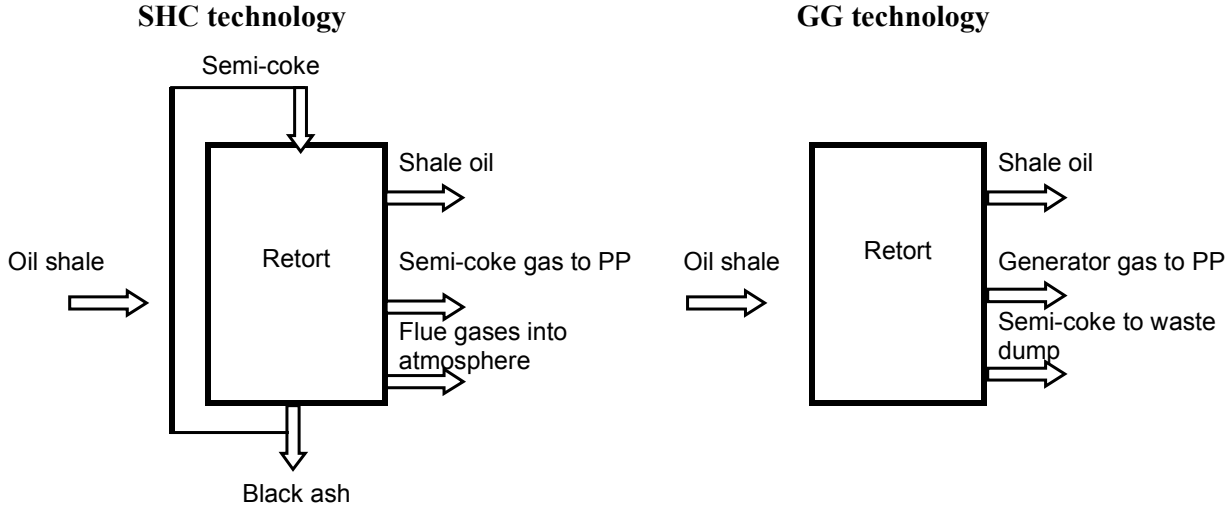
Annex 2. Detailed discussion of methodology and data for estimating CO_2 emissions from fossil fuel combustion

Description of shale oil production technologies and detailed methodology for estimation of carbon emission factors of oil shale gases

There are two different technologies for shale oil production in Estonia: oil shale thermal processing with solid heat carrier (SHC technology) and oil shale thermal processing with gaseous heat carrier in gas generators (GG technology). In 2010 three oil production companies and 5 oil plants were in operation:

1. AS Eesti Energia Narva Oil Plant – SHC technology plant;
2. Viru Chemistry Group AS (VKG) Oil Plant – SHC technology plant (since 2010) and GG technology plant;
3. Kiviõli Oil Plant – SHC technology plant (since 2010) and GG technology plant.

The following simplified schemes describe the output products and waste by different oil shale thermal processing technologies.



During oil shale thermal processing in retort shale oil (a liquid fuel) and semi-coke or generator gas will by formed (depending of technology used). Oil shale gases are usually delivered to power plants nearby for combustion and no GHG or other emissions will be emitted at oil plant. The waste product of the oil shale processing is semi-coke. Using GG technology formed semi-coke will be delivered to waste dump and the small amount of carbon in semi-coke will be stored. Using SHC technology formed semi-coke will be delivered for combustion in aerofountain chamber. The combustion product – flue gases have been used for oil shale draining and after that delivered into atmosphere. To find the amount of CO_2 emitted with flue gases into atmosphere a carbon balance method has been developed.

The idea of carbon balance method is very simple: from the carbon amount delivered with oil shale into retorting process will be take off carbon amount of shale oil, semi coke gas and black ash. The rest of the carbon is the amount which will be emitted into atmosphere.

For generator gas technology the carbon balance method was used to estimate the amount of carbon delivered with semi-coke to waste dump.

Table A.2.1. Composition of semi-coke gas from the Narva Solid Heat Carrier-140 processes

Composition of semi-coke gas	Content in volume %	Carbon mole ratio	Density (kg/Nm^3)	Density rate (kg/Nm^3)	Rate of C in gas volume, %	Rate of C in gas weight, %	Heat value of gas Q^r_{scg} (MJ/Nm^3)	Rate of Q^r_{scg} (MJ/Nm^3)
1	2	3	4	5=2×3/100	6=2×3	7=6×4/Σ5	8	9=2×8/100
CO_2	9.54	12/44	1.964	0.187	2.60	3.88		
H_2S	2.53		1.520	0.038	0.00	0.00	23.38	0.59
N_2	1.1		1.257	0.014	0.00	0.00		0.00
O_2	0.15		1.428	0.002	0.00	0.00		0.00
CO	9.53	12/28	1.250	0.119	4.08	3.87	12.64	1.20
H_2	13.31		0.090	0.012	0.00	0.00	10.80	1.44
CH_4	16.80	12/16	0.720	0.121	12.60	6.88	35.82	6.02
C_2H_6	10.00	24/30	1.340	0.134	8.00	8.13	63.75	6.38
C_2H_4	13.01	24/28	1.250	0.163	11.15	10.58	59.07	7.68
C_3H_8	4.25	36/44	1.970	0.084	3.48	5.20	91.26	3.88
C_3H_6	8.23	36/42	1.880	0.155	7.05	10.06	86.01	7.08
C_4H_{10}	1.29	48/58	2.590	0.033	1.07	2.10	118.65	1.53
C_4H_8+C_4H_6	5.68	48/56	2.500	0.142	4.87	9.23	113.51	6.45
C_5H_{12}	1.22	60/72	3.220	0.039	1.02	2.48	146.08	1.78
C_5H_{10}	1.40	60/70	3.120	0.044	1.20	2.84	140.78	1.97
C_6H_{10}	0.97	72/82	3.210	0.031	0.85	2.07	141.57	1.37
Total	**99.01**			**1.318**		**67.335**		**47.372**

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

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

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.

Q^r_{scg} – lower heating value of semi-coke gas: = **47.372 MJ/Nm^3**,
ρ_{scg} – density of semi-coke gas 1.318 kg/Nm^3 and
$Q^{r'}_{scg} = Q^r_{sg/}\ \rho_{sg} = 47.37/1.318 =$ **35.93 MJ/kg.**

The carbon emission factor of Narva semi-coke gas:

$$q_{c\ scg} = 10 \times C_\Sigma / Q^{r'}_{scg} = 10 \times 57.97/35.93 = \mathbf{18.74\ tC/TJ}$$

Table A.2.2. Composition of semi-coke gas from the VKG Solid Heat Carrier-140 (Petroter) processes

Composition of semi-coke gas	Content in volume %	Carbon mole ratio	Density (kg/Nm^3)	Density rate (kg/Nm^3)	Rate of C in gas volume, %	Rate of C in gas weight, %	Heat value of gas Q^r_{scg} (MJ/Nm^3)	Rate of Q^r_{scg} (MJ/Nm^3)
1	2	3	4	5=2×3/100	6=2×3	7=6×4/Σ5	8	9=2×8/100
CO_2	10.37	12/44	1.964	0.204	2.828	4.479		
H_2S	1.97		1.52	0.030			23.384	0.461
N_2	5.31		1.257	0.067				0.000
O_2	0.33		1.428	0.005				0.000
CO	10.56	12/28	1.25	0.132	4.526	4.562	12.636	1.334
H_2	14.32		0.09	0.013		0.000	10.798	1.546
CH_4	18.06	12/16	0.72	0.130	13.545	7.865	35.82	6.469
C_2H_6	9.12	24/30	1.34	0.122	7.296	7.884	63.751	5.814
C_2H_4	13.41	24/28	1.25	0.168	11.494	11.587	59.066	7.921
C_3H_8	2.83	36/44	1.97	0.056	2.315	3.679	91.256	2.583
C_3H_6	7.65	36/42	1.88	0.144	6.557	9.941	86.005	6.579
C_4H_{10}	0.88	48/58	2.59	0.023	0.728	1.521	118.651	1.044
C_4H_8+C_4H_6	2.65	48/56	2.5	0.066	2.271	4.579	113.514	3.008
C_5H_{12}	2.54	60/72	3.22	0.082	2.117	5.497	146.084	3.711
C_5H_{10}		60/70	3.12	0.000	0.000	0.000	140.780	0.000
C_6H_{10}		72/82	3.21				141.571	0.000
Total	**100**			**1.240**		**61.595**		**40.470**

Using the formula 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.

Q^r_{scg} – lower heating value of semi-coke gas: = **40.47 MJ/Nm^3**,
ρ_{scg} – density of semi-coke gas 1.24kg/Nm^3 and
$Q^{r'}_{scg} = Q^r_{sg/}\ \rho_{sg} = 40.47/1.24 =$ **32.631 MJ/kg.**

The carbon emission factor of VKG semi-coke gas:

$$q_{c\ scg} = 10 \times C_{\Sigma\ /}\ Q^{r'}_{scg} = 10 \times 61.595/32.631 = \textbf{18.876 tC/TJ}$$

Table A.2.3. Composition of semi-coke gas from the Kiviõli Solid Heat Carrier-140 processes

Composition of semi-coke gas	Content in volume %	Carbon mole ratio	Density (kg/Nm^3)	Density rate (kg/Nm^3)	Rate of C in gas volume, %	Rate of C in gas weight, %	Heat value of gas Q^r_{scg} (MJ/Nm^3)	Rate of Q^r_{scg} (MJ/Nm^3)
1	2	3	4	5=2×3/100	6=2×3	7=6×4/Σ5	8	9=2×8/100
CO_2	2.44	12/44	1.96	0.05	0.67	1.05		
H_2S	0.045		1.52	0.00			23.38	0.01
N_2	28.565		1.26	0.36				0.00
O_2	4.48		1.43	0.06				0.00
CO	8.133	12/28	1.25	0.10	3.49	3.51	12.64	1.03
H_2	13.883		0.09	0.01		0.00	10.80	1.50
CH_4	13.902	12/16	0.72	0.10	10.43	6.05	35.82	4.98
C_2H_6	7.188	24/30	1.34	0.10	5.75	6.21	63.75	4.58
C_2H_4	10.218	24/28	1.25	0.13	8.76	8.83	59.07	6.04
C_3H_8	2.307	36/44	1.97	0.05	1.89	3.00	91.26	2.11
C_3H_6	6.123	36/42	1.88	0.12	5.25	7.96	86.01	5.27
C_4H_{10}	0.842	48/58	2.59	0.02	0.70	1.46	118.65	1.00
C_4H_8+C_4H_6	1.888	48/56	2.50	0.05	1.62	3.26	113.51	2.14
C_5H_{12}		60/72	3.22	0.00	0.00	0.00	146.08	0.00
C_5H_{10}		60/70	3.12	0.00	0.00	0.00	140.78	0.00
C_6H_{10}		72/82	3.21				141.57	0.00
Total	**100.0**			**1.140**		**41.339**		**28.648**

Using the formula 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.

Q^r_{scg} – lower heating value of semi-coke gas: = **28.648 MJ/Nm^3**,
ρ_{scg} – density of semi-coke gas 1.14 kg/Nm^3 and
$Q^r_{scg} = Q^r_{sg/}\ \rho_{sg}$ = 28.648/1.14 = **25.141 MJ/kg.**

The carbon emission factor of Kiviõli semi-coke gas:

$$q_{c\ scg} = 10 \times C_{\Sigma\ /}\ Q^r_{scg} = 10 \times 41.339/25.141 = \mathbf{16.443\ tC/TJ}$$

Table A.2.4. Composition of the VKG generator gas

Composition of generator gas	Content in volume %	Carbon mole ratio	Density (kg/Nm^3)	Density rate (kg/Nm^3)	Rate of C in gas volume, %	Rate of C in gas weight, %	Heat value of gas Q^r_{gg} (MJ/Nm^3)	Rate of Q^r_{gg} (MJ/Nm^3)
1	2	3	4	5=2×3/100	6=2×3	7=6×4/Σ5	8	9=2×8/100
CO_2	17.3	12/44	1.964	0.340	4.72	7.03		
H_2S	0.4		1.520	0.006	0.00	0.00	23.38	0.09
N_2	65.8		1.257	0.827	0.00	0.00		0.00
O_2	1.1		1.428	0.016	0.00	0.00		0.00
CO	7.3	12/28	1.250	0.091	3.13	2.96	12.64	0.92
H_2	5.4		0.090	0.005	0.00	0.00	10.80	0.58
C_mH_n (C_2H_4)	2.7	24/28	1.250	0.034	2.31	2.19	59.07	1.59
Total	**100.00**			**1.319**		**12.184**		**3.194**

Using the formula 1,

where

$q_{c\ scg}$ – 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.

Q^r_{scg} – lower heating value of generator gas: = **3.194 MJ/Nm^3**,
ρ_{scg} – density of generator gas 1.14 kg/Nm^3 and
$Q^{r'}_{scg} = Q^r_{sg/}\ \rho_{sg}$ = 3.194/1.319 = **2.42 MJ/kg.**

The carbon emission factor of VKG generator gas:

$$q_{c\ scg} = 10 \text{ x } C_\Sigma / Q^{r'}_{scg} = 10 \text{ x } 12.184/2.42 = \textbf{50.3 tC/TJ}$$

Table A.2.5. Composition of the Kiviõli generator gas

Composition of generator gas	Content in volume %	Carbon mole ratio	Density (kg/Nm^3)	Density rate (kg/Nm^3)	Rate of C in gas volume, %	Rate of C in gas weight, %	Heat value of gas Q^r_{gg} (MJ/Nm^3)	Rate of Q^r_{gg} (MJ/Nm^3)
1	2	3	4	5=2×3/100	6=2×3	7=6×4/Σ5	8	9=2×8/100
CO_2	17.241	12/44	1.964	0.3386	4.70	7.34		
H_2S	0.451		1.520	0.0069	0.00	0.00	23.384	0.105
N_2	67.783		1.257	0.8520	0.00	0.00		0.000
O_2	2.016		1.428	0.0288	0.00	0.00		0.000
CO	4.126	12/28	1.25	0.0516	1.77	1.76	12.636	0.521
H_2	5.423		0.09	0.0049	0.00	0.00	10.798	0.586
CH_4	1.659	12/16	0.72	0.0119	1.24	0.71	35.820	0.594
C_2H_6	0.291	24/30	1.34	0.0039	0.23	0.25	63.751	0.186
C_3H_8	0.099	36/44	1.97	0.0020	0.08	0.13	91.256	0.090
C_4H_{10}	0.046	48/58	2.59	0.0012	0.04	0.08	118.651	0.055
C_2H_4	0.590	24/28	1.25	0.0074	0.51	0.50	59.066	0.348
C_3H_6	0.213	36/42	1.88	0.0040	0.18	0.27	86.005	0.183
C_4H_8	0.063	48/56	2.50	0.0016	0.05	0.11	113.514	0.072
Total	**100.00**			**1.315**	**8.81**	**11.14**		**2.74**

Using the formula 1,

where

$q_{c\ scg}$ – 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.

Q^r_{scg} – lower heating value of generator gas: = **2.74 MJ/Nm^3**,
ρ_{scg} – density of generator gas 1.14 kg/Nm^3 and
$Q^{r'}_{scg} = Q^r_{sg/}\ \rho_{sg} = 2.74/1.315 =$ **2.084 MJ/kg.**

The carbon emission factor of Kiviõli generator gas:

$$q_{c\ scg} = 10 \times C_\Sigma / Q^{r'}_{scg} = 10 \times 11.14/2.084 = \mathbf{53.43\ tC/TJ}$$

A.2.6. Carbon Balances

Activity data used in calculations in carbon balances are collected from private companies and are therefore considered confidential.

AD on oil shale, shale oil and oil shale gases production by oil companies and calculations of carbon balances are not part of the national inventory report and are allocated into archive. The data can be made available during the review process for review team.

Table A.2.7. Carbon stored with semi-coke

Narva	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Amount of black ash to landfill	TJ	76	42	63	103	115	104	112	124	103	99	140	151	163	188	197	215	202	199	268	317	357
Carbon stored with black ash	Gg	2.30	1.27	1.93	3.14	3.51	3.18	3.40	3.79	3.15	3.03	4.25	4.59	4.97	5.73	6.01	6.56	6.17	6.06	8.17	9.67	10.87

VKG	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Semi-coke to landfill	TJ	2 974	2 678	2 541	2 820	2 866	2 820	3 012	2 983	1 857	1 367	1 887	2 148	2 251	2 355	2 457	2 484	2 763	2 906	2 803	2 893	2 962
Carbon stored with semi-coke	Gg	122.27	107.69	96.32	121.14	67.47	118.18	106.42	113.83	91.85	57.92	73.99	112.43	83.17	85.98	91.91	104.83	96.36	90.98	87.68	83.40	101.18
Semi-coke to landfill	TJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.92
Carbon stored with black ash	Gg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.55

Kiviõli	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Semi-coke to landfill	TJ	681	673	675	684	615	650	665	680	531	60	662	663	694	708	733	745	747	768	783	781	791
Carbon stored with semi-coke	Gg	53.31	47.26	44.06	47.79	40.99	44.15	45.56	48.66	36.53	3.48	41.73	40.73	44.06	42.46	29.66	20.11	14.98	13.62	9.00	11.02	12.11
Semi-coke to landfill	TJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.65
Carbon stored with black ash	Gg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.66

Total carbon stored with semi-coke

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Oil shale total	TJ	3 731	3 393	3 279	3 607	3 596	3 574	3 789	3 788	2 491	1 526	2 689	2 961	3 108	3 251	3 386	3 444	3 712	3 872	3 854	3 991	4 149
Carbon stored with semi-coke and black ash	Gg	177.89	156.23	142.31	172.08	111.96	165.51	155.38	166.27	131.53	64.43	119.97	157.76	132.21	134.17	127.58	131.50	117.51	110.66	104.85	104.09	125.37

Table A.2.8. Fuel combustion by fuel types, PJ

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Solid fuels	**237.55**	**215.08**	**173.09**	**131.96**	**137.78**	**127.00**	**130.91**	**127.99**	**114.12**	**107.51**	**107.89**	**105.96**	**102.80**	**121.10**	**121.17**	**115.08**	**108.28**	**134.65**	**124.32**	**105.68**	**146.19**
Oil Shale	215.38	195.44	158.51	121.33	128.04	115.20	118.47	116.97	106.75	101.54	100.49	97.13	94.99	113.56	113.37	107.38	99.57	123.70	113.06	95.38	132.12
Peat (milled)	1.81	1.13	1.17	1.12	1.22	1.81	1.32	1.35	0.99	0.76	0.69	1.17	1.22	1.18	0.97	1.01	1.22	1.60	1.26	1.44	1.66
Peat (sod)	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.85	0.87	0.68	0.69	0.60	0.75	0.76	0.79	0.59	0.57	0.61	0.59	0.57	0.50
Peat Briquette	3.59	3.34	2.61	2.03	1.58	2.16	2.00	1.10	0.55	0.51	0.47	0.27	0.30	0.33	0.24	0.21	0.19	0.21	0.27	0.16	0.18
Coal	9.29	9.00	5.69	2.93	2.19	2.50	2.80	2.41	1.83	1.95	2.29	2.96	1.61	1.19	1.56	1.50	1.89	3.54	3.48	2.35	1.62
Oil shale semi-coke gas	0.70	0.37	0.54	0.70	0.91	0.90	1.00	1.05	0.92	0.79	1.04	1.26	1.26	1.32	1.48	1.59	1.62	1.53	2.00	2.40	6.34
Oil shale generator gas	6.37	5.48	4.49	3.76	3.80	4.40	4.28	4.26	2.17	1.24	2.17	2.44	2.64	2.74	2.76	2.78	3.21	3.46	3.65	3.38	3.77
Coke	0.41	0.32	0.09	0.08	0.05	0.03	0.03	0.02	0.03	0.03	0.05	0.13	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01
Liquid fuels	**121.83**	**110.96**	**61.64**	**59.84**	**58.33**	**46.82**	**49.90**	**48.49**	**48.33**	**43.73**	**36.13**	**42.18**	**43.30**	**42.24**	**42.33**	**42.67**	**42.73**	**44.76**	**41.89**	**38.91**	**41.19**
Heavy fuel oil	67.84	61.69	26.86	28.66	23.40	14.41	15.72	13.05	13.52	10.98	3.73	3.34	2.38	1.21	0.67	0.51	0.23	0.26	0.20	0.19	0.22
Light fuel oil	5.05	3.69	1.60	0.86	0.73	0.97	1.69	1.96	2.23	2.69	3.21	4.88	4.73	4.70	4.34	4.00	2.56	2.88	2.81	2.14	2.06
Motor gasoline	22.84	20.26	9.85	10.10	12.49	10.75	12.07	13.14	12.68	12.04	12.15	14.42	13.37	13.00	12.40	12.47	13.53	14.20	14.05	12.91	11.96
Diesel Oil	24.44	23.77	14.40	13.26	14.31	12.98	14.18	14.11	15.12	12.65	12.43	14.18	17.70	18.23	19.50	20.62	22.18	24.04	21.45	20.63	23.40
Shale oil	0.00	0.00	8.37	6.57	6.90	7.35	5.86	5.83	4.37	5.01	4.25	4.97	4.83	4.78	5.09	4.73	3.95	3.02	3.00	2.74	3.16
LPG	1.58	1.47	0.54	0.33	0.47	0.32	0.33	0.35	0.38	0.32	0.33	0.36	0.27	0.29	0.29	0.31	0.27	0.35	0.36	0.28	0.36
Aviation gasoline	0.08	0.08	0.03	0.05	0.04	0.05	0.04	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.02	0.03	0.02	0.02
Gaseous fuels	**43.46**	**44.21**	**26.41**	**13.41**	**16.53**	**19.37**	**21.93**	**21.23**	**19.88**	**19.45**	**23.58**	**25.35**	**23.81**	**25.10**	**27.93**	**28.55**	**28.98**	**29.00**	**27.43**	**21.40**	**23.55**
Natural gas	43.46	44.21	26.41	13.41	16.53	19.37	21.93	21.23	19.88	19.45	23.58	25.35	23.81	25.10	27.93	28.55	28.98	29.00	27.43	21.40	23.55
Other	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.13**	**0.35**	**0.39**	**0.78**	**0.61**	**0.60**	**0.77**	**0.95**	**0.52**	**0.56**
Waste Oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.13	0.33	0.34	0.73	0.60	0.57	0.65	0.59	0.25	0.17
Plastics	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02
MSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.06	0.05	0.01	0.03	0.11	0.35	0.24	0.38
Biomass	**8.63**	**8.47**	**8.11**	**7.73**	**12.54**	**20.35**	**24.28**	**24.78**	**21.12**	**21.27**	**21.43**	**22.56**	**22.89**	**24.10**	**24.99**	**24.51**	**22.05**	**24.93**	**26.85**	**29.42**	**35.01**
Solid biomass	8.63	8.47	8.11	7.73	12.52	20.26	24.22	24.72	21.05	21.16	21.35	22.47	22.78	23.98	24.91	24.36	21.85	24.73	26.59	29.23	34.51

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Liquid biomass*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.02	0.18	0.07	0.32
Biogas	0.00	0.00	0.00	0.00	0.02	0.09	0.06	0.06	0.07	0.11	0.08	0.08	0.11	0.11	0.08	0.15	0.15	0.18	0.08	0.12	0.18

**Biodiesel and Bioethanol*

Table A.2.9. CO_2 emissions from fuel combustion, Tg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Solid fuels	**24.03**	**21.83**	**17.47**	**13.17**	**13.72**	**12.73**	**13.07**	**12.74**	**11.24**	**10.52**	**10.53**	**10.32**	**9.99**	**11.77**	**11.68**	**10.98**	**10.33**	**13.03**	**11.79**	**9.79**	**13.50**
Oil Shale	21.31	19.43	15.66	11.82	12.45	11.20	11.50	11.31	10.35	9.85	9.65	9.27	9.03	10.83	10.72	10.02	9.24	11.69	10.42	8.55	11.97
Peat (milled)	0.19	0.12	0.12	0.12	0.13	0.19	0.14	0.14	0.10	0.08	0.07	0.12	0.13	0.12	0.10	0.11	0.13	0.17	0.13	0.15	0.17
Peat (sod)	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.09	0.09	0.07	0.07	0.06	0.08	0.08	0.08	0.06	0.06	0.06	0.06	0.06	0.05
Peat Briquette	0.34	0.31	0.25	0.19	0.15	0.20	0.19	0.10	0.05	0.05	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.03	0.01	0.02
Coal	0.89	0.87	0.55	0.28	0.21	0.24	0.27	0.23	0.18	0.19	0.22	0.28	0.15	0.11	0.15	0.14	0.18	0.34	0.34	0.23	0.16
Oil shale semi-coke gas	0.05	0.03	0.04	0.05	0.06	0.06	0.07	0.07	0.06	0.05	0.07	0.09	0.09	0.09	0.10	0.11	0.11	0.10	0.14	0.16	0.43
Oil shale generator gas	1.21	1.04	0.85	0.70	0.71	0.83	0.80	0.80	0.41	0.23	0.40	0.45	0.49	0.51	0.51	0.52	0.60	0.64	0.68	0.63	0.70
Coke	0.04	0.03	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquid fuels	**9.13**	**8.31**	**4.62**	**4.50**	**4.37**	**3.50**	**3.72**	**3.61**	**3.59**	**3.25**	**2.67**	**3.11**	**3.19**	**3.11**	**3.11**	**3.14**	**3.14**	**3.28**	**3.07**	**2.85**	**3.02**
Heavy fuel oil	5.20	4.72	2.06	2.20	1.79	1.10	1.20	1.00	1.04	0.84	0.29	0.26	0.18	0.09	0.05	0.04	0.02	0.02	0.02	0.01	0.02
Light fuel oil	0.37	0.27	0.12	0.06	0.05	0.07	0.12	0.14	0.16	0.20	0.24	0.36	0.35	0.34	0.32	0.29	0.19	0.21	0.21	0.16	0.15
Motor gasoline	1.67	1.48	0.72	0.74	0.91	0.78	0.88	0.96	0.93	0.88	0.89	1.05	0.98	0.95	0.90	0.91	0.99	1.04	1.02	0.94	0.87
Diesel Oil	1.79	1.74	1.06	0.97	1.05	0.95	1.04	1.03	1.11	0.93	0.91	1.04	1.30	1.34	1.43	1.51	1.63	1.76	1.57	1.51	1.72
Shale oil	0.00	0.00	0.64	0.50	0.53	0.56	0.45	0.45	0.34	0.38	0.33	0.38	0.37	0.37	0.39	0.36	0.30	0.23	0.23	0.21	0.24
LPG	0.10	0.09	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Aviation gasoline	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gaseous fuels	**2.39**	**2.43**	**1.45**	**0.74**	**0.91**	**1.06**	**1.21**	**1.17**	**1.09**	**1.07**	**1.30**	**1.39**	**1.31**	**1.38**	**1.54**	**1.57**	**1.59**	**1.59**	**1.51**	**1.18**	**1.29**
Natural gas	2.39	2.43	1.45	0.74	0.91	1.06	1.21	1.17	1.09	1.07	1.30	1.39	1.31	1.38	1.54	1.57	1.59	1.59	1.51	1.18	1.29
Other	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.03**	**0.03**	**0.06**	**0.05**	**0.04**	**0.06**	**0.07**	**0.04**	**0.04**
Waste Oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.009	0.025	0.025	0.054	0.044	0.042	0.048	0.044	0.018	0.012
Plastics	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001
MSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.001	0.001	0.004	0.004	0.001	0.002	0.009	0.028	0.019	0.031

Table A.2.10. CH_4 emissions from fuel combustion, Gg CO_2 eq

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Solid fuels	**30.46**	**31.10**	**13.21**	**7.54**	**4.17**	**8.27**	**11.36**	**10.54**	**8.01**	**8.32**	**7.12**	**6.71**	**7.32**	**5.37**	**7.63**	**6.97**	**6.11**	**5.24**	**4.46**	**3.79**	**3.99**
Oil Shale	1.33	1.23	0.99	0.53	0.82	0.74	0.71	0.57	0.84	0.52	0.57	0.55	0.50	0.45	0.50	0.67	0.55	1.03	0.75	0.58	0.65
Peat (milled)	1.15	0.71	0.74	0.74	0.79	1.15	0.86	0.88	0.65	0.48	0.43	0.73	0.77	0.75	0.61	0.64	0.77	1.01	0.80	0.91	1.04
Peat (sod)	0.00	0.00	0.00	0.00	0.00	0.00	0.64	0.55	0.55	0.44	0.44	0.38	0.48	0.48	0.50	0.37	0.36	0.39	0.37	0.36	0.31
Peat Briquette	3.74	3.46	2.73	2.05	1.54	2.15	2.04	1.11	0.56	0.54	0.49	0.28	0.31	0.32	0.23	0.22	0.18	0.21	0.28	0.15	0.18
Coal	23.75	25.28	8.50	4.05	0.85	4.01	6.92	7.23	5.29	6.30	5.11	4.66	5.18	3.29	5.71	4.98	4.14	2.51	2.12	1.67	1.59
Oil shale gas	0.41	0.34	0.24	0.15	0.15	0.22	0.19	0.19	0.11	0.04	0.07	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.15	0.12	0.21
Coke	0.09	0.07	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquid fuels	**27.68**	**25.04**	**12.92**	**12.87**	**13.72**	**12.40**	**12.70**	**14.05**	**11.21**	**12.50**	**11.18**	**13.04**	**11.75**	**10.60**	**9.72**	**9.37**	**9.11**	**8.88**	**8.76**	**8.65**	**8.75**
Heavy fuel oil	4.85	4.31	1.73	1.97	1.49	0.90	0.99	0.82	0.86	0.69	0.23	0.21	0.15	0.08	0.04	0.03	0.01	0.02	0.01	0.01	0.01
Light fuel oil	0.71	0.52	0.25	0.10	0.07	0.09	0.18	0.19	0.23	0.29	0.36	0.71	0.65	0.57	0.51	0.46	0.30	0.31	0.32	0.21	0.20
Motor gasoline	19.45	17.71	8.92	8.83	10.05	9.17	9.40	10.92	7.82	9.49	8.65	9.94	8.43	7.50	6.64	6.35	6.28	6.04	6.01	6.01	5.99
Diesel Oil	2.52	2.36	1.45	1.50	1.63	1.76	1.76	1.76	1.99	1.68	1.63	1.83	2.17	2.11	2.18	2.20	2.23	2.28	2.17	2.21	2.31
Shale oil	0.00	0.00	0.53	0.43	0.44	0.45	0.34	0.34	0.28	0.32	0.27	0.31	0.30	0.30	0.32	0.29	0.25	0.19	0.19	0.18	0.20
LPG	0.14	0.15	0.05	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04
Aviation gasoline	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00
Gaseous fuels	**1.56**	**1.55**	**1.11**	**0.68**	**0.80**	**0.83**	**0.86**	**0.83**	**0.86**	**0.81**	**0.89**	**0.97**	**0.84**	**1.00**	**1.11**	**1.16**	**1.20**	**1.26**	**1.22**	**0.87**	**0.94**
Natural gas	1.56	1.55	1.11	0.68	0.80	0.83	0.86	0.83	0.86	0.81	0.89	0.97	0.84	1.00	1.11	1.16	1.20	1.26	1.22	0.87	0.94
Other	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.08**	**0.22**	**0.25**	**0.49**	**0.38**	**0.38**	**0.48**	**0.60**	**0.33**	**0.36**
Waste Oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.08	0.21	0.21	0.46	0.38	0.36	0.41	0.37	0.16	0.10
Plastics	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01
MSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.03	0.01	0.02	0.07	0.22	0.15	0.24
Biomass	**39.11**	**37.22**	**33.83**	**35.63**	**54.88**	**99.00**	**115.69**	**120.44**	**94.98**	**92.78**	**93.51**	**92.94**	**92.75**	**97.62**	**99.53**	**87.56**	**84.49**	**106.66**	**109.58**	**116.95**	**122.98**
Solid biomass	39.11	37.22	33.83	35.63	54.88	99.00	115.69	120.44	94.98	92.78	93.51	92.94	92.74	97.62	99.53	87.56	84.49	106.65	109.58	116.95	122.97
Liquid biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.012
Biogas	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.004	0.002	0.002	0.004

Table A.2.11. N_2O emissions from fuel combustion, Gg CO_2 eq

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Solid fuels	**16.73**	**15.38**	**10.36**	**6.90**	**6.31**	**8.15**	**9.03**	**7.34**	**6.24**	**5.17**	**5.17**	**5.64**	**5.26**	**4.71**	**7.95**	**11.33**	**11.92**	**13.72**	**13.33**	**10.99**	**11.65**
Oil Shale	2.70	2.52	2.01	1.05	1.64	1.48	1.41	1.11	1.68	1.02	1.11	1.06	0.96	0.83	3.95	7.66	7.96	8.71	8.72	6.88	7.53
Peat (milled)	2.25	1.41	1.45	1.39	1.52	2.24	1.64	1.68	1.23	0.95	0.85	1.44	1.51	1.47	1.20	1.25	1.52	1.98	1.56	1.78	2.05
Peat (sod)	0.00	0.00	0.00	0.00	0.00	0.00	1.24	1.05	1.08	0.85	0.85	0.75	0.93	0.94	0.97	0.73	0.70	0.76	0.73	0.71	0.62
Peat Briquette	4.45	4.14	3.24	2.52	1.96	2.67	2.48	1.37	0.68	0.64	0.59	0.34	0.37	0.40	0.29	0.27	0.24	0.26	0.34	0.19	0.22
Coal	6.92	6.97	3.48	1.76	1.03	1.58	2.09	1.96	1.46	1.64	1.65	1.88	1.36	0.93	1.40	1.28	1.35	1.85	1.80	1.24	0.91
Oil shale gas	0.22	0.18	0.16	0.14	0.15	0.16	0.16	0.16	0.10	0.06	0.10	0.11	0.12	0.13	0.13	0.14	0.15	0.15	0.17	0.18	0.31
Coke	0.19	0.15	0.04	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.02	0.06	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Liquid fuels	**82.26**	**78.92**	**49.91**	**47.97**	**41.78**	**41.72**	**48.30**	**45.74**	**40.82**	**34.77**	**38.12**	**55.19**	**61.49**	**44.28**	**45.12**	**43.23**	**37.89**	**38.62**	**37.12**	**40.73**	**42.68**
Heavy fuel oil	12.62	11.47	5.00	5.33	4.35	2.68	2.92	2.43	2.51	2.04	0.69	0.62	0.44	0.23	0.12	0.09	0.04	0.05	0.04	0.04	0.04
Light fuel oil	0.94	0.69	0.30	0.16	0.14	0.18	0.31	0.36	0.41	0.50	0.60	0.91	0.88	0.87	0.81	0.74	0.48	0.54	0.52	0.40	0.38
Motor gasoline	15.81	14.88	6.60	8.59	15.35	18.22	23.44	21.93	16.09	19.14	23.92	41.89	40.16	17.85	17.53	16.99	11.53	11.15	11.13	11.20	11.11
Diesel Oil	52.78	51.78	36.43	32.62	20.62	19.23	20.48	19.89	20.95	12.11	12.08	10.80	19.07	24.41	25.67	24.49	25.08	26.29	24.84	28.56	30.53
Shale oil	0.00	0.00	1.56	1.22	1.28	1.37	1.09	1.08	0.81	0.93	0.79	0.92	0.90	0.89	0.95	0.88	0.73	0.56	0.56	0.51	0.59
LPG	0.05	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Aviation gasoline	0.06	0.06	0.02	0.04	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.02	0.02	0.02	0.03	0.02	0.02
Gaseous fuels	**1.35**	**1.37**	**0.82**	**0.42**	**0.51**	**0.60**	**0.68**	**0.66**	**0.62**	**0.60**	**0.73**	**0.78**	**0.74**	**0.78**	**0.86**	**0.88**	**0.90**	**0.90**	**0.85**	**0.66**	**0.73**
Natural gas	1.35	1.37	0.82	0.42	0.51	0.60	0.68	0.66	0.62	0.60	0.73	0.78	0.74	0.78	0.86	0.88	0.90	0.90	0.85	0.66	0.73
Other	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**	**0.17**	**0.43**	**0.49**	**0.97**	**0.76**	**0.75**	**0.95**	**1.17**	**0.65**	**0.70**
Waste Oils	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.16	0.41	0.42	0.90	0.74	0.71	0.81	0.73	0.31	0.21
Plastics	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.02
MSW	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.07	0.06	0.02	0.03	0.14	0.43	0.30	0.48
Biomass	**10.70**	**10.50**	**10.05**	**9.58**	**15.52**	**25.13**	**30.04**	**30.66**	**26.10**	**26.24**	**26.48**	**27.87**	**28.25**	**29.74**	**30.89**	**30.21**	**27.10**	**30.68**	**32.99**	**36.25**	**42.83**
Solid biomass	10.70	10.50	10.05	9.58	15.52	25.12	30.04	30.65	26.10	26.24	26.48	27.87	28.24	29.74	30.89	30.20	27.09	30.67	32.97	36.24	42.79
Liquid biomass	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.001	0.035
Biogas	0.000	0.000	0.000	0.000	0.001	0.003	0.002	0.002	0.002	0.003	0.002	0.003	0.003	0.004	0.003	0.005	0.005	0.005	0.003	0.004	0.006

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March 14, 2011 nr

Subject: Possible methane emission from
Estonian oil shale mining

In reply to your question whether methane exists in Estonian oil shale mining and in which kinds of Estonian studies this topic is treated, our answer is the following:

Estonian underground mines are continually ventilated and quality of air inside the mines is controlled. Oil shale is a mixture of clay and kerogen matter, and does not emit methane. During the 90-year long period of mining in Estonia there have never been any problems related to methane. Methane is non-existent in Estonian oil shale.

Risk of fire is related only to the kerogen matter in the oil shale, which can ignite. While oil shale is being crushed, fine dust is produced and it may explode.

So as methane does not exist in Estonian mines, it has not been an issue for scientific studies and there are no related publications dealing with Estonia.

Sincerely

Prof. Ingo Valgma
Director

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