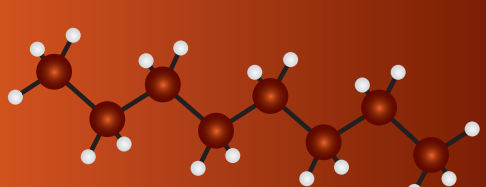
P1 PETROCHEMICALS

WHAT IS PETROLEUM?

CHEMICAL INDUSTRIES
RESOURCE PACK

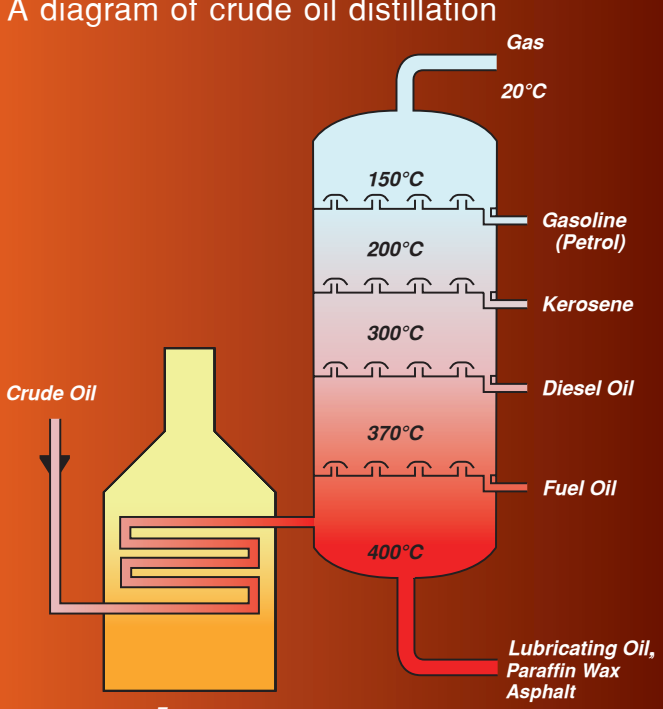
Arial photograph of Sasolburg

Two representations of octane, a hydrocarbon found in petroleum



Source: Wikimedia Commons

A diagram of crude oil distillation



Petroleum

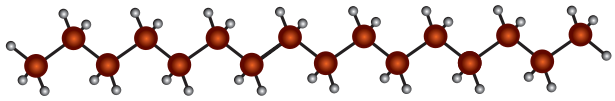
Petroleum is a mixture of several different hydrocarbons; the most commonly found molecules are alkanes (linear or branched), cycloalkanes, aromatic hydrocarbons, or more complicated chemicals like asphaltenes. Each petroleum variety has a unique mix of molecules which defines its physical and chemical properties, like colour and viscosity.

The alkanes, also known as paraffins, are saturated hydrocarbons with straight or branched chains which contain only carbon and hydrogen and have the general formula C_nH_{2n+2}. They generally have from 5 to 40 carbon atoms per molecule, although trace amounts of shorter or longer molecules may be present in the mixture.

The alkanes from pentane (C_5H_{12}) to octane (C_8H_{18}) are refined into petrol; the ones from nonane (C_9H_{20}) to hexadecane ($C_{16}H_{34}$) into diesel fuel and kerosene (primary component of many types of jet fuel); and the ones from hexadecane upwards into fuel oil and lubricating oil. At the heavier end of the range, paraffin wax is an alkane with approximately 25 carbon atoms, while asphalt has 35 carbon atoms or more. These are usually cracked (split) by modern refineries into more valuable products.

The shortest molecules, those with four or fewer carbon atoms, are in a gaseous state at room temperature. They are the petroleum gases.

Depending on demand and the cost of recovery, these gases are either flared off, sold as liquefied petroleum gas under pressure, or used to power the refinery's own burners. During the winter, butane (C_4H_{10}) is blended into the gasoline pool in large quantities because butane's high vapour pressure assists with cold starts. Liquefied at pressures slightly above atmospheric, butane is best known for powering cigarette lighters, but it is also a main fuel source in many developing countries. Propane can be liquefied under modest pressure and is consumed in just about every application relying on petroleum for energy, from cooking to heating to transportation.

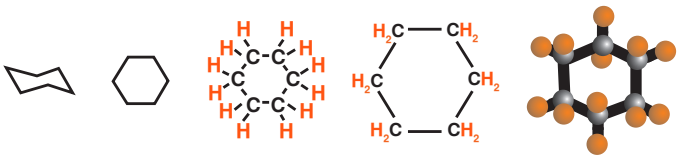


A ball and stick model of hexadecane

Source: Wikimedia Commons

Petroleum chemistry

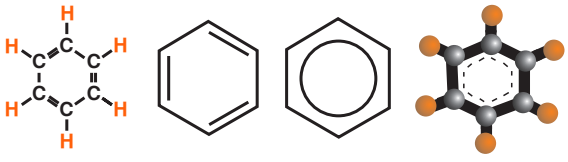
The cycloalkanes, also known as naphthenes, are saturated hydrocarbons which have one or more carbon rings to which hydrogen atoms are attached according to the formula C_nH_{2n}. Cycloalkanes have similar properties to alkanes but have higher boiling points.



Different representations of cyclohexane

Source: Wikimedia Commons

The aromatic hydrocarbons are unsaturated hydrocarbons which have one or more planar six-carbon rings called benzene rings, to which hydrogen atoms are attached with the formula C_nH_n. They tend to burn with a sooty flame and many have a sweet aroma. Some are carcinogenic (causes cancer). Benzene, C_6H_6, is also known as benzol or cyclohexa-1,3,5-triene.



Different representations of benzene

Source: Wikimedia Commons

These different molecules are separated by fractional distillation at an oil refinery to produce petrol, jet fuel, kerosene, and other hydrocarbons. For example, 2,2,4-trimethylpentane (iso-octane), widely used in petrol, has a chemical formula of C_8H_{18} and reacts with oxygen exothermically to form carbon dioxide and water.

$$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$$

Incomplete combustion of petrol or gasoline results in production of toxic by-products. Too little oxygen results in the formation of carbon monoxide.

$$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$$

Due to the high temperatures and high pressures involved, exhaust gases from petrol combustion in car engines usually include nitrogen oxides which are responsible for the creation of photochemical smog. Nitrogen oxides are formed by nitrogen and oxygen in the air reacting together under high temperatures as found in the exhausts of fossil fuel-burning engines in cars, trucks and in coal-fired power plants.

Oil rig

Source: Petroleum Agency of South Africa

DID YOU KNOW?

Photochemical smog is air pollution produced by the action of light on oxygen, nitrogen oxides and unburned fuel from car exhausts to form ozone and other pollutants.

3D-hydrocarbon chains that make up petrochemicals.

P2 PETROCHEMICALS

CRUDE OIL

CHEMICAL INDUSTRIES
RESOURCE PACK

Introduction

Crude oil, or petroleum, remains an important raw material for many of the products we use daily, ranging from plastics to gasoline.

Where does crude oil come from?

Crude oil is formed from ancient microscopic plants and plankton that lived in the ocean and saltwater seas millions of years ago. The micro-organisms are buried in silt and sand when they die; over time sediment settles over them. As sediment layers build up, the mud is compressed and heated, eventually forming crude oil. The oil flows from its source and accumulates in more porous limestone or sandstone as a reservoir.

How is crude oil used?

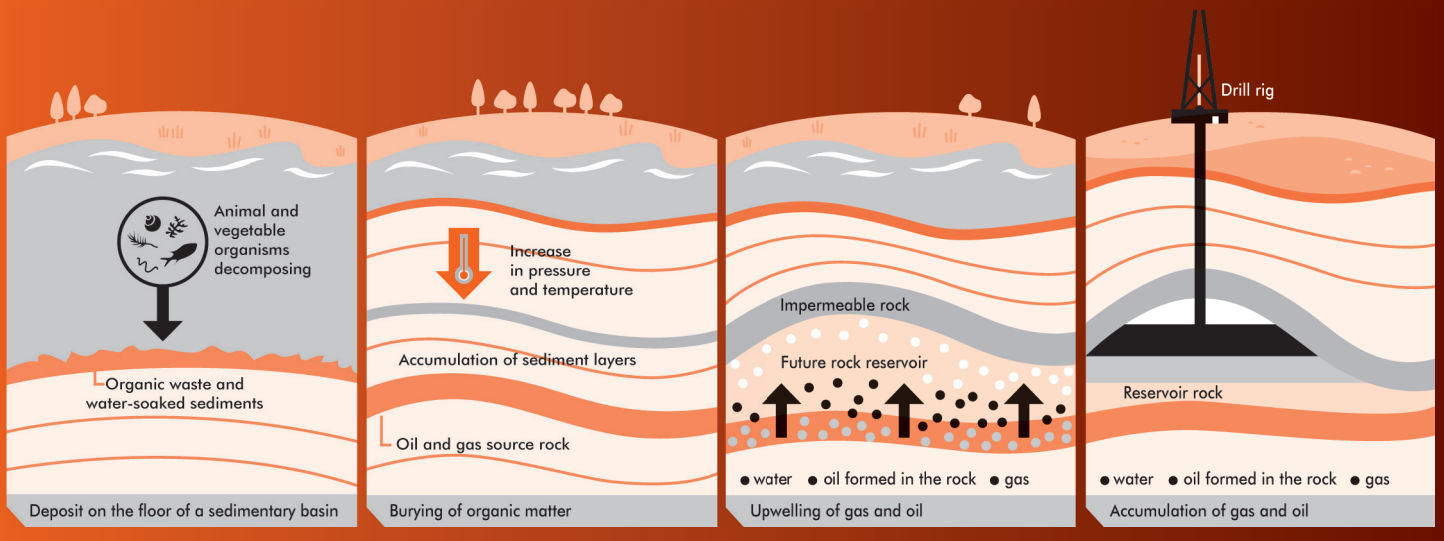
Crude oil is a smelly, yellow-to-black liquid and is usually found in underground areas called reservoirs. Scientists and engineers explore a chosen area by studying rock samples from the earth. Measurements are taken and, if the site seems promising, drilling begins. Above the hole, a structure called a 'derrick' is built to house the tools and pipes that go into the well.

Crude oil

When finished, the drilled well will bring a steady flow of oil to the surface. The world's top five crude oil-producing countries are Saudi Arabia, Russia, the United States, Iran and China.

This material was obtained from the website www.odec.ca. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Wong, J. 2006. Oil. [Online]. Available: http://www.odec.ca/projects/2006/wong6j2/oil.html [12 May 2010].

How crude oil is formed



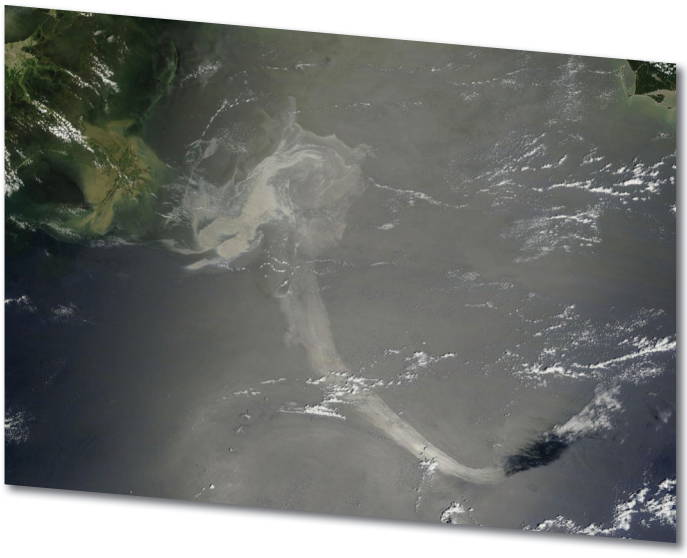
Source: www.black-tides.com

DID YOU KNOW?

The word "petroleum" means "rock oil" or "oil from the earth."

Deepwater Horizon oil spill	
Location	Gulf of Mexico near Mississippi River Delta
Date	20 April 2010 - 15 July 2010, well officially sealed on 19 September 2010
Cause	Wellhead blowout
Casualties	17 injured, 11 dead
Spill characteristics	
Volume	up to 100 000 barrels per day
Area	6 500 to 180 000 km ^{2}

The oil slick as seen from space by NASA's Terra Satellite on May 17, 2010



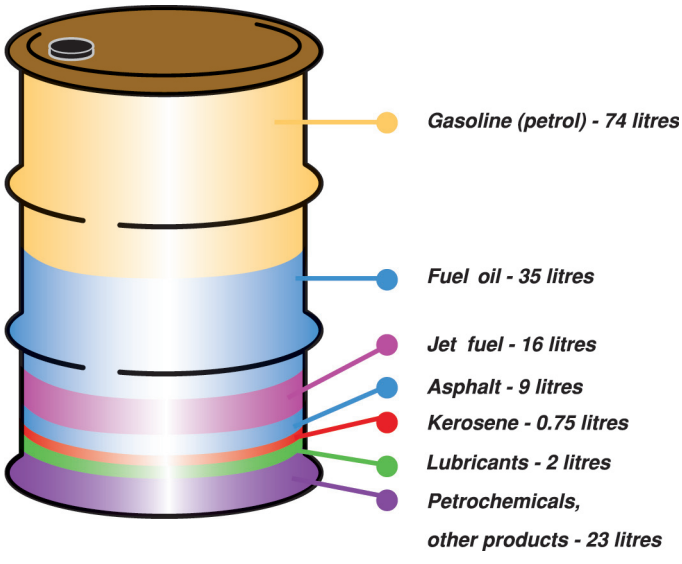
After crude oil is removed from the ground, it is sent to a refinery by pipeline, ship or barge. At the refinery, different parts of the crude oil are separated into useable petroleum products. Some of the products made from petroleum include: ink, crayons, bubblegum, dishwashing liquids, deodorant, eyeglasses, tyres, ammonia, and heart valves.

Oil and the environment

When petroleum products such as gasoline (used in cars), diesel fuel (used in trucks), and heating oil (used to heat homes) are burned as fuel, they give off carbon dioxide. Drilling for oil also has an impact on the environment. Companies use advanced technology and comply with government rules and regulations for safe drilling and petroleum production.

This material was obtained from the website www.globalenvironment.co.uk. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Global Environment. 2003. Oil. [Online]. Available: http://www.admwebstudios.co.uk/Energy4.htm [12 May 2010].

Products obtained from a typical barrel of oil



Source: www.bp.com

Deepwater Horizon oil spill

The Deepwater Horizon oil spill was an oil spill in the Gulf of Mexico which flowed for three months in 2010. Although the well has been capped, the impact of the spill continues. It is the largest accidental marine oil spill in the history of the petroleum industry. The spill stemmed from a sea-floor oil gusher that resulted from the Deepwater Horizon drilling rig explosion on 20 April 2010. The explosion killed 11 platform workers and injured 17 others. On 15 July, the leak was stopped by capping the gushing wellhead. By this time about 4,9 million barrels (780×10^3 m^3) of crude oil had been released into the ocean. It was estimated that 53 000 barrels per day (8 400 m^3/d) were escaping from the well just before it was capped. It is believed that the daily flow rate diminished over time, starting at about 62 000 barrels per day (9 900 m^3/d) and decreasing as the reservoir of hydrocarbons feeding the gusher was gradually depleted. On 19 September the relief well process was successfully completed and the federal government declared the well "effectively dead".

The spill has caused extensive damage to marine and wildlife habitats as well as the Gulf's fishing and tourism industries. Skimmer ships, floating containment booms, anchored barriers, and sand-filled barricades along shorelines were used in an attempt to protect hundreds of miles of beaches, wetlands and estuaries from the spreading oil. Scientists have also reported immense underwater plumes of dissolved oil not visible at the surface. The U.S. Government has named BP as the responsible party, and officials have committed to holding the company accountable for all cleanup costs and other damage. After its own internal probe, BP admitted that it made mistakes which led to the Gulf of Mexico oil spill.

This article was published on Wikipedia. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Wikipedia. 2010. Deepwater Horizon Oil Spill. [Online]. Available: http://en.wikipedia.org/wiki/Deepwater _ Horizon _ oil _ spill [23 September 2010].

P3 PETROCHEMICALS

FROM CRUDE OIL TO PETROL

CHEMICAL INDUSTRIES RESOURCE PACK

Introduction

All fossil fuels consist of a mixture of chemicals. Before these chemicals can be used effectively, they must be separated in a refinery. A refinery uses the traditional refining process of **fractional distillation.**

Fractional distillation: making petrol and diesel from crude oil

Crude oil is a mixture of many chemicals. Most chemicals are in the liquid phase; where solid and gaseous chemicals are present they are dissolved in the liquid phase. To separate the mixture of chemicals, scientists make use of the physical property of boiling point - each chemical has a unique and constant temperature at which it changes from a liquid into a gas. This temperature is determined largely by the molar mass of the chemical.

Crude oil is heated to about 400°C and injected into the bottom of a fractionating tower. The fractionating tower is a tall vertical column, sometimes up to 100 m in height.

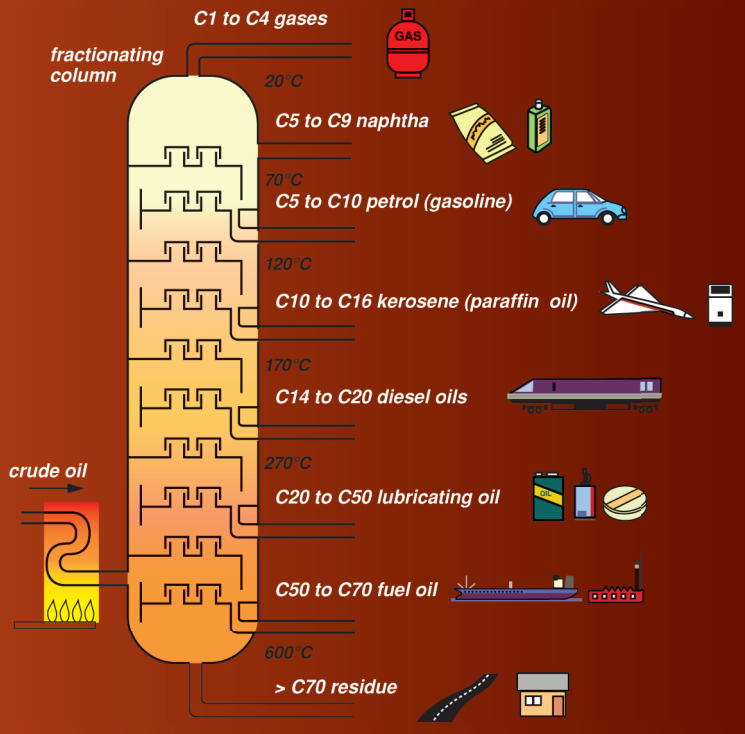
On the inside it contains many stainless steel collecting trays at various levels. There is a temperature gradient inside the column - the base of the column is hot and the temperature decreases slowly as the height above the base increases. The coolest part is at the top of the column. At the base most of the oil boils and the vapour rises up the column.

As the vapour moves up the tower, the temperature decreases, and when the condensation point of a certain fraction of chemicals is reached, that fraction condenses in a tray and is removed from the vapour. The rest of the oil, which is still in vapour form, rises up to the next level where the next fraction condenses, and so on. The many levels of the fractionating tower separate the oil into many fractions. The smallest molecules with the lowest boiling points are collected at the top of the tower. The wax and tar that do not evaporate are collected from the base of the tower. This separation of crude oil into separate fractions by using their boiling points is called fractional distillation.

A fractional distillation column is designed to separate the crude oil into the following fractions according to the diagram below.

A fractionating tower

Source: www.energybulletin.net



Fraction	# of C atoms	Boiling Range (°C)	Uses
Gas	1 - 4	-162 - 30	Fuel gas; starting material for plastics manufacture
Petroleum ether	5 - 6	30 - 60	Solvents, petrol additives
Petrol (gasoline)	5 - 12	40 - 200	Petrol
Kerosene	11 - 16	175 - 275	Diesel fuel; jet fuel; heating oil
Heating oil	15 - 18	275 - 375	Industrial heating
Lubricating oil	17 - 24	> 350	Lubricants
Paraffin	20 and up	Solid residue	Candles; toiletries; wax paper
Asphalt	30 and up	Solid residue	Road surfacing

Everyday products that make use of these molecules

Further refining of fractions

The fractions received from fractional distillation are then treated to separate the chemicals further. These processes include vacuum distillation to separate lubricating oils and waxes from the residue, desulfurisation to remove sulfur and cracking to produce more petrol and alkenes.

Catalytic cracking

The demand for naphtha and petrol exceeds the amount of this fraction received from primary distillation, so higher boiling fractions containing larger molecules are broken down to produce more petrol and naphtha. This process is called catalytic cracking. The fraction of high molecular mass alkanes is mixed with a catalyst (typically Co or Pt) in a reactor at a temperature of about 500°C. The smaller alkanes and alkenes that form can be separated by distillation. For example, decane ($C_{10}H_{22}$) is vapourised and passed through a bed of catalyst powder.

The decane molecules split apart, or crack, on the surface of the catalyst. One possible reaction that can occur is:

$CH_3(CH_2)_8CH_3 \rightarrow CH_2{=}CH_2 + CH_3(CH_2)_6CH_3$

decane → ethene (ethylene) + octane

Ethene (also known as ethylene) can be used to make polyethylene (PE). Octane is part of the petrol fraction and therefore used in fuel for cars.

Petrol blending

Petrol is a mixture of about 300 different hydrocarbons and other additives. The hydrocarbon fractions must be blended (mixed) to deliver a product with the same specifications every time. In colder climates different petrol blends are made for summer and winter.

Chevron up after power outage

Feb 21, 2006 20:11

Cape Town - The Chevron refinery in Cape Town is expected to resume full production by the end of this week after shutting down following a power failure on Sunday, the company said. "We already started producing on Sunday and we will be in full production by the end of the week," Phumi Nhlapo, spokesperson for the refinery told Reuters.

The refinery shut down early on Sunday during blackout that hit large parts of South Africa's Western Cape Province, which includes Cape Town. Nhlapo said the refinery, which is the only oil refinery serving the Western Cape, had sufficient stocks to cover the shortfall.

This news article was obtained from the website www.fin24.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Fin24.com. 2006. Chevron up after power outage. [Online]. Available: http://www.fin24.com/Companies/Chevron-up-after-power-outage-20060221 [21 May 2010].

Introduction

Modern petrol engines require a high proportion of branched-chain alkanes for efficient combustion. Straight-chain alkanes, which make up about 10% of the distilled product of crude oil, are heated in the presence of a platinum catalyst to form branched-chain isomers.

There are a number of different chemical reactions that occur in the catalytic reforming process, all of which occur in the presence of a catalyst and a high hydrogen partial pressure. Depending upon the type of catalytic reforming used, the reaction conditions range from temperatures of about 495 - 525°C and from pressures of about 5 - 45 atm.

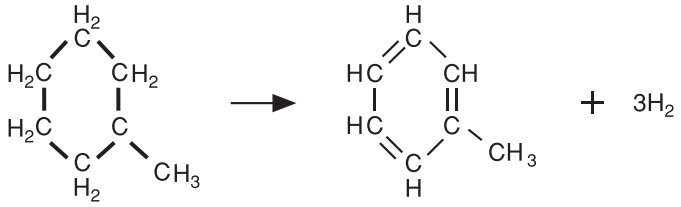
DID YOU KNOW?

Catalytic reforming is a chemical process used to convert petroleum refinery naphtha, typically having low-octane ratings, into high-octane liquid products called reformates which are components of high-octane petrol.

The four major catalytic reforming reactions are:

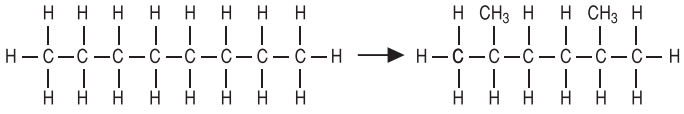
1: The **dehydrogenation** of naphthenes to convert them into aromatics, for example in the conversion of methylcyclohexane (a naphthene) to toluene (an aromatic), as shown below:

methylcyclohexane ⟶ toluene + $3H_2$



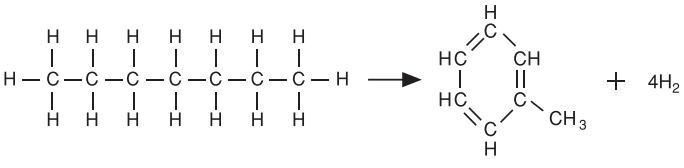
2: The **isomerisation** of normal paraffins to isoparaffins, for example in the conversion of normal octane (n-octane) to 2,5-dimethylhexane (an isoparaffin), as shown below:

n-octane ⟶ 2,5-dimethylhexane



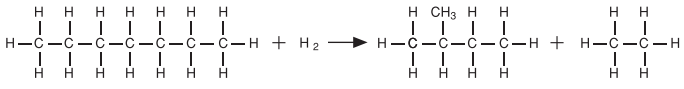
3: The **dehydrogenation and aromatisation** of paraffins to aromatics (commonly called dehydrocyclisation), for example in the conversion of normal heptane to toluene, as shown below:

n-heptane ⟶ toluene + $4H_2$



4: The **hydrocracking** of paraffins into smaller molecules, for example, the cracking of normal heptane into isopentane (2-methylbutane) and ethane, as shown below:

n-heptane + H_2 ⟶ isopentane + ethane



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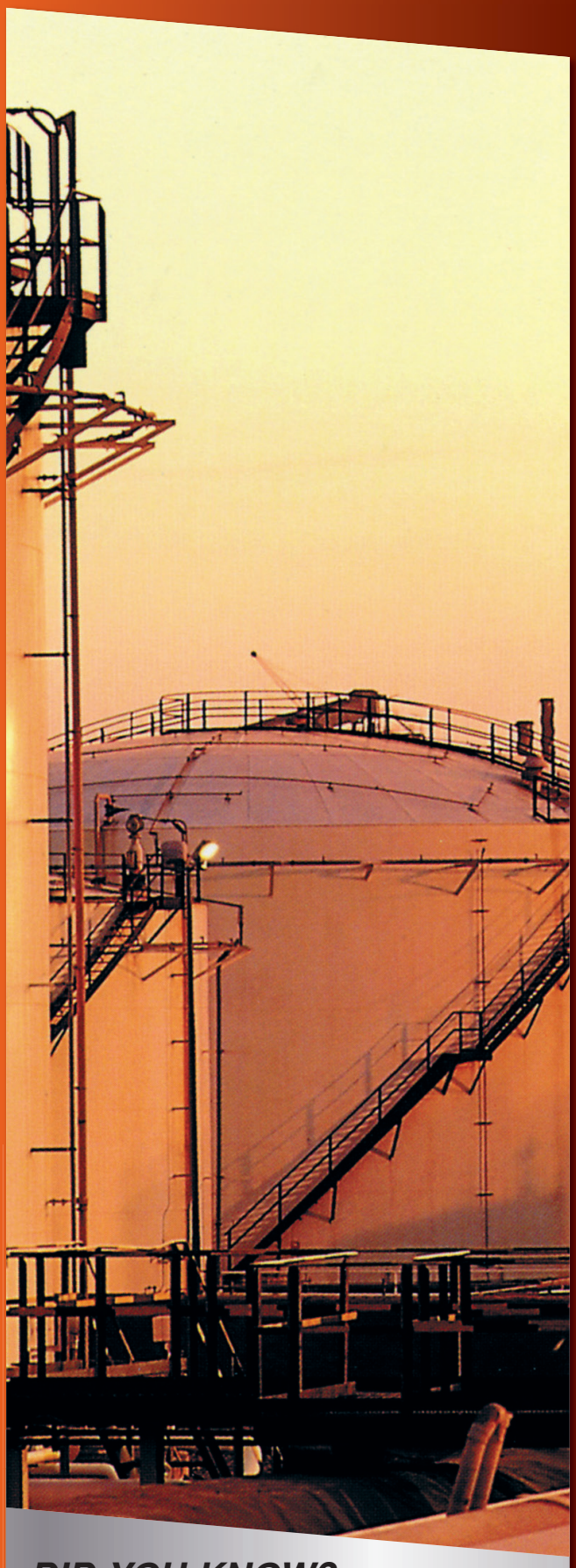


DID YOU KNOW?

'Paraffins' is another word used for hydrocarbons.
The word 'normal' as in normal octane (n-octane) is used to indicate a straight chain hydrocarbon.

Executive briefing: explanation for the petrol price increase

Release Date: 06 May 2008
Since the beginning of 2007, the petrol price in South Africa has risen by about 50%. This note sets out the mechanism used to determine fuel prices in South Africa and the reasons for the recent price increases.

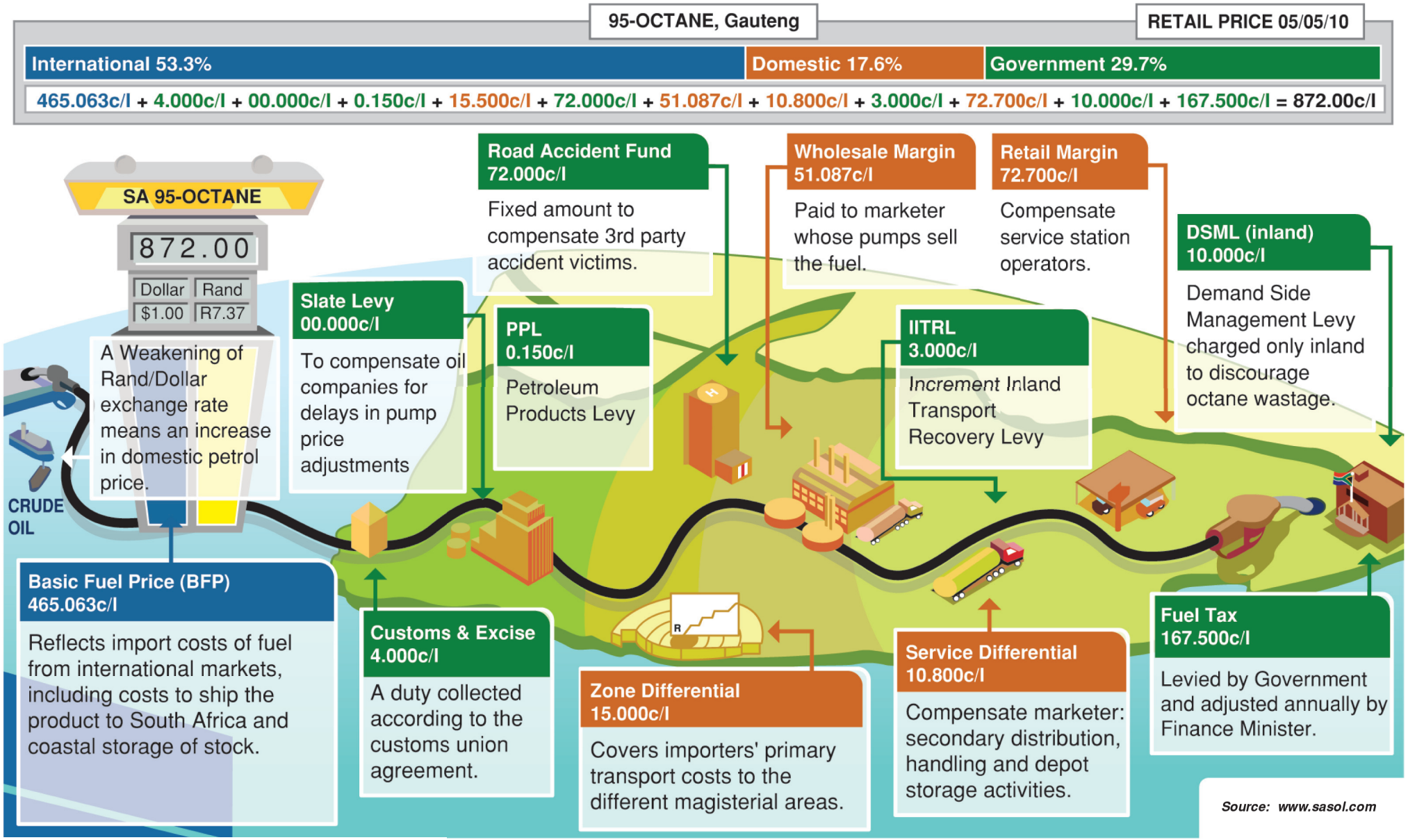
Pricing mechanism
The underlying principle used by the Department of Minerals and Energy in setting the price of petrol in South Africa is import parity. What this simply means is that the price is set based on what it would have cost if the product had been imported from the major export refinery in Singapore, the Arabian Gulf and the Mediterranean. Petrol is categorised as a commodity product and therefore there is very little difference between petrol of the same grade across the globe. Where competition exists, prices before taxes and levies are also very similar. Basing the local price on the import alternative or import parity price means local prices reflect what is happening in global markets for petroleum products.

Price increase explanation
While there have been significant increases in the dealer profit margin and taxes and levies, the principle cause of the higher price for petrol has been the higher cost of product due to rising international product prices and deterioration in the Rand/US$ exchange rate.

Why is diesel so much more expensive than petrol?
Although diesel and petrol are produced together from the same refineries, they are very different products with different applications in the world economy. Typically, diesel is used in industries such as manufacturing, mining, heavy vehicle transport and as a heating fuel, although the use of diesel for private motorists is also growing. In contrast, petrol is used primarily by private motorists. Given their different uses, petrol and diesel have different demand patterns and, therefore, different prices. In economics, price is set at the point where demand and supply meet, and therefore, the higher demand for diesel has pushed up its price across the globe. It doesn't cost more to produce diesel, but if the price didn't rise there would be a shortage in the global economy.

This material was obtained from the website www.bp.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: BP. 2010. Executive briefing: explanation for the petrol price increase. [Online]. Available: http://www.bp.com/genericarticle.do?categoryId =9018984&contentId=7044309 [12 May 2010].

PETROL PRICING IN SOUTH AFRICA



P6 PETROCHEMICALS

OCTANE RATING

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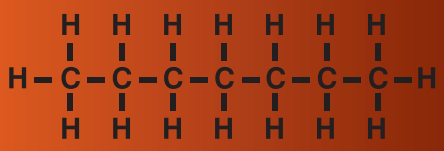
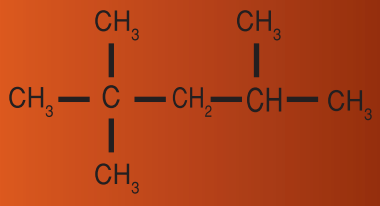


Heptane
Octane number = 0



Isooctane (2,2,4-trimethylpentane)
Octane number = 100

Gulf oil spill in the news

24 May 2010
BP plans to use heavy mud and cement to stop the breach, a manoeuvre called a top kill. Suttles said on the CBS Early Show the effort should start on Wednesday morning and they'll know the same day if it works. BP said on Monday its costs for responding to the spill had grown to about $760m, including containment efforts, drilling a relief well to stop the leak permanently, grants to Gulf states for their response costs and paying damage claims. On Sunday, some brown pelicans coated in oil couldn't fly away on Barataria Bay off the Louisiana coast. All they could do was hobble. Their usually brown and white feathers were jet black, and eggs were glazed with a rust-coloured substance.

2 June 2010
The oil has been spreading in the Gulf since the Deepwater Horizon rig exploded six weeks ago, killing 11 workers and eventually sinking. Shares in British-based BP were down 3% on Wednesday morning in London trading after a 13% fall the day before. BP has lost $75bn in market value since the spill started with an April 20 oil rig explosion and analysts expect damage claims to total billions more.

Introduction

One of the factors that determine a fuel's effectiveness is its ease of ignition. If petrol ignites too quickly, the engine will not run smoothly and the engine will make a metallic noise. This is called 'knocking'. On the other hand, if petrol is too difficult to ignite, the engine will be difficult to start, especially in cold weather. The relationship between knocking and the structure of the hydrocarbons in petrol depends on the following:

- branched alkanes and cycloalkanes burn more evenly than straight-chain alkanes
- short alkanes (e.g. C_4H_{10}) burn more evenly than long alkanes (e.g. C_7H_{16})
- alkenes burn more evenly than alkanes
- aromatic hydrocarbons burn more evenly than cycloalkanes.

Petrol pumps display different numbers: 91, 93 or 95. These numbers are called the petrol's **octane number** or antiknock rating and are a measure of the petrol's ability to burn without knocking. The octane number compares a fuel with a mixture of two reference fuels - isooctane (2,2,4-trimethylpentane) which is a good fuel and resists knocking; and heptane, a poor fuel that knocks readily.

The following table shows the octane numbers of some pure hydrocarbons. High-quality petrol contains many branched hydrocarbons.

Hydrocarbon	Octane number
Heptane	0
Hexane	25
1 - heptane	60
Pentane	62
1 - pentane	84
Butane	91
Cyclohexane	97
Isooctane	100
Toluene	112

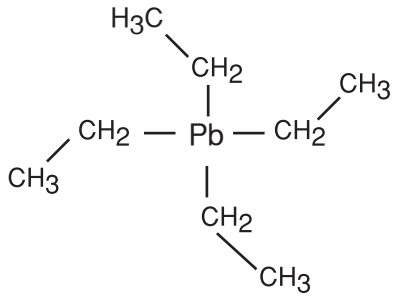
The news articles were published on www.news24.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: News24.com. 2010. Gulf oil spill plug hits new snag. [Online]. Available: http://www.news24.com/World/News/Gulf-oil-spill-plug-hits-new-snag-20100602. [21 July 2010].

Additives to petrol

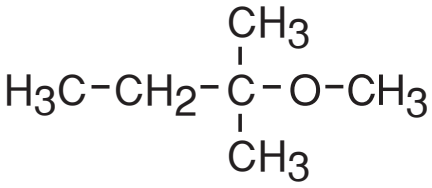
Several compounds can be added to petrol to boost its anti-knocking properties. The best-known of these additives is tetraethyl-lead, but this causes high levels of lead in the air, particularly in cities. Lead is poisonous and can cause brain damage in young children. Modern cars are fitted with catalytic converters to remove pollutants from the exhaust gases. Lead and other metals poison the catalyst in the catalytic converter and inhibit its catalytic ability.

The negative effects of lead have prompted bans on lead additives in petrol for some years in the USA, Europe and other countries. South Africa has conformed and only unleaded petrol has been sold since January 2006.

A lead-replacement petrol for older cars has been developed as an interim measure. Other, more environment-friendly additives to replace lead have also been developed. These additives e.g. the oxygenate TAME (tertiary amyl methyl ether), can boost the anti-knocking properties of petrol.



Tetraethyl-lead



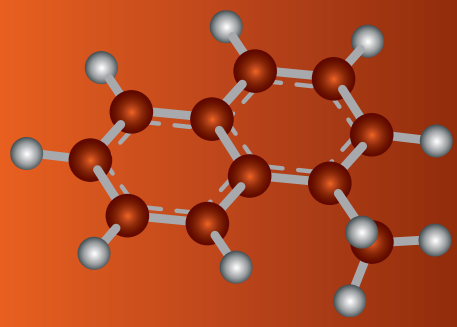
Tertiary amyl methyl ether (TAME) or 1,1-dimethylpropyl methyl ether

Impurities in diesel

Diesel consists of a heavier hydrocarbon fraction than petrol and has a higher boiling point. The ease of ignition of diesel is indicated by its cetane number. Cetane (hexadecane) has a cetane number of 100 and 1-methylnaphthalene has a cetane number of zero. A diesel with a cetane number of 48 will have the same ignition quality as a mixture of 48% cetane and 52% 1-methylnaphthalene.

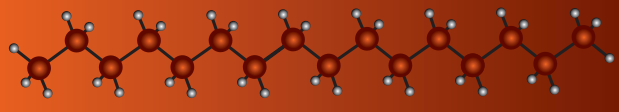
This article was obtained from Sasol Group Services. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: UCT Chemical Engineering Schools Project. 2010. Chemical Industries Resource Pack. Cape Town.

1-Methylnaphthalene



Source: Wikimedia Commons

Hexadecane



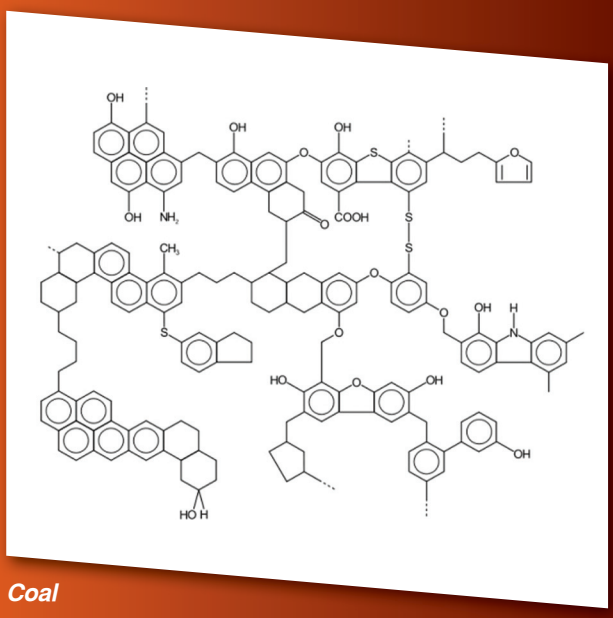
Source: Wikimedia Commons

Source: Mind over Matter, www.sasol.com

P7 PETROCHEMICALS

NATURAL GAS

CHEMICAL INDUSTRIES
RESOURCE PACK



Coal

Source: Wikipedia

South African Refinery Capacity, 2008

Refinery	Capacity (bbl/d)
Sapref	180,000
Enref	125,000
Natref	100,000
Sasol	92,000
PetroSA	450,000
Total	**692,000**

Source: South African Petroleum Association

Coal mining

Source: Mind over Matter, www.sasol.com

Introduction

Natural gas is a gaseous fossil fuel composed mainly of methane (CH_4). It is formed alongside oil fields and coal beds. Natural gas burns with relatively low emissions and can be safely stored, making it a convenient and efficient source of energy for heating and electricity generation.

Natural gas formation and extraction

The most common sources of natural gas are oil fields and natural gas fields. Gas fields are a result of anaerobic (oxygen-lacking) digestion of dead plant matter deep under the Earth's surface. Much like oil, natural gas is drilled for, then pumped to processing stations. Processing stations will remove "heavy hydrocarbons" such as butane and propane to ensure that the gas burned will emit low pollution.

Natural gas can also be released from coal through the process of coal gasification. In coal gasification, coal is exposed to high temperatures and pressures in order to break it apart into gaseous components. However, it is a very expensive process. There has also been research into capturing methane produced from landfills and biogas produced from cattle.

Generating power from natural gas

Electricity is produced from natural gas similar to the way coal generates energy. Natural gas is burned to release heat, which boils water and creates steam. The pressure from the steam is used to turn a turbine and a generator. The efficiency of this process can be further increased by using a combined cycle system. This system uses a natural gas fuel turbine, along with heat-recovery generator and steam turbine. As a result, 60% of heat from natural gas can be harnessed to generate electricity.

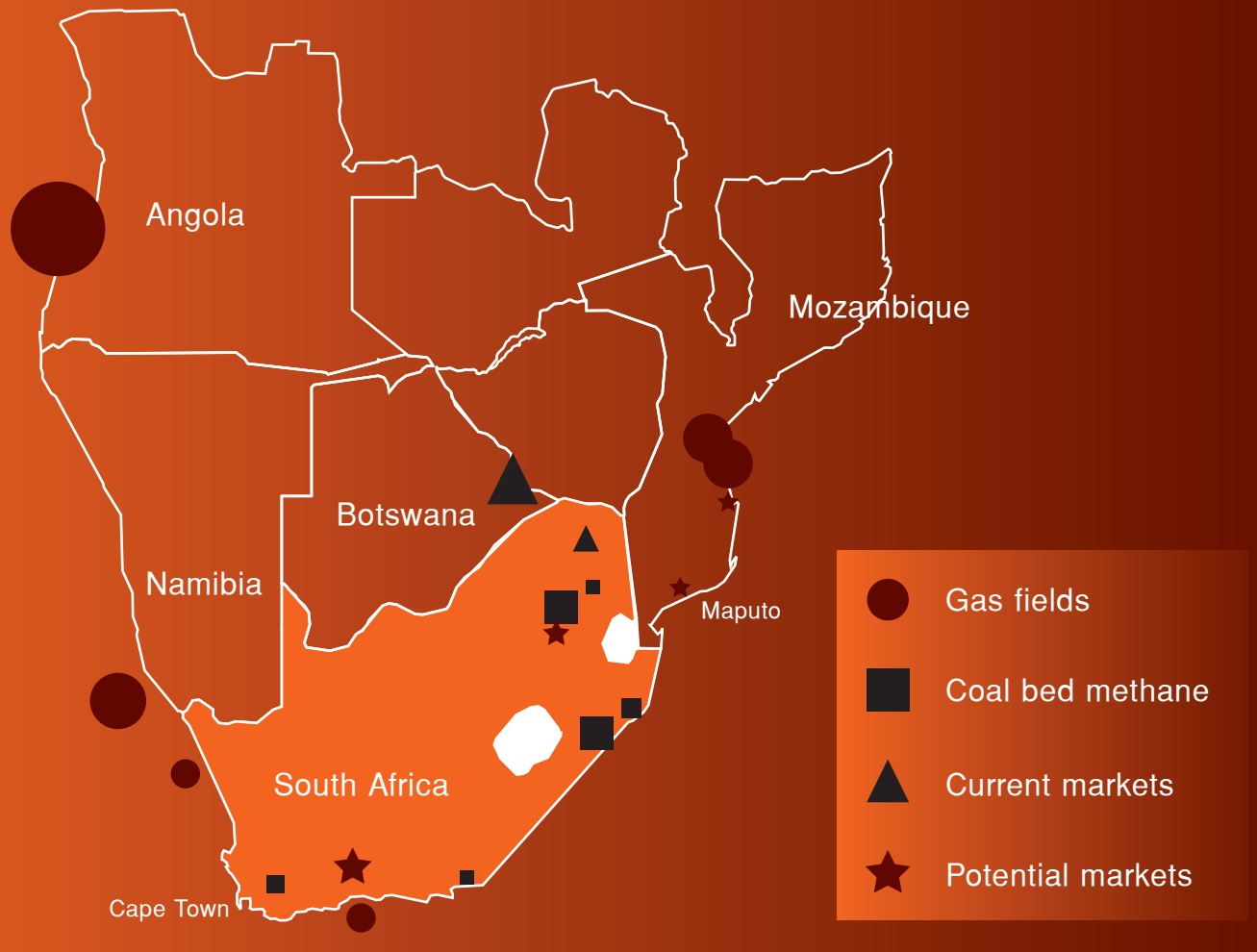
Natural gas energy: advantages and disadvantages

Advantages	Disadvantages
* Relatively low emissions compared to other fossil fuels (for the same amount of heat, produces 30% less carbon dioxide than burning oil and about 45% less than burning coal) * Safely stored and burned * Affordable * Many gas mines are still underutilised	* Limited supply as is a non-renewable resource * Tends to be more expensive compared to other fossil fuels * Less concentrated form of energy (170 cubic metres = 1 barrel of oil)

Summary

Natural gas is the cleanest burning of all the fossil fuels, though its higher cost prohibits more widespread use. Since we rely less on natural gas for power generation, it may outlast coal and oil. Yet, natural gas remains a non-renewable energy source, which makes its long-term viability limited.

Natural gas resources in Southern Africa



Source: EIA

P8 PETROCHEMICALS

FISCHER-TROPSCH TECHNOLOGY

CHEMICAL INDUSTRIES
RESOURCE PACK

Introduction

Franz Fischer and Hans Tropsch were chemists working at the Kaiser Wilhelm Institute for Coal Research in Mulheim, Ruhr. The institute was formed in 1913, but the research on which Fischer and Tropsch worked only started to produce results in the 1920s. Their aim was to develop a system that produced hydrocarbon molecules from coal-derived gas. They reacted hydrogen and carbon monoxide together at reasonable temperatures and pressures and produced a range of molecules that could be used as fuels and other feedstock chemicals. Their process was patented in 1925. Sasol uses Fisher-Tropsch technology to synthesise the wide range of chemicals they produce. The Sasol Advanced Synthol process uses a high-temperature synthesis to produce C_1-C_{20} hydrocarbons. The Slurry Phase Distillate (SPD™) process uses a lower temperature synthesis to produce linear hydrocarbon waxes and paraffins.

Sasol Advanced Synthol (SAS™) process

The SAS™ process uses a catalytic reaction at a temperature of about 340°C to synthesise low molecular hydrocarbons from synthesis gas.

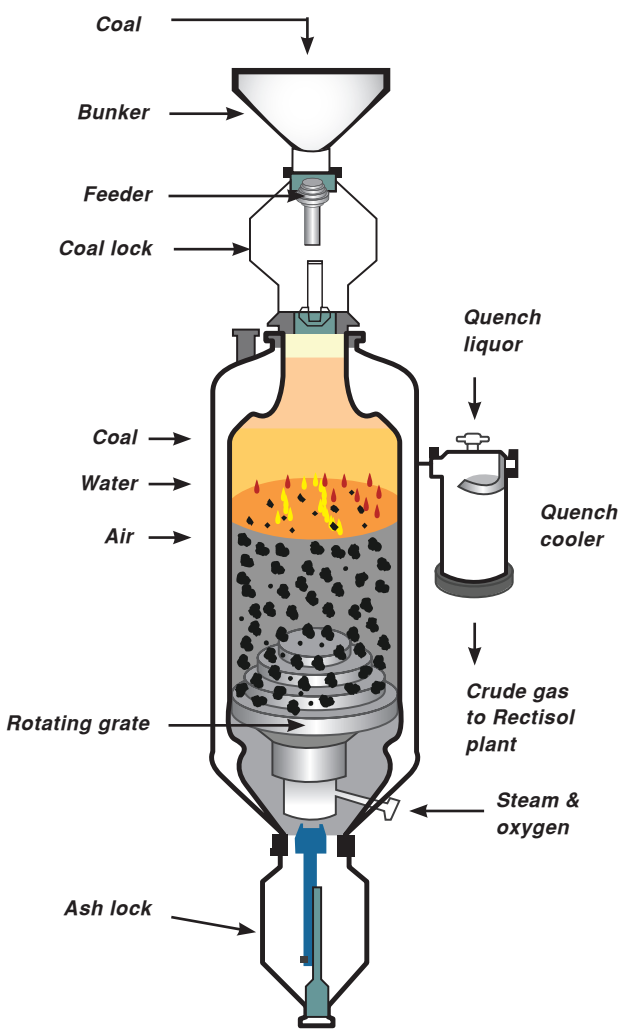
Gasification

Synthesis gas is obtained from coal that is gasified. After the mixed coal is screened the coarse coal goes to the 80 Lurgi gasifiers. At the top of the gasifier is the coal lock. It takes about 8 tonnes of coal. When the coal lock is filled, the lid is closed tight and gas is fed into it. The bottom of the lock is then opened and the coal falls into the body of the gasifier. High-pressure steam and oxygen also enter the gasifier to combust the coal at temperatures of 800 - 1400°C. The reaction is exothermic and excess heat is removed by circulating water through the wall of the reactor. The unbalanced net reaction inside the gasifier is:

C (coal) + H_2O + O_2 → CO + H_2 + CO_2 + small quantities of CH_4, other hydrocarbons and impurities.

The product from gasification is called the raw synthesis gas. This gas is cooled to 35°C at a pressure of 2700 kPa and fed to the Rectisol plant. The raw synthesis gas produced by the gasifiers contains not only the hydrogen and carbon monoxide needed for the next stage, but also contaminants like hydrogen sulfide, ammonia, carbon dioxide and phenol. These contaminants are removed during the Rectisol process. This is important, because these contaminants would poison the reactor's iron oxide catalyst. Methanol at -70°C is used to absorb the impurities and pure gas leaves this process.

Gasifier



Source: Mind over Matter, www.sasol.com

Two impurity fractions leave the Rectisol reactor - the naphtha stream and the off-gas which contains 97% CO_2, 1,5% H_2S and other impurities. The unsaturated chemicals in the naphtha stream are extracted for further processing.

The off-gas is treated in the Sulfolin process. Originally the hydrogen sulfide from the Rectisol process was released into the air, but this caused problems. The rotten-egg smell can travel for hundreds of kilometres in the air and can be smelt in a ratio as small as a few parts per billion. Sasol developed the Sulfolin process in which H_2S is oxidised to sulfur.

The sulfur is used to manufacture sulfuric acid. Sasol was the first company in the world to use both the Rectisol and Sulfolin processes on a commercial scale. The purified synthesis gas is then finally ready for the reactor.

Conversion

The purified synthesis gas is sent to the Sasol Advanced Synthol (SAS™) reactors. The hydrogen and carbon monoxide gases react under pressure in the presence of a fluidised, iron-based catalyst at a temperature of about 340°C to yield C_1 to C_{20} hydrocarbons.

The SAS™ process also produces oxygenated hydrocarbons and reaction water. Hydrocarbons from the SAS™ reactors are cooled slowly in a product recovery plant until most components become liquefied.

The differences in boiling points are used to separate the different hydrocarbon fractions and the methane-rich gas. Some of the methane-rich gas is sold as pipeline fuel gas and the remainder is sent to a reformer to be converted back to synthesis feed gas. The gas is then routed back to the SAS™ reactors.

The C_2-rich stream is separated into ethylene (C_2H_4) and ethane (C_2H_6). The ethane is cracked in a high-temperature furnace to produce ethylene for further purification. Propylene (C_3H_6) is also separated from the light hydrocarbon gases. Some of this propylene is converted into polypropylene at Secunda and some into butanol at Sasolburg.

The C_4 to C_{20} hydrocarbons - the heavy cut - contain large quantities of C_5 to C_{11} olefins. The three alpha olefins recovered from this mixture, 1-pentene (C_5H_{10}), 1-hexene (C_6H_{12}) and 1-octene (C_8H_{16}), are sold to the international market. The rest of the oil stream is routed to a refinery where liquefied petroleum gas (LPG), propane, butane, fuel oil, illuminating paraffin, petrol and diesel are produced.

The oxygenates in the aqueous stream from the SAS™ process are also separated and purified to produce alcohols, acetic acid and ketones, including acetone and methyl ethyl ketone.

This article was obtained from Sasol Group Services. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: UCT Chemical Engineering Schools Project. 2010. Chemical Industries Resource Pack. Cape Town.

Raw gas from gasifier	Pure gas leaving the Rectisol process
39% H_2	55% H_2
23% CO	31% CO
10% CH_4	12% CH_4
28% CO_2	<1% CO_2
Traces of C_nH_{2n}, H_2S_7, N_2 and NH_3	

Rectisol gas purification columns

DID YOU KNOW?

'Olefin' is another word for alkene.

Source: Mind over Matter, www.sasol.com

A graphic representation of the Sasol Slurry Phase Distillate process, which employs unique technology that will be key in producing high-quality diesel

Source: www.sasol.com

Comparison between conventional diesel and Fischer-Tropsch diesel

	Conventional diesel	Fischer-Tropsch diesel
Sulfur content	500 ppm	< 5 ppm
Aromatics content	10 - 25 %	< 1,0 %
Cetane number	45 - 55	> 70

Slurry Phase Distillate (SPD™) process

The SPD™ process converts natural gas at a lower temperature than in the SAS™ reactors to yield linear hydrocarbon waxes and paraffins. The waxes and paraffins are reformed to produce mainly diesel.

Natural gas

Natural gas is typically a mixture of methane and ethane and may also contain propane, butane, pentane and other, heavier, hydrocarbons. Other gases are also found in natural gas, including nitrogen, carbon dioxide, hydrogen, hydrogen sulfide and rare gases like helium. The gas also contains water vapour.

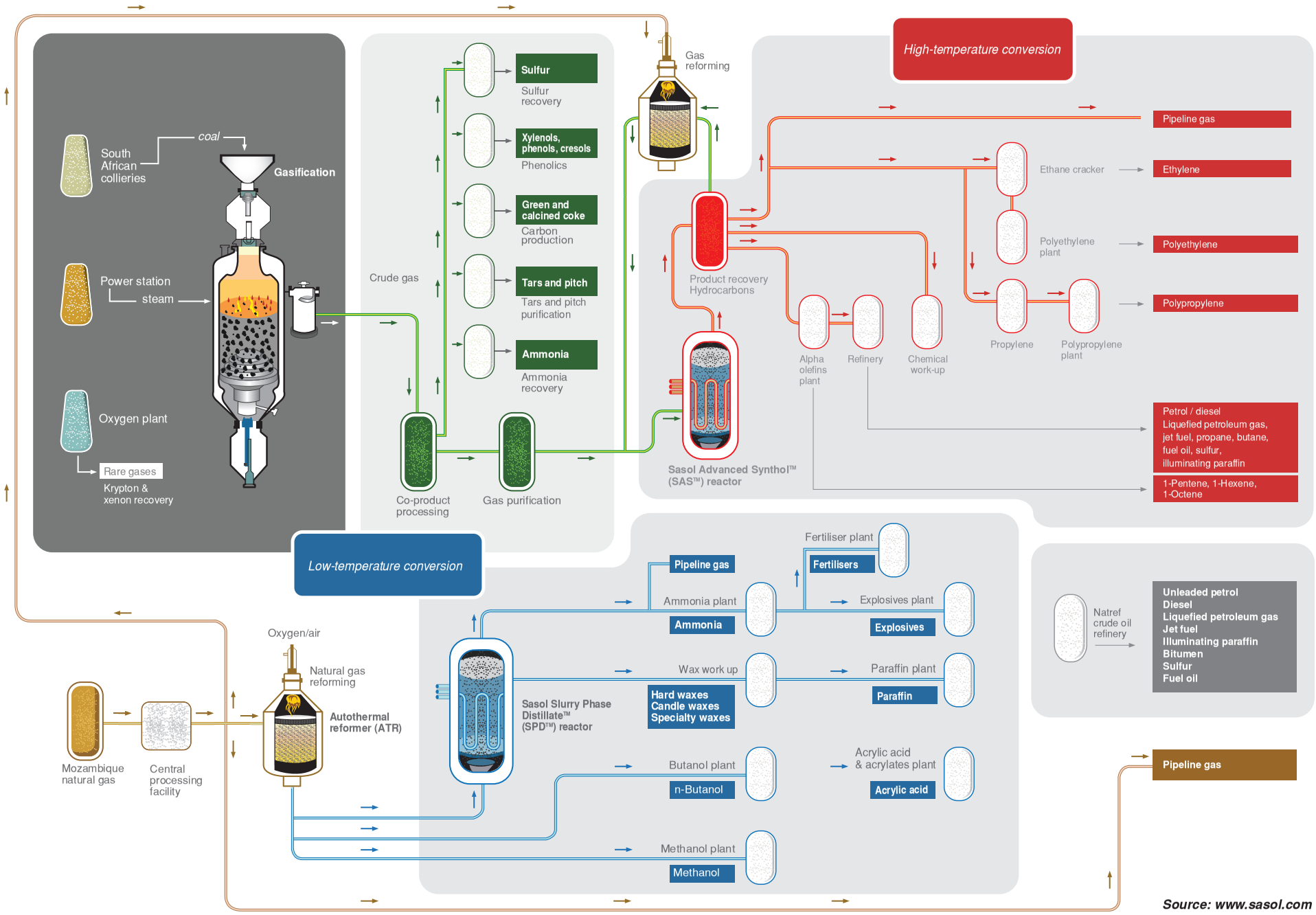
A pipeline pumps natural gas from the Pande region of central Mozambique to Secunda and Sasolburg. The natural gas is first reformed to synthesis gas in two autothermal reformers. Methane in the natural gas is reacted with steam and oxygen over a catalyst and at high temperatures to produce synthesis gas, a mixture of carbon monoxide and hydrogen.

Conversion

The synthesis gas is converted in a low-temperature (220°C) Fischer-Tropsch synthesis process to produce intermediate hydrocarbons that contain mainly long-chained linear hydrocarbon waxes. These intermediate products are upgraded and refined through cracking and isomerisation to produce diesel, kerosene and naphtha. The synthesis gas is also used to produce methanol, butanol and other higher value compounds.

The diesel produced by the SPD™ process is of much higher quality than diesel derived from crude oil. It is virtually sulfur-free, has a high cetane number, low aromatics and good cold flow properties. Emission levels of hydrocarbons, carbon monoxide and particulates produced by SPD™ diesels are also much lower than conventional diesels. The table on the left shows the results produced by independent laboratory tests.

Petrochemical processes in South Africa



Source: www.sasol.com

P10 PETROCHEMICALS

WHERE DID IT ALL START?

CHEMICAL INDUSTRIES
RESOURCE PACK

Introduction

In the 1920s two German chemists, Franz Fischer and Hans Tropsch, developed a process to convert solid coal into a gas called synthesis gas or syngas. This process is called the Fischer-Tropsch process. Synthetic crude oil can be produced by combining syngas with hydrogen under high pressure and temperature. South Africa does not have natural deposits of crude oil and only limited deposits of natural gas near the Mossel Bay coast, but we have fossil fuel deposits in the form of vast coalfields. In the mid-20th century the industrial leaders in the country realised that if coal from these coalfields could be turned into petrol, diesel and oil, it would benefit South Africa greatly. It would help to industrialise the economy, create more jobs, reduce imports and save foreign currency, and make South Africa more self-sufficient and less vulnerable to war and other interruptions in the rest of the world.

In 1950 the government appointed a committee to investigate all options of producing petroleum from coal. The South African Coal, Oil and Gas Corporation Ltd., commonly known as Sasol, was established in September 1950 as a state-owned company. Etienne Rousseau was Sasol's first general manager and held the position for 18 years. He spearheaded the investigation into different options, and it was decided to use coal-to-oil technology based on the Fischer-Tropsch process.

Two types of plants were commissioned - the Kellogg reactors from the USA and the Arge reactors from Germany. The Kellogg reactors followed a high temperature process that produced petrol, light petroleum gas and a range of other smaller hydrocarbon molecules. The Arge process operated at lower temperature and produced larger molecules such as diesel, oils and lubricants, and waxes. The first Sasol plant was built in the Free State just south of the Vaal River. The town of Sasolburg was originally established to accommodate Sasol's workers. The plant produced its first petrol and other chemicals in 1955. In 1960 the National Petroleum Refiners of South Africa (Pty) Ltd., known as Natref, was established in Sasolburg. Imported crude oil is pumped from the coast and refined and cracked at Natref to produce petrol, diesel and other chemicals.

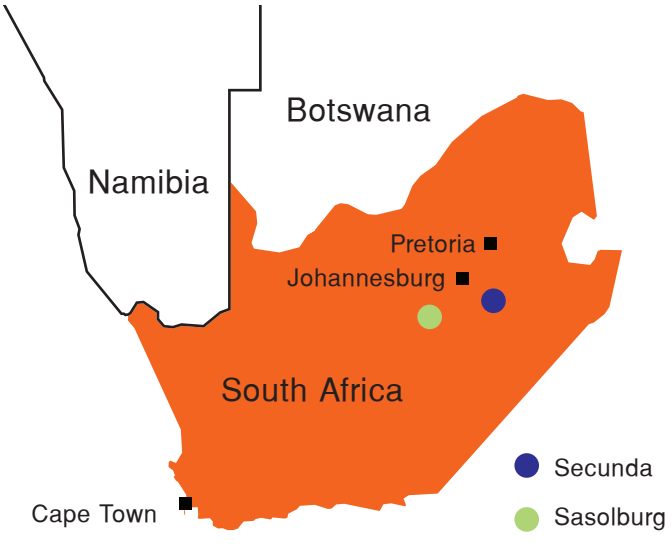
The next step was to exploit the various by-products from the synthetic fuels (synfuels) processes. The first chemicals to be manufactured were butadiene and styrene, (the feedstock for synthetic rubber), and ammonia for fertilisers. In 1973 the first oil crisis threatened supplies from the Middle-East and prompted Sasol to develop the Secunda mining operations and a second synfuels plant, called Sasol 2 in 1980. In 1982 Sasol 3 was built adjacent to Sasol 2. Sasol's Secunda plant still operates as one of the world's only commercial synthetic fuel-from-coal facilities.

Alpha olefin plant

Source: Mind over Matter, www.sasol.com

Sasol

Sasol was listed on the JSE (Johannesburg Stock Exchange) in 1979 and on the NYSE (New York Stock Exchange) in 2003. In 1990 Sasol decided to go global and opened its first international office in Birmingham, United Kingdom. Today Sasol operates in more than 30 countries and is one of the largest industrial companies listed on the JSE. During 2004 Sasol started to extract natural gas from the Pande and Temane regions in Mozambique. This gas is piped to Secunda and Sasolburg for use in the SPD™ process. Recently a plant was also commissioned to produce high purity ethanol, n-butanol and ethyl acetate. Sasol has the largest liquid oxygen plant in the world. It produces 39 000 tonnes of oxygen per day for the gasification reactors, nitrogen for the ammonia plant, liquid nitrogen and liquid argon. Sasol Wax has factories in Sasolburg and Hamburg, Germany. It produces a diverse range of products including paraffin waxes, petroleum jelly, candle wax, wax crayons and floor polish. New innovative products include citrus fruit coatings and cheese coatings, chewing gum, lipstick and other cosmetics, skin and hand creams, packaging coatings and many others.



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Aircraft fuel threat

05/02/2008

Cape Town - The Airports Company of SA (ACSA) says it is monitoring supplies of aircraft fuel available
in Cape Town after a power outage last week caused a local refinery's aviation fuel plant to close down.

"As of today (Tuesday), we can confirm that we have seven days' worth of aviation fuel supply in Cape Town, which means that normal flight operations will not be affected for the time being," Cape Town's airport manager said.

The fuel consortium that supplied the airport was currently discussing the situation, and had undertaken to advise ACSA by Thursday morning at the latest of "what steps they have taken to restore fuel supply".

According to *Business Report* on Tuesday, the process of restarting the knocked-out refinery fuel plant takes seven days.

This news article was obtained from the website www.news24.com. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: News24.com. 2008. Aircraft fuel threat. [Online]. http://www.new24.com/Economy/Aircraft-fuel-threat-20080205 [21 May 2010].

Sasol takes to the skies with the world's first fully synthetic jet fuel

21/09/2010

Lanseria, Johannesburg – Sasol, the world's leading producer of synthetic fuels from coal and natural gas, today flew the world's first passenger aircraft exclusively using the company's own-developed and internationally approved fully synthetic jet fuel.

The fuel, produced by Sasol's proprietary Coal to Liquids (CTL) process, is the world's only fully synthetic jet fuel to have received international approval as a commercial aviation turbine fuel.

Sanctioned by the global aviation fuel specification authorities the jet fuel is the first fully synthetic fuel to be approved for use in commercial airliners. This marks a significant development in the adoption of clean burning alternate fuels for the aviation industry. The engine-out emissions of Sasol's synthetic jet fuel, are lower than those from jet fuel derived from crude oil, due to its limited sulfur content.

This article was adapted from a media statement by Sasol Ltd on 21 September 2010. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list. Sasol. 2010. Sasol takes to the skies with the world's first fully synthetic jet fuel. [Online]. Available: www.sasol.com [24 September 2010].

P11 PETROCHEMICALS

PETROCHEMICAL COMPANIES IN SA

CHEMICAL INDUSTRIES
RESOURCE PACK

Sasol Limited

Sasol is a global company involved in mining, energy, chemicals and synthetic fuels. They use coal, oil and gas reserves to produce liquid fuels, fuel components and chemicals using the Fischer-Tropsch process. Sasol mines coal in South Africa, produces gas in Mozambique and oil in Gabon. They have chemical manufacturing and marketing operations both locally and internationally.

www.sasol.com

PetroSA

The core business activity of PetroSA is

* the exploration and production of oil and natural gas;
* the participation and acquisition of local, as well as international upstream petroleum ventures;
* the production of synthetic fuels, procured from offshore gas at the world's largest commercial Gas-to-Liquids (GTL) plant;
* the marketing and trading of oil and petrochemicals; and
* the storage of crude oil on behalf of the Strategic Fuel Fund.

Some of the commodities produced by PetroSA include leaded & unleaded petrol, kerosene (paraffin), diesel propane, liquids (oxygen/nitrogen), distillates, eco-fuels and alcohols.

www.petrosa.co.za

The British Petroleum Company plc

British Petroleum is of one of the world's largest energy companies, providing its customers with fuel for transportation, energy for heat and light, retail services and petrochemical products for everyday items.

BP's history in South Africa dates back to the early 1920s. Today, BP Southern Africa's head office is in Cape Town. The business is focused on the refining and marketing of fuels and lubricants. At the Sapref refinery, 16km south of Durban on the East Coast of South Africa, the crude oil is processed while the manufacture of lubricants takes place at an oil blending plant at nearby Island View. In addition to a national network of BP branded service stations, BP operates eight owned depots and three coastal installations.

www.bp.com

Shell

As one of the world's leading energy companies Shell plays a key role in helping to meet the world's growing energy demand in economically, environmentally and socially responsible ways. In South Africa, Shell South Africa (Pty) Ltd, employs over 1500 people and is involved in the Retail and Commercial Fuels, Lubricants and Oils, Chemicals and Manufacturing Sectors. Shell came to South Africa in 1902. Shell South Africa's main focus at the time was on paraffin and kerosene, which brought both light and heat to communities across Southern Africa. Today, Shell South Africa is mainly involved in the Retail and Commercial Fuels, Lubricants and Oils, Chemicals and Manufacturing sectors.

www.shell.com

Chevron

Chevron is a leading refiner and marketer of petroleum products in South Africa. Their network of Caltex-branded service stations helps make them one of the country's top four petroleum brands. They operate a refinery in Milnerton, Cape Town, that produces gasoline, diesel and aviation fuel, kerosene, fuel oil, and other products. Chevron also has interests in a lubricant oil manufacturing plant in Durban.

Worldwide, nearly a quarter of all Chevron's Caltex-branded service stations are in South Africa. These retail outlets sell products such as transportation fuels and axle grease. Their Cape Town refinery produces a range of fuels as well as sulfur, liquefied petroleum gas and paving asphalt. Chevron's share in the refinery is 110 000 barrels per day.

www.chevron.com

Engen

Engen is an African-based energy group focused on the refining and marketing of petroleum and petroleum-based products, and the provision of retail convenience services, through an extensive network of service stations across 17 countries in Sub-Saharan Africa. Engen also exports its products to more than 30 other territories, mostly in Africa and the Indian Ocean Islands.

Key facts and figures

* Offices in 17 Sub-Saharan African countries
* Refinery capacity of 135 000 barrels per day
* A lubricating oils blending plant, producing up to 8 million litres of finished lubricants per month
* Market leader (26%) in South Africa and several other countries
* Over 1200 service stations across South Africa, 66 depots, 7 terminals, and aviation facilities for 22 airports in South Africa
* Engen holds shares in Petrochemical Shipping Ltd, which owns a 45 000 and a 16 500 metric ton product tanker. They have a further two vessels on time charter.

www.engen.co.za

PetroSA invests R80m in desalination plant for Mossel Bay refinery

National oil company PetroSA would invest R80 million on the construction of a 200 $m^3.h^{-1}$ seawater desalination plant, which would alleviate the impact of drought on the company's Mossel Bay gas-to-liquids (GTL) refinery, as well as for the nearby communities. The desalination plant would be located at PetroSA's logistics base, close to the Mossel Bay harbour, as there is already sufficient power supply to the base and as it is close to the refinery's water supply line.

The plant would provide five million litres a day of treated water, which would, along with other water savings measures that had already been undertaken, be sufficient to satisfy PetroSA's water requirements for operating the Mossel Bay GTL refinery.

This news article was obtained from the online publication Engineering News. Learners - if you use any part of it you need to write it in your own words and include the following in your reference list: Engineering News. 2010. PetroSA invests R80m in desalination plant for Mossel Bay refinery. [Online]. www.engineeringnews.co.za [27 May 2010].

P12 PETROCHEMICALS

PRODUCTS OF THE PETROCHEMICAL INDUSTRY

CHEMICAL INDUSTRIES RESOURCE PACK

Organic solvents

Organic solvents are used in many industries, notably those producing paint, inks, coatings, adhesives, cosmetics and pharmaceuticals. Solvents are used to dissolve other substances (solutes) without chemically changing them. This enables the solutes in inks, paints and other coatings to be spread over a surface. The solvent eventually evaporates, leaving behind only the solutes. In the cosmetic industry, for example, solvents allow the essential oils in a perfume to be dabbed on ear lobes. How a solvent works is that the molecules of the solute get mixed up with those of the solvent, provided the force binding the solute's molecules together is of similar strength to that binding the solvent's molecules. Since the strength of the binding force can vary greatly between different substances, there are dozens of solvents on the market.

Perfumes and cosmetics require high-purity solvents

Source: Mind over Matter, www.sasol.com

Solvents are used in paints and adhesives

Source: Mind over Matter, www.sasol.com

A fire dancer with Poi sticks dipped in kerosene

Kerosene (paraffin)

The name kerosene is derived from the Greek word *keros* which means wax. The word kerosene was registered as a trademark by Abraham Gesner in 1854, and for several years only the North American Gas Light Company and the Downer Company (to which Gesner had granted the right) were allowed to call their lamp oil kerosene.

It is also called paraffin (sometimes paraffin oil) in the UK, South East Asia and South Africa (not to be confused with the much more viscous paraffin oil used as a laxative, or the waxy solid also called paraffin wax or just paraffin); the term kerosene is used in much of Canada, the United States, Australia (where it is usually referred to colloquially as kero) and New Zealand.

Kerosene is widely used to power jet-engined aircraft (jet fuel) and some rockets, but is also commonly used as a heating fuel.

Disposal of plastics

Plastics are light, cheap, corrosion-resistant, versatile, and can be dyed in any colour. These properties have made plastics so popular that they have replaced many conventional materials, such as paper and metal alloys, in commodity items. But it is the same properties that also present problems when we want to dispose of the plastics. Plastic litter is highly visible and can be seen where it has been discarded along the streets and roads, in the countryside and on the beaches.

Contrary to popular belief, plastic packaging does not fill our landfill sites. Analysis of the waste stream shows that plastics represent only 7% by mass and 11% by volume of all waste. Paper represents 38% by mass of the waste stream. The inertness of plastics makes them effective stabilisers in a landfill.

There are more effective and economical methods of dealing with waste polymers than its disposal in landfill. Polymers are hydrocarbons and they should make good fuels. Unfortunately the pollution from the incineration (burning) of plastics is high, and care must be taken not to release toxic fumes into the air. The obvious option is to recycle.

Some plastics are more suitable for recycling than others. Thermoplastic cooldrink bottles made from PET can easily be heated at low temperatures to melt the polymer and remoulded into new thermoplastic products.

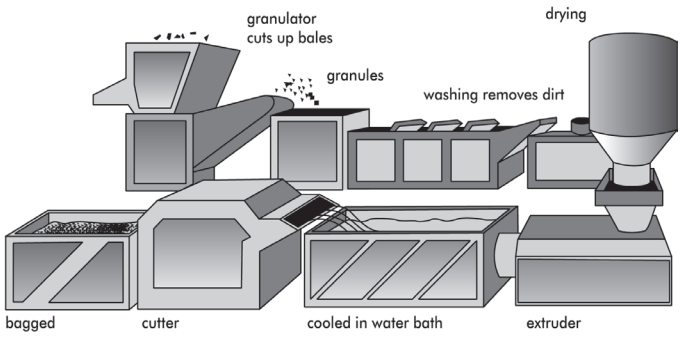
Each type of plastic needs specific recycling treatments, and to accommodate the recycling option, an international identifying system for packaging plastics has been introduced. Plastics are divided into seven groups, each with an identifying number inside the logo. These logos are moulded into the plastic, usually at the base of the article. This makes it easier to sort plastic waste for each type to be treated differently for recycling.

The recycling process

In South Africa, the plastics industry took responsibility for the post-consumer disposal of plastics via the Plastics Industry Environmental Initiative, Enviromark, Petco, Buyisa-e-bag, the Polystyrene Packaging Council and various recycling and recovery projects. Wire cages are placed in communities and retail areas to collect plastics for recycling. Most recycled waste plastics come from plastics packaging, especially films and bottles. In fact 30% of plastics used for packaging is recycled. Products made from recycled packaging include refuse bags, building film, containers, buckets, dustbins and agricultural piping.

Plastic materials are collected from various sources such as households, supermarkets, factories and garbage dumps. The collected materials are then sorted by type of plastic and colour, baled, and transported to the plastics recycler. The recycler opens the baled plastics and feeds them into a granulator which cuts up the incoming material into flakes or granules. The granules then go through a washing plant to remove labels, residual contents and soil. After drying the granules, they are fed into an extruder where the dry granules are melted down. The molten plastic is then forced though a multi-hole screen and strings are formed. The strings are water-cooled in a bath, and chopped up into pellets by a revolving cutter. The pellets are bagged and sold to a factory that uses them to produce new plastic articles.

The recycling process



Numbering plastics

1	PET	polyethylene terephthalate
2	PE-HD	high-density polyethylene
3	PVC	polyvinyl chloride
4	PE-LD	low-density polyethylene
5	PP	polypropylene
6	PS	polystyrene
7	Others	e.g. multilayer plastics and other engineering plastics

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