Oil Shale, 2011, Vol. 28, No. 1S, pp. 127–139
doi: 10.3176/oil.2011.1S.05
ISSN 0208-189X

ESTIMATION OF CARBON EMISSION FACTORS FOR THE ESTONIAN SHALE OIL INDUSTRY

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In this paper the country-specific carbon emission factors for the by-products from oil shale thermal processing (generator gas, semi-coke gas and semi-coke) for different technologies are presented. Today these emission factors have still not been determined in Estonia. As the shale oil production will increase significantly in the future, major attention should be paid to the oil shale production-related emission factors.

Introduction

Estonia is the biggest shale oil producer in Europe and one of four countries in the world (Russia, Brazil and China) commercially producing shale oil. There is some use and production of shale oils also in Austria and Germany for the medicine and cosmetics industries, but the quantities there are not comparable, either with the industrial production or the use of oils.

Shale oil production has gained importance in the light of higher oil prices, declining petroleum supplies and rapidly increasing demand from emerging economies.

Shale oil refers to any synthetic oil obtained by destructive retorting of oil shale. During the extraction process, the stable organic matter embedded in oil shale is thermally cracked and converted into oil, combustible gases, solid ash and semi-coke. The composition of shale oil depends on the used extraction technique, composition of kerogen and presence of non-organic phases such as sulphur, phosphate or nitrates.

In Estonia the Kiviter-type internal combustion vertical retorts and Galoter or Solid Heat Carrier units are used for shale oil production. During

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the shale oil production, combustible by-products are formed: generator gas, semi-coke gas and semi-coke.

For oil shale retorting in the Kiviter-type retorts a certain amount of generator gas is burned to get gaseous heat carrier (hot combustion products) for oil shale retorting, while the rest of generator gas is burned in power plant boilers. Semi-coke is not burned, but stored in the oil shale waste dump. In SHC units semi-coke is burned in the aerofountain furnace to get solid heat carrier (hot ash) for oil shale retorting. The generator gas is completely burned in power plant boilers.

Shale oil production technologies

In Estonia, thermal processing of oil shale for shale oil production is carried out in three different enterprises:

- Kohtla-Järve oil plant of the *Viru Keemia Grupp AS (VKG AS*),
- Narva oil plant *(Eesti Energia Õlitööstus AS*) and
- Kiviõli oil plant (*Kiviõli Keemiatööstuse OÜ).*

The total production of shale oil in these enterprises made about 500,000 tons in 2009 (Fig. 1).

There are two different oil shale thermal processing technologies applied in Estonia: the Kiviter-type internal combustion vertical retort [1] and the Galoter type or Solid Heat Carrier (SHC 140) unit [2]. In the present paper a brief overview of these two different oil shale processing technologies is given.

Oil shale processing in the vertical Kiviter retorts (so-called gas generators) with the gaseous heat carrier is a universal technology suitable for retorting high-calorific lump oil shale with the particle size of 25–125 mm. The vertical retort is a metal vessel lined inside with refractory bricks. The oil shale loading device (F), semi-coke unloading device (E) and extractor are arranged on the top and in the lower part of the retort vessel, respectively. Thermal processing of oil shale is carried out in the retorting chamber (C) in the cross flow of gaseous heat carrier (combustion products of generator gas). Hot gases heat up and dry oil shale, and after reaching the required temperature for retorting (450–550 °C), organic matter of oil shale starts to decompose. The mixture of heat carrier, oil and water vapour flows into the collector chamber (G) while semi-coke (retorted oil shale) moves downward to the cooling chamber (D). Oil vapours and gas are discharged from the retort to the oil separation system (H) via the outlet connections. Some of the discharged generator gas is burned in the combustion chamber of retort (A) for producing gaseous heat carrier. The most of generator gas is directed for firing into the power plant boilers. The simplified layout of oil shale retorting in vertical gas generators is given in Fig. 2.

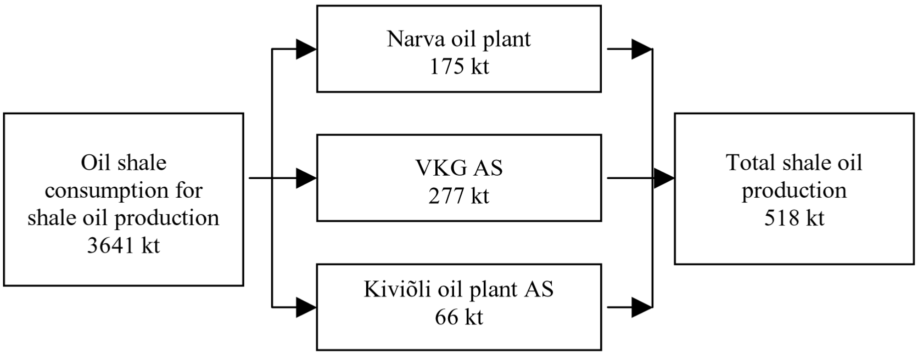

Fig. 1. Shale oil production in the Estonian oil plants in 2009, thousand tons. *Source: Oil plants data*

For the oil shale retorting process with solid heat carrier (the Galoter process), the oil shale with a particle size of 0–20 mm (as received) is used. Oil shale is heated up and dried with hot flue gases from the combustion of semi-coke in the aerofountain dryer (I). Dry oil shale is mixed with hot ash (750–800 °C) – a solid heat carrier. The ash is a by-product of semi-coke combustion in the aerofountain furnace (D). The ratio of heat carrier to oil shale is regulated by the required temperature of oil vapours leaving the retort and is controlled by the position of valve arranged in the heat carrier by-pass E. Dried oil shale and hot ash (heat carrier) are mixed. The mixture of oil shale and heat carrier is fed into the horizontal rotating retort (A). Thermal treatment of oil shale starts in the mixer (K) and continues in the retort. The contact of oil shale with heat carrier results in intensive formation of shale oil vapours and semi-coke. Fine semi-coke particles are removed from the gas and oil vapours in the dust removal chamber (B) and separator (C). After shale oil being condensed from oil vapours in the oil condensation system (O), the remained semi-coke gas is directed into the power plant boilers for production of heat and power. Semi-coke leaving the retort at 460 °C is delivered to the aerofountain furnace (D) for combustion. The gases from AFC contain combustible compounds and surplus of heat in the gases makes it possible to carry out the afterburning of these gases in waste heat boiler H. Flue gases from the aerofountain dryer (I) are cleaned in the electric precipitator (L) and discharged into the atmosphere through the oil plant stack (P). A simplified layout of the solid heat carrier retorting is given in Fig. 3.

For heat generation required in oil shale processing in the described retorts different combustible by-products of oil shale oil production are used.

In order to get a gaseous heat carrier some of the generator gas is burned in the combustion chamber during oil shale retorting in the vertical retort.

Combustion products of generator gas do not emit directly from the oil plant into the atmosphere, but remain in the generator gas as its components.

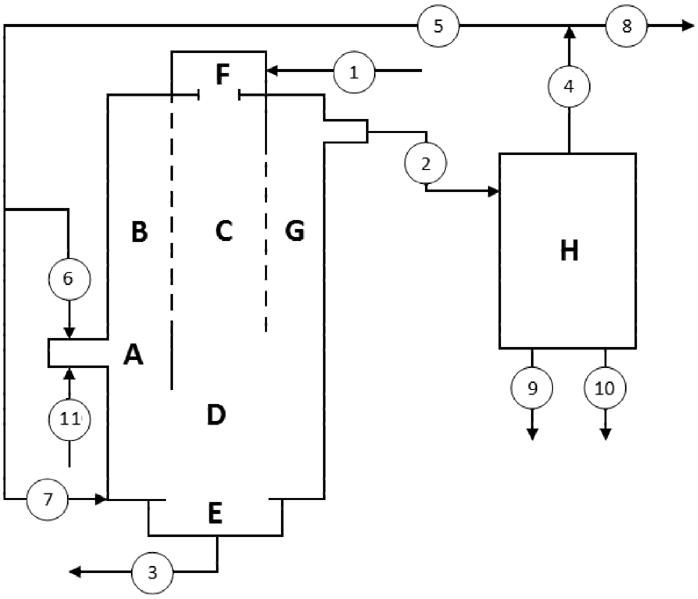

Fig. 2. Principal flow chart of oil shale retorting in the vertical retort.

Abbreviations:
A – generator gas combustion chamber; B – distribution chamber of hot gaseous combustion products (gaseous heat carrier); C – oil shale retorting chamber; D – semi-coke cooling chamber; E – semi-coke unloading device; G – collector chamber; F – oil shale loading device; H – oil separation system.

Main material flows:
1 – oil shale, 2 – oil vapours and gas; 3 – semi-coke into the oil shale waste dump; 4 – generator gas; 5 – generator gas into the retort; 6 – generator gas for burning in the retort; 7 – generator gas into the cooling chamber; 8 – generator gas for firing in the power plant boilers; 9 – shale oil to the fuel storage of oil plant; 10 – fusses; 11 – air.

Most of the generator gas is delivered to the power plants of neighbouring oil factory where it is burned for heat and power generation in the boilers. The yield of semi-coke in vertical retorts is approximately 49% per ton of raw oil shale [9]. The semi-coke which contains about 7–11.5% of carbon is not used, but stored in the dumps. In the future semi-coke will be used as a raw material in the cement industry.

Hot semi-coke ash is used for heating oil shale in the solid heat carrier retort. Hot products of semi-coke combustion are used for drying raw oil shale and after cleaning discharged into the atmosphere through the oil plant stack. Semi-coke gas is completely burned in the boilers of power plant, and its combustion products are sent into the atmosphere through the power plant stacks together with the flue gases of other fuels.

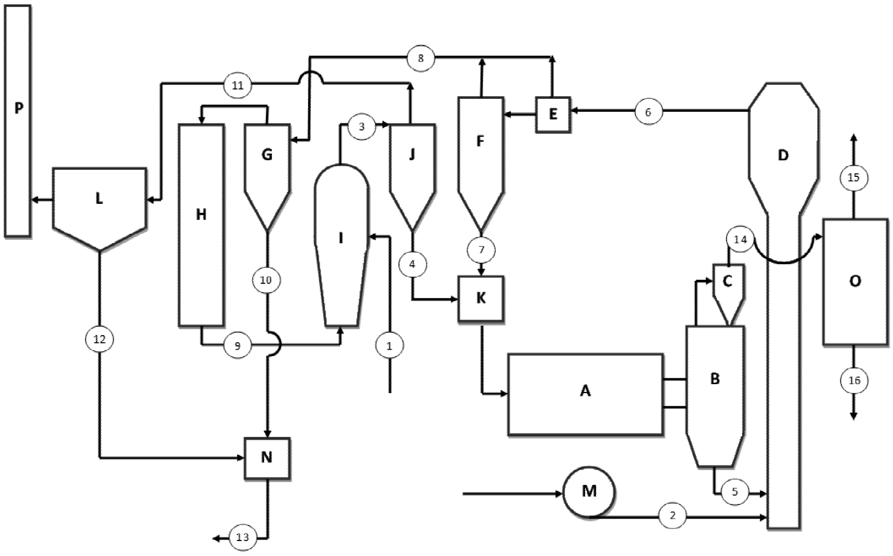

Fig. 3. Principal flow chart of retorting process with solid heat carrier.

Abbreviations:

A – reactor for oil shale pyrolysis; B – dust removal chamber; C – separator of gas and oil vapours; D – aerofountain combustor (AFC); E – by-pass; F – hot ash (heat carrier) separation cyclone; G – ash separation cyclones (1st, 2nd and 3rd stage); H – waste heat boiler; I – aerofountain dryer (AFD); J – dried oil shale separation cyclones (the 1st, 2nd and 3rd stage); K – dried oil shale and hot ash (heat carrier) mixer; L – electrostatic separator; M – centrifugal air blower; N – pulp tank; O – oil condensation system; P – stack.

Main material flows:

1 – raw oil shale, 2 – compressed air; 3 – dried oil shale with flue gases; 4 – dried oil shale; 5 – semi-coke; 6 – hot ash (solid heat carrier) with gases after semi-coke combustion in AFC;7 – hot ash (heat carrier); 8 – mixture of ash and AFC gases after partly separated hot ash required for the oil shale pyrolysis process; 9 – flue gas; 10 – ash; 11 – flue gas to the electric precipitator; 12 – electric precipitator ash; 13 – ash pulp of the retort to the dredger unit of the power plant; 14 – oil vapours after cleaning; 15 – semi-coke gas for firing in power plant boilers; 16 – shale oil to the fuel storage of the oil factory.

Method for estimating the carbon emission factors of semi-coke gas and semi-coke for solid heat carrier technologies

During the combustion of semi-coke and semi-coke gas, carbon dioxide will be formed. For estimating the amounts of CO_2 emissions carbon emission factors for semi-coke and semi-coke gas should be worked out.

The semi-coke gas formed in the solid heat carrier is characterised with a high content of burning compounds and its approximate lower heating value is 39.8–46.8 MJ/kg [3]. Besides methane, ethane and ethene are also the main compounds of the semi-coke gas. The composition of semi-coke gas by single compounds varies somewhat in different sources, because the composition of gas depends on the thermal processing regime. At the same time those differences are not significant.

Carbon emission factor of SHC-140 semi-coke gas

Table 1 shows the composition and heating value of semi-coke gas. The data was received from the Narva oil plant.

Table 1. **Composition of semi-coke gas from the Solid Heat Carrier-140 process**

Composition of semi-coke gas	Content in volume, %	Carbon mole ratio	Rate of C in gas, %	Heat value of gas Q^r_{scg}, MJ/nm^3	Rate of Q^r_{scg}, MJ/nm^3	Specific weight, kg/nm^3	Density rate, kg/nm^3
1	2	3	4=2×3	5	6=2×5/100	7	8=2×7/100
CO_2	9.54	12/44	2.60			1.964	0.187
H_2S	2.53			23.384	0.592	1.52	0.038
N_2	1.1					1.257	0.014
O_2	0.15					1.428	0.002
CO	9.53	12/28	4.08	12.636	1.204	1.25	0.119
H_2	13.31			10.798	1.437	0.09	0.012
CH_4	16.80	12/16	12.60	35.820	6.018	0.72	0.12
C_2H_6	10.00	24/30	8.00	63.751	6.375	1.34	0.13
C_2H_4	13.01	24/28	11.15	59.066	7.684	1.25	0.16
C_3H_8	4.25	36/44	3.48	91.256	3.878	1.97	0.08
C_3H_6	8.23	36/42	7.05	86.005	7.078	1.88	0.15
C_4H_{10}	1.29	48/58	1.07	118.651	1.531	2.59	0.03
C_4H_8+C_4H_6	5.68	48/56	4.87	113.514	6.448	2.50	0.14
C_5H_{12}	1.22	60/72	1.02	146.084	1.782	3.22	0.04
C_5H_{10}	1.40	60/70	1.20	140.780	1.971	3.12	0.04
C_6H_{10}	0.97	72/82	0.85	141.571	1.373	3.21	0.03
Total	99.01		57.97		47.37		1.318

Source: The detailed data on the composition of semi-coke gas was received from the Narva oil plant in 2009. The same data was used for preparing the Company Standard document while the data on unsaturated hydrocarbons was summarised [3, 4].

The factor of carbon emission from semi-coke gas combustion can be calculated by the following formula:

$$q_{c\ scg} = 10\,(12/16 \cdot CH_4 + 24/30 \cdot C_2H_6 + 24/28 \cdot C_2H_4 + 36/44 \cdot C_3H_8 + 36/42 \cdot C_3H_6 + 48/58 \cdot C_4H_{10} + 48/56 \cdot C_4H_8 + 60/72 \cdot C_5H_{12} + 60/70 \cdot C_5H_{10} + 72/82\ C_6H_{10} + 12/44 \cdot CO_2 + 12/28 \cdot CO)/Q^{r'}_{scg},\ \mathrm{tC/TJ}, \qquad (1)$$

where

$q_{c\ scg}$ – carbon emission factor of semi-coke gas, tC/TJ;
C_{Σ} – total carbon content in semi-coke gas, % and
$Q^{r'}_{gg}$ – lower heating value of semi-coke gas, MJ/kg.

Calculations:

Q^{r}_{scg} – lower heating value of semi-coke gas = 47.37 MJ/ nm^3;
ρ_{scg} – density of semi-coke gas 1.318 kg/nm^3 and
$Q^{r'}_{scg} = Q^{r}_{sg/}\ \rho_{sg} = 47.37/1.318 = 35.94$ MJ/kg.

The carbon emission factor of semi-coke gas:

$$q_{c\ scg} = 10 \cdot C_{\Sigma} / Q^{r'}_{scg} = 10 \cdot 57.97 / 35.94 = 16.13\ \mathrm{tC/TJ}.$$

Carbon emission factor of SHC-140 semi-coke

For the production of shale oil in a SHC unit, raw oil shale with the average lower heating value $Q^{r}_{os} = 8.34$ MJ/TJ[*] is used.

Since the average organic content of the solid heat carrier (semi-coke and oil shale dust) leaving the retort is 3.79% (C = 3.69% and H = 0.1%) and the ratio of semi-coke to ash equals 1/1.878, the carbon content of semi-coke could be calculated: (1+1.878) · 3.69 = 10.62% [4].

For calculating the carbon emission factor of semi-coke, heating value of oil shale (not of semi-coke) is used, and that allows calculating CO_2 emissions from the combustion of semi-coke based on the used oil shale. Due to a smaller extent of carbonate decomposition, the improved lower heating value of oil shale can be calculated (see Formula 4) [5]. The decomposition rate of the carbonate part of semi-coke in the aerofountain furnace is calculated as follows:

$$k_C = 0.47 \cdot CO_{2scg} / (CO_2)^{r}_{os}, \qquad (2)$$

where

k_C – decomposition rate of of semi-coke;
0.47 – ratio of semi-coke gas to gas-vapour mixture [6];
CO_{2scg} – content of CO_2 in semi-coke gas, % (see Table 1) and
$(CO_2)^{r}_{os}$ – content of CO_2 in oil shale as received, % [7].

$$k_c = 0.47 \cdot 9.54 / 20.1 = 0.223$$

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[*] Eesti Energia AS data

The carbon emission factor of semi-coke is calculated using the following formula:

$$q_{c\ sc} = 10 \cdot [C^{r}_{sc} + k_c \cdot (CO_2)^{r}_{M} \cdot 12/44]/Q^{r'}_{os,}\ \text{tC/TJ}, \tag{3}$$

where

$q_{c\ sc}$ – carbon emission factor of semi-coke;

C^{r}_{sc} – carbon content of semi-coke, %;

$(CO_2)^{r}_{M}$ – content of mineral CO_2 in oil shale, %;

k_c – decomposition rate of the carbonate part of semi-coke in the aerofountain furnace;

$Q^{r'}_{os}$ – improved heating value of oil shale, MJ/kg.

$$Q^{r'}_{os} = Q^{r}_{os} + \Delta Q \tag{4}$$

where

Q^{r}_{os} – lower heating value of oil shale, MJ/kg and

ΔQ – heat effect caused by non-decomposition of carbonates, MJ/kg [9].

$$\Delta Q = 0.0406\ (1 - k_c)\ (CO_2)^{r}_{M,} \tag{5}$$

$$\Delta Q = 0.0406 \cdot (1 - 0.223) \cdot 17.6 = 0.5552$$

$$Q^{r'}_{os} = 8.34 + 0.5552 = 8.895\ \text{MJ/kg}$$

$$q_{c\ sc} = 10 \cdot [10.62 + 0.223 \cdot 17.6 \cdot 12/44]/8.895 = 13.14\ \text{tC/TJ}$$

The combustion of semi-coke in the aerofountain furnace is performed under the conditions of air shortage ($\alpha < 1$). Therefore the value of oxidation factor (k_{ox}) by the combustion of semi-coke is approximately 0.7. CO_2 emission factor of semi-coke can be calculated as follows:

$$q_{CO2\ sc} = q_{c\ sc} \cdot k_{ox} \cdot 44/12\ \text{tCO}_2\text{/TJ}, \tag{6}$$

where

$q_{CO2\ sc}$ – CO_2 emission factor of semi-coke;

k_{ox} – oxidation factor of semi-coke.

$$q_{CO2\ sc} = 13.14 \cdot 0.7 \cdot 44/12 = 33.73\ \text{tCO}_2\text{/TJ}.$$

During oil shale retorting in the SHC-140, carbon dioxide will be formed at semi-coke combustion in the aerofountain furnace. The amount of CO_2 can be calculated by multiplying the amount of processed raw oil shale (measured in terajouls) with the carbon dioxide emission factor.

Estimation of the carbon emission factor for generator gas formed as a by-product of shale oil production in the Kiviter-type vertical retorts

The carbon emission factor of the VKG oil plant generator gas:

In Table 2 the composition of generator gas from the VKG oil plant is presented. Based on the composition the heating value and specific weight of the generator gas were calculated.

Table 2. **Composition of the generator gas from the Kiviter type vertical retort (in the VKG oil plant) [8]**

Composition of generator gas	Content in volume, %	Carbon mole ratio	Rate of C in gas, %	Heat value of gas Q^r_{gg}, MJ/nm^3	Rate of Q^r_{gg}, MJ/nm^3	Rate of Q^r_{gg}, kcal/nm^3	Specific weight, kg/nm^3	Density rate kg/nm^3
1	2	3	4=2×3	5	6=2×5/100	6=2×5/100	7	8=2×7/100
CO_2	17.3	12/44	4.72				1.964	0.3398
H_2S	0.4			23.384	0.094	22.34	1.52	0.0061
N_2	65.8						1.257	0.8271
O_2	1.1						1.428	0.0157
CO	7.3	12/28	3.13	12.636	0.922	220.31	1.25	0.0913
H_2	5.4			10.798	0.583	139.27	0.09	0.0049
CmHn(1)	2.7	24/28	2.31	71.179	1.922	459.00	1.251	0.0338
Total Σ	100.00		10.16		3.52	840.92		1.3186

[1] When the content of unsaturated hydrocarbons in the gas remains below 3%, the sum of these gases is equalled to ethene (C_2H_4) with lower heating value of 71.179 MJ/nm^3 [9].

The carbon emission factor for the generator gas can be calculated by using the formula (1).

$$q_{c\ gg} = 10 \cdot C_\Sigma / Q^{r'}_{gg}\ \text{tC/TJ}, \tag{7}$$

where

$q_{c\ gg}$ – carbon emission factor of generator gas, tC/TJ;
C_Σ – total carbon content in generator gas, % and
$Q^{r'}_{gg}$ – lower heating value of generator gas, MJ/kg.

Calculations:

Q^r_{gg} – lower heating value of generator gas: 3.52 MJ/nm^3;
ρ_{gg} – density of generator gas: 1.3186 kg/nm^3 and
$Q^{r'}_{gg} = Q^r_{gg} / \rho_{gg} = 3.52/1.3186 = 2.67$ MJ/kg (without heating value of benzene gas).

Carbon emission factor of generator gas (VKG oil factory):

$$q_{c\ gg} = 10 \cdot 10.16 / 2.67 = 38.06\ \text{tC/TJ}.$$

Carbon emission factor of Kiviõli oil plant generator gas

In Table 3 the composition of generator gas from the Kiviõli oil plant is presented.

Table 3. **Composition of the generator gas from the Kiviter type vertical retort in Kiviõli [10]**

Composition of generator gas	Content in volume, %	Carbon mole ratio	Rate of C in gas, %	Heat value of gas Q^r, MJ/nm^3	Rate of Q^r, MJ/nm^3	Rate of Q^r, kcal/nm^3	Specific weight, kg/nm^3	Density rate, kg/nm^3
1	2	3	4=2×3	5	6=2×5/100	6=2×5/100	7	8=2×7/100
CO_2	17.2	12/44	4.69				1.964	0.3378
H_2S	0.3			23.384	0.070	16.76	1.52	0.0046
N_2	67.0						1.257	0.8422
O_2	0.8						1.428	0.0114
CO	3.5	12/28	1.50	12.636	0.442	105.63	1.25	0.0438
H_2	7.0			10.798	0.756	180.53	0.09	0.0063
CmHn[1)]	1.8	24/28	1.54	71.179	1.281	306.0	1.251	0.0225
Total Σ	**97.6**		**7.73**		**2.55**	**608.92**		**1.2686**

[1] When the content of unsaturated hydrocarbons in the gas remains below 3%, the sum of these gases is equalled to ethene (C_2H_4) with lower heating value of 17,000 kcal/nm^3 [9].

The carbon emission factor for the generator gas can be calculated with using the formula (1).

$$q_{c\ gg} = 10 \cdot C_{\Sigma} / Q^{r'}_{gg} \text{ tC/TJ}, \qquad (8)$$

where

$q_{c\ gg}$ – carbon emission factor of generator gas, tC/TJ;

C_{Σ} – total carbon content in generator gas, % and

$Q^{r'}_{gg}$ – lower heating value of generator gas, MJ/kg.

Calculations:

Q^{r}_{gg} – lower heating value of generator gas: 2.55 MJ/nm^3;

ρ_{gg} – density of generator gas: 1.2686 kg/nm^3 and

$Q^{r'}_{gg} = Q^{r}_{gg} / \rho_{gg} = 2.55/1.2686 = 2.01$ MJ/kg (without heating value of benzene gas).

Carbon emission factor of generator gas (in Kiviõli):

$$q_{c\ gg} = 10 \cdot 7.73 / 2.01 = 38.46 \text{ tC/TJ}.$$

Corrected carbon emission factors of generator gas

The generator gas contains benzene gas gases: in the VKG oil plant *b* = 16–24 g/nm^3 (mean – 20 g/nm^3) [8] and in the Kiviõli oil plant *b* = 8–40 g/nm^3, (mean 24 g/nm^3) [10]. If to take into consideration the benzene gas content of generator gases, the corrected carbon emission factor for the generator gas can be calculated as

$$q_{c\ ggb} = q_{c\ gg} \cdot Q^r_{gg} / (Q^r_{gg} + b \cdot Q^r_{gb}) + q_{c\ gb} \cdot b \cdot Q^r_{gb} / (Q^r_{gg} + b \cdot Q^r_{gb}),\ \text{tC/TJ}, \quad (9)$$

where

$q_{c\ ggb}$ – carbon emission factor of generator gas with benzene gas, tC/TJ;
$q_{c\ gb}$ – carbon emission factor of benzene gas, tC/TJ;
Q^r_{gb} – heating value of benzene gas, MJ/kg and
b – benzene gas content of generator gas, kg/nm^3.

Table 4. **Corrected carbon emission factors of generator gas**

	VKG oil plant	Kiviõli oil plant
Carbon emission factor of generator gas, tC/TJ	38.06	38.46
Carbon emission factor of benzene gas, tC/TJ [11]	19.91	19.91
Heating value of generator gas, MJ/ nm3	3.52	2.55
Heating value of benzene gas, MJ/kg [11]	44.0	44.0
Medium benzene gas content of generator gas, kg/nm3	0.02	0.024
Corrected carbon emission factor (generator gas with benzene gas), tC/TJ	34.43	33.03

Carbon stored in semi-coke

Semi-coke removed from vertical retorts contains a small amount of organic matter that can be fired. Up to now, semi-coke has not been used but stored in the shale waste dump near the oil plants. The carbon content factor of semi-coke for calculating the carbon amount stored in semi-coke can be found by the following formula:

$$q_{c\ sc} = 10 \cdot C^d_{sc} / Q^r_{sc}\ \text{tC/TJ}, \quad (10)$$

where

C^d_{sc} – carbon content of semi-coke, %;
Q^r_{sc} – heating value of semi-coke, MJ/kg.

The carbon content factor of semi-coke for calculating the carbon amount stored in semi-coke from the VKG AS (C^d_{sc} = 11.3%; Q^r_{sc} = 4.0 MJ/kg) is:

$$q_{c\ sc} = 10 \cdot 11.3 / 4.0 = 28.25\ \text{tC/TJ}.$$

Conclusions

In the present paper the carbon emission factors of by-products from oil shale thermal processing and calculation methods for the emission factors are presented for the first time. The results are given in Table 5.

The carbon content factor of semi-coke can be found by the formula (10) and used for calculating the stored carbon amount in semi-coke.

Table 5. **Carbon emission factors of by-products from oil shale thermal processing**

Technology	By-product	Carbon emission factor, tC/TJ	
Narva oil plant			
SHC-140 process	Semi-coke gas	$q_{c\ scg}$	16.13
SHC 140 process	Semi-coke	$q_{c\ sc}$	13.14 1)
VKG oil plant			
Kiviter-type vertical retorts	Generator gas	$q_{c\ gg}$	34.43
Kiviõli oil plant			
Kiviter-type vertical retorts	Generator gas	$q_{c\ gg}$	33.03

1) The amount of carbon in semi-coke combustion products can be calculated by multiplying the amount of used raw oil shale (in terajouls) with the carbon emission factor $q_{c\ sc}$.

In this paper the carbon emission factors of by-products from oil shale thermal processing are calculated basing on available data. If the composition of generator gas, semi-coke gas or semi-coke will be specified, the proposed calculation method of carbon emission factors for these fuels could be used.

The results of the paper will be used in the annual Estonian National Greenhouse Gas Inventories for reporting to the European Commission and UNFCCC Secretariat according to the Estonia's Commitment under the Kyoto Protocol.

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Received October 12, 2010