Flaring at oil refineries in south Durban and Denmark

SDCEA-DN Local Action Project 2004-2005: Output 1

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Engen Refinery: flaring incident at night
Source: SDCEA

Acronyms

API	American Petroleum Industry
BAT	Best Available Technology
Bcm	Billion Cubic Metres
CO	Carbon Monoxide
CO_2	Carbon Dioxide
DN	Danmarks Naturfredningsforening (The Danish society for conservation of nature)
EUB	Energy and Utilities Board (Alberta, Canada)
GAO	(US) Government Accountability Office
GIS	Geographic Information Systems
HCR	Hydrocarbon Relief System
HSR	Hydrogen Sulphide Relief System
H_2S	Hydrogen Sulphide
IR	Infra Red
MJ/scm	Mega Joule per standard cubic metre
MPP	Multi-Point Plan
MRG	Methane Rich Gas
NGO	Non-Governmental Organisation
NO_x	Nitrogen Oxide Gases
03	Ozone
PM_{10}	Particulate Matter (10 micrometre)
SDCEA	South Durban Community Environmental Alliance
SO_2	Sulphur Dioxide Gas
SRP	Sulphur Recovery Plant
SRU	Sulphur Recovery Unit
TRS	Total Reduced Sulphur
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

Executive Summary

This book came about during the project between Danmarks Naturfredningsforening (DN) and the South Durban Community Environmental Alliance (SDCEA), where DN provided technical assistance in looking at the local refineries. The flaring book became a reality due to the high number of flaring complaints in south Durban, and a need for organisations and the community to understand aspects of flaring.

In this book we discuss the relevant issues of flaring and give a community perspective of living next to flares. We have also compared refineries in both Denmark and South Africa* to see what the differences are between flaring in a developed world and developing world context.

Denmark is a country with a population of 5.38 million people[1] and the country covers 43 094 square kilometres. The refineries are 85 kilometres apart. The refineries that we are examining in South Africa both are situated in close proximity to each other (i.e. one and a half kilometres) and also to the local community. These two refineries are in a province called KwaZulu-Natal and this province alone is twice the size of Denmark and consist 92 100 square kilometres, while the population is 9 426 017[2].

The refineries compared are Shell and Statoil in Denmark and Engen and SAPREF in South Africa. The operations of the two sets of refineries vary significantly in capacity, type of crude processed, processing technology etc. Whilst the operation and practices are varied between the refineries, the flaring system has elements of Best Available Technology (BAT) to varying degrees.

Recommendations of possible action to reduce flaring and venting include:

1. Local, provincial and national authorities could improve on the way they collect data on the refining industry. This needs to include flare monitoring of volumes and content of flare gas, as well as video monitoring.

2. There needs to be a reform of the gas market, so that excess gas can easily be utilised by other industries, both locally and nationally.[3] The World Bank Report states that: "In many developing countries the relatively low financial returns developers can expect from investing in the construction of a gas network have undermined the prospects for a developing gas market. Part of the problem is often subsidies for competing energy sources (oil, coal, nuclear, hydropower), which lead to low prices for competing fuels."[4] This point is extremely pertinent to the South African context.

3. A possible solution to the noise, continuous flaring and light problems relating to flaring would be to reduce the need for flaring through more efficient operating procedures and Best Available Technology (BAT) at the refineries. Flare gas recovery systems need to be of a sufficient size to handle most upsets.

** The refineries involvement in the compilation of this book has been limited to the supply of factual data concerning flaring at their refineries. They do not necessarily agree with or endorse any of the findings or conclusions in this book, nor can they be responsible for the way this book has utilised the data supplied by the refineries.*

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[1] http://www.lonely planet.com/destinations/europe/denmark

[2] Statistics South Africa – Census 2001, Census in Brief

[3] Pg 2 World Bank Group – Public Policy for the Private Sector Note 279 *Gas Flaring and Venting: A Regulatory Framework and Incentives for Gas Utilization* (Authors:Franz Gerner, Bent Svensson and Sasha Djumena

[4] Ibid Pg 4

4. As many flaring incidents are alleged to be caused by power failures, refineries and power suppliers need to look at alternative power sources and back up systems for when there is a power failure that causes the supply to the refineries to be interrupted. Root cause analysis of each flare incident will identify prevention measures. Refineries should also ensure operating procedures are in place to minimise flaring requirements when such interruptions do take place.

5. Enforcement of any permitting system is crucial to achieve the reduction in flaring, and to ensure that industry becomes more accountable.

6. In Alberta, if the refinery operators do not solve a flaring problem, the public can submit a written objection to the EUB (Energy and Utilities Board). The board will consider the application for a permit and the objection. Ideally, we want a similar situation here, where residents were acknowledged as being crucial in terms of public participation, and are valued for bringing potential problems to the fore. In California, flare monitoring and control rules are being developed where citizens can sue companies that have repeat and smoking flares. Legislation like this would be appropriate in south Durban and South Africa.

7. In South Africa, as well as in south Durban, people who are specialists in the refining field, other than the refinery operators, are needed. Skilled personnel are needed in local, provincial and national departments, as well as in community organisations.

Flaring incident at SAPREF (Shell and BP) Refinery, Durban
Source: Bobby Peek

COMMUNITY'S FREQUENTLY ASKED QUESTIONS – BRIEF OVERVIEW

1. What is flaring?

The word flaring is used to describe a naked (open) flame that is burning off excess gas. This usually occurs at oil refineries, as well as at certain chemical plants. Gases are generated when the process is not operating properly, when there is loss of power or when gases are vented during maintenance. Far more flaring takes place at gas and oil production facilities than at refineries. It also occurs at some mines and many land fill sites.

2. What are the main problems with flaring?

Flares release very large volumes of gas onto the atmosphere in a brief period of time. They are prone to problems of wind turbulence and lack of time to burn the gases and variable temperature, which contribute to an "unclean" burn.

One of the main problems with flaring is that flaring efficiencies are essentially unknown. Often, refineries quote manufacturers' specifications, as they don't know their actual efficiency. Research from the Alberta Research Council (Canada) also suggests that the number and volume of potentially toxic compounds released due to incomplete combustion was much higher than expected.[5]

Flaring also contributes to a number of environmental problems such as eco inefficiency, resource depletion, global warming and acid deposition.

3. Why do refineries flare?

Flares are designed to protect the refinery equipment, and blow gases beyond the immediate workplace area – they are not designed to protect the offsite public.

Refineries regard flaring as a necessary safety device, for getting rid of excess gas. This is a safety mechanism for the refinery. If too much gas builds up, parts of the refineries could overpressure and explode.

Some refineries flare more than they should, as this is an easy way to get rid of a refinery's waste.[6] In south Durban, refineries flare due to operational upsets and maintenance as well as emergencies. It is interesting to note that in terms of Engen's new permit, issued on 31st December 2004, they are prohibited from flaring for economic reasons.

4. Why are some flares smoky?

If a flare is smoky, then it is not a good flare, because what is being released is not being burnt completely i.e. incomplete combustion. Both Engen and SAPREF in south Durban add steam to their flares, and this helps the flare burn properly. If a flare is smoky or the flame is remarkably high, it should be reported. Flares also smoke because the volume of gas overwhelms the capacity of the flare to burn efficiently.

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5 http://www.ec.gc.ca/energ/oilgas/flaring/flaring_general2_e.htm

6 http://www.groundwork.org.za/Pamphlets/flaring.htm and *Enforcement Alert* Volume 3 Number 9 (Put out by the Environmental Protection Agency (EPA)

5. Why is there such a strong smell when flaring occurs?

Many gases are released during flaring. If the flare is "good" flare, only carbon dioxide (CO_2) and water are released. Since monitoring of gases does not occur at the fare tip, it could be argued that this only happens in a laboratory! There are two gases that could cause a flare to smell – sulphur dioxide and hydrogen sulphide.

Sulphur dioxide (SO_2) is a colourless gas and has a strong smell. It irritates the respiratory system, and can cause and aggrevate asthma and bronchitis. Continued exposure in pregnant women can result in babies being born with a pre-condition to asthma.[7]

Hydrogen sulphide (H_2s) is an extremely dangerous chemical. It has a rotten egg smell. According to a Handbook Hydrogen Sulphide issued by Shell Safety Committee December 1986, "The major hazard of hydrogen sulphide is its ability to cause sudden death due to accidental exposure" in high concentrations.

The concentrations during flaring are normally far below the accidental level but high enough to be recognised by the smell and health symptoms such as nausea and vomiting.

Another point to note regarding hydrogen sulphide is that the continued exposure to this chemical leads to a reduced olfactory response which means that the more one is exposed to this, the less one can smell it. It could be present in a dangerous concentration, and one would not be able to smell it.

6. What is put into the air when refineries flare?

According to the Canadian Public Health Association 2000 Position Paper, 250 different toxins have been identified during flaring, that have been released into the air. These include:

- Particulate matter (soot)
- Benzene
- Benzopyrene
- Carbon di-sulphide (CS_2)
- Carbonyl sulphide (COS)
- Toluene
- Mercury
- Arsenic
- Chromium
- Sour gas with hydrogen sulphide and sulphur dioxide
- Nitride oxides (NO_x)
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Polycyclic aromatic hydrocarbons (PAH)

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7 Settlers Primary School Health Study, November 2002

8 Page 3 *Hydrogen Sulphide* Shell Safety Committee December 1986

7. **Does flaring affect my health?**

Certain compounds that may be released will aggravate respiratory diseases such as asthma. The US EPA Enforcement Alert October 2000 states: "hydrogen sulphide is regarding as a toxin similar to cyanide in toxicity. Flaring can produce high ambient concentrations of sulphur dioxide. Short-term exposures to elevated sulphur dioxide levels while at moderate exertion may result in reduced lung function accompanied by such symptoms as wheezing, chest tightness, or shortness of breath..."

(Refer to table on page 12)

8. **What can I do when I see a flare?**

In south Durban, when the flares are smoky or large, members of the public can report it to the eThekwini Health Department 031 – 3003136 or the 24 hour pollution complaint centre on 031 361 0000. Ask for a log number. Then you can report it to SDCEA 031-4611991 who will then log it on the Geographic Information System (GIS). It is useful to know which refinery has the flare, what time the flaring started and when it finished, so that we can relate this information to the air quality data that we have.

Other useful numbers to report flaring from petro-chemical industries in South Africa are:

Sasolburg: 016 9603439

Sasol Secunda: Pierre de Jager 082 414 5196

Caltex Cape Town: Steve Woodruff MD of refinery 021 508 3200

SAPREF: 0800 3300 90

Engen: 0800 3300 99

SCDEA: 031 461 1991

eThekwini Health Department: 031 3003136

9. **Does flaring affect air quality?**

Flaring can affect air quality, especially if the flares are not burning efficiently. The air monitoring stations have detected increased levels of particulate matter during flaring episodes. Ground level hydrogen sulphide concentrations are also known to increase. Flaring also increases carbon dioxide levels. Incomplete combustion results in harmful hydrocarbons and particulate matter (soot) being released into the atmosphere. Studies in Houston, Texas indicate that smog levels can rise as the result of excess flaring because of excess flaring because of VOCs and sulphur dioxide releases.

10. **How is air quality monitored?**

In Durban, air quality is being measured by the eThekwini Air Quality Monitoring Network. At present we can log onto a website www2.nilu.no/airquality/ to check on a daily basis. From time to time, SDCEA will be offering workshops on how to understand this information. Contact the SDCEA offices on 031 461 1991 for more details.

11. How does a shut down affect flaring?

Generally as a process unit is shut down, there can be higher flaring rates than base line levels. This occurs because the equipment is being cleaned and depressured for maintenance work. Poor control by plant staff results in smoky and larger than necessary flares. Waste gases are routinely "cleaned" out of units by venting them to flare during refinery shutdown and maintenance. Emergency shutdown occurs at a refinery, when the said refinery experiences serious problems either in their processes or in their plant, which threatens life or machinery. The operations should find a safe way to shut down the plant without any danger. Scheduled shutdowns also occur, and are planned well in advance. The plant is then systematically shut down.

12. Who do companies have to notify when performing planned flaring?

It is interesting to note that under Engen's new permit, prior to all planned flaring they have to apply to the eThekwini Municipality for permission to do it. They have to provide information regarding time and date of flaring, expected duration of the event, gas composition and expected flow, total emissions associated with the flaring on a pollutant specific basis as well as estimates of ground level concentrations of pollutants associated with the flaring.[9]

What is even more interesting is that in Alberta, operators are required to provide 24 hours advance notice to all residents within a 3 km radius for sour well testing, regardless of its hydrogen sulphide content. Also, additional "good neighbour" notification, including notice for short-duration events, "should be conducted where members of the public have identified themselves as being sensitive to emissions from the facility or if they are interested in receiving notice of planned flaring for other reasons"[10] The Alberta Energy and Utilities Board expects operators to provide an information package to the public, outlining relevant information.

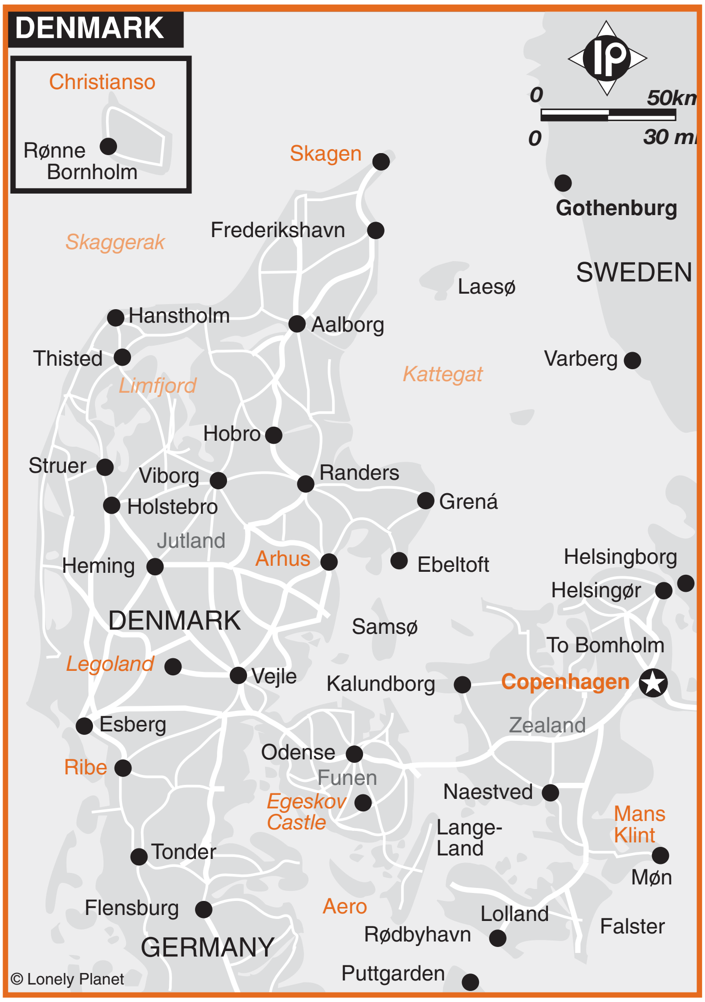
In California, refineries have to measure flare gas flows and content as well as video tape flares as part of the local authority regulations.

SAPREF Refinery: Black Wednesday (flaring incident), 21st April 2004
Source: Tony West

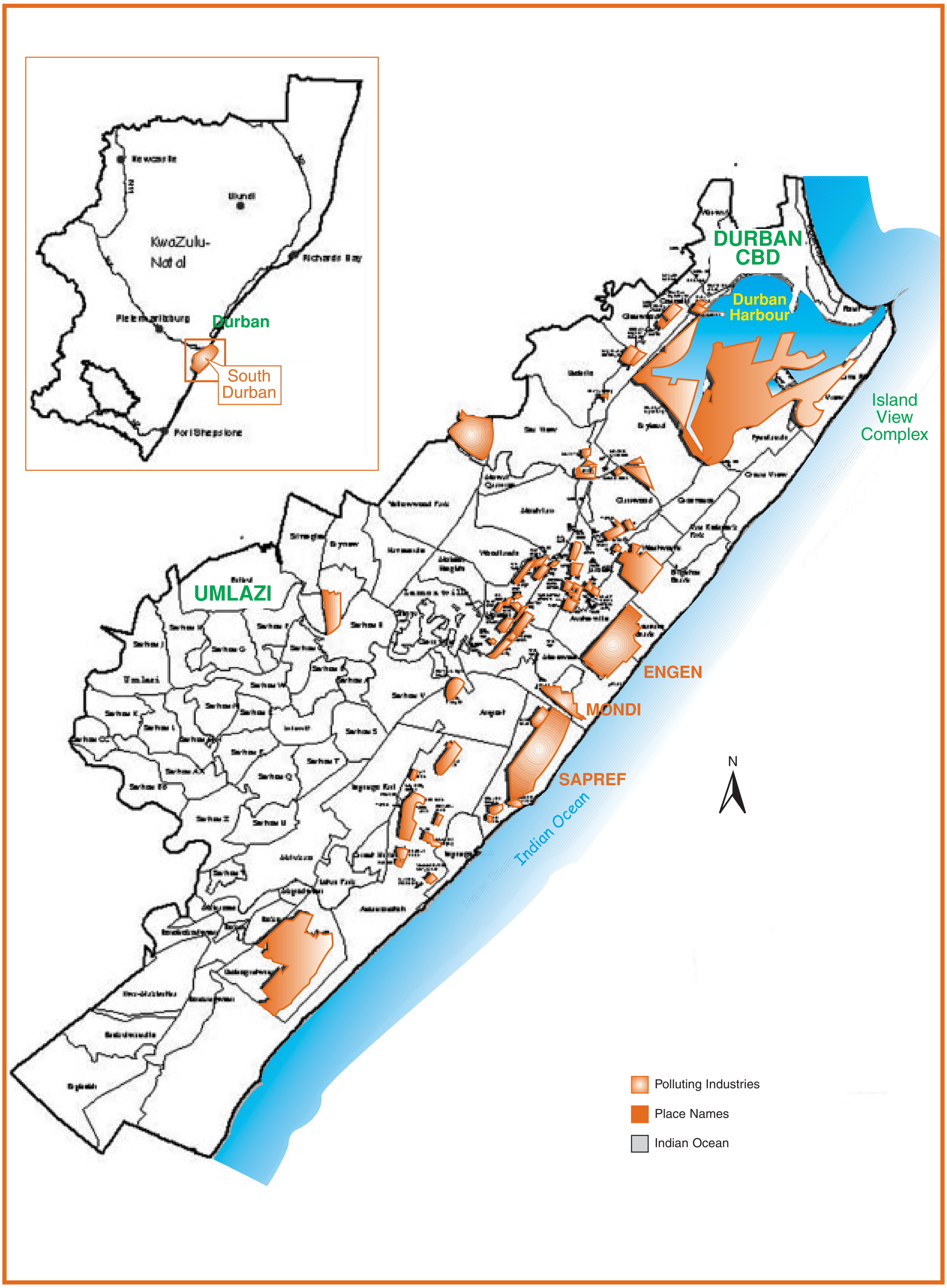
[9] Engen Permit, issued 31 December 2004, Page 10

[10] http://www.eub.gov.ab.ca/BBS/public/EnerFAQs/EnerFAQS6.htm

Maps of Denmark with Refinery locations



Map of South Durban



1 Introduction

Flaring is a controversial issue, especially when oil refineries are located in the heart of local communities, as is the case of both in south Durban (South Africa) and Denmark. There are many myths about flaring, as well as, strong emotions about this activity. Apart from the conflict between residents and refineries, there is uncertainty in the refining industry and within local and national authorities as to what is "acceptable" flaring.

The idea of examining flaring practices was stimulated by several reasons.

- Firstly, there are a number of complaints from members of the Durban community regarding flaring, and these are recorded on the SDCEA Geographic Information System (GIS).
- Secondly, the assumption that the volume of hydrocarbons burned in flares in the Danish Refineries is substantially less than the volume burnt in the refineries in South Africa.
- Thirdly, to develop a common understanding of flaring and the issues relating to flaring, by the communities, refineries and local authorities.
- Fourthly, to compare the flaring practices of the four refineries against the best available technology and practice.

In this booklet we give an overview of the important issues and to understand and explain the various points of view that we explore. The book starts by examining flaring in the global context and provides a brief introduction to flaring technology. After that we compare flaring practices between refineries in south Durban and Denmark. Finally, we look at the roles of various affected parties in dealing with flaring and offer recommendations. This study follows up on the previous DN/SDCEA publication: *A 2002 Snapshot: Comparison of Refineries in Denmark and south Durban.*

Basic description of flaring

In order to contextualise the rest of this book, it is necessary to provide some basic description of flaring:

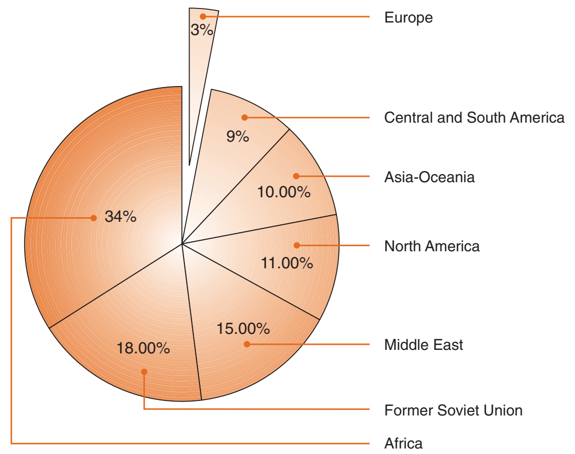
Flaring is a combustion control process in which volatile organic compounds (VOC) are piped to a location and burned in an open flame in open air, using a specially designed burner tip to obtain nearly complete destruction of the VOC. It is intended to be the safe burning of gases released from various process units in a refinery.[11]

One of the objectives of this study is to compare flaring data and attitudes towards flaring from four refineries (two in Denmark and two in Durban). To meet this objective, a comprehensive questionnaire was developed and forwarded to the refineries for responses. The responses received have been analysed, summarized and presented in this report. (The original data are available at the SDCEA offices). In addition to this booklet, an information pamphlet on flaring has been produced and will be distributed to local communities.

[11] Sapref definition given at presentation delivered on the 16 August 2004

The global context of flaring and Venting

The World Bank estimates that 110 billion cubic metres (bcm) of natural gas is flared and vented annually. This gas that is 'lost' could provide the annual gas consumption of Central and South America or that of Germany or Italy[12]. Gas flared in Africa alone is 37 bcm, and that could produce 200 terawatt hours of electricity, "about half the power consumption of the continent and more than twice that of Sub-Saharan Africa (excluding South Africa)"[13]. Developing countries account for more than 85% of gas flaring.[14] The reason for this is that many of the developing countries that flare a lot produce oil and gas for export. Developing countries do not have the same legislation as developed countries, and thus poor practices are perpetuated.



Source: The World Bank

1) Pie chart showing regional Flaring and Venting as a percentage of World Flaring and Venting

Country	Flared gas (bcm)[a]	Perentage of world total (%)[b]
Algeria	6.8	6.0
Angola	4.3	4.0
China	3.2	3.0
Egypt	0.9	1.0
Indonesia	4.5	4.0
Iran	10.5	10.0
Mexico	5.6	5.0
Nigeria	17.2	16.0
North Sea[c]	2.7	3.0
Russia	11.5	11.0
United States	2.8	3.0
Venezuela	4.5	4.0
Other Countries	33.0	30.0
Total	107.5	100.0%

Source: The World Bank – which included data from Cedigaz, EIA, OPEC, IEA, World Bank and IHS Energy Group.
Note: [a]Billion cubic meters [b]Percentages are rounded
[c]North Sea includes Denmark, Norway and the United Kingdom, since Germany and the Netherlands did not flare in 2000, according to Cedigaz.

2) Estimated gas flared and vented by selected countries (table)

According to the GAO[15] Report (2004), flaring and venting are concentrated in certain parts of the world, namely: Algeria, Angola, Indonesia, Iran, Mexico, Nigeria, Russia and Venezuela. These countries alone account for 60% of natural gas flared and vented.[16] This report also notes that there is very little consistent information, and in the United States, often information that is given to authorities is done so on a voluntarily basis, and is not mandatory. This lack of information is probably a global issue.

[12] World Bank Group – Public Policy for the Private Sector Note 279 Gas Flaring and Venting: A Regulatory Framework and Incentives for Gas Utilization (Authors: Franz Gerner, Bent Svensson and Sasha Djumena Page 1

[13] Ibid

[14] Ibid

[15] This report stems from the US Government Accountability Office (GAO)

[16] GAO Report July 2004 *Natural Gas Flaring and Venting – Opportunities to Improve Data and Reduce Emissions* Pg 10.

The US EPA, states in Enforcement Alert (October 2000) "...investigations suggest that flaring frequently occurs in routine, non-emergency situations or is used to bypass pollution control equipment. This results in unacceptably high releases of sulphur dioxide and other noxious pollutants and may violate the requirements that companies operate their facilities in a manner consistent with good air pollution practices for minimizing emissions."[17]

This report goes on to say that: "One day of acid gas flaring can easily release more sulphur dioxide than is released in a single year of permitted SRP (Sulphur Recovery Plant) activity. On numerous occasions, US EPA has uncovered information on acid gas flaring incidents that shows that 100 tons or more of sulphur dioxide can be released in such flaring over a 24-hour period."

It seems that around the world, many exceedences are experienced during upsets and this is particularly noticeable in south Durban.

2 The impacts of flaring

The refining of oil is a mature industry, and pollution abatement programmes have been carried out to different extents in some refineries around the world for a long time. The extent to which refineries have engaged in pollution abatement programmes differs from country to country, and often the extent to which the refinery has engaged in pollution abatement programmes is dependent on local or national legislation.

The full detrimental impact of the resulting emissions from flaring on human, plant, and animal life have not been fully quantified. However, all investigations and studies to date list the following as some of potential detrimental impact of flaring operations:

- Gas flaring and venting from gas fields, oil fields and refinering operations etc, has a direct impact on Greenhouse gas emissions, and thus contributes towards global warming.[18]
- The emissions from varying flaring conditions include carbon particles (soot) unburned Volatile Organic Compounds (VOC), carbon monoxide (CO) and other partially burned and altered hydrocarbons. Also emitted are Nitrogen Oxide Gases (NO_x), hydrogen sulphide, mercaptans, and sulphur dioxide. These emissions contribute adversely to health and well being of the people in surrounding communities. The impacts of these emissions are summarized in Table 1 and is described in greater detail in the previous two DN/SDCEA publications: *A 2002 Snapshot: Comparison of Refineries in Denmark* and *South Durban and Applied Meteorology and Climatology in South Durban.*

  Noise, heat, luminosity and vibration are also undesirable effects of flare operations.
- The lost energy could be used productively, as opposed to causing pollution/greenhouse gas effects.
- Acid deposition is the combination of nitrogen, sulphur oxides (released from flaring) and water in the atmosphere to form acids that are deposited either directly or with precipitation. The acids can fall near flaring activities or be carried for hundreds or thousands of kilometres before being deposited.

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[17] US EPA, *Enforcement Alert*, October 2000

[18] Greenhouses gases include Methane and Carbon Dioxide.

Table 2: Health Effects of Chemicals (Dependent on flaring efficiency)

Name of Chemical/s	Symbol	Use/where found	Health Effect
Ground Level Ozone	O_3	It is related to emissions from vehicles and refineries.	In low concentrations it causes eye irritations and in higher concentrations can cause severe respiratory problems, especially in the elderly and children.
Hydrogen Sulphide	H_2S	Gas may be released when flaring.	Accidental release of a large quantity of hydrogen sulphide may have serious health effects. In lower levels it can have an effect on the eyes, nausea, loss of sleep and headaches. (See Shell Safety Committee December 1986 *Hydrogen Sulphide)*.
Nitrogen Dioxide			This affects the deep lung and peripheral airways, and it aggravates asthmatic symptoms. High concentrations result in the formation of methaemoglobin, which prevents the blood from absorbing oxygen.
Particulate Matter	PM	Vehicle and stack emissions.	It is believed to cause cancer and heart attacks.
Sulphur Dioxide	SO_2	The burning of fossil fuel, coal and oil fired plants and boilers, oil refineries etc.	This can result in irritation of the respiratory system, leading to and aggravating asthma and bronchitis. This was proved in the Settlers Primary School Study). Continued exposure in pregnant women can result in babies being born with a predisposition to asthma.[19]
Alkanes include methane, ethane and propane		They are used in products such as solvents, degreasers thinners and. enamelst.	At low concentrations they act as irritants causing inflammation, itching and swelling of the skin. At high concentrations, they cause acute eczema and pulmonary oedema.
Alkenes (including ethylene and propylene)		Produced by the refining process and are found in products such as petrol and aviation fuel.	Causes weakness, nausea and vomiting.
Aromatics (Benzene, toluene and isomers of Xylene are the most common aromatic compounds found in petrol		Benzene is used in in the chemical industry.	These are toxic and carcinogenic, and are designated as priority pollutants by the US EPA. They act on the nervous system, and in low concentrations they can cause blood abnormalities. It is associated with leukaemia. They also cause skin irritation, depression and excitation. Benzene and Toluene particulates irritate the mucous membranes and can contain toxic substances that can enter through mucus membranes.

The information for the above table was taken from the two DN/SDCEA publications: *A 2002 Snapshot: Comparison of Refineries in Denmark and south Durban* and *Applied Meteorology and Climatology in South Durban (2004)*, as well as the *Settlers Primary School Health Study (2002)*.

[19] Settlers Primary School Health Study, November 2002

Researchers from the University of Alberta have also uncovered some interesting facts. They discovered that in sour gas flares (which is what we have in south Durban) any unburned fuel emissions are particularly toxic. They go on to state "The emissions of the products of incomplete combustion can also cause health concerns for animals and people."[20] Inefficiencies of flaring are associated with the number of hydrocarbons emitted, and not the amount of carbon dioxide emitted. "Basic input parameters such as wind speed, fuel exit velocity, fuel consumption and flare diameter all have varying effects on the efficiency of the flare."[21]

2.1 Denmark

Denmark is situated in the north of Europe surrounded by the Baltic Sea and the North Sea. There are two refineries in Denmark and the crude oil refined in Denmark comes from the North Sea.

Statoil, Norwegian owned and the larger refinery of the two, is situated just outside the city of Kalundborg with about 20,000 inhabitants. The residents closest to the refinery live on the fenceline.

The Shell refinery, which is part of the Shell group, is situated 1 km outside the city of Fredericia with about 55,000 inhabitants.

4.7 million tonnes and 3.4 million tonnes oil respectively are being refined every year at the Danish refineries. It is interesting to note that Statoil only received 4 complaints in 2003, and three of these were in connection with the noise of the flare.

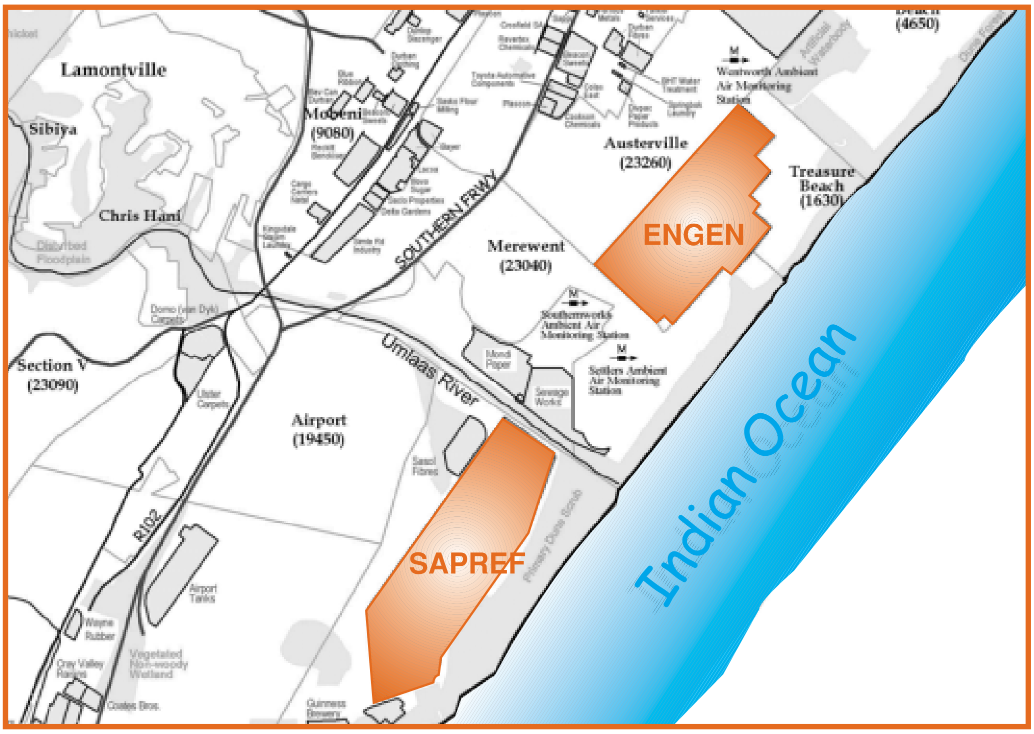
Map of Denmark showing the proximities of the Refineries

[20] *University of Alberta, 2004 Flare Research Project – Final Report September 2004*

[21] Ibid Page 116

2.2 South Durban, South Africa

South Durban consists of two oil refineries with a total processing capacity of approximately 14, 5 million tonnes per annum and are situated approximately 1, 5 km apart. Of the 300 industries, there are 150 smoke stack industries. This includes the Mondi Paper Mill that contributes to the emissions in the area. The daily average combined flaring from refineries is 32, 63 tonnes of gas (hydrocarbons and sulphur oxides). For refineries situated close to residential areas, communities live on the fence line and nuisances can become issues in the discussions between the refinery and the neighbours. A topic that often becomes a case for neighbour concern is flaring, as it is both noisy, visible and increases emissions in the area when done. Most of the complaints recorded on the SDCEA GIS system, involve flaring. In addition, residents frequently complain about the odour. One of the sources of odour could be the flare system. Odours in a refinery are mainly created by sulphur compounds as Hydrogen Sulphide (H_2S), sulphur dioxide and mercaptans and also by some hydrocarbons (e.g. aromatics). Flaring at night can cause a light nuisance in the surrounding areas.



Map of south Durban showing the close proximities of the refineries.

Light, vibration and noise pollution problems associated with flaring have been largely ignored by industry and the authorities in south Durban despite repeated complaints from residents in the area. *(See figure below)* Light and noise problems result in sleep disruption and contribute to fatigue and stress amongst residents.

While there are no concrete provisions for the control of light from flares, there are provisions in environmental and health legislation for the control of nuisance conditions.

One other factor that needs to be taken into consideration is that the south Durban Basin has complex weather conditions. In particular, the area is prone to temperature inversions in winter. These conditions affect the atmospheric stability and reduce the dispersion of odours, toxic concentrations and smoke. Hence in winter, when emissions from industries including the refineries are trapped beneath the clouds.[22]

[22] For further information see *Applied Meteorology and Climatology in South Durban*

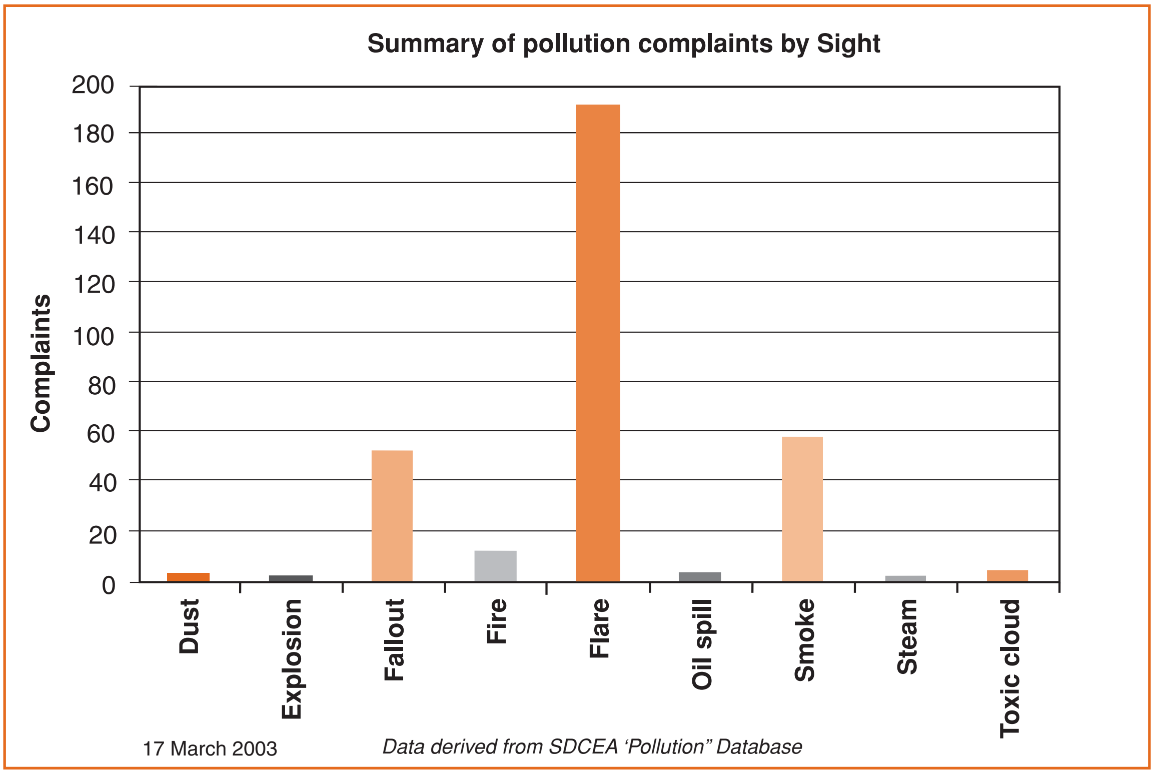


Figure 1 shows resident's complaints registered on the SDCEA GIS system since 1998. In 2003, there were 49 flaring complaints, amongst many other pollution complaints.

South Durban has been identified by national government as a key priority area in South Africa for a pilot study to develop an integrated approach to air quality management. This national government initiative, managed by the eThekwini Municipality, referred to as the Multi-Point Plan (MPP), has the following components:

- Health Risk Assessment and Epidemiological Study,
- Establishing an air quality management system,
- Phasing out dirty fuels,
- Inputs into national strategy for vehicle emissions
- Setting air quality standards

Trade permits issued by the eThekwini Municipality have been identified as the key mechanism towards sustainable development and improving the air quality in the Durban South area. Since November 2004, the trade permits issued to the refineries in the area, include specific clauses and conditions relating to meeting the objectives of the Multi-Point Plan (MPP). The specific references to flaring in the new refinery trade permits are discussed briefly later in Chapter 6 in this booklet.

2.2.1 The impact of flaring on air quality in south Durban

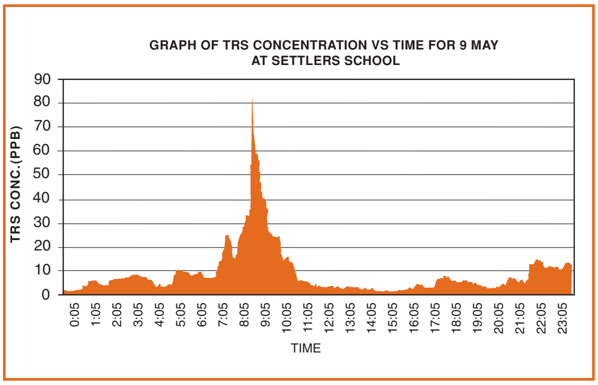


Figure 2

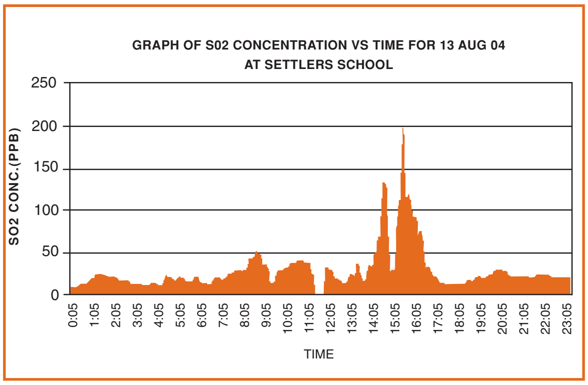


Figure 3

The graphs presented in figures 2 and 3 are of two possible pollutants that could be emitted during flaring.

It is widely documented that flaring can result in emissions of hydrogen sulphide and/or sulphur dioxide. To assess the impact of flaring on air quality in south Durban, TRS (total reduced sulphur) and sulphur dioxide data from the air monitoring stations were examined on dates when flaring was known to have occurred. One of the components of total reduced sulphur is hydrogen sulphide. Total reduced sulphur is thus an indicator of hydrogen sulphide. The flaring dates were obtained from SDCEA's complaints register.

The results of the assessment confirmed that on several occasions, pollution levels increased during flaring episodes. Figures 2 and 3 present examples of days when air quality was possibly compromised as a result of flaring. The data was supplied by eThekwini Health Department.

Engen Refinery flaring incident at night
Source: SDCEA

3 Flaring in the refinery

The main objective of oil refining is the conversion of crude oil into a range of useful products: petrol, diesel, kerosene, waxes, etc. This is achieved via a range of separation operations (distillation, absorption, adsorption, crystallisation, etc) and chemical conversion operations (catalytic cracking, alkylation, isomerization, etc). All these operations are designed to operate within a certain range of flow rates, temperatures, pressures, and compositions. The deviation from these designed operational ranges will be considered to be an "upset condition". This may result in the release (via safety devices or bypass lines) of process gases streams to the flare system.

A flare system is an essential part of the safe operation of a refinery because flares can prevent damage, fires and explosions, and injuries to employees. Flares are used for safety and environmental control of discharges, undesired or excess combustibles and for surges of gases in emergency situations or upsets. The operation of gas flaring is aimed at converting flammable, toxic or corrosive vapours into either less hazardous emissions or to acceptable means by means of combustion. A flare is normally visible and generates both noise and heat. The composition of the emissions exiting a flare will be dependent on the combustion efficiency and the composition of the gas sent to the flaring system. A low combustion efficiency will mean that a greater amount of volatile organic compounds will be emitted via the flare. Efficient combustion in the flame depends on achieving good mixing between the fuel gas and air and on the absence of liquids.
The combustion efficiency of a well designed and operated flare is in the high 90 percent range – often greater than 98 %.

Routine sources of flare gas include some process releases, and flare system pilot/purge gas. Generally, during routine operations the flare system burns smokelessly, quietly and largely unseen. During routine flaring, the burned gas generates mainly water vapour, carbon dioxide and sulphur dioxide. Some of the gas can normally be compressed and returned to the fuel gas system or used for power generation.

Upset sources arise from individual pressure reliefs and during start-up or shut-down of major process units. This generally results in larger quantities of gas being sent to the flare.

Emergency conditions such as equipment failure or power failure are likely to result in substantial quantities of gas being flared, which would normally exceed the range of smokeless operation due to inadequate steam supply. However, emergency flaring should be a rare event. These upset and emergency conditions may arise for a number reasons, these include:

- Change in feedstock
- Equipment failure
- Ageing infrastructure
- Inadequate maintenance
- Human error
- Deviation from operating procedures
- Power failures
- Operating above design operational capacity

Many refineries have multiple flare systems. Some process units may have their own dedicated flare, some large sites may have flares for different sections of the site. As it is desirable to avoid mixing sour gas and water, sour gas flares do not have water seal vessels and seperate sour gas collection systems. A sour gas flare could be equipped with different burners to that of the hydrocarbon flare to allow more efficient combustion of sour gases (H_2S). Flares may become an important sulphur dioxide emitters when clean fuels are to be produced by the refineries.

The ideal operating condition would be to eliminate the need for flares, as they waste hydrocarbons, which could become products and improve profits. However, for facilities to recover large amounts of hydrocarbons under emergency conditions are not economically feasible to install. Recovery of released hydrocarbons during routine plant operations is justifiable and is in use in many refineries. It is an oil company's interest to minimise the amount of gas flared in order to realise as much value as possible from the hydrocarbons being produced. For environmental and resource conservation reasons, flaring and venting should always be minimised as much as practicable, consistent with safety considerations.

> *"Venting, where gas is released straight into the atmosphere without being burnt,"*
>
> *Shell state that their gases are not vented from the flare as a practice.*
>
> *SAPREF states that it does not "vent" gas as a practice. On a small number of units, during an upset, a small flow may be routed to an atmospheric vent at a safe location. Action is taken to reroute the stream back to the furnace as soon as possible after a trip.*[24]

4 Technology of flaring

There are basically two types of flares that are used in refineries, an elevated flare and a ground flare. Ground flares are used when it is necessary to conceal the flare (for various reasons) otherwise the elevated flare is commonly chosen because it can handle larger flow releases more economically with better dispersion. Sometimes a refinery has both a ground flare and an elevated flare. In that case the ground flare is used to combust small amounts of continuous vents and small relief loads.

The elevated flare is always a vital part of the refinery complex, its primary purpose being safety. This flare system is designed to conduct easily ignitable and toxic vapours from the process area to a remote elevated location. A basic comparison of this these two types of flares is given in Table 2 below.

Ground flare in Nigeria
Source: groundWork

[24] SAPREF questionnaire

Characteristics	Elevated Flare	Ground Flare (Multijet)
Smoke	Can be made smokeless except at high loads.	Relatively smokeless.
Noise	Can be noisy, if excessive stream is used for smoke reduction.	Relatively quiet.
Luminosity	High, but can be reduced with steam.	Some.
Air Pollution Dispersion	Best obtainable, provided elevation is adequate.	Poor dispersion due to low elevation. Severe problems if poor combustion or flameout.
Major Problems	High cost due to elevation; visual and noise pollution; heat radiation requires wide spacing.	High cost; high maintenance; ow level odour; hazardous if flameout occurs.
Applications	General choice for total flare load. Only acceptable flare where products of combustion or partial combustion can be toxic.	Use for base loads or partial flaring where noise and visual pollution are critical. Suitable only for clean burning gases. Not suitable upwind of residential areas.

Table 3: Comparison of an elevated flare with a ground flare

4.1 Flare system

Flare systems normally can be divided into two main sections, i.e. the flare collection system with a flare knock out drum and the flare stack itself. When dealing with large refinery complexes separate knock-out drums may be installed in different process areas with 'blocking-in' facilities to allow maintenance during shut downs of these areas. A typical flaring system generally consists of the following major components and subsystems:

1. A gas collection header and piping for the collecting gases from processing units.
2. A knockout drum (de-entrainment drum) to remove and store condensable and entrained liquids.
3. A propriety seal, water seal, or purge gas supply to prevent flash-back.
4. A flare stack with a single or multiple burner units.
5. Flare pilot burners and a fuel gas system to supply the gas pilots and igniters to ignite the pilot burners.
6. A provision for external momentum force (steam injection or forced air) to maintain smokeless burning.
7. The controls and instrumentation for optimal operation of the system.

SHELL & BP (SAPREF) Refinery – flaring incident, Durban
Source: SDCEA

Shell Refinery – flaring incident, Frederica
Source: SDCEA

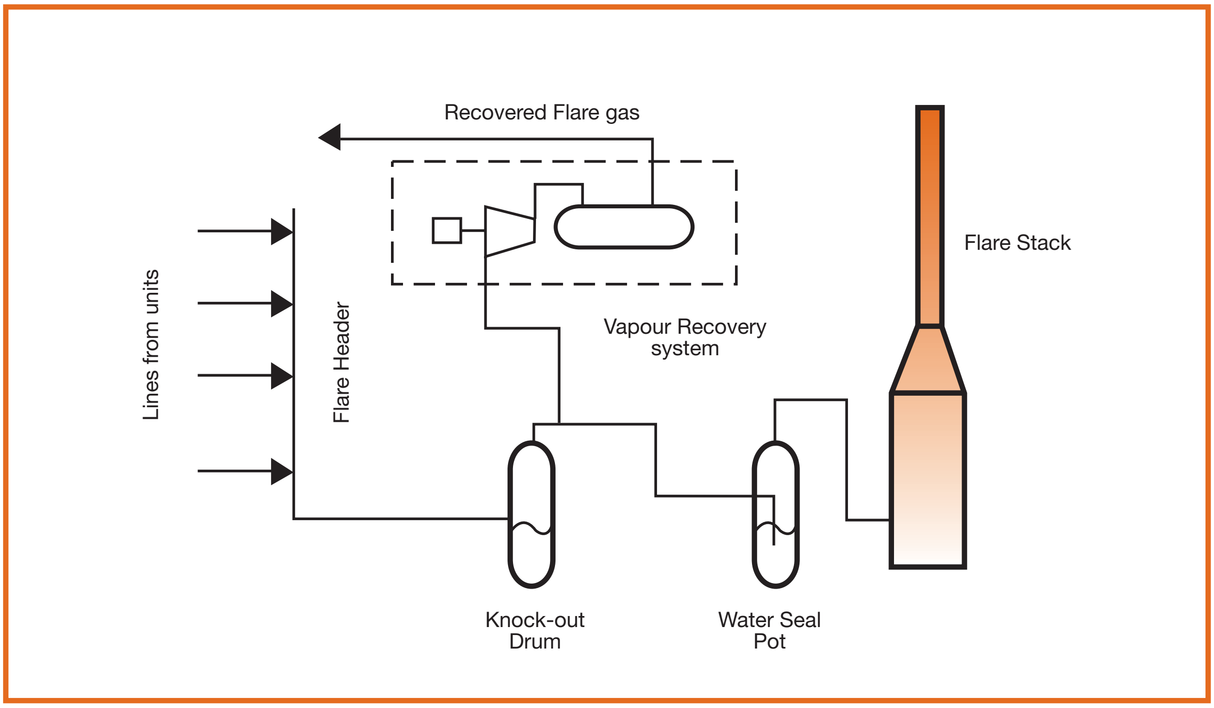


Figure 4: Simplified flow diagram for a flare system

4.2 Flaring efficiency:

Flare efficiency is defined as a performance index determined by the ratio of hydrocarbon consumed in combustion relative to the total hydrocarbon stream released to the flare. Combustion is complete if all volatile organic compounds are converted to carbon dioxide and water. Incomplete combustion results in some of the volatile organic compounds being unaltered or converted to other organic compounds. The completeness of combustion in a flare is governed by flame temperature, residence time in the combustion zone, turbulent mixing of gas stream components, and the amount of oxygen available for combustion.

Emissions from flaring can include carbon particles (soot) unburned hydrocarbons; carbon monoxide and other partially burned and altered hydrocarbons. Also emitted are NO_x and sulphur-containing material such as hydrogen sulphide, mercaptans, and sulphur dioxide. The quantities of hydrocarbon emissions generated relate to the degree of combustion efficiency. The degree of combustion efficiency depends largely on the rate and extent of fuel-air mix and on the flame temperature achieved and maintained. Properly operated flares achieve at least 98% combustion efficiency in the flare plume, meaning that hydrocarbon and carbon monoxide emissions amount to less than 2 % of hydrocarbons in the gas stream. If oxygen deficiency occurs and if the carbon particles are cooled to below their ignition temperature smoking occurs. Therefore it is important to keep the right temperature in the combustion zone. If there is not quite enough air to burn the gas completely, combustion will still occur but it will leave some of the gas unburned. Smoking may also result from combustion depending on gas composition and the amount and distribution of air. Gas containing heavier paraffins, olefins and aromatics tends to smoke.

The following configurations ensure optimal combustion in most refinery flares:

- A well-controlled steam injection system is installed. This type of flare system injects steam into the combustion zone to promote turbulence for mixing, induce air into the flame, and achieve smokeless burning. The purpose of the addition of steam is to reduce smoking by hydrocarbon flames and has a multiple effect in a flare flame in its qualities for smoke suppression. Primarily, steam acts as a "heat-sink" and reduces the flame temperature long enough to reduce the amount of free carbon available to make smoke. Additionally, the jet energy of the steam injection may be utilized to entrain and mix air into the flame and produce turbulence, which speeds up the combustion and minimizes the time available for formation of carbon chains.
- Pilot burners are normally installed to take care of constant ignition of released vapours. The pilot burners give reliable ignition to the vent gases because they are designed not to be extinguished in high winds. More than one pilot is normally fitted to each flare to minimise the changes of a flame-out.
- The waste gas must have a heating value of at least 11 MJ/scm (Mega Joule per standard cubic metre) for complete combustion otherwise fuel must be added to the flare to obtain complete combustion.[24]

4.3 Other key operational components of a flare system:

4.3.1 Knock-out drum:

Heavier components tend to condense in the flare header. This liquid in the waste gases can cause an irregular flame, soot formation, and the formation of “flaming rain” if it were routed to the burner tip. Knock–out pots should be installed on flare lines, fitted with appropriate seals and a liquid disposal system to prevent the entrainment of liquids into the combustion zone. It is used to prevent hazards associated with flaring gas that contain liquids droplets.

4.3.2 Flashback protection system:

Flare systems are subject to potential flashback and internal explosion since flammable vapour/ air mixtures may form in the stack or inlet piping, and the pilot provides a continuous ignition source. Flares should therefore always be provided with flashback protection, which prevents a flame front from travelling back to the upstream piping and equipment. This can be achieved by installing a liquid seal drum, or flame arresters, or a gas purging system, or a combination of these systems.

[24] Air Pollution Control Technology Fact Sheet. EPA-CICA

4.3.3 Flare gas recovery system:

Flare gas recovery systems lower emissions by recovering flare gases before they are combusted by the flare. In practice, a flare gas recovery system collects gas from the flare header before it reaches the flare, compresses the gas and cools it for re-use in the refinery fuel-gas system or may also be recycled as a refinery feedstock. The practice of flare gas recovery offers many benefits, including: increase in overall plant efficiency, reduced fuel gas costs, reduced emissions, and reduced auxiliary flare utilities (pilot gas, steam, etc.).

4.3.4 Auxiliary equipment

Other key components of an efficient flaring system include: control systems to maintain the required steam and air to waste gas ratio; continuous pilot system with alarm to signal pilot loss; automatic re-ignition systems; flame monitor with alarm for flame loss; waste gas quantitative flow measuring device; and waste gas analysers. All these components contribute significantly to the integrity and reliability of the flare system. Flare design and flow rate give the best indication of the ability to meet typical combustion efficiencies expected from a flare.

5 Best Available Technology and practice

While manufacturers are able to design flares with ever improving combustion efficiencies under test conditions, the difficulty of guaranteeing flare efficiency in the field is well recognised. Factors such as crosswind velocities, the temperature of combustion of the flared stream and exit velocities among others, all contribute to the variability of the actual combustion efficiency. Therefore it can be difficult to compare flare efficiency within refineries. There are however some suitable design characteristics and guidance for operation that can lead to efficient and stable flaring. Proper design and operation of flare systems, leading to optimum flare performance, include consideration of the following:

1. Minimise risk of flare blow out by installing a reliable flare system:
   a. ensure sufficient exit velocity from flare;
   b. provide wind guards for pilot burners;
   c. ensure use of a reliable ignition sytem.
2. Minimise liquid carry over and entrainment in the gas flare stream by ensuring a suitable liquid separation system is in place.
3. Maximise combustion efficiency by proper control and optimisation of flare/air/steam flow rates to ensure the correct ratio of assist stream to the flare tip.
4. A flashback protection system must be provided to prevent ignition of hydrocarbon mixture inside the stack.
5. Implement proper burner maintenance and replacement programs to ensure maximum flare efficiency and meet best practice.

In summary, the BAT elements for flaring are to:

- use flaring only as a safety system (start-up, shutdown upsets and emergencies) but not for routine disposal of gases.
- ensure smokeless and reliable operation
- minimising flaring by a suitable combination of:
  - balancing the refinery fuel gas system
  - installing a gas recovery system to recover and use the gas first
  - using high-integrity relief valves
  - applying advanced process control
- reducing relief gas to flare by management/good housekeeping practices

A group under the World Bank issued a report in May 2004 on "Global Gas Flaring Reduction". This voluntary standard gives some recommendations in regard to global gas flaring and the reduction. One recommendation is that flared gas volumes should at a minimum be estimated through sound engineering mass and energy balance calculations. It is also being recommended that flare volumes be more accurately measured through metering, where possible.
This recommendation is consistent with the movement towards implementing best practice as a part of continual improvement.

6 The permitting of flaring[25]

The permit is a tool in which environmental improvements can be made in a systematic and enforceable manner. They provide conditions and goals for industry to attain that are measurable, achievable and enforceable. They should also provide avenues for public complaint and public participation.

The permitting of polluting companies in Denmark dates back to 1974 when Denmark had its first Environmental Law. The purpose of the law was "to contribute to the protection of nature and environment, so that development of society is sustainable and in respect of conditions of life for people, plants and animals".

Core issues in the law are the reduction of environmental impact from industry by promoting development and marketing of cleaner products and the implementation of Best Available Technology (BAT).

Denmark is an open society, and information is freely available. This is unlike south Durban in South Africa, where industry frequently denies access to information due to its "sensitive" nature using the National Keypoints Act in its defence.

[25] SDCEA/DN has also written a booklet on permitting. See this booklet for further information. Extracts from this booklet are found above.

Engen Refinery flaring incident, 7th October 2004
Source: SDCEA

The issuing of permits in south Durban takes place largely through the eThekwini Municipality. It has done this since 1979, when the Municipality passed the Scheduled Trade and Occupational By-Laws. These are a set of regulations, which attempted to permit and regulate industry. Most municipalities in South Africa have local by-laws, which dictate certain conditions, and they have to be in line with National and Provincial Regulations.

Environmental noise is governed by regulations promulgated in terms of the Environment Conservation Act. These regulations recommend the adoption of the 7DbA rule, which in effect means that noise levels from the flares should not be more than 7 decibels above the ambient noise levels.

As mentioned in a previous section, the Multi-Point Plan of the eThekwini Municipality has set objectives to improve the air quality in the Durban South Basin. The trade permit is being used as one of many mechanisms to fulfil these objectives. The specific references to flaring in the new refinery trade permits issued by the local authority has made a significant shift to best practise with visionary approach to the reduction in the quantity of waste gas flared. Some of the key components of the new trade permit relating to Flaring (see appendix one for details) are:

- Specific definitions as what constitutes a reportable flaring incident.
- Specific reduction targets with time frames.
- Installation of continuous emission monitoring systems.
- Quarterly reporting to local authority of flaring incidents with root causes and remedial action.

However, provisions for the control of noise and light emissions from flares should also be included in the permits that will be issued to industry in terms of the new air pollution legislation.

The success of the new trade permitting process will depend on compliance and enforcement.

7 Comparison of refinery flaring practices

One of the objectives of this study has been to compare flaring data and attitudes towards flaring from the four refineries. To meet this objective, a comprehensive questionnaire was developed and forwarded to the refineries for responses. Here, attempts are made to provide a summary and comment on the four refineries practices. Due consideration must be given to the following factors when comparisons are being made:

- The production capacity of the refinery
- The type of feedstock handled by the refinery
- The complexity of the process of each refinery, and
- The difference in processing operations of each refinery

The crude oil processed by the four refineries differ in density and sulphur content, with the South African refineries processing the heavier crude with a higher sulphur content. Whilst most of the separation and conversion operations are similar in nature in the four refineries, the South African refineries also have catalytic cracking and alkylation as key processes in their refining operations. A detailed comparison on the crudes processed and process operations of the four refineries can be found in the previous DN/SDCEA publication: A 2002 Snapshot: *Comparison of Refineries in Denmark and south Durban.*

The following comparison below is based on these data. In addition to the data supplied by the refineries information from the companies' web sites has been used.

7.1 Total emissions from all four refineries 1999 - 2003

Figure 5: Total SO_2 emissions

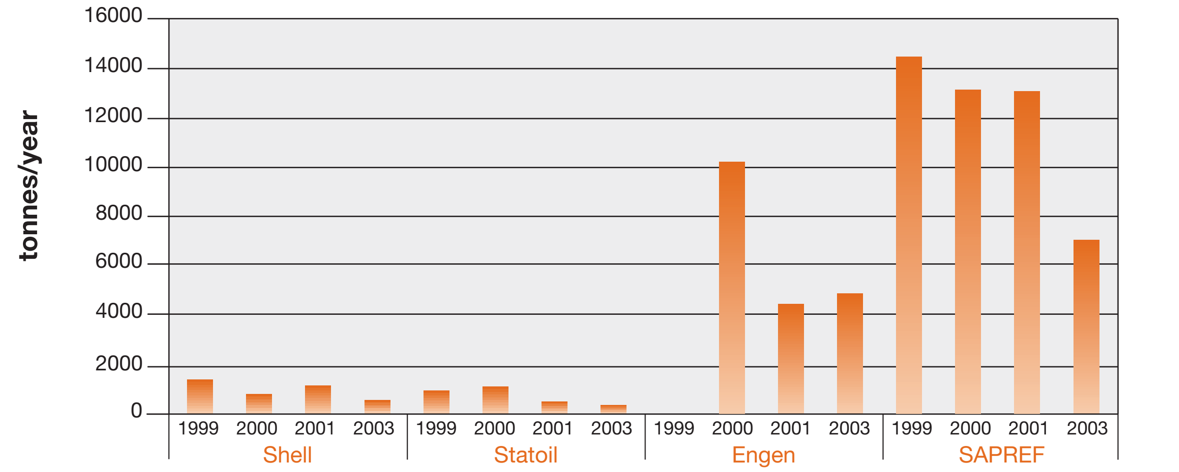


Figure 6: Total NO_x emissions

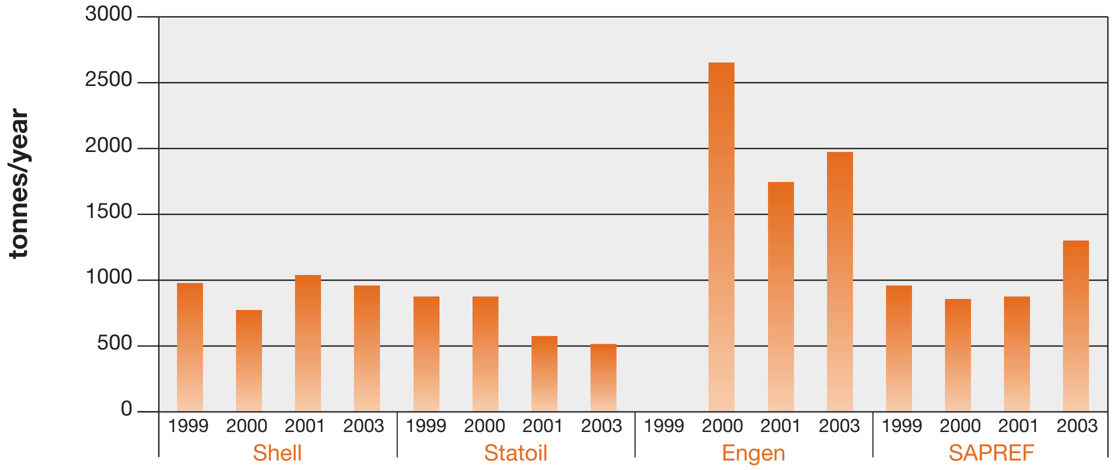
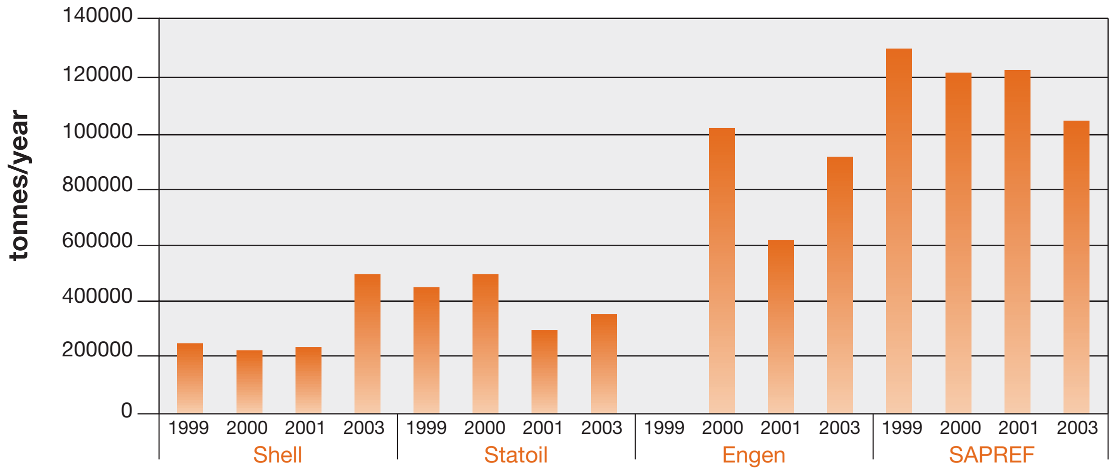


Figure 7: Total CO_2 emissions



The three figures above show some of the emissions from the four refineries. Figures from 1999 to 2001 are from *A 2002 snapshot, Comparison of refineries in Denmark and south Durban in an Environmental and Societal Context.* The figures from 2003 have been reproduced from the Green Accounts from Shell and Statoil in Denmark, from the Engen Sustainability Report 2004 and from information on the SAPREF web site. For quality assurance the figures from the *Snapshot* report has been checked with public information on the companies' websites.

Here, brief comparisons of flaring practices of the four refineries are made. The synopsis presented is derived from the detailed answers received from the two Danish and two south Durban refineries. The questions we have asked have been both technical in regard to the actual flaring system but also in regard to the view on flaring and the use of it. The compiled answers can be seen at the SDCEA offices.

This comparison focuses on the use of best available technology and practices.

7.2 Flaring to Production Ratio

From the flaring to production ratio, there is a great variation in flaring practices in Denmark. Statoil flares at approximately twice the rate of Shell (DK) per ton of crude processed. The South African refinery, SAPREF (Shell & BP), have a higher flaring to production ratio than Shell (DK). This indicates that this SA refinery flares more than their Danish counterparts per ton of crude processed. There appears to be consistency in flaring practices in the two South African refineries which have approximately the same flaring to production ratio. The difference in flaring ratios could be attributed to a number of factors – which include: the type of crude processed, different processing operations, more operability problems (upsets) etc.

Table 3: Emission and production data for the four refineries

Shell, DK	Shell, DK	Statoil	Engen	SAPREF
Production (million tonnes) per annum	3,4	4,7	5,1	8.5
Total gas Flared (tonnes/day)	6	16,6	11.95	19.4
Flaring to Production ratio[1]	0,644	1,29	0,835	0,833

[1]Kilograms of gas flared/tonnes of crude processed per day

7.3 Type of flare:

All four refineries use steam-assisted flares. This is a technology with single burner tips that burns the vented gas in a diffusion flame. This type of flare is the predominant flare type found in refineries. To secure adequate air supply and good mixing, this type of flare injects steam into the combustion zone.

7.4 Flare Gas analysis and combustion efficiency:

All four refineries have constant visual monitoring of the flares in the control rooms and the normal production monitoring will be pilot temperature or infra red flame detectors to determine if pilots are still burning, flow of gas and flow of steam. The amount of carbon in the flare gas would be an interesting parameter to examine because it can give some idea about the destruction done at the burners. All four refineries do not measure actual combustion efficiency, but calculate the amount of carbon emitted by assuming a high combustion efficiency. The reason given for this is that the flare gas composition leaving the flare after burning cannot be routinely measured. These concentrations can only be estimated from knowledge of the waste gas composition and combustion efficiency. This is the commonly used approach by most refineries in the world. The actual efficiency in the destruction of hydrogen sulphide within a flare system is also not determined by any of the refineries.

According to a US EPA paper on flaring the waste gas must have a heat of combustion of at least 11 MJ/scm for complete combustion otherwise additional fuel must be added to the flare to obtain complete combustion.

Shell uses auxiliary fuel gas in their flares, including in the HSR flare. SAPREF uses auxillary fuelgas in their H_2S flare to prevent air ingress. Statoil and Engen inform us in their questionnaire that they do not add auxiliary fuel to the flare. However Engen has a project in progress to investigate the use of Methane Rich Gas (MRG) in a pilot flare.

7.5 Knock-out and Flashback systems:

A properly designed flare system includes at least two special purpose vessels as safety devices. Each has a specific function; the liquid seal protects the flare header from air infiltration and the knock-out drum collects liquids before they enter the flare system.

All refineries have a knock out drum and liquid seal vessel connected to each flare system. These are being maintained on a 4 to 5 year cycle at SAPREF; Engen has not given any interval for the maintenance cycle, but state that they are being maintained according to operational procedures.

7.6 Vapour recovery systems:

A BAT solution at refineries is the installation of a vapour recovery systems at the flare. Engen and Statoil do not have vapour recovery systems. This could explain why Statoil has a higher flaring to production ratio. SAPREF has installed a flare gas recovery compressor that recovers gas from a point between the liquid knock out vessels and the water seal vessels on the HCR system (connected to all four flares). This compressor has a nominal capacity of 50 tonnes per day.

Shell has a flare gas recovery system. The recovered gases are burned in the furnaces as refinery fuel gas.

7.7 Waste gas analysis:

Shell, Statoil and Engen notes that the flare components are hydrocarbons and acid gas, they give no indication whether they measure the composition or concentration of compounds.

Engen points out that a project is in progress to investigate the installation of a flare composition sampling system to enable determination of components in flare gas.

SAPREF take samples from the gas stream to the flare system three times a week for analysis using a gas chromatograph. When combining the analysis results with the continuous monitoring of the gas stream the emissions can be calculated with respect to accepted emissions factors or combustion efficiency.

Ambient air Quality Monitoring is being done within the APP in south Durban.

7.8 Flare improvements with expansions:

All four refineries have made improvements of their flare systems in the past five years. When increases of the refineries capacity or expansion projects are carried through there is also a procedure for increasing the flare capacity. SAPREF notes, "When new processing units are built, or existing units are modified, there is a systematic procedure which is followed to determine that the flare infrastructure (from gas source right up to flare tip) has sufficient capacity for the maximum discharge that may occur such as various upsets (e.g. power failure, partial power failure, fire conditions).

At Shell IR (infra red) monitors have been installed on the pilot burners and automation of fuel gas flow to hydrogen sulphide- flare (possibility for manual operation) has been implemented over the last five years.

At Engen both flares, steam flow control has been automated (ratio control with flare load) this was done to ensure that sufficient air is available for combustion.

Sapref notes that several improvements have been made in terms of the reliability aspects of their flares e.g. flare pilot flames have been upgraded to make them more robust under severe weather conditions. Each flare pilot flame now has a temperature sensor fitted. If a pilot flame goes out, an alarm is received in the control room and it is to be relit. The pilot flame igniter system has been made more robust; each flare has its own igniter system that can be used to ignite any of the flare pilots on the main flare structure. The installation of Panametric flow meters on all flared gas streams have improved the accuracy and reliability of measurement of flared gas.

7.9 Reasons for abnormal flaring

SAPREF defines abnormal flaring "as situations that are induced by external influences e.g. power failures."[26]

Both refineries in south Durban inform us that the most frequent reason for abnormal flaring is external power failure. SAPREF adds that unplanned operating conditions and scheduled shutdowns and start-ups for planned maintenance activities also can cause excessive flaring. It is worth noting that Statoil in their answers also gives start up and shut downs as the cases where most flaring occurs. Furthermore Statoil informs that they have written procedures to avoid flaring in these cases.

If a general power failure takes place it will result in the overpressure of equipment. There will be a loss of cooling due to the fact that electrically powered cooling fans or cooling water circulation pumps stops operating. As a result the pressure in the process units increase and the gas has to be released to flare to protect the equipment and prevent incidents that may lead to fire and explosion. Power failure may also result in the loss of the steam flow to the flares with a resultant partial combustion of gases, leading to a smoky flare.

SAPREF have upgraded their flare pilots to make them less prone to high winds and temperature sensors have been installed to provide an alarm in the control room in the event that a pilot is extinguished. Flare stacks are also equipped with additional pilots to provide flaring security.

7.10 Flaring database

Knowledge about the registration of incidents at the refineries is important information for a neighbour to a refinery. For uncontrolled flaring incidents the Danish refineries do not register these incidents, and are not required in their permits to do so.

Engen notes that in 2002 and 2003, 67 and 109 flaring incidents occurred.[27]

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[26] From SAPREF questionnaire
[27] From the Engen questionnaire

The number of incidents registered by Engen is defined by their definition of normal and abnormal flaring. "As flaring is part of normal operation when it is either within the guidelines given below and/or the flare is smokeless. Flaring is unacceptable when flaring is such that the flow rate of flare gas to the flare exceeds 72 ton/day for the south flare and 58 ton/day for the north flare continuously for a period greater than 15 minutes".

SAPREF notes that "Abnormal" flaring is defined as situations that are induced by external influences (e.g. power failure). All other situations whether resulting in flaring or not, are considered to be "normal" operation. As a consequence, SAPREF answers that 0 (zero) incidents took place in the two years. In 2003, one flaring incident was reported due to power failure.

7.11 Alternatives to flaring:

As SAPREF is aware that the community does not like flaring and as it impacts SAPREF economically, SAPREF's aim is to avoid all flaring irrespective of its cause. However, flaring is an essential safety feature of a refinery and there will be unforeseen events that necessitate the reduction of pressure in the refinery process. The only feasible alternative in many cases would be to vent gas directly to atmosphere without combustion, which would be far less desirable than flaring. Process upsets (equipment failure) can result in flaring, which is then carried out in order to safeguard the integrity of the facility and protect human life. Reducing process upsets is a major focus within the refinery and this is expected to result in future decreases in flaring events".

Statoil answers that they try, as much as possible, to avoid flaring. They have procedures that shall avoid flaring both under normal conditions and under shut downs / start up which are the cases where most flaring occurs. Flaring is a safety aspect and is acceptable as such.

For Engen, acceptable flaring is that which provides for process equipment to immediately release gases to flare for quick and safe incineration. This prevents damage and fires.

SAPREF finds that the only reason for flaring is to protect people and plant, and it therefore has to be considered as acceptable.

SDCEA would encourage refineries to install flare gas recovery systems to use the gases first, as Shell has done at Fredericia (Denmark) and SAPREF (south Durban), and other Shell refineries around the world (e.g. Deer Park, TX in the United States of America).

7.12 Logging and recording of flaring incidents:

Shell in Fredericia do not keep records of flaring incidents, the refinery does keep a record of complaints, which includes those caused by flaring. Flaring caused by units/plant upsets during office hours will be reported by phone or e-mail to the local authority so that they the authorities are in a position to answer any question from the public.

The environmental permits for Statoil states that the refinery has to report on flaring from the large flare (no. 1). All incidents in where more than 2.5 tons steam/hour are used has to be recorded and incidents in which than 3 tons steam/hour is used, have to be explained.

The requirement is set to control noise problems – if Statoil gets complaints about their flare it due to the noise.

Engen record all flaring incidents that fall in the categories of unacceptable flare according to the definition given above. There records are matched to the complaints from the community.

SAPREF states that: "if an odour complaint is received, an investigation is carried out to determine if the source of the complaint can be related to an upset at SAPREF or whether it is due to other reason. The investigation is carried out as per the work instruction for Environmental Complaints Management.

Significant flaring (e.g. April 21 2004 incident caused by total loss of power at SAPREF) is recorded and reported to the authorities. The investigation includes reviewing the results from continuous monitors set up by the authorities to determine if there is any perceptible change in ambient air quality.

7.13 Reaction to Flaring:

When a flaring incident has happened corrective actions are carried out at all four refineries to determine the reason and to take actions to prevent the same incident from happening again. The cause of the flaring event is determined by the "root cause analysis" procedure and recommendations to prevent the reoccurrence of the incident are implemented.

7.14 Training and education:

All four refineries provide a range of training courses for all plant personnel.

7.15 Future plans:

We have asked the refineries whether they have any plans to improve their flare systems in the near future. Shell in Fredericia has no plans. They explain that at present the refinery meets or exceeds the requirements of legislation and our environmental permit and therefore have no plans for further improvements of the flare system.

Engen plans on implementing a flare gas composition sampling system and a Flare gas and fuel gas analyser.

At SAPREF the expenditure over the last few years has been focused on improving the reliability of the flare system. The equipment at present meets the current plant needs in terms of capacity and is considered "best in class". Hence no further expenditure is planned for the immediate future.

Summary of responses on key issues –Table 5

Category	Shell	Statoil	Engen	SAPREF
Steam assisted flaring	Yes	Yes	Yes	Yes
Measurement of combustion efficiency	No	No	No	No
Vapour Recovery Sysem	Yes	No	No	Yes
Knockout and flashback system	Yes	Yes	Yes	Yes
Recording of Flaring incidents *(each refinery view this defnition differently)	No	No	Yes (109 incidents for 2003)	Yes (none have been recorded for past 2 years (2002 & 2003)
Training of operators	Yes	Yes	Yes	Yes
Plans for Future improvements	No	No	Yes	No

8 Government's response to flaring

8.1 How is the eThekwini Municipality Addressing Flaring?

The eThekwini Municipality has recognised flaring as a problematic issue in south Durban. The following are some of the more recent measures implemented to address flaring:

- Flaring activities of industry are now permitted (see Section 6). The flaring component of the permit was developed in close collaboration with experts from the US EPA. The primary intention of the permit is to achieve US based flaring standards over a five-year period.
- Environmental cameras have been installed at Wentworth Reservoir that focuses on the refinery flares. The cameras provide real-time images of flaring activities. These are broadcasted to the eThekwini Health Department.
- A new complaints management system has been developed to improve the general response of officials to complaints. Together with the cameras, this is certain to improve the response to flaring complaints.

8.2 How is National Government handling the flaring?

The National Government is currently drawing up permitting guidelines, and it is assumed that flaring will be covered under these. To some degree this is covered in the newly promulgated Air Quality Management Act, 2004 which regulates air quality.

8.3 How do community Organisations handle flaring?

Currently, community organisations encourage members of the community to report flaring when they see it, especially if it seems "excessive". SDCEA encourages affected residents to also log their complaints with the local municipality, in order for the authorities follow-up on it. All flaring complaints are registered on the SDCEA GIS system with the log number that has just been described. This increases the credibility of SDCEA's on-going research. SDCEA also follows up on complaints with the respective refinery or authority. If necessary, incidents are followed up with further research or a press release to local media.

Community groupings as a whole need to learn more about flaring in order to apply pressure on Industry and government to utilise best available technology.

Another way that SDCEA and the community handle flaring is by taking bucket samples. The air sample is then analysed. Many components have been identified through this method.

9 Recommendations and conclusion

In this booklet we have looked at a number of aspects of flaring. Firstly, answers to the community's most frequently asked questions were provided. We have examined a definition of flaring, and looked at flaring in the global context. We have looked at the issue as it relates to Denmark and south Durban. Impacts of flaring on local (i.e. south Durban) air quality have been examined and how flaring is used in the oil refinery context. The technology of flaring has been examined, as well as the Best Available Technology and practice. Permitting of flaring was briefly looked at, and the permitting conditions relating to flaring from Engen's permit can be found in appendix one.

The definitions and conditions in the Trade Permits issued leave room for different interpretations. This may reduce the intended motivation for reduced flaring. The ambiguities in the permits need to be reviewed to ensure compliance and enforcement. *(See appendix one)*.

The refineries were then examined and compared. Whilst the four refineries' flare systems have the components of the best available technology and practices, the data collected can make no inferences as to whether the refineries have been operated optimally.

We also looked at how the eThekwini Municipality, National Government and local organisations handle flaring complaints.

It is clearly evident from the responses that clear and concise guidelines by local and national authorities are required to define what constitutes routine, upset, and emergency flaring.

SDCEA would like to define acceptable flaring which is a flare that is non-smoky, with an acceptable flow rate[29] , and with a noise level falling into the acceptable decibel zone i.e. 7 db higher than the surrounding noise levels.

Recommendations of possible action to reduce flaring and venting include:

1. Local, provincial and national authorities could improve on the way they collect data on the refining industry. This needs to include flare monitoring of volumes and content of flare gas, as well as video monitoring.
2. There needs to be a reform of the gas market, so that excess gas can easily be utilised by other industries, both locally and nationally.[30] The World Bank Report states, "In many developing countries the relatively low financial returns developers can expect from investing in the construction of a gas network have undermined the prospects for a developing gas market. Part of the problem is often subsidies for competing energy sources (oil, coal, nuclear, hydropower), which lead to low prices for competing fuels.[31] This point is extremely pertinent to the South African context.

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[29] These are the flow rates that the municipality wish to aim for through the implementation of the new Schedule Trade Permits:

Flow Rate Duration

>600 kg/h	Continuous period of at least 30 min	>900 kg/h	Continuous period of at least 15 min
>1200 kg/h	Continuous period of at least 10 min		

[30] Pg 2 World Bank Group – Public Policy for the Private Sector Note 279 *Gas Flaring and Venting: A Regulatory Framework and Incentives for Gas Utilization* (Authors: Franz Gerner, Bent Svensson and Sasha Djumena

[31] Ibid Pg 4

3. A possible solution to the noise, continuous flaring and light problems relating to flaring would be to reduce the need for flaring through more efficient operating procedures and Best Available Technology (BAT) at the refineries. Flare gas recovery systems need to be of a sufficient size to handle most upsets.

4. As many flaring incidents are alleged to be caused by power failures, refineries and power suppliers need to look at alternative power sources and back up systems for when there is a power failure that causes the supply to the refineries to be interrupted. Root cause analysis of each flare incident will identify prevention measures.

5. Enforcement of any permitting system is crucial to achieve the reduction in flaring, and to ensure that industry becomes more accountable.

6. In Alberta, if the refinery operators do not solve a flaring problem, the public can submit a written objection to the EUB (Energy and Utilities Board). The board will consider the application for a permit and the objection. Ideally, we want a similar situation here, where residents are acknowledged as being crucial in terms of public participation, and are valued for bringing potential problems to the fore. In California, flare monitoring and control rules are being developed where citizens can sue companies that have repeat and smoking flares. Legislation like this would be appropriate in south Durban (and South Africa).

7. In South Africa, as well as in south Durban, people who are specialists in the refining field, other than the refinery operators are needed. Skilled personnel are needed in local, provincial and national departments, as well as in community organisations.

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Source: groundWork

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Source: SDCEA Member

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Appendix One

Appendix 2 Engen's permitting conditions as they relate to flaring

4.4 Flaring

4.4.1 General

4.4.1.1 The permit holder must operate, manage and maintain all plant equipment and processes in such a manner that flaring incidents are kept to a minimum and ensure that flares are used only for emergencies and not as a pollution control device.

4.4.1.2 The permit holder is prohibited from undertaking flaring for economic reasons. Economic reasons will include the routine and/or non routine routing of gas to the flare system to create capacity to maintain and/or increase production rates.

4.4.1.3 A reportable flaring incident is defined as an event where gas is releasthe followrates aning flow rates and durations.

North

Flow Rate	Duration
>500 kg/h	Continuous period of at least 30 min
>700 kg/h	Continuous period of at least 15 min
>1000 kg/h	Continuous period of at least 10 min

South

Flow Rate	Duration
>10000 kg/h	Continuous period of at least 30 min
>1300 kg/h	Continuous period of at least 15 min
>1500 kg/h	Continuous period of at least 10 min

The permit holder is required to achieve the above levels with the time frame specified in the table below.

			Reduction Time Frames				
Flare Location	Current Flow Rate	Duration	2005 20% kg/h	2006 15% kg/h	2007 10% kg/h	2008 10% kg/h	2009 10% kg/h
North Flare	>1000 kg/h	Continuous period – 30 minutes	800	680	612	550	500
South Flare	>2000 kg/h	Continuous period – 30 minutes	1600	1360	1225	1100	1000
North Flare	>1400 kg/h	Continuous flare for 15 minutes	1120	950	855	770	700
South Flare	>2500 kg/h	Continuous flare for 15 minutes	2000	1700	1530	1370	1300
North Flare	>2000 kg/h	Continuous flare for 10 minutes	1600	1360	1225	1100	1000
South Flare	>3000 kg/h	Continuous flare for 10 minutes	2400	2040	1835	1650	1500

4.4.1.4 For all gas streams routinely sent to flares the concentration of hydrogen sulphide must be maintained below 160 ppm. The concentrations are to be measured with a continuous emission monitoring system (CEMS) by December 2005.

The permit holder is required to detail all calibration and other activities taken to ensure that flow meters and CEMS are functioning normally.

4.4.1.5 The permit holder shall take, as expeditiously as practicable, such interim and/or long-term corrective actions, if any, as are consistent with good engineering practices to minimise the likelihood of the root cause and all contributing causes of a flaring incident.

4.4.1.6 The flare monitoring systems shall be maintained in good operating condition at all times when the flare is operational, except when out of service due to:

- Breakdown or unplanned system maintenance which shall not exceed 110 hours, cumulatively per quarter for each annual reporting period; or

- Planned maintenance which shall not exceed 10 days per annum provided that a written notification detailing the reason for maintenance and methods to be used during the maintenance period to determine emissions associated with recordable flare events is provided to eThekwini Health Department?? at least 48 hours prior to the removal of the continuous monitoring systems from service.

4.4.1.7 The permit holder is required to submit to the permitting authority by June 2005 the following:

(a) A facility plot plan showing the location of each flare in relation to the general plant layout.

(b) Detailed information regarding type of flare, design capacity, operation and maintenance to each flare including issues such as turndown ratio of flare, combustion efficiencies at different throughputs (combustion efficiency curve), performance testing, etc.

(c) Drawings, preferably to scale with dimensions and an as-built process flow diagram of the flares identifying major components such as flare heads, flare stack, flare tips/burners, purge gas systems, pilot gas system, ignition systems, assist system, water seal, knockout drum and molecular seal.

(d) A representative flow diagram showing the interconnections of the flare gas systems process units, vapour recovery systems if any and other equipment as applicable.

(e) A complete description of the assist systems, process control, flare detection and pilot ignition systems.

(f) Drawings with dimensions, preferably to scale showing the following information for flare gas:

  - Sampling location;
  - Flow meter device and/or on/off flow indicators locations and the method used to determine the location.

(g) A complete description of proposed analytical and sampling methods or estimation methods, if applicable, for determining total sulphur content of the flare gas.

(h) A complete description of the methods used to determine, monitor and record total volume of gases sent to a flare for each flaring incident.

(i) A detailed description of the methods used to calculate criteria pollutant emissions from the flares.

(j) The following information regarding pilot and purge gas for each flare:

  - Types of gas used;
  - Actual set operating flow rates;
  - Maximum total sulphur content for each type of gas used;
  - Average higher (gross) heating value expected to each type of gas used.

(k) complete description of the methods used to alert personnel designated to collect samples once a recordable flare event has started.

(l) A complete description of the method used to determine emissions associated with reportable incidents during periods when the flare monitoring system is out of service.

4.4.1.8 The permit holder is required by December 2005, to perform a comparison between its existing flaring system and BAT.

4.4.2 Flare Reporting Requirements

4.4.2.1 The permit holder must within 24 hours of the start of a reportable flaring incident (acid gas or hydrocarbon) submit a **preliminary incident report** to the Head: Health that includes the following:

(a) The date and time the flaring incident started and ended,

(b) A preliminary estimation of the quantity of SO_2, hydrocarbons etc. that were emitted,

(c) Actions/steps, if any, undertaken by the permit holder to limit the duration and/or quantity of SO2, hydrocarbons, etc. emissions associated with the flaring incident.

4.4.2.2 The permit holder must, within 14 days of a reportable flaring incident (acid gas or hydrocarbon) occurring, submit to the Head: Health a detailed report that includes the following:

(a) The date and time the flaring incident started and ended;

(b) Estimation of the quantity of SO_2, hydrocarbons, etc. that were emitted and the calculations that were used to determine the quantity.

(c) Actions/steps if any undertaken by the permit holder to limit the duration and/or quantity of SO_2, hydrocarbons, etc. emissions associated with the flaring incident;

(d) A detailed root cause analysis that identifies the contributing causes of the flaring incident to the extent determinable.

(e) An analysis of the measures that are available to reduce the likelihood of a recurrence of the flaring incident resulting from the root cause analysis or other contributing causes in the future. The analysis must discuss alternatives if any, that are available, the probable effectiveness and cost of the alternatives and whether or not an independent consultant should be retained to assist in the analysis. Possible design, operations and maintenance changes shall be evaluated. If corrective actions are required the report shall include a description of the actions and a schedule for its implementation including time frames. If the permit holder concludes that corrective action is not required, the report shall explain the basis for that conclusion.

4.4.2.4 For all planned flaring, the permit holder is required to submit an application for approval to the permitting authority, which contains inter alia:

(a) The time and date of the planned flaring event;

(b) The expected duration of the event;

(c) Gas composition, mass and flow rate;

(e) Total emissions associated with the flaring event on a pollutant specific basis;

(e) Estimates of ground level concentrations of pollutants associated with the flaring event and any possible health or nuisance related consequences.

The permitting authority in assessing such applications will consider issues such as reasons for flaring, potential health related impacts, meteorological conditions, etc.

In all instances the permit holder must prove to the permitting authority that all reasonable and practical measures will be taken to minimise flaring.

For all flaring due to turnaround activities, maintenance and other non-routine procedures, the permit holder shall report all measures that were taken to minimise emissions to the atmosphere such as: sulphur shedding, process unit shutdowns and turn down actions.

4.4.2.5 The permit holder shall submit a quarterly report to the Head: Health on or before 30 days after the end of each quarter. Each quarterly report should include:

(a) The daily, hourly and quarterly emissions of criteria pollutants from each flare with all information used to calculate each flare's emissions such as volumes, heating values, sulphur content, etc. of the representative samples of vent gases.

(b) Flare monitoring system downtime periods, including dates and times and explanation for each period.

Glossary

Air Pollution – Degradation of air quality resulting from unwanted chemicals or other materials occurring in the air.

Aromatics – Hydrocarbons characterized by unsaturated ring structures of carbon atoms. Commercial petroleum aromatics are benzene, toluene, and xylene (BTX).

Benzene, Toluene, Ethylbenzene, Xylene (BTEX) – Benzene, Toluene, Ethylbenzene, Xylenes (BTEX), and substituted benzene are the most common aromatic compounds in petroleum, making up to a few percent of the total mass of some crude oils. BTEX are also hazardous, carcinogenic, and neuro-toxic compounds subject to hazardous materials regulations.

Best Available Technology (BAT) – BAT is a term used to describe up-to-date methods, systems, techniques, and processes applied to new and modified sources of air pollution in order to achieve the most feasible pollution emission control. BAT is the more stringent of:

(a) The most effective control device, emission unit, or technique that has been achieved in practice for the type of equipment comprising the stationary source; or

(b) The most stringent limitation contained in any State Implementation Plan; or

(c) Any other emission control device or technique determined after public hearing to be technologically feasible and cost effective

For sources permitted, BAT is an emission limitation based on the maximum degree of reduction for each pollutant that would be emitted from any new or modified stationary source, which on a case-by-case basis, taking into account energy, environment, and economic impacts and other costs, is achievable for such a source or modification through application of production processes or available methods, systems, and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of such a pollutant.

Bypass – A pipe connection around a valve or other control mechanism that is installed to permit passage of fluid through the line while adjustments or repairs are being made on the control.

Capacity (production) – The maximum amount of product that can be produced from processing facilities.

Condensate – A natural gas liquid with a low vapour pressure, compared with natural gasoline and liquefied petroleum gas. It is produced from a deep well where the temperature and pressure are high. Gas condenses as it rises up the well bore and reaches the surface as condensate. Similarly, condensate separates out naturally in pipelines or in a separation plant by the normal process of condensation.

Control Measure – A strategy to reduce the emissions of air pollution caused by a specific activity or related group of activities. An existing control measure is a measure, which is currently being implemented as a rule.

Crude Oil – An unrefined liquid petroleum consisting of a mixture of hydrocarbons. It ranges in gravity from 9 degrees API to 55 degrees API and in colour from yellow to black. Crude oils may be referred to as heavy or light, according to API gravity, with lighter weight oil exhibiting the higher gravity. Viscosity varies with gravity; crude oils with lower gravity are more viscous and oils with higher gravity are less viscous.

Crude Oil (Sour) – Oil containing Hydrogen Sulphide or other acidic gases.

Crude Oil Qualities – Refers to two properties of crude oil, the sulphur content and API gravity, which affect refinery processing complexity and product characteristics.

Distillation – The process of driving off gas or vapour from liquids or solids usually by heating, and condensing the vapour back to liquid to purify, fractionate, or form new products.

Downstream – Refers to facilities or operations performed after those at the point of reference. For example, refining is downstream from fossil fuel extraction; marketing is downstream from refining.

Emission Standard – The maximum amount of a pollutant that is allowed to be discharged from a polluting source such as an automobile or smoke stack.

Feedstock – Crude oil (wet or dry) or natural gas input to a processing facility.

Flammable – Term describing material that can be easily ignited. Petroleum products with a flash point of 80ºF (or 27oC) or lower are classed as flammable.

Flaring – A process to dispose of surplus combustible vapours by igniting and burning them in the atmosphere.

Gas – Any fluid, either combustible or non-combustible, that has neither independent shape nor volume and tends to expand indefinitely if unconfined. Gas is any substance that exists in a gaseous state at the surface under normal conditions. Gas includes methane (CH_4), carbon monoxide, other gaseous hydrocarbons, and nitrogen.

Gas (Acid) – A gas that forms an acid when mixed with water. In petrol production and processing, the most common acid gases are hydrogen sulphide and carbon dioxide. They both cause corrosion, and hydrogen sulphide is very poisonous.

Gas (Inert) – Any one of six gases that, under normal conditions, are not inclined to react with any of the other elements or compounds. The inert or inactive gases are Helium, Neon, Argon, Krypton, Xenon, and Radon.

Gas (Liquefied Petroleum) (LPG) – A gaseous by-product of petroleum refining that is compressed to a liquefied form for sales. LPG consists of ethane, ethylene, propane, propylene, normal butane, butylene, isobutane, and isobutylene produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas plant liquids

Gas (Natural) – Natural Gas is a mixture of hydrocarbons and small quantities of various non-hydrocarbons existing in the gaseous phase or in solution with crude oil in underground reservoirs. A compressible and expansible mixture of hydrocarbons having a low specific gravity and occurring natural in a gaseous form. Natural gas ordinarily consists principally of methane and heavier entrained hydrocarbons, and may contain appreciable quantities of Nitrogen, Helium, carbon dioxide, and contaminants such as Hydrogen Sulphide and water vapour.

Gas (Sour) – Gas containing more than trace amounts of toxic compounds, including hydrogen sulphide and other chemicals.

Gas (Sweet) – Natural gas that does not contain hydrogen sulphide (H_2S), or only contains trace amounts of H_2S.

Gas (Wet) – Natural gas prior to the removal of water.

Header – a large-diameter pipe, into which a number of smaller pipes are perpendicularly attached, either welded or screwed; a collection point for oil or gas gathering lines.

Hydrocarbons – Compounds consisting of molecules of hydrogen and carbon. Hydrocarbons exist in a variety of compounds because of the strong affinity of the carbon atom for other atoms and for itself. The smallest molecules of hydrocarbons are gaseous while the largest are solids. Both oil and unprocessed "wet" natural gas are mixtures of many hydrocarbons.

Hydrogen – The lightest of all gases, occurring chiefly in combination with oxygen in water; exists also in acids, bases, alcohols, petroleum, and other hydrocarbons.

Hydrogen Sulphide (H_2S) – is a colourless, acidic gas, H_2S may be present in crude oil and natural gas produced from oil and gas wells. Inhalation of large doses can cause immediate death. Inhalation of smaller doses can cause injury or death.

Lower Flammability Limit (LFL) – The minimum concentration of a vapour or gas in air that will ignite and propagate flame. Also expressed as lower explosive limit (LEL).

Mercaptans – Organic compounds containing sulphur, present in certain refined products that impart objectionable odour to the product.

Naphtha – A volatile, colourless liquid blend obtained from petroleum distillation used as a solvent in the manufacture of paint, as a dry-cleaning fluid, and for blending with casing head gasoline in producing motor gasoline.

Nitrogen Oxides (Oxides of Nitrogen, NO_x) – A general term pertaining to compounds of nitric acid (NO), nitrogen dioxide (NO_2), and other oxides of nitrogen. Nitrogen oxides are typically created during combustion processes, and are major contributors to smog formation and acid deposition. NO_2 is a criteria air pollutant, and may result in numerous adverse health effects; it absorbs blue light, resulting in a brownish-red cast to the atmosphere and reduced visibility.

Ozone – A strong smelling, pale blue, reactive toxic chemical gas consisting of three oxygen atoms. It is a product of the photochemical process involving the sun's energy. Ozone exists in the upper atmosphere ozone layer as well as at the earth's surface. Ozone at the earth's surface causes numerous adverse health effects caused and is a criteria air pollutant. It is a major component of smog.

Particulate Matter (PM) – Any material, except pure water, that exists in the solid or liquid state in the atmosphere, such as soot, dust, smoke, fumes, and aerosols. The size of particulate matter can vary from coarse, wind-blown dust particles to fine particle combustion products.

Petrochemical Feedstocks – Chemical feedstocks derived from petroleum principally for the manufacture of chemicals, synthetic rubber, and a variety of plastics.

Petroleum – A naturally occurring complex, liquid hydrocarbon that may contain varying degrees of impurities. Petroleum is obtained from rocks below the surface of the Earth by drilling down into a reservoir rock and piping the minerals to the surface.

Petroleum Products – Petroleum products are obtained from the processing of crude oil (including lease condensate), natural gas, and other hydrocarbon compounds. Petroleum products include unfinished oils, liquefied petroleum gases, pentanes plus, aviation gasoline, motor gasoline, naphtha-type jet fuel, kerosene-type jet fuel, kerosene, distillate fuel oil, residual fuel oil, petrochemical feedstocks, special naphthas, lubricants, waxes, petroleum coke, asphalt, road oil, still gas, and miscellaneous products.

Refinery – A modern refinery is a large plant of many diverse processes. A refinery receives its charge stock, or crude oil, from the field via pipeline or from a tanker if the plant is located on a waterway. By processes that include heating, fractionating, pressure, vacuum, re-heating in the presence of catalysts, and washing with acids, the crude is divided into hundreds of components: from exotic light gases to volatile liquids down through gasoline, naphtha, kerosene, gas oils, and light and heavy lubricating oil stocks to heavy bunker fuel, residual oil, and finally petroleum coke, the bottom of the barrel.

Stream – A stream (whether oil, gas, or product) is what is being pumped through a pipeline, moved from one process unit into another.

Sulphur Dioxide (SO_2) – A strong smelling, colourless gas that is formed by the combustion of fossil fuels. Power plants, which may use coal or oil high in sulphur content, can be major sources of SO_2. SO_2 and other sulphur oxides contribute to the problem of acid deposition. SO_2 is a criteria pollutant.

Toluene (C6H5CH3) – Colourless liquid of the aromatic group of petroleum hydrocarbons, made by the catalytic reforming of petroleum naphtha's containing methyl cyclohexane. A high-octane gasoline-blending agent, solvent, and chemical intermediate, base for TNT.

Upstream – Facilities or operations performed before those at the point of reference. Fossil fuel is upstream from pipeline transportation, and transportation is upstream from refining.

Valve – A device used to control the rate of flow in a line, to open or shut a line, or to serve as an automatic or semiautomatic safety device.

Vapour – A substance in the gaseous state, capable of being liquefied by compression or cooling.

Vapour Recovery Systems – Mechanical systems that collect and recover chemical vapours resulting from transfer of gasoline from operations such as tank-to-truck systems at refineries, tanker-to-pipeline systems at offshore oil operations, and pump-to-vehicle systems at gasoline stations.

Volatile Organic Compound (VOC) – This term is generally used similarly to the term "reactive organic compounds" but excludes ethane, which the national government does not consider to be reactive. VOC's are hydrocarbon compounds that exist in the ambient air and contribute to the formation of smog and/or may themselves be toxic. VOC's often have an odour, and some examples include gasoline, alcohol, and the solvents used in paints.

Xylene ($C_6H_4(CH_3)_2$) – Colourless liquid of the aromatic group of hydrocarbons made by the catalytic reforming of certain napthenic petroleum fractions. Used as solvent and chemical intermediates. Isomers are metaxylene, orthoxylene, and paraxylene.

STATOIL Refinery – Kalundborg

SHELL Refinery – Frederica

Notes