%, real estate 12%, private equity 6%, others 30%. Stocks management is widely distributed between different funds: 30 different funds manage stocks, 8 funds for bonds, 6 manage real estate and 20 other type of investments by different funds. Depending on the term of the lease, either 25% or 50% of the revenues collected is deposited in the Permanent Fund. The remainder goes to the General Fund and the School Fund. Total income from oil and gas royalties and rents was $2.9 billion in 2014.

The APFC performs in-state investment within Fund's real estate portfolio but does no preference to investments in Alaska. After 5 year fund build-up period, from 1982 through 2013, the dividend program paid out about $18.8 billion to Alaskans through the annual distribution of dividend checks. In year 2012 $567 million was distributed among 646 805 Alaskan residents making per capita dividend 878 USD. The main motive to establish APFC was to address concern that majority of natural resource benefits are being reaped by non-Alaskans.(Goldsmith, 2010) Winderquist et al (2012) argue that unique resource dividends have contributed to the fact that Alaska is most economically equal of all 50 states in US and helped to increase of equality.

Alberta Heritage Savings Trust Fund (AHF) was created in 1976 with $1.5b initial allocation to AHF and initially 30 % of Alberta's non-renewable resource revenue was transferred to the Fund. Before establishment of AHF 2/3 of revenue flowed into general province budged and 1/3 to municipalities.

As Alberta experienced tough economic times in the early 1980s, 30% resource revenue allocation was reduced to 15 % and eventually cut to zero in 1987. However the size of the fund and its earnings have enabled annual payments to province budget totalling $344 million in 2012. By 2014 asset value of AHF had increased to $18 billion, giving 8.2% rate of return. Asset distribution was 53% global equities, 15% real estate, 10% alternative investments, 22% fixed income. Only 8% is invested in Canadian equities. (Alberta Heritage Savings Trust Fund, 2014)

In the 27 years that all investment yields have been diverted from the Fund to Alberta government revenues, the payout has been excess of $28b. Baena et al (2012) covers well how investment decisions were politically motivated or at least financially not robust with regards to loans to other provinces ($1.9bn), non-financial Capital Projects Division (3,5 bn) and majority to Alberta Investment Division (AID). "The primary use of AID was as a private placement banker for various provincial government- owned corporations, including Alberta Government Telephones. These loans totalled over half of AHF total size and many placements failed." One major success however was saving of Syncrude Oil Sands project.

In 1997 AHF was restructured based on response by Albertans in 1995 survey. The Fund can no longer be used by government for direct economic development or social investment purposes. A new business plan was implemented, with a plan to increase long-term investments and avoid mistakes of previous decades. (Ascah, 2013)

Permanent Wyoming Mineral Trust Fund (PWMTF) was established in 1975 and receives about 40% of all Wyoming's severance tax collections totalling 878 million in 2009. PWMTF market value in 2013 reached $6,3 billion. The PWMTF grew by $494 million in the 2011 fiscal year, at 10.2% increase. The fund is limited to allocate up to 55% of assets into equities. While domestic investments are not prohibited, funds stated objective is saving and revenue stabilization. (National Resource Revenue Institute, 2013)

The PWMTF contributed $215 million of the Wyoming state budget revenues in the 2011 fiscal year. In 2011 total of $1 billion in severance tax was collected with $0.44 billion from gas, $0.29 surface coal, $0.22 oil. Coal taxation rate was in 2011 thus 0.67USD per tonne. (Wyoming Department of Revenue, 2014) Resource revenue was distributed between Permanent Fund $377 million, general budget $240 million, $268 million to budget reserve, $23million Wyoming water development fund, $20 million to municipalities and $ 26 million to other environmental and development projects.

New Mexico Severance Tax Permanent Fund (STPF) was established by the legislature in 1973 to receive severance taxes collected on natural resources extracted from New Mexico lands. Severance tax revenues first pay the required debt service on state severance tax bonds that have funded various capital projects, and the remaining (approximately 12.5%) severance tax receipts are then transferred to the Severance Tax Permanent Fund. The STPF is diversified permanent fund except for its Economically Targeted Investments. STPF had assets of more than $4 billion in 2012 and Land Grant Permanent Fund (LTPF) leasing state lands for mineral development had assets of $10.8 billion. In 2012 both STPF and LTPF paid out to state budget and other beneficiaries about the same amount as they received and made in earnings on assets.

Total state revenues on resources other than oil and gas were $34,9 million for 2010 and $1 600 million from oil and gas. (New Mexico Taxation and Revenue Department, 2011)

New Mexico STPF has special NM Private Equity Investment Program funding investments that ”enhance the economic development objectives of the state; provided such investments offer a rate of return and safety comparable to other private equity investments currently available." This program has $259 million in net deployed capital, close to 5% of total STPF size. 28 funds have received commitments and invested in 62 New Mexico-based companies. In the period 1993 to 2003 NMPEIP made negative net returns, but since 2004 primary focus has been returns leading to 4,5% IRR of investments (New Mexico State Investment Council, 2015)

Scandinavian development funds

Three Scandinavian examples show that very developed economies either from resource revenues or other sources establish government investment funds to support equity and fixed asset investments in their domestic economy.

Largest SWF in the world is Norway’s Government Pension Fund Global with value of 771 billion USD by end of 2014. Notably, 36,5% of the total value has been achieved due to returns on investments. Much less known is Government Pension Fund Norway (GPFN) with assets valued 22,3 billion USD invested 85% in Norwegian and 15% Nordic region equities (60%) and fixed income assets (40%). Average annual gross return on the GPFN is calculated at 7.3 percent from January 1998 to yearend 2014. The fund is managed by specialized fund manager Folketrygdfondet with clear mandate not to invest more than 15% to any single company equity. Norwegian Ministry of Finance (2015)

Finnish Industry Investment (FII) is in 1995 established development fund with €53 million proceeds of the privatisation of state-owned companies. By year end of 2012 its investments and commitments were €718 million in 500 companies directly or through funds and in 2012 made €57 new investments and made €7,3 million in profit. Finnish Industry Investment (2015)

Swedish Sixth National Pension Fund was created by Parliament in 1996 with $1.57 billion payment which value to date has increased to $3 billion with +4.2% annual average return. The Sixth AP Fund invests in unlisted companies and private equity funds. 6AP has 40% of its assets in Nordic regions 60 companies direct equity, 28% in 280 different funds and 32% liquidity. Sixth AP Fund (2012)

What is also relevant is the portion of the revenue allocated between annual public budget and RF. Also relevant is the way RF is set up: its institutional independence, investment policy mandate and amount of payments out of the fund. Table 1 describes some basic characteristics of selected resource funds

Table 1. Characteristics of selected resource funds

	Alaska	Alberta	Wyoming	New Mexico	Norway
Share of resource revenue to RF	25%	5.25 or 50%*	40%	12.5%	100% (2014)
Share of earnings payment to the budget	37.5%**	0-70%	40%	100%	0%
Fund institutional independence	Independent corporation/ funds	Independent fund manager	State treasury management	State Investment Council	Public fund manager

* – dependent on resource revenue respectively below $10, $15 or above $15 billion
** – dividend payment to citizens

In conclusion, empirical evidence displays large variety how resource revenue funds have been set up in historical context and how some part of it is allocated to investments into domestic economy.

4. Case Estonia

Estonia is used as a model for an industrialised country with fairly high endowment of mineral resources and collections of resource revenue, yet with no resource fund. The main mineral deposit in Estonia is oil shale that has been mined and processed since 1916 in excess of 1 billion tons. Still reserves in excess of 3.4 billion tons at energy levels of 30 GJ/m2 are mineable. Oil shale is mainly being used for power generation (11 million tons in 2012) and increasingly for oil production (4 million tons in 2012). Given EU climate policy, balance of oil shale utilization is clearly moving in favour of oil production. Oil shale oil production in 2014 was 660 000 tons which is 11 391 barrels a day or 0.01 mbpd. There are active plans by companies to more than triple oil production by 2020 utilizing some 15 million tons of oil shale and to process the oil into EuroV class diesel fuel. (Steiger, 2013). This development remains conditional of oil prices and regulatory environment in Estonia.

Taxation of the oil shale sector occurs by means of environmental charges that are levied on each ton mined, mining water disposal, mining waste and in processing phase for atmospheric emissions, waste water disposal and depositing of oil shale ash. In total 70% of environmental charges received by the state are from the oil shale sector. Pro rata environmental charges have increased substantially (some 12 to 28 times) between 2002 and 2015, substantially impacting the production costs.

The main aim of applying environmental charges is to motivate companies to invest into production facilities with lower environmental impact and to use natural resources more efficiently and sustainably. A special public Fund for Environmental Investments (FEI) receives funds retained by the state and re-distributes these for environmental projects across the country, from waste and water management to renewable energy and environmental awareness, often as co-financing to capital from the EU's Structural Funds.

There have been several changes on the way charges are distributed, especially during the economic crisis of 2009-2010, when the state urgently needed additional funds. Current law fixes the absolute rate received by municipalities where mining takes place and the rate received, so their revenue will not increase even if the overall tax rate increases. Of the 97 million EUR collected as taxes to the country's total budget in year 2015, some 47 million are retained by the state for discretionary spending, 34 million EUR is forwarded to FEI and the remaining 16 million EUR is forwarded to municipalities (Rahandusministeerium, 2015).

The state additionally receives substantial revenues as 100% owner of AS Eesti Energia, a major oil shale miner that is also involved in power generation, power distribution and oil shale oil production. Eesti Energia mines and processes roughly 80% of the country's oil shale. Since 2005 Eesti Energia has contributed annual dividend revenues between 50 and 90 million EUR to the state budget.

Suitable resource fund selection for Estonia

Under the current setup of the Estonian resource revenue model several objectives of RFs are not met. Though FEI funds some renewable energy investments like biogas development, there is no return criteria for investments. Currently there is no revenue saving, thus there is no revue stream or assets if mining activity stops, which given European Union's climate policy is likely to happen for oil shale some time around 2050. Intergenerational fairness goal is met only so far as can be argued that general fiscal expenditure generates social capital.

Suitable revenue fund model should depending on base resource and development level of jurisdiction achieve following goals: a) value saving over time to achieve intergenerational fairness; b) insulate against price volatility and exchange rate pressures; c) improve fiscal discipline; d) capital allocation to and development of non-resource sectors.

To consider what resource revenue model is suitable for Estonia, four parameters appear most relevant from literature and previous section case studies:

a) size of public revenue stream relative to GDP – if the size of revenue stream would be large relative to GDP, it would suggest higher saving in international assets to avoid Dutch disease;
b) period of revenue stream – if the revenue stream is short term (few decades) it suggests higher saving ratio into liquid assets to ensure intergenerational equity and lower the risk of short term rent seeking;
c) economic development level of the country – if country economic development relative to region is lower it would suggest higher investment in assets contributing to domestic economic development and vice versa;
d) institutional development – if the institutional development of the country is strong enough and ensures transparency, it is less likely that investments in domestic assets would encourage rent seeking and corruption.

Table 2 gives overview of data on selected four factors in different jurisdictions and suggested suitable model. The way and variety how resource revenue is being collected seems to have little effect on way of revenue fund model. Norway considers for example also dividend revenue from Statoil S.A. as part of oil revenue and directs it into Government Pension Fund. Factor that is relevant of course is whether stated resource revenue policy is well defined or not, but it is harder to measure or quantify.

Table 2. Resource fund factors in different jurisdictions

Region, Resource	Alaska oil	Wyoming oil, gas, coal	Alberta oil sands, oil, gas	New Mexico oil, gas	Estonia oil shale, etc (2015)
Revenue stream % GDP	$ 3 bn 6.7%	$ 1 bn 3.6%	$5 bn 2.7%	$1,6 bn 2%	€182 mln 1%
Period of revenue stream	50 years	50-100 years	100+ years	50-100 years	100+ years
Development level, GDP per capita in region	$45 665 110% US average	$ 47 898 115% US average	$ 49 562 159% Canada average	$ 34 133 82% US average	$ 20 700 67% EU average (2011, PPS terms)
Institutional development WB GI score[1] TI CPI score[2]	High 73	High 73	High 84	High 73	High 64
Suitable model	Fiscal with PIF	Fiscal w PIF	Fiscal w PIF	Mixed PIF/fiscal/ SDF	Mixed fiscal /SDF

1 – World Bank Governance Index
2 – Transparency International Corruption perception Index

Thus due to relatively small and long of revenue stream from oil shale and other minerals, due to lower relative development level and sufficient institutional development, Estonia would do well to both continue fiscal expenditure, but also add Sovereign Development Fund as revenue allocation. This is even more relevant if planned ad valorem oil shale royalty is introduced increasing fiscal variability.

Based on examples in above section, withdrawals from the fund should be limited to some proportion of the investment earnings. The result of such a revenue fund would be a sustainable increase in domestic equity market liquidity and improved access to lending capital. Also such a fund it would create intergenerational fairness and long term vision regarding exhaustible resources.

Estonian case shows that while there is currently some allocation of resource revenue, it is in fact all fiscally consumed and no saving occurs. However, Estonian institutional strength and relatively moderate economic development level suggest that the Development Fund option based on some resource revenue is advisable.

6. Conclusion

Resource funds are a valuable instrument that have evolved from a simple savings fund to a means of investment policy for diversifying and developing economies in a transparent way. This paper has shown that resource funds are not exclusive for developing oil and gas rich countries, but can be meaningful tools for other industrial countries with strong institutions, and contribute to effective capital allocation.

While resource funds have evolved in a particular historical context, key factors influencing the choice of the model depend on the nature of the resource, intensity of the revenue stream and development level of the country. Countries with strong institutions and not relatively intense revenue streams benefit from directing resource revenue to domestic capital investments. Particularly in Estonia, it makes sense to divert resource revenues into a Development Fund that can be used to improve equity and lending capital access to the private sector.

Further empirical research is necessary to analyse how a resource fund can best contribute to economic development of a resource rich country. All countries are well advised to have a long term plan for resource revenue flows and revenue utilization.

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Article II

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ECONOMIC SUSTAINABILITY OF ESTONIAN SHALE OIL INDUSTRY UNTIL 2030

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Abstract. *The objective of this paper is to elucidate the sustainability of Estonian shale oil industry until the year 2030 in terms of the full cycle breakeven cost of oil. The full cycle cost is rapidly increasing due to increasing necessary capital expenditure, increased national taxation and the European Union (EU) carbon (C) emissions abatement policies. There is a fair amount of uncertainty about all three components, which makes scenario analysis an appropriate tool to estimate the survivability of Estonian shale oil industry scenarios in the next 15 years.*

Past economic performance alone is not a proper guide for future in case of Estonian oil shale industry. However, heavy investments have been made in the industry since 2011 and several hundred million euros are being invested or planned to invest in the replacement of old capacity and raising new oil production capacity.

Analysis shows that, indeed, in certain scenarios the shale oil breakeven price is at the highest end of global crude oil production projects, thus raising questions of the industry's survivability in case of multiyear sustained global oil prices below 90 USD/bbl. Conclusions of the study are relevant to analyzing the full cycle costs of other promising global shale oil projects.

Keywords: *national energy policy, industrial policy, resource taxation, shale oil, mining regulations.*

1. Introduction

Since the 2000s there has been a substantial global effort to have a diversified supply of liquid fuels from nonconventional sources [1]. Oil shale represents a large energetic resource with the resource estimate of 2.8 trillion barrels of crude oil, the US Green River formation with 1.5 trillion barrels of crude oil signifying its equivalent [2]. This potential has been exploited globally on a relatively small scale with the exception of Estonia where oil shale means the country's major energy supply. Historically the main utiliza-

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tion of oil shale in Estonia since the 1960s has been in power generation, but for several years there has been a significant development of new technology in the direction of shale oil (SO) production. Other global shale oil producers are currently China and Brazil. Estonia's experience is much appreciated globally in tapping large oil shale reserves in Jordan, the U.S., Morocco, Ukraine and elsewhere. Thus, Estonian case is relevant in terms of understanding the economics of and limitations on the use of these reserves because there is a lack of empirical data on shale oil commerciality [3].

Nationally oil shale represents a major industry for Estonia with three companies and an aggregate turnover of over 1 billion EUR, a high contribution to the state budget, employment of more than 7000, and as an indispensable element in national power supply. Due to the rise of oil prices in 2004–08, there is a strong drive to increase oil shale utilization in oil production and decrease in power generation in the coming years, but that drive has been recently stymied by concerns over national taxation, the European Union (EU) CO_2 abatement policies and the sharp fall in oil prices since mid-2014. Given that there is a fair amount of uncertainty regarding cost components such as capital cost, CO_2 cost and taxation, it appears that scenario analysis is the most appropriate tool to examine the full cycle cost of shale oil. No such analysis has been performed or published so far.

The objective of this study is to find out the sustainability of Estonian shale oil industry until the year 2030 in terms of the full cycle breakeven cost of oil and consider it in relationship with other global crude oil projects. The author used data of Estonian oil shale company Viru Keemia Grupp AS (VKG) as an example to investigate his firsthand knowledge and VKG's position as an oil producer having the newest facilities (mines, oil processing units, etc.).

The current study is organized as follows. Chapter 2 discusses the full cycle cost of oil. Chapter 3 considers the current situation of Estonian oil shale industry and risks involved. Chapter 4 presents a model for assessing the full cycle breakeven cost of oil in different scenarios. Chapter 5 examines implications of the model and Chapter 6 draws conclusions.

2. Full cycle cost of oil

While shale oil is a somewhat unique product mainly used as a heavy fuel oil or bunker fuel, it should also be said that most global crude oils from particular deposits are similarly unique with the individual American Petroleum Institute (API) gravity, sulphur content and molecular characteristics. In cooperation with international partners, VKG has developed technical and economical solutions to refine shale oil to diesel fuel, but plans to build a refinery in 2013 were put on hold. Ultimately, shale oil is a particular kind of crude oil competing on the market with the latter for market place as a product and investment opportunity. The direct pricing mechanism for SO is based on heavy fuel oil with a 1% sulphur content, which is priced at Rotterdam. Thus the same economic analysis applies to shale oil as to other conventional and unconventional crude oils.

The full cycle conventional oil project cost might be represented as follows:

1. Property Acquisition Costs: The cost of acquiring unproved property is an on-going part of the business.
2. Exploration Costs: The company must cover the cost of geological and geophysical work (G&G), licensing rounds, signature bonuses and the costs of drilling exploration wells.
3. Development Costs: The company must cover the costs of acquiring, constructing and installing production facilities and drilling development wells.
4. Production Costs: These are the costs incurred to operate and maintain wells and related equipment and facilities, including depreciation and applicable operating costs of support equipment and facilities and other costs of operating and maintaining those wells.
5. Transportation Costs: The company must cover the cost of transporting its product to market.
6. Production Taxes: An international oil company (IOC) must pay production taxes or royalties to the host state.
7. Return on Capital: An IOC must at least cover its cost of capital over the medium term. Otherwise it is destroying value for its shareholders.

Specific to Estonia is that geological exploration for the greatest part of the Estonian oil shale deposit was carried out in 1960–86. Currently there is no need to acquire land for deposit exploration and development because oil shale and most of the land are owned by the state and the land lease rate is quite low. However, applying for mining and relevant environmental permits is a rather expensive and lengthy process. In case of Estonian oil shale the related costs might be represented as follows:

1. mining permit costs: costs related to applying for an oil shale mining permit;
2. deposit development costs: costs related to opening a new oil shale mine;
3. technology development costs: costs related to developing and implementing an innovative technology or adapting it to a particular situation to achieve a continuous commercial production of SO and related products (heat, steam, power, chemicals);
4. production costs: costs of materials, equipment, manpower, services, capital and interests, and other consumables utilized in the production process;
5. production taxes: environmental charges and other taxes incurred during production;
6. return on capital.

Over the long term, the oil and gas industry must incur certain costs in order to find, develop and produce oil and gas. This full set of costs the industry needs to incur in order to sustain or grow production is known as full cycle costs. If crude oil or natural gas prices are generally persisting above these full cycle costs, the industry has an incentive to sustain investment and activity in the sector. However, if the margin between full cycle costs and prices is squeezed for prolonged periods, the industry finds, before too long, that investment is not sustainable and capital spending, production and reserve replacement will begin to fall off as a result [4]. This will eventually lead to production decline and shutdown. Figure 1 gives an overview of major global oil capacity projects compiled by Citi Research.

While it would be rational to consider that most companies would want to develop projects in the 1st and 2nd quartiles with low breakeven prices and presumably profitability, the reality in the last years has been that there have just been no cheap projects left globally and companies need to develop also more expensive projects to replace their reserves and production capacities in the medium term [6]. This has led to a substantial exploration and production capital cost inflation in recent years as illustrated by Figure 2.

Another breakeven cost curve is shown in Figure 3. Among projects added within the past two years, none had a breakeven price below 70 USD/bbl and most had breakeven prices within the 80–100 USD/bbl band. The latter group includes higher-cost US shale oil and deepwater projects as well as the majority of Canadian oil sands projects. The US Goldman Sachs Group [7] clearly states: ”The oil price required for the western

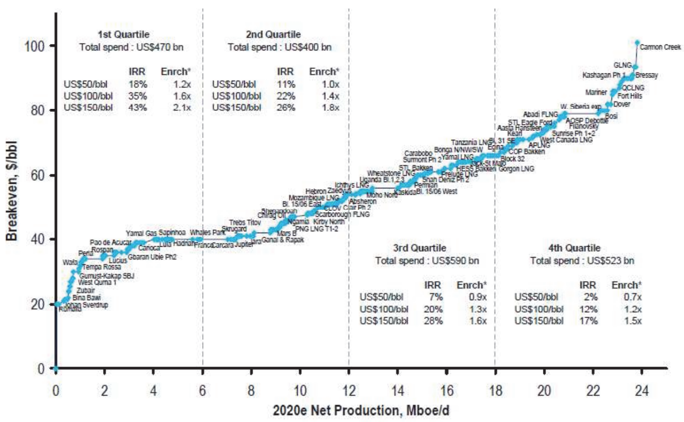

Fig. 1. New investment cost curve by quartiles of breakeven price [5]. (Abbreviations used: IRR – internal rate of return, bbl – barrels, bn – billion, Mboe – millions barrels of oil equivalent.)

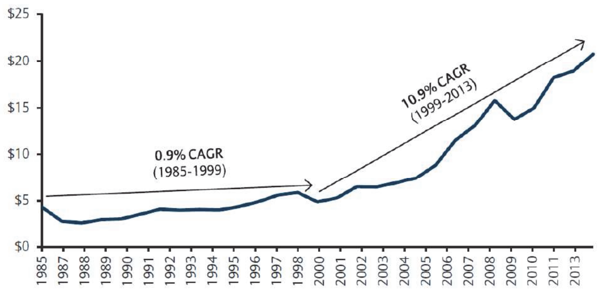

Fig. 2. Exploration and production capital cost in 1985–2013 [7]. (Abbreviation used: CAGR – compound annual growth rate.)

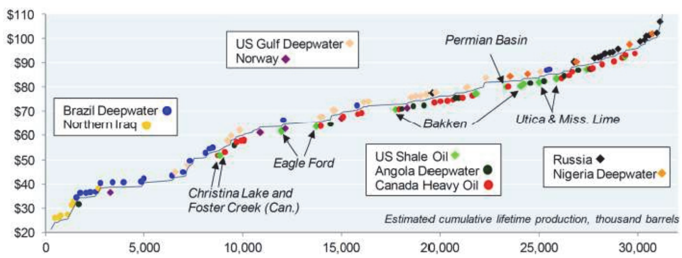

Fig. 3. Breakeven cost curve of new oil projects including fiscal costs [7].

oil Majors to be free cash flow neutral after capex (capital expenditure) and dividends is much higher than is implied by the major new projects On our estimates it has increased from c $80/bl in 2008–11 to over $120/bl currently, as a result of higher decline rates, increasing maintenance capex and higher costs.“ The past few years have provided ample global examples of major oil projects if breakeven cost was not achievable or had a high degree of uncertainty, projects were delayed or abandoned entirely [6].

The substantial fall of oil prices in the second half of 2014 and levelling at 60–65 USD/bbl has led to an about 25% reduction or 100 billion USD in new capital expenditure or project delays into new oil upstream capacity, particularly in Canadian oil sands projects, according to a consultancy Rystad Energy [8]. Breakeven prices presented in Figures 1 and 3 do not represent short-term price fluctuations, but rather long-term, 10+ years price levels need to break even. It is relevant to note that breakeven prices are not constant in time even for particular oil plays. Recent examples are reduction of breakeven costs in US shale oil plays through increased productivity of wells, higher selectivity in drilling and other methods [9].

The profitability measure used in full cycle breakeven cost assessment is universally Return on Investment (ROI), which is calculated Net Profit as percentage of Long-term Investments (Long-term Liabilities plus Stockholder's Equity). ROI displays the yield which the company generates on Long-term Investments.

Essentially similar is Return on Capital Employed (ROCE), which is the relationship of Earnings Before Interest and Tax (EBIT) to Capital Employed where Capital Employed is Total Assets minus Current Liabilities. Both concepts benefit, compared to Return on Assets or Return on Equity, from inclusion of long-term liabilities into the equation. For these and the reason of available data the concept ROI has been employed in the current analysis.

3. Estonian oil shale industry

3.1. Current situation

Estonian oil shale industry today, with the mining output and processing of approximately 15 million t of oil shale, consists of three enterprises. The largest is the 100% Estonian government owned Eesti Energia AS (EE) that utilizes 11 million t of oil shale for power generation, producing 10 TWh of electricity, and 1.7 million t for oil production, producing 200 000 t of oil. EE's turnover was 822 million EUR in 2013 [10]. The second largest is the private company Viru Keemia Grupp AS (VKG) that processes and produces 370 000 t of oil and whose turnover was 220 million EUR in the year 2013 [11]. Third is the private enterprise Kiviõli Keemiatööstus OÜ (KKT) that processes 0.6 million t of oil shale, producing 60 000 t of oil. The turnover of KKT was 35 million EUR [12]. As of early 2014, the total production of Estonian oil industry was around 30 000 barrels per day.

Most of the mines and production units in the industry are the heritage from the Soviet period, though, with many renovations and technology improvements in the last 15 years. The oil industry in Estonia almost went bankrupt and was on the verge of shutdown in 1997–98 due to the collapse of world oil prices, but ever since the increase of prices has seen a steady investment in the replacement of aging capacity and launching new capacity. The most active investor has been VKG that completed a new oil shale processing unit Petroter in 2010 and another in 2014, opened a new oil shale mine in Ojamaa in 2013 and is currently constructing a third Petroter unit. Thus 59% of the oil will be produced from new units by the year 2016. The new Petroter unit will require further investments in a new single oil shale processing unit for power generation to utilize pyrolysis gases, investments in emission gases purification, oil shale ash depositing and other measures to the amount of 20 million EUR.

Slightly behind in investments is EE that in 2015 brought into production a new 300 MWe circulating fluidized bed power generation unit and a new oil production unit named Enefit 280, which is able to process 2 million t of oil shale and produce 5000 barrels of shale oil per day. EE has ambitious plans to replace within 10 years most of the current oil shale power generation units with oil production units, which also produce power from cogeneration and waste gases. KKT has plans to build four new small generator units, but strategically to use up all of its oil shale mining capacity of 1.9 million t from the current level of 0.6 million t. In total, the industry employs directly around 7000 people of the 82 500 labour force in Ida-Virumaa region, is a major government revenue source with close to 300 million EUR tax and dividend revenue and a substantial national industrial sector [13].

3.2. Risk factors of Estonian shale oil industry

Despite the high crude oil prices in 2010–early 2014, Estonia's oil shale sector faces many industry and EU specific risks.

3.2.1. EU climate policy

The Council of the European Union (Council) has set the objective to reduce in the European Union (EU) greenhouse gas (GHG) emissions by the year 2050 by 80–95% compared to 1990 levels, driven by the efforts of developed countries to reduce their GHG emissions to a similar degree. The Council's key tool is the European Union Emissions Trading System (EU ETS), which was launched in 2005. The EU ETS is now in its third phase, running from 2013 to 2020. Today, emission allowances (EUAs) are sold at auction, no free allocation of EUAs takes place.

However, Estonia is making use of a derogation (under Article 10c of the revised EU ETS Directive), which allows allocation of an annually decreasing number of free allowances to the country's operating power plants and oil shale companies during the transitional period until 2019. From 2020 onwards there will be no free allocation of EUAs any longer and also the amount of EUAs subject to auctioning by EU governments will be annually decreasing by 1.74%. This will likely increase the price of EUA. By 2030, GHG emissions in the EU shall be reduced by 40% below 1990 levels.

Since 2009, due to economic depression confusing renewable energy push and other poorly planned elements, the EUA price has been much lower than anticipated by the European Commission (Commission). Thus, following the Commission's proposals and the voting in the European Parliament (Parliament), there will be intervention on the back-loading of 900 million EUAs in 2013–2016 to increase the EAU price in the short term. It is believed that this will increase the expected EUA price after 2015 from 12 to 15 EUR/t [14]. The reference scenario foresees that the price of CO_2 will be 35 EUR/t in 2030 and 100 EUR/t in 2050 [15].

Thus, there is a push to establish an economically reasonable price of EUA. At the same time, the EU climate policy will inevitably be continuously dependent on global policies and the EU's ability to bear the related costs. Hence, some uncertainty about the future CO_2 prices will remain.

3.2.2. National taxation

Estonia has a complicated system of environmental charges and fines with a relatively high level of costs to industry [16]. Part of the charges is related to environmental impacts such as SOx, NOx and particles emissions to air, disposal of oil shale processing water, disposal of mining water, depositing of mining residue (limestone), oil shale processing waste (semi-coke) and oil shale ash. The other part is resource charges (mining royalty), which are calculated on the basis of each ton of oil shale reserve used. Table 1 provides environmental charges rates and cost per ton of shale oil produced based on VKG's data at 2013 rates, and environmental charges rates and cost per ton of shale oil proposed by the Ministry of the Environment for the year 2015.

The Estonian government (the government) established mining royalty rates and mining water disposal charges for 2015, but these were declared invalid by the Estonian Supreme Court on 16.12.2013 (case 3-4-1-27-13) as unconstitutional. Thus, the current rates and charges are those established by the government earlier for 2013 and there was foreseen a 5% annual increase of rates until 2015. The rates for the post-2015 period included a 2.5% annual increase until 2020 and from then onwards a 5% annual increase until 2025. The new government agreed on setting ad valorem mining royalties but as of early 2015, there were no public figures available yet.

This study reveals that shale oil production accounts for 87% of VKG's environmental charges costs because oil products of its subsidiary, VKG Oil, make up just this much of the total revenue of VKG's oil shale production value chain (oil, power, heat).

Table 1. Environmental charges rates and cost per ton of shale oil in Estonia in 2013 and 2015, EUR/t

Type of environmental charge	2013 charges rates	2013 cost per t of shale oil	ME proposed 2015 charges rates	ME proposed 2015 cost per t of shale oil
Mining royalty	1.39	14.6	2.4*	21.0
Charge for mining waste disposal	1.09	3.1	1.09	3.1
Charge for mining water disposal	49.7***	0.76	76.69*	1.1
Charge for oil shale ash depositing	2.07	7.0	2.98	10.2
Charge for SO_2 emission to atmosphere**	86.08	4.7	145.46	6.8
Charge for NO_2 emission to atmosphere**	101.10		122.32	
Charge for particles emission to atmosphere	86.5		146	
Total		30.2		42.2

* – rates declared invalid by the Supreme Court;
** – coefficient 1.5 if emitted by oil shale companies in Kiviõli and Kohtla-Järve cities;
*** – EUR/1000 m^3;
ME – Ministry of the Environment.

In international resource taxation comparison all taxes borne by producer related to production are compared to earnings of a mining operation, thus arriving at total tax rate [17], average government take [18] or average effective tax rate [19]. Estonian taxation or environmental charges per ton of mined oil shale are inflexible, being thus very different from ad valorem royalties. Regarding mining waste, mining water, oil shale ash and most atmospheric emissions (with the exception of SO_2), there are currently no good technical or economic solutions to reduce the quantities generated. Thus, all environmental charges are fixed on the basis of the cost per unit of kerogen oil produced.

Carried out by order of the Estonian Association of Mining Enterprises, Ernst & Young Baltic AS showed in its study that while the international total mining tax rate (TTR) in 2010 was 39%, as found by PricewaterhouseCoopers (PWC) [17], then Estonia's corresponding rate for oil shale processing in 2011 was 62% and, given the aggressive increase of the rate, would have reached 83% by 2015 [16]. In 2014, the TTR for VKG was around 68% at the oil price of 105 USD/bbl. For Canadian Alberta oil sands, the average government take in 2010 was 67%, with a high degree of certainty [18]. It is important to note that also conventional oil projects are highly diverse, ranging from mature onshore fields to deep offshore wells in adverse climatic conditions and from minor fields with short economic production life to major fields producing constant flows for decades. Also, all projects have dynamic breakeven cost over their lifetime. given actual production and cost uncertainties over the lifetime of a project. Added to this are highly variable government fiscal regimes ranging from simple royalty system to production sharing, concessions and other contractual arrangements such as investment uplift or loss carryforward [20]. Thus, calculating the government take requires a deep understanding of the subject and is just as dynamic as full cycle breakeven prices.

Globally, royalty rates are generally set from 5 to 25%, but most are nearer 10 to 15% of production [21]. Global TTR in upstream oil production according to four studies quoted by Agalliu [18] varies from 18.5 to 98%, but the average stands around 50%. Government take in the U.S. is from 47 to 56%. A higher take is possible in areas of lower production cost or production fields with long production life and carried capital expenses such as some Arabian and North Sea fields.

An additional cost for the producer, VKG, arises from the fact that due to the fixed allocation of oil shale resource, the company has to purchase 0.8 million t of oil shale from another producer, Eesti Energia. The latter, however, sells oil shale at a very high price, 30 EUR/t, considering that the production cost at the new Ojamaa mine is 19 EUR/t. This means an extra cost of approximately 10 million EUR per year for VKG. With the reduction of oil price in late 2014, the processing capacity that required purchasing oil shale has been laid aside, which in turn resulted in the loss of 200 jobs.

Johnston [22] observes: "More realistic risks include such things as creeping nationalization through expanding taxes, progressive labor legislation, or price controls." The investigator also states: "Policy shifts constitute the most prevalent and immediate risks that confront industry. These include changes in government a fluctuating tax laws. In some countries, the rate of change is excessive. Democracies, for example, have a habit of making changes that affect business community nearly as often as elections are held."

The risk related to taxation is oil shale sector governance competence. Currently the oil shale sector taxation is governed and regulated by the Ministry of the Environment, in whose analyses, however, total state revenues and benefits in the long term have not been taken into account. The National Audit Office (NAO) has suggested that analysis of oil shale utilization in terms of state revenue should be continuously performed, considering that by 2016 oil production should significantly increase compared to 2014. According to NAO, to reach the goals set in the oil shale sector, the new National Development Plan of the Energy Sector and the National Development Plan for Utilization of Oil Shale should lay down the principles of taxation of oil shale utilization and bases for changing the taxes [23].

3.2.3. National and EU regulations

Besides the EU's charge for CO_2 emission and national taxation, both the EU and national institutions have set additional regulatory requirements for the industry, such as maximum allowed SO_2 emission levels, requirements laid down in environmental permits, and waste depositing requirements, which all means further capital cost. While SO_2 emission and waste depositing requirements are well known for a short term, there is a possibility that the requirement for emitting SO_2 of very high purity only will be established, incurring a potential capital cost on the industry to the amount of 100–150 million EUR per year.

3.2.4. Oil pricing

Having been volatile during the period of 2001–10, oil prices reached a certain plateau and stabilized at 100 USD/bbl in 2010–14. If oil prices increase at inflation rate and in lack of major supply or demand shocks, there seems to be strategically some balance between increase in demand by emerging economies and increase of supply from non-conventional oil sources [1]. However, if there are major macroeconomic shocks, there could be a sharp downward adjustment as witnessed in 2008–09. In 2015, such a shock triggered by the slowdown of Chinese economy and increased oil supply was present.

A highly relevant factor is that in order to satisfy bank loan terms shale oil producers need to sell part of their production at forward prices, often not capturing revenues from high market price or having defense from short-term price declines. For example, EE stated in its 2012 annual report that the average price without forward contracts for 2012 was 480 EUR/t (99.2 USD/bbl), but with forward contracts 411 EUR/t and for the year 2013, 67% of production was covered by forward contracts [24].

3.2.5. Shale oil product risk

There is a substantial difference in pricing between crude oil and heavy fuel oil with 1% sulphur content, which is the actual shale oil pricing reference. This difference is called crack spread and it varied in the period of 31.01.2013–31.01.2014 from 71.8 to 163 USD/t. This means that when Brent crude oil price was 790 USD/t, then that of heavy fuel oil was 626 USD/t, thus the perception that high oil prices necessarily result in higher revenues for shale oil producers is not always true. Indeed, the correlation between the two values for the above-mentioned period was calculated by the author to be 0.767.

Another product risk arises from the EU Directive on the sulphur content in marine fuels (Directive 1999/32/EC), which aims at reducing SOx emissions from maritime transport by limiting the sulphur content of marine fuels in environmentally protected areas, such as the Baltic Sea and the North Sea, from the current 1% to 0.1% from January 2015 and that of all marine fuels to 0.5%, according to Annex VI of the International Convention for the Prevention of Pollution from Ships. The effect of the Directive on the use of shale oil is difficult to assess, but it will certainly decrease SO's competitiveness as a marine fuel and/or require further investments, considering its current 0.8% sulphur content.

3.2.6. Currency exchange rate

Pricing of oil and heavy oils is carried out in US dollars, but related costs are calculated in euros. Since mid-2014, due to quantitative easing in European monetary policy concurrent with monetary tightening in the U.S., EUR/USD rate decreased from 1.36 to 1.1 by early 2015. This means that in the middle of 2014, 100 USD/bbl was equivalent to 73.5 EUR/bbl but in early 2015, with the exchange rate of 1.1 EUR/USD, 64 USD/bbl was equivalent to 58 EUR/bbl instead of 47 EUR/bbl, i.e. the amount it would have been at the EUR/USD exchange rate of 1.36. However, close to parity is historically low exchange rate and the average for the 2005–15 period was around 1.25.

4. Analysis and results

4.1. Analysis model

Analysis of different quantifiable risks was carried out on the basis of VKG's actual financial data, which were calibrated with the 2010–13 actual annual public financial data of the company and shale oil price calculations made by Siirde [25]. The current analysis model also employed nonpublic information regarding the free allocation of EUAs, and emissions. The author participated in the design of and data preparation for Ernst & Young Baltic AS 2014 study "Macroeconomic effects of oil shale sector policies", one of the key scenarios of which included similar assumptions of capital expenditure.

4.2. Scenarios until 2030

Table 2 presents scenario assumptions and names. National taxation rate means total tax rate. The assumption of a high or very high TTR suggests its linear, 3 or 5% rise per annum by 2020, independent of oil prices. Moderate TTR would assume its accommodation to oil price. The assumption for CO_2 price would signify its linear rise to 20 EUR/t by 2020 and staying at that level. In case of the high CO_2 price scenario the price is assumed to increase linearly to 50 EUR/t by 2030.

Table 2. Scenario assumptions and names

	National taxation and charges		
CO_2 price	TTR moderate, 65%	TTR high, 80%	TTR very high, 100%
50 EUR/t	Development50	Green Policy50	Resource nationalism50
20 EUR/t	Development20	Green Policy20	Resource nationalism20

The scenarios would all take effect gradually and realize by 2030. Due to the low reliability of long-term price predictions it is not practical to foresee any changes after 2030, also in view of the fact that the current legally binding EU energy and CO_2 abatement policies will be in place until 2030.

A key element regarding capital expenditure is the necessity to replace the aging oil and power production units and other infrastructure with efficient and ecological equipment, thus increasing capital cost. All scenarios foresee the same investments in production, meaning equal capital costs. Currently investments are being made in the construction of Petroter II and III units, upgrading of power generation units and building of a new lime production unit. Future investments will include those in the retrofitting of obsolete Kiviter oil production units, construction of new defenolation equipment, new boilers, novel integrated desulphurization (NID) units for flue gases purification and a new storage tank system, upgrading of the power grid, establishing of a new ash deposit, etc. In 2017, a new, Petroter IV unit is planned to construct to replace part of the Kiviter capacity, which means that by 2020, about 66% of oil will be produced from new, more efficient Petroter units. A further major investment, to the amount of approximately 150 million EUR, will be made in 2023–26 in the construction of a new underground mine in Sonda.

4.3. Results

Results of the modeling of four scenarios are presented in Table 3 and shown in Figure 4. It should be noted that for commercial confidentiality reasons, not all details concerning VKG's business have been publicized. This is mostly because VKG is an integrated company consisting of eight different production units and therefore, costs, investments and revenues of those units that are not related to shale oil production (transportation, electric grid, construction blocks production, etc.) have been excluded from the current analysis.

Even more relevant than the average breakeven cost of SO over a certain period of time are trends of different scenarios. If the trend is towards continuously increasing production cost of SO with no certainty about the increase of global crude oil price, it is apparently a loss-making perspective. Thus only a low CO_2 price and a moderate or low tax rate would allow the breakeven price that will not necessarily lead to an unsustainable outcome. The scenario of a continuously increasing CO_2 price or increasing taxation will increase the breakeven cost, being thus unsustainable.

Table 3. Average full cycle breakeven shale oil production cost in 2015–2030, USD/bbl

	National taxation and charges		
CO_2 price	Moderate TTR, 65%	High TTR, 80%	Very high TTR, 100%
50 EUR/t	86.7	87.4	91.4
20 EUR/t	84.3	85.6	87.7

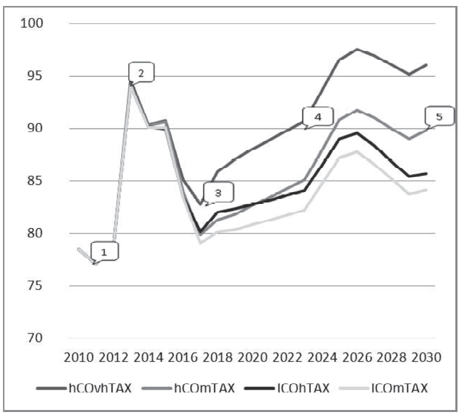

Fig. 4. Full cycle breakeven cost of VKG shale oil in 4 scenarios.

The numbers at the curves in Figure 4 refer to the following:

1 – higher production cost in 2010 due to the increased capital costs of construction of Petroter I unit (around 80 million EUR), with production launched gradually in 2011–12, as well as the increased cost of oil shale purchased from EE;

2 – the effect of a rapid increase in the price of purchased oil shale due to the increase of the oil shale selling price of EE and the higher cost of own-produced oil shale; the effect of high capital expenditure on the operation of the new mine, and of other investments without the increase of production in 2013; the effect of the rise of environmental charges;

3 – the effect of launching Petroter II and III units and other investments in production, leading to a decrease in full cycle breakeven cost; reduced total investment and reduced maintenance per new production unit;

4 – the effect of investment in the new Sonda mine (around 150 million EUR), the higher oil shale cost due to the longer transportation distance (20 km on rail compared to the 12 km on the conveyor belt);

5 – the effect of a higher CO_2 price coupled with a higher CO_2 deficit (the need to purchase more units from the market); higher maintenance cost of aging Petroter units.

One has to draw attention to the effect the inflexible system of allocation of the annual mining quota has on VKG, making the company purchase oil shale from EE at prices above 30 EUR/t, while for EE, the cost of mining oil shale from old mines is 13 EUR/t and from the new Ojamaa mine, 19 EUR/t. On condition that VKG uses up all of its own oil shale resource of 4.9 million t instead of the current quota of 2.8 million t, the company would save 21 million EUR annually and the breakeven price of oil would be reduced from 105 to 97 USD/bbl. In the reduced oil price environment in late 2014–early 2015, VKG had to shut down the capacity for which oil shale for processing had to be bought from EE. This, coupled with the reduced labour force of 200, decreased investments and also significantly reduced workers compensation costs. However, as at the time of writing this paper, VKG's Annual Report 2015 data were not available yet, which would have enabled the author to assess the impact of the reduced oil price on the company as a whole, then only a rough estimation of this impact is presented here (see Table 4). Though, it should be mentioned that 2015 saw a major investment in the construction of Petroter III unit, which was launched and started to yield revenue in the 2nd half of 2015. However, running on a very low capital expenditure in 2016–19 would be possible only with the relatively new equipment and only for a few years, after which the maintenance costs will inevitably rise. Obviously, in crisis mode, there will be no return on investment and all costs will be minimized, leading eventually to the closure of Kiviter processing units. However, the reduction of costs in response to market conditions will unavoidably realize with a certain delay.

Table 4. Rough estimation of the effect of crisis-mode oil cost reduction on breakeven cost

	2015	2016	2017	2018	2019
Breakeven oil cost, USD/bbl	66	52	52	53	54

It is possible to say that future oil prices will increase sufficiently enough to upset any cost increases in SO breakeven price, given concerns over the future supply and increasing non-OECD demand. However, it can also be claimed that increasing unconventional OECD demand, fiscally driven OPEC supply [26] and demand decrease with macroeconomic setbacks [27] will decrease the price. That happened in late 2014. Indeed, there are no credible long-term oil price projections, but a large number of past long-term ones that have ended up being erroneous (see Fig. 5).

Analysis by Yergin [29] correctly shows that market prices change substantially only in combination of both supply- and demand-driven factors. Given the large multitude of both factors in different directions, any argument over the necessarily lower or higher real long-term oil prices are highly speculative.

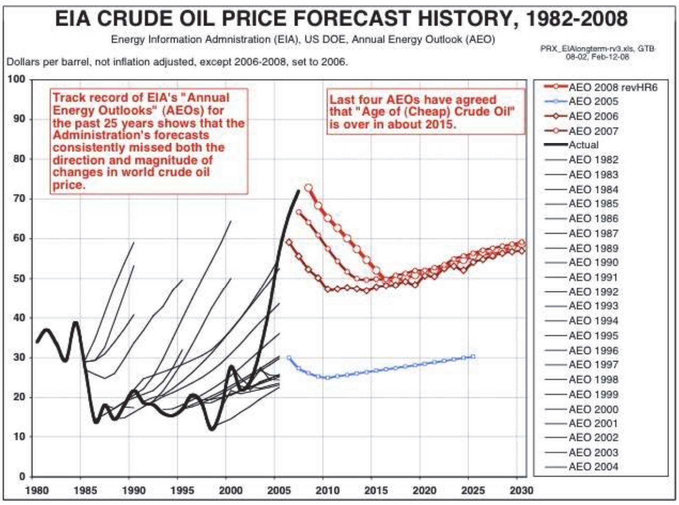

Fig. 5. US Energy Information Agency (EIA) oil price forecasts 1982–2008 [28].

5. Conclusions

Utilization of mineral resources is economically dependent on deposit location, resource quality, mining technology and cost, processing technology and cost, and national regulatory and fiscal regime issues. In case of Estonian oil shale the location, resource quality and mining and processing technology are favourable, as well as the skills level of the personnel may be considered excellent due to experience acquired during the continuous development of the resource for 100 years. However, the requirements of EU and national regulations, as well as the national fiscal regime have created a situation where shale oil production is not economically sustainable without high or increasing oil prices.

The current study shows that the full cycle breakeven cost of Estonian shale oil for producer employing new facilities is in the range of 100–110 USD/bbl for the period of 2015–30. Estonian shale oil producers, with the total capacity of 30 000 barrels per day, are nondiversified minor businesses at high risk regarding oil prices and other industry-related factors. Further analysis of the prospects of the industry for survival during the short- or medium-term period of oil price below 90 USD/bbl will be required.

However, considering the significant unavoidable capital expenditure to replace capacity, and the EU CO_2 policy, which can only mildly be influenced by the Estonian government, it is obvious that Estonia needs to review its oil shale sector's regulatory and taxation system to enable the industry to sustain in the long term.

The current study demonstrated the economic feasibility of shale oil development in Estonia. A key to the industry's economic sustainability is a friendly and long-term stable regulatory environment to allow large-scale investments to be made to earn a competitive return on them.

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Article III

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EFFECT OF INNOVATION IN UNCONVENTIONAL OIL INDUSTRY: CASE OF ESTONIA AND CANADA

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Abstract. *The objective of this paper is to compare the economic effects of innovation in an unconventional oil industry, based on Estonian and Canadian experiences with oil shale and oil sands, respectively. Both unconventional oil resources face similar challenges and need to resolve these through innovation. Based on empirical evidence, this paper concludes that innovation is a key mechanism of increasing efficiencies and triggering investments. Investments themselves, due to their nature, represent the best measure of the economic effect of cumulative innovation in the unconventional hydrocarbons industry.*

The paper proceeds in the following manner. First, we will briefly review the relevant literature and identify definitions of innovation and its impact on economic growth. In the second part, we will point out the effects of innovation in the energy industry on economic growth, and the uniqueness of energy innovation. Then we will present data on public and private R&D expenditure in the oil sands industry in Canada, as well as evidence of the results and economic effect comparatively to the R&D effort in Estonian oil shale industry. Lastly, we will draw conclusions by discussing our findings. The results are relevant to indicate R&D expenditure necessary to sustain investments and economic effects of developing unconventional hydrocarbon mineral resources.

Keywords: *unconventional oil industry, national energy policy, industrial policy, innovation policy.*

Part 1. Innovation and its economic impact

The creation and application of new knowledge and technology is a major contributor to overall human wellbeing and economic growth and has thus

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become on the agenda of different policies [1]. For example, the European Union (EU) has set a strategy for improving the conditions for research and development and is pursuing this goal through increasing combined public and private investment in R&D to 3% of GDP [2].

Endogenous growth models, which estimate that growth has been driven by technological change through R&D, have been known for some time [3, 4]. The difference in R&D between countries can explain some of the gap between their growth levels and economic development stages [5, 6]. Endogenous growth models link knowledge accumulation through education, training and research to innovation or new technology, which in turn influences overall output. Therefore, setting the agenda for innovation through increased R&D investments seems straightforward.

However, the notion of innovation remains ambiguous in some contexts. In a survey of literature on innovation, Edison et al. [7] found over 40 definitions. The most widely used definition develops on the core ideas of Joseph Schumpeter [8] and is now used in the Community Innovation Survey by Eurostat as defined on p. 46 in the Oslo Manual: "Innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations" [9]. The key is implementation, i.e. introduction to the market, which distinguishes innovation from invention.

Besides R&D, the local or national innovation system influences innovative activity [10, 11]. The innovation system theory itself describes the institutional environment and its synergy, how well the different features are interlinked and supporting each other. These features can be framework institutions such as the financial legislative environment, attitude towards entrepreneurship or taxes, but also educational environment for human capital, infrastructure, business support, financial services or business standards, and governing political environment [12]. There are complementarities involved for the innovating agent even within some of these links, such as the university-industry R&D [13].

Still, one of the most widely accepted policy instruments is dealing directly with R&D expenditure [14]. Seminal works from Arrow [15] and Nelson [16] have pointed out the need for public support for entrepreneurs due to the lack of demand certainty and return on investments leading to suboptimal levels of investment and, hence, societal loss. This gap between private and social returns is the principal argument for government intervention in innovative activity. A straightforward linear model in case of which R&D turns into inventions, products and sales dates from the 1940s [17]. Much later, studies have indeed estimated that social returns to R&D have been greater than private returns, effectively arguing for R&D subsidies to generate spillovers [18, 19].

Studies have measured R&D and its effects, rate of return and spillovers since the late 1950s. Hall et al. [20] conclude that on the whole the R&D rate of return in developed economies is positive and is most likely between 20 and 30%. Measuring social returns is more complex. These spillovers can be in the form of knowledge or rent [19]. This means that knowledge generated from an R&D project can be used by other firms for their own purposes. Hall et al. [20] point out four spillover sources for a firm: a) other firms in the same sector, b) firms in other industries, c) public research laboratories and universities, and d) firms, laboratories, universities and governments in other countries. There is no universal rate of return of R&D spillovers; measurements across countries, sectors and time have high variability, implying that R&D spillover rate of return is different in different locations, but it should be noted that it is almost always positive. Parsons and Phillips [21] estimate that the Canadian median R&D domestic external rate of return is 56%. The investigators have not found evidence for a similarly constructed study in Estonia.

Part 2. Innovation in energy industry and its economic effects

The energy sector has an abundance of multinational enterprises and R&D spillovers should be measured on an international level. Innovations have a cumulative nature and incremental innovations tend to diffuse over time, turning into widespread technological innovations [22]. To illustrate, it took several decades from the 1860s to 1920s to have wide use of petrol as transportation fuel [23]. In the energy sector, commercialization of innovations is costly, therefore R&D is linked also with demonstration. This happens at the early stage of technical development, before commercialization, and it may never be followed by actual deployment [24]. Another element of innovation, learning-by-doing, applies to all stages of innovative activity, from the early stages of R&D to reducing costs in production through experience.

Bettencourt et al. [25] studied global energy patents from 1970 to 2009 in conjunction with R&D investments. They found that market-driven investments and public R&D complemented each other in creating technological development. They added that according to their modelling, the effect of these investments persisted over the long term, supporting the ideas of tacit knowledge and absorptive capacity.

Innovation in the energy sector has led to higher supply (making difficult resources economically accessible), lower costs and prices to consumer, lower environmental impact, higher safety (especially relevant in nuclear energy) and security of supply. On a large scale, these elements cannot be captured as private rent, but accrue benefit to the wider society, justifying public funding of related R&D. Each innovation can also lead to major wealth transfer effect and macroeconomic benefits, for example, utilization of tight oil and gas in the USA has led to a substantial decrease of oil imports and increased oil supply, as well as oil industry, transport and other professional services within the USA [26].

It has been estimated that the decline of technological innovations in the US energy sector between the 1970s and 1990s was mostly influenced by reduction of investment in government funded R&D [27, 28]. Margolis and Kammen [28] conclude that this disinvestment hampers the US ability to provide long-term energy security and deal appropriately with global environmental sustainability. Indeed, by the 2000s US oil imports had grown to levels that started to be considered a strategic security problem [29].

Significant volatility and inconsistency in funding can also have significant adverse effects and in the USA there have been substantial funding shifts from year to year for both large research fields (e.g., coal, nuclear power) and smaller research areas (e.g., carbon capture and sequestration, nuclear safety) [30]. It is also telling that the US energy industry invests only 0.42% of its revenue in research. In contrast, the pharmaceutical industry puts 20.5% of sales into R&D, and the aerospace and defense industry spends 11.5%. At US federal level 60% of R&D spending goes on defense, about 25% on health and the energy sector receives just 2% [31].

Part 3. Data on public and private R&D expenditure in the oil sands industry in Canada and evidence of the results and economic effect comparatively to Estonian oil shale industry

Canadian oil sands are either loose sands or partially consolidated sandstones containing a naturally occurring mixture of sand, clay, and water, saturated with a dense and extremely viscous form of petroleum technically referred to as bitumen. Athabasca-Wabiskaw oil sands in Canadian province of Alberta cover over 140 000 square kilometers and contain approximately 1.75 Tbbl (280×109 m^3) of crude bitumen. About 10% of the oil in place, or 173 Gbbl (27.5×109 m^3), is estimated by the Government of Alberta to be recoverable at current prices, using current technology. This recoverable quantity amounts to 75% of total North American petroleum reserves. Only about 20% of the recoverable oil contained in the 3% of the oil sands area can be produced by surface mining, so the remaining 80% will have to be produced using in-situ wells.

Already in 2014, 58% of the oil sands volumes were produced using in situ methods. Alberta will continue to rely to an ever increasing extent on in situ production in the future, as 80% of the province's proven bitumen reserves are too deep underground to recover using mining methods [32]. In situ or Steam Assisted Gravity Drainage (SAGD) was indeed developed in 1984–87 by the publicly funded Alberta Oil Sands Technology and Research Authority (AOSTRA) Underground Test Facility [33]. This technology has led to several billions of dollars in investment and annual revenue from production facilities. The multiplier effect of this particular innovation is in the order of multiple thousands. AOSTRA has been converted to Alberta

Innovates – Energy and Environment Solutions (AI-EES) which has set itself equally high targets for 2030 [34]:

- 50% reduction in GHG intensity;
- 20% of new in situ production partially upgraded; and
- 15% production from challenging reservoirs.

In 2015 it invested $17.5 million in 89 projects aligned to meet these targets. The value of these projects over their lifetime is $312.2 million, of this AI-EES will have provided $82.9 million, leading to an approximate leverage factor of 2.8. AI-EES supports the development of innovation capacity by investing $7.7 million at universities for two Centres, 12 Chairs, and 36 individual researches [35]. In 2015 it completed the Oil Sands Competitiveness Study.

The major focus of AI-EES is National Partial Upgrading Program. Started as the "next generation upgrading" initiative over 10 years ago, AI-EES realized that given the market conditions, full upgrading of the heavy bitumen was uneconomical for the near future. Therefore the Competitiveness Study quickly evolved into an exercise to quantify the partial upgrading opportunities for Alberta's bitumen. In this three-stage study, AI-EES worked with industry and governments of Alberta, Saskatchewan and Canada to understand: a) the refining value of Western Canadian bitumen in different regions; b) selection of partial upgrading technologies with most potential; c) the potential value back to the producer for a partially upgraded product in Western Canada. The program has funded two technologies for development and commercialization. Results of the Competitiveness Study show a partial upgraded crude product could net an additional $5 to 10 billion in annual gross revenue for Western Canadian producers by 2035 [36].

Also Alberta Innovates Technology Futures funds in large-scale oil sands related R&D. Its 2015–2016 budget was approximately $150 million, while in 2014, about $50 million came from the private sector and $100 million from the public sector [37]. One example of research focus can be Materials and Reliability in Oil Sands (MARIOS) program initiated in 2009 to reduce maintenance cost and unscheduled shutdowns. It is estimated that the oil sands sector spends over $3 billion on maintenance every year and forfeits another $5 to $7 billion in lost revenue due to both scheduled and unscheduled shutdowns. As a result, there is a strong incentive for oil companies and their supply chain to improve the run-life and reliability of components, equipment and processes in their operations.

At national level, Sustainable Development Technology Canada (SDTC) has been leading Canada's investment in energy, agriculture, forestry, mining, transportation and energy efficiency industry since 2000. In 2015, SDTC approved 32 projects for funding by it, bringing the total number of SDTC funded projects to 320 with 928 million dollars allocated. Out of the 320 supported projects, 73 were commercialized as of 2015. SDTC's support has enabled these companies to raise estimated $2 billion follow-on financing. This has in total created 9200 jobs direct and indirectly. Estimated

Annual Revenues generated by SDTC funded companies in the market at the end of 2015 were $1.4 billion. Of the 141 SDTC funded projects completed by December 2015, a total of 73 have climate change mitigation benefits and together these technologies have realized an annual GHG emissions reduction of approximately 6.3 megatons CO_2e in 2015 [38].

Having been established in 2005 in partnership with Imperial Oil, the University of Alberta Institute for Oil Sands Innovation (IOSI) is the leading oil sands centre in basic research to find breakthrough technologies for oil sands processing. To date, IOSI has received funding amounting to $51 million from public and private funds and supports more than 160 top researchers from around the world. In 2015 they published 21 academic technical papers and during 2007–2015 carried out 18 study projects on cleaning and partial upgrading, 16 on extraction, and 5 on tailings process fundamentals [39].

The key for the innovation to have economic impact is its penetration into wider use. While innovation by individual company creates competitive advantage, sharing and wider penetration of technology can actually be limited. Oil sands producers have overcome this problem by a mutual technology sharing platform called Canada Oil Sands Innovation Alliance. It consists of 13 member oil sands companies that have shared 814 distinct individually developed technologies and innovations that cost almost $1.3 billion to develop [40]. These innovative solutions reduce greenhouse gases, minimize impact on land, reduce water use and improve tailings management.

In 2015–16, when oil prices were below 50 USD/bbl, the focus of innovation shifted to cost reduction and revenue maximization. Findlay [41] has found in his study "The Future of the Canadian Oil Sands" that the challenge for current and proposed mining and steam-assisted gravity drainage projects is to develop technological improvements to a magnitude that meet, and ideally exceed, the detriment of decreasingly prolific rock. There certainly is hope with novel solutions like in situ tech-solvent extraction, Electro-Thermal Dynamic Stripping Process and microwave heating. Producers have their own large R&D budgets – Canadian Natural Resources Limited leads the pack with 450 million CAD spent in 2014, while Suncor, Syncrude, Imperial Oil and Cenovus each spend roughly 100–200 million CAD annually.

Research groups such as CERA, IHS, and the Conference Board of Canada, among others, have developed in-depth calculations to demonstrate the economic value added by oil sands development. Though the estimates vary, annual GDP impact hovers around CAD$100 billion and supported more than 478 000 direct, indirect and induced Canadian jobs in 2012 (3% of all jobs in the country), though this did drop in 2015 with the depressed prices for crude and reduced capital investment. This amounts to approximately 5% of Canada's GDP. In 2012, oil sands production directly accounted for almost one-third of Alberta provincial government revenues and 6% of federal revenues [42].

In the first decade of the 21st century alone, $117 billion oil sands-related investment has taken place. The Conference Board of Canada's analysis shows that $1 billion in oil sands investment generates 2200 person years employment direct effect, 2700 supply chain and 1400 in income effect person years employment in Alberta [43]. Additional employment will take place also in British Columbia due to transportation and refining of products and Ontario due to supply chain and income effects in the most populous Canadian province. The Figure illustrates the extension of supply chain effect to various sectors of the economy.

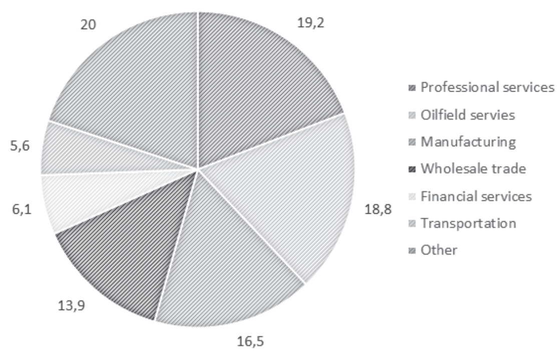

Figure. Sectors experiencing supply chain effects (share of employment, %) [43].

Canadian public research and development financing totaled 9.5 billion CAD in 2013, yet its total R&D funding has fallen from 2.09% of GDP in 2000 to 1.61% in 2014 [44]. The total government energy sector research funding was estimated to be $941.9 million for 2014–15 (CAD 439 million federal and CAD 503 million provincial and state-owned enterprises), down from CAD 1.34 billion in 2013–14, according to the International Energy Agency (IEA). IEA suggests increasing public R&D funding for energy projects [45].

However, Canadian R&D funding ecosystem is very robust, providing support in all stages from basic research to applied, demonstration, commercialization and market development. Each of those is crucial to have economic impact from R&D. Canada has every reason to fund energy research as it has substantial conventional coal, gas and oil reserves, and the country has developed its own original nuclear power reactor design on heavy water called CANDU. Canada also possesses substantial hydropower and renewable energy potential, but technically and environmentally the most challenging and with the highest economic potential are large Alberta oil sand deposits.

A technically and environmentally similar unconventional hydrocarbon resource is Estonian oil shale that has been mined and utilized mainly for oil production and power generation since 1916. After Estonia re-established its independence in 1991, there have taken place structural and proprietary changes in the oil shale industry as well and today, it consists of one state-owned and two private companies with a combined turnover of 933 million euros in 2014 and with 15 million tons of oil shale mined annually. Since the increase of oil prices in 2005–2007, the companies have invested substantially in research and development to work out new techniques to reduce environmental impact, increase energy efficiency, and process effectively fine oil shale, which accounts for the majority of material produced by mining.

In 2012–2013, the oil shale sector R&D expenditure was more than 20% of total Estonian R&D expenditure. It needs to be noted that substantial innovative technology investments (such as part of cost of Enefit 260 and Petroter oil shale processing units) were listed as R&D expenditure. Based on the Estonian Patent Office's data, Estonian oil shale research accounts for approximately 9% of all patents and 6% of all useful models issued.

In 2012–2013, the largest Estonian oil shale company, Eesti Energia AS, in partnership with a Finnish Outotec company, invested in a technology development company Enefit Outotec Technology. Through its subsidiaries Eesti Energia invested in the feasibility studies of Utah and Jordanian oil shale projects. By the spring of 2017, the latter project will be finalized as a 2.1 billion USD agreement in place on building a 554 MW oil shale-fuelled power plant.

The economic impact of oil shale industry in Estonia is quite relevant in terms of GDP impact, net exports, government revenue, and as employer. Indirectly, the industry offers employment to 17 372 people [46]. In 2014, the net government revenue from the oil shale industry was 174 million euros [47].

Estonian public funding of energy related applied R&D has been significantly driven by the European Union's Structural Funds and criteria, with the EU funds financing amounting to about 50% of total funding. Started in 2010, three major programs are: 1) Support of Energy Technology Research and Development managed by Enterprise Estonia (EAS) and Archimedes (7.1 million euros), 2) Smart Specialization (26 million euros), and 3) Support of Strategic R&D managed by the Estonian Research Council (28 million euros, with the EU funding of 23.7 million euros). The former program was totally focused on energy technology and 40% of financing was used for oil shale related research. The latter two programs include some elements of oil shale and energy related research, but these account for no more than 10–20% of the total program. In the case of EU funded programs there have been set rules for program management and financing, which enables no proactive research agenda direction by a program managing organization.

An exception is the Environmental Investment Centre that funds studies and research related to energy and environment from environmental fee revenues, albeit the share of R&D is still smaller than in the abovementioned programs. In the case of the Support of Energy Technology Research and Development program, there was prepared an interim report containing several recommendations for improvement [48], but no final report on the results and economic effect of the studies was presented. Thus, the economic impact, the leverage factor of the studies, is to a great extent unreported. According to oil shale field professionals, the practical effectiveness of the program funded research is yet low.

In its 2013 report about Estonian energy sector, the International Energy Agency concludes that the country's pertinent policy agenda has been set in a number of documents such as various development plans until 2020, and recommends, among other things, "to continue to promote research and development of oil shale technologies" [49]. According to the European Commission, Estonia with Germany are the only two EU member states that are not using any R&D tax incentives in any form [50]. In general, with 1.4% of GDP, Estonia's R&D funding is lower than the EU's average (2.1%) or the official goal set in the Estonian Entrepreneuship Growth Strategy 2020 (2%) [51] or the 3.2% of GDP of the leading peer group countries, Sweden and Finland equally [52].

According to the IEA, in 2014 the share of energy related research in total R&D in its member countries was on average 4%, being far down from the 11% of 1981. With 12% Japan was the leading country in 2014. In the EU member states, the equivalent is much lower, averaging 3%, with Finland's figure being, for example, 9% and Estonia's 1.6%. The average ratio of public energy research, development and demonstration (RD&D) budget per unit of GDP is 0.4 (RD&D budgets per thousand units of GDP) and varies greatly, ranging from less than 0.1 in Portugal and Spain to over 1 per thousand in Finland. Among fossil fuel producers, the respective US figure is 0.35, Canada's 0.7, Norway's 0.86 and Poland's 0.23. Estonia with 0.12 strikes the eye as a country with one of the lowest public energy RD&D budgets per unit of GDP, spending almost 6 times less than Canada (see Table 1) [53].

Table 2 presents comparative economic output data for power and oil production in Estonia. Comparative data for Canadian oil sands and Estonian oil shale industries are presented in Tables 3 and 4, with an obvious difference in magnitude. However, several clarifications are necessary: only one-third of oil shale mined in Estonia is processed for oil production, the rest is used for power generation. There is a substantial economic difference between the two applications summarized in Table 2, the main difference being in that the value generated per unit of raw material is more than twice higher, and labor intensity is higher as well [54].

Table. 1. R&D spending of selected International Energy Agency member countries in 2014

Member country	Energy related research in total R&D funding, %	Public energy RD&D budget per 1000 units of GDP
Finland	9.0	1.0
Canada	7.2	0.7
Estonia	1.6	0.12
IEA average	4.0	0.4

Table 2. Comparative economic output of power and oil production from oil shale in Estonia [54]

Economic indicator	Power generation	Oil production
Energy efficiency, %	35–40	65–78
Capital intensity, mil eur per mil t oil shale processed a year	265 (Auvere CFB)	87 (Petroter I)
Labour intensity, persons per mil t oil shale processed a year	25	125
Secondary outputs	Heat	Power, heat

Table 3. Summary of economic impacts of unconventional hydrocarbons production in Canada and Estonia for the year 2014 [55-57]

Economic indicator	Canada (oil sands)	Estonia (oil shale)
Oil production, bbl/d	2300000	22000 (60000)*
Sales revenue, mil eur	40000	450/933**
Investment, mil eur	22700	263
Public energy R&D, mil eur	650	3.2
Private R&D, mil eur	606	5.2
Direct employment	22340	6683
Indirect employment	478000	17372
Government revenue, mil eur	4800	174

* – 60000 bbl/d would be oil production if all mined oil shale would be processed to oil. It is necessary to calculate relative impact in Table 4 because data on oil shale industry R&D, investment, sales, employment, etc., is not distributed between oil and power generation.

** – includes produced heat and power revenue.

Also evident from Table 4 is, on a relative scale, the lower investment ratio that can be explained by a very active investment period of Canadian oil sands of the period and presence of legacy capacity in Estonian oil shale. The difference in R&D effort is evident in both the private and public sectors. Substantially larger direct employment of oil shale compared to oil sands is an expected result. Maybe less expected result of comparison is the larger direct government revenue from oil shale. Explanation for the latter is a 100% government ownership and dividend revenues from the largest oil shale company, Eesti Energia.

Table 4. Comparison of economic impacts of unconventional hydrocarbons production in Canada and Estonia per millions of barrels produced for the year 2014

Economic indicator	Canada (oil sands)	Estonia (oil shale)
Sales revenue	47.6	42.4
Investment	27.0	12.0
Public energy R&D	0.8	0.15
Private R&D	0.7	0.24
Direct employment	26.6	303.0
Indirect employment	569.4	789.0
Government revenue	5.7	7.9

Part 4. Innovation led energy industry investments as a proxy for economic effect

Multiplier effect captures the indirect and induced effects of a particular economic activity. However, estimating multiplier effects is not precise and their variability in time is significant given commodity price, employment, cost structure changes, etc. Generated by research & development, the size of investment is a measure in the capital-intensive energy industry, which remains constant after the investment is made, and has to create economic activity, employment and revenue to earn back the investment and return. Investments themselves, due to a well-defined investment decision based on the best available information, the need to earn back the invested capital over time as well as the need to employ a large amount of direct and indirect economic inputs over time to ensure economic production, represent the best measure of the economic effect of cumulative innovation in the energy industry. Thus, we suggest using investment as a best proxy to measure the economic effect of research and development.

In 2009–2015 Estonian oil shale companies spent a total of 25.9 million euros on research and development, which contributed to the 434.6 million euros' worth innovation led investments in physical capital in the whole value chain of oil shale mining and processing by three companies (see Table 5). Thus during that period the multiplier factor of research and development was 13.2. In the same period, the total investment by company was as follows: 428.8 million euros for Viru Keemia Grupp, 60 million euros for Kiviõli Keemiatööstus and 1100 million euros for Eesti Energia, totalling 1589 million euros.

Oil shale industry in future has high potential for further value added gains through research and development. Most relevant is the aspect that shale oil trades as heavy fuel oil with 1% at substantial 30% price discount compared to crude oil dated Brent. This is due to the unique chemical composition of shale oil having high sulphur, arsenic, nitrogen and oxygen contents and some ash content, which makes its processing impossible even if blended with other crude oils in regular refineries. However, it is entirely possible and likely that with research and development upgrading of shale oil to higher value oil products is possible, increasing the value of the product 30–40% and necessitating investments of several million euros in the upgrading of processing units. This partial upgrading opportunity of Estonian oil shale is very similar in nature to that of Canadian heavy bitumen.

Table 5. R&D expenditure and innovation led investments by Estonian oil shale companies (based on company data gathered by the authors)

Year	2009	2010	2011	2012	2013	2014	2015
Total R&D expenditure	440460	8791 51	2014245	3405938	4339255	5196411	1792327
R&D led investments	38965817	27028862	2857538	118801217	109131259	90261953	47589366

Another potential is processing of the pyrolysis gases to separate out more valuable ethylene (C_2H_4), ethane (C_2H_6), butene (C_4H_8) and other gases that comprise 31% of total pyrolysis gases of Enefit and Petroter technologies and are of higher value as chemicals than as burning fuel [58]. There is also potential to increase mining efficiency with long-wall mining under study by Eesti Energia, increase utilization of beneficiation waste limestone, oil shale ash and low-pressure heat. Even the production units already in exploitation are subject to intensive innovation. For example, Petroter III oil shale processing unit, which was built in 2013–2015 after Petroter II unit (built in 2012–2014), underwent about 60 minor and major innovations [59].

All suggested measures pertaining oil shale related research will require substantial public and private effort relatively similar to Canadian R&D expenditure given in Table 4. Then, provided suitable price environment as well, it is likely to lead to further investments and these in turn to related economic impact.

Part 5. Discussion and conclusions

Compared to other policy options for unconventional hydrocarbons development and economic impact, such as taxation, mineral resource allocation, environmental regulation, R&D has the highest economic effect. It is only due to innovation that we are able to utilize more sophisticated energy sources than human labor. After ratification of the Paris climate agreement, reduction of greenhouse gas emissions in unconventional hydrocarbons production and carbon capture demand a high level of attention. This cannot be resolved through other means than innovative processes developed through constant trial and error together with healthy scientific and commercial competition methods.

Canadian oil sands industry has a multitude of major and minor companies developing innovative solutions to maintain competitive edge and improve bottom line to their investors. Almost all companies are competing for mineral rights concessions and for investors at the stock exchange. Alberta Province and Canadian government consider it justified to support the industry research and development effort on a large scale.

Estonian oil shale industry is fairly segmented with a major state-owned company and two smaller private companies. None are stock exchange listed and competition for resource is limited to a legal battle in court and with the permitting authority. In addition, their budget for R&D is much more limited. However, the relative size of oil shale industry for Estonia is just as significant as that of oil sands industry for Canada. Given the legal status of minerals (they are state-owned), it is justified that Estonian government is more engaged in R&D effort to ensure the economic and environmental sustainability of the mineral sector.

Considering the competitive and environmental challenges of the oil shale industry and other energy sector needs, the authors suggest that compared with the 2014 levels, Estonian government should increase its energy related research and expenditure 7 to 8 times and private businesses 3 to 4 times. Also, given the relative low effectiveness of the 2010–2015 Support of Energy Technology Research and Development program and based on Canadian example, skilled innovation management institution or professionals are necessary for the government to have R&D funding that has practical value added to the industry as well as economic effect. It is also relevant that research programs with the corresponding mechanism are continuous, as innovation is not a project, but a non-linear process of trial and error. Externalities justify Estonian government also to act to facilitate innovation cooperation similarly to Canada Oil Sands Innovation Alliance's.

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Hariduskäik

1986–1997	Taebla Gümnaasium
1997–2002	Tallinna Tehnikaülikool, B.A. rahvamajandus
2007–2008	EBS, M.A. rahvusvaheline finantsjuhtimine
2009–2018	doktorantuur Tallinna Tehnikaülikooli majandusteaduskond

Keelteoskus

Eesti keel	emakeel
Inglise keel	kõrgtase
Saksa keel	kõrgtase

Teenistuskäik

1999–2000	ministri abi, Rahandusministeerium
2001–2002	Justiitsministeerium, siseaudiitor
2002–2003	Eesti Reformierakond, noortekogu peasekretär
2004–2009	OÜ Gutsch, juhatuse liige
2009–2011	MTÜ Eesti Tuumajaam, tegevjuht
2011–2014	AS Viru Keemia Grupp, projektijuht
2014–2015	Riigikogu XII koosseisu asendusliige, majanduskomisjon
2015–2018	Majandus-ja Kommunikatsiooniministeerium; nõunik
2017–	SA Ida-Viru Tööstuspargid nõukogu esimees
2018–	Eesti Geoloogiateenistus, asedirektor