



# NETL Life Cycle Inventory Data

## Process Documentation File

**Process Name:** Petroleum Based Gasoline Energy Conversion Facility  
**Reference Flow:** 1 kg of Gasoline  
**Brief Description:** This process includes all inputs required for the conversion of crude oil to gasoline, based on the production of 1 kg of petroleum gasoline finished fuel.

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### Section I: Meta Data

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**Geographical Coverage:** US                                      **Region:** N/A  
**Year Data Best Represents:** 2005  
**Process Type:** Energy Conversion (EC)  
**Process Scope:** Gate-to-Gate Process (GG)  
**Allocation Applied:** Yes  
**Completeness:** All Relevant Flows Captured

**Flows Aggregated in Data Set:**

Process                       Energy Use                       Energy P&D                       Material P&D

**Relevant Output Flows Included in Data Set:**

**Releases to Air:**     Greenhouse Gases                       Criteria Air Pollutants                       Other  
**Releases to Water:**  Inorganic Emissions                       Organic Emissions                       Other  
**Water Usage:**                       Water Consumption                       Water Demand (throughput)  
**Releases to Soil:**     Inorganic Releases                       Organic Releases                       Other

**Adjustable Process Parameters:**

S3\_DELTA\_GHGA                      *Adjusts refinery CO<sub>2</sub> emissions per change in crude oil source*

S3\_FENERGY                                      *Fraction of refinery energy attributable to a chosen refinery product – i.e., attributable to gasoline*

S3\_FH2    *Fraction of refinery hydrogen attributable to a chosen refinery product – i.e., attributable to gasoline*

S3\_RHO\_BBL    *Density of refinery product, based on the specific gravity of input crude*



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### Tracked Input Flows:

Crude Oil NETL [Crude oil products]      *The quantity of crude oil used to run the energy conversion facility (refinery) process*

### Tracked Output Flows:

Gasoline [Valuable substance]      *Finished gasoline produced and ready for transport to the end user*

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## Section II: Process Description

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### Associated Documentation

This unit process is composed of this document and the data sheet (DS) *DS\_ECF\_Gasoline\_Refinery\_2011.02.xls*, which provides additional details regarding relevant calculations, data quality, and references.

### Goal and Scope

The scope of this unit process covers all aspects of the energy conversion facility (ECF) in support of gasoline production prior to transport of the finished fuel to the end user. This process is applicable only to gasoline fuels produced at the ECF. Other types of fuels produced at the ECF, including diesel and kerosene jet fuel, are treated in separate processes. This process evaluates inputs and environmental flows associated with conventional petroleum-based gasoline refining, as shown in **Figure 1**. At the downstream boundary of the process, one kilogram of finished petroleum-based gasoline is delivered to the life cycle (LC) Stage #4 boundary. LC Stages #1 and #2 (raw materials acquisition and raw materials transport) are treated separately in separate unit processes.

### Boundary and Description

LC Stage #3, energy conversion in support of petroleum-based gasoline production, includes all operation procedures required for the production of gasoline fuel from crude oil. The scope for this process does not include construction of the refinery, nor does it include refinery commissioning/decommissioning. Within refinery operation, upstream processes (i.e., hard coal, hydrogen, and steam) are included. The plan for the ECF for petroleum-based gasoline is provided in **Figure 1**.

Figure 1: Plan for Petroleum Gasoline Energy Conversion Facility

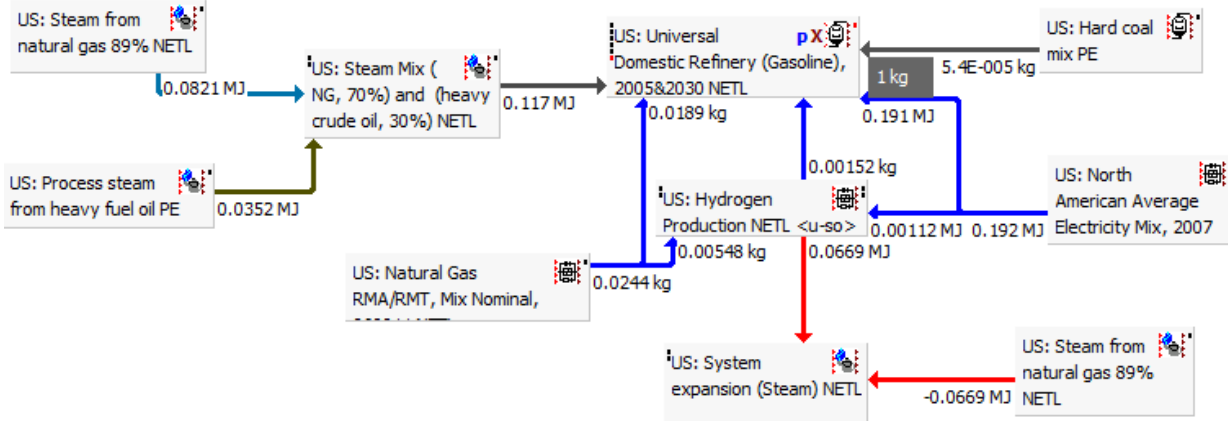
## Stage #3: Universal-Domestic Fuel Conversion Facility (Gasoline)

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GaBi 4 process plan:Reference quantities

ENERGY CONVERSION FACILITY OPERATIONS. INPUTS INCLUDE CRUDE OIL FROM AN UNSPECIFIED SOURCE, HYDROGEN, AND PUCHAGED FUELS. OUTPUTS INCLUDE REFINERY PRODUCTS AND EMISSIONS.

NOTE: ADJUST PARAMETERS FOR EACH CASE



Energy conversion in support of conventional gasoline production is comprised of a single refinery operations unit process, as shown below. Therefore, no assembly process is required, and linkages with other processes are non-existent, within LC Stage #3. The single operation unit process for the conversion facility operation requires crude oil, steam, and hydrogen gas as primary inputs and calculates emissions resulting from the refining process. All allocation for the refinery is calculated within the operations unit process. As noted previously, construction and commissioning/decommissioning are not considered. The following unit process is included for the gasoline ECF:

- Gasoline Refinery Operations  
(DS/DF\_Stage3\_O\_Petroleum\_Refinery\_2010.02.doc)

The profiles included for the ECF in support of petroleum-based gasoline fuel production are provided in **Table 1**. Those shown in bold face were developed by NETL.

**Table 1: Profiles and Processes Included in ECF for Petroleum Based Gasoline**

Stage #3: Universal-Domestic Fuel Conversion Facility (Gasoline)  
 North American Average Electricity Mix, 2007 070111 NETL  
 US: Hard coal mix PE  
 US: Hydrogen Production NETL <u-so>  
 US: Natural Gas RMA/RMT, Mix Nominal, 060911 NETL  
 US: Process steam from heavy fuel oil PE  
 US: Steam from natural gas 89% NETL  
 US: Steam from natural gas 89% NETL  
 US: Steam Mix (NG, 70%) and (heavy crude oil, 30%) NETL  
 US: System expansion (Steam) NETL  
 US: Universal Domestic Refinery (Gasoline), 2005&2030 NETL

### Parameters and Balances

The parameters for the highest level modeling plans for the petroleum gasoline ECF are shown in **Table 2**. These parameters may or may not include the adjustable parameters shown previously, depending on how the model was created. **Table 3** presents the input and output balances for resources and emissions of interest for the ECF model plan.

**Table 2: Adjustable Parameters for Petroleum Gasoline ECF**

Plan	Parameter	Value	Comment
<b>LC Stage #1</b>			
Stage #3: Petroleum Based Gasoline Energy Conversion Facility	S3_DELTA_GHGA	0.000421	[dimensionless] Adjustable parameter; adjusts refinery CO2 emissions per change in crude oil source (e.g., 0.0 = no change; 0.2 = 20% increase)
Stage #3: Petroleum Based Gasoline Energy Conversion Facility	S3_FENERGY	0.474	[dimensionless] Fraction of refinery energy attributable to a chosen refinery product (gasoline)
Stage #3: Petroleum Based Gasoline Energy Conversion Facility	S3_FH2	0.430	[dimensionless] Fraction of refinery hydrogen attributable to a chosen refinery product (gasoline)
Stage #3: Petroleum Based Gasoline Energy Conversion Facility	S3_RHO_BBL	117	[kg/bbl] density of refinery product (based on specific gravity of input crude)

**Table 3: Inputs and Output Balances for Gate-to-Gate Petroleum Based Gasoline ECF (kg/kg produced)**

Process or Category	Gate to Gate (ECF)
<b>Inputs</b>	
Flows	2.512E+00
Resources	2.512E+00
Energy resources	5.263E-02
Non renewable energy resources	5.263E-02
Crude oil (resource)	2.134E-03
Crude oil Algeria	1.201E-05
Crude oil Angola	4.212E-05
Crude oil Argentina	8.940E-06
Crude oil Australia	8.020E-06
Crude oil Austria	4.841E-07
Crude oil Bolivia	7.186E-12
Crude oil Brazil	8.008E-06
Crude oil Brunei	4.715E-10
Crude oil Bulgaria	3.537E-11
Crude oil Cameroon	3.361E-06
Crude oil Canada	1.743E-04
Crude oil Chile	1.423E-10
Crude oil China	2.266E-06
Crude oil CIS	8.235E-05
Crude oil Colombia	2.915E-05
Crude oil Czech Republic	3.247E-08
Crude oil Denmark	1.535E-05
Crude oil Ecuador	1.299E-05
Crude oil Egypt	1.984E-06
Crude oil France	7.318E-07
Crude oil Gabon	2.087E-05
Crude oil Germany	2.689E-06
Crude oil Greece	9.651E-08
Crude oil Hungary	4.017E-10
Crude oil India	3.268E-11
Crude oil Indonesia	6.655E-06
Crude oil Iran	1.398E-05
Crude oil Iraq	6.518E-05

Process or Category	Gate to Gate (ECF)
Crude oil Ireland	2.930E-12
Crude oil Italy	3.112E-06
Crude oil Kuwait	2.862E-05
Crude oil Libya	2.222E-05
Crude oil Malaysia	2.319E-10
Crude oil Mexico	1.814E-04
Crude oil Netherlands	1.985E-06
Crude oil New Zealand	1.604E-07
Crude oil Nigeria	7.980E-05
Crude oil Norway	1.040E-04
Crude oil Oman	2.006E-06
Crude oil Poland	1.247E-07
Crude oil Qatar	1.137E-06
Crude oil Romania	1.937E-07
Crude oil Saudi Arabia	2.061E-04
Crude oil Slovakia	2.378E-12
Crude oil South Africa	3.749E-12
Crude oil Spain	1.608E-07
Crude oil Syria	2.018E-10
Crude oil Trinidad and Tobago	7.940E-06
Crude oil Tunisia	9.038E-07
Crude oil Turkey	7.578E-16
Crude oil United Arab Emirates	1.382E-06
Crude oil United Kingdom	1.325E-04
Crude oil USA	6.697E-04
Crude oil Venezuela	1.786E-04
Hard coal (resource)	1.335E-02
Hard coal Australia	1.840E-05
Hard coal Belgium	1.614E-08
Hard coal Bosnia and Herzegovina	3.009E-09
Hard coal Brazil	2.907E-08
Hard coal Canada	7.002E-05
Hard coal Chile	1.488E-08
Hard coal China	2.247E-06
Hard coal CIS	3.487E-06
Hard coal Colombia	1.274E-04

Process or Category	Gate to Gate (ECF)
Hard coal Czech Republic	7.315E-07
Hard coal France	3.235E-07
Hard coal Germany	1.592E-05
Hard coal India	1.675E-09
Hard coal Indonesia	2.599E-05
Hard coal Italy	3.684E-10
Hard coal Japan	4.364E-12
Hard coal Malaysia	8.115E-12
Hard coal Mexico	1.509E-07
Hard coal New Zealand	1.218E-08
Hard coal Poland	5.966E-06
Hard coal Portugal	1.559E-11
Hard coal South Africa	1.413E-05
Hard coal Spain	3.538E-07
Hard coal Turkey	3.676E-12
Hard coal United Kingdom	3.958E-06
Hard coal USA	1.302E-02
Hard coal Venezuela	4.590E-05
Hard coal Vietnam	8.851E-08
Lignite (resource)	5.982E-04
Lignite Australia	3.465E-06
Lignite Austria	5.983E-08
Lignite Bosnia and Herzegovina	6.950E-09
Lignite Bulgaria	4.101E-09
Lignite Canada	1.294E-05
Lignite CIS	6.808E-08
Lignite Czech Republic	3.827E-07
Lignite France	8.615E-08
Lignite Germany (Central Germany)	4.779E-05
Lignite Germany (Lausitz)	1.479E-05
Lignite Germany (Rheinisch)	2.872E-05
Lignite Greece	1.250E-07
Lignite Hungary	2.052E-08
Lignite India	3.351E-10
Lignite Macedonia	9.310E-09
Lignite Poland	2.291E-07

Process or Category	Gate to Gate (ECF)
Lignite Romania	1.073E-09
Lignite Serbia and Montenegro	5.392E-08
Lignite Slovakia	3.206E-09
Lignite Slovenia	1.780E-08
Lignite Spain	7.454E-07
Lignite Turkey	9.392E-14
Lignite USA	4.887E-04
Natural gas (resource)	3.655E-02
Natural gas Algeria	5.038E-05
Natural gas Angola	5.368E-06
Natural gas Argentina	9.482E-07
Natural gas Australia	8.848E-07
Natural gas Austria	6.268E-08
Natural gas Bolivia	1.444E-08
Natural gas Brazil	9.467E-07
Natural gas Brunei	4.080E-06
Natural gas Bulgaria	2.974E-12
Natural gas Cameroon	8.377E-07
Natural gas Canada	6.123E-03
Natural gas Chile	3.384E-08
Natural gas China	2.579E-07
Natural gas CIS	1.749E-05
Natural gas Colombia	3.178E-06
Natural gas Czech Republic	2.466E-09
Natural gas Denmark	1.644E-06
Natural gas Ecuador	1.447E-06
Natural gas Egypt	2.003E-07
Natural gas France	1.535E-07
Natural gas Gabon	3.081E-06
Natural gas Germany	8.853E-06
Natural gas Greece	6.481E-09
Natural gas Hungary	1.075E-09
Natural gas India	1.294E-10
Natural gas Indonesia	3.490E-07
Natural gas Iran	1.598E-06
Natural gas Iraq	6.570E-06



Process or Category	Gate to Gate (ECF)
Natural gas Ireland	6.544E-09
Natural gas Italy	4.033E-07
Natural gas Japan	1.393E-12
Natural gas Kuwait	2.763E-06
Natural gas Libyan	6.052E-07
Natural gas Malaysia	4.060E-06
Natural gas Mexico	2.348E-05
Natural gas Netherlands	1.386E-05
Natural gas New Zealand	1.062E-08
Natural gas Nigeria	3.222E-05
Natural gas Norway	1.091E-05
Natural gas Oman	4.268E-06
Natural gas Poland	8.816E-09
Natural gas Qatar	6.135E-05
Natural gas Romania	1.242E-08
Natural gas Saudi Arabia	1.932E-05
Natural gas Slovakia	2.517E-11
Natural gas South Africa	3.215E-09
Natural gas Spain	2.169E-08
Natural gas Syria	2.169E-11
Natural gas Trinidad and Tobago	2.644E-04
Natural gas Tunisia	1.183E-07
Natural gas Turkey	7.663E-17
Natural gas United Arab Emirates	1.541E-07
Natural gas United Kingdom	1.428E-05
Natural gas USA	2.980E-02
Natural gas Venezuela	1.721E-05
Pit Methane	5.063E-05
Uranium (resource)	3.323E-07
Uranium natural	3.323E-07
Renewable energy resources	2.269E-07
Primary energy from geothermics	0.000E+00
Primary energy from hydro power	0.000E+00
Primary energy from solar energy	0.000E+00
Primary energy from wind power	0.000E+00
Wood	2.269E-07

Process or Category	Gate to Gate (ECF)
Land use	0.000E+00
Occupation	0.000E+00
Biotic Production	0.000E+00
Erosion Resistance	0.000E+00
Groundwater Replenishment	0.000E+00
Mechanical Filtration	0.000E+00
Physicochemical Filtration	0.000E+00
Transformation	0.000E+00
Biotic Production	0.000E+00
Erosion Resistance	0.000E+00
Groundwater Replenishment	0.000E+00
Mechanical Filtration	0.000E+00
Physicochemical Filtration	0.000E+00
Material resources	2.459E+00
Non renewable elements	4.389E-12
Iron	1.092E-13
Lead	1.533E-17
Sulphur	4.280E-12
Non renewable resources	8.785E-02
Barium sulphate	1.572E-15
Basalt	3.083E-06
Bauxite	4.971E-07
Bentonite	2.936E-04
Calcium chloride	1.609E-13
Chromium ore (39%)	5.530E-08
Clay	1.775E-05
Colemanite ore	5.809E-09
Copper - Gold - Silver - ore (1,0% Cu; 0,4 g/t Au; 66 g/t Ag)	1.805E-07
Copper - Gold - Silver - ore (1,1% Cu; 0,01 g/t Au; 2,86 g/t Ag)	1.099E-07
Copper - Gold - Silver - ore (1,16% Cu; 0,002 g/t Au; 1,06 g/t Ag)	6.205E-08
Copper - Molybdenum - Gold - Silver - ore (1,13% Cu; 0,02% Mo; 0,01 g/t Au; 2,86 g/t Ag)	1.512E-07
Copper ore (0.14%)	1.271E-06
Copper ore (1.2%)	1.871E-08
Copper ore (4%)	1.184E-16
Copper ore (sulphidic, 1.1%)	1.405E-13
Dolomite	1.694E-09

Process or Category	Gate to Gate (ECF)
Ferro manganese	7.667E-18
Fluorspar (calcium fluoride; fluorite)	1.156E-09
Gypsum (natural gypsum)	1.147E-05
Heavy spar (BaSO <sub>4</sub> )	7.101E-04
Inert rock	8.518E-02
Iron ore (56,86%)	2.219E-04
Iron ore (65%)	1.633E-08
Kaolin ore	1.035E-08
Lead - zinc ore (4.6%-0.6%)	5.710E-05
Limestone (calcium carbonate)	1.049E-03
Magnesit (Magnesium carbonate)	2.264E-10
Magnesium chloride leach (40%)	7.230E-06
Manganese ore	1.106E-08
Manganese ore (R.O.M.)	2.220E-06
Molybdenite (Mo 0,24%)	9.292E-08
Natural Aggregate	2.113E-04
Nickel ore (1,5%)	1.609E-11
Nickel ore (1.6%)	7.872E-06
Olivine	8.433E-17
Peat	3.805E-07
Phosphate ore	8.709E-11
Phosphorus minerals	2.281E-10
Potassium chloride	1.023E-10
Precious metal ore (R.O.M)	4.529E-09
Quartz sand (silica sand; silicon dioxide)	3.896E-06
Raw pumice	1.005E-09
Slate	1.418E-16
Sodium chloride (rock salt)	3.569E-07
Sodium sulphate	1.269E-12
Soil	4.784E-05
Sulphur (bonded)	2.142E-12
Talc	2.660E-10
Tin ore	1.363E-16
Titanium ore	8.055E-07
Zinc - copper ore (4.07%-2.59%)	9.819E-06
Zinc - lead - copper ore (12%-3%-2%)	4.021E-06

Process or Category	Gate to Gate (ECF)
Zinc - lead ore (4.21%-4.96%)	4.043E-17
Zinc ore (sulphidic, 4%)	2.431E-16
Renewable resources	2.371E+00
Water	2.104E+00
Water	1.683E+00
Water (ground water)	1.683E-02
Water (river water)	0.000E+00
Water (sea water)	0.000E+00
Water (surface water)	4.043E-01
Air	2.672E-01
Carbon dioxide	2.242E-04
Nitrogen	2.640E-12
Oxygen	3.847E-07
<b>Output</b>	
Flows	1.042E+00
Resources	3.047E-01
Material resources	3.047E-01
Renewable resources	3.047E-01
Water	3.047E-01
Water (river water)	3.046E-01
Water (sea water)	8.166E-05
Emissions to air	7.268E-01
Heavy metals to air	6.183E-08
Antimony	3.844E-10
Arsenic (+V)	4.802E-09
Arsenic trioxide	3.953E-14
Cadmium (+II)	2.536E-10
Chromium (+III)	8.919E-12
Chromium (unspecified)	4.776E-10
Cobalt	2.791E-10
Copper (+II)	5.789E-10
Heavy metals to air (unspecified)	2.594E-12
Hydrogen arsenic (arsine)	3.281E-12
Iron	3.219E-10
Lanthanides	2.775E-14
Lead (+II)	4.736E-09

Process or Category	Gate to Gate (ECF)
Manganese (+II)	1.263E-09
Mercury (+II)	6.722E-10
Molybdenum	2.140E-11
Nickel (+II)	2.868E-09
Palladium	4.454E-18
Rhodium	4.300E-18
Selenium	1.108E-08
Silver	8.830E-19
Tellurium	1.189E-12
Thallium	8.710E-12
Tin (+IV)	4.188E-09
Titanium	2.115E-12
Vanadium (+III)	2.384E-08
Zinc (+II)	6.033E-09
Inorganic emissions to air	5.069E-01
Ammonia	3.935E-06
Ammonium	1.396E-13
Ammonium nitrate	1.251E-14
Barium	4.541E-07
Beryllium	6.435E-11
Boron compounds (unspecified)	7.738E-08
Bromine	3.296E-08
Carbon dioxide	3.930E-01
Carbon dioxide (biotic)	7.683E-05
Carbon disulphide	1.968E-13
Carbon monoxide	1.624E-04
Chloride (unspecified)	2.024E-09
Chlorine	4.893E-13
Cyanide (unspecified)	1.408E-10
Fluoride	9.013E-09
Fluorides	4.411E-12
Fluorine	1.048E-12
Helium	2.074E-10
Hydrogen	2.658E-08
Hydrogen bromine (hydrobromic acid)	2.109E-11
Hydrogen chloride	3.245E-07

Process or Category	Gate to Gate (ECF)
Hydrogen cyanide (prussic acid)	5.963E-12
Hydrogen fluoride	5.412E-08
Hydrogen iodide	1.385E-14
Hydrogen phosphorous	8.897E-15
Hydrogen sulphide	3.459E-07
Lead dioxide	9.220E-15
Nitrogen (atmospheric nitrogen)	1.527E-05
Nitrogen dioxide	2.046E-04
Nitrogen monoxide	1.562E-12
Nitrogen oxides	1.141E-04
Nitrous oxide (laughing gas)	6.344E-06
Oxygen	1.568E-04
Scandium	1.184E-14
Steam	1.126E-01
Strontium	4.984E-13
Sulphur dioxide	5.449E-04
Sulphur hexafluoride	6.374E-13
Sulphuric acid	2.144E-10
Tin oxide	8.023E-16
Zinc oxide	1.605E-15
Zinc sulphate	8.244E-11
Organic emissions to air (group VOC)	6.550E-04
Group NMVOC to air	1.764E-04
Group PAH to air	3.249E-09
Anthracene	8.214E-12
Benzo(a)anthracene	4.132E-12
Benzo(a)pyrene	6.616E-12
Benzo(ghi)perylene	3.687E-12
Benzo(a)fluoranthene	7.373E-12
Chrysene	1.015E-11
Dibenz(a)anthracene	2.298E-12
Indeno[1,2,3-cd]pyrene	2.744E-12
Naphthalene	8.625E-10
Phenanthrene	2.709E-10
Polycyclic aromatic hydrocarbons (PAH)	2.070E-09
Halogenated organic emissions to air	6.412E-09

Process or Category	Gate to Gate (ECF)
Dichloromethane (methylene chloride)	6.223E-17
Dioxins (unspec.)	3.178E-16
Halogenated hydrocarbons (unspecified)	3.071E-17
Polychlorinated biphenyls (PCB unspecified)	7.190E-12
Polychlorinated dibenzo-p-dioxins (2,3,7,8 - TCDD)	2.444E-15
R 11 (trichlorofluoromethane)	2.438E-09
R 114 (dichlorotetrafluoroethane)	2.497E-09
R 12 (dichlorodifluoromethane)	5.243E-10
R 13 (chlorotrifluoromethane)	3.292E-10
R 22 (chlorodifluoromethane)	5.730E-10
Tetrafluoromethane	8.289E-12
Vinyl chloride (VCM; chloroethene)	3.387E-11
Acetaldehyde (Ethanal)	8.500E-09
Acetic acid	3.829E-08
Acetone (dimethylcetone)	8.412E-09
Acrolein	5.796E-11
Aldehyde (unspecified)	7.932E-10
Alkane (unspecified)	2.069E-07
Alkene (unspecified)	1.764E-07
Aromatic hydrocarbons (unspecified)	3.217E-09
Benzene	2.635E-08
Butadiene	1.376E-13
Butane	2.085E-06
Butane (n-butane)	6.153E-08
Cyclohexane (hexahydro benzene)	4.512E-12
Diethylamine	3.489E-18
Ethane	7.692E-06
Ethanol	1.772E-08
Ethene (ethylene)	1.212E-10
Ethyl benzene	1.748E-07
Fluoranthene	2.675E-11
Fluorene	8.488E-11
Formaldehyde (methanal)	1.142E-07
Heptane (isomers)	4.633E-09
Hexamethylene diamine (HMDA)	8.097E-15
Hexane (isomers)	7.518E-09

Process or Category	Gate to Gate (ECF)
Mercaptan (unspecified)	4.450E-10
Methanol	1.616E-08
NMVOG (unspecified)	1.577E-04
Octane	2.549E-09
Pentane (n-pentane)	1.106E-06
Phenol (hydroxy benzene)	5.309E-13
Propane	6.120E-06
Propene (propylene)	1.589E-08
Propionic acid (propane acid)	9.836E-12
Styrene	4.997E-15
Toluene (methyl benzene)	8.168E-08
Trimethylbenzene	7.815E-15
Xylene (dimethyl benzene)	7.323E-07
Methane	4.785E-04
Organic chlorine compounds	6.293E-15
VOC (unspecified)	1.074E-07
Other emissions to air	2.192E-01
Exhaust	2.189E-01
non used primary energy from wind power	0.000E+00
Particulate Matter, unspecified	3.612E-05
Unused primary energy from solar energy	0.000E+00
Used air	1.963E-04
Waste heat	0.000E+00
Particles to air	8.654E-06
Dust (PM10)	5.852E-07
Dust (PM2.5)	3.026E-06
Dust (unspecified)	5.042E-06
Metals (unspecified)	4.861E-14
Wood (dust)	2.961E-13
Radioactive emissions to air	2.856E-09
Antimony (Sb124)	0.000E+00
Argon (Ar41)	0.000E+00
Carbon (C14)	0.000E+00
Cesium (Cs134)	0.000E+00
Cesium (Cs137)	0.000E+00
Cobalt (Co58)	0.000E+00



Process or Category	Gate to Gate (ECF)
Cobalt (Co60)	0.000E+00
Hydrogen (H3)	0.000E+00
Iodine (I129)	0.000E+00
Iodine (I131)	0.000E+00
Krypton (Kr85)	0.000E+00
Krypton (Kr85m)	0.000E+00
Plutonium (Pu alpha)	0.000E+00
Radon (Rn222)	0.000E+00
Uranium (total)	2.856E-09
Uranium (U234)	0.000E+00
Uranium (U235)	0.000E+00
Uranium (U238)	0.000E+00
Xenon (Xe131m)	0.000E+00
Xenon (Xe133)	0.000E+00
Xenon (Xe133m)	0.000E+00
Xenon (Xe135)	0.000E+00
Xenon (Xe135m)	0.000E+00
Xenon (Xe137)	0.000E+00
Xenon (Xe138)	0.000E+00
Emissions to fresh water	1.023E-02
Analytical measures to fresh water	2.470E-05
Adsorbable organic halogen compounds (AOX)	3.628E-09
Biological oxygen demand (BOD)	7.972E-07
Chemical oxygen demand (COD)	2.265E-05
Solids (dissolved)	4.166E-07
Total dissolved organic bounded carbon	4.926E-13
Total organic bounded carbon	8.348E-07
Heavy metals to fresh water	2.376E-03
Antimony	4.760E-06
Arsenic (+V)	1.521E-05
Cadmium (+II)	1.470E-06
Chromium (+III)	6.435E-10
Chromium (+VI)	5.020E-18
Chromium (unspecified)	2.632E-05
Cobalt	4.835E-12
Copper (+II)	2.207E-05

Process or Category	Gate to Gate (ECF)
Heavy metals to water (unspecified)	3.207E-11
Iron	1.133E-03
Lead (+II)	5.149E-05
Manganese (+II)	3.717E-08
Mercury (+II)	2.585E-07
Molybdenum	7.105E-09
Nickel (+II)	4.081E-04
Selenium	1.219E-09
Silver	4.642E-06
Strontium	9.780E-08
Thallium	1.386E-12
Tin (+IV)	1.567E-11
Titanium	7.540E-10
Vanadium (+III)	2.209E-09
Zinc (+II)	7.084E-04
Inorganic emissions to fresh water	7.197E-03
Acid (calculated as H+)	6.066E-10
Aluminum (+III)	2.304E-07
Aluminum ion (+III)	5.368E-04
Ammonia	5.814E-03
Ammonium / ammonia	2.013E-07
Barium	2.068E-09
Beryllium	8.557E-12
Boron	8.469E-08
Bromine	1.083E-12
Calcium (+II)	1.315E-05
Carbonate	1.025E-07
Chloride	1.663E-04
Chlorine (dissolved)	3.088E-07
Cyanide	4.320E-05
Fluoride	3.818E-05
Fluorine	4.518E-10
Hydrogen chloride	9.035E-12
Hydrogen fluoride (hydrofluoric acid)	1.520E-12
Hydroxide	2.654E-10
Magnesium (+III)	2.740E-06

Process or Category	Gate to Gate (ECF)
Magnesium chloride	1.212E-12
Neutral salts	1.898E-17
Nitrate	1.341E-06
Nitrogen	1.564E-10
Nitrogen organic bounded	1.713E-08
Phosphate	3.986E-09
Phosphorus	5.130E-04
Potassium	1.158E-09
Silicate particles	1.787E-12
Sodium (+)	2.103E-05
Sodium chloride (rock salt)	3.622E-12
Sodium hypochlorite	3.181E-13
Sulphate	4.588E-05
Sulphide	1.712E-08
Sulphite	2.542E-08
Sulphur	4.381E-10
Sulphuric acid	1.165E-09
Organic emissions to fresh water	9.740E-07
Halogenated organic emissions to fresh water	9.388E-12
1,2-Dibromoethane	1.060E-15
Chlorinated hydrocarbons (unspecified)	1.392E-17
Chloromethane (methyl chloride)	9.381E-12
Dichloropropane	6.499E-18
Polychlorinated dibenzo-p-dioxins (2,3,7,8 - TCDD)	1.491E-22
Vinyl chloride (VCM; chloroethene)	5.427E-15
Hydrocarbons to fresh water	9.107E-08
Acenaphthene	3.495E-13
Acenaphthylene	1.381E-13
Acetic acid	1.941E-10
Acrylonitrile	4.753E-13
Anthracene	3.862E-13
Aromatic hydrocarbons (unspecified)	8.024E-09
Benzene	6.167E-10
Benzo(a)anthracene	5.673E-14
Benzo(a)fluoranthene	4.464E-14
Chrysene	2.828E-13

Process or Category	Gate to Gate (ECF)
Cresol (methyl phenol)	1.135E-11
Ethyl benzene	3.339E-11
Fluoranthene	8.027E-14
Hexane (isomers)	1.240E-12
Hydrocarbons (unspecified)	2.635E-09
Methanol	4.381E-08
Oil (unspecified)	3.172E-08
Phenol (hydroxy benzene)	5.952E-10
Polycyclic aromatic hydrocarbons (PAH, unspec.)	2.566E-09
Toluene (methyl benzene)	4.272E-10
Xylene (isomers; dimethyl benzene)	4.302E-10
Carbon, organically bound	8.829E-07
Naphthalene	1.848E-11
Organic chlorine compounds (unspecified)	6.527E-15
Organic compounds (dissolved)	3.017E-14
Organic compounds (unspecified)	2.338E-25
Other emissions to fresh water	0.000E+00
non used primary energy from water power	0.000E+00
Unused primary energy from geothermal	0.000E+00
Waste heat	0.000E+00
Particles to fresh water	6.353E-04
Metals (unspecified)	2.799E-13
Soil loss by erosion into water	2.348E-11
Solids (suspended)	6.353E-04
Radioactive emissions to fresh water	0.000E+00
Americium (Am241)	0.000E+00
Antimony (Sb124)	0.000E+00
Antimony (Sb125)	0.000E+00
Carbon (C14)	0.000E+00
Cesium (Cs134)	0.000E+00
Cesium (Cs137)	0.000E+00
Cobalt (Co58)	0.000E+00
Cobalt (Co60)	0.000E+00
Curium (Cm alpha)	0.000E+00
Hydrogen (H3)	0.000E+00
Iodine (I129)	0.000E+00

Process or Category	Gate to Gate (ECF)
Iodine (I131)	0.000E+00
Manganese (Mn54)	0.000E+00
Plutonium (Pu alpha)	0.000E+00
Radium (Ra226)	0.000E+00
Ruthenium (Ru106)	0.000E+00
Silver (Ag110m)	0.000E+00
Strontium (Sr90)	0.000E+00
Uranium	0.000E+00
Emissions to sea water	1.301E-04
Analytical measures to sea water	1.334E-06
Adsorbable organic halogen compounds (AOX)	9.815E-14
Biological oxygen demand (BOD)	1.083E-07
Chemical oxygen demand (COD)	1.118E-06
Total organic bounded carbon	1.083E-07
Heavy metals to sea water	2.999E-08
Arsenic (+V)	4.459E-10
Cadmium (+II)	1.735E-09
Chromium (unspecified)	1.905E-09
Cobalt	1.374E-10
Copper (+II)	6.401E-09
Iron	2.102E-09
Lead (+II)	1.427E-09
Manganese (+II)	2.173E-10
Mercury (+II)	3.337E-11
Molybdenum	3.216E-12
Nickel (+II)	1.746E-09
Silver	9.542E-12
Strontium	9.896E-09
Tin (+IV)	1.143E-11
Titanium	1.164E-12
Vanadium (+III)	9.567E-11
Zinc (+II)	3.822E-09
Inorganic emissions to sea water	4.259E-05
Aluminum (+III)	3.748E-11
Ammonia	1.114E-09
Barium	7.291E-09

Process or Category	Gate to Gate (ECF)
Beryllium	7.674E-12
Boron	6.060E-10
Calcium (+II)	6.618E-08
Carbonate	4.586E-07
Chloride	3.958E-05
Magnesium	3.487E-08
Nitrate	5.945E-10
Sodium (+I)	2.162E-06
Sulphate	1.962E-07
Sulphide	8.348E-08
Sulphur	3.243E-10
Organic emissions to sea water	2.655E-08
Hydrocarbons to sea water	2.633E-08
Acenaphthene	6.401E-12
Acenaphthylene	2.428E-12
Acetic acid	1.092E-11
Anthracene	2.400E-12
Aromatic hydrocarbons (unspecified)	1.083E-09
Benzene	1.868E-09
Benzo(a)anthracene	1.374E-12
Benzofluoranthene	1.494E-12
Chrysene	7.688E-12
Cresol (methyl phenol)	8.399E-12
Ethyl benzene	1.634E-10
Fluoranthene	1.719E-12
Hexane (isomers)	9.170E-13
Oil (unspecified)	1.820E-08
Phenol (hydroxy benzene)	3.043E-09
Toluene (methyl benzene)	1.103E-09
Xylene (isomers; dimethyl benzene)	8.292E-10
Naphthalene	2.167E-10
Particles to sea water	8.616E-05
Solids (suspended)	8.616E-05
Emissions to industrial soil	1.036E-06
Heavy metals to industrial soil	2.922E-07
Arsenic (+V)	2.775E-13

Process or Category	Gate to Gate (ECF)
Cadmium (+II)	3.470E-12
Chromium (+III)	8.630E-14
Chromium (unspecified)	5.861E-10
Cobalt	1.020E-11
Copper (+II)	4.662E-12
Iron	7.395E-10
Lead (+II)	2.548E-13
Manganese (+II)	1.403E-10
Mercury (+II)	9.743E-15
Nickel (+II)	2.143E-10
Strontium	2.904E-07
Zinc (+II)	5.726E-11
Inorganic emissions to industrial soil	7.321E-07
Aluminum (+III)	5.802E-10
Ammonia	4.288E-07
Bromide	8.740E-11
Calcium (+II)	9.484E-09
Chloride	1.025E-07
Fluoride	2.913E-09
Magnesium (+III)	1.312E-09
Phosphorus	4.723E-08
Potassium (+I)	5.862E-08
Sodium (+I)	8.293E-10
Sulphate	1.138E-08
Sulphide	6.827E-08
Organic emissions to industrial soil	1.213E-08
Oil (unspecified)	1.213E-08

### Embedded Unit Processes

NETL (2010). NETL Life Cycle Inventory Data – Unit Process: Petroleum Refinery. U.S. Department of Energy, National Energy Technology Laboratory. Last Updated: May 2012 (version 02). [www.netl.doe.gov/energy-analyses](http://www.netl.doe.gov/energy-analyses) (<http://www.netl.doe.gov/energy-analyses>)

### References

None.

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**Section III: Document Control Information**

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[www.netl.doe.gov/energy-analyses](http://www.netl.doe.gov/energy-analyses) (<http://www.netl.doe.gov/energy-analyses>)

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