PlasticsEurope
Association of Plastics Manufacturers

Eco-profiles of the
European Plastics Industry

NAPHTHA

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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OIL REFINING

Crude oil is a complex mixture of hydrocarbons together with impurities such as sulphur and some heavy metals. Apart from removing the non-hydrocarbon components, oil refining splits the crude oil into a series of fractions, each of which contain hydrocarbons having boiling points within a specified range.

This is possible because the boiling point of a hydrocarbon increases as the molecular weight increases as shown in Figure 1.

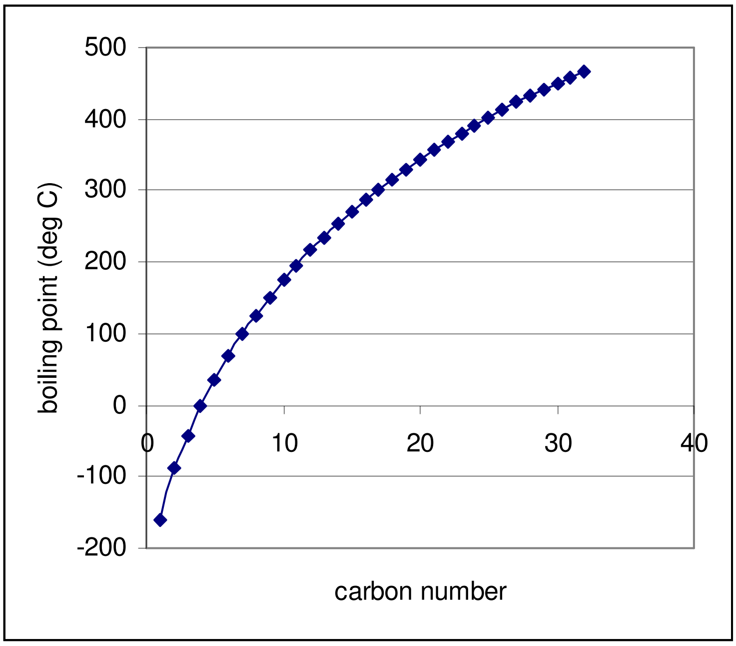

Figure 1
Boiling point as a function of carbon number for the linear alkanes.

FRACTIONAL DISTILLATION

The first stage in oil refining is fractional distillation. Figure 2 shows schematically a distillation column. Essentially the crude oil is fed into a column containing a number of perforated trays. There is a temperature gradient along the column with the highest temperature at the bottom. When hydrocarbons inside the column reach a region with the same temperature as their boiling point, they condense and can be drawn off at intermediate stages in the column, as shown in Figure 2. These drawn off products are referred to as *cuts* or *fractions*.

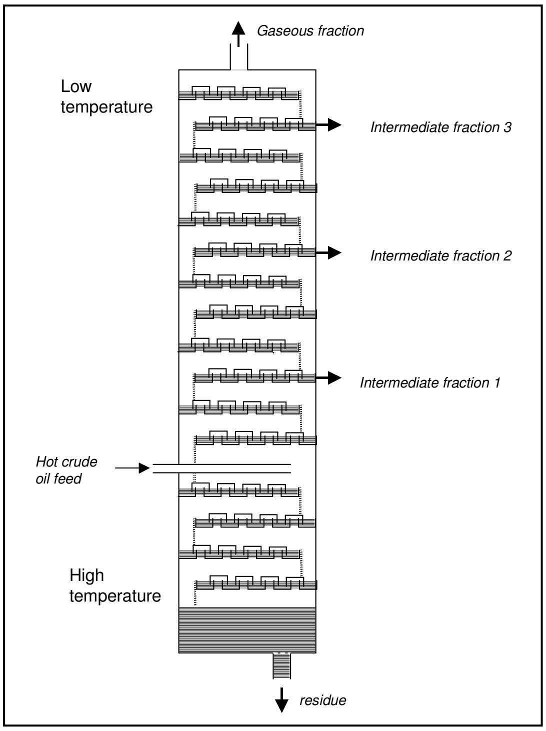

Figure 2
Schematic diagram of a fractionating column.

In practice it is not possible to obtain all of the products that are required in a single stage and so many of the fractions may be repeatedly distilled to obtain a sufficiently characterised product.

Within the petroleum industry the fractions that are separated within different boiling ranges are given names. Unfortunately there is no standardised naming system and this can be confusing when reading the literature. Table 1 lists some of the names that are used, the temperature ranges to which they refer and the approximate range of carbon numbers that are extracted within that temperature range. The principal fraction used in the petrochemical industry is naphtha.

The operating characteristics of different refineries depend on the type of crude oil to be processed and the demand for the different fractions. Some refineries, for example, may choose to maximise naphtha production whereas others may seek to maximise gasoline production. For the petrochemical industry, naphtha and, to a lesser extent, gasoline, are the most commonly used. Table 2 shows the different fractions that could be obtained from a sample of Kuwaiti crude oil and it is clear that by varying the refinery conditions different quantities of the products could be obtained.

Table 1
Some of the names that are applied to the different cuts of crude oil

Name	Temperature range (°C)	Approx number of carbon atoms in the molecules in the fraction
Light naphtha	1 – 150	1 – 9
Gasoline	1 – 180	1 – 10
Gasoline	30 – 210	5 – 12
Naphtha	100 – 200	8 – 12
Heavy naphtha	150 – 205	9 – 13
Kerosene	150 - 250	9 – 13
Jet fuel	150 – 250	9 – 13
Kerosene	205 – 260	11 – 14
Stove oil	205 – 290	11 – 16
Diesel	160 – 400	9 – 25
Fuel oil	160 – 400	9 – 25
Light diesel	232 – 343	13 – 20
Light gas oil	260 – 315	14 – 19
Gas oil	220 – 345	12 – 20
Heavy gas oil	315 – 425	18 – 27
Heavy fuel oil	315 – 540	18 - 45
Wax distillate	371 – 525	22 – 40
Lubricating oil	400+	25+
Vacuum gas oil	425 – 600	27+
Atmospheric residue	450+	30+
Bitumen	525+	40+
Residuum	600+	50+
Vacuum residue	615+	60+

Table 2
Refinery cuts that could be obtained from a sample of Kuwaiti crude oil by fractionating in different ways.

Fraction	Temperature range (°C)	wt%
Gas	<15	1.77
Gasoline 1	15 – 95	6.05
Gasoline 2	15 – 149	13.55
Naphtha	95 – 175	11.60
Kerosene	149 – 232	12.25
Diesel 1	232 – 343	17.00
Diesel 2	343 – 371	4.15
Fuel oil 1	>343	55.45
Fuel oil 2	>371	51.30
Wax distillate	371 – 525	19.85
Bitumen	>525	30.30

In the early days of oil industry the simple fractions, often referred to as straight run were directly used as saleable products. Nowadays, however, the properties and quality of almost all petroleum products have to be specially tailored to meet stringent market demands. It is often difficult to meet these requirements and, at the same time, make the various products in the proportions demanded by the market. By taking advantage of the different characteristics of crude oils from different fields, it is often possible to provide a blend of oils as refinery feed that is best suited to a specific product pattern. This is one of the reasons why countries, apparently self sufficient in oil, import oils from around the world.

One important consequence of the varying composition of crude oils from different sources is that their calorific values will be different. In all later calculations, the actual calorific value is used when this is known. When calorific value is not known, a value of 45 MJ/kg has been used (gross calorific value).

CRUDE OIL REFINING

Data on oil refining have been obtained from two separate sources: direct returns from seven oil refineries and world data from the IEA statistics. The former give emission data as well as process inputs. The latter give only energy inputs. Coincidentally when the energy characteristics of the refinery operations are calculated separately from these two data sources, the final results are within 3% of each other.

The combined average data for refinery performance is shown in Table 3. Note the data of Table 3 refer to the refinery operation alone.

Table 3
Average input-output data for the production of 1 kg of refinery naphtha from crude oil.

INPUTS	Crude oil	45.03685	MJ
	Solid fuels	0.20895	MJ
	Natural gas	0.53268	MJ
	Oil products	1.79659	MJ
	Electricity	0.19611	MJ
AIR EMISSIONS	Dust	11	mg
	CO	24	mg
	CO2	71818	mg
	SOX	538	mg
	NOX	141	mg
	CH4	285	mg
	Mixed hydrocarbons	162	mg
WATER EMISSIONS	COD	10.00	mg
	BOD	3.00	mg
	Na+	2.00	mg
	NO3	0.30	mg
	Metals	0.02	mg
	NH4+	2.00	mg
	Cl-	5.00	mg
	Suspended solids	1.00	mg
	Hydrocarbons	0.10	mg
	Phenol	0.02	mg
	Dissolved org	5.00	mg
	Phosphate	0.10	mg
SOLID WASTE	Mixed industrial	0.00017	kg
	Regulated	0.00026	kg

Within the refinery the inputs and outputs have been partitioned on the basis of the energy content (gross calorific values) of the products.

ECO-PROFILE OF REFINERY NAPHTHA

Table 4 shows the gross or cumulative energy to produce 1 kg of crude oil feedstock and deliver it to the refinery and Table 5 gives this same data expressed in terms of primary fuels. Table 6 shows the energy data expressed as masses of fuels. Table 7 shows the raw materials requirements and Table 8 shows the demand for water. Table 9 shows the gross air emissions and Table 10 shows the corresponding carbon dioxide equivalents of these air emissions. Table 11 shows the emissions to water. Table 12 shows the solid waste generated and Table 13 gives the solid waste in EU format.

Table 4
Gross energy required to produce 1 kg of naphtha. (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	1.27	0.18	0.30	-	1.75
Oil fuels	0.06	2.14	0.09	45.00	47.29
Other fuels	0.06	1.20	<0.01	-	1.26
Totals	1.39	3.53	0.38	45.00	50.30

Table 5
Gross primary fuels required to produce 1 kg of naphtha. (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	0.25	0.01	0.10	-	0.36
Oil	0.63	2.31	0.11	45.00	48.05
Gas	0.33	1.20	0.09	-	1.62
Hydro	0.01	<0.01	<0.01	-	0.01
Nuclear	0.16	<0.01	0.07	-	0.24
Lignite	<0.01	<0.01	<0.01	-	<0.01
Wood	<0.01	<0.01	<0.01	-	<0.01
Sulphur	<0.01	<0.01	<0.01	-	<0.01
Biomass (solid)	<0.01	<0.01	<0.01	-	0.01
Hydrogen	<0.01	<0.01	<0.01	-	<0.01
Recovered energy	<0.01	<0.01	<0.01	-	<0.01
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)	0.01	<0.01	<0.01	-	0.01
Industrial waste	<0.01	<0.01	<0.01	-	<0.01
Municipal Waste	<0.01	<0.01	<0.01	-	<0.01
Wind	<0.01	<0.01	<0.01	-	<0.01
Totals	1.39	3.53	0.38	45.00	50.30

Table 6
Gross primary fuels used to produce 1 kg of naphtha expressed as mass.

Fuel type	Input in mg
Crude oil	1100000
Gas/condensate	31000
Coal	13000
Metallurgical coal	4
Lignite	<1
Peat	<1
Wood	<1

Table 7
Gross raw materials required to produce 1 kg of naphtha.

Raw material	Input in mg
Air	1
Barytes	<1
Bauxite	<1
Bentonite	<1
Biomass (including water)	2000
Calcium sulphate (CaSO4)	<1
Chalk (CaCO3)	<1
Clay	<1
Cr	<1
Cu	<1
Dolomite	<1
Fe	10
Feldspar	<1
Ferromanganese	<1
Fluorspar	<1
Granite	<1
Gravel	<1
Hg	<1
Limestone (CaCO3)	2
N2	1
Ni	<1
O2	<1
Olivine	<1
Pb	<1
Phosphate as P2O5	<1
Potassium chloride (KCl)	<1
Rutile	<1
S (bonded)	<1
S (elemental)	<1
Sand (SiO2)	<1
Shale	<1
Sodium chloride (NaCl)	<1
Talc	<1
Unspecified	<1
Zn	<1

Table 8
Gross water consumption required for the production of 1 kg of naphtha. (Totals may not agree because of rounding)

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	180	-	180
River canal	<1	<1	<1
Sea	<1	46	47
Well	<1	<1	<1
Unspecified	36000	25000	62000
Totals	37000	25000	62000

Table 9
Gross air emissions associated with the production of 1 kg of naphtha. (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)	94	16	<1	190	-	-	300
CO	710	47	3	430	-	-	1200
CO2	120000	89000	6200	74000	<1	-	290000
SOX as SO2	440	380	120	540	-	-	1500
H2S	<1	-	<1	-	-	-	<1
mercaptan	<1	<1	<1	-	-	-	<1
NOX as NO2	780	250	30	140	-	-	1200
NH3	<1	-	<1	-	-	-	<1
Cl2	<1	-	<1	-	-	-	<1
HCl	7	<1	<1	-	-	-	7
F2	<1	-	<1	-	-	-	<1
HF	<1	<1	<1	-	-	-	<1
hydrocarbons not specified	270	34	10	1100	-	-	1400
aldehyde (-CHO)	<1	-	<1	-	-	-	<1
organics	<1	-	<1	-	-	-	<1
Pb+compounds as Pb	<1	-	<1	-	-	-	<1
Hg+compounds as Hg	<1	-	<1	-	-	-	<1
metals not specified elsewhere	<1	<1	<1	-	-	-	<1
H2SO4	<1	-	<1	-	-	-	<1
N2O	<1	-	<1	-	-	-	<1
H2	10	-	<1	-	-	-	10
dichloroethane (DCE) C2H4Cl2	<1	-	<1	-	-	-	<1
vinyl chloride monomer (VCM)	<1	-	<1	-	-	-	<1
CFC/HCFC/HFC not specified	<1	-	<1	-	-	-	<1
organo-chlorine not specified	<1	-	<1	-	-	-	<1
HCN	<1	-	<1	-	-	-	<1
CH4	710	91	<1	1500	-	-	2300
aromatic HC not specified elsewhere	<1	-	<1	-	-	-	<1
polycyclic hydrocarbons (PAH)	<1	-	<1	-	-	-	<1
NMVOC	<1	-	<1	-	-	-	<1
CS2	<1	-	<1	-	-	-	<1
methylene chloride CH2Cl2	<1	-	<1	-	-	-	<1
Cu+compounds as Cu	<1	-	<1	-	-	-	<1
Cd+compounds as Cd	<1	-	<1	-	-	-	<1
Zn+compounds as Zn	<1	-	<1	-	-	-	<1
Cr+compounds as Cr	<1	-	<1	-	-	-	<1
Ni+compounds as Ni	<1	-	<1	-	-	-	<1

Table 10
Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of naphtha. (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	160000	95000	6200	170000	<1	-	430000
100 year equiv	130000	92000	6200	110000	<1	-	340000
500 year equiv	120000	90000	6200	89000	<1	-	310000

Table 11
Gross emissions to water arising from the production of 1 kg of naphtha. (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	10	10
BOD	<1	-	<1	3	3
Pb+compounds as Pb	<1	-	<1	-	<1
Fe+compounds as Fe	<1	-	<1	-	<1
Na+compounds as Na	<1	-	<1	2	2
acid as H+	<1	-	<1	-	<1
NO3-	<1	-	<1	<1	<1
Hg+compounds as Hg	<1	-	<1	-	<1
metals not specified elsewhere	<1	-	<1	<1	<1
ammonium compounds as NH4+	<1	-	<1	2	2
Cl-	<1	-	<1	5	5
CN-	<1	-	<1	-	<1
F-	<1	-	<1	-	<1
S+sulphides as S	<1	-	<1	-	<1
dissolved organics (non-	<1	-	<1	5	5
suspended solids	4	-	<1	1	5
detergent/oil	<1	-	<1	-	<1
hydrocarbons not specified	<1	-	<1	<1	<1
organo-chlorine not specified	<1	-	<1	-	<1
dissolved chlorine	<1	-	<1	-	<1
phenols	<1	-	<1	<1	<1
dissolved solids not specified	<1	-	<1	-	<1
P+compounds as P	<1	-	<1	<1	<1
other nitrogen as N	<1	-	<1	-	<1
other organics not specified	<1	-	<1	-	<1
SO4--	<1	-	<1	-	<1
dichloroethane (DCE)	<1	-	<1	-	<1
vinyl chloride monomer (VCM)	<1	-	<1	-	<1
K+compounds as K	<1	-	<1	-	<1
Ca+compounds as Ca	<1	-	<1	-	<1
Mg+compounds as Mg	<1	-	<1	-	<1
Cr+compounds as Cr	<1	-	<1	-	<1
ClO3--	<1	-	<1	-	<1
BrO3--	<1	-	<1	-	<1
TOC	<1	-	<1	-	<1
AOX	<1	-	<1	-	<1
Al+compounds as Al	<1	-	<1	-	<1
Zn+compounds as Zn	<1	-	<1	-	<1
Cu+compounds as Cu	<1	-	<1	-	<1
Ni+compounds as Ni	<1	-	<1	-	<1

Table 12
Gross solid waste associated with the production of 1 kg of naphtha. (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
Paper	<1	-	<1	-	<1
Plastics	<1	-	<1	-	<1
Metals	<1	-	<1	-	<1
Putrescibles	<1	-	<1	-	<1
Unspecified refuse	320	-	<1	-	320
Mineral waste	6	-	2	-	8
Slags & ash	860	21	1	-	880
Mixed industrial	320	-	<1	170	490
Regulated chemicals	400	-	<1	260	660
Unregulated chemicals	300	-	<1	-	300
Construction waste	<1	-	<1	-	<1
Waste to incinerator	<1	-	<1	-	<1
Inert chemical	<1	-	<1	-	<1
Wood waste	<1	-	<1	-	<1
Wooden pallets	<1	-	<1	-	<1
Waste to recycling	<1	-	<1	-	<1
Waste returned to mine	2400	-	<1	-	2400
Tailings	<1	-	<1	-	<1
Municipal solid waste	-440	-	-	-	-440
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.					

Table 13
Gross solid waste in EU format associated with the production of 1 kg of naphtha. 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	8
010102 non-metal min'l excav'n waste	2400
010306 non 010304/010305 tailings	<1
010308 non-010307 powdery wastes	<1
010399 unspecified met. min'l wastes	<1
010408 non-010407 gravel/crushed rock	<1
010411 non-010407 potash/rock salt	<1
010499 unsp'd non-met. waste	<1
010505*oil-bearing drilling mud/waste	380
010508 non-010504/010505 chloride mud	300
010599 unspecified drilling mud/waste	320
020107 wastes from forestry	<1
050107*oil industry acid tars	260
050199 unspecified oil industry waste	180
050699 coal pyrolysis unsp'd waste	3
060101*H2SO4/H2SO3 MFSU waste	<1
060102*HCl MFSU waste	<1
060204*NaOH/KOH MFSU waste	<1
060313*h. metal salt/sol'n MFSU waste	<1
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
060703*BaSO4 sludge with Hg	<1
060704*halogen pr. acids and sol'ns	<1
060799 unsp'd halogen pr. waste	<1
070107*hal'd still bottoms/residues	<1
070108*other still bottoms/residues	<1
070111*org. chem. dan. eff. sludge	<1
070199 unsp'd organic chem. waste	<1
070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	<1
070213 polymer ind. waste plastic	<1
070214*polymer ind. dan. additives	<1
070299 unsp'd polymer ind. waste	<1
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	870
100102 coal fly ash	<1
100105 FGD Ca-based reac. solid waste	<1

continued over …..

Table 13 - continued
Gross solid waste in EU format associated with the production of 1 kg of naphtha. Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

100114*dangerous co-incin'n ash/slag	<1
100115 non-100115 co-incin'n ash/slag	<1
100116*dangerous co-incin'n fly ash	<1
100199 unsp'd themal process waste	<1
100202 unprocessed iron/steel slag	3
100210 iron/steel mill scales	<1
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
150103 wooden packaging	<1
170107 non-170106 con'e/brick/tile mix	<1
190199 unspecified incin'n/pyro waste	<1
190905 sat./spent ion exchange resins	<1
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	-2
200301 mixed municipal waste	<1
200399 unspecified municipal wastes	-110
Note: Negative values correspond to consumption of waste e.g. recycling or	