Presentation by the European Academies Science Advisory Council on the meeting of the Committee on Industry, Research and Energy of the European Parliament, 12 April 2007

Oil shale industry – viewed in the light of the Estonian experience

Mihkel Veiderma, Andres Siirde

Oil shale (OS) is a sedimentary rock containing up to 50 % organic matter, representing a mixture of high-molecular polyfunctional organic compounds and known as kerogen. OS of different deposits differ by genesis, composition of organic and mineral matter. For example, the element composition of the Estonian OS kerogen corresponds to the formula $C_{10} H_{15.2} O_{0.93} S_{0.08} Cl_{0.03} N_{0.03}$ (i.e. ratio atoms H/C is about 1.5 instead of 2 in usual crude oil), its mineral part consists mainly of carbonates and sandy-clayey minerals**.** In comparison with coal, kerogen is rich in hydrogen and for this reason it is directly convertible by retorting into oil. The calorific value of OS, depending on kerogen content, is at least 2-3 times lower than that of coal.

The world OS resources are estimated to amount to 11 trillion tons, i.e. 12 times more of proved reserves of anthracite, coal and lignite, all of them in aggregate. Due to differences in quality it is more correct to report resources of OS in barrels of oil obtainable by retorting. By this technique of counting, resources of OS form more than 3 trillion bbl (Fig. 1).

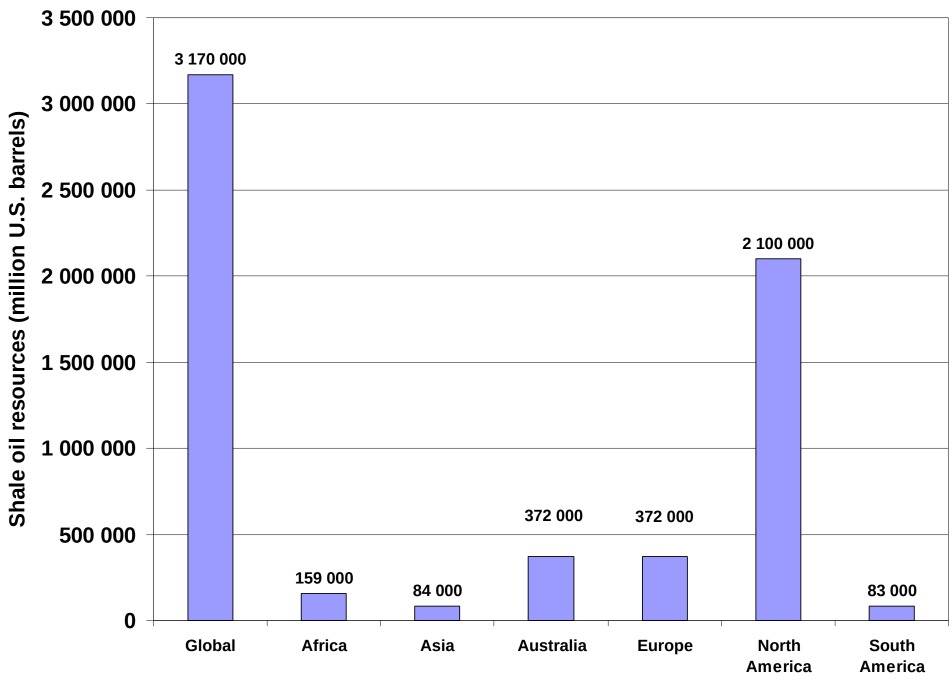


Fig. 1. Global shale oil resources (million US barrels)

The world resources of OS are divided irregularly – 66 % are located in North America, 12 % in Europe. The grade of OS deposits also differs much – the high-grade resources with the oil yield more than 90 l/t form 32 % of total resources (Fig. 2).

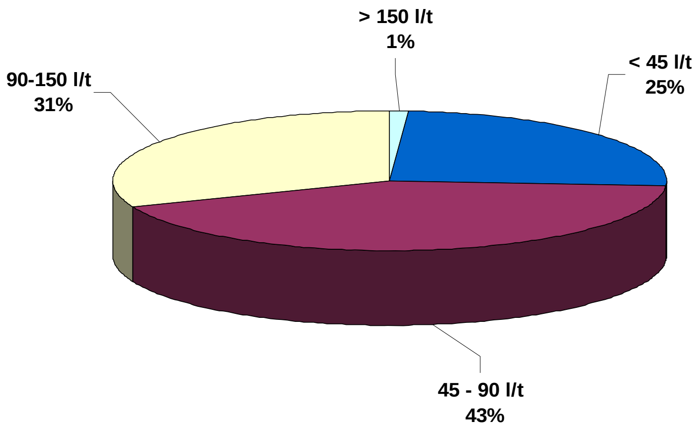


Fig. 2. Grade of the global oil shale deposits in liters of oil per ton

About 2/3 of European resources of OS are located in Russia, most of the balance accounted for by deposits in Italy (20 %) and Estonia (5 %) (Fig. 3).

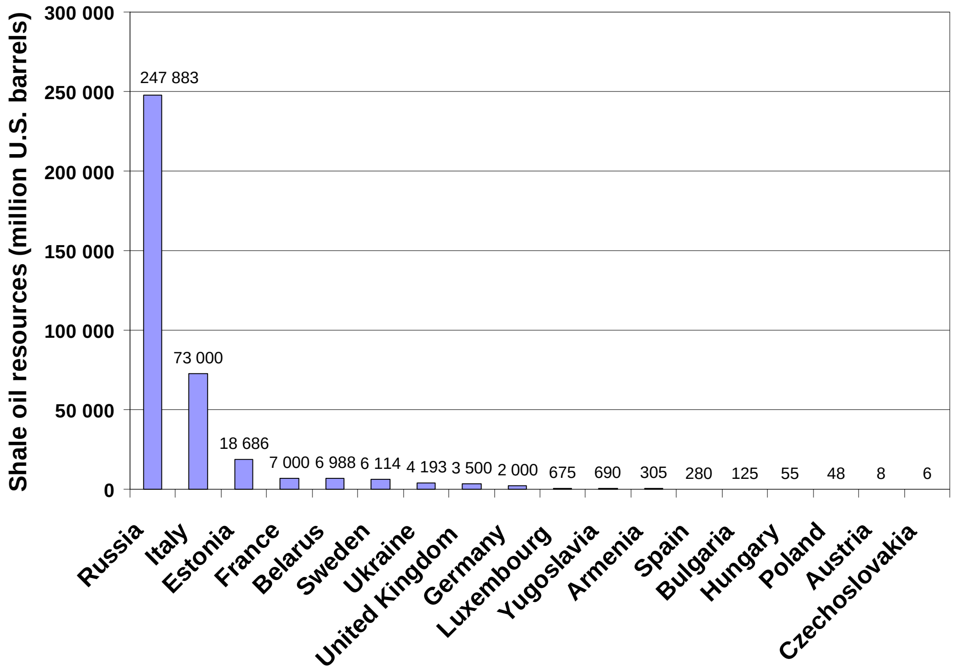


Fig. 3. European shale oil resources (million US barrels)

The resources of EU member states, put together are more than 100 billion barrels. The strategic significance of the EU`s oil shale deposits is not susceptible to a simple yes/no. This is partly because the issue has so many dimensions, involving political and social judgments as well as scientific evidence and analysis. The only true well studied EU reserves of OS being economically exploited in large amount are in Estonia.

Though the production of OS started already in the beginning of the 18th century in Scotland , today considerable quantities of OS are mined only in Estonia , Russia , China and Brazil . World production of OS peaked in 1980 when 47 Mt of OS were mined, more than 70 % of that in Estonia (Fig. 4).

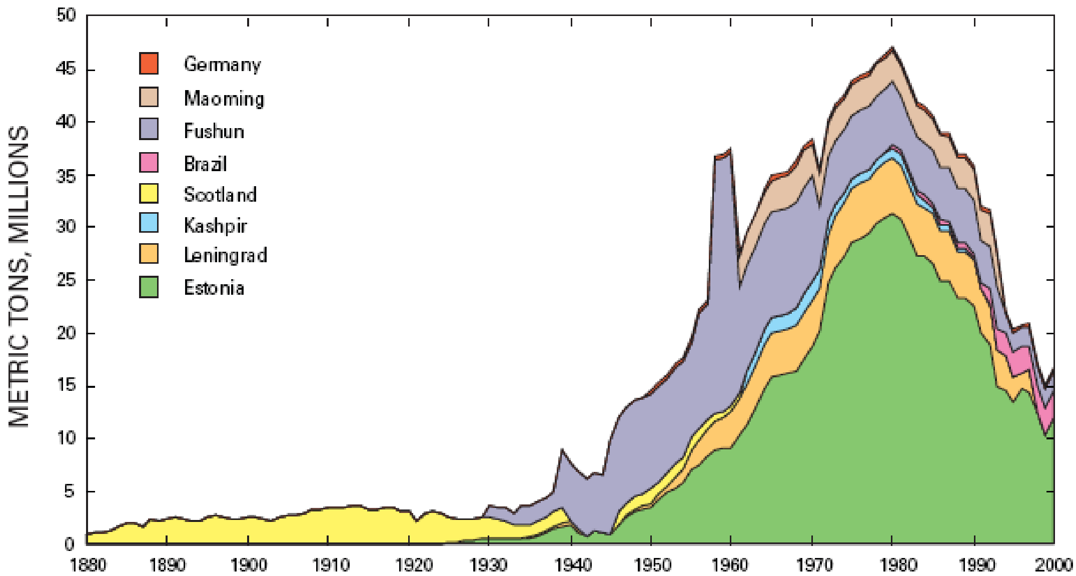
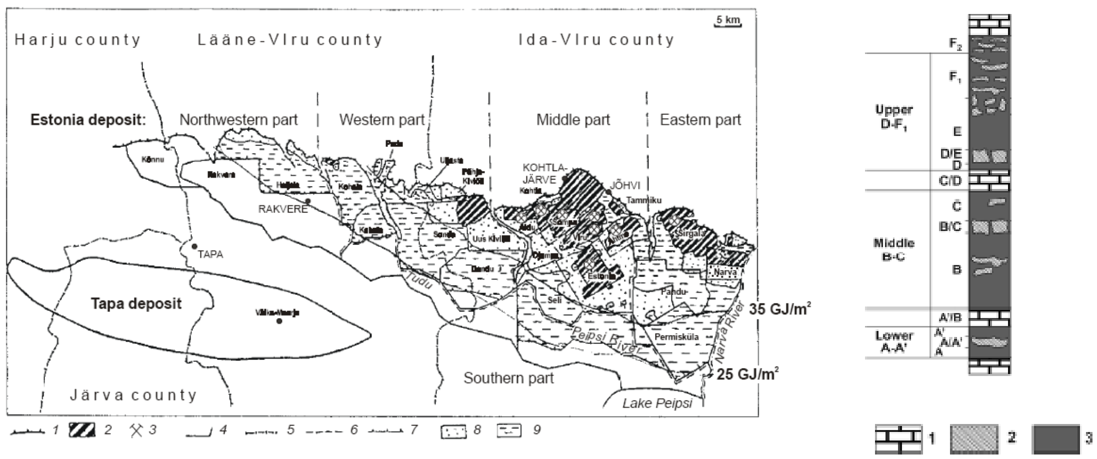


Fig. 4. Production of oil shale in million metric tons from selected oil shale deposits from 1880 to 2000

Since then the production has declined and forms now in Estonia 14 Mt/y. In connection with the limitedness of the oil resources and the rise of oil prices the interest in OS utilization has greatly increased. Recently, in accordance with the presidential energy program experimental large-scale field-works on in-situ OS conversion process have started in US. New construction of high-capacity surface retorting unit has been undertaken in Australia. More than 80 years experience of Estonia in OS usage is of importance for countries starting exploitation of their deposits.

The OS deposits are located in North East Estonia with resources 5 Bt, including 1.5 Bt of active reserves (Fig. 5).

a) b)



a) 1 – outcrop line of the shale bed; 2 – exhausted areas; 3 – operating mines and opencasts; 4 – mine field boundary; 5 – county boundary; 6 – boundaries of parts of Estonia deposit; 7 – southern boundary of Estonia deposit; 8 – active reserve; 9 – passive reserve
b) 1- limestone, 2 – limestone kerogeneous, 3 – oil shal, thickness of the layer 2-3m

Fig. 5. Estonian oil shale reserves by fields and structure of the layer

Thickness of the OS layer is 2-3 m, the OS seams in the bed alternate with limestone inter beds.

OS is mined, depending on depth of the layer, in opencasts (<25m) or in underground mines**.** Mining is connected with voluminous dewatering and changes in the hydrogeological situation. When the quality of mined OS does not correspond to the requirements of consumers, OS is enriched by either jigging or in heavy suspensions. Reforestation of exhausted opencast areas is progressing well (till now in the area 12000 hectares).

From 1 t of OS (2030 kcal/kg) can be produced by retorting 125 kg shale oil (9500 kcal/kg) and 35 Nm3 retort gas (11200 kcal/m3), by combustion - 850 kWh electricity**.** OS is used also for heating and cement production. Material flow demonstrates the current situation in OS industry (Fig. 6).

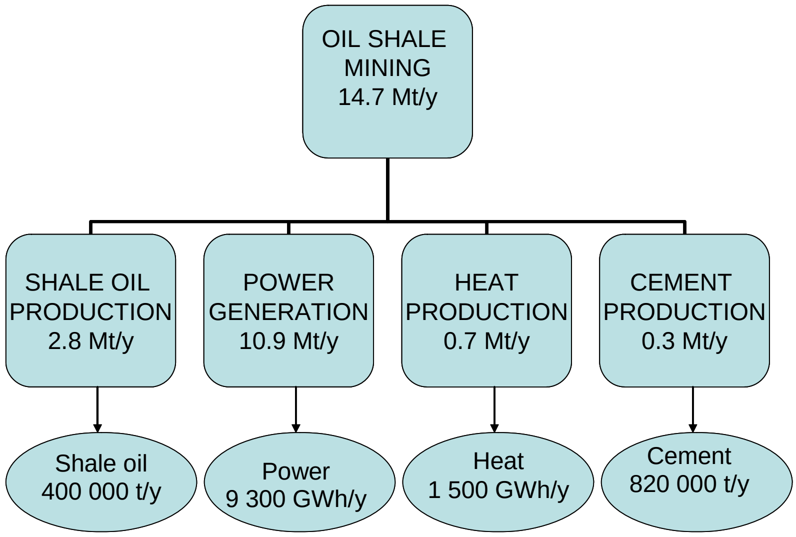


Fig. 6. Material flow in the Estonian Oil Shale industry, 2005

The Estonian experience in thermal processing of OS is long-term and rather diverse, both by the way and amount of production and implemented technologies (Table 1).

Table 1. The development of thermal processing of oil shale in Estonia

Low-temperature (500–550 ºC) thermal processing	
The use of lumpy oil shale (25–125mm)	
1924 to date	**Internally heated vertical retorts, (Pintsch retorts →Kiviter process) 10t → 40t →100t →200t →1000t (→ 1500t, designed) oil shale per day**
1928–1960s	**Tunnel ovens (horizontal, internally heated) 400t oil shale per day**
1931–1961	**The Davidson rotary retorts (horizontal, externally heated) 25t oil shale per day**
The use of fine-grained oil shale (<25mm)	
1980 to date	**Galoter process with solid heat carrier 3000t oil shale per day**
High-temperature (> 700 ºC) thermal processing of lumpy oil shale (25–125mm)	
1948–1970	**Chamber ovens for gasification of oil shale 400 million m3 gas per year**

The basic direction in thermal processing of OS has been semi-coking (retorting) to produce shale oil. At least five different technologies for retorting of OS with capacities of the retorts up to 3000 t per day have been developed and put into operation. As a result the improved vertical Kiviter retorts and horizontal Galoter units with solid heat carrier have proved to be the best ones and have served as the basis for further developments. Shale oil is used mainly as fuel for boiler-houses and cogeneration plants, and due to its special properties (lower viscosity and pour point) also for export as fuel for merchant marine and navy. Studies on enhancement of the product value (motor-fuels, chemical products) are well underway. To the point, in 1950-1960s, town gas was produced by gasification of OS for heating Leningrad and Tallinn.

From 1960s electricity generation became the most capacious branch in the OS use (Table 2).

Table 2. Development of power and heat production from oil shale in Estonia

Construction date	Plant	MW electricity	MW heat
1930s	Tallinn	11	
1949–1967	Kohtla-Järve	39	534
1952–1957	Ahtme	20	338
1959–1971	Balti	1624 inc. 4 blocks at 200 MWe and 8 blocks at 100 MWe pulverized firing boilers	686
1969–1973	Eesti	1610 inc. 8 blocks at 200 MWe pulverized firing boilers	84
1995	renovation of turbines, extra repairs of boilers, new electrostatic precipitators, demolition of old blocks		
2004	two 215 MW Circulated Fluidized Bed (CFB) units commissioned in Balti and Eesti Power Plant		

Two big power plants with total capacity 3200 MW based on combustion pulverized OS were commissioned. The electricity production reached its peak in 1980 (19 TWh) and from that time on has been gradually decreasing. In 2005 the OS based electricity production was 9.3 TWh, which covered 92 % of Estonian power consumption and enabled to export nearly 2 TWh.

The generating capacities of OS power plants exceed the demand of Estonia, but at the same time the working resource of the old boilers is drawing to a close, they are obsolete, which has resulted in high specific consumption of fuel and high emissions (Fig. 7). While the reduction of emissions in 1990-1995 was attained mainly by decrease in production, the same end is being achieved now with intensive development works.

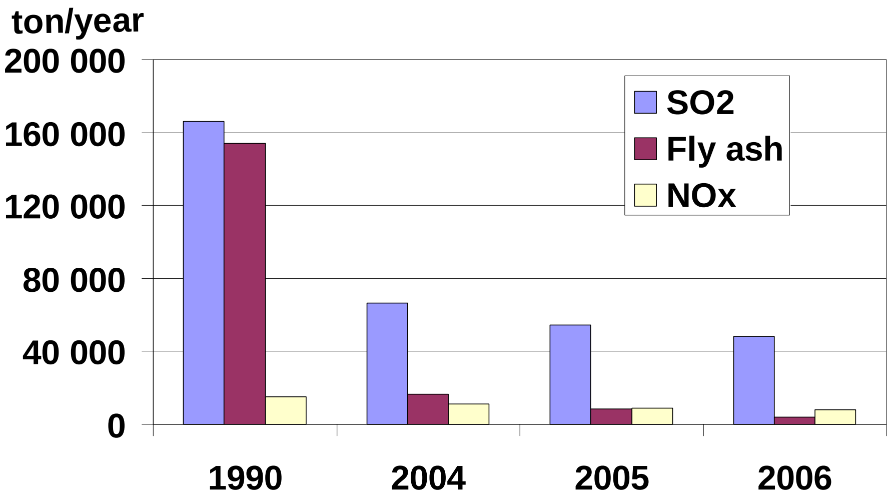


Fig. 7. Emissions from Oil Shale Power Plants 1990-2004, 2005, 2006

In particular replacing four old PC boilers by CFB boilers has yielded splendid results (Table 3).

Table 3. Emissions from oil shale fired boilers

	PC Boilers	CFB Boilers
SO2 bounded	80 %	almost 100 %
SO2 emissions	800-2000 mg/Nm3	0 – 20 mg/Nm3
NOx emissions	300 mg/Nm3	90 – 170 mg/Nm3
Fly Ash Emissions	< 200 mg/Nm3	< 30 mg/Nm3
Net Efficiency of Power Generation	28-30%	34-36%
CO2 kg/kWhe	1.18 kg/kWhe	1.0 kg/kWhe

In case of new boilers the efficiency in power generation has increased by 6-7 %, emission of SO2 has been reduced almost to zero, NOx two times, CO2 by 20 %. Thus the emission of CO2 has decreased to the same level as in coal firing power plants. Using deeper enrichment of OS and putting into practice some other measures (for example, remineralization of CO2 by ash) the CO2 emission can be reduced more.

As part of the accession negotiations the European Commission gave OS a temporary status, thus postponing implementation of some relevant EU directives, including SO2 emission limitations, reconstruction of ash handling systems, closing old PC boilers**.** Fulfillment of the EU requirements is going on well in accordance with established terms.

For Estonia , which regained independence in 1991, it is very important that the OS complex should provide for energy security and self-sufficiency in power and heating oil to the country, at moderate prices. By the National Fuel and Energy Sector Development Plan local generating power should, until 2015 cover the domestic electricity consumption needs, preserve its competitiveness in the open market conditions and increase its efficiency by applying modern technologies**.**

The production price of OS based power has increased during the last decade relatively little and amounts now to 28,2 euros per MWh, which competes with the production price of nuclear power in Lithuania and Finland (24-27 euros per MWh). The OS electricity price includes resource and environmental taxes in the amount worth mentioning (altogether 12%), although by EC Directive 2004/74 OS taxation in any form is not required before 01.01.2009. The selling price of shale oil depends on crude oil price in the European market, though it is much lower – now about 230-250 euros per t (31-34 euros per barrel) - and its production is highly profitable. This price competes well with the estimated price of shale oil in USA , in case of production in large quantities.

Estonia also stands out by its contribution to the power supply of other Baltic States (Table 4).

Table 4. Energy balance in Baltic countries, 2005

	Estonia	**Total in Baltic**
Consumption of primary energy, M toe	**5.64**	**19.34**
• **own production, %**	**71.1**	**62.2**
Total capacity power plants, MW	**2300**	**8800**
• **after closure of Ignalina *), MW**		**7500 *)**
Production of electricity, TWh	**10.3**	**34.3**
• **nuclear, %**	**-**	**44.1**
• **hydro, %**	**-**	**11.8**
• **natural gas, %**	**6.6**	**14.0**
• **oil shale, %**	**92.6**	**27.8**
• **renewable, %**	**0.8**	**2.3**

Up to now, the Baltic countries have formed an island, isolated from the EU power grid. The first link with Finland put into operation in the end of 2006 is of slight importance due to low capacity of its cable (360 MW) and lack of generating capacities in Finland. The security of power supply of Baltic countries will become complicated, too by the closing of the Ignalina nuclear plant in 2010. The construction of new nuclear reactors, as well as new power links (first of all Lithuania-Poland) may drag on for long time. That's why the development and modernization of the OS based power plants are an important task also on regional level.

Studies and development works in OS utilization must be first and foremost directed to the increase in the use of the total energy and chemical potential hidden in OS, to the enhancement of product value (motor fuels, chemicals etc.), to the better protection of the environment.

Conclusions

1. Huge oil shale resources in the world represent an important source for future energy supply.
2. Oil shale could be a useful part of the overall EU energy policy. Oil shale usage contributes to the security of energy supply in the Baltic region.
3. Direct combustion of oil shale for electricity production as also thermal processing of oil shale to oil products has shown a good technical progress and economic efficiency.
4. The long-term experience of oil shale utilization in Estonia has turned into valuable know-how for using oil shale of different deposits over the world.
5. EU should support efforts to further exploitation of the energy potential hidden in oil shale of the EU member states.