

*Eco-profiles of the  
European Plastics Industry*

REFORMER HYDROGEN

*A report by*

I Boustead

*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](http://www.plasticseurope.org).

Plastics*Europe* may be contacted at

Ave E van Nieuwenhuyse 4  
Box 3  
B-1160 Brussels

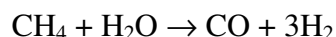
Telephone: 32-2-672-8259  
Fax: 32-2-675-3935

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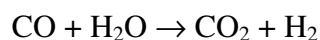
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## STEAM REFORMING

Most industrial hydrogen is produced by steam reforming low molecular weight hydrocarbons, especially methane. There are essentially two reactions. The first, known as reforming, produces a mixture of hydrogen and carbon monoxide known as *synthesis gas*. The reaction is:



The second reaction, known as the shift reaction, then converts the carbon monoxide to carbon dioxide with the production of further hydrogen.



## ECOPROFILE OF REFORMER HYDROGEN

Table 2 shows the gross or cumulative energy to produce 1 kg of reformer hydrogen and Table 3 gives this same data expressed in terms of primary fuels. Table 4 shows the energy data expressed as masses of fuels. Table 5 shows the raw materials requirements and Table 6 shows the demand for water. Table 7 shows the gross air emissions and Table 8 shows the corresponding carbon dioxide equivalents of these air emissions. Table 9 shows the emissions to water. Table 10 shows the solid waste generated and Table 11 gives the solid waste in EU format.

*Table 2*

*Gross energy required to produce 1 kg of reformer hydrogen. (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	14.02	9.98	0.07	-	24.07
Oil fuels	0.25	2.43	0.04	<0.01	2.73
Other fuels	3.06	59.21	0.13	0.02	62.42
Totals	17.34	71.62	0.24	0.02	89.22

*Table 3*

*Gross primary fuels required to produce 1 kg of reformer hydrogen. (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	1.80	0.97	<0.01	<0.01	2.77
Oil	0.76	2.71	0.19	<0.01	3.66
Gas	4.09	66.42	0.04	<0.01	70.55
Hydro	1.82	3.35	0.01	-	5.18
Nuclear	8.01	4.14	<0.01	-	12.15
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)	0.51	0.34	<0.01	<0.01	0.85
Hydrogen	<0.01	0.02	<0.01	-	0.02
Recovered energy	<0.01	-6.55	<0.01	-	-6.55
Unspecified	<0.01	<0.01	<0.01	-	<0.01
Peat	0.23	0.16	<0.01	-	0.39
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)	0.01	0.01	<0.01	-	0.02
Industrial waste	0.02	0.01	<0.01	-	0.03
Municipal Waste	0.04	0.02	<0.01	-	0.05
Wind	0.01	0.01	<0.01	-	0.02
Totals	17.34	71.62	0.24	0.02	89.22

*Table 4*

*Gross primary fuels used to produce 1 kg of reformer hydrogen expressed as mass.*

Fuel type	Input in mg
Crude oil	81000
Gas/condensate	1300000
Coal	97000
Metallurgical coal	40
Lignite	<1
Peat	44000
Wood	71

*Table 5*  
*Gross raw materials required to produce 1 kg of reformer hydrogen.*

Raw material	Input in mg
Air	38000
Animal matter	<1
Barytes	740
Bauxite	9
Bentonite	<1
Biomass (including water)	98000
Calcium sulphate (CaSO <sub>4</sub> )	<1
Chalk (CaCO <sub>3</sub> )	<1
Clay	<1
Cr	770
Cu	<1
Dolomite	1
Fe	100
Feldspar	<1
Ferromanganese	<1
Fluorspar	5
Granite	<1
Gravel	<1
Hg	<1
Limestone (CaCO <sub>3</sub> )	16000
Mg	<1
N <sub>2</sub>	48000
Ni	<1
O <sub>2</sub>	55000
Olivine	1
Pb	1
Phosphate as P <sub>2</sub> O <sub>5</sub>	<1
Potassium chloride (KCl)	<1
Quartz (SiO <sub>2</sub> )	<1
Rutile	<1
S (bonded)	<1
S (elemental)	1300
Sand (SiO <sub>2</sub> )	1300
Shale	<1
Sodium chloride (NaCl)	34000
Sodium nitrate (NaNO <sub>3</sub> )	<1
Talc	<1
Unspecified	<1
Zn	<1

*Table 6*  
*Gross water consumption required for the production of 1 kg of reformer hydrogen. (Totals may not agree because of rounding)*

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	5000000	-	5000000
River canal	4	14	18
Sea	8	490	490
Well	<1	<1	1
Unspecified	1000000	88000000	89000000
Totals	6000000	88000000	94000000

Table 7

Gross air emissions associated with the production of 1 kg of reformer hydrogen. (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)	670	2400	3	160	-	-	3300
CO	2700	690	31	<1	-	-	3500
CO2	480000	3700000	8100	9	-62	-	4200000
SOX as SO2	3000	3800	110	<1	-	-	6900
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	2800	24000	59	<1	-	-	27000
NH3	<1	-	<1	<1	-	-	<1
Cl2	<1	<1	<1	<1	-	-	<1
HCl	51	<1	<1	<1	-	-	52
F2	<1	<1	<1	<1	-	-	<1
HF	2	<1	<1	<1	-	-	2
hydrocarbons not specified	890	12000	17	<1	-	<1	13000
aldehyde (-CHO)	<1	-	<1	<1	-	-	<1
organics	<1	<1	<1	<1	-	-	<1
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	26	<1	<1	5	-	-	31
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	140000	3000	<1	1	-	<1	140000
aromatic HC not specified	<1	-	<1	<1	-	<1	<1
polycyclic hydrocarbons (PAH)	<1	<1	<1	<1	-	-	<1
NMVOC	<1	-	<1	<1	-	-	<1
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	<1	-	-	<1
oxygen	-	-	-	<1	-	-	<1
asbestos	-	-	-	<1	-	-	<1
dioxin/furan as Teq	-	-	-	<1	-	-	<1
benzene C6H6	-	-	-	<1	-	<1	<1
toluene C7H8	-	-	-	<1	-	<1	<1
xylenes C8H10	-	-	-	<1	-	<1	<1
ethylbenzene C8H10	-	-	-	<1	-	<1	<1
styrene	-	-	-	<1	-	<1	<1
propylene	-	-	-	<1	-	-	<1

*Table 8*

*Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of ethylene. (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	9100000	4000000	8300	55	-62	<1	13000000
100 year equiv	3700000	3900000	8300	26	-62	<1	7500000
500 year equiv	1500000	3800000	8300	15	-62	<1	5300000



Table 9

Gross emissions to water arising from the production of 1 kg of ethylene.  
(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	1	-	<1	1	3
BOD	<1	-	<1	<1	<1
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	1	1
Na+compounds as Na	<1	-	<1	600	600
acid as H+	1	-	<1	22	23
NO3-	<1	-	<1	1	1
Hg+compounds as Hg	<1	-	<1	<1	<1
metals not specified elsewhere	<1	-	<1	100	100
ammonium compounds as NH4+	1	-	<1	<1	1
Cl-	<1	-	<1	1400	1400
CN-	<1	-	<1	<1	<1
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-	<1	-	<1	<1	<1
suspended solids	26	-	5	1800	1800
detergent/oil	<1	-	<1	<1	<1
hydrocarbons not specified	<1	<1	<1	<1	<1
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	480	480
P+compounds as P	<1	-	<1	<1	<1
other nitrogen as N	<1	-	<1	<1	<1
other organics not specified	<1	-	<1	<1	<1
SO4--	<1	-	<1	140	140
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	2	2
Mg+compounds as Mg	<1	-	<1	1	1
Cr+compounds as Cr	<1	-	<1	13	13
ClO3--	<1	-	<1	3	3
BrO3--	<1	-	<1	<1	<1
TOC	<1	-	<1	<1	<1
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	2	2
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

*Table 10*

*Gross solid waste associated with the production of 1 kg of ethylene. (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	13	13
Metals	<1	-	<1	<1	<1
Putrescibles	<1	-	<1	<1	<1
Unspecified refuse	980	-	<1	<1	980
Mineral waste	31	-	49	1600	1700
Slags & ash	11000	32	19	32	11000
Mixed industrial	-710	-	2	4	-710
Regulated chemicals	1200	-	<1	1500	2700
Unregulated chemicals	910	-	<1	2800	3700
Construction waste	<1	-	<1	<1	<1
Waste to incinerator	<1	-	<1	<1	<1
Inert chemical	<1	-	<1	13000	13000
Wood waste	<1	-	<1	1	1
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	<1	<1
Waste returned to mine	19000	-	2	2300	21000
Tailings	1	-	2	2	5
Municipal solid waste	-5100	-	-	<1	-5100
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.					

Table 11

Gross solid waste in EU format associated with the production of 1 kg of ethylene. 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	2400
010102 non-metal min'l excav'n waste	20000
010306 non 010304/010305 tailings	5
010308 non-010307 powdery wastes	3
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	39
010499 unsp'd non-met. waste	<1
010505*oil-bearing drilling mud/waste	1200
010508 non-010504/010505 chloride mud	910
010599 unspecified drilling mud/waste	980
020107 wastes from forestry	1
050106*oil ind. oily maint'e sludges	<1
050107*oil industry acid tars	<1
050199 unspecified oil industry waste	35
050699 coal pyrolysis unsp'd waste	20
060101*H <sub>2</sub> SO <sub>4</sub> /H <sub>2</sub> SO <sub>3</sub> 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	1600
060314 other salt/sol'n MFSU waste	<1
060399 unsp'd salt/sol'n MFSU waste	170
060404*Hg MFSU waste	<1
060405*other h. metal MFSU waste	2600
060499 unsp'd metallic MFSU waste	8
060602*dangerous sulphide MFSU waste	<1
060603 non-060602 sulphide MFSU waste	3
060701*halogen electrol. asbestos waste	3
060702*Cl pr. activated C waste	<1
060703*BaSO <sub>4</sub> sludge with Hg	<1
060704*halogen pr. acids and sol'ns	15
060799 unsp'd halogen pr. waste	8
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
070107*hal'd still bottoms/residues	<1
070108*other still bottoms/residues	<1

continued over .....

*Table 11 - continued*

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

070111*org. chem. dan. eff. sludge	<1
070112 non-070111 effluent sludge	<1
070199 unsp'd organic chem. waste	2
070204*polymer ind. other washes	<1
070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	<1
070209*polymer ind. hal'd fil. cakes	<1
070213 polymer ind. waste plastic	<1
070214*polymer ind. dan. additives	<1
070216 polymer ind. silicone wastes	<1
070299 unsp'd polymer ind. waste	<1
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	11000
100102 coal fly ash	1
100104*oil fly ash and boiler dust	<1
100105 FGD Ca-based reac. solid waste	<1
100113*emulsified hyrdocarbon fly ash	<1
100114*dangerous co-incin'n ash/slag	<1
100115 non-100115 co-incin'n ash/slag	2
100116*dangerous co-incin'n fly ash	<1
100199 unsp'd themal process waste	2
100202 unprocessed iron/steel slag	30
100210 iron/steel mill scales	2
100399 unspecified aluminium waste	<1
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	<1
130208*other engine/gear/lub. oil	<1
150101 paper and cardboard packaging	<1
150102 plastic packaging	<1
150103 wooden packaging	<1
150106 mixed packaging	<1
170107 non-170106 con'e/brick/tile mix	<1
170904 non-170901/2/3 con./dem'n waste	<1
190199 unspecified incin'n/pyro waste	<1
190905 sat./spent ion exchange resins	13000
200101 paper and cardboard	<1
200108 biodeg. kitchen/canteen waste	<1
200138 non-200137 wood	<1
200139 plastics	13
200140 metals	<1
200199 other separately coll. frac'ns	-1700
200301 mixed municipal waste	<1
200399 unspecified municipal wastes	-4200
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	