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# Flaring from refineries

## Environmental impacts and quality of life

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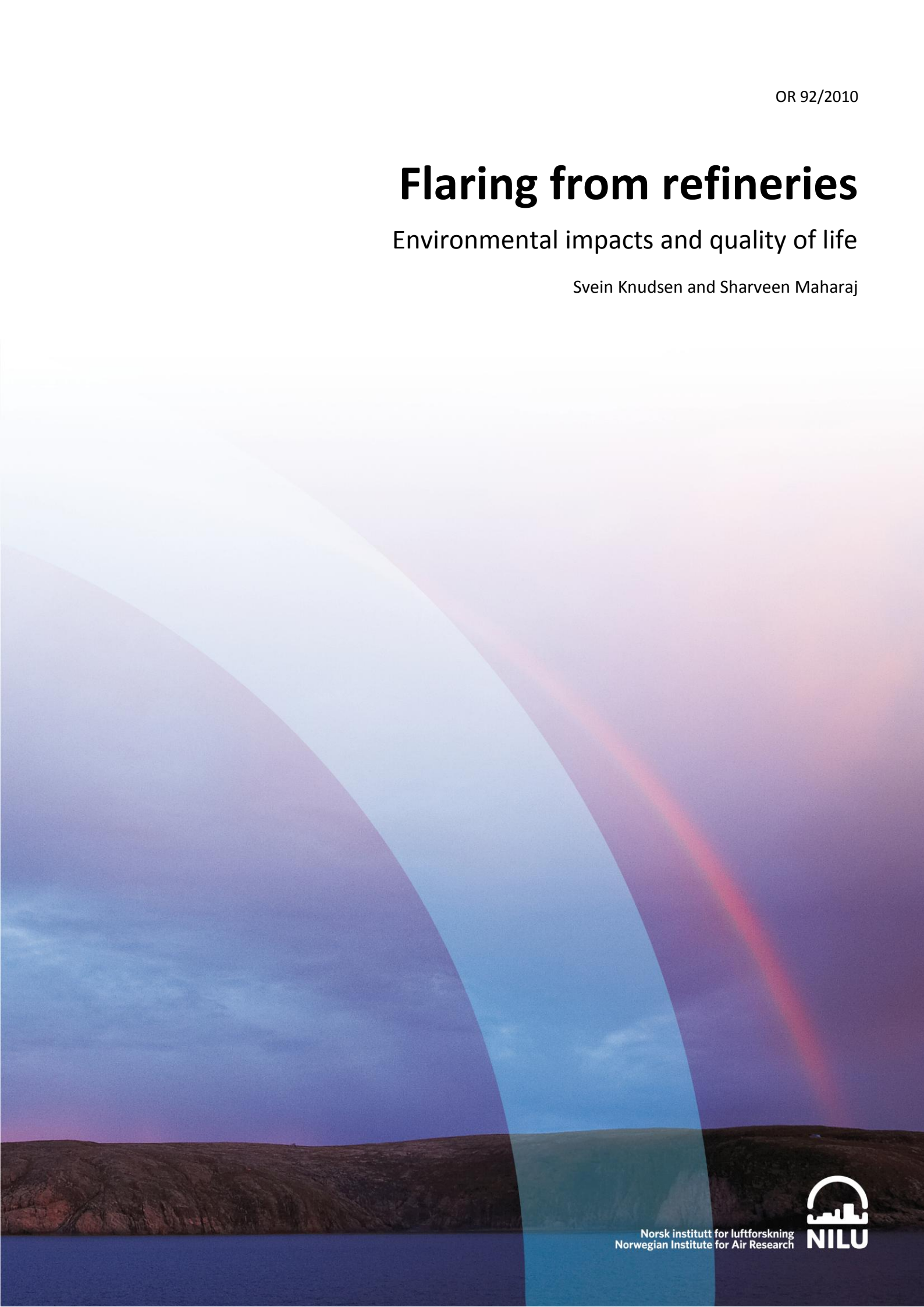

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# Summary and conclusions

***The South Durban Basin in eThekwini has been troubled by poor air quality for a long time. Through the multi point plan and the engagement and support from the stakeholders, the municipality has been able to create an atmosphere of will to improve the air quality in the area and the conditions have become substantially better over the last 10 years.***

***This report is a part of the abatement and implementation strategy from the eThekwini AQMP on air pollution in the municipality. One of the areas identified as in need of attention is flaring from the refineries. This report covers this issue.***

***The report builds on an earlier work by E K Cairncross (2005) "Flaring and other unregulated emissions from the South Durban oil refineries – Engen and Sapref".***

Flaring needs to be looked into holistically. A flare is normally an indication that there are problems in the refinery. An upset in the refinery can be connected to emissions to air from other parts of the refinery. These emissions are not covered by this report.

The feed to the flare will vary substantially both in amount and composition. This means that the flaring device must be designed accordingly. When the composition or quantity is not according to the design of the flare, severe incidents of air quality can occur. To abate this it is necessary to make the mixture and quantity within specifications of the flaring device. For low volumes this can be done by adding hydrocarbons to the substances fed to the flare. For large volumes this is more difficult and the flare must be designed for these volumes.

Normally the flare will generate sufficient heat for the gases to have a substantial plume rise and not impact the local environment. However, it will impact regionally and contribute to GHG emissions. If the quantity fed to the flare is small or the substance fed to the flare is not burning properly the impact to the local environment can be substantial. The impact will be on the non prioritized pollutants and the population will be exposed to odours and other pollutants depending on the substances flared.

This means that to protect human health and wellbeing the flare, when flaring, must be run according to standard operational procedures. This means that the flare is lit and the amounts should be within the lower and upper design criteria.

A document describing the reasons for precious flaring, the substances flared, possible impacts to the environment, as well as a demonstration that the problem is understood should be made available by the emitter. Such a document, with comments from the relevant governmental institutions, should be the base for the emission permit.

The permit should address the relevant problems. If additional problems arise, the report should be updated and the permit revised.

When the problem description is done the permit is rather easy to write. If there are problems, the problems have to be addressed and impacts minimized through abatement and implementation plans with follow up activities. These should be part of the permit. Dates of compliance must be given.

If the refineries are flaring a report should be filed. Reporting should be made mandatory and specified in the permit. The documentation should be more comprehensive if the flaring is outside the design criteria stated in the permit for the flaring device. Every report should contain a video of the flare for evaluation. The reports should contain flow measurements, specification of substances, reason for flaring and time of flaring.

If an incident happens the report should be more comprehensive and include an evaluation of if the incident could be avoided, an investigation into why it happened. The reports of flaring should be followed closely. When handling the permit it is important to communicate the contents to the stakeholders and send it out on a hearing.

The main emission of GHG from flaring is $CO_2$ and hydrocarbons. A report on the emission of greenhouse gasses should be delivered in the end of every year. This should be included in the emission report that the companies have to submit yearly.

# Flaring from refineries
# Environmental impacts and quality of life

## 1 Introduction

The South Durban Basin in eThekwini has been troubled by poor air quality for a long time. Through the multi point plan and the engagement and support from the stakeholders the municipality have been able to create an atmosphere of will to improve the air quality in the area and the conditions have become substantially better over the last 10 years.

This report is a part of the abatement and implementation strategy from the eThekwini AQMP on air pollution in the municipality. One of the areas identified as in need of attention is flaring from the refineries. This report covers this issue.

The report builds on an earlier work by E K Cairncross (2005) "Flaring and other unregulated emissions from the South Durban oil refineries – Engen and Sapref".

Several pollution problems are related to flaring of hydrocarbons. Firstly, a flare from the refineries is an indication that the refinery has a problem with one or several processes in the plant. The flare is a safety precaution for the refinery to prevent damage to the plant. When an upset in the plant occurs, emissions from other sources at the refinery may occur. This report does not cover other emissions from these sources.

Flaring will also have impacts on different geographical scales. This report is mainly confined to dealing with the local air pollution problems. The emissions of GHG will only be covered superficial.

There are several pollutants connected to a flare from the refineries. The substance flared normally contains hydrocarbons that are burnt, and in the burning process these substances are destroyed. The main substances emitted are $SO_2$, $CO_2$, VOC, Soot/PM, $H_2S$ and PAH. This report will focus on $H_2S$ (Odours) and $CO_2$.

### 1.1 Structure of report

The first part of the report focus on understanding the impacts from flaring on the environment and determining which problems flaring cause or contribute to. To do this the theoretical understanding of the actual dispersion and impacts will be described. When possible the theory will be backed by measurement results.

The second part of the report will focus on the occurrence of these impacts and the documentation of the incidents both from the industry and the surrounding community. Industry has through the permit the obligation of filing a report from severe flaring incident. This report will be discussed and recommendations on improvements will be made. In addition to this a complaint register is in operation

at the air quality section at eThekwini health. This will give an indication on the severity of the problem especially the odour problem in the area.

The third part of the report will focus on permitting and licensing. The objective of the permitting and licensing activity is to make sure that the emissions does not create unacceptable effects. The discussion in this part of the report will focus on the content of the permit to avoid adverse effects. It will also focus on how to report the incidents and what is an incident that triggers a report.

### 1.2 Building blocks for control

The control of the air quality in an area like the South Durban Basin can be described through the following building blocks.

- Legislation
- Understanding of problem
- Stakeholder buy in
- Permitting

The **legislation** will give the acceptable levels and should be given on the basis of possible effects in the environment or for human health. The legislation should have safety factors dependent on the uncertainty in the knowledge. If there is no legislation that is directly giving levels, an agreement between the stakeholders should be reached on acceptable levels or effects. This will apply to the odour problem. Odours are difficult because of the individual nature of the problem.

To be able to take actions for abating the problem it is important to **understand** the mechanisms that are causing the problem. When the understanding of the problem is reached this needs to be explained to the stakeholders.

It is important to have **stakeholder buy in**. This is important because the emitter will have restrictions on the emissions, and therefore will have to take action. The NGOs and the population in general will need to understand what is done and to agree that this is the problem. Government will need the understanding to write the permit.

The development of the **permit** should be collaboration between government, industry and the other stakeholders to reach a common understanding of the reasoning behind the permit.

## 2 Impacts of flaring

### 2.1 Impacts from flares

The impacts from flaring are dependent on the design of the flare, the content and amount that is flared. Normally the flare will have a good combustion. This means that the flare combust the gasses to $CO_2$ and water. There will be some hydro carbons left after combustion depending on the efficiency of the flare. In a well performing flare there will be little soot and the majority of $H_2S$ is transformed to $SO_2$.

When the gas is combusted in the flare a lot of heat is generated from the burning of hydrocarbons. This heat will induce buoyancy and the plume will gain altitude in the atmosphere. The height that the gases will reach is dependent on the amount of energy released in the combustion process and the atmospheric conditions such as wind speed, wind direction and atmospheric stability. If a large amount of gas is flared the gases will rise to substantial heights and not impact locally as seen from Figure 1 where the flue gas is rapidly rising to several thousand meters. The flare from the refinery is overloaded and is therefore producing large quantities of particulate matter. The picture is from November 2007. The picture was taken from Morningside and it is seen that the smoke from the flare is rising and travels over Morningside and have no impact at Morningside but further away. The pollutants in this case will not have a big impact locally, but will have a regional effect.

*Figure 1: Flaring from the SAPREF refinery show that the main body of the pollution is travelling aloft. The picture is taken from Morningside.*

The flaring device has certain upper design criteria. These are based on the needs of the refinery and there will be an upper amount that the flare is designed for. This is based on assessment of risks.

There is normally not a lower design criterion and because of the lower heat generation when flaring small amounts of gas the pollution is dispersed closer to the ground and is therefore more likely to impact locally. The impact to local air quality will therefore come from small amounts of gas being flared. The flare will under these circumstances not have complete combustion and the substances put to the flare will therefore not be completely burnt or destroyed. The combustion of the gases will not release large amounts of heat and the plume from the flare will not have a substantial plume rise after it have left the flaring device. If gases that can cause odour are flared severe odours downwind of the flare can occur.

There are three main conditions when flaring of small quantities. The first is that the gas directed to the flare is easy to combust and the combustion is more or less

complete. This is the less conflictive scenario, because the gases are transformed into known gasses and the impacts are measured to be low.

The next scenario, which is probably the most common, is when the flaring device has a low load and the substance directed to the flare is only partly combusted. The flue gas left after the combustion is partly the same as the ones put to the flare in the first place. From a refinery $H_2S$ can cause odours in the vicinity. Other substances can also be in the gas. Because of the incomplete combustion the plume rise will be less and the gases transported closer to the ground.

The third scenario is that the gas is not combusted as intended. This could be because the substance put to the flare is difficult to combust, the wind speed is too strong, or the flare is not run properly. This will cause the substances to spread directly into the atmosphere. This will have a larger GHG footprint because hydrocarbons especially methane is a stronger GHG than $CO_2$. In addition the emitted substances will expose the population. These substances can be dangerous or have a low odour threshold.

The conclusions are that the flaring activity if within the design criteria of the flaring device and if run according to specifications is impacting with acceptable concentration levels regionally and globally. If the amounts are small the flare will probably impact locally with several effects in the vicinity such as odours, $SO_2$ and other substances depending on the content of the gas flared. The level of impact strongly depends on the ability of the flaring device to fully combust the substances put to the flare. Flaring should always be kept to a minimum.

### *2.1.1 Main indicators*

An indicator must be relevant, representative, possible to measure and easy to interpret. The main indicators for flaring are: odours, $SO_2$, that the flare is visible, noise and heat. The options for monitoring are $H_2S$, $SO_2$, TRS and soot/$PM_{10}$. Also the complaint register can be used for detecting impacts from flaring. The human nose is a device that is very accurate and good for identification of odours. A smelling panel can be used for identification and detection of the odour strength.

The indicator that is recommended is the odours characterized through a smelling panel, and the visible identification of the different modes of combustion in the flare. This can be done through a web camera that is filming the flare and by grab samples for later analysis by an odour panel.

### *2.1.2 Odours*

One of the major impacts to the population is the presence of odours. These odours can come from several sources in the SDB, but through measurements of meteorology coupled to the main indicators the source of the odours can be established. The best way to measure odour strength is through an odour panel. (See description in the odour report). One must however take care not to blame the flaring device for emissions caused by the upset in the refinery causing the flaring.

### 2.2 Technical equipment

The technical equipment and the use of the flaring device are crucial for the impacts that it is causing to the environment. A good flaring device should provide a complete combustion of the substances that is put to the flare. If this is not satisfactory the flaring device must be changed or the conditions while flaring changed so that the substance is combusted. The problems of incomplete combustion normally arise when the flaring device is used for quantities outside the design criteria or that the flare is not operated properly. This applies both for small and large flow rates.

### 2.3 What options exist to avoid impact from flaring

Flaring is a safety device; it is also known that refineries use a flare to get rid of substances that is difficult or expensive to dispose of. To limit the impacts to the local environment from flaring it is important to ensure the complete combustion of the substance put to the flare. This is achieved by keeping the amounts flared within the specified range. When the amount fed to the flare is too small or that the substances are difficult to combust hydrocarbons could be added to get the amount within the design criteria.

Large flares are difficult to avoid when they first occur. To avoid these flaring incidents it is necessary to be pro active and plan up front to avoid these incidents. To minimize the impact from the flare the flaring capacity must match the quantity for worst case. A refinery might have several flares for several purposes.

When small amounts of substance is flared and the volume is smaller than the lower limit this can be treated alternatively. The substance could be loaded into a pressure vessel and fed into a furnace and destroyed this way. By doing this the energy from the substance is used for heat in the other processes. The pressure vessel should be at a size that allows storing until it can be disposed of or used in the processes.

## 3 Quantification options

The impact of the flaring activity is difficult to measure partly because flaring is an indication that the refineries have upset conditions. Upset conditions are connected to a higher emission rate from other sources, both stacks and diffuse sources. These emissions could be of the same pollutant as the one coming from the flare. In addition the flaring is random in nature and the measurement station would be outside the impacted zone. Emissions from the flare will typically be $SO_2$, particulate matter and substances causing odours. These substances will also have other emissions in the area apart from the flare, so if used as indicators, they must be interpreted with care.

$SO_2$ and $H_2S$ are relatively easy to measure. This means that these two gasses can be used as indicators for impacts from flares. However $H_2S$ is not giving the whole picture of possible smells.

It is costly and labour intensive to measure other substances with a sufficient time resolution, and with a detection limit necessary to do a proper evaluation. Therefore a relative technique has been developed. This is done through a smelling panel of 5-10 persons trained to recognise smell. The panel is trained to identify the smelling substance and to determine how much the sample collected needs to be diluted before 50% of the panel do not smell the substance. This is identifying the strength of the smell. This options can be used for all problems connected to odours and therefore also odours from flares. With a well educated smelling panel there will also be possibilities to identify the source or where in the process the smelling substance originate.

### 3.1 Logging of every flare

It is necessary to log all flaring incidents small and large. There should be a separate form to fill in every time a flaring incident occurs. This form should include time of day, length of flaring and amount flared. A video clip of the flare should be included in the form for visual inspection. This will indicate how the flare behaves and if the flare is lit or not. The video clip should be of high resolution. The form should also indicate from where do the substance originate and possible components. Apart from this contact details and time limits for delivery should be stated.

### 3.2 Complaint register

There is a complaint register in the eThekwini municipality. This should be linked to the flaring incidents and seen how they correlate. There should be a report from this every year to identify the number of complaints that can be referred back to the refineries.

### 3.3 Monitoring network

The monitoring network that is in place in SDB is sufficient to survey the indicators. Special tool kits should be put together to take grab samples for analysis by a smell panel. This will determine the substance and possibly the source in addition to the odour strength.

### 3.4 Meaningful reports

There should be different reports with deadlines that should end up in a summary report concluding on the flaring incident. All flaring incidents should be reported however there should be reporting on different levels. A standard report should be made for all incidents. For flows through the flaring device that is smaller or bigger than the intended design more comprehensive reports should be done and this should be made as a report and a hearing where the responsible person could be interviewed on the incidence. This will also serve as an eye opener and make this a personal responsibility.

### 3.5 Permitting and licensing

To be able to licence and permit emissions to the atmosphere from a flare it is necessary to understand what the fate of the emissions and possible effects on

human health and the environment. There are several steps that need to be answered. This could be done through the following steps:

1. Is the activity (flaring) likely to cause an adverse impact? If yes, this has to be described and made available to the permitting process. If documentation is not available this must be done before the process can be finalized.
2. If there are no effects and that this is well documented the permitting process can continue.
3. If there is a possible problem and the problem is sufficiently documented and understood, the severity of the impact must be evaluated.
    a. If it is a new plant the emissions should not be allowed to impact close to the ambient standards to allow for new development.
    b. If it is an existing emission and there are adverse effects, a plan for reduction of impacts or change of emission characteristics must be made.
    c. This plan must include and ensure implementation to reduce impacts to acceptable levels.
    d. The future plans for the area must be considered. The plan should be part of the permit.

### 3.6 Information and documentation necessary to issue a permit

To understand the problem it is necessary to quantify the impact and to analyse data and information to get connections between emissions and impacts. In the case of flaring the emissions are partly understood, and data for quantification do exist.

The TRS measurements need to be connected to the flaring activity. In this way it is possible to relate flaring to the air quality. In general it is seen that the flaring incidents are connected to elevated air pollution in general. This is seen from the average concentration during flaring. Flaring is a diverse activity where the feed to the flare can be a wide range of substances. The feed to the flare need to be identified and quantified to a certain effect. If possible it is good to obtain the content of the gas flared. This is however more important when an environmental problem is identified.

The polluter should be responsible for providing the information.

### 3.7 Flaring and green house gases

The most important GHG are $CO_2$, $O_3$, $CH_4$, $N_2O$ and Halocarbons. These are mostly long lived GHG this means that they stay in the atmosphere for a long time. Other compounds relevant to climate include among others particles, $H_2O$ and clouds. All these gasses are relevant to Climate Change. Estimates of the different GHG and the importance of them are indicated in Figure 2.

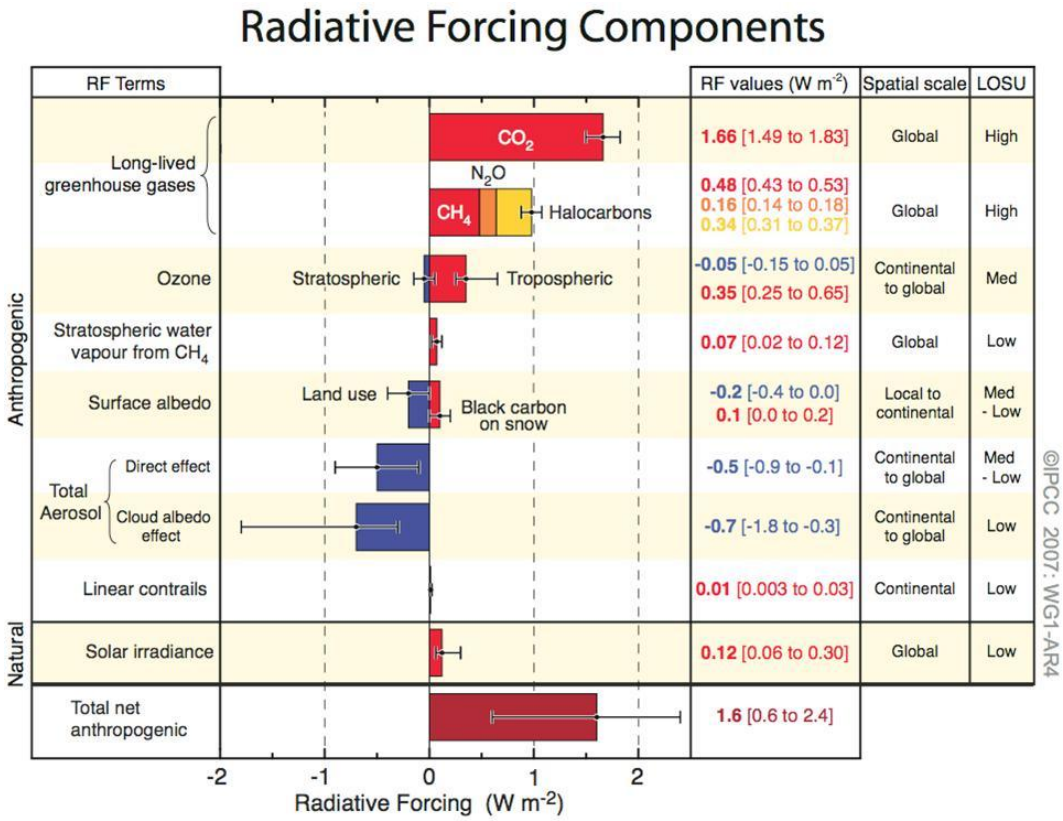


*Figure 2: Importance of the different impacts of Climate Change and the different GHG.*

The emissions of GHG from flaring will vary substantially according to the efficiency of the combustion in the flare and the content of the feed for the flare. If the combustion is assumed to be complete the main GHG is $CO_2$. The emissions of $CO_2$ are computed from the total amount of hydro carbons that is directed to the flaring devise.

In addition to the $CO_2$ emissions there will be emissions of VOCs. These will depend on which VOC is emitted since different VOCs have different impact on climate. The combustion will not be complete and an assumption of 5-10% of the VOCs not combusted. $CH_4$ is a strong GHG (23 times stronger than $CO_2$ in a 100-year perspective). The emissions could be calculated from the VOC assumption that 10% of the VOC is $CH_4$.

In addition to this a $SO_2$ and particles are emitted from the flares. The particulate matter is the more important of the two. If particles settle on surfaces with high albedo, the albedo will be reduced and the ground will absorb more heat. This is especially important for emissions that are likely to be transported to snow covered areas, such as the Antarctica. The amounts of particles coming from a flare are hard to estimate and are grossly dependent on the combustion in the flare. A modern flare will be able to run with low particle emissions but on occasions such as black Wednesday where the SAPREF refinery was emptied, particles where formed due to poor combustion.
The emissions of greenhouse gasses that are emitted from the refinery must be given. The flaring activity needs to be specified and included in the emission numbers.

### 3.8 Reporting

The problem description and the documentation should be provided by the polluter and should be developed in the same way as the EIA process. The report should contain information on the incident and compare this to previous flaring incidents to reach a better understanding. The process starts with a scoping phase where the most important topics are introduced. A report elaborating on these subjects needs to be done. Comments to the report should be made from stakeholders and then the final document that follows the permit should be issued.

### 3.9 Content of permit

The objective of the permit is to ensure that the air quality is acceptable for the stakeholders and that the emitter will have continuity in the relation to government and can perform long term planning. Apart from the formality the permit needs to be supported by documentation. The documentation must put forward recommendation on how to act and if there are environmental impacts that needs to be solved. The document should also give a way forward to solve these problems.

The permit should refer to this document and reflect the findings. For flaring the following main topics should be included:

1. The feed and substance fed to the flaring device must be within the design of the device with respect to lower flaring volume, upper flaring volume and substance fed to the flare.
2. Control that the flare is combusting the substance (video surveillance.)
3. State the current number of flaring incidents, and goals and strategies for reduction.
4. Plans and information on time frames and activities
5. Reporting on different flaring incidences. There should be an increased reporting when the flare is fed large quantities and small quantities. The performance of the flare must be recorded and made available.
6. The reporting of flares not within specification of the flaring device or with poor combustion should be comprehensive, including analysis of the reasons of occurrence and abatement measures.

### 3.10 Follow up

The reporting of the flaring should be scrutinized by government. The process must give feedback to the industry, and government needs to acknowledge the report. These reports must focus on finding the root cause of the flaring and the impact on the surroundings. Government must enforce the content of the permit if industry is not in compliance. The reports must be public available.

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REPORT PREPARED FOR
eThekwini Municipality
Health unit
Old fort road
Durban
South Africa

ABSTRACT
Activities around flaring from two main refineries have been assessed. Recommendations on process, permitting and involvement of the different stakeholders are given.

NORWEGIAN TITLE

Fakling fra raffinerier effekter på miljø og livskvalitet


| KEYWORDS | | |
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ABSTRACT (in Norwegian)
Fakling fra to raffinerier har blitt undersøkt. Det er gitt råd om prosess, utslippstillatelser og involvering av berørte parter.

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*A Unclassified (can be ordered from NILU)*
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