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Eco-profiles of the European Plastics Industry

POLYURETHANE RIGID FOAM

A report by

I Boustead

for

PlasticsEurope

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IMPORTANT NOTE

Before using the data contained in this report, you are strongly recommended to look at the following documents:

1. Methodology

This provides information about the analysis technique used and gives advice on the meaning of the results.

2. Data sources

This gives information about the number of plants examined, the date when the data were collected and information about up-stream operations.

In addition, you can also download data sets for most of the upstream operations used in this report. All of these documents can be found at: www.plasticseurope.org.

Plastics*Europe* may be contacted at

Ave E van Nieuwenhuyse 4
Box 3
B-1160 Brussels

Telephone: 32-2-672-8259
Fax: 32-2-675-3935

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POLYURETHANES

A special feature of polyurethanes is their method of production. Generally, metering and mixing two or more streams of liquid components containing polyurethane precursors at the processing stage produces polyurethanes. Thus the final, high molecular weight polymer is normally manufactured by the individual polyurethane processor and not in the plant of the producer of the polyurethane precursors.

Furthermore, the relative amounts of the precursors that have to be combined to produce a specific polyurethane product are usually tailored to the type of product and to the production process. The precise formulations are known to the polyurethane processors but this information is sometimes proprietary and is not commonly known or made available to those outside of the industry. This report is therefore intended to give some general guidance on the use of the data for polyurethane precursors (MDI, TDI and polyols) when attempting to establish data for the full life cycle of polyurethane products.

The sequence of operations used in the production and delivery of polyurethane products is shown in Figure 1.

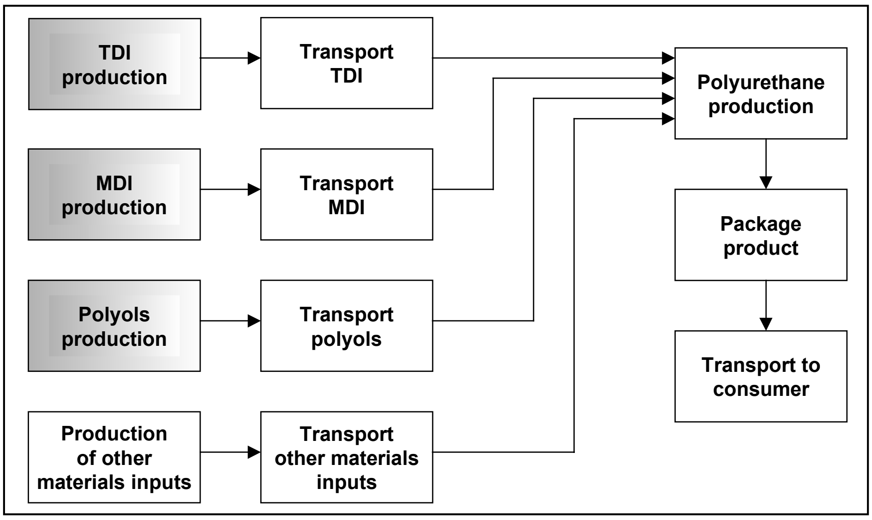

Figure 1
Schematic flow chart for the production and delivery of polyurethane products.

Data for the production of TDI, MDI and polyols, shown shaded in Figure 1, are provided elsewhere as separate reports.

In addition to TDI, MDI and polyols, a number of other chemicals are used in the commercial production of polyurethane products. Additives such as catalysts, surfactants, pigments, etc. are usually added in small quantities (typically less than 1 to 2%). Data for the production of many of these components are not available and they are often neglected in the calculations. It is common practice to replace them with the main ingredients MDI, TDI and polyols. Thus although their precise production data are not used in the calculations, their substitution by the main ingredients will contribute to the final result and the error will be less than if they were assumed to have zero production energy and emissions, as would be the case if they were simply omitted from the calculations.

However, other additives used in the fabrication of some polyurethane products pose more problems. Flame retardants, which are essential in products used in the building and construction industries, cross linking agents, which are needed to achieve special mechanical properties in elastomeric products, and blowing agents for foams may be used in significant quantities; proportions of 2% to 20% by input mass are common. Neglecting these additives cannot be justified but there is, unfortunately, very little data currently available for the production of these materials. Moreover, it is doubtful whether such information will become available in the near future since they are frequently manufactured by very few companies – in some cases there is only one producer – so that an industry average on a European basis is impossible. Most of these materials are not made by member companies of ISOPA resulting in the additional difficulty of obtaining a commitment from producing companies to engage in the time consuming and potentially costly exercise of collecting LCI data.

There are two approaches that can be used in resolving this problem of chemicals for which data are not available. The first is to use data for a different but chemically similar compound for which data are available. Some care is however needed in this approach because it is possible to replace the unknown chemical by one that has a much simpler production route. The second approach is to replace the unknown chemical by polyurethane precursors; the basis of this assumption is that polyurethane precursors represent a good substitute. Whichever method is adopted it is essential to carry out a sensitivity analysis to ensure that the assumption does not significantly affect the final results for the complete life cycle.

SAMPLE CALCULATIONS

To illustrate the way in which data for final polyurethane products may be calculated, this report presents some illustrative calculations. It is important to note that the results obtained do not purport to be definitive values for European practice but are expected to be a reasonable approximation to current practice.

Packaging polyurethane precursors

Processors using large quantities of polyurethane precursors, such as the major producers of thermal insulation foam for the construction industry, usually receive their supplies in bulk tankers by road or rail. The more specialist processors, who use relatively smaller quantities, may receive their supplies in drums.

For polyols, returnable steel drums holding 215 kg are typically of mass 18.5 kg and are expected to last, on average, 1.25 trips before they are lost from the system; that is, only about 20% of the drums are returned and re-used. Although there is a trend towards greater trippage rates, the value of 1.25 trips has been used in the calculations. On this basis, the demand for drums per kg of polyol packed is:

$$18.5/(215 \times 1.25) = 0.069 \text{ kg}$$

Isocyanates are delivered in steel drums of mass 21.5 kg and typically hold 215 kg of product. It is assumed that there is no re-use of isocyanate drums and so the demand for drums per kg of product is

$$21.5/250 = 0.086 \text{ kg}$$

In the calculations, drums have been treated as cold rolled steel and it has been assumed that the inputs and outputs associated with drum fabrication and with drum cleaning are negligible compared with the inputs and outputs associated with the production of the steel.

Transport of polyurethane precursors

The inputs and outputs associated with the transport of polyurethane precursors depend upon the distance travelled, the type of vehicle and the load carried. In all of the calculations, a nominal one-way transport distance of 100 km has been assumed and it has further been assumed that all deliveries are by road.

Bulk deliveries are assumed to be in fully laden 20 tonne payload road tankers with an empty return load. Drums are assumed to be delivered on 15 tonne payload trucks carrying a load of 10 tonnes.

Production of polyurethane products

In carrying out an analysis for a specific plant, the precise composition of the product manufactured should be obtained. However, Table 1 gives an indication of the expected compositions of a number of different polyurethane products.

Table 1
Typical input requirements for some polyurethane products. All data are given in parts by weight with ranges shown in parentheses.

Polyurethane type	Typical application	Polyol	MDI	TDI
Flexible block foam	Furniture Bedding Clothing Leisure goods	100	-	50 (26-56)
Flexible moulded foam	Car seats Furniture			
- hot cure		100	-	40 (33-48)
- cold cure TDI		100	-	40 (35-45)
- cold cure MDI		100	55 (45-65)	-
- cold cure MDI/TDI		100	10 (8-12)	30 (26-34)
Rigid foams	White goods Insulation Building materials Construction	100	160 (150-250)	-
Other automotive				
- semi rigid foam	Dashboards	100	40 (35-50)	
- energy absorbing foams	Bumpers	100	200 (100-300)	
- flexible integral skin foam	Steering wheels	100	40 (35-50)	
- rigid integral skin foam	Door panels	100	150 (120-170)	
- RIM (glycol extended)	Bumpers/panels	100	100 (60-140)	
- RIM (amine extended)	Bumpers/panels	100	50 (40-65)	

PRODUCTION OF A RIGID FOAM

To illustrate the method of calculation, consider the production of a rigid PUR-foam blown with pentane such as might be used in insulation applications. The inputs and outputs at the production plant might typically be as shown ion Table 2.

Table 2
Input-output data for a hypothetical rigid foam producing operation

Inputs	Pentane	0.054	kg
	Polyol	0.386	kg
	MDI	0.616	kg
	Electricity	1.500	MJ
Output product	PUR foam	1.000	kg
Air emissions	Pentane	0.003	kg
Solid waste	Waste foam	0.020	kg

RESULTS FOR RIGID POLYURETHANE FOAM

Table 3 shows the gross or cumulative energy to produce 1 kg of rigid polyurethane foam and Table 4 gives this same data expressed in terms of primary fuels. Table 5 shows the energy data expressed as masses of fuels. Table 6 shows the raw materials requirements and Table 7 shows the demand for water. Table 8 shows the gross air emissions and Table 9 shows the corresponding carbon dioxide equivalents of these air emissions. Table 10 shows the emissions to water. Table 11 shows the solid waste generated and Table 12 gives the solid waste in EU format.

Table 3
Gross energy required to produce and deliver 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding)

Fuel type	Fuel prod'n & delivery energy (MJ)	Energy content of delivered fuel (MJ)	Energy use in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Electricity	14.63	6.50	0.44	-	21.57
Oil fuels	0.47	14.10	0.24	19.77	34.58
Other fuels	1.69	26.24	0.10	17.29	45.33
Totals	16.79	46.84	0.78	37.07	101.48

Table 4
Gross primary fuels required to produce and deliver 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding)

Fuel type	Fuel prod'n & delivery energy (MJ)	Energy content of delivered fuel (MJ)	Fuel use in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Coal	4.77	5.36	0.12	0.29	10.54
Oil	1.26	14.46	0.47	20.70	36.89
Gas	4.44	25.52	0.10	16.04	46.10
Hydro	0.36	0.20	0.01	-	0.56
Nuclear	5.14	2.33	0.08	-	7.55
Lignite	0.30	0.27	<0.01	-	0.57
Wood	<0.01	<0.01	<0.01	0.01	0.01
Sulphur	<0.01	<0.01	<0.01	0.03	0.03
Biomass (solid)	0.23	0.44	<0.01	<0.01	0.67
Hydrogen	<0.01	0.65	<0.01	-	0.65
Recovered energy	<0.01	-2.52	<0.01	-	-2.52
Unspecified	<0.01	<0.01	<0.01	-	<0.01
Peat	<0.01	<0.01	<0.01	-	<0.01
Geothermal	0.03	0.02	<0.01	-	0.05
Solar	<0.01	<0.01	<0.01	-	<0.01
Wave/tidal	<0.01	<0.01	<0.01	-	<0.01
Biomass (liquid/gas)	0.09	0.04	<0.01	-	0.14
Industrial waste	0.04	0.02	<0.01	-	0.07
Municipal Waste	0.09	0.04	<0.01	-	0.14
Wind	0.03	0.01	<0.01	-	0.04
Totals	16.79	46.84	0.78	37.07	101.48

Table 5
Gross primary fuels used to produce and deliver 1 kg of rigid polyurethane foam expressed as mass.

Fuel type	Input in mg
Crude oil	800000
Gas/condensate	890000
Coal	370000
Metallurgical coal	11000
Lignite	38000
Peat	260
Wood	970

Table 6
Gross raw materials required to produce and deliver 1 kg of rigid polyurethane foam.

Raw material	Input in mg
Air	600000
Animal matter	<1
Barytes	400
Bauxite	610
Bentonite	67
Biomass (including water)	91000
Calcium sulphate (CaSO4)	7
Chalk (CaCO3)	<1
Clay	5
Cr	4
Cu	1
Dolomite	190
Fe	850
Feldspar	300
Ferromanganese	1
Fluorspar	13
Granite	<1
Gravel	3
Hg	2
Limestone (CaCO3)	220000
Mg	<1
N2	180000
Ni	<1
O2	140000
Olivine	8
Pb	2
Phosphate as P2O5	970
Potassium chloride (KCl)	6400
Quartz (SiO2)	<1
Rutile	<1
S (bonded)	<1
S (elemental)	3100
Sand (SiO2)	1300
Shale	19
Sodium chloride (NaCl)	1100000
Sodium nitrate (NaNO3)	<1
Talc	<1
Unspecified	<1
Zn	<1

Table 7
Gross water consumption required for the production and delivery of 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding)

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	49000000	<1	49000000
River canal	19000000	158000000	177000000
Sea	440000	34000000	35000000
Well	36000	23000	59000
Unspecified	5200000	72000000	77000000
Totals	74000000	264000000	338000000

Table 8
Gross air emissions associated with the production and delivery of 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding)

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
dust (PM10)	1500	290	15	2500	-	-	4300
CO	3000	1000	170	740	-	-	5000
CO2	1200000	1900000	25000	390000	-95000	-	3400000
SOX as SO2	6000	4700	210	390	-	-	11000
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	3400	4000	230	600	-	-	8200
NH3	<1	-	<1	130	-	-	130
Cl2	<1	<1	<1	320	-	-	320
HCl	130	28	<1	2	-	-	160
F2	<1	<1	<1	<1	-	-	<1
HF	5	1	<1	<1	-	-	6
hydrocarbons not specified	1400	380	66	4300	-	1	6100
aldehyde (-CHO)	<1	-	<1	1	-	-	1
organics	<1	<1	<1	390	-	-	390
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Hg+compounds as Hg	<1	-	<1	<1	-	-	<1
metals not specified elsewhere	1	2	<1	<1	-	-	3
H2SO4	<1	-	<1	15	-	-	15
N2O	<1	10	<1	<1	-	-	11
H2	230	<1	<1	2200	-	-	2500
dichloroethane (DCE) C2H4Cl2	<1	-	<1	<1	-	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	-	<1	<1
CFC/HCFC/HFC not specified	<1	-	<1	7	-	-	7
organo-chlorine not specified	<1	-	<1	16	-	-	16
HCN	<1	-	<1	<1	-	-	<1
CH4	29000	840	<1	2500	-	<1	32000
aromatic HC not specified	<1	-	<1	48	-	1	50
polycyclic hydrocarbons (PAH)	<1	1	<1	1	-	-	2
NMVOC	<1	-	<1	11	-	-	11
CS2	<1	-	<1	1	-	-	1
methylene chloride CH2Cl2	<1	-	<1	<1	-	-	<1
Cu+compounds as Cu	<1	<1	<1	<1	-	-	<1
As+compounds as As	-	-	-	<1	-	-	<1
Cd+compounds as Cd	<1	-	<1	<1	-	-	<1
Ag+compounds as Ag	-	-	-	<1	-	-	<1
Zn+compounds as Zn	<1	-	<1	<1	-	-	<1
Cr+compounds as Cr	<1	1	<1	<1	-	-	1
Se+compounds as Se	-	-	-	<1	-	-	<1
Ni+compounds as Ni	<1	1	<1	<1	-	-	1
Sb+compounds as Sb	-	-	<1	<1	-	-	<1
ethylene C2H4	-	-	<1	2	-	-	2
oxygen	-	-	-	<1	-	-	<1
asbestos	-	-	-	<1	-	-	<1
dioxin/furan as Teq	-	-	-	<1	-	-	<1
benzene C6H6	-	-	-	1	-	3	4
toluene C7H8	-	-	-	<1	-	1	1
xylenes C8H10	-	-	-	<1	-	<1	<1
ethylbenzene C8H10	-	-	-	<1	-	<1	<1
styrene	-	-	-	<1	-	<1	<1
propylene	-	-	-	2	-	-	2

Table 9
Carbon dioxide equivalents corresponding to the gross air emissions for the production and delivery of 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding)

Type	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
20 year equiv	3000000	1900000	26000	560000	-95000	10	5400000
100 year equiv	1900000	1900000	26000	460000	-95000	5	4200000
500 year equiv	1400000	1900000	26000	420000	-95000	3	3600000

Table 10
Gross emissions to water arising from the production and delivery of 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding).

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	Totals (mg)
COD	6	<1	<1	4700	4700
BOD	1	<1	<1	820	820
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	6	6
Na+compounds as Na	<1	-	<1	280000	280000
acid as H+	6	-	<1	9	16
NO3-	<1	<1	<1	2400	2400
Hg+compounds as Hg	<1	-	<1	<1	<1
metals not specified elsewhere	2	-	<1	58	60
ammonium compounds as NH4+	6	<1	<1	110	110
Cl-	1	<1	<1	520000	520000
CN-	<1	-	<1	<1	<1
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-	1	-	<1	380	390
suspended solids	100	-	18	22000	23000
detergent/oil	<1	<1	<1	11	11
hydrocarbons not specified	8	<1	<1	4	12
organo-chlorine not specified	<1	-	<1	3	3
dissolved chlorine	<1	-	<1	1	1
phenols	<1	-	<1	1	1
dissolved solids not specified	<1	-	<1	8400	8400
P+compounds as P	<1	<1	<1	380	380
other nitrogen as N	1	<1	<1	900	900
other organics not specified	<1	-	<1	120	120
SO4--	<1	<1	<1	6200	6200
dichloroethane (DCE)	<1	-	<1	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	<1
K+compounds as K	<1	-	<1	110	110
Ca+compounds as Ca	<1	-	<1	57000	57000
Mg+compounds as Mg	<1	-	<1	89	89
Cr+compounds as Cr	<1	-	<1	4	4
ClO3--	<1	-	<1	130	130
BrO3--	<1	-	<1	<1	<1
TOC	<1	-	<1	960	960
AOX	<1	-	<1	12	12
Al+compounds as Al	<1	-	<1	1	1
Zn+compounds as Zn	<1	-	<1	47	47
Cu+compounds as Cu	<1	-	<1	<1	<1
Ni+compounds as Ni	<1	-	<1	5	5
CO3--	-	-	<1	990	990
As+compounds as As	-	-	<1	<1	<1
Cd+compounds as Cd	-	-	<1	<1	<1
Mn+compounds as Mn	-	-	<1	<1	<1
organo-tin as Sn	-	-	<1	<1	<1
Sr+compounds as Sr	-	-	<1	<1	<1
organo-silicon	-	-	-	<1	<1
benzene	-	-	-	<1	<1
dioxin/furan as Teq	-	-	<1	<1	<1
Mo+compounds as Mo	-	-	-	<1	<1

Table 11
Gross solid waste associated with the production and delivery of 1 kg of rigid polyurethane foam. (Totals may not agree because of rounding)

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	Totals (mg)
Plastic containers	<1	-	<1	<1	<1
Paper	<1	-	<1	4	4
Plastics	<1	-	<1	20000	20000
Metals	<1	-	<1	43	43
Putrescibles	<1	-	<1	<1	<1
Unspecified refuse	1500	-	<1	<1	1500
Mineral waste	17000	-	180	62000	79000
Slags & ash	23000	6500	70	3000	32000
Mixed industrial	-1800	-	7	15000	13000
Regulated chemicals	1800	-	<1	19000	21000
Unregulated chemicals	1400	-	<1	5300	6700
Construction waste	<1	-	<1	83	83
Waste to incinerator	<1	<1	<1	6400	6400
Inert chemical	<1	-	<1	4300	4300
Wood waste	<1	-	<1	18	18
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	300	300
Waste returned to mine	61000	-	7	690	61000
Tailings	2	-	6	160	170
Municipal solid waste	-13000	-	-	<1	-13000

Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.

Table 12
Gross solid waste in EU format associated with the production of 1 kg of rigid polyurethane foam. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

Emission	Totals (mg)
010101 metallic min'l excav'n waste	40000
010102 non-metal min'l excav'n waste	81000
010306 non 010304/010305 tailings	130
010308 non-010307 powdery wastes	7
010399 unspecified met. min'l wastes	27000
010408 non-010407 gravel/crushed rock	7
010410 non-010407 powdery wastes	27
010411 non-010407 potash/rock salt	2000
010499 unsp'd non-met. waste	2300
010505*oil-bearing drilling mud/waste	1800
010508 non-010504/010505 chloride mud	1400
010599 unspecified drilling mud/waste	1500
020107 wastes from forestry	18
030399 unsp'd wood/paper waste	<1
050106*oil ind. oily maint'e sludges	8
050107*oil industry acid tars	170
050199 unspecified oil industry waste	220
050699 coal pyrolysis unsp'd waste	140
060101*H2SO4/H2SO3 MFSU waste	4
060102*HCl MFSU waste	5
060106*other acidic MFSU waste	<1
060199 unsp'd acid MFSU waste	<1
060204*NaOH/KOH MFSU waste	<1
060299 unsp'd base MFSU waste	1100
060313*h. metal salt/sol'n MFSU waste	2700
060314 other salt/sol'n MFSU waste	360
060399 unsp'd salt/sol'n MFSU waste	600
060404*Hg MSFU waste	130
060405*other h. metal MFSU waste	430
060499 unsp'd metallic MFSU waste	1100
060602*dangerous sulphide MFSU waste	<1
060603 non-060602 sulphide MFSU waste	6
060701*halogen electrol. asbestos waste	76
060702*Cl pr. activated C waste	<1
060703*BaSO4 sludge with Hg	14
060704*halogen pr. acids and sol'ns	160
060799 unsp'd halogen pr. waste	1100
061002*N ind. dangerous sub. waste	<1
061099 unsp'd N industry waste	<1
070101*organic chem. aqueous washes	<1
070103*org. halogenated solv'ts/washes	<1
070104*other organic solv'ts/washes	<1
070107*hal'd still bottoms/residues	21000
070108*other still bottoms/residues	3300
070111*org. chem. dan. eff. sludge	<1
070112 non-070111 effluent sludge	4
070199 unsp'd organic chem. waste	2600
070204*polymer ind. other washes	<1

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Table 12 - continued

Gross solid waste in EU format associated with the production of 1 kg of rigid polyurethane foam. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	120
070209*polymer ind. hal'd fil. cakes	<1
070213 polymer ind. waste plastic	20000
070214*polymer ind. dan. additives	140
070215 non-0702130 additive waste	<1
070216 polymer ind. silicone wastes	<1
070299 unsp'd polymer ind. waste	170
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	25000
100102 coal fly ash	2600
100104*oil fly ash and boiler dust	65
100105 FGD Ca-based reac. solid waste	<1
100113*emulsified hyrdocarbon fly ash	12
100114*dangerous co-incin'n ash/slag	15
100115 non-100115 co-incin'n ash/slag	110
100116*dangerous co-incin'n fly ash	<1
100199 unsp'd themal process waste	2100
100202 unprocessed iron/steel slag	240
100210 iron/steel mill scales	12
100399 unspecified aluminium waste	12
100501 primary/secondary zinc slags	1
100504 zinc pr. other dust	<1
100511 non-100511 Zn pr. skimmings	<1
100899 unspecified o.n.f.m. waste	<1
101304 lime calcin'n/hydration waste	9
110199 unspecified surf. t waste	<1
130208*other engine/gear/lub. oil	<1
150101 paper and cardboard packaging	3
150102 plastic packaging	1
150103 wooden packaging	<1
150106 mixed packaging	1600
150110*dan. sub. contam'd packaging	<1
150202*dan. sub. absorbents	<1
160807*spent dangerous sub. catalyst	<1
170107 non-170106 con'e/brick/tile mix	<1
170405 iron and steel	<1
170904 non-170901/2/3 con./dem'n waste	91
190199 unspecified incin'n/pyro waste	<1
190905 sat./spent ion exchange resins	4300
200101 paper and cardboard	<1
200108 biodeg. kitchen/canteen waste	<1
200138 non-200137 wood	<1
200139 plastics	210
200140 metals	41
200199 other separately coll. frac'ns	-3300
200301 mixed municipal waste	53
200399 unspecified municipal wastes	-12000
Note: 1. Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	

POSTSCRIPT

All life cycle inventories are concerned with describing the behaviour of industrial systems, not products; a product is simply one materials flow within the system. The system itself is identified in terms of its function. Consequently if any comparisons are to be attempted, then they must be confined to comparing systems that perform identical functions. This is the basis of all life cycle assessments. Despite this requirement, which has been stated many times, there are still some users of life cycle inventories who continue to compare materials on the basis of 1 kg of polyurethane versus 1 kg of some other material. Such comparisons are meaningless.

Also, when comparing systems, which perform equivalent functions, it is important to compare the data for the whole life cycle and not just data for those elements of the life cycle that differ. Comparison of parts of systems can lead to misleading conclusions. For example, if polyurethane foam is used to insulate a house, the value of the exercise is demonstrated by a comparison of the system describing the un-insulated house with that describing the insulated house. Essentially the investment of a small amount of energy and feedstock in the production of the foam insulant leads to a saving of at least 100 times this initial investment in heating fuels over the lifetime of the house. The investment of 1 unit of energy results in a saving of 99 units. If a different type of insulant is used with a production energy that is 25% greater than the polyurethane, the net energy saving will be 98.75 units for every 1.25 units of initial investment.

Such a comparison indicates that the important feature is to install insulation materials of any type to achieve the saving of energy. Comparing the insulation materials on the basis of their production energies is a marginal exercise of little value since the difference in production energies of different materials is trivial compared with the ultimate saving.

European Diisocyanate and Polyol Producers Association
Avenue E. van Nieuwenhuyse Laan 4,
1160 Brussels
Belgium
Tel: ++32 2 676 7475
Fax: ++32 2 676 7479
Email: main@isopa.org
Website: www.isopa.org

ISOPA is an affiliated organisation within the European Chemical Industry Council (Cefic)

Association of Plastics Manufacturers in Europe
Avenue E. van Nieuwenhuyse Laan 4,
1160 Brussels
Belgium
Tel: ++32 2 675 32 97
Fax: ++32 2 675 39 35
Website: www.plasticseurope.org