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Eco-profiles of the European Plastics Industry

CRACKER HYDROGEN

A report by

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for

Plastics*Europe*

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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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INTRODUCTION

The output fractions from an oil refinery are complex mixtures of predominantly unreactive, saturated hydrocarbons. The first step in converting such fractions into feedstocks suitable for the petrochemical industries is cracking. Essentially the cracker performs two functions by (a) reducing the complexity of the input mixture into a smaller number of low molecular mass hydrocarbons and (b) introducing unsaturation into the hydrocarbons so that they become more reactive.

CRACKING

Cracking is a three stage operation as shown in Figure 1. Although it is possible to identify schematically the three processes, in practice they behave as a single unit and information about the performance characteristics of a cracker is usually only available for the overall system.

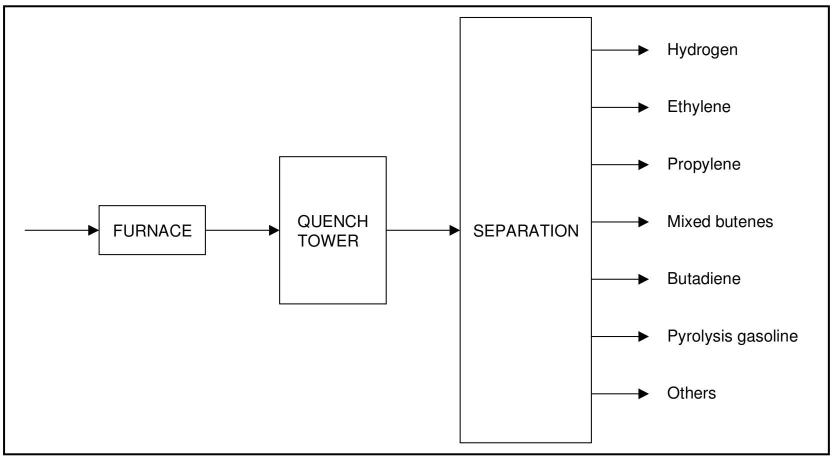

Figure 1.
Schematic diagram of a cracker.

The raw hydrocarbon feed from the refinery is usually pre-heated, mixed with steam and fed to the furnace section. Here it is raised to a high temperature (typically in the range 810-880°C). The reaction products that are formed depend upon the composition of the feed, the temperature of the furnace and the time that the hydrocarbons are held within the furnace (residence time). Residence time is typically 1 second or less. The cracker operator chooses temperature and residence time to optimise the product mix from a given feedstock.

Upon leaving the furnace section, the gaseous mixture of hydrocarbon products is quench cooled to stop any further reactions and is then sent to the separation section where the individual hydrocarbons are separated from one another.

Cracker feeds may be the naphtha fraction from oil refining, natural gas, gas condensates or a mixture of all three. When natural gas feeds are used, the primary function of the cracker is to introduce unsaturation into the molecules.

This report is concerned with cracker hydrogen. Depending on the requirements of the petrochemical plant, cracker hydrogen may be used as a reactant or it may be used as a fuel.

At the end of 1999 there were 50 crackers operating in Western Europe with a total *ethylene* capacity of 21.1 million tonnes.[1] The present report examined the performance characteristics of 17 crackers all of which supplied the petrochemical industry. The mix of products produced is shown in Table 1.

Table 1
Mix of products from the 17 crackers examined.

Product	Output/Mt	%
Ethylene	7.78	42.1
Propylene	3.63	19.6
Butenes (mixed)	1.52	8.2
Butadiene	0.98	5.3
Hydrogen	0.22	1.2
Pyrolysis gasoline	4.37	23.6
Total	18.5	100.0

PARTIONING IN CRACKERS

In the calculations, the inputs and outputs of the crackers were partitioned amongst the products on a simple mass basis using the total output of the crackers as the normalising parameter.

ECOPROFILE OF CRACKER HYDROGEN

Table 2 shows the gross or cumulative energy to produce 1 kg of cracker 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.

[1] *Petrochemical Activity Review 1999-2000*. CEFIC, Brussels. 2001.

Table 2

Gross energy required to produce 1 kg of cracker 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	2.57	0.69	0.46	-	3.72
Oil fuels	0.14	11.86	0.07	21.37	33.45
Other fuels	0.33	6.87	0.02	27.46	34.67
Totals	3.04	19.42	0.54	48.84	71.84

Table 3

Gross primary fuels required to produce 1 kg of cracker 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	0.70	0.54	0.15	<0.01	1.39
Oil	0.54	12.00	0.12	21.37	34.03
Gas	1.05	8.75	0.14	27.46	37.41
Hydro	0.04	0.02	<0.01	-	0.06
Nuclear	0.65	0.19	0.11	-	0.95
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)	0.02	0.01	<0.01	<0.01	0.02
Hydrogen	<0.01	<0.01	<0.01	-	<0.01
Recovered energy	<0.01	-2.09	<0.01	-	-2.09
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	0.01	<0.01	<0.01	-	0.02
Wind	<0.01	<0.01	<0.01	-	<0.01
Totals	3.04	19.42	0.54	48.84	71.84

Table 4

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

Fuel type	Input in mg
Crude oil	760000
Gas/condensate	740000
Coal	49000
Metallurgical coal	150
Lignite	<1
Peat	390
Wood	3

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

Raw material	Input in mg
Air	710000
Animal matter	<1
Barytes	<1
Bauxite	2
Bentonite	110
Biomass (including water)	6600
Calcium sulphate (CaSO4)	11
Chalk (CaCO3)	<1
Clay	<1
Cr	<1
Cu	<1
Dolomite	5
Fe	380
Feldspar	<1
Ferromanganese	<1
Fluorspar	<1
Granite	<1
Gravel	1
Hg	<1
Limestone (CaCO3)	370
Mg	<1
N2	140000
Ni	<1
O2	7
Olivine	4
Pb	<1
Phosphate as P2O5	<1
Potassium chloride (KCl)	<1
Quartz (SiO2)	<1
Rutile	<1
S (bonded)	<1
S (elemental)	91
Sand (SiO2)	71
Shale	31
Sodium chloride (NaCl)	540
Sodium nitrate (NaNO3)	<1
Talc	<1
Unspecified	<1
Zn	<1

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

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	180000	-	180000
River canal	560000	10000	570000
Sea	780000	6200000	7000000
Well	<1	<1	<1
Unspecified	540000	67000000	67000000
Totals	2100000	73000000	75000000

Table 7
Gross air emissions associated with the production of 1 kg of cracker 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)	180	61	1	190	-	-	430
CO	910	1200	8	450	-	-	2500
CO2	220000	910000	6100	98000	-2	-	1200000
SOX as SO2	880	660	110	380	-	-	2000
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	860	1100	33	140	-	-	2100
NH3	<1	-	<1	<1	-	-	<1
Cl2	<1	<1	<1	<1	-	-	<1
HCl	20	2	<1	<1	-	-	22
F2	<1	<1	<1	<1	-	-	<1
HF	1	<1	<1	<1	-	-	1
hydrocarbons not specified	480	44	11	1200	-	<1	1700
aldehyde (-CHO)	<1	-	<1	<1	-	-	<1
organics	<1	<1	<1	380	-	-	380
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Hg+compounds as Hg	<1	-	<1	<1	-	-	<1
metals not specified elsewhere	<1	<1	<1	<1	-	-	<1
H2SO4	<1	-	<1	<1	-	-	<1
N2O	<1	<1	<1	<1	-	-	<1
H2	29	<1	<1	2	-	-	30
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	14000	180	<1	3600	-	<1	18000
aromatic HC not specified elsewhere	<1	-	<1	8	-	<1	8
polycyclic hydrocarbons (PAH)	<1	<1	<1	<1	-	-	<1
NMVOC	<1	-	<1	14	-	-	14
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	1100000	930000	6200	320000	-2	<1	2400000
100 year equiv	560000	920000	6200	180000	-2	<1	1700000
500 year equiv	320000	920000	6200	130000	-2	<1	1400000

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	150	150
BOD	<1	-	<1	37	37
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	<1	<1
Na+compounds as Na	<1	-	<1	160	160
acid as H+	<1	-	<1	1	1
NO3-	<1	-	<1	6	6
Hg+compounds as Hg	<1	-	<1	<1	<1
metals not specified elsewhere	<1	-	<1	9	9
ammonium compounds as	<1	-	<1	1	2
Cl-	<1	-	<1	74	74
CN-	<1	-	<1	<1	<1
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-	<1	-	<1	9	9
suspended solids	12	-	1	110	130
detergent/oil	<1	-	<1	20	20
hydrocarbons not specified	13	<1	<1	<1	13
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	15	15
P+compounds as P	<1	-	<1	<1	<1
other nitrogen as N	<1	-	<1	4	4
other organics not specified	<1	-	<1	<1	<1
SO4--	<1	-	<1	480	480
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	<1	<1
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	52	52
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	170	170
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	<1	<1
Metals	<1	-	<1	<1	<1
Putrescibles	<1	-	<1	<1	<1
Unspecified refuse	530	-	<1	<1	530
Mineral waste	10	-	9	420	440
Slags & ash	2900	190	3	1100	4200
Mixed industrial	330	-	<1	330	660
Regulated chemicals	660	-	<1	240	900
Unregulated chemicals	490	-	<1	180	670
Construction waste	<1	-	<1	<1	<1
Waste to incinerator	<1	-	<1	120	120
Inert chemical	<1	-	<1	390	390
Wood waste	<1	-	<1	<1	<1
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	180	180
Waste returned to mine	9500	-	<1	1	9500
Tailings	<1	-	<1	<1	1
Municipal solid waste	-1800	-	-	<1	-1800

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	290
010102 non-metal min'l excav'n waste	9600
010306 non 010304/010305 tailings	1
010308 non-010307 powdery wastes	1
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	1
010499 unsp'd non-met. waste	<1
010505*oil-bearing drilling mud/waste	630
010508 non-010504/010505 chloride mud	490
010599 unspecified drilling mud/waste	530
020107 wastes from forestry	<1
050106*oil ind. oily maint'e sludges	5
050107*oil industry acid tars	180
050199 unspecified oil industry waste	170
050699 coal pyrolysis unsp'd waste	7
060101*H2SO4/H2SO3 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	2
060314 other salt/sol'n MFSU waste	<1
060399 unsp'd salt/sol'n MFSU waste	1
060404*Hg MSFU waste	<1
060405*other h. metal MFSU waste	<1
060499 unsp'd metallic MFSU waste	<1
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*BaSO4 sludge with Hg	<1
060704*halogen pr. acids and sol'ns	1
060799 unsp'd halogen pr. waste	<1
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	36
070111*org. chem. dan. eff. sludge	<1
070112 non-070111 effluent sludge	<1

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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

070199 unsp'd organic chem. waste	76
070204*polymer ind. other washes	<1
070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	170
070209*polymer ind. hal'd fil. cakes	<1
070213 polymer ind. waste plastic	<1
070214*polymer ind. dan. additives	150
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	3100
100102 coal fly ash	950
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	59
100115 non-100115 co-incin'n ash/slag	2
100116*dangerous co-incin'n fly ash	<1
100199 unsp'd themal process waste	<1
100202 unprocessed iron/steel slag	110
100210 iron/steel mill scales	9
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	16
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	390
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	-200
200301 mixed municipal waste	1
200399 unspecified municipal wastes	-1100
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	