Technical Appendix: Final Motivation for the Additional Postponement of Compliance Timeframes in terms of Regulation 11 of the Section 21 NEM:AQA Minimum Emissions Standards

Report Prepared by

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Foreword

This appendix presents technical information regarding Natref's investigations into solutions for compliance with existing plant standards and new plant standards as prescribed in the MES, specified in Part 3 of GN 893.

Each chapter represents technical information pertaining to a particular listed activity, and is structured as follows:

- Applicable MES for the given process or listed activity is provided.
- A short description of the production process involved is presented (as included in the main report, but with more detail, as pertinent).
- A discussion on the various technology options investigated to achieve compliance with the applicable MES and the constraints involved in implementing them.
- Proposed alternative emission limits informed by all these inputs.

This technical work on technology options for compliance with the MES informed the chapter on "Reasons for applying for postponement" in the accompanying Natref motivation report, and the alternative emission limits requested.

Although this additional postponement application relates to the 2015 existing plant standards, for completeness' sake, this appendix also outlines the challenges faced in meeting new plant standards.

A note on the assessment of feasibility of compliance with the prescribed MES

In this technical appendix, statements are incorporated regarding the feasibility of identified technologies as emissions abatement solutions. Assessments of these technologies were triggered in some instances by Natref's internal policies regarding continuous improvement, and in others, by the requirement to comply with the MES. The assessment of feasibility is a holistic assessment of the implications of compliance from multiple perspectives, including but not limited to:

- The viability of a technology to achieve the desired emission reduction outcome.
- The integration viability of technologies.
- The upstream and downstream impacts of implementing a technology.
- Operability of the technology.
- Implementation considerations including process safety risks, construction risks, production risks and general overhaul (GO) scheduling implications.
- Financial implications, including upfront capital expenditure and lifecycle operating costs.
- Environmental cross-media impacts.
- Ambient air quality benefits arising.

These assessments inform decision-making regarding the holistic 'feasibility' of a compliance technology.

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Glossary

Definitions of terms as per GN 893, that have relevance to this application:

Existing Plant - any plant or process that was legally authorized to operate before 1 April 2010 or any plant where an application for authorisation in terms of the National Environmental Management Act 1998 (Act No.107 of 1998), was made before 1 April 2010.

Fugitive emissions - means emissions to the air from a facility, other than those emitted from a point source.

New Plant - any plant or process where the application for authorisation in terms of the National Environmental Management Act 1998 (Act No.107 of 1998), was made on or after 1 April 2010.

Point source - a single identifiable source and fixed location of atmospheric emission, and includes smoke stacks.

Point of compliance – means any point within the off gas line, where a sample can be taken, from the last vessel closest to the point source of an individual listed activity to the open-end of the point source or in the case of a combination of listed activities sharing a common point source, any point from the last vessel closest to the point source up to the point within the point source prior to the combination/interference from another Listed Activity.

Definitions of terms as per the NEM:AQA that have relevance to this application:

Priority area - means an area declared as such in terms of Section 18.

Priority area air quality management plan - means a plan referred to in Section 19.

Additional terms provided for the purpose of clarity in this application:

Additional postponement applications – Natref submitted draft applications for exemption in terms of Section 59 of NEM:AQA from certain MES, along with draft applications for postponement from certain MES. These exemptions were motivated on the basis that the applicable standards were presently infeasible based on, amongst others, technology, brownfields, environmental and economic constraints. Since the conclusion of the stakeholder engagement process, Natref has been directed to rather seek postponement from the compliance timeframes in the MES to address its challenges. Consequently the exemption application will instead be submitted as a postponement application, in addition to its existing postponement applications which have already been submitted to the National Air Quality Officer. Natref now therefore makes application for postponement in respect of those applications which were previously submitted, advertised and made available for public comment, as exemption applications. These are referred to herein as additional postponement applications.

Alternative emissions limits – the standard proposed by Natref based on what is considered reasonable and achievable as a consequence of the assessments conducted and which Natref proposes as an alternative standard to be incorporated as a licence condition with which it must comply during the period of postponement. The alternative emissions limits are specified as *ceiling emissions limits* or *maximum emission concentrations*, as defined in this Glossary. In all instances, these alternative emission limits seek either to maintain emission levels under normal operating conditions as per current plant operations, or to reduce current emission levels, but to some limit which is not identical to the promulgated minimum emissions standards. Specifically, these alternative emissions limits do not propose an increase in current average baseline emissions.

Atmospheric Impact Report - in terms of the Minimum Emission Standards an application for postponement must be accompanied by an Atmospheric Impact Report as per Section 30 of NEM:AQA. Regulations Prescribing the Format of the Atmospheric Impact Report (AIR) were published in Government Notice 747 of 2013).

Ambient standard - The maximum tolerable concentration of any outdoor air pollutant as set out in the National Ambient Air Quality Standards in terms of Section 9(1) of the NEM:AQA.

Ceiling emissions limit - Synonymous with “maximum emission concentrations”. The administrative basis of the Minimum Emissions Standards is to require compliance with the prescribed emission limits specified for existing plant standards and new plant standards under all operational conditions, except shut down, start up and upset conditions, based on daily average concentrations as defined in Part 2 of the MES. Whereas average emission values reflect the arithmetic mean value of emissions measurements for a given process under all operational conditions over a 3 year period, the ceiling emission would be the highest daily average emission concentration obtained. Hence, ceiling emission values would be higher than average emission values, and the difference between ceiling and average values being dependent on the range of emission levels seen under different operational conditions. Since the Minimum Emissions Standards specify emissions limits as ceiling emissions limits or maximum emission concentrations, Natref has aligned its alternative emissions limits with this format, to indicate what the 100^{th} percentile emissions measurement value would be under any operational condition (excluding shut down, start up and upset conditions). It is reiterated that Natref does not seek to increase emission levels relative to its current emissions baseline through its additional postponement applications and proposed alternative emissions limits (specified as ceiling emission limits), but rather proposes these limits to conform to the administrative basis of the Minimum Emissions Standards.

Criteria pollutants – Section 9 of NEM:AQA provides a mandate for the Minister to identify a national list of pollutants in the ambient environmental which present a threat to human health, well-being or the environment, which are referred to in the National Framework for Air Quality Management as “criteria pollutants”. In terms of Section 9, the Minister must establish national standards for ambient air quality in respect of these criteria pollutants. Presently, eight criteria pollutants have been identified, including sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), lead (Pb), particulate matter (PM_{10}), particulate matter ($PM_{2.5}$), benzene (C_6H_6). In this document, any pollutant not specified in the National Ambient Air Quality Standards (NAAQS) is called a “non-criteria pollutant”.

Existing plant standards - The emission standards which existing plants are required to meet. Emission parameters are set for various substances which may be emitted, including, for example, particulate matter, nitrogen oxides and sulphur dioxide.

Listed activity - In terms of Section 21 of NEM:AQA, the Minister of Environmental Affairs has listed activities that require an atmospheric emissions licence. Listed Activities must comply with prescribed emission standards. The standards are predominantly based on ‘point sources’, which are single identifiable sources of emissions, with fixed location, including industrial emission stacks.

Maximum emission concentrations – Synonymous with “ceiling emissions limits”. Refer to glossary definition for ceiling emissions limits.

Minimum emissions standards – prescribed maximum emission limits and special arrangements for specified pollutants and listed activities. These standards are published in Part 3 of GN 893.

Minister – the Minister of Environmental Affairs.

New plant standards - The emission standards which existing plants are required to meet, by April 2020, and which new plants have to meet with immediate effect. Emission parameters are set for various substances which may be emitted, including, for example, particulate matter, nitrogen oxides and sulphur dioxide.

Postponement – a postponement of compliance timeframes for existing plant standards and new plant standards and their associated special arrangements, in terms of Regulations 11 and 12 of GN 893. In the context of Natref's applications, these postponements are referred to as *initial postponements* and *additional postponements*, as defined in this Glossary.

GN 893 – Government Notice No. 893, 22 November 2013, published in terms of Section 21 of the National Environmental Management: Air Quality Act (Act No 39 of 2004) and entitled '*List of Activities which Result in Atmospheric Emissions which have or may have a Significant Detrimental Effect on the Environment, Including Health and Social Conditions, Economic Conditions, Ecological Conditions or Cultural Heritage'*. GN 893 repeals the prior publication in terms of Section 21, namely Government Notice No. 248, 31 March 2010. GN 893 deal with aspects including: the identification of activities which result in atmospheric emissions; establishing minimum emissions standards for listed activities; prescribing compliance timeframes by which minimum emissions standards must be achieved; detailing the requirements for applications for postponement of stipulated compliance timeframes.

Natref – National Petroleum Refiners of South Africa (Proprietary) Limited, a joint venture between Sasol Oil (Pty) Ltd (63.64%) and Total South Africa (Pty) Ltd (36.36%).

Special arrangements –specific compliance requirements associated with a listed activity's prescribed emissions limits in Part 3 of GN 893 of NEM:AQA. These include, among others, reference conditions applicable to the listed activity prescribed emission limits, abatement technology prescriptions and transitional arrangements.

List of Abbreviations

AEL – Atmospheric Emissions Licence

AIR - Atmospheric Impact Report

BAT - Best Available Techniques

CONCAWE – Conservation of Clean Air and Water in Europe (oil companies' European association for environment, health and safety in refining and distribution)

BID - Background Information Document

BREF - Best Available Techniques Reference documents

CRR - Comment and Response Report

CO_2 – Carbon dioxide

EET – Emissions Estimation Technique

ESP – Electrostatic Precipitator

FCC - Fluidized Catalytic Cracker

NAAQS - National Ambient Air Quality Standards

NAQF – National Framework for Air Quality Management

NAQO - National Air Quality Officer

NEMA - National Environmental Management Act (Act 107 of 1998)

NEM:AQA - National Environmental Management: Air Quality Act (Act 39 of 2004)

NO_x – Oxides of nitrogen

NO_2 – Nitrogen dioxide

MES - Minimum Emissions Standards

$PM_{2.5}$ – Particulate Matter with radius of less than 2.5 µm

PM_{10} – Particulate Matter with radius of less than 10 µm

PM – Total particulate matter that is a solid contained in a gas stream

ppm – parts per million (10^{-6})

ppb – parts per billion (10^{-9})

RCD - Residual Crude Desulphurisation

SO_2 - Sulphur dioxide

SRU – Sulphur Recovery Unit

SWS – Sour Water Stripper

TSS -Third Stage Separators

VOCs or TVOCs – (Total) Volatile Organic Compounds

VTAPA – Vaal Triangle Air-shed Priority Area

1 Refinery Operations: Postponement request for PM, SO_2, NO_x

1.1 Gas Fired Boilers: Postponement request for NO_x

1.1.1 Applicable standards

Minimum Emission Standards (MES) Category 1.4 prescribes emission limits applicable to gas combustion installations.

Table 1: Excerpt from MES Category 1.4 – Gas Combustion Installations

Description	Gas combustion (including gas turbines burning natural gas) used primarily for steam raising or electricity generation.		
Application:	All installations with a design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used.		
Substance or mixture of substances		**Plant status**	**mg/Nm^3 under normal conditions of 3% O_2, 273 Kelvin and 101.3 kPa.**
Common name	**Chemical symbol**		
Particulate Matter	N/A	New	10
		Existing	10
Sulphur dioxide	SO_2	New	400
		Existing	500
Oxides of Nitrogen	NOx expressed as NO_2	New	50
		Existing	300

Notwithstanding that the additional postponement is made in terms of 2015 existing plant standards, for completeness' sake, this chapter outlines the challenges faced in meeting the new plant NO_x standard of 50 mg/Nm^3.

1.1.2 Description of the plant

There are currently two 63 ton/h (58MW) boilers at Natref used for steam generation. Their primary purpose is steam generation for refining processes. Steam is used inside the refinery to provide indirect heat for process units, vacuum for steam ejectors and as a reactant in some process units e.g. hydrogen production.

In order to produce steam, fuel is combusted in a chamber and transferred to water in tubes. The flue gas from the combustion chamber then exits the boiler through an exhaust stack. Air emissions occur both from the combustion of fuel impurities (e.g. particulates and sulphur) and from the combustion process itself (e.g. NO_x and CO). Steam boilers can use refinery fuel gas or residual refinery fuel oil as fuel. The potential air emissions are the least with gaseous fuel and are the higher with residual oil as a fuel. Boilers are designed to be dual (oil/gas) fired to allow flexibility in the refinery fuel system. When the boiler feed is fired on refinery fuel gas, subcategory 1.4 of the MES applies. When the boiler is fired on residual refinery fuel oil, subcategory 1.2 of the MES is applicable.

The Natref boilers differ from other utility scale electricity boilers (covered in Category 1.1 of the MES) in a number of important ways, including:

- The boilers are integrated with the Refinery facility and are used for steam generation and are not used for baseload electricity generation as in the case of a standard power plant.

- The two boilers have a design capacity 58 MW each, and not the large units >800 MW typical of power plants.
- The steam boilers are integrated with the refinery main stack for atmospheric emission dispersion purposes. Boiler flue gas exits via the refinery main stack which is 145 m high.
- The steam boilers are situated in the middle of the refinery complex. Consequently, plot space constraints result from the surrounding integrated petrochemical facility, which are more restrictive than those arising for standalone power generation facilities.

Boiler availability is essential for process steam production which directly affects the production stability of Natref. Any additional outage time on boilers effects fuel production levels of the facility, with significant financial as well as product (i.e. petrol, diesel and jet fuel) supply implications. Thus, any boiler work, including maintenance, retrofits of compliance technology and any renewals or upgrades of equipment components, is planned to take place during a strictly adhered to shutdown schedule, with planned boiler outages. This schedule is closely coordinated with the shutdown activities of other fuel refineries (to avoid an inland fuel shortage).

1.2 Fuel Oil Fired Boilers: Postponement request for PM, SO_2 and NO_x

1.2.1 Applicable standards

MES Category 1.2 prescribes emission limits applicable to Natref's fuel oil fired boilers.

Table 2: Excerpt from MES Category 1.2 – Liquid Fuel Combustion Installations

Description	Liquid fuel combustion installations used primarily for steam raising or electricity generation		
Application:	All installations with a design capacity equal or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used.		
Substance or mixture of substances		**Plant status**	**mg/Nm^3 under normal conditions of 3% O_2, 273 Kelvin and 101.3 kPa.**
Common name	**Chemical symbol**		
Particulate Matter	N/A	New	50
		Existing	75
Sulphur dioxide	SO_2	New	500
		Existing	3500
Oxides of Nitrogen	NO_x expressed as NO_2	New	250
		Existing	1100

This additional application pertains to the existing plant standards for PM, SO_2 and NO_x standards. Notwithstanding that the additional postponement is made in terms of 2015 existing plant standards, for completeness' sake, this chapter outlines the challenges faced in meeting the PM, SO_2 and NO_x new plant standards as well.

1.2.2 Description of the plant

As described in Section 1.1.2, there are currently two 63 ton/h (58MW) boilers at Natref used for steam generation. As indicated above, these Steam boilers can use refinery fuel gas or residual refinery fuel oil as fuel. The potential air emissions are the least with gaseous fuel and are the most with residual fuel oil as a fuel. Boilers are designed to be dual (oil/gas) fired to allow flexibility in the refinery fuel system i.e. manage refinery fuel oil levels and prevent fuel gas flaring. When the boiler feed is refinery fuel gas fired, subcategory 1.4 of the MES applies. For instances where the boiler feed is refinery fuel oil fired, subcategory 1.2 of the MES is applicable.

1.3 Refinery Furnaces: Postponement request for PM and SO_2 point source standards

1.3.1 Applicable standards

MES Category 2.1 prescribes emission limits applicable combustion installations.

Table 3: Excerpt from MES Category 2.1 – Combustion Installations

Description	Combustion installations not used primarily for steam raising or electricity generation (furnaces and heaters).		
Application:	All refinery furnaces and heaters.		
Substance or mixture of substances		**Plant status**	**mg/Nm^3 under normal conditions of 10% O_2, 273 Kelvin and 101.3 kPa.**
Common name	**Chemical symbol**		
Particulate Matter	N/A	New	70
		Existing	120
Sulphur dioxide	SO_2	New	1000
		Existing	1700
Oxides of Nitrogen	NOx expressed as NO_2	New	400
		Existing	1700

The following special arrangement shall apply:

- A bubble cap of all Combustion Installations and Catalytic Cracking Units shall be at 1.2 kg SO_2/ton for existing plants.
- A bubble cap of all Combustion Installations and Catalytic Cracking Units shall be at 0.4 kg SO_2/ton for new plants.

This additional postponement application pertains to the existing plant standard for PM and SO_2 standards (point source emission limits). Notwithstanding that the additional postponement is made in terms of 2015 existing plant standards, for completeness' sake, this chapter outlines the challenges faced in meeting the PM and SO_2 new plant standards.

1.3.2 Description of the plant

Many of the individual refinery processes and utility systems combust fuel (gas and/or refinery residual fuel oil) in dedicated furnaces to supply the heat necessary for the process. Fired process heaters are the main heat producers and transfer the heat released in the combustion process directly to the process stream.

A variety of furnaces and burner types are used in refineries, largely determined by the heat release characteristics required by a particular process. Some furnaces are designed to fire fuel gas while others are designed to fire predominantly fuel oil, others are designed to fire combination of fuel gas and refinery fuel oil. Furnaces are designed for dual firing to allow flexibility in the refinery fuel system (maintain fuel oil stock levels and prevent flaring of fuel gas). Refinery process heaters are typically rectangular or cylindrical enclosures with multiple fired burners of specialised design. Furnaces and heaters are an integral part to refinery operation since most processes in refineries are based on the heating and partial evaporation of the hydrocarbons.

Availability of all refinery furnaces is essential for processes and directly affects the production stability of Natref. Any additional outage time on furnaces effects fuel production levels of the facility, with significant product supply (petrol, diesel and jet fuel) and financial implications. Thus, any work, including maintenance, retrofits of compliance technology and any renewals or upgrades of equipment components, is planned to take place during a strictly adhered to shutdown schedule, with planned outages. This schedule is closely coordinated with the shutdown activities of other fuel refineries (to avoid an inland fuel shortage).

1.4 Refinery Bubble: Challenge in meeting new plant standard for SO_2

1.4.1 Applicable standards

MES Categories 2.1 and 2.2 contain an additional bubble limit, to be complied with along with the point source standards for sources under categories 2.1 and 2.2.

The following special arrangement shall apply:

- A bubble cap of all Combustion Installations and Catalytic Cracking Units shall be at 1.2 kg SO_2/ton for existing plants.
- A bubble cap of all Combustion Installations and Catalytic Cracking Units shall be at 0.4 kg SO_2/ton for new plants.

This outlines the challenges faced in meeting the new plant bubble cap of 0.4 kg SO_2/ton.

1.4.2 Description of the plant

As discussed in the motivation report, Natref has already reduced SO_2 emissions by more than 50% since 2000 by measures including the use of lower sulphur crude and the routing of Sour Water Stripper off-gas, a significant source of emissions, to the Sulphur Recovery Unit (SRU). As part of the improvements implemented to achieve this reduction, Natref upgraded and installed the Crude Distillation Unit (CDU) furnaces in 2013.

2 Technology Options for Compliance: PM, SO_2 and NO_X

2.1 Technology options for compliance: PM

If refinery fuel oil is fired on boilers and furnaces, existing and new plant standards cannot be met. PM emissions result from the release of metals and the combustion of sulphur present in refinery fuel oil. As such, emissions are directly related to the sulfur and metal content of crude oil. An international technology scan was conducted, and a variety options and technologies were investigated for the purpose of bringing PM emissions into compliance with the standards. The following options for compliance with PM emission limits were investigated:

- Replacement of fuel oil as a fuel source: Increasing the use of Gas.
- Processing of Low Sulphur Crudes.
- Hydrotreatment of liquid refinery fuels.
- Installation of bag filters.
- Installation of an Electrostatic precipitator (ESP).

The various options were evaluated at conceptual development level to establish the optimal solution for Natref that had the least negative impact in all the areas.

2.1.1 Replacement of refinery fuel oil

Fuel oil contributes to SO_2, NO_x and PM due to due to fuel oil sulphur and ash content. A full switch to a 100% gas-fired refinery would reduce SO_2 emissions by up to 99 % and NOx by 30 - >50 %. The use of gas generates very little PM and very low SO_2 emissions, as the refinery gases are cleaned in amine scrubbers. Particulate emissions including heavy metals will be reduced. Replacing the fuel oil currently fired in the boilers and furnaces with an alternative fuel could reduce emissions to below the MES.

Natref is one of the few complex refineries in the world. It was built, and has been upgraded, to minimise fuel oil production. Natref upgrades 98 vol % of crude of into finished products (Petrol/Diesel/Jet Fuel - 92 vol %, Fuel Oil - 3 vol % and Bitumen – 3 vol %). The conventional refinery which upgrades only 65 – 70 vol % into finished products at equivalent crude mix and the rest is fuel oil. These refineries are able to sell the large amounts of fuel oil to ships to be used as bunker fuel. With virtually no inland fuel oil market, Natref upgrades significantly more raw material into final products.

At Natref gaseous or liquid fuels are used to supply the necessary energy and power requirements. The fuels are produced in the various refinery processes. These fuels often consist of process streams that cannot be easily converted into marketable products i.e. refinery gases and heavy residual hydrocarbon streams. These fuels supply the base load of the energy demand of the refinery. The fuel oil typically has a sulphur content of 3% by weight, leading to SO_2 emissions.

Given Natref's inland location, the refinery fuel gas and refinery fuel oil stock levels and availability need to be carefully balanced with respect to supply and demand. Replacing refinery fuel oil with an alternate fuel is not feasible for the following reasons:

Availability of an alternate fuel source: Fuel gas generated by refinery processes is insufficient to meet process energy demands. An alternate fuel would need to be sourced and imported into the refinery to provide the energy requirements currently provided by refinery fuel oil. There is currently no such fuel source available. Should an alternative fuel become available, variable cost for Natref is expected to increase significantly, putting the refining margin and sustainability of the refinery under severe strain.

Disposal of excess refinery fuel oil: A market or alternate destination for disposal of excess fuel oil will be required. The reason for this is that conventional refineries are sited next to the coast where they have access to a Bunker fuel market for their fuel oil. Natref does not have a bunker fuel market. The inland market for high sulphur fuel oil is limited and is expected to further decline in future due to strict air emissions Regulations. Should fuel oil firing no longer be possible, Natref will have to transport the excess fuel oil to the coast by truck or rail, which has a negative impact on environment due to increased electricity requirements or increased tail pipe emissions. Even if fuel oil was to be sent to the coast the same fuel oil would be burnt by ships as bunker fuel, thus overall SO_2 emissions would not decrease. This option is not only impractical but also uneconomical.

2.1.2 Processing of Low Sulphur Crudes

The nitrogen, sulphur, particulates and metals content of the fuel used in refineries are determined by the crude that is used at the refinery and by the process units it has passed through. Liquid refinery fuel streams originate from various processes such as crude distillation units, vacuum distillation, thermal cracking, catalytic cracking and hydrocracking of residues. Except for the latter one, the sulphur content of these residues can only be controlled by feedstock choice.

Crude oil with a sulphur content of less than 1% (by mass) is referred to as low sulphur crude while that with sulphur content of more than 1% is referred to as high sulphur crude. Natref is well suited to process higher sulphur crudes, due to the installation of the complex RCD, Fluidised Catalytic Cracker (FCC) and hydrocracking processes, which were installed to upgrade heavy bottom distillation fractions to white products. Despite the capability of processing higher sulphur crudes, Natref has chosen to steadily decrease high sulphur crude in its crude mix, reducing the sulphur content of the feed from more than 1.2% in 2007 to less than 1% in 2012 (see figure below). The process of reducing higher sulphur crudes has been to comply with Vaal Triangle Air-shed Priority

Area (VTAPA) commitments The use of low sulphur crudes reduces the SO_2 emissions from the refinery as less sulphur enters the refinery through the feed.

Over the years Natref has steadily increased its processing of low sulphur crudes, reducing the sulphur content of the feed from higher than 1.2% in 2007 to less than 1% on 2012. Given the crude slate processed the average sulphur content of the fuel oil at Natref is 3% by weight.

Natref continues to process low sulphur crudes within economically feasible limits, given that low sulphur crudes are substantially more expensive than high sulphur crudes. Natref is constrained in further reducing sulphur content in its crude feedstocks, since the refinery was never designed to process low sulphur crudes. Natref's refining margin would be further reduced and potentially compromise business sustainability, if the refinery processed even lower sulphur crudes. The business implications of not going for even lower sulphur content crudes must also be seen in the light of the additional high cost refinery upgrades that are required to meet the Clean Fuels II specifications.

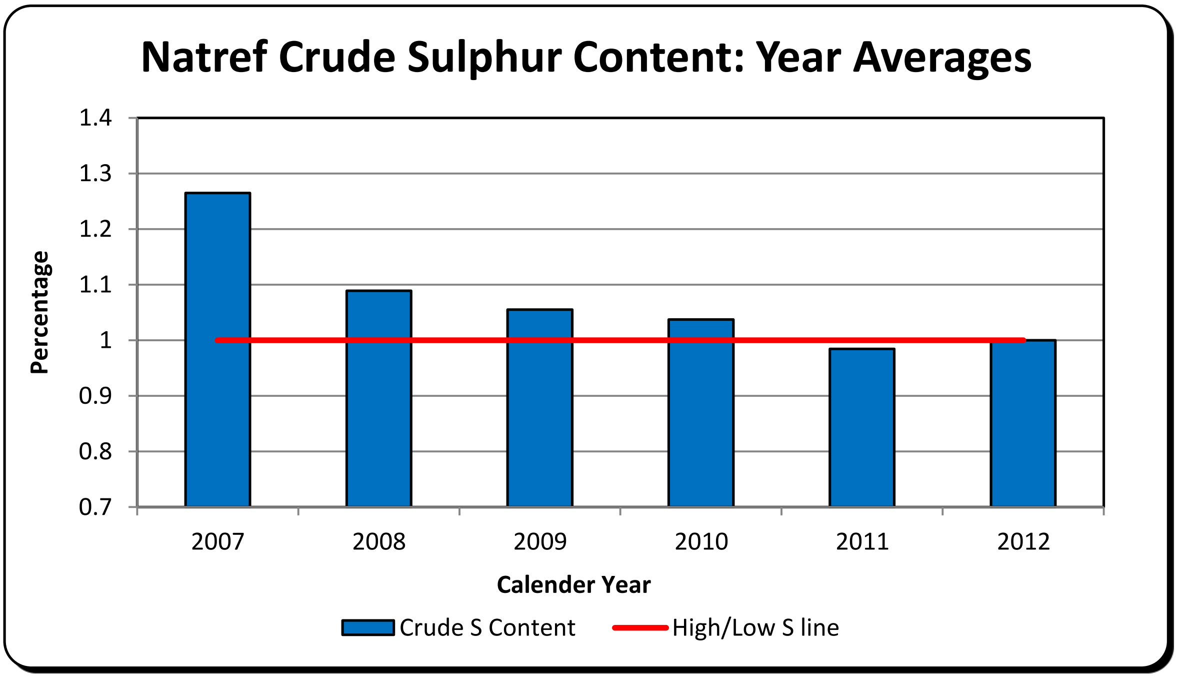

Figure 1: Natref Crude Sulphur Content: Year Averages.

2.1.3 Flue Gas Desulphurisation

Flue gas desulphurisation techniques are primarily utilised to reduce SO_s, but has the added benefit of PM reduction. Flue gas desulphurisation options therefore primarily reduce SO_2 and additionally PM concentrations in flue gas. The following options were considered: caustic scrubbing, lime scrubbing, regenerative SO_2 removal and SNO_x.

Caustic Scrubbing: SO_2 in the flue gas is reacted with the caustic soda in the scrubbing water to form sodium sulphates (Na_2SO_4). Particulate matter is also collected. Waste water containing these compounds is purged from the scrubber. For cases where the SO_2 amount is high caustic scrubbing becomes impractical from the perspective of caustic consumption and salt production. At Natref waste water containing approximately 90 tons/day Na_2SO_4 would be generated and would require waste handling and disposal. The estimated amounts of NaOH required for the process is excessive (>5200tons/year) and water required for the process is in excess of 300 Megalitres/year. Over 2000 tons/year solid filtercake would have to be disposed of and over 100 Megalitres/year of waste water would also require disposal.

Lime Scrubbing: SO_2 in the flue gas is reacted with the lime in the scrubbing water. Lime scrubbing is an inherently more complex process than caustic scrubbing. In this case the SO_2 is converted to solid $CaSO_4$ (gypsum); the required sulphite to sulphate oxidation takes place in the scrubber. The scrubber contents are partly solid, and the solid gypsum product would have to be dewatered and handled (likely disposed to landfill). The amount of gypsum waste produced is in the order of 88 ton/day (as pure CaSO4).

The solid and liquid wastes generated from caustic and lime scrubbing are excessive. Given Natref's inland location, apart from disposal to landfill there are currently no feasible solutions for disposal liquid and solid effluents generated from caustic or lime scrubbing.

This technology would also require frequent annual shut down for maintenance which is not aligned with the shutdown and maintenance schedules for refineries: units run typically for several years between shutdowns. Natref's technical assessment was unable to identify a refinery that had installed this technology.

Regenerative SO_2 Removal: Regenerative SO_2 removal selectively removes SO_2 from flue gas in a scrubber using an absorption solution containing phosphate salts. The SO_2-laden solution is thermally regenerated, the regenerated absorption solution returns to the scrubber (similar to amine-based acid gas removal). Solids contained in the flue gas are removed. A purge stream is required to remove non-regenerable salts (mainly originating from SO_3 in the flue gas). The SO_2 is stripped out as a concentrated gas stream. Disposal of this stream is required.

Disposal options include:

- Use as feedstock for an H_2SO_4 plant
- Routing to SRU for conversion to elemental sulphur with H_2S from refinery amine regenerators
- Production of liquid SO_2 (only feasible if a market exists)

Regenerative wet scrubbing systems are used only very rarely with few commercial references. The disadvantage of this process is the capital cost of the installation as well as its operating cost (steam, power).

SNO_x: Another option is to oxidise SO_2 contained in the flue gas to SO_3, which then reacts with water contained in the flue gas and condenses as H_2SO_4. The process removes NO_x as well as converting SO_2 to low-strength H_2SO_4 by an oxidation step, followed by cooling and condensing of low-strength sulphuric acid in a special glass condenser. Inherently the process also removes PM (by means of an electrostatic precipitator at the process front end), as this is required to keep the downstream de-NO_x and SO_2 oxidation catalysts clean.

2.1.4 Bag Filters

A further option for flue gas PM removal are bag filters. Bag filters are temperature-sensitive and are typically used in applications where the flue gas exit temperature is below 200 ºC. The Natref flue gas temperatures exceed 200°C. Standards bags are unable to withstand these temperatures, thus specialised bag material would be required. The specialised bags have high maintenance requirements (bag replacements every +/- 4 years) and bag filters have high energy requirements to compensate for the large pressure drop over the system. Due to these negative operational impacts, bag filters are not considered a sustainable abatement technology for the Natref operation.

2.1.5 ESP

In order to remove PM from flue gas, the gas is ionised in passing between a high-voltage electrode and an earthed (grounded) electrode; the dust particles become charged and are attracted to the earthed electrode. The precipitated dust is removed from the electrodes mechanically, usually by vibration, or by washing in so called wet electrofilters. ESP are capable of collecting bulk quantities of dust including very fine particles, <2 µm, at high efficiencies. ESP can achieve values of 5 - 50 mg/Nm^3 (95 % reduction or higher with higher inlet concentration only).

The introduction of high voltage inside a process stream, as is done in an ESP introduces a new safety risk in refineries. A reduction of the environmental impact is best achieved if a useful outlet is found for the collected solid dust material. Dust collection is essentially a shift of an air emission problem to a waste problem.

Table 4: Summary of technology feasibility assessment associated with installation of abatement technologies at the Natref refinery for compliance with the MES for PM

TECHNICAL OPTION	EMISSION SPECIES ADDRESSED	ASSESSMENT OF FEASIBILITY	SUMMARY OF REASONS FOR FEASIBILITY ASSESSMENT
Replacement of refinery fuel oil	SO_2, PM and NO_x reduction	Not feasible	Availability of suitable alternative fuel. Availability of a market for refinery fuel oil.
Flue gas desulphurisation – Caustic and Lime Scrubbing	SO_2 and PM reduction	Not feasible	Large volume of effluent produced. High additional salt load to be treated. Large amounts of fresh water required. Brine stream to be treated and disposed considering strict inland water discharge requirements. High capital investment required.
Flue gas desulphurisation – Regenerative SO_2 Removal	SO_2 and PM reduction	Not feasible	Infeasible high capital investment required. Effluent produced. Additional salt load to be treated. Large amounts of fresh water required. Brine stream to be treated and disposed considering strict inland water discharge requirements Not widely commercialized.
Flue gas desulphurisation – SNO_X	SO_2, PM and NO_x reduction	Not feasible	Infeasible high capital investment required. Sulphuric acid market required. Not widely commercialized. Inherently complex due to sulphuric acid handling.
Processing of Low Sulphur Crudes	SO_2,NO_x and PM reduction	Not feasible	Natref is already processing crudes with sulphur content of <1wt%, further reductions are not feasible
Bag Filters	PM Reduction	Not feasible	Only appropriate below 200°C. Natref furnaces and boilers exceed this temperature.
ESP	PM reduction	Feasible, depending on application	Requires vast amounts of plot area. Complex process with associated safety risks – electric current in an oxygen and CO rich environment. Extensive changes to all furnaces required to re-route ducting. Likely infeasible on natural draft furnaces due to pressure requirement. Additional waste to be disposed.

2.2 Technology options for compliance: SO_2

Existing and new plant standards for SO_2 cannot be met if fuel oil is utilised. In this case SO_2 emissions result from the combustion of sulphur present in refinery fuel oil. As such, emissions are directly related to the sulphur content of crude oil. An international technology scan was conducted, and a variety options and technologies were investigated for the purpose of bringing SO_2 emissions into compliance with the standards. The following options for compliance with SO_2 emission limits were investigated:

- Replacement of fuel oil as a fuel source: Increasing the use of Gas.
- Processing of Low Sulphur Crudes.
- Hydrotreatment of liquid refinery fuels.
- Flue gas desulphurisation options including: Caustic scrubbing, Lime scrubbing, regenerative SO_2 Removal and SNO_x.

The various options were evaluated at conceptual development level to establish the optimal solution for Natref that had the least negative impact in all the areas.

2.2.1 Replacement of fuel oil

Fuel oil contributes to SO_2, NO_x and PM due to due to fuel oil sulphur and ash content. A full switch to a 100% gas-fired refinery would reduce SO_2 emissions by up to 99 % and NO_x by 30 - >50 %. The use of gas generates very little dust and very low SO_2 emissions, as the refinery gases are cleaned in amine scrubbers. Particulate emissions including heavy metals will be reduced. Replacing the fuel oil currently fired in the boilers with an alternative fuel could reduce emissions to below the MES.

Natref is one of the few complex refineries in the world. It was built, and has been upgraded, to minimize fuel oil production. Natref upgrades 98 vol % of crude of into finished products (Petrol/Diesel/Jet Fuel - 92 vol %, Fuel Oil - 3 vol % and Bitumen – 3 vol %). The conventional refinery which upgrades only 65 – 70 vol % into finished products at equivalent crude mix and the rest is fuel oil. Typical refineries are at much lower white product conversion (typical 65 – 70 vol%) and produce much more fuel oil at equivalent crude mix these refineries are able to sell the large amounts of fuel oil to ships to be used as bunker fuel. With virtually no inland fuel oil market, Natref upgrades significantly more raw material into final products.

At Natref gaseous or liquid fuels are used to supply the necessary energy and power requirements. The fuels are produced in the various refinery processes. These fuels often consist of process streams that cannot be easily converted into marketable products i.e. refinery gases and heavy residual hydrocarbon streams. These fuels supply the base load of the energy demand of the refinery. The fuel oil typically has a sulphur content of 3wt%, leading to increased SO_2 emissions.

Given Natref's inland location, the refinery fuel gas and refinery fuel oil stock levels and availability need to be carefully balanced with respect to supply and demand. Replacing refinery fuel oil with an alternate fuel is not feasible for the following reasons:

Availability of an alternate fuel source: Fuel gas generated by refinery processes is insufficient to meet process energy demands. An alternate fuel would need to be sourced and imported into the refinery to provide the energy requirements currently provided by refinery fuel oil. There is currently no such alternative fuel source available. Should an alternative fuel become available, the operating cost for Natref is expected to increase significantly putting the refining margin and sustainability of the refinery under severe strain.

Disposal of excess refinery fuel oil: A market or alternate destination for disposal of excess fuel oil will be required. The reason for this is that conventional refineries are sited next to the coast where they have access to a Bunker fuel market for their fuel oil. Natref does not have a bunker fuel market. The inland market for high sulphur fuel oil is limited and is expected to further decline in future due to strict air emissions Regulations. Should fuel oil firing no longer be possible, Natref will have to transport the excess fuel oil to the coast by truck or rail, which has a negative impact on environment due to increased electricity requirements or increased tailpipe emissions. Even if fuel oil was to be sent to the coast the same fuel oil would be burnt by ships, thus overall SO_2 emissions would not decrease. This option is not only impractical but also uneconomical.

2.2.2 Processing of Low Sulphur Crudes

The nitrogen, sulphur, particulates and metals content of the fuel used in refineries are determined by the crude that is used at the refinery and by the process units it has passed through. Liquid refinery fuel streams originate from various processes such as crude distillation units, vacuum distillation, thermal cracking, catalytic cracking and hydrocracking of residues. Except for the latter one, the sulphur content of these residues can only be controlled by feedstock choice.

Crude oil with a sulphur content of less than 1% (by mass) is referred to as low sulphur crude while that with sulphur content of more than 1% is referred to as high sulphur crude. Natref is well suited to process higher sulphur crudes, due to the installation of the complex RCD, FCC and hydrocracking processes, which were installed to upgrade heavy bottom distillation fractions to white products. Despite the capability of processing higher sulphur crudes, Natref has chosen to steadily decrease high sulphur crude in its crude mix, reducing the sulphur content of the feed from more than 1.2% in 2007 to less than 1% in 2012 (see figure below). The process of reducing higher sulphur crudes has been to comply with VTAPA commitments The use of low sulphur crudes reduces the SO_2 emissions from the refinery as less sulphur enters the refinery through the feed.

Over the years Natref has steadily increased its processing of low sulphur crudes, reducing the sulphur content of the feed from higher than 1.2% in 2007 to less than 1% on 2012. Given the crude slate processed the average sulphur content of the fuel oil at Natref is 3wt%.

Natref continues to process low sulphur crudes within economically feasible limits, given that low sulphur crudes are substantially more expensive than high sulphur crudes. Natref is constrained in further reducing sulphur content in its crude feedstocks, since the refinery was never designed to process low sulphur crudes. Natref's refining margin would be further reduced and potentially compromise business sustainability, if the refinery processed even lower sulphur crudes. The business implications of not going for even lower sulphur content crudes must also be seen in the light of the additional high cost refinery upgrades that are required to meet the Clean Fuels II specifications. Even with further reduction in crude sulphur content and thus further reduction in fuel oil sulphur content (even as low as 1%), the existing and new plant limits in category 2.1 cannot be met.

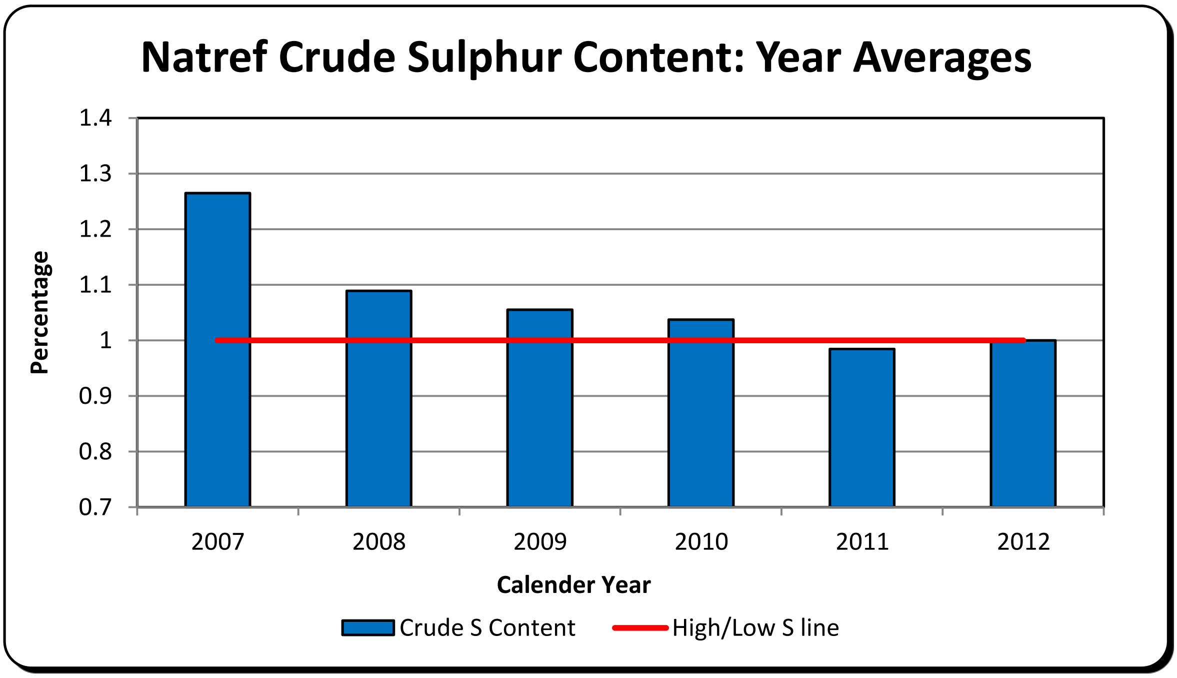

Figure 2: Natref Crude Sulphur Content: Year Averages.

2.2.3 Hydrotreatment of liquid refinery fuels

The liquid refinery fuel oil often consists of heavy residues, in which the sulphur of the crude is concentrated. Theoretically speaking it is possible to treat the liquid fuel in a hydrotreating process in order to remove the sulphur. Hydrotreatment of fuels can reduce the sulphur, nitrogen and metal content of the refinery fractions to 0.03 – 1 %. The process uses catalysts in the presence of substantial amounts of hydrogen under high pressure and temperature to react the feedstocks and impurities with hydrogen. The hydrotreating process can be divided into a number of reaction categories: hydrodesulphurisation, hydrodenitrification, saturation of olefins and saturation of aromatics. A hydrotreater unit specifically employed to remove sulphur is usually called a hydrodesulphurisation unit (HDS).

Achieved environmental benefits of hydrotreating of fuels reduce the feed nitrogen, sulphur and metals content, which in turn reduces the SO_2, NO_x and particulate emissions. The hydrotreatment of fuels is an extremely energy intensive process requiring high pressures and temperatures resulting in increased fuel oil, fuel gas, electricity and steam requirements. Moreover, effluent water and waste (used catalyst) are generated. The process is also very expensive (due to high capital costs of equipment), increasing the cost of the liquid refinery fuel beyond feasible limits.

2.2.4 Flue gas desulphurisation

Flue gas desulphurisation options primarily reduce SO_2 and additionally PM concentrations in flue gas. The following options were considered: caustic scrubbing, lime scrubbing, regenerative SO_2 removal and SNO_x.

Caustic Scrubbing: SO_2 in the flue gas is reacted with the caustic soda in the scrubbing water to form sodium sulphates (Na_2SO_4). Particulate matter is also collected. Waste water containing these compounds is purged from the scrubber. For cases where the SO_2 amount is high that caustic scrubbing becomes impractical from the perspective of caustic consumption and salt production. At Natref waste water containing approximately 90 tons/day Na_2SO_4 would be generated and would require waste handling and disposal. The estimated amounts of NaOH required for the process is excessive (>5200tons/year) and water required for the process is in excess of 300 Megalitres/year.

Over 2000 tons/year solid filtercake would have to be disposed of and over 100 Megalitres/year of waste water would also require disposal.

Lime Scrubbing: SO_2 in the flue gas is reacted with the lime in the scrubbing water. Lime scrubbing is an inherently more complex process than caustic scrubbing. In this case the SO_2 is converted to solid $CaSO_4$ (gypsum); the required sulphite to sulphate oxidation takes place in the scrubber. The scrubber contents are partly solid, and the solid gypsum product must be dewatered and handled (likely disposed to landfill). The amount of gypsum waste produced is in the order of 88 ton/day (as pure $CaSO_4$).

The solid and liquid wastes generated from caustic and lime scrubbing are excessive. Given Natref's inland location, apart from disposal to landfill there are currently no feasible solutions for disposal liquid and solid effluents generated from caustic or lime scrubbing.

This technology would also require annual shutdown and maintenance which is not aligned with the shutdown and maintenance schedules for refineries, where units run typically for several years in between shutdowns. Natref's technical assessment was unable to identify a refinery that had installed this technology.

Regenerative SO_2 Removal: Regenerative SO_2 removal selectively removes SO_2 from flue gas in a scrubber using an absorption solution containing phosphate salts. The SO_2-laden solution is thermally regenerated, the regenerated absorption solution returns to the scrubber (similar to amine-based acid gas removal). Solids contained in the flue gas are removed. A purge stream is required to remove non-regenerable salts (mainly originating from SO_3 in the flue gas). The SO_2 is stripped out as a concentrated gas stream. Disposal of this stream is required.

Disposal options include:

- Use as feedstock for an H_2SO_4 plant
- Routing to SRU for conversion to elemental sulphur with H_2S from refinery amine regenerators
- Production of liquid SO_2 (only valid if a market exists)

Regenerative wet scrubbing systems are used only very rarely with few commercial references. The disadvantage of this process is the capital cost of the installation as well as its operating cost (steam, power).

SNO_X: Another option is to oxidise SO_2 contained in the flue gas to SO_3, which then reacts with water contained in the flue gas and condenses as H_2SO_4. The process removes NO_x as well as converting SO_2 to low-strength H_2SO_4 by an oxidation step, followed by cooling and condensing of low-strength sulphuric acid in a special glass condenser. Inherently the process also removes PM (by means of an electrostatic precipitator at the process front end), as this is required to keep the downstream de-NO_x and SO_2 oxidation catalysts clean.

Table 5: Summary of technology feasibility assessment associated with compliance with the MES for SO_2

TECHNICAL OPTION	EMISSION SPECIES ADDRESSED	ASSESSMENT OF TECHNOLOGY FEASIBILITY	SUMMARY OF REASONS FOR FEASIBILITY ASSESSMENT
Replacement of refinery fuel oil	SO_2, PM and NO_x reduction	Not feasible	Availability of suitable alternative fuel. Availability of a market for fuel oil.
Processing of Low Sulphur Crudes	SO_2, NO_x and PM reduction	Not feasible	Natref is already processing crudes with sulphur content of <1wt%, further reductions are not feasible.
Hydrotreatment of refinery fuel oil	SO_2, PM and NO_x reduction	Not feasible	Energy intensive process – very high operating cost. Increases the cost of refinery fuel oil beyond feasible limits. Infeasible high CAPEX required.
Flue gas desulphurisation – Caustic and Lime Scrubbing	SO_2 and PM reduction	Not feasible	Large volume of effluent produced. High additional salt load to be treated. Large amounts of fresh water required. Brine stream to be treated and disposed considering strict inland water discharge requirements. High capital investment required. Large amount of caustic/lime to be stored.
Flue gas desulphurisation – Regenerative SO_2 Removal	SO_2 and PM reduction	Not feasible	Infeasible high capital investment required Effluent produced. Additional salt load to be treated/disposal. Brine stream to be treated and disposed considering strict inland water discharge requirements. Not widely commercialized.
Flue gas desulphurisation – SNO_X	SO_2, PM and NO_x reduction	Not feasible	Infeasible high capital investment required. Sulphuric acid market required. Not widely commercialised. Inherently complex due to sulphuric acid handling

2.3 Technology options for compliance: NO_x

NO_x emissions are considered as the sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2). NO_x emissions from refineries depend on the fuel type, fuel nitrogen and hydrogen content, combustor equipment design, and operating conditions. Accordingly, large differences in the NO_x emission level can be expected between refineries and even within different combustion equipment at the same refinery at different times.

Differences in temperature, residence time, and oxygen concentration result in varying levels of thermally formed NO_x. The influence of temperature is most important with NO_x emissions increasing exponentially with temperature. As a first approximation, NO_x emissions are magnified by the use of hydrogen and residual fuels containing fuel bound nitrogen. High hydrogen fuels result in higher flame temperatures, which lead to higher NO_x levels. Although all the fuel nitrogen does not end up as NO_x emissions, the fuel NO_x contributions can range from negligible, as in the case of natural gas fuelled equipment, to several times the thermal NO_x contribution of the equipment for refinery fuels. Refinery gaseous fuels often contain nitrogen containing amines and other compounds.

For gas fired boilers and furnaces, existing plant standards for NO_x are already met, however new plant standards for NOx are not currently met for fuel oil fired boilers.

For fuel oil fired boilers, NOx emissions result from the combustion of nitrogen present in refinery fuel oil. As such, emissions are directly related to the nitrogen content of crude oil. Oil burning normally leads to higher levels of NOx releases for several reasons, especially the problem of fuel NOx arising from the nitrogen content, the need to balance NOx and particulate releases and the frequent design requirement for firing in combination with gas.

For refinery fuel oil fired boilers the exceedingly stringent point source standard in the MES is not aligned with international practice. The EU (European Union) limit for NOx is 450 mg/Nm^3 for combustion installations using liquid production residues as non-commercial fuel for own consumption with a total rated power not exceeding 500 MW (applicable to plants operating prior to November 2003). The EU limits make provision for the fact that it is difficult to meet stringent limits with existing plants which need to be retrofitted with NO_x abatement technology. This limit is supported by Best Available Technique (BAT) and Best Available Techniques Reference documents (BREF) references and is significantly less stringent than the standard required by the MES. The 250 mg/Nm^3 prescribed by the MES is seen as unrealistic for an existing plant fired on refinery fuel oil. The EU (European Union) limit for NO_x on fuel gas fired boilers is 300mg/Nm^3 for plants operating prior to November 2003, the limit for plants built after 2003 is 200 mg/Nm^3.The EU limits make provision for the fact that it is difficult to meet stringent limits with existing plants which need to be retrofitted with NOx abatement technology. The EU limits also recognise that different limits are applicable when firing different fuel sources (e.g. Natural gas vs. fuel gas), whereas the MES does not make any distinction. The EU limits are significantly less stringent than the new plant standard required by the MES. The 50 mg/Nm^3 prescribed by the MES are considered unrealistic for an existing plant fired on refinery fuel gas.

An international technology scan was conducted, and a variety of options and technologies were investigated for the purpose of bringing NO_x emissions into compliance with the standards. Techniques to reduce NO_x emissions fall into two broad categories. Primary techniques include NO_x control techniques, such as pre-combustion operational changes and combustion modifications. Secondary techniques include the post-combustion flue gas treatments or NO_x abatement techniques.

The following options were evaluated for compliance with NOx emission limits:

- Installation of Low NO_x burners

- Installation of Ultra Low NO_x burners
- Flue gas recirculation
- Reburning (fuel staging)
- Selective Non-Catalytic Reduction
- Selective Catalytic Reduction
- Hydrotreatment of liquid refinery fuels
- Flue gas desulphurisation options: SNO_x

The various options were evaluated at conceptual development level to establish the optimal solution for Natref that had the least negative impact in all the areas.

2.3.1 Installation of Low NO_x Burners

Low-NO_x burners, have the aim of reducing peak temperature, reducing oxygen concentration in the primary combustion zone and reducing the residence time at high temperature, thereby decreasing thermally formed NO_x. Low-NO_x burners achieve NO_x reduction performances of 40 - 60% for gaseous fuels and 30 - 50% for liquid fuels.

Application is straightforward for new installations of both fired heaters and boilers. Some liquid fuels are not suitable for the latest generation of low-NO_x burners and some older fired heaters are fitted with large high intensity burners which cannot be retrofitted with new low-NO_x burners. Retrofitting of low-NO_x burners depends on the furnace design and may be difficult or, because of the increased flame volume, impossible without changing the furnace. For instance the increased length of low-NO_x burners may restrict applicability in furnaces built low above-ground. NO_x abatement on older furnaces and boilers is less effective due mainly to the need to avoid flame impingement on the furnace tubes. According to CONCAWE retrofitting existing boilers with Low-NO_x burners is not always possible since the boiler may not be designed to handle increased flame lengths.

The installation of Low-NO_x Burners would reduce the NO_x emissions, but will not reduce NO_x to below the new plant standard. Additional investment is needed to reduce NO_x to meet requirements, e.g. ultra Low-NO_x burners (this is very uncommon for refineries).

2.3.2 Installation of Ultra- Low NO_x Burners

Ultra-low-NO_x burners add internal recirculation of flue gases to the features of the low-NO_x burner, enabling further NO_x reductions. Ultra-low-NO_x burners applied to process heaters and boilers can achieve a 60 - 75 % reduction of NO_x emissions. Retrofitting existing boilers with ultra-low NO_x burners is usually not practical or possible due to fuel incompatibility and flame lengths as described above. Furthermore, for oil firing there is a direct link between NO_x and particulates i.e. reduction in NO_x decreases flame temperature which leads to incomplete burnout with a resultant increase in particulates. For the same reason, CO emissions would also be increased.

Refinery gas firing with ultra-low-NO_x burners in both forced and natural draft conditions may show signs of instability, particularly at low turndown and low excess air. Burner testing to explore the limits of combustion prior to site installation is required. Installation of ultra-low NOx burners normally requires major changes to the furnace floor structure and controls.

2.3.3 Flue gas recirculation

External flue gas recirculation (FGR) is applied to boilers and heaters to increase the diluent effect, hence to reduce combustion temperature. Typically 20% of the available flue gas from the boiler stack is ducted to mix with fresh combustion air.

The process is difficult to control especially during turndown. In a boiler retrofit, FGR increases hydraulic loads, and shifts the heat load towards the convective Section. It is therefore not usually possible to retrofit existing boilers with FGR. Safety considerations due to the possibility of explosion in the event of a tube burst make FGR impractical for fired heater applications.

2.3.4 Reburning

Fuel staging, also called reburning, is based on the creation of different zones in the furnace by staged injection of fuel and air. The aim is to reduce NO_x emissions, which have already been formed back to nitrogen. This technique adds to the flame cooling a reaction by which organic radicals assist in the breakdown of NO_x. This technique is applicable to new furnaces.

2.3.5 Selective Non-Catalytic Reduction

SNCR is a non-catalytic process for removing oxides of nitrogen from the flue gas by gas phase reaction of ammonia or urea at high temperature. Ammonia is injected into the area just above the boiler combustion chamber. The reaction only occurs in a limited temperature window of between 900 and 1100°C. Below this temperature, ammonia does not react and ammonia slip will occur, causing ammonia emissions to atmosphere. Above this temperature window, sticky ammonium bisulphate forms which can cause fouling of the air heaters. An USA study reports that SNCR is not used frequently for control of NO_x and that only 12 of the 150 boilers/heater installations of 8 refineries use this type of technique. The reason for this is due to operational risk to the boiler if it is not operated and controlled carefully. Application is complicated when flue gases to treat come from the combustion of heavy fuel oil.

In addition, SNCR has the following consequences:

- Risk of NH_3 or urea emissions (storage and non-reacted) leading to additional particulate matter formation ($PM_{2.5}$) through secondary chemical reactions, and possible side reactions leading to increased nitrous oxide emissions
- Turndown is problematic, due to the strict level of control required.
- A side reaction of particular concern is the formation of ammonium sulphates when firing sulphur-containing fuels such as liquid refinery fuel. Sulphates give rise to the fouling and corrosion of downstream equipment.
- Storage of gaseous ammonia has a great hazardous potential. The use of urea causes higher emissions of CO and N_2O and can cause high-temperature corrosion.
- The experience of application of SNCR on oil-fired heaters is limited.

The Natref boilers operate at temperatures in the range of 400°C which is below the temperature window for the effective operation of SNCR. SNCR is not deemed feasible for NO_x reduction in the Natref boilers.

2.3.6 Selective Catalytic Reduction

A further deNO_x technique is known as catalytic deNO_x. The ammonia vapour is mixed with the flue gas through an injection grid before being passed through a catalyst to complete the reaction. Various catalyst formulations are available for different temperature ranges: zeolites for 300 - 500 °C, traditional base metals employed between 200 - 400 °C, for low temperature applications 150 - 300 °C metals and activated carbon are used. With SCR removal efficiencies of 80 to 95 % can be obtained. Residual NO_x stack levels of 10 - 20 mg/Nm3 can be obtained by application of SCR in gas fired boilers and furnaces. When firing heavy residues emissions of < 100 mg/Nm3.

Even though substantial NO_x reductions can potentially be achieved using SCR, the following renders the process infeasible:

- When the temperature is lower than required it is necessary to reheat-up the flue gas with the consequent use of energy.
- The systems also need the equipment necessary for the storage of ammonia or urea.

- Disadvantages also included NH_3 slipping to atmosphere (5 - 40 mg/Nm^3), leading to additional particulate matter formation (PM $_{2.5}$) through secondary chemical reactions, and possible side reactions leading to increased nitrous oxide emissions.
- The installations are bulky and require significant plot space, which is not available within the refinery. The introduction of an SCR-system into an existing installation is also a challenge due pressure and temperature problems.
- Pressure drop can be an important consideration as to whether SCR can be applied to a flue gas system, which makes natural draft furnaces infeasible

In light of the significant negative operating risks, and associated low relative NO_x reduction achievable by this technology, it is deemed not feasible for NO_x reduction in the Natref boilers.

Table 6: Summary of technology feasibility assessment associated with compliance with the MES for NO_x

TECHNICAL OPTION	ASSESSMENT OF TECHNOLOGY FEASIBILITY	SUMMARY OF REASONS FOR FEASIBILITY ASSESSMENT
Low NO_x Burners on refinery fuel gas fired boilers	50mg/Nm^3 - Not feasible	Will not be able to reach the new plant standard due to technology limitations and retrofit requirements.
Low NO_x Burners on refinery fuel gas fired boilers	250-300 mg/Nm^3 - Feasible	250 mg/Nm^3 is achievable when retrofitting existing boilers.
Ultra Low NO_x Burners	Not feasible for retrofit	Not possible to retrofit existing boilers with Ultra Low NO_x burners due to increased flame lengths.
Flue Gas Recirculation	Not feasible for retrofit	The process is difficult to control especially during turndown. In a boiler retrofit, FGR increases hydraulic loads, and shifts the heat load towards the convective Section. It is therefore not usually possible to retrofit existing boilers with FGR. Safety considerations due to the possibility of explosion in the event of a tube burst make FGR impractical for fired heater applications.
Reburning	Not feasible for retrofit	Applicable to new furnaces.
SNCR	Not feasible for retrofit	Not applicable for Natref boilers (high combustion temperatures required).
SCR	Not feasible for retrofit	Space constraints. High capital and operating cost technology. Safety risks associated with construction in very constrained space. Very careful control of operating parameters within a narrow range is required, due to the environmental risk of ammonia slip and the significant operational risk of fouling of air heaters. Reduction of boiler efficiency and availability. Increased greenhouse gas emissions due to lower efficiencies.

2.4 Postponement request

2.4.1 Postponement Request: gas fired boilers

Natref intends to retrofit the existing two steam boilers with Low NO_x burners. With Low NO_x burners, a NO_x emission level of 250mg/Nm^3 is achievable. Natref therefore applies for a five-year postponement from the MES for its Gas Combustion Installations, as indicated in Table 7. Natref proposes the following maximum emission concentrations as alternative emissions limits to be incorporated in its Atmospheric Emissions Licence as set out in Table 7, to prevail during the period of postponement.

Table 7: Alternative emission limit request for the Gas Fired Boilers

Emission component(s)	**Emission standard for existing plants**	**Emission standard for new plants**	**Alternative Emission Limit Requested (*ceiling limit*)[a]**	**Averaging period for compliance monitoring**
	All values specified at 3O_2 273 K and 101.3 kPa, mg/Nm^3			
NO_x	300	50	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report. From 1 April 2018 until 31 March 2020: 500 From 1 April 2020: 250*	Daily average

[a] Since the MES prescribes ceiling limits, the alternative emissions limits requested are aligned to the maximum emission levels expected under all normal operating conditions. The alternative emissions limits proposed are based on a daily averaging period for compliance monitoring.

* As confirmed in the foreword to this appendix, this application relates to postponement of the 2015 existing plant standard only. However, for completeness' sake, these are the limits which Natref could meet in the longer term, based on current available information.

2.4.2 Postponement request: fuel oil fired boilers

Natref applies for a five-year postponement from the MES for its liquid fuel combustion installations. Natref proposes the following maximum emission concentrations as alternative emissions limits to be incorporated in its Atmospheric Emissions Licence as set out in Table 8, to prevail during the period of postponement.

Table 8: Alternative emissions limit request for the Fuel Oil Fired Boilers

Emission component(s)	Emission standard for existing plants	Emission standard for new plants	Alternative Emission Limit Requested (*ceiling limit*)[a]	Averaging period for compliance monitoring
	All values specified at 3% O_2 273 K and 101.3 kPa, mg/Nm^3			
PM	75	50	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report. From 1 April 2018 until 31 March 2020: 300 From 1 April 2020: 300*	Daily average
SO_2	3500	500	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report From 1 April 2018 until 31 March 2020: 5 200 From 1 April 2020: 5 200*	Daily average
NO_x	1100	250	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report From 1 April 2018 until 31 March 2020: 500 From 1 April 2020: 500*	Daily average

[a] Since the MES prescribes ceiling limits, the alternative emission limits requested are aligned to the maximum emission levels expected under all normal operating conditions. The alternative emission limits proposed are based on a daily averaging period for compliance monitoring.

* As confirmed in the foreword to this appendix, this application relates to postponement of the 2015 existing plant standard only. However, for completeness' sake, these are the limits which Natref could meet in the longer term, based on current available information.

2.4.3 Postponement request: Refinery Heaters excluding Vacuum Off-gas Furnace

Natref applies for a five-year postponement for its fired heaters. Natref proposes the following maximum emission concentrations as alternative emission limits to be incorporated in its Atmospheric Emissions Licence, as set out in Table 9, to prevail during the period of postponement.

Table 9: Alternative emissions limit request for the Refinery heaters excluding Vacuum Off-gas Furnace

Emission component(s)	Emission standard for existing plants	Emission standard for new plants	Alternative Emission Limit Requested (*ceiling limit*)[a]	Averaging period for compliance monitoring
	All values specified at 10% O_2 273 K and 101.3 kPa, mg/Nm^3			
PM	75	50	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report From 1 April 2018 until 31 March 2020: 150 From 1 April 2020: 150*	Daily average
SO_2	3500	500	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report From 1 April 2018 until 31 March 2020: 3 200 From 1 April 2020: 3 200*	Daily average

[a] Since the MES prescribes ceiling limits, the alternative emission limits requested are aligned to the maximum emission levels expected under all normal operating conditions. The alternative emissions limits proposed are based on a daily averaging period for compliance monitoring.

* As confirmed in the foreword to this appendix, this application relates to postponement of the 2015 existing plant standard only. However, for completeness' sake, these are the limits which Natref could meet in the longer term, based on current available information.

2.4.4 Outlook on achievable 2020 emissions: Refinery Bubble

Notwithstanding the fact that Natref will comply with the existing plant bubble standard for SO_2, it has outlined the challenge it will face in respect of meeting the stringent new plant standard for the SO_2 bubble, and indicates in Table 10 that the existing plant standard can be upheld over the longer term, based on present information.

Table 10: Outlook on achievable 2020 emissions for the Refinery Bubble

Emission component(s)	Emission standard for existing plants	Emission standard for new plants	Achievable 2020 refinery bubble (*ceiling limit*)	Averaging period for compliance monitoring
	Kg SO_2/ton crude			
SO_2 bubble	1.2	0.4	1.2	Daily average

* As confirmed in the foreword to this appendix, this application relates to postponement of the 2015 existing plant standard only. However, for completeness' sake, these are the limits which Natref could meet in the longer term, based on current available information.

3 Vacuum Pre-flash Off-gas Furnace

3.1 Applicable standards

MES Category 2.1 prescribes emission limits applicable combustion installations.

Table 11: Excerpt from MES Category 2.1 – Combustion Installations

Description	Combustion installations not used primarily for steam raising or electricity generation (furnaces and heaters).		
Application:	All refinery furnaces and heaters.		
Substance or mixture of substances		**Plant status**	**mg/Nm³ under normal conditions of 10% O_2, 273 Kelvin and 101.3 kPa.**
Common name	**Chemical symbol**		
Particulate Matter	N/A	New	70
		Existing	120
Sulphur dioxide	SO_2	New	1000
		Existing	1700
Oxides of Nitrogen	NO_x expressed as NO_2	New	400
		Existing	1700

The following special arrangement shall apply:

- A bubble cap of all Combustion Installations and Catalytic Cracking Units shall be at 1.2 kg SO_2/ton for existing plants.
- A bubble cap of all Combustion Installations and Catalytic Cracking Units shall be at 0.4 kg SO_2/ton for new plants.

This additional postponement application pertains to the existing plant standard PM and SO_2 standards. Notwithstanding that the additional postponement is made in terms of 2015 existing plant standards, for completeness' sake, this chapter outlines the challenges faced in meeting the PM and SO_2 new plant standards.

3.2 Description of the point source

The Vacuum off-gas furnace is utilised for the combustion of H_2S containing vacuum pre-flash off-gas and a polymer from the Alkylation unit. The combustion of H_2S containing gas results in SO_2 emissions. The flue gas from this furnace is a very small stream contributing negligibly to the overall refinery SO_2 emissions. However, due to the small flow rate of the flue gas, elevated SO_2 concentrations are seen from this source.

3.3 Technology options for compliance

Natref will investigate alternative routing of the H_2S containing streams. In order to re-route these streams, modifications to the furnace will be required. Modifications to this furnace can only be done during a planned maintenance shutdown. The vacuum unit undergoes a planned maintenance shutdown every five years. Major tie-ins required for projects to connect existing and new equipment are completed during these shutdowns. Once the re-routing of the H_2S containing streams has been implemented, the vacuum pre-flash off gas furnace would reduce its high SO_2 concentrations to the same level of the other furnaces, described in the preceding Section.

3.4 Postponement request

Natref applies for a five-year postponement for its fuel oil fired heaters. Natref proposes the following maximum emission concentrations as alternative emissions limits to be incorporated in its Atmospheric Emissions Licence, as set out in Table 12, to prevail during the period of postponement.

Table 12: Alternative emissions limit request for the Vacuum pre-flash Off-gas Furnace

Emission component(s)	Emission standard for existing plants	Emission standard for new plants	Alternative Emission Limit Requested (*ceiling limit*)[a]	Averaging period for compliance monitoring
	All values specified at 10% O_2 273 K and 101.3 kPa, mg/Nm³			
PM	75	50	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report. From 1 April 2018 until 31 March 2020: 150 From 1 April 2020: 150*	Daily average
SO_2	3500	500	From 1 April 2015 to until 31 March 2018: As per main stack measurements, as detailed in the motivation report. From 1 April 2018 until 31 March 2020: 50 000 From 1 April 2020: 3 200*	Daily average

Since the MES prescribes ceiling limits, the alternative emissions limits requested are aligned to the maximum emission levels expected under all normal operating conditions. The alternative emissions limits proposed are based on a daily averaging period for compliance monitoring.

* As confirmed in the foreword to this appendix, this application relates to postponement of the 2015 existing plant standard only. However, for completeness' sake, these are the limits which Natref could meet in the longer term, based on current available information.