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Greenhouse Gas Emissions Analysis of Energy Production Processes from Estonian Oil Shale

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Background

- **The Fuel Quality Directive** imposes on fuel suppliers the obligation to reduce the *lifecycle greenhouse gas intensity* of fuel and other energy supplied for road vehicles by the year 2020 by at least 6% compared with the 2010 baseline.
- The proposal of implementation act of FQD sets the **average** default greenhouse gas intensity values for petrol (131.3 gCO2eq/MJ) and diesel (133.7 gCO2eq/MJ) made of oil shale (based on research of Dr. Brandt).
- Dr. Brandt has found, **based on the literature for technology ATP** (Alberta Taciuk Processor) system, that the CO2 lifecycle emissions in case of oil shale lies between 110 and 160 grams per MJ.

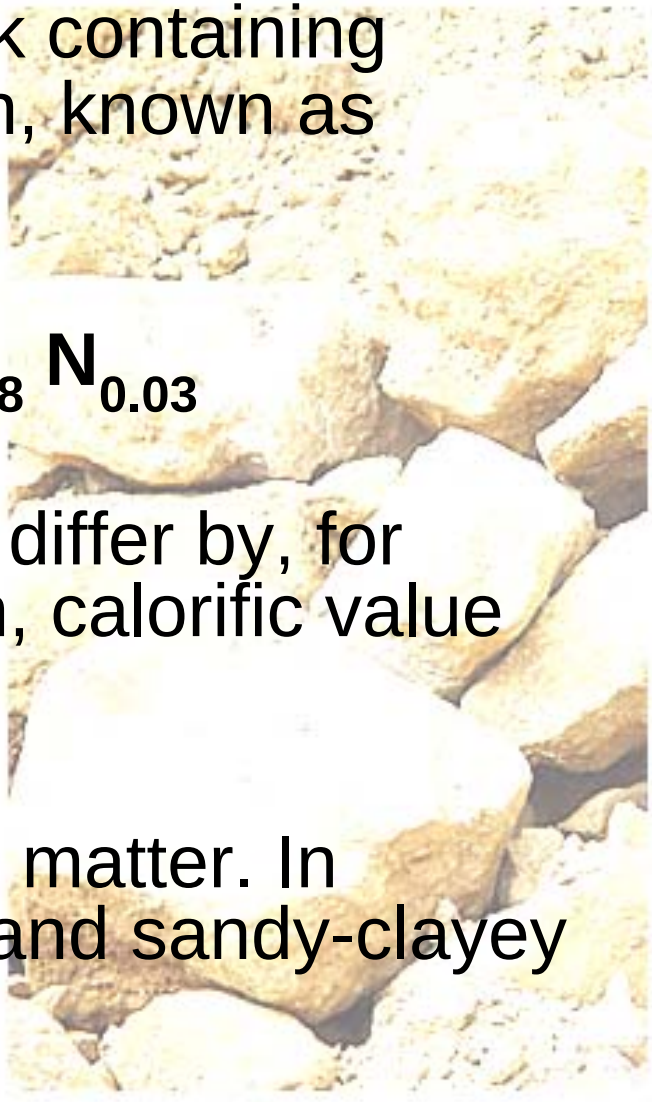
What is Oil Shale?

Oil shale is a sedimentary rock containing organic matter rich in hydrogen, known as kerogen Estonian oil shale:

$$C_{10}\ H_{15.2}\ O_{0.93}\ S_{0.08}\ N_{0.03}$$

Oil shales of different deposits differ by, for example, genesis, composition, calorific value and oil yield

Oil shale also contains mineral matter. In Estonian oil shale carbonates and sandy-clayey minerals



Estonian Oil Shale

resource for oil, energy and chemicals

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What can we produce from 1 ton of Estonian oil shale?

From 1 ton of oil shale (2030 kcal/kg)

125 kg of shale oil (9 500 kcal/kg)
35 Nm³ of retort gas (11 200 kcal/m³)

850 kWh of electricity

Estonian Oil Shale Uniqueness

- **Oil shale based product shale oil is the alternative fuel for crude oil.**
- Oil shale (the rock) can be found in China, Brazil, Australia, USA, Russia, Morocco, Jordan, Estonia and also in other EU countries (Italy Germany, Austria, France e.g.).
- Currently the biggest oil shale processors and shale oil producers are **Estonia,** China, Brazil.
- **Estonia is only shale oil producer in the EU.**
- **Estonia have long the 90 years experience to produce shale oil, the first shale oil plant was opened in 1924.**

Shale Oil production

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Today there are three (3) companies producing more as 600 thousand t of shale oil per year.

Today Estonian producers are producing three main fractions of shale oils and blends from these fractions. The main fractions of shale oils are:

- Shale Oil, **Light** with the boiling range 50-180, +/- 30°C
- Shale Oil, **Middle** fraction with the boiling range 120-330,
- Shale Oil, **Heavy** with the boiling range 330+ °C

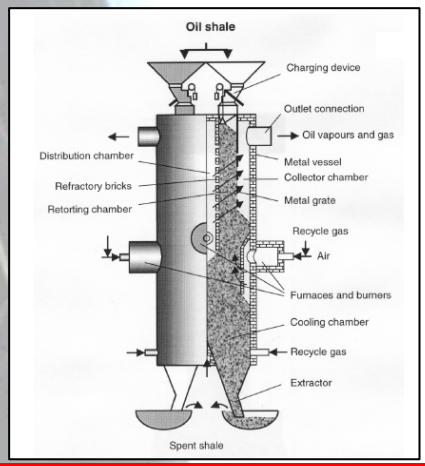
The main consumers of our products are:

- marine fuel producers (bunkering)
- boiler houses & small power plants
- approx 80% of produced shale oil is exported
- approx 20% is used by local heat producers

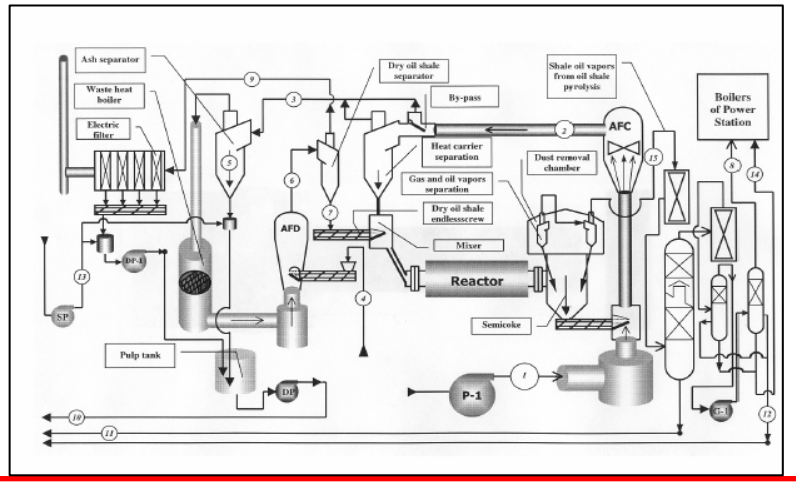
Based on the investment plans envisaged by the industry the probable amount of diesel from oil shale is approximately 15 000 -20 000 barrels per day.

Estonian oil shale processing technologies

KIVITER



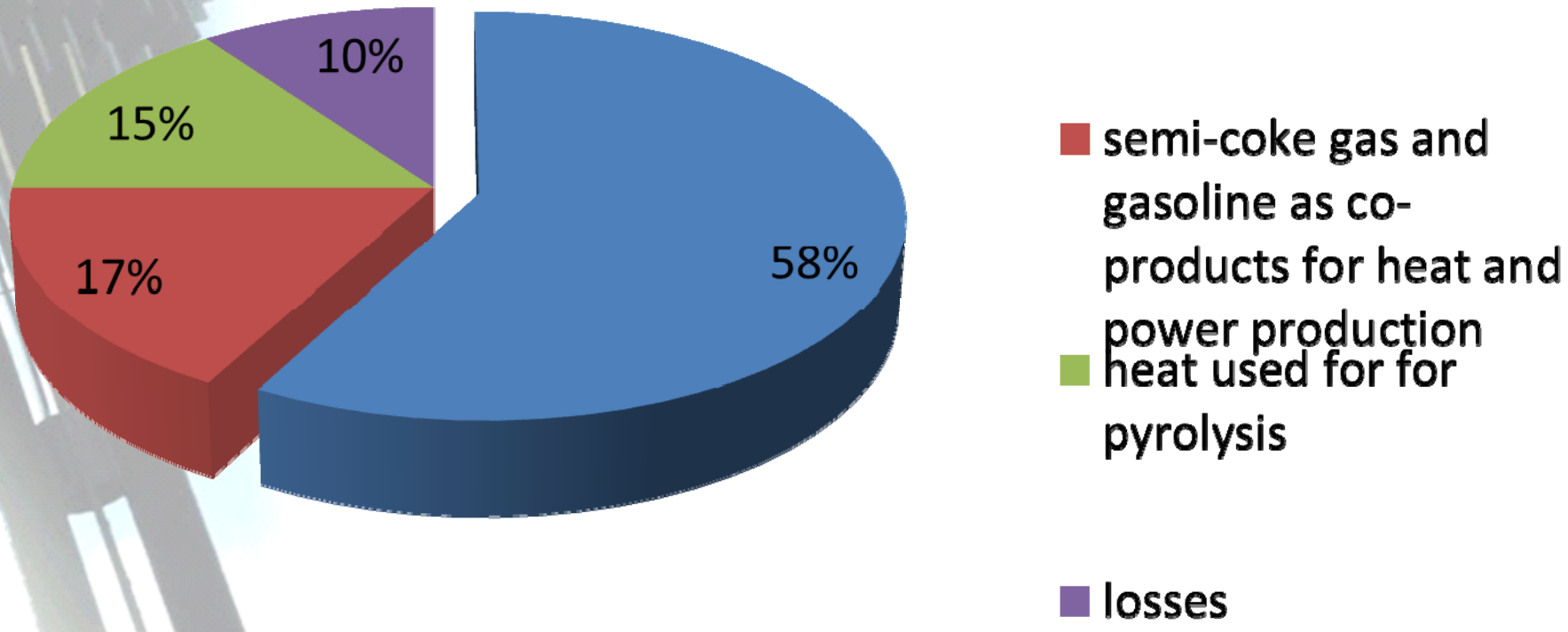
GALOTER- SHC-Petroter-ENEFIT



Factual data from the shale oil processing plants **located in the Republic of Estonia** needs to be used for definition of lifecycle greenhouse gas intensity

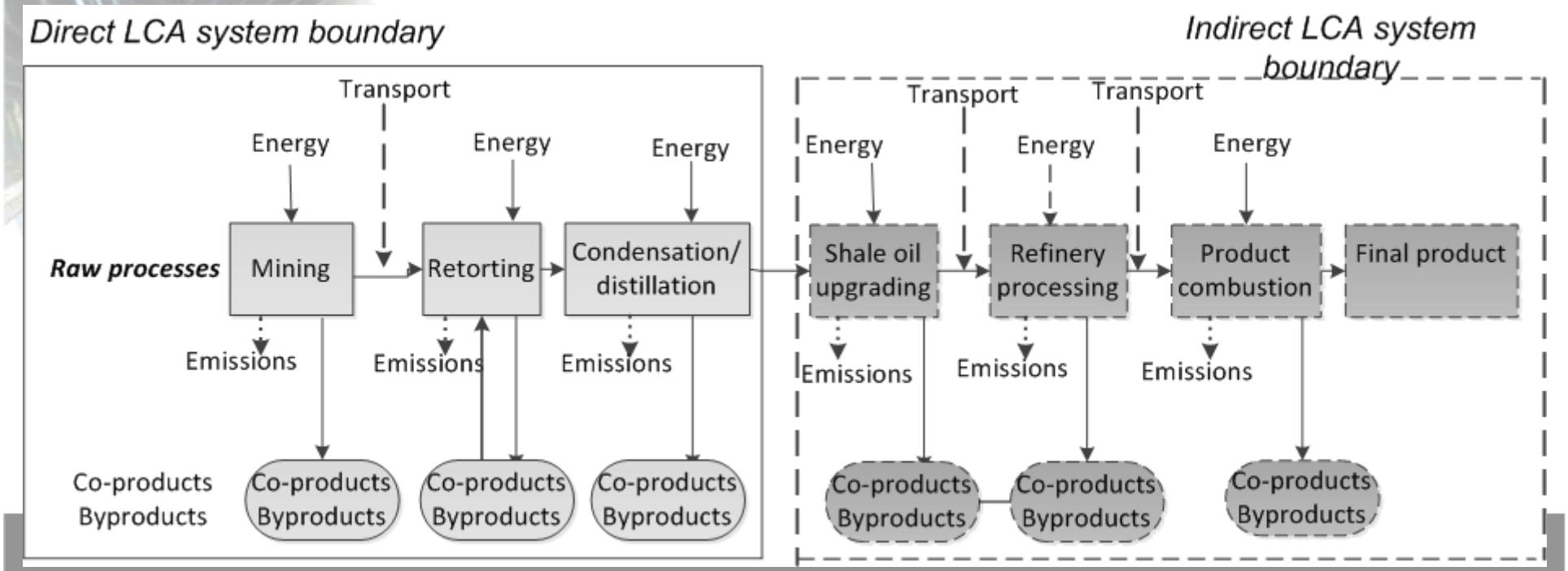
Scientific paper «Greenhouse Gas Emissions Analysis of Energy Production Processes from Estonian Oil Shale»

Heat balance of shale oil processing



Definition of oil shale emission factor via Life Cycle Assessment

- Based on the requirements of ISO 14040 and ISO 14044
- Time boundary: Data 2011-2012
- Geographical boundary: Estonia



Life Cycle Assessment modelling

- *SimaPro* modelling tool used

***SimaPro* is a professional tool developed by a Dutch engineering company *PRé Consultants* to collect, analyze,monitor and to measure the environmental impacts across all life cycle stages. Well equipped for life cycle analysis of energy production systems.**

- **The functional unit:** tonnes CO2-eq./1 TJ of shale oil produced from mining to retorting.

Life Cycle Inventory

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Stage	Data source*
Shale rock mining (energy requirements, quality of shale rocks)	• Monitoring data of Eesti Energia and VKG minings • European Union LIFE-Environment demonstration project OSELCA - Introduction and Implementation of Life Cycle Assessment Methodology in Estonia: Effects of Oil Shale Electricity on the Environmental Performance of Products
Transportation (distance, types of vehicles, fuel used, etc.)	• Eesti Energia Oil Industry and VKG Oil AS monitoring data on shale oil processing
Retorting, condensation and distillation (process description parameters, energy requirements, losses, reused energy, etc.)	• Eesti Energia Oil Industry and VKG Oil AS monitoring data on shale oil processing • Verification Report of Petroter Solid Heat Carrier-2011 • The greenhouse gas emissions reports of the operators

** Collected acc. to the ISO 14064*

NB: Eliminated emissions generated from reuse of residues of shale rocks in different sectors (for ex. road construction) are not included in the model.

Actual greenhouse gas intensity value for diesel made of shale oil

System stage	Gaseous heat carrier (Kiviter)	Solid heat carrier (Petroter)
	LCEF,(gCO2eq/MJ final product diesel)	LCEF,(gCO2eq/MJ final product diesel)
Mining	0.3	0.5
Transportation	0.2	0.3
Retorting, condensation and distillation	10.0	9.9
Shale oil upgrading and final refining	23.0	23.0
TOTAL	33.6	33.7
Final consumption	83	83
TOTAL	**116.6**	**116.7**

**LCEF - life cycle CO2 emissions factors*

LCA Conclusions

1. The first inclusive LCA analysis case study for the Estonian oil shale processing is developed and actual lifecycle greenhouse gas intensity value of diesel produced from oil shale defined as 116,7 gCO2eq/MJ.

2. Presented lifecycle greenhouse gas intensity for fuel made of shale oil based on the actual technological processes and data of the oil shale industries in the European Union, and take properly into account co-products.

3. Defined results corresponds to the shale oil processing plants located in the Republic of Estonia and are limited within this geographical and also technological boundary. Lifecycle greenhouse gas intensity depends on (1) oil shale processing technology and (2) raw material quality, extraction and transportation processes.

Established trends of oil shale use in Estonia

- Two usage trends have developed: using oil shale as solid fuel for production of electricity ; processing oil shale into shale oil, co-product gas and products of oil shale chemistry.
- According the Estonian „Oil shale development plan“ the maximum limit of oil shale mining is set to 20 million tons a year
- Estonia would like to become less carbon intensive in electricity production and therefore we constantly reduce the oil shale share in our electricity production mix.
- The losses of energy are remarkably lower in that case and the emissions per energy unit will be reduced more than twice.
- Production of shale oil in fact uses 5,8 times less water and generates 1,6 times less waste compared to the use for electricity. There is also significant decrease in terms of pollutants to the atmosphere.

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Full version of the scientific paper
A.Siirde, M.Eldermann, P.Rohumaa, J.Gusca. Greenhouse Gas Emissions Analysis of Energy Production Processes from Estonian Oil Shale
available at the Scientific Journal «Oil Shale» (ISSN 0208-189x), 2013, Vol. 30, Issue 2 s.
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