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Best Available Technology (BAT) Report

Hamriyah IPP Sharjah UAE

25 May 2018

395137

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Acronyms

AEL	Associated Emission Level
BAR	Barometric pressure
BAT	Best Available Technology
BATNEEC	Best Available Technology Not Exceeding Excessive Cost
BREF	BAT reference guidance
CCGT	Combined Cycle Gas Turbine
CEMS	Continuous emissions monitoring systems
CO	Carbon monoxide
EHS	Environmental Health and Safety Guidelines
GIIP	Good International Industry Practice
GTs	Gas turbines
HRSG	Heat Recovery Steam Generator
IED	Industrial Emissions Directive
IFC	International Finance Corporation
IPP	Independent power producer
MW	Megawatt
MWth	Megawatt thermal
NGO	Non-government organisations
NO	Nitrogen monoxide
NO_x	Oxides of nitrogen
NO_2	Nitrogen dioxide
%	Percent
SNOC	Sharjah National Oil Corporation
SO_2	Sulphur dioxide
SO_x	Sulphur oxides

1 Introduction

1.1 Overview

This report describes the Best Available Technology Not Exceeding Excessive Cost (BATNEEC) (hereafter referred to as BAT) assessment undertaken for the Hamriyah Independent Power Plant (IPP) in Sharjah UAE, hereafter referred to as the proposed project.

1.2 Project location

The proposed project will be located on the Arabian Gulf coast 5km south-west of Al Hamriyah, 6.5km north-east of Al Owan and 21.5km west-north-west of Al Zubair in the Emirate of Sharjah, United Arab Emirates (GPS location: 25° 27.649'N 55° 28.665'E).

1.3 Summary project description

The proposed project will be based on combined cycle gas turbine technology with a nominal capacity of 1800MW delivered by three identical power blocks. Each power block will consist of the following major equipment:

- GE 9HA.01 gas turbine
- Hydrogen cooled generator, directly cooled to the gas turbine
- Triple pressure re-heat heat recovery steam generator (HRSG) dedicated to the gas turbine. HRSG is equipped with both main and bypass stacks.
- Triple pressure re-heat steam turbine
- Air cooled generator directly cooled to the steam turbine
- Direct cooled condenser to condense steam from the steam turbine
- Usual balance of plant equipment such as pumps, pipes and cables/power lines.

The gas turbines will be fired on either natural gas, imported liquified natural gas (LNG), or fuel oil as a back-up fuel in the event of unavailability of suitable gas. The gas will be supplied directly to the plant by the Sharjah National Oil Corporation (SNOC) through a single gas pipeline, the terminal point for the plant will be at the site boundary. Considering the operational experience of the existing Al Hamriyah power plant back up oil firing will be minimal, considering the operational experience of the existing Hamriyah plant oil is likely to be used for a few hours each year for testing purposes.

The Hamriyah project site already has an existing tank farm for the storage of fuel oil. The proposed project will connect to the existing tanks thus no new large-scale oil storage tanks will be required; small day-tanks may be required for emergency generators.

Seawater will be used to feed the plants cooling systems. Seawater, will be drawn via the existing sea intake structure, albeit through newly installed bays, screens and pumps. Cooling Water will be discharged to the existing sea outfall. Other waste water streams will also be discharged to the outfall after suitable treatment to render the effluent in line with the environmental standards.

The power generated by the proposed project will be evacuated to the Hamriyah 220kV substation which is located within the facility boundary in the GIS building. To accept the power from the proposed project, the substation will be expanded as part of the IPP contract.

Transmission cables will run from the power plant to the substation in covered concrete trenches.

1.4 Best available technology (BAT) overview

BAT is defined by the Industrial Emissions Directive (IED) 2010 [Ref 1] as: *"the most effective and advanced stage in the development of activities and their methods of operation which indicates the practical suitability of particular techniques for providing the basis for emission limit values and other permit conditions designed to prevent and, where that is not practicable, to reduce emissions and the impact on the environment as a whole"*

The concept of BAT is location and facility specific, with consideration being given to the environmental context of the facility. There are several sources of information which help to inform BAT. For this assessment, the following sources have been consulted:

- Integrated Pollution Prevention and Control (IPPC) European BAT reference guidance (BREF) for Large Combustion Plants 2017 [Ref 2]
- Industrial Emissions Directive (2010/75/EU) (IED) adopted in 2010 [Ref 1]
- The International Finance Corporation (IFC) Environmental Health and Safety (EHS) Guidelines for Thermal Power Plants [Ref 3]

This assessment has been undertaken accounting for the BAT conclusions presented in the European BAT reference guidance (BREF) for Large Combustion Plants 2017 [Ref 2]. The BREF 2017 presents the results of an exchange of information between numerous experts from EU Member States, environmental non-government organisations (NGO) and industry. The BREF sets out a range of limits which are achievable for existing and new plants and sets out the evidence base for the conclusions it presents.

The IED focusses on the limitation of emissions of certain pollutants into the air from large combustion plants, which are defined as having a thermal input above 50MW. The emission limits in the IED are more stringent than those featured in the IFC EHS Guidelines.

The IFC EHS Guidelines for thermal power plants contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs, commonly known as Good International Industry Practice (GIIP). The guidelines are currently in the process of being updated and a draft version is currently being consulted on. The proposed emission limits for gas turbines specified in the revised draft guidelines do not differ significantly from those contained within the current guidelines.

2 Method

2.1 Overview

The assessment evaluates BAT considerations relevant to the proposed project and the equipment proposed before providing an overall BAT conclusion. The BAT assessment has been split into the following sections.

Section 3.1 presents an evaluation of process-specific BAT considerations for the proposed project, focusing upon general BAT criteria for gas turbines (GTs)

Section 3.2 presents an evaluation of GT design efficiency

Section 3.3 presents relevant emission limits, guideline and BAT associated emission levels (AELs) from the IED and, IFC EHS Guidelines for thermal power plants and BREF 2017.

Section 3.4 provides discussion on the BAT AELs that the proposed project will not meet.

This assessment focuses on the proposed project operating in combined cycle mode only. The plant is designed as a combined cycle gas turbine and will only operate in abnormal operating circumstances if either the HRSG or Steam turbine is not operational.

3 BAT Considerations

3.1 Combined cycle gas turbines (CCGT) BAT considerations

Table 1 evaluates process-specific BAT considerations for the gas turbines (GTs) and have been taken from BREF 2017.

Table 1: Gas turbines: General BAT criteria

BREF 2017 BAT criteria summary	Current status or potential upgrade to meet BAT	Overall BAT conclusion
Environment management systems: In order to improve the overall environmental performance, BAT is to implement and adhere to an environmental management system (EMS) that incorporates all the requirements as set out in Appendix A	The IPP project company shall prepare and implement a comprehensive health, safety and environment (HSE) policy and associated procedures after the Effective Date, that will govern the IPP project company's actions at all times during the design preparation and construction of the IPP project as well as during the operating phase of the IPP Plant.	Proposed plans are considered to meet the requirements of BAT.
Monitoring: BAT is to monitor key process parameters relevant for emissions to air and water including, Flue gas flow, oxygen content, temperature, pressure, waste water flow, pH and temperature. Monitoring to be carried out in accordance with European standards. If European standards are not available, BAT is to use ISO, national or other international standards.	Emissions to air will be continuously monitored via a continuous emissions monitoring system (CEMS) and will record NO_x, SO_2, CO and O_2 emissions. Other parameters such as temperature and water content will also be monitored to enable pollutant concentrations to be reported at the appropriate normalised concentrations for comparison with emission limits and guarantees. Water discharges will be continuously monitored for required parameters. The final monitoring plan will be developed during the ESIA phase.	Proposed plans are considered to meet the requirements of BAT.
Advanced control systems: The use of a computer-based automatic system to control combustion efficiency and support prevention and/or reduction of emissions. This also includes the use of high-performance monitoring.	To be achieved by running the plant via an advanced operational system.	Proposed design is considered BAT.
Water/steam addition: Water or steam is used as a diluent for reducing the combustion temperature in combustion plants and the thermal NOx formation, either by being premixed with the fuel prior to its combustion or directly injected in the combustion chamber (water/steam injection).	When burning fuel oil, the NO_x emission shall be controlled by water injection (if required).	Proposed design is considered BAT.
Dry low-NOx burners (DLN): Gas turbine burners that include the premixing of the air and fuel before entering the combustion zone. By mixing air and fuel before	When burning natural gas in turbines, such turbines will be equipped with dry low NOx burners.	Proposed design is considered BAT.

BREF 2017 BAT criteria summary	Current status or potential upgrade to meet BAT	Overall BAT conclusion
combustion, a lower flame temperature is achieved, resulting in lower NOx emissions.		
Low-load design concept :] Adaptation of the process control and related equipment to maintain good combustion efficiency when the demand in energy varies, e.g. by improving the inlet airflow control capability or by splitting the combustion process into decoupled combustion stages.	To be achieved by running the plant via an advanced operational system.	Proposed design is considered BAT.
Selective catalytic reduction (SCR) Selective reduction of nitrogen oxides with ammonia or urea in the presence of a catalyst. The technique is based on the reduction of NO_X to nitrogen in a catalytic bed by reaction with ammonia (in general aqueous solution) at an optimum operating temperature of around 300–450°C. Several layers of catalyst may be applied.	Not considered in plant design as secondary abatement not required to meet emissions limits.	N/A
Reduction of CO emissions: BAT is to ensure optimised combustion and/or to use oxidation catalysts.	Operation will ensure optimised combustion to minimise CO emissions. Oxidation catalysts will not be used	Proposed design is considered BAT.

Source: BREF 2017 and Hamriyah IPP MFS

3.2 Energy efficiency combined cycle gas turbines BAT

Table 2 evaluates BAT considerations for GT design efficiency taken from BREF 2017.

Table 2: Gas Turbines: General design efficiency BAT

BREF 2017 summary BAT criteria	Current Status or potential upgrade to meet BAT	Overall BAT conclusion
Combined cycle	Combination of two or more thermodynamic cycles, e.g. a Brayton cycle (gas turbine/combustion engine) with a Rankine cycle (steam turbine/boiler), to convert heat loss from the flue-gas of the first cycle to useful energy by subsequent cycle(s).	Proposed design is considered BAT.
Computerised control of the main combustion parameters enables the combustion efficiency to be improved	To be achieved by running the plant via an advanced operational system.	Current status is considered BAT.
For a new CCGT plant with electrical output >600MW efficiency between 57-60.5% is considered BAT.	The plant will generate electricity directly and utilise 'waste' heat from the turbine to generate steam to be used in the steam turbine adding to electricity generating capacity. The total electrical efficiency of the plant is expected to be approximately 61%.	Proposed design is considered BAT.

Source: BREF 2017 and Hamriyah IPP MFS

3.3 Emissions to air combined cycle gas turbines

Table 3 and Table 4 evaluate emission limits for GTs firing on natural gas and fuel oil based on international standards and presents the 2017 BREF BAT AELs which are the achievable range of emissions for new plants.

The term ‘dust’ is used when describing emissions of all particular matter (PM) including PM_{10} which has an aerodynamic diameter of less than 10 microns.

Table 3: Emission limit guidelines for CCGT plants firing natural gas

Pollutant	Industrial emissions directive (IED) limit (mg/Nm^3)	IFC Environmental, Health and Safety (EHS) Guidelines limit (mg/Nm^3)	2017 BREF BAT Associated Emission Levels (mg/Nm^3)	Proposed design	Overall BAT conclusion
NO_x	50	51	10-30	The MFS sets out an emission limit guarantees for NO_x of 51 mg/Nm^3. The proposed project will use dry low NOx burners and advanced control systems to manage NOx emissions.	Does not meet the current BAT AEL. See discussion in Table 5
CO	100	-	-	The MFS sets out an emission limit guarantees for CO of 100 mg/Nm^3. The proposed project will use advanced control systems to manage combustion.	Proposed design is considered BAT.

Source: BREF 2017, IED, IFC EHS Thermal Power Guidelines (2007) and Hamriyah IPP MFS
Notes: Reference conditions @ 15% O2, dry, 1013 Pa and 0°C

Table 4: Emission limit guidelines for CCGT plants firing fuel oil

Pollutant	Industrial emissions directive (IED) limit (mg/Nm^3)	IFC Environmental, Health and Safety (EHS) Guidelines limit (mg/Nm^3)	2017 BREF BAT Associated Emission Levels (mg/Nm^3)	Proposed design	Overall BAT conclusion
NO_x	50	152	145-250	The MFS sets out an emission limit guarantee for NO_x of 152 mg/Nm^3. This emission guarantee will be meet through the use of water injection. Further secondary abatement such as SCR is not considered proportionate for a secondary fuel considering its limited use. The BREF states that for plants operated less than 500 hours per year SCR is not applicable.	Proposed design is considered BAT
CO	100	-	-	The MFS sets out an emission limit guarantee for NO_x of 100 mg/Nm^3. The Plant will use advanced control systems to manage combustion.	Proposed design is considered BAT
SO_2	-	Use of 1% sulphur fuel assuming the airshed is non- degraded Use of 0.51% sulphur fuel assuming the airshed is degraded	35-60	Limitation of sulphur dioxide (SO_2) shall be through the burning fuel oil with low sulphur content.	Proposed design is considered BAT
Dust	-	50 assuming the airshed is non-degraded 30 assuming the airshed is degraded	2-5	The MFS sets out an emission limit guarantee for dust of 30 mg/Nm^3.	Does not meet the current BAT AEL. See discussion in Table 5 below

Source: BREF 2017 and Hamriyah IPP MFS

3.4 BAT considerations

Table 5 provides further discussion on the emission to air where the gap analysis has identified that the proposed emission guarantees to do not meet the new BAT AELs.

Table 5: Emissions to air which do not meet BAT AELs

Pollutant	Techniques listed as BAT in BREF 2017	Discussion
NO_x when firing on natural gas	For new CCGT plants the use of dry low NO_x burners and low NO_x burners and/or SCR are considered the primary measures to achieve the BAT NO_x emission level of 10-30mg/Nm^3. It should be noted that these BAT levels are based on operational data from existing plants across Europe which do not include new H class gas turbines which are new bigger more efficient models than existing gas turbines in operation. Any reduction in NOx emission performance compared to older gas turbines models such as F class machines is partly as a result of the improved thermal efficiency and reduction in CO_2 emissions that the H class machines achieve.	The GTs will feature dry low NO_x burners, which will be guaranteed to meet the IFC guidelines and IED emission limits. Under normal operation, it would be expected that the emission performance would be lower than the guaranteed level although given the proposed gas turbines are based on the new H class design it cannot be confirmed of the BAT AEL range can be achieved. However, it would not be considered BAT to install SCR to guarantee the emissions in the BAT AEL range. This is because the lower emissions would have only a small environmental benefit on ground level air quality and a case could be made that this would not be considered BAT when accounting for the additional cost associated with the SCR unit.
Dust when firing on fuel oil	The BREF 2017 sets dust AEL's at 2-5 mg/Nm3 for new plants firing on gas oil. No clear BAT conclusion of how this should be achieved is provided although it is assumed through either electrostatic precipitators of fabric filters.	The proposed project will run on natural gas so dust emission levels are expected to be well below 5mg/Nm^3 without any additional technologies when firing on its primary fuel. Guaranteed emissions limits for dust are in-line with the lowest values specified by the IFC EHS guidelines and these are considered appropriate as it would not be economically viable to install secondary dust abatement for a secondary fuel. In addition, the BAT AELs are specified for gas oil which has different properties compared to light crude oil (LCO) which the guarantees are based on for this project

Source: BREF 2017

4 Conclusion

This assessment has reviewed the current design of the proposed project operating in CCGT mode and concluded whether the current design status is BAT. Overall, it can be concluded that the current status of the proposed project is considered to meet relevant emission limits specified in the IED, and the emission guidelines specified in the IFC EHS Guidelines for thermal power plants.

The project is not guaranteed to meet all BAT AELs, of which NOx emissions are the main concern. The air quality assessment that has been undertaken as part of the environmental impact assessment has modelled the proposed project with a number of worst cast operating parameters. These included all three of the projects GTs operating continuously all year at the guaranteed emission level which is consistent with IED and IFC requirements. The results show that the air quality impact are insignificant and resultant concentrations are well below relevant air quality standards. The assessment also demonstrates that the maximum impacts are located where there is no relevant human exposure; the maximum short-term impacts are located over the sea and the maximum annual mean impacts are located within the Hamriyah Free Zone.

It is estimated that the capital costs of SCR are likely to be in the range of EUR 10-50/KWe based on information presented in the BREF 2017. Therefore, assuming the lower end of the scale, and a GT output of 446MW, the cost of SCR for the proposed project could be in the region of 4.5million EUR (5.2million USD) per unit which would be approximately 13.5million EUR (15.6million USD) for the proposed project. On this basis, not accounting for the ongoing operational costs of the SCR, no secondary measures such as SCR are considered proportionate based on the current air quality impacts and the improvements in air quality that could be achieved compared to the associated costs.

5 References

1. European Union (November 2010), *"Directive on Industrial Emissions (Integrated Pollution Prevention and Control) (Recast)",* Directive 2010/75/EU Official Journal, vol. 334, pp. 0017-0119.
2. European Commission (2017), *"Reference Document on Best Available Techniques for Large Combustion Plants"* (Integrated Pollution Prevention and Control) (BREF), EUR 28836 EN
3. The International Finance Corporation (IFC) (2007). 'Environmental Health and Safety (EHS) Guidelines for Thermal Power Plants.'

Appendices

A. Environmental and social management system (ESMS) requirements

ESMS BAT requirements include:

i. commitment of the management, including senior management

ii. definition, by the management, of an environmental policy that includes the continuous improvement of the environmental performance of the installation

iii. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment

iv. implementation of procedures paying particular attention to:

(a) structure and responsibility
(b) recruitment, training, awareness and competence
(c) communication
(d) employee involvement
(e) documentation
(f) effective process control
(g) planned regular maintenance programmes
(h) emergency preparedness and response
(i) safeguarding compliance with environmental legislation

v. checking performance and taking corrective action, paying particular attention to:
(a) monitoring and measurement (see also the JRC Reference report on monitoring of emissions to air and water from IED-installations – ROM)
(b) corrective and preventive action
(c) maintenance of records
(d) independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained

vi. review, by senior management, of the EMS and its continuing suitability, adequacy and effectiveness

vii. following the development of cleaner technologies

viii. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life including
(a) avoiding underground structures
(b) incorporating features that facilitate dismantling
(c) choosing surface finishes that are easily decontaminated
(d) using an equipment configuration that minimises trapped chemicals and facilitates drainage or cleaning
(e) designing flexible, self-contained equipment that enables phased closure
(f) using biodegradable and recyclable materials where possible

ix. application of sectoral benchmarking on a regular basis.

Specifically for this sector, it is also important to consider the following features of the EMS, described where appropriate in the relevant BAT:

x, quality assurance/quality control programmes to ensure that the characteristics of all fuels are fully determined and controlled (see BAT 9)

xi. a management plan in order to reduce emissions to air and/or to water during other than normal operating conditions, including start-up and shutdown periods (see BAT 10 and BAT 11)

xii. a waste management plan to ensure that waste is avoided, prepared for reuse, recycled or otherwise recovered, including the use of techniques given in BAT 16

xiii. a systematic method to identify and deal with potential uncontrolled and/or unplanned emissions to the environment, in particular:
(a) emissions to soil and groundwater from the handling and storage of fuels, additives, by-products and wastes
(b) emissions associated with self-heating and/or self-ignition of fuel in the storage and handling activities

xiv. a dust management plan to prevent or, where that is not practicable, to reduce diffuse emissions from loading, unloading, storage and/or handling of fuels, residues and additives

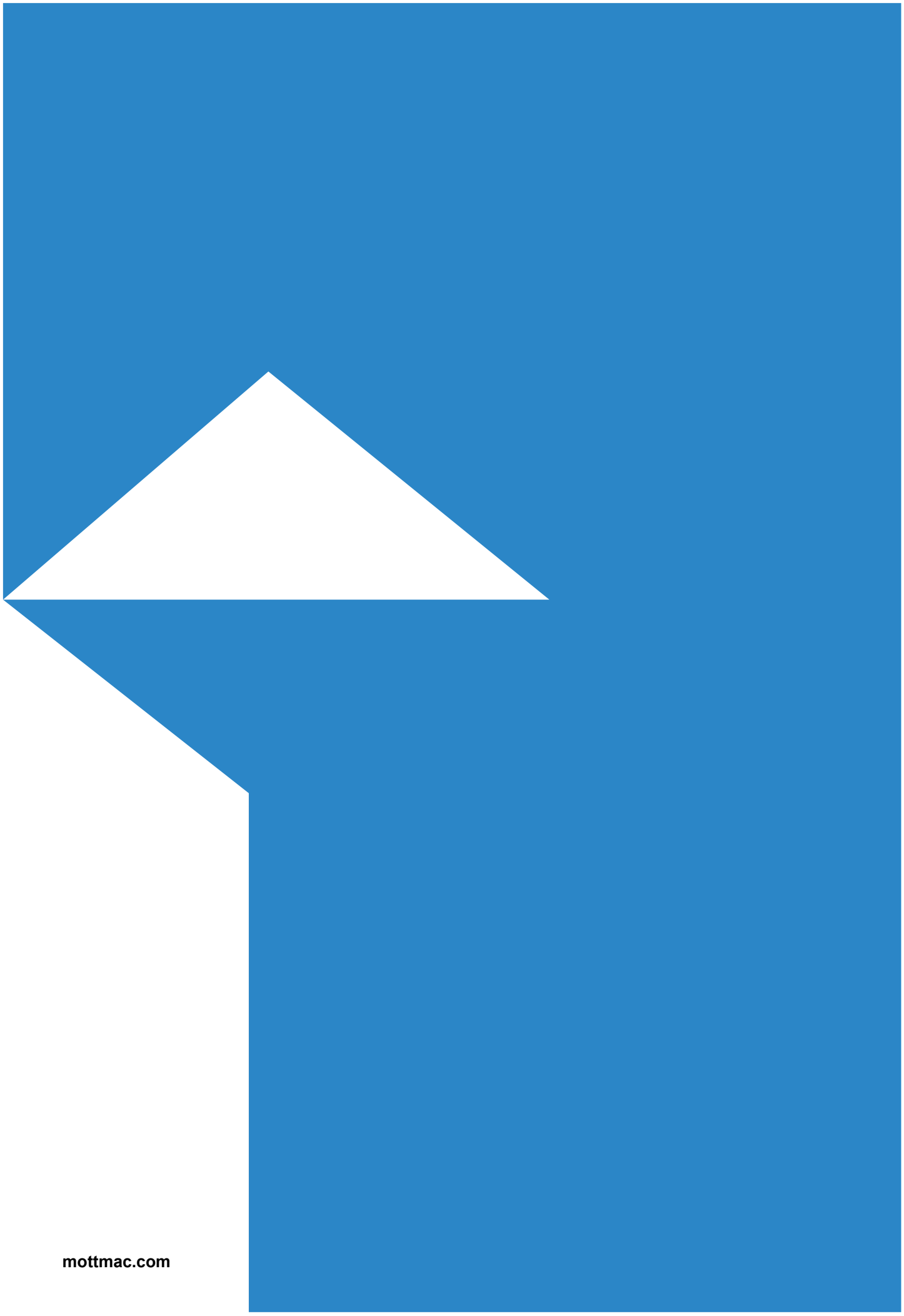
xv. a noise management plan where a noise nuisance at sensitive receptors is expected or sustained, including:
(a) a protocol for conducting noise monitoring at the plant boundary
(b) a noise reduction programme
(c) a protocol for response to noise incidents containing appropriate actions and timelines
(d) a review of historic noise incidents, corrective actions and dissemination of noise incident knowledge to the affected parties

xvi. for the combustion, gasification or co-incineration of malodourous substances, an odour management plan including:
(a) a protocol for conducting odour monitoring
(b) where necessary, an odour elimination programme to identify and eliminate or reduce the odour emissions
(c) a protocol to record odour incidents and the appropriate actions and timelines
(d) a review of historic odour incidents, corrective actions and the dissemination of odour incident knowledge to the affected parties.

Where an assessment shows that any of the elements listed under items x to xvi are not necessary, a record is made of the decision, including the reasons.

Applicability

The scope (e.g. level of detail) and nature of the EMS (e.g. standardised or non-standardised) is generally related to the nature, scale and complexity of the installation, and the range of environmental impacts it may have.



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