

*Eco-profiles of the
European Plastics Industry*

STYRENE

A report by

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for

PlasticsEurope

Data last calculated

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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.

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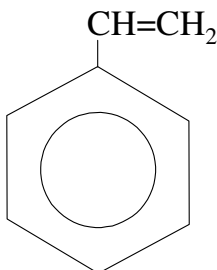
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STYRENE

Styrene has the structure:



Styrene is produced from ethyl benzene by two methods.

1. The older method, which still dominates the market, is the dehydrogenation of ethyl benzene. This is usually carried out at a temperature of 630°C in the presence of catalysts consisting of the oxides of zinc, chromium, magnesium or iron. The conversion rate is low ($\approx 40\%$) so the unreacted ethyl benzene must be recovered for reuse.
2. The more recent method is called the oxirane process. Ethyl benzene is oxidised to the hydroperoxide and then reacted with propylene to produce methyl benzyl alcohol and propylene oxide. The alcohol can then be dehydrated at relatively low temperatures to produce styrene.

Styrene readily polymerises and so a radical scavenger is added to prevent this. One of the most common additives is butylated hydroxy toluene (BHT).

ECO-PROFILE OF STYRENE

Table 1 shows the gross or cumulative energy to produce 1 kg of styrene and Table 2 gives this same data expressed in terms of primary fuels. Table 3 shows the energy data expressed as masses of fuels. Table 4 shows the raw materials requirements and Table 5 shows the demand for water. Table 6 shows the gross air emissions and Table 7 shows the corresponding carbon dioxide equivalents of these air emissions. Table 8 shows the emissions to water. Table 9 shows the solid waste generated and Table 10 gives the solid waste in EU format.

Table 1

Gross energy required to produce 1 kg of styrene. (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	3.15	1.05	0.37	-	4.57
Oil fuels	0.48	14.14	0.11	28.67	43.40
Other fuels	0.81	17.20	0.04	16.57	34.63
Totals	4.44	32.39	0.53	45.24	82.60

Table 2

Gross primary fuels required to produce 1 kg of styrene. (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	0.78	2.60	0.12	<0.01	3.51
Oil	0.88	14.32	0.18	28.67	44.06
Gas	1.46	17.93	0.12	16.57	36.08
Hydro	0.09	0.05	<0.01	-	0.15
Nuclear	1.16	0.45	0.09	-	1.69
Lignite	<0.01	<0.01	<0.01	-	<0.01
Wood	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur	<0.01	<0.01	<0.01	<0.01	<0.01
Biomass (solid)	0.01	<0.01	<0.01	<0.01	0.02
Hydrogen	<0.01	0.38	<0.01	-	0.38
Recovered energy	<0.01	-3.35	<0.01	-	-3.35
Unspecified	<0.01	<0.01	<0.01	-	<0.01
Peat	<0.01	<0.01	<0.01	-	<0.01
Geothermal	0.01	<0.01	<0.01	-	0.01
Solar	<0.01	<0.01	<0.01	-	<0.01
Wave/tidal	<0.01	<0.01	<0.01	-	<0.01
Biomass (liquid/gas)	0.02	<0.01	<0.01	-	0.03
Industrial waste	0.01	<0.01	<0.01	-	0.01
Municipal Waste	0.02	0.01	<0.01	-	0.02
Wind	<0.01	<0.01	<0.01	-	0.01
Totals	4.44	32.39	0.53	45.24	82.60

Table 3

Gross primary fuels used to produce 1 kg of styrene expressed as mass.

Fuel type	Input in mg
Crude oil	980000
Gas/condensate	710000
Coal	120000
Metallurgical coal	140
Lignite	35
Peat	91
Wood	58

Table 4
Gross raw materials required to produce 1 kg of styrene.

Raw material	Input in mg
Air	280000
Animal matter	<1
Barytes	1
Bauxite	870
Bentonite	88
Biomass (including water)	5000
Calcium sulphate (CaSO ₄)	9
Chalk (CaCO ₃)	<1
Clay	<1
Cr	<1
Cu	210
Dolomite	4
Fe	350
Feldspar	<1
Ferromanganese	<1
Fluorspar	17
Granite	<1
Gravel	1
Hg	<1
Limestone (CaCO ₃)	410
Mg	<1
N ₂	120000
Ni	31
O ₂	2600
Olivine	3
Pb	<1
Phosphate as P ₂ O ₅	<1
Potassium chloride (KCl)	8
Quartz (SiO ₂)	<1
Rutile	<1
S (bonded)	1
S (elemental)	190
Sand (SiO ₂)	350
Shale	25
Sodium chloride (NaCl)	2200
Sodium nitrate (NaNO ₃)	<1
Talc	<1
Unspecified	<1
Zn	34

Table 5
Gross water consumption required for the production of 1 kg of styrene. (Totals may not agree because of rounding)

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	930000	-	930000
River canal	890000	910000	1800000
Sea	550000	6400000	6900000
Well	<1	150000	150000
Unspecified	1300000	132000000	134000000
Totals	3700000	140000000	143000000

Table 6

Gross air emissions associated with the production of 1 kg of styrene. (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)	330	220	3	200	-	-	750
CO	1200	1900	29	460	-	-	3600
CO2	270000	1900000	10000	210000	-62	-	2400000
SOX as SO2	1200	4600	160	470	-	-	6500
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	1100	2800	68	270	-	-	4300
NH3	<1	-	<1	<1	-	-	<1
Cl2	<1	<1	<1	1	-	-	1
HCl	21	23	<1	1	-	-	45
F2	<1	<1	<1	<1	-	-	<1
HF	1	1	<1	<1	-	-	2
hydrocarbons not specified	940	280	21	1200	-	5	2500
aldehyde (-CHO)	<1	-	<1	<1	-	-	<1
organics	<1	<1	<1	240	-	-	240
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	<1	-	-	<1
N2O	<1	<1	<1	<1	-	-	<1
H2	23	<1	<1	28	-	-	51
dichloroethane (DCE) C2H4Cl2	<1	-	<1	<1	-	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	-	<1	<1
CFC/HCFC/HFC not specified	<1	-	<1	<1	-	-	<1
organo-chlorine not specified	<1	-	<1	1	-	-	1
HCN	<1	-	<1	<1	-	-	<1
CH4	27000	460	<1	2300	-	1	30000
aromatic HC not specified elsewhere	<1	-	<1	23	-	3	26
polycyclic hydrocarbons (PAH)	<1	5	<1	<1	-	-	5
NM VOC	<1	-	<1	39	-	-	39
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	3	<1	<1	-	-	3
Se+compounds as Se	-	-	-	<1	-	-	<1
Ni+compounds as Ni	<1	5	<1	<1	-	-	5
Sb+compounds as Sb	-	-	<1	<1	-	-	<1
ethylene C2H4	-	-	<1	9	-	-	9
oxygen	-	-	-	<1	-	-	<1
asbestos	-	-	-	<1	-	-	<1
dioxin/furan as Teq	-	-	-	<1	-	-	<1
benzene C6H6	-	-	-	7	-	17	24
toluene C7H8	-	-	-	<1	-	3	3
xylenes C8H10	-	-	-	<1	-	1	1
ethylbenzene C8H10	-	-	-	2	-	4	6
styrene	-	-	-	1	-	3	4
propylene	-	-	-	6	-	-	6

Table 7

Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of styrene. (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	1900000	1900000	11000	350000	-62	51	4200000
100 year equiv	900000	1900000	11000	260000	-62	29	3100000
500 year equiv	460000	1900000	11000	230000	-62	20	2600000

Table 8

Gross emissions to water arising from the production of 1 kg of styrene. (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	2	5	<1	390	400
BOD	<1	1	<1	52	53
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	<1	<1
Na+compounds as Na	<1	-	<1	230	230
acid as H+	1	-	<1	3	4
NO3-	<1	1	<1	7	8
Hg+compounds as Hg	<1	-	<1	<1	<1
metals not specified elsewhere	<1	-	<1	34	34
ammonium compounds as NH4+	1	<1	<1	10	11
Cl-	1	8	<1	370	380
CN-	<1	-	<1	<1	<1
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-	1	-	<1	7	7
suspended solids	30	-	4	150	190
detergent/oil	<1	<1	<1	28	28
hydrocarbons not specified	10	<1	<1	4	14
organo-chlorine not specified	<1	-	<1	<1	<1
dissolved chlorine	<1	-	<1	<1	<1
phenols	<1	-	<1	<1	<1
dissolved solids not specified	<1	-	<1	250	250
P+compounds as P	<1	<1	<1	1	1
other nitrogen as N	<1	<1	<1	3	3
other organics not specified	<1	-	<1	<1	<1
SO4--	<1	13	<1	370	380
dichloroethane (DCE)	<1	-	<1	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	<1
K+compounds as K	<1	-	<1	<1	<1
Ca+compounds as Ca	<1	-	<1	19	19
Mg+compounds as Mg	<1	-	<1	<1	<1
Cr+compounds as Cr	<1	-	<1	<1	<1
ClO3--	<1	-	<1	1	1
BrO3--	<1	-	<1	<1	<1
TOC	<1	-	<1	40	40
AOX	<1	-	<1	<1	<1
Al+compounds as Al	<1	-	<1	1	1
Zn+compounds as Zn	<1	-	<1	<1	<1
Cu+compounds as Cu	<1	-	<1	<1	<1
Ni+compounds as Ni	<1	-	<1	<1	<1
CO3--	-	-	<1	120	120
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 9

Gross solid waste associated with the production of 1 kg of styrene. (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	<1	<1
Plastics	<1	-	<1	4	4
Metals	<1	-	<1	<1	<1
Putrescibles	<1	-	<1	1	1
Unspecified refuse	1500	-	<1	<1	1500
Mineral waste	49	-	38	1000	1100
Slags & ash	3300	2300	15	3400	9000
Mixed industrial	1100	-	1	440	1600
Regulated chemicals	1800	-	<1	560000	560000
Unregulated chemicals	1400	-	<1	440	1800
Construction waste	<1	-	<1	49	49
Waste to incinerator	<1	1	<1	20000	20000
Inert chemical	630	-	<1	2000	2600
Wood waste	<1	-	<1	1	1
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	160	160
Waste returned to mine	24000	-	1	18000	42000
Tailings	<1	-	1	8700	8700
Municipal solid waste	-2200	-	-	920	-1200
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.					

Table 10

Gross solid waste in EU format associated with the production of 1 kg of styrene. 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	1200
010102 non-metal min'l excav'n waste	24000
010306 non 010304/010305 tailings	8
010308 non-010307 powdery wastes	2
010399 unspecified met. min'l wastes	2
010408 non-010407 gravel/crushed rock	<1
010410 non-010407 powdery wastes	<1
010411 non-010407 potash/rock salt	10
010499 unsp'd non-met. waste	3
010505*oil-bearing drilling mud/waste	1800
010508 non-010504/010505 chloride mud	1400
010599 unspecified drilling mud/waste	1500
020107 wastes from forestry	<1
050106*oil ind. oily maint'e sludges	1
050107*oil industry acid tars	210
050199 unspecified oil industry waste	200
050699 coal pyrolysis unsp'd waste	11
060101*H ₂ SO ₄ /H ₂ SO ₃ MFSU waste	<1
060102*HCl MFSU waste	<1
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	<1
060313*h. metal salt/sol'n MFSU waste	10
060314 other salt/sol'n MFSU waste	1
060399 unsp'd salt/sol'n MFSU waste	450
060404*Hg MFSU waste	<1
060405*other h. metal MFSU waste	1
060499 unsp'd metallic MFSU waste	3
060602*dangerous sulphide MFSU waste	<1
060603 non-060602 sulphide MFSU waste	<1
060701*halogen electrol. asbestos waste	<1
060702*Cl pr. activated C waste	<1
060703*BaSO ₄ sludge with Hg	<1
060704*halogen pr. acids and sol'ns	2
060799 unsp'd halogen pr. waste	5
061002*N ind. dangerous sub. waste	<1
061099 unsp'd N industry waste	<1
070101*organic chem. aqueous washes	560000
070103*org. halogenated solv'ts/washes	<1
070104*other organic solv'ts/washes	5
070107*hal'd still bottoms/residues	<1
070108*other still bottoms/residues	19000
070111*org. chem. dan. eff. sludge	<1
070112 non-070111 effluent sludge	130
070199 unsp'd organic chem. waste	470
070204*polymer ind. other washes	<1
070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	900

continued over

Table 10 - continued

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

070209*polymer ind. hal'd fil. cakes	39
070213 polymer ind. waste plastic	3
070214*polymer ind. dan. additives	180
070216 polymer ind. silicone wastes	<1
070299 unsp'd polymer ind. waste	290
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	5600
100102 coal fly ash	380
100104*oil fly ash and boiler dust	<1
100105 FGD Ca-based reac. solid waste	630
100113*emulsified hyrdocarbon fly ash	<1
100114*dangerous co-incin'n ash/slag	2800
100115 non-100115 co-incin'n ash/slag	1
100116*dangerous co-incin'n fly ash	240
100199 unsp'd themal process waste	25
100202 unprocessed iron/steel slag	100
100210 iron/steel mill scales	8
100399 unspecified aluminium waste	17
100501 primary/secondary zinc slags	<1
100504 zinc pr. other dust	<1
100511 non-100511 Zn pr. skimmings	<1
101304 lime calcin'n/hydration waste	12
130208*other engine/gear/lub. oil	2
150101 paper and cardboard packaging	<1
150102 plastic packaging	<1
150103 wooden packaging	<1
150106 mixed packaging	<1
150110*dan. sub. contam'd packaging	1
150202*dan. sub. absorbents	15
160807*spent dangerous sub. catalyst	19
170107 non-170106 con'e/brick/tile mix	<1
170405 iron and steel	<1
170904 non-170901/2/3 con./dem'n waste	49
190199 unspecified incin'n/pyro waste	<1
190905 sat./spent ion exchange resins	2000
200101 paper and cardboard	<1
200108 biodeg. kitchen/canteen waste	<1
200138 non-200137 wood	<1
200139 plastics	1
200140 metals	<1
200199 other separately coll. frac'ns	-370
200301 mixed municipal waste	4
200399 unspecified municipal wastes	270
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	