Environmental Impacts Of Oil Shale Mining And Processing In the Past, Present And Future

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Estonian Oil Shale Industry Timeline

*Estonia has almost 100 years of commercial oil shale experience*

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1916</td>
<td>First oil shale mines in Estonia</td>
</tr>
<tr>
<td>1918</td>
<td>Continuous mining</td>
</tr>
<tr>
<td>1924</td>
<td>First oil plant &amp; oil shale-fired power plant</td>
</tr>
<tr>
<td>1931</td>
<td>Gasoline refinery</td>
</tr>
<tr>
<td>1949-69</td>
<td>Four oil shale fired power plants</td>
</tr>
<tr>
<td>1980</td>
<td>Enefit’s Narva Oil Plant</td>
</tr>
<tr>
<td>2004</td>
<td>New CFB units for Narva Power Plants</td>
</tr>
<tr>
<td>2009</td>
<td>Investment decision for new generation Enefit oil plant</td>
</tr>
<tr>
<td>2011</td>
<td>Investment decision for new 300 MW power plant</td>
</tr>
<tr>
<td>2012</td>
<td>New Enefit280 unit operational</td>
</tr>
<tr>
<td>2015</td>
<td>New 300 MW power plant operational</td>
</tr>
<tr>
<td>2016</td>
<td>22,000 bbl/day domestic shale oil industry</td>
</tr>
</tbody>
</table>

More than 1,1 billion tons of oil shale has been mined

More than 600 TWh electricity has been produced from oil shale

Nearly 200 million barrels of shale oil has been produced

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Oil Shale Value Chain and Influences

Legislation: permits, monitoring, reporting, limit values etc.

Mining

Processing

Upgrading, refining

Landscape, resources

Waste and residuals

Air

Water
Legislation Development

- In early stages of the oil shale industry, activities were mainly regulated through mining laws, which also covered environmental elements. Other impacts were regulated through the reduction of possible hazard to human health.
- During the “Soviet” period, all industrial activities incl. oil shale mining and processing were regulated through limit values and normatives focusing on primarily human health and secondarily to preserve the environment.
- From the end of the 90s, Estonia started to integrate the EU environmental regulation into its legal system with all their scopes and priorities.
Legislation Today

- **Mining** is regulated through the **Earth Crust Law** and **mining permits**
- **Environmental impacts** are regulated:
  - Through **separate permits** for **water** (use and emissions, ELV), **air** (ELV, emissions) and **waste** (conditions, volumes, End Off Waste etc.)
  - Through the **integrated IPPC permit**, where all those topics are present
- Separate permits are issued for a certain **time period**, IPPC permits are **without an expiration date** but a **subject** to **yearly review**.
- Additionally, there is an extensive amount of **mandatory monitoring (CEM)**, **sampling** and **reporting**
- All permit conditions are based on **Environmental Impact Assessment (EIA)** or **Strategic Environmental Impact Assessment (SEIA) results**
- Legal framework and principles are based on the **EU Environmental legislation**, i.e. directives, decrees and regulations
Additional Volunteer Actions

In addition to requirements by law:

- Monitoring (CEM)
- Regular sampling
- Regular volunteer reporting

- Life Cycle Analysis (LCA) of our activities:
  - Electricity production from oil shale (OSELCA)
  - Environmental product declaration (EPD) for electricity
  - Liquid fuels production from oil shale for certain compounds

- EROI and other analysis and calculations
Mining activities

Main Impacts to Environment:
- Changes to the landscape
- Enrichment residuals
- Need to pump water for dry mining conditions

Regulating instruments:
- Mining permits to set the mining conditions (volumes, area, resource etc.)
- Waste, water and air permits to set relevant conditions (volumes, ELV, monitoring, reporting, sampling etc.)
- EIA process for renewing and applying new permits
- Regular inspection by the authorities
Water Pumping

Water pumping for mining is needed to maintain dry conditions during mining activities. Water from open pit mines consists of 75-80% surface and 20-25% groundwater. For an underground mine, it is up to 55% surface and at least 45% groundwater.

Possible impact to the water is the elevation of suspended solids and sulfates concentrations. Suspended solids are taken out in sedimentation ponds. Sulfate content will decrease by time and is not hazardous.

\[
\text{FeS}_2 + \frac{15}{4}\text{O}_2 + \frac{7}{2}\text{H}_2\text{O} \rightarrow 2\text{H}_2\text{SO}_4 + \text{Fe(OH)}_3
\]

\[
\text{H}_2\text{SO}_4 + \text{CaCO}_3 \rightarrow \text{Ca}^{2+} + \text{SO}_4^{2-} + \text{H}_2\text{O} + \text{CO}_2
\]

Over 500-600 mg/l CaSO\textsubscript{4} ↓
Mining Activities Environmental Performance

- Opencast mine
- Reforestation
- Recreation area
- Enrichment residuals
- Recreation objects
- Building materials
- Water pumping
- Settling ponds
- Trout farming or river
Closing Aidu Opencast Mine to Valuable Recreation Area for Local Community
Processing

Main Impacts to Environment:
- Air emissions
- Waste management
- Water use and emissions

Regulating instruments:
- IPPC permits that regulate all impacts, resource use (incl. fuels, chemicals, water etc.), monitoring, sampling, reporting etc.
- EU ETS permit and monitoring plan
- EIA process for renewing and applying for new permits
- Regular inspection by the authorities
Processing Environmental Performance

PP in 60s and 70s → Additional filtering system → PP today

SO2 emissions reductions from 190,000 t/y to 25,000 t/y

PM emissions reductions from 183,000 t/y to 5,500 t/y
Processing Environmental Performance

Estonian oil shale contains circa 1.5 – 1.7% sulfur and several times more calcium to bind it.

In the Pulverized Combustion (PC) process, 65-75% of the sulfur is bound by the calcium in fuel. By adding limestone (less enriched oil shale), the binding percent can rise to 80-85%.

The Alstom NID system, which uses the activated (wetted) flyash at lower temperatures can increase the binding percent to 95% and even high by adding additional CaO.

Changing from the PC process to Circulating Fluidized Bed (CFB) will increase the binding to 99.9%.
## Environmental Effect of Investments to Generation

<table>
<thead>
<tr>
<th></th>
<th>Old PC</th>
<th>Retrofitted PC</th>
<th>Repowered CFB</th>
<th>New CFB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Available Capacity, MWe</strong></td>
<td>180</td>
<td>180</td>
<td>215</td>
<td>300</td>
</tr>
<tr>
<td><strong>Unit net efficiency, %</strong></td>
<td>30</td>
<td>29-30</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td><strong>Emissions, mg/Nm$^3$ (new unit; old unit)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{SO}_2$ (200 mg/Nm$^3$; 95% S binding rate)</td>
<td>2400</td>
<td>200-400</td>
<td>0-20</td>
<td>0-20</td>
</tr>
<tr>
<td>$\text{NO}_x$ (200; 200 mg/Nm$^3$)</td>
<td>240-380</td>
<td>200</td>
<td>90-175</td>
<td>90-150</td>
</tr>
<tr>
<td>$\text{Fly ash}$ (10;30 mg/Nm$^3$)</td>
<td>150-300</td>
<td>10-30</td>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>
Handling of the Oil Shale Ash

• The majority of oil shale ash is stored/landfilled in the ash deposit by hydro transportation. Through proper operating, monitoring and improvements, this is the most **feasible** and **environmentally sound** method for oil shale ash **handling**.

• As alternative to deposits, we are **developing**, **testing** and **implementing** possible **reuse/recycling** options for the oil shale as **valuable** and **interesting** raw material. The goal is to increase the reuse rate by at least a factor of five during the next few years.
Upgrading and Refining

Main Impacts to Environment:
- Air emissions
- Waste management
- Water use and emissions

Regulating instruments:
- IPPC permits that regulate all the impacts, resources use (incl. fuels, chemicals, water etc.), monitoring, sampling, reporting etc.
- EIA process for renewing and applying for new permits
- Regular inspection by the authorities
Conclusions

• During the long history of oil shale use, the whole industry always had relevant developing legislation.
• If there is no direct oil shale legislation, it is possible to use other relevant legal acts to the same effect.
• Through our own additional activities, there is an extensive amount of information available regarding the stages of the oil shale use value chain.
• Constant investments and efforts have improved the environmental performance and created new opportunities for other industries and local community.
• Oil shale is viable energy option also from an environmental point of view.
Thank You for the Attention!

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