

Annex 3. Other detailed methodological descriptions for individual source or sink categories, including for KP-LULUCF activities

A.3.1. Energy

Oil Shale consumption in Estonia

The main industrial activities, where the oil shale is used are electricity generation (67%), heat generation (4.8%), and conversion to other forms of fuels (shale oil, oil shale gas, etc)- 27%.

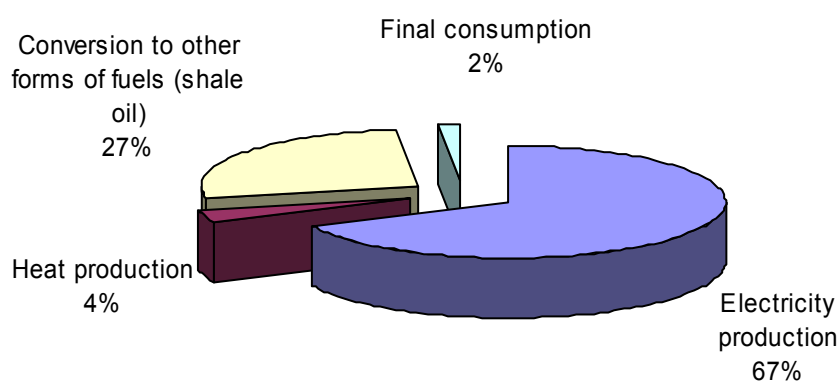


Figure 1. Oil shale consumption by activities, 2008 [SE].

The structure of oil shale consumption from 1990 to 2008 has changed, as it is seen from the Figure 1 and 2. In 1990, 75% of the total oil shale produced was consumed for electricity generation, 11% for heat generation and 8% for shale oil production. In 2008 the corresponding figures are 67% for electricity, 4% for heat and 27% for shale oil production. Final consumption of oil shale totalled 3% in 1990 and 2% in 2008.

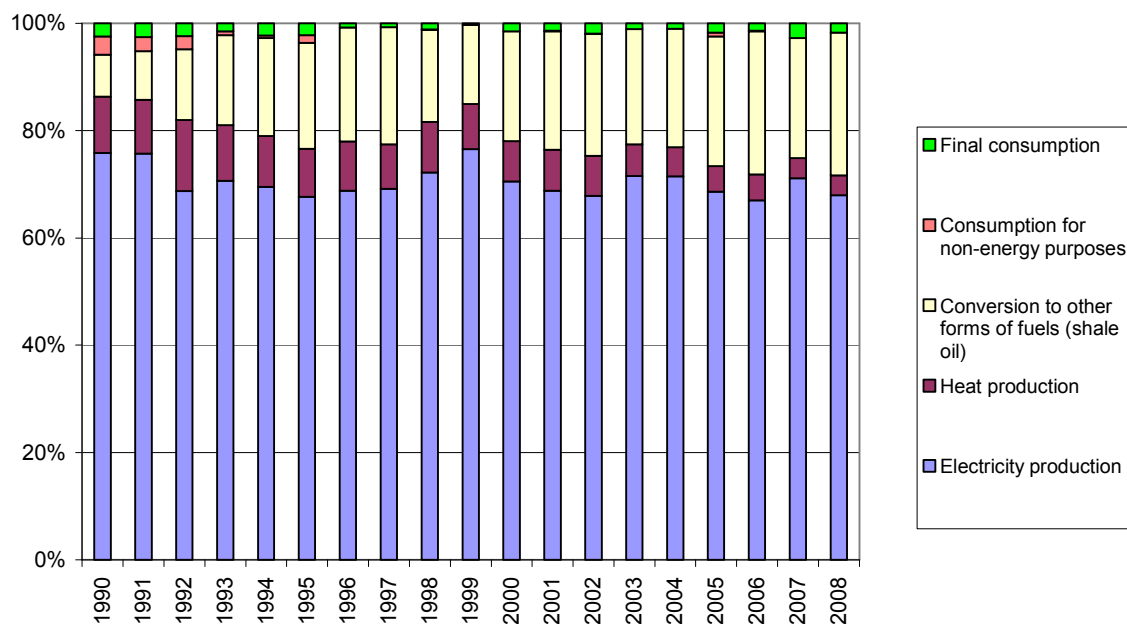


Figure.1 The structure of oil shale use by years 1990-2008

About 91% of generated electricity in Estonia was produced from oil shale in 2008; the share of heat generation from oil shale was about 5.4% of the total heat generation in Estonia in 2008.

Carbon dioxide emissions from the shale oil production

In Estonia, the oil shale thermal processing for shale oil production takes place in three plants: in ***Kiviõli Keemiatööstuse OÜ*** (*Kiviõli Oil Shale Processing and Chemicals Plant Ltd.*), in ***Viru Keemia Grupp AS*** (*Viru Chemistry Group Ltd.* in Kohtla-Järve) and in ***Narva Power Plants AS*** at the Eesti Power Plant.

There are two different technologies in use: the technology of processing large-particle oil shale in vertical retorts with gaseous heat carrier, and since 1980 that of processing fine-grained oil shale with solid heat carrier (SHC) are in operation. In Kohtla-Järve and Kiviõli vertical retorts and in the Narva PP the solid heat carrier technology is used.

The technology of processing oil shale in **vertical retorts** with gaseous heat carrier is universal technology and suitable for retorting high-calorific oil shale. The vertical retort is a metal vessel lined from inside with refractory bricks. The oil shale charging device and spent shale discharge chute and extractor are arranged on the top and in the lower part of the retort vessel, respectively. Thermal processing of oil shale takes place in retorting chambers in the cross flow of gaseous heat carrier. By influence of gases oil shale is warmed and dried up and after achieving needful

temperature for retorting, the organic part of oil shale starts quickly to decompose. The mixture of the heat carrier with oil and water vapour moves into collector chambers, semi-coke (retorted oil shale) moves downward to cooling chambers. Oil vapour and gas are let out of the retort via outlet connections to condensation system. (J. Soone, S. Doilov, 2003). Cleaned generator gas is delivered to heating boilers for burning (relevant emissions are reported under source category 1.A.1.a). Thermal processing of oil shale in vertical retorts takes place without any contact with the ambient atmosphere; therefore no pollutants are emitted.

In **Solid Heat Carrier installation (SHC)**, hot oil shale dust as a heat carrier is used. Pre-dried fine-grained oil shale with hot oil shale dust (800°C) is delivered to a horizontal rotating reactor where during just a few minutes the retorting process is occurring. The mixture of heat carrier with oil and water vapours moves into dust separation chamber. Oil vapours and gas are sent to the condensing chamber where the condensed oil is separated and semi-coke gas is sent for burning to power plant. Mixture of semi-coke and dust will delivered to an aero fountain combustor chamber, where semi-coke is burned and flue gases separated. The flue gases are partly used for pre-heating of oil shale in dryer but partly emitted into atmosphere. Dust is delivered to ash fields but partly back to the reactor.

By both shale oil production technologies oil shale gases as by-products will be formed (from Vertical Retorts- generator gas and from Solid Heat Carrier – semi-coke gas) which will be incinerated in power plants.

CO₂ emissions are emitted into atmosphere from oil shale semi-coke combustion in aerofountain chamber and are calculated by following formula:

$$M_{CO_2, SHC} = 10^{-3} \cdot B^1_{oil\ shale} \cdot q_{semi-coke} \cdot k_{semi-coke} \cdot 44/12 \quad (Gg\ CO_2)$$

Where:

$M_{CO_2, SHC}$	=	CO ₂ emissions from oil shale use in solid heat carrier
$B^1_{oil\ shale}$	=	oil shale consumption as received (non-enriched) (TJ)
$q_{semi-coke}$	=	carbon emission factor of oil shale semi-coke (tC/TJ).
$k_{semi-coke}$	=	oxidation factor $_{semi-coke}$, $K=0.97$
44/12	=	molecular weight of CO ₂

The combustion of semi-coke in the aerofountain chamber takes place in combustion air shortage conditions.

$$q_{semi-coke} = 10[C_{semi-coke} + k_c + (CO_2)_M \cdot 12/44]/ Q_{oil\ shale}$$

$q_{\text{semi-coke}}$	carbon emission factor of semi coke , tC/TJ
$C_{\text{semi-coke}}$	carbon content of semi-coke, = 10.2%
K_c	decomposition rate of the semi-coke, = 0.7
$(CO_2)_M^r$	content of mineral CO_2 in oil shale, = 17.7%
44/12	molecular weight of CO_2
$Q_{\text{oil shale}}$	improved lower heating value of oil shale, 8.78 MJ/kg

$$q_{\text{semi-coke}} = 10[10.2 + 0.7 \times 17.7 \times 44/12] / 8.78 = \mathbf{15.45 \text{ tC/TJ}}$$

In the Table 1 oil shale consumption for shale oil production is given in total (first row) and separately by technologies used. In the second row oil shale consumption used in Narva Oil Plant (SHC technology) is presented and in the third row oil shale consumption in vertical retorts (VR) In Kiviõli and Kohtla –Järve Oil Plants is given.

Activity data on total oil shale consumption is received from national statistics but activity data on oil shale used in solid heat carrier are obtained directly from AS Eesti Energia. The third row is calculated (total oil shale consumption – oil shale used in SHC).

Table 1. Emissions from shale oil production

	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Oil Shale consumption in Narva	TJ	18 670	19 886	24 406	23 849	27 692	27 696	30 286	30 847	20 877	16 436	24 257	25 674	26 087	29 027	29834	31 728	33192	33237	37020
SHC	TJ	6 721	7 159	8 786	8 586	9 969	9 971	10 903	11 105	7 516	5 917	8 733	8 575	8 713	8 273	10 740	11 739	11 949	10 503	10606
in generators	TJ	11949	12727	15620	15263	17723	17725	19383	19742	13361	10519	15524	17099	17374	20754	19094	19989	21243	22734	20731.2
EF of semi-coke	tC/TJ	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45	15.45
Oxidation factor		0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
CO ₂ SHC	Gg	369.33	393.39	482.80	471.79	547.81	547.89	599.12	610.22	412.99	325.14	479.86	471.21	478.79	454.59	590.18	645.08	656.61	577.13	895.08
CH ₄	kg/TJ	0.007	0.007	0.009	0.009	0.010	0.010	0.011	0.011	0.008	0.006	0.009	0.009	0.009	0.008	0.011	0.012	0.012	0.011	0.016
	0.1																			
N ₂ O	kg/TJ	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002
NO _x	kg/TJ	0.739	0.787	0.966	0.944	1.097	1.097	1.199	1.222	0.827	0.651	0.961	0.943	0.958	0.910	1.181	1.291	1.314	1.155	1.792
CO	kg/TJ	0.17	0.19	0.23	0.22	0.26	0.26	0.28	0.29	0.20	0.15	0.23	0.22	0.23	0.22	0.28	0.31	0.31	0.27	0.42
NM ₂ VOC	kg/TJ	0.40	0.43	0.53	0.52	0.60	0.60	0.65	0.67	0.45	0.36	0.52	0.51	0.52	0.50	0.64	0.70	0.72	0.63	0.98
SO ₂ SHC	kg/TJ	0.59	0.63	0.78	0.76	0.88	0.88	0.96	0.98	0.67	0.52	0.77	0.76	0.77	0.73	0.95	1.04	1.06	0.93	1.44
SO ₂ generators	kg/TJ	1.78	1.90	2.33	2.27	2.64	2.64	2.89	2.94	1.99	1.57	2.31	2.55	2.59	3.09	2.84	2.98	3.17	3.39	3.09
SO ₂ Total	Kg/TJ	2.38	2.53	3.10	3.03	3.52	3.52	3.85	3.92	2.66	2.09	3.09	3.31	3.36	3.82	3.80	4.02	4.22	4.32	4.53

SHC – Solid Heat Carrier

Carbon Stored in oil shale semi-coke

For calculation of carbon stored with semi-coke an IPCC calculation table was used (see Table 2).

In column 'C' is reported semi-coke amount in TJ-s and in column 'D' CO₂ emission factor for semi-coke $_{VR}$, CO₂ EF_{semi-coke, VR} = 28,25 tC/TJ (CS, A. Martins).

Carbon stored in semi-coke is estimated by multiplying semi-coke amount with emission factor (see column 'H' of the Table 2. These results are reported in the CRF Table 3.

Table 2. Estimation of carbon stored in semi-coke dumped on landfills

	A Estimated Fuel Quantities	B Conversion Factor (TJ/Unit)	C Estimated Fuel Quantities (TJ)	D Carbon Emission Factor * (t C/TJ)	E Carbon Content (t C)	F Carbon Content (Gg C)	G Fraction of Carbon Stored	H Carbon Stored (Gg C)
FUEL TYPES			C=(AxB)		E=(Cx D)	F=(E/1000)		H=(FxG)
Oil Shale								
1990			2583.18	28.25	72 974.87	72.97	1	72.97
1991			2751.43	28.25	77 727.81	77.73	1	77.73
1992			3503.09	28.25	98 962.32	98.96	1	98.96
1993			3423.14	28.25	96 703.77	96.70	1	96.70
1994			3974.74	28.25	112 286.50	112.29	1	112.29
1995			3975.32	28.25	112 302.72	112.30	1	112.30
1996			3975.32	28.25	112 302.72	112.30	1	112.30
1997			4427.59	28.25	125 079.51	125.08	1	125.08
1998			2996.56	28.25	84 652.80	84.65	1	84.65
1999			2359.12	28.25	66 645.28	66.65	1	66.65
2000			3481.70	28.25	98 358.14	98.36	1	98.36
2001			3685.38	28.25	104 111.96	104.11	1	104.11
2002			3744.37	28.25	105 778.49	105.78	1	105.78
2003			4449.40	28.25	125 695.65	125.70	1	125.70
2004			4127.83	28.25	116 611.26	116.61	1	116.61
2005			4326.75	28.25	122 230.61	122.23	1	122.23
2006			4592.45	28.25	129 736.57	129.74	1	129.74
2007			4889.74	28.25	138 135.29	138.14	1	138.14
2008			4470.22	28.25	126683.75	126.28	1	126.28

* Emission factor of the semi-coke from the vertical retorts (the second shale oil production technology)

Table 3. CRF 1.AD Feedstock and non energy use (oil shale)

OIL Shale	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fuel Consumption*	TJ	2583.18	2751.43	3503.09	3423.14	3974.74	3975.32	3975.32	4427.59	2996.56	3481.70	3685.38	3744.37	4449.40	4127.83	4326.75	4592.45	4889.74	4470.22
Fraction of carbon stored	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carbon stored																			
C	Gg	72.97	77.73	98.96	96.7	112.29	112.3	112.3	125.08	84.65	98.36	104.11	105.78	125.7	116.61	122.23	129.74	138.14	126.28
Implied emission factor																			
C	t/TJ	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25	28.25
Additional information																			
CO ₂ not emitted	Gg	267.56	285.01	362.85	354.57	411.73	411.77	411.77	458.63	310.38	360.65	381.74	387.86	460.90	427.57	448.18	475.71	506.51	463.03
Subtracted from energy sector (specify source category)																			
Associated CO ₂ emissions	Gg	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA	RA
		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

* Semi-coke _{vr}

A.3.2. Industrial Processes

Other detailed methodological descriptions for individual source or sink categories in Industrial Processes sector is provided in Chapter 4.

A.3.3. Agriculture

Other detailed methodological descriptions for individual source or sink categories in Agriculture sector is presented in Annex 9, Appendix A_VI. Estimating of nitrogen excretion factor of dairy cattle and pig.

A.3.4. LULUCF

Algorithms employed to estimate carbon flows related to land use and land use change activities are provided in Chapter 7.

A.3.5. Waste

The data presented in the following figures, illustrate the flows of the most important waste flows of biodegradable waste in Estonia in 2008. As seen from the figures the input flows (including the amount of waste in stock at beginning of the year, waste generation and waste import) equate with the output flows (including the amount of waste in stock at the end of the year, waste export, recovery, destruction of waste, disposal on landfills and other activities) due to the regularity in the movement of the quantities of the wastes between the different waste handling activities.

Disposal operations

- D1** Deposit into or onto land (e.g. landfill, etc.)
- D2** Land treatment (e.g. biodegradation of liquid or sludgy discards in soils, etc.);
- D3** Deep injection (e.g. injection of pumpable discards into wells, salt domes or naturally occurring repositories, etc.);
- D4** Surface impoundment (e.g. placement of liquid or sludgy discards into pits, ponds or lagoons, etc.);

- D5** Specially engineered landfill (e.g. placement into lined discrete cells which are capped and isolated from one another and the environment, etc.);
- D6** Release into a water body except seas/oceans;
- D7** Release into seas/oceans including sea-bed insertion;
- D8** Biological treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12;
- D9** Physico-chemical treatment not specified elsewhere in this Annex which results in final compounds or mixtures which are discarded by means of any of the operations numbered D 1 to D 12 (e.g. evaporation, drying, calcination, etc.);
- D10** Incineration on land;
- D11** Incineration at sea;
- D12** Permanent storage (e.g. emplacement of containers in a mine, etc.);
- D13** Blending or mixing prior to submission to any of the operations numbered D 1 to D 12;
- D14** Repackaging prior to submission to any of the operations numbered D 1 to D 13;
- D15** Storage pending any of the operations numbered D 1 to D 14 (excluding temporary storage, pending collection, on the site where it is produced).

Recovery operations

- R1** Use principally as a fuel or other means to generate energy;
- R2** Solvent reclamation/regeneration;
- R3** Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes);
- R4** Recycling/reclamation of metals and metal compounds;
- R5** Recycling/reclamation of other inorganic materials;
- R6** Regeneration of acids or bases;
- R7** Recovery of components used for pollution abatement;
- R8** Recovery of components from catalysts;
- R9** Oil re-refining or other reuses of oil;
- R10** Land treatment resulting in benefit to agriculture or ecological improvement;
- R11** Use of wastes obtained from any of the operations numbered R 1 to R 10;

R12 Exchange of wastes for submission to any of the operations numbered R 1 to R 11;

R13 Storage of wastes pending any of the operations numbered R 1 to R 12 (excluding temporary storage, pending collection, on the site where it is produced.

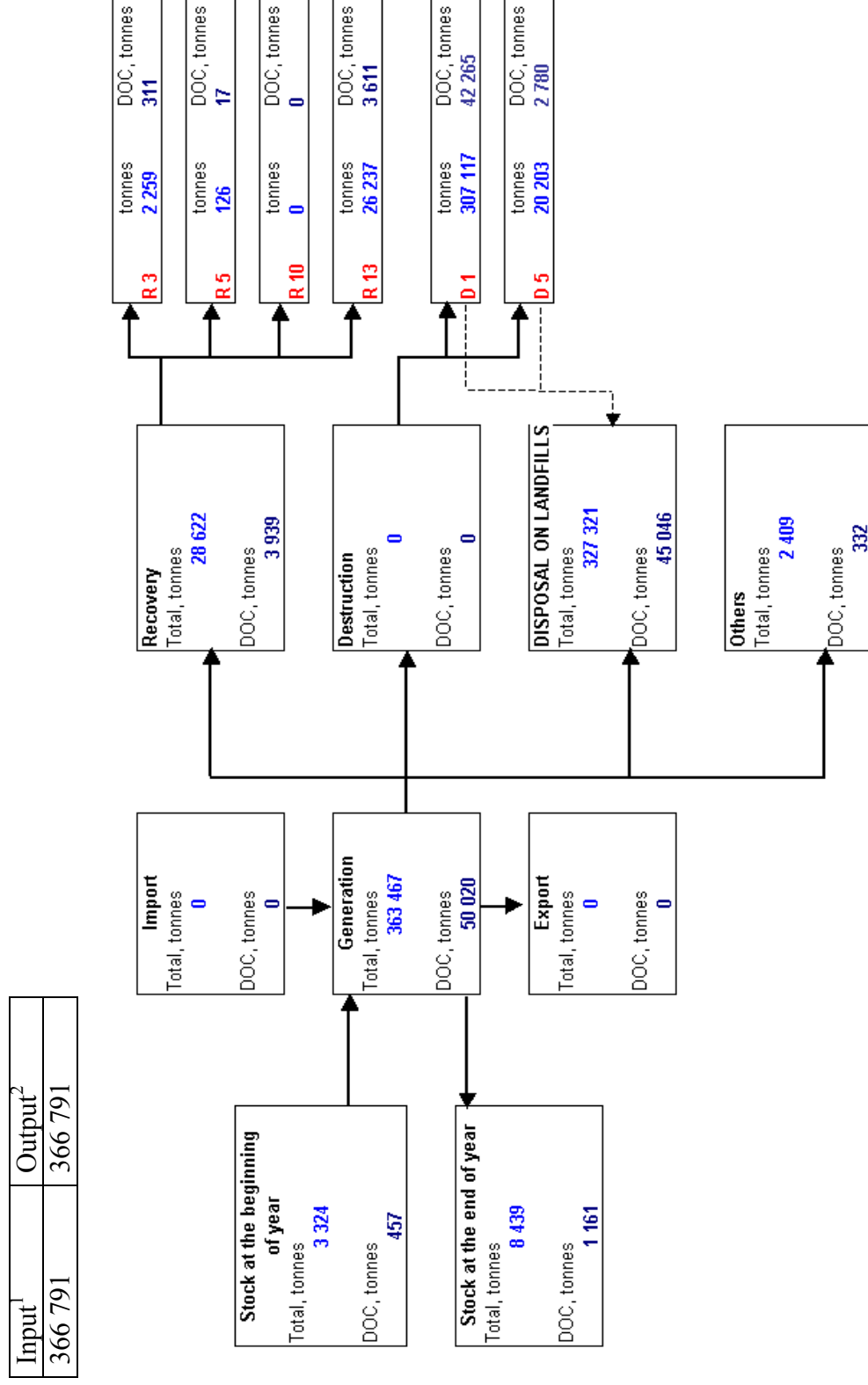


Figure 2 Flows of mixed municipal waste in Estonia in 2008, tonnes

¹ Input flows: Stock at the beginning of the year, Generation, Import

² Output flows: Stock at the end of the year, Export, Recovery, Destruction, Disposal on landfills, Other activities

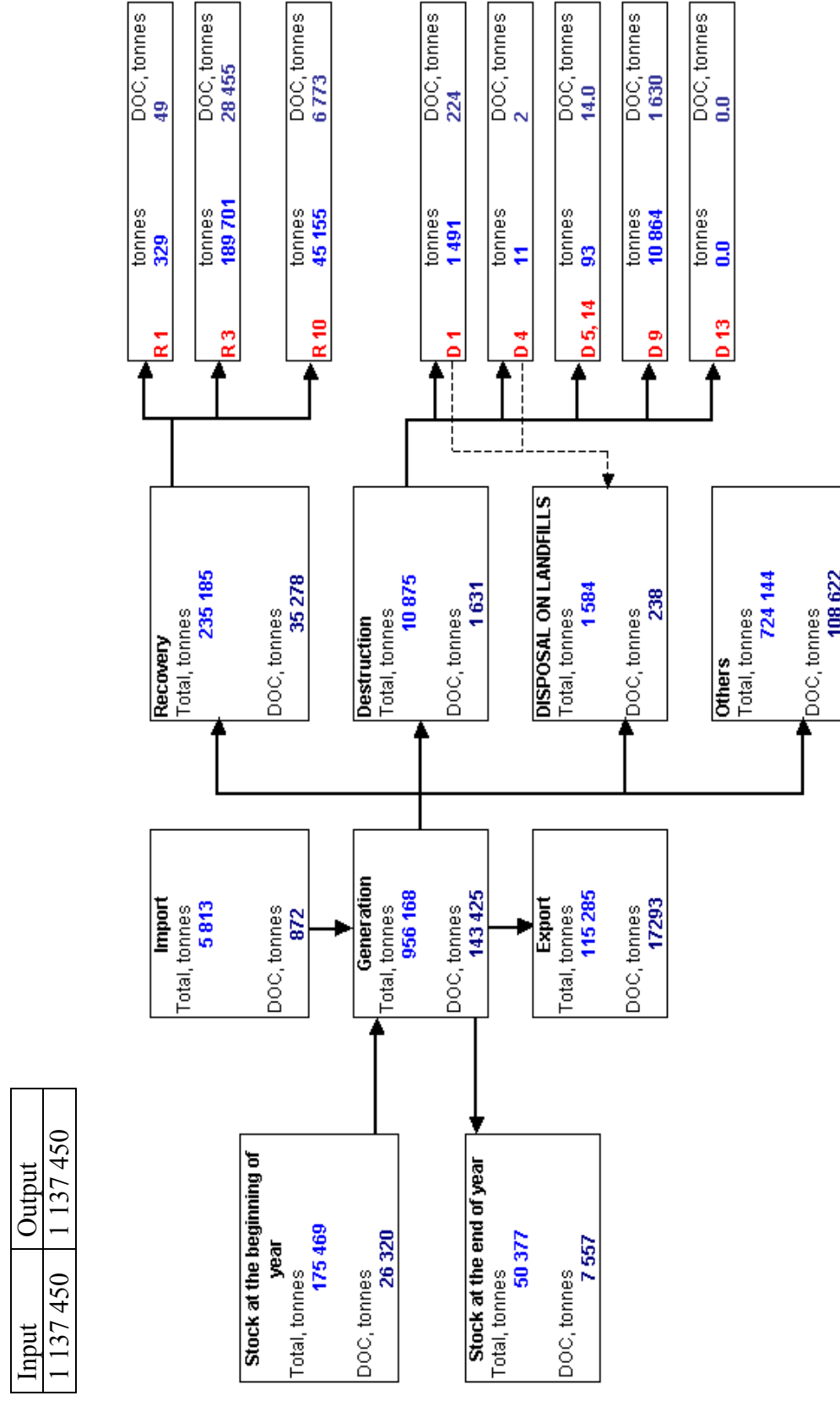


Figure 3 Flows of organic waste in Estonia in 2008, tonnes

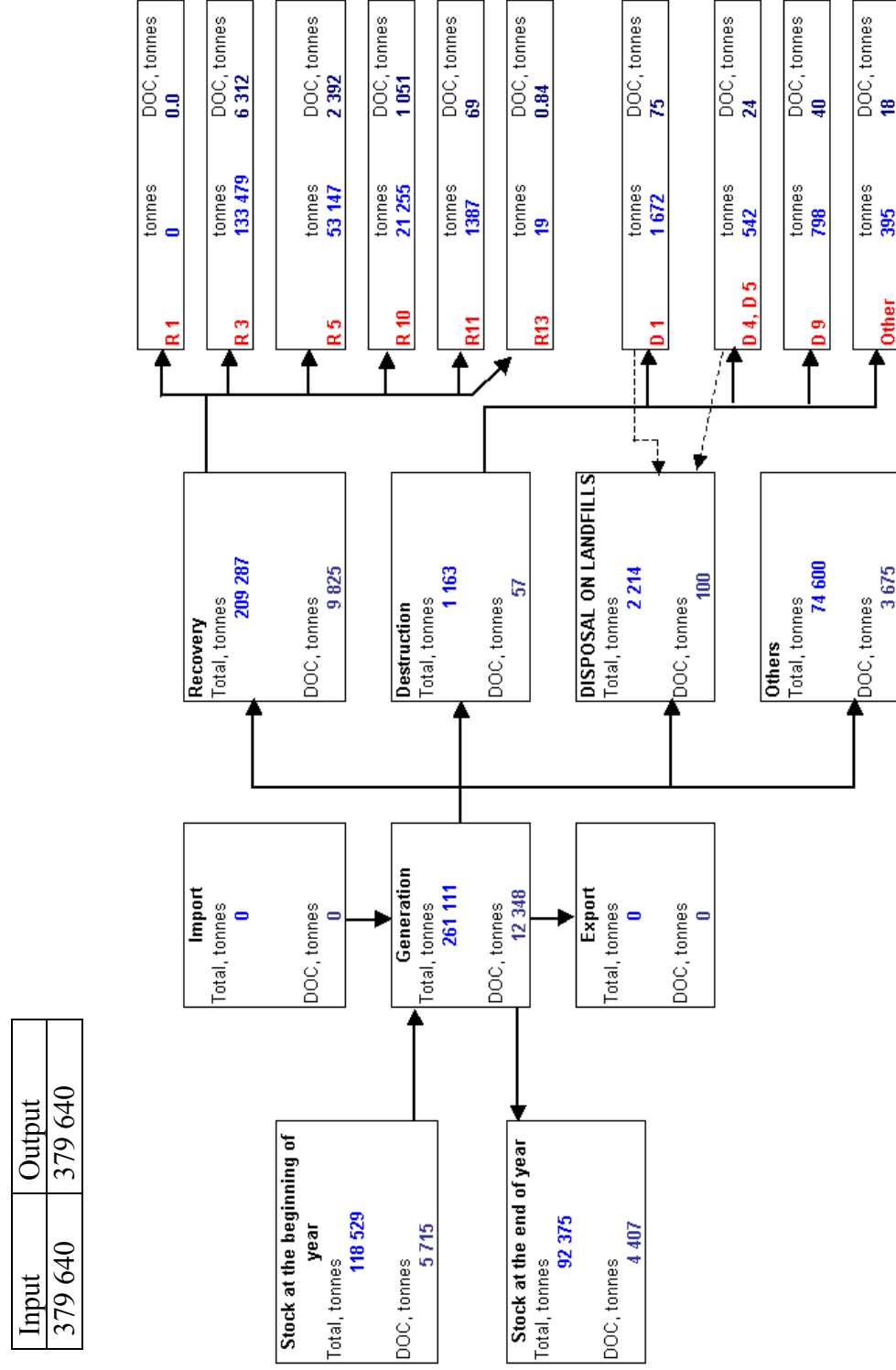


Figure 4 Flows of sludge (municipal and industrial) waste in Estonia in 2008, tonnes

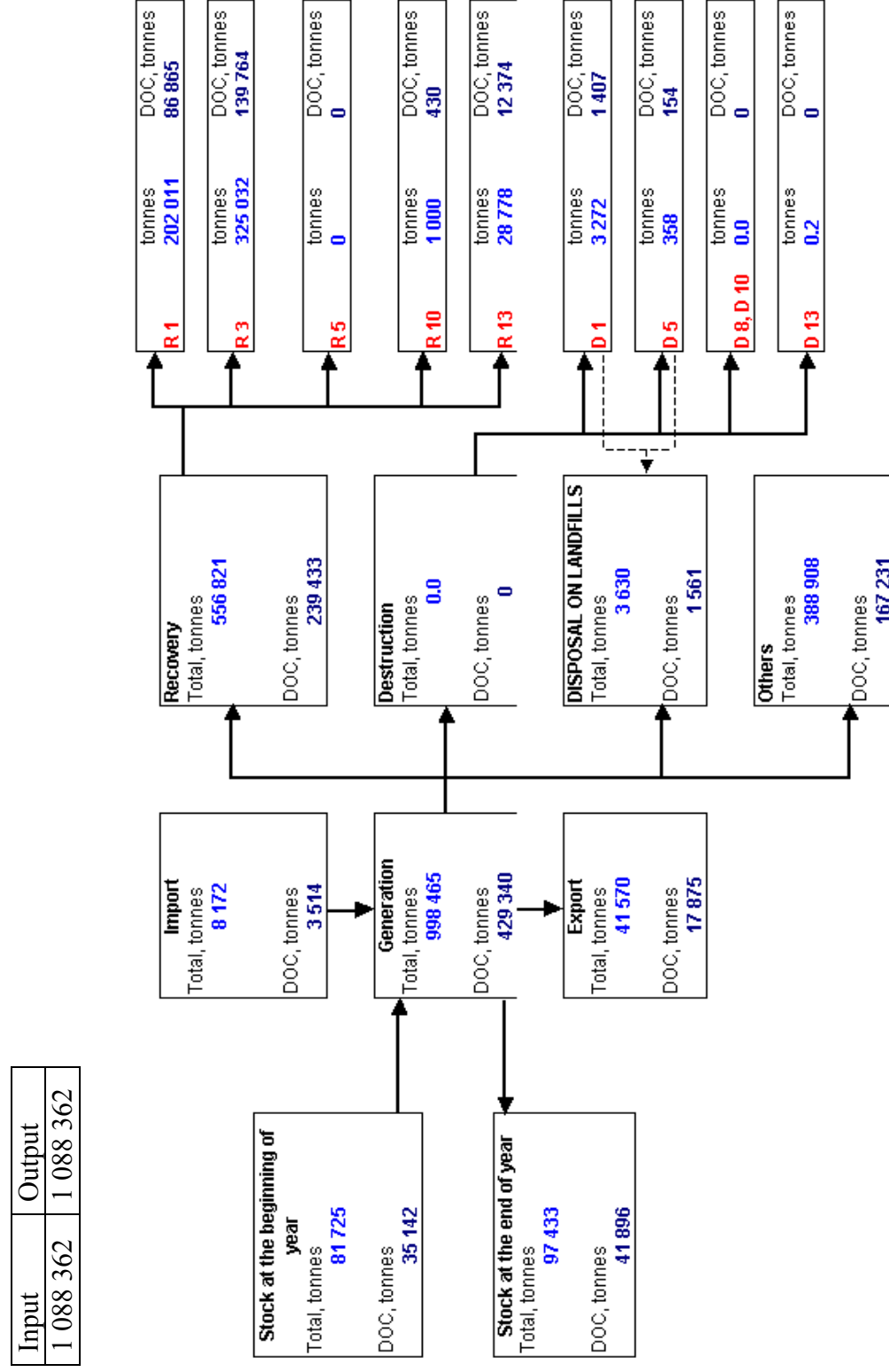


Figure 5 Flows of wood waste in Estonia in 2008, tonnes

A.3.6. KP-LULUCF

Algorithms employed to estimate carbon flows related to land use and land use change activities are provided in Chapter 7.

