

ENERTRAG SOUTH AFRICA (PTY) LTD

HENDRINA WIND ENERGY AND GREEN AMMONIA FACILITY ATMOSPHERIC IMPACT REPORT

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ENERTRAG SOUTH AFRICA (PTY) LTD

REPORT (FINAL VERSION)

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1 INTRODUCTION

ENERTRAG South Africa (Pty) Ltd (ENERTRAG), propose to establish a renewable energy complex near Hendrina, Mpumalanga. The proposed renewable energy complex will include:

- Hendrina North Wind Energy Facility (WEF): up to 200 MW power generation from 27 wind turbines.
- Hendrina South WEF: up to 200 MW power generation from 26 wind turbines.
- Grid North Infrastructure: up to 275 kV overhead powerline feeding into the national energy grid.
- Grid South Infrastructure: up to 275 kV overhead powerline feeding into the national energy grid.
- Green hydrogen and ammonia production facility including electrical grid connection and water pipeline infrastructure.

Ammonia (NH₃) production in excess of 100 tons per annum triggers listed activity *Subcategory 7.1: Production and or use in Manufacturing of Ammonia, Fluorine, Fluorine Compounds, Chlorine and Hydrogen Cyanide* of Government Notice Regulation 893 of 2013¹, promulgated in line with Section 21 of the National Environmental Management: Air Quality Act (Act 39 of 2004) (NEM:AQA)². As per Section 22 of NEM:AQA, all activities listed require an Atmospheric Emissions License (AEL).

An Atmospheric Impact Report (AIR) is required as a prerequisite for the application for an AEL. WSP Group Africa (Pty) Ltd (WSP) was appointed to compile the AIR, assessing the ambient air quality impacts of the proposed facility. In line with the *Regulations Regarding Air Dispersion Modelling*³ (hereafter referred to as ‘the *Modelling Regulations*’) a Plan of Study was submitted to the licensing authority (in this case, the *Environmental Management Unit* for Nkangala District Municipality (NDM)) on 19 January 2022. The Plan of Study and the case specific limitations around quantitative assessment at this time (as detailed herein) were presented to the NDM atmospheric licensing officers on 11 March 2022. It was agreed that this AIR will thus comprise a qualitative impact assessment with further quantitative assessment conducted when operational information and site monitoring data is available to do so and will form part of the Provisional Atmospheric Emissions License (PAEL) review process.

This AIR pertains to ENERTRAG’s proposed Green NH₃ Production Facility for Hendrina only.

¹ Department of Environmental Affairs: (2013): List of Activities which result in Atmospheric Emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage (No. R. 893), Government Gazette, 22 November 2013, (No. 37054), as amended by GN 551 in 2015 and GN 1207 in 2018.

² South Africa (2005): *National Environmental Management: Air Quality Act* (No. R. 39 of 2004) Government Gazette, 24 February 2005 (No. 27318)

³ Department of Environmental Affairs (2014): *Regulations Regarding Air Dispersion Modelling* (No. R. 533), Government Gazette, 11 July 2014, (No. 37804).

2 ENTERPRISE DETAILS

2.1 FACILITY IDENTIFICATION INFORMATION

Facility details are presented in **Table 2-1** below.

Table 2-1: Facility information

Enterprise Name	ENERTRAG South Africa (Pty) Ltd
Trading As / Site Name	ENERTRAG South Africa (Pty) Ltd
Type of Enterprise	Company
Company/Close Corporation/Trust Registration Number	2017/143710/07
Registered Address	Suite 104, 1 st Floor, Albion Spring, 183 Main Road, Rondebosch, 7700
Postal Address	N/A
Telephone Number (General)	+27 21 207 2185
Fax Number (General)	N/A
Industry Type/Nature of Trade	Green ammonia production
Land Use Zoning as per Town Planning Scheme	Not confirmed
Site Name	Hendrina
Physical Address of the Facility	N/A
Description of Site (Where No Street Address)	Site option 1: Dunbar 189 IS (Portion 1 and 3) Site option 2: Dunbar 189 IS (Portion 3) and Weltevreden 193 IS (Portion 18) Site option 3: Weltevreden 193 IS (Portion 14 and 15)
Coordinates of Approximate Centre of Operations	Site option 1: -26.197972°S; 29.551636°E Site option 2: -26.204347°S; 29.561228°E Site option 3: -26.188528°S; 29.584092°E
Extent (km²)	0.25
Elevation Above Mean Sea Level (m)	1665
Province	Mpumalanga
Metropolitan/District Municipality	Nkangala District Municipality
Local Municipality	Steve Tshwete Local Municipality
Designated Priority Area	Highveld Priority Area
AEL reference number	N/A
EIA reference number	Environmental Authorisation is pending
Air quality assessment consultant	WSP Group Africa (Pty) Ltd

2.2 LOCALITY AND STUDY SITE

The proposed Hendrina renewable energy complex is located in the Steve Tshwete Local Municipality which falls within one of South Africa's key air quality regions known as the Highveld Priority Area (HPA). The Highveld area is associated with poor air quality and elevated concentrations of criteria pollutants due to the high volume of both industrial and non-industrial emission sources. The HPA was declared on 23 November 2007, covers an

area of 31,106 km² and encompasses multiple municipal jurisdictions including a single metropolitan municipality and nine local municipalities across the Gauteng and Mpumalanga provinces⁴.

The site for the proposed Green Ammonia processing facility is approximately 17 km west-southwest of the town of Hendrina. Proximate land uses (within 10 km) include coal mining activities at varying distances from the southeast through to the northwest (**Figure 2-1**). Notable mining activity includes:

- The Weltevreden colliery 3.4 km to the southeast with mineral conveyor and transfer points linking to the Halfgewonnen colliery 3.6 km to the southwest.
- The Overlooked colliery, 4.7 km to the south-southwest.
- The Forzando North colliery and mine dump 4.9 km to the south.
- The Middelkraal colliery 8.3 km to the west.
- The Bultfontein colliery 9.7 km to the northwest.
- The Kleinfontein colliery 9.9 km to the west-northwest.

The remaining land is either under cultivation or is open veld (potentially earmarked for future mining prospects). There are no known industrial sources of NH₃ within the assessment area. Localised and transient increases in ambient NH₃ concentrations may be expected from intermittent agricultural activities, such as crop spraying and burning for field clearing.

Three site alternatives are under consideration for the proposed Green Ammonia processing facility. All three sites are at an approximate elevation of 1,665 m above mean sea level and 0.2 km² in extent. Elevations within the surrounding landscape gently undulate within 100 m of this and thus the local topography is considered flat.

Sensitive receptors (i.e. places where sensitive individuals may be impacted, such as residences) identified within a 5 km radius of the general study site are listed in **Table 2-2** and presented in **Figure 2-2**.

⁴ Department of Environmental Affairs (2011): Highveld Priority Area Air Quality Management Plan (URL: <http://saaqis.environment.gov.za/>)

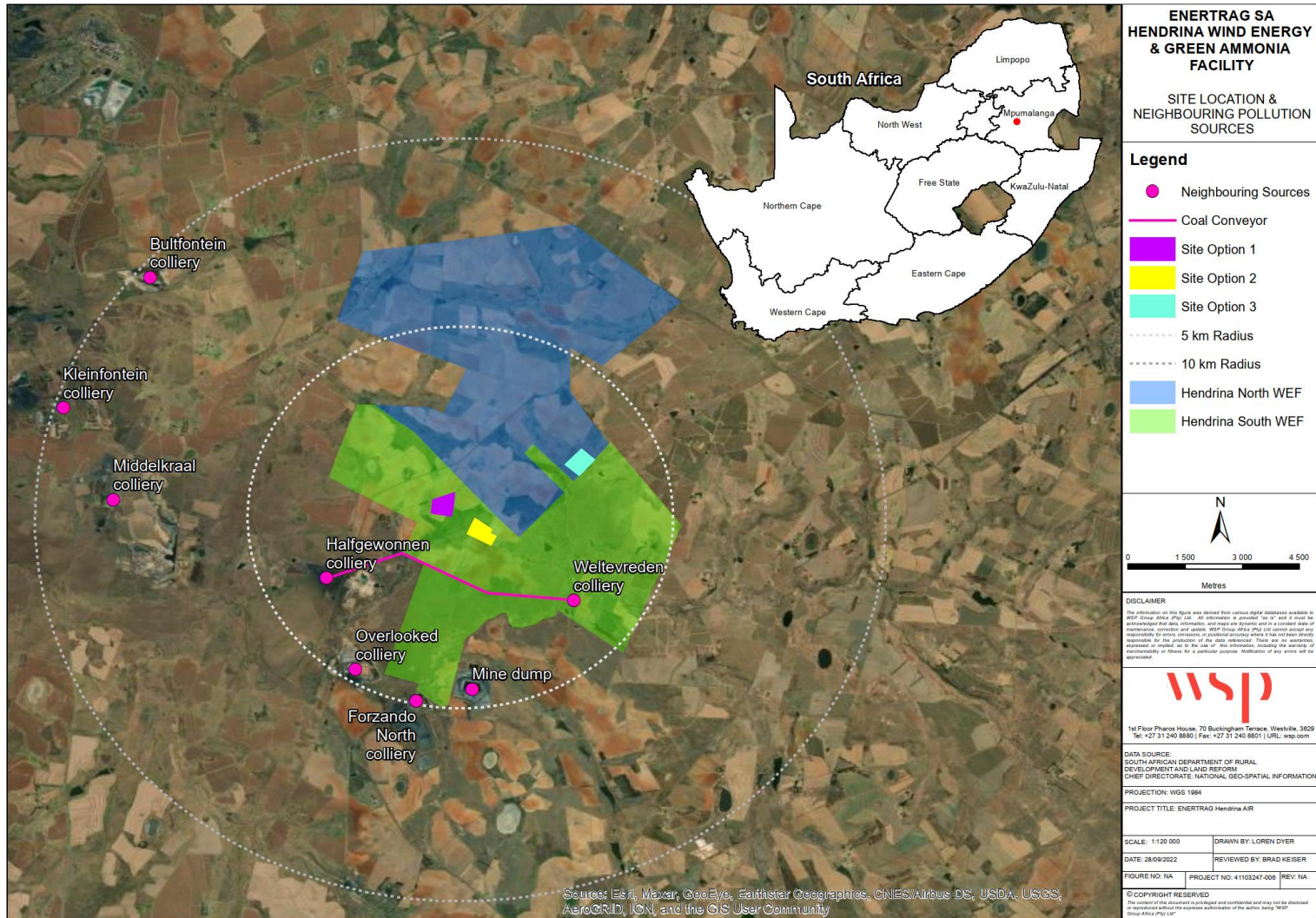


Figure 2-1: Site location and neighbouring emission sources

Table 2-2: Sensitive receptors

ID	Receptor Name	Receptor Type	Distance (km) from site			Cardinal direction			Latitude (°S)	Longitude (°E)
			Site option 1	Site option 2	Site option 3	Site option 1	Site option 2	Site option 3		
1	Halfgewonnen Office	Commercial	1.4	2.3	4.7	WSW	W	WSW	26.201068	29.538816
2	Residence 1	Residential	4.2	4.0	1.4	NE	NE	NNE	26.175948	29.586500
3	Residence 2	Residential	2.7	1.6	3.6	SE	SSE	SSW	26.217541	29.568418
4	Residence 3	Residential	4.9	3.8	2.5	ESE	E	SE	26.206837	29.599529
5	Residence 4	Residential	3.3	3.5	2.0	NE	NNE	NW	26.174362	29.572278
6	Residence 5	Residential	2.1	3.3	5.2	WNW	NW	W	26.192119	29.531528
7	Residence 6	Residential	4.3	4.5	7.4	SW	WSW	SW	26.228052	29.524666

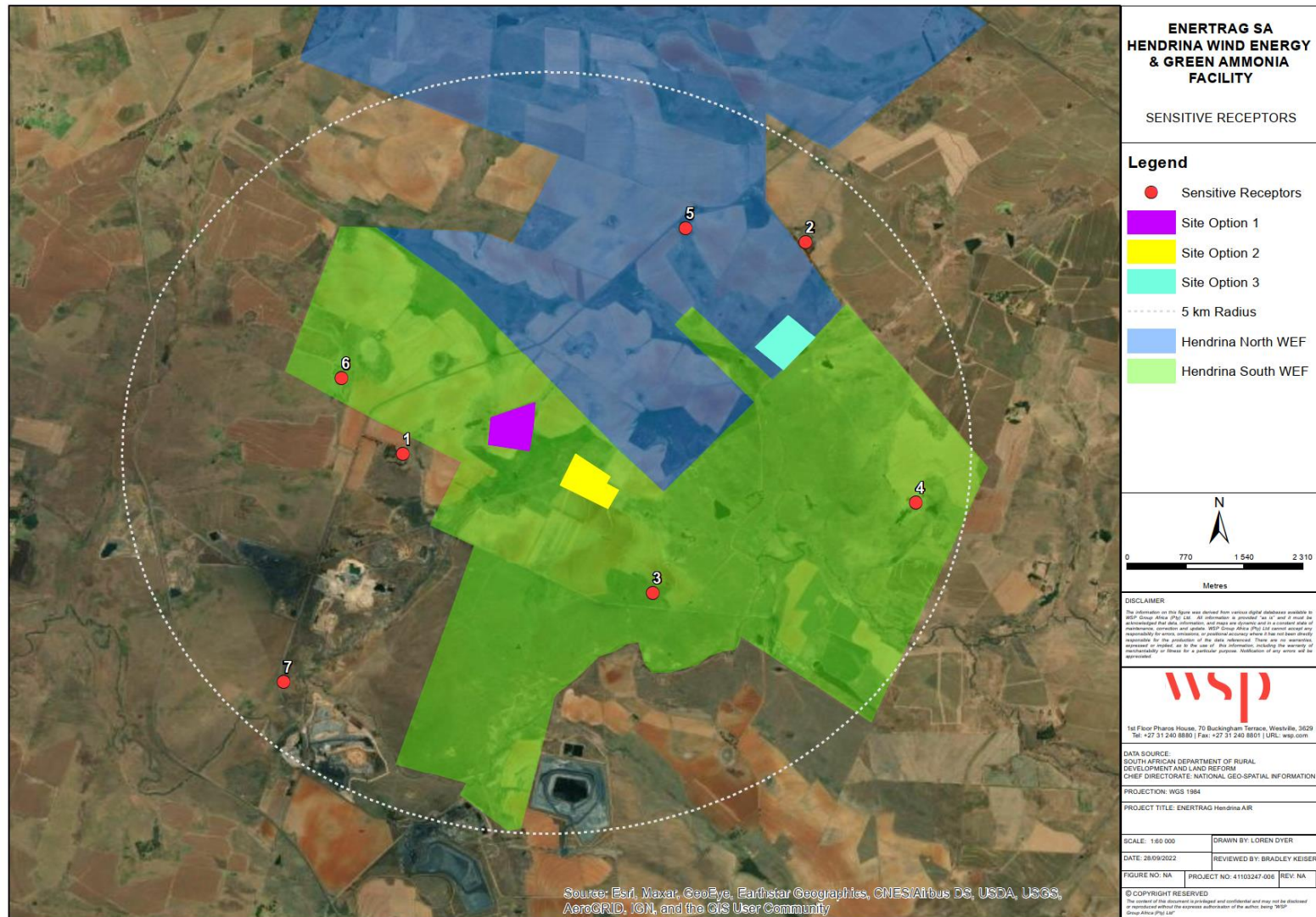


Figure 2-2: Sensitive receptors within 5 km

2.3 PROCESS DESCRIPTION

2.3.1 BACKGROUND TO GREEN AMMONIA PRODUCTION

‘Green Ammonia’ is NH_3 made using renewable energy, air and water (**Figure 2-3**). The process uses electrolysis (direct electric current to drive an otherwise non-spontaneous chemical reaction) and air separation to split water and air into its primary components i.e. hydrogen (H) and oxygen (O_2) from water, and nitrogen (N) and oxygen from air. NH_3 is then synthesised from the separated components using the Haber-Bosch method (the standard industrial process used to make NH_3). The Haber-Bosch process combines stoichiometric amounts of hydrogen and nitrogen in a moderate temperature ($\sim 400 - 500\text{ }^\circ\text{C}$), high pressure (100 barg⁵) reactor. The process requires a catalyst (usually iron-based) promoting NH_3 mixture equilibrium. The NH_3 gas generated is rapidly cooled to form anhydrous (liquid) NH_3 for easy and safe storage and transport. Any unreacted nitrogen and hydrogen is recycled back into the reactor⁶.

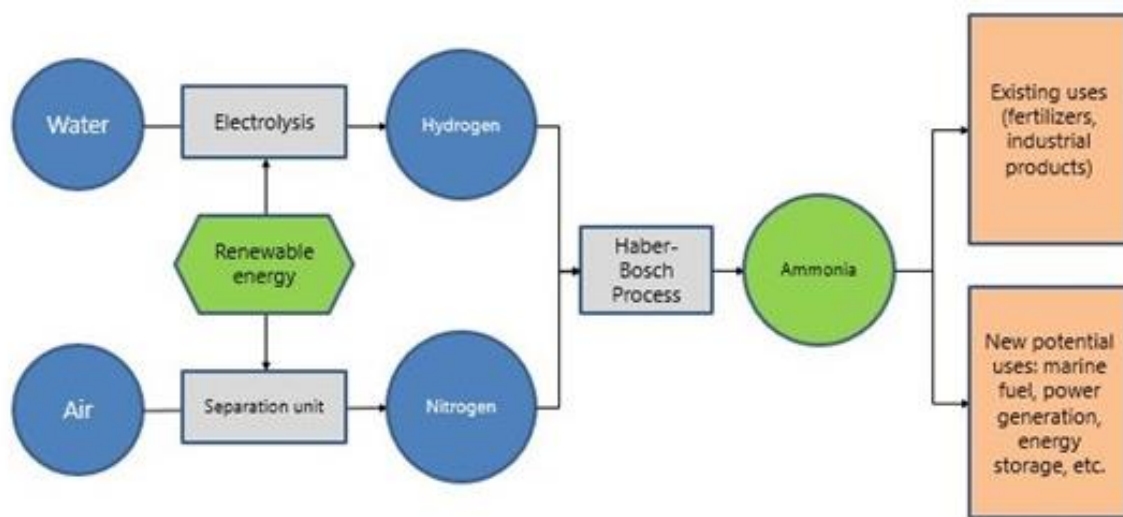


Figure 2-3: Green NH_3 production and end uses⁷

Anhydrous NH_3 is easily stored in bulk tanks and used widely as an agricultural fertilizer as well as in industrial processes. When powered by renewable energy sources (i.e. wind or solar generated electricity) the production process is 100% carbon-free. NH_3 can also be used as a fuel in combustion engines (releasing nitrogen and water vapour as opposed to harmful emissions associated with the combustion of fossil fuels) or it can be cracked back into its components and the separated hydrogen used in other applications e.g. a fuel cell for charging battery powered electric vehicles. Hydrogen derived from renewable sources is also a viable substitute for fossil fuels, however, is difficult to store and transport in bulk. NH_3 is an effective and safe storage medium for hydrogen. Green Ammonia as a hydrogen carrier, thus presents an opportunity to capture renewable energy in a form that can be stored, safely transported and used in multiple applications⁸.

2.3.2 PROPOSED PROCESS DESCRIPTION

ENERTRAG’s proposed renewable energy complex at Hendrina includes wind turbines and powerlines for the supply of renewable energy to the proposed Green NH_3 Processing Facility. The WEF and all associated Electrical Grid Infrastructure (EGI) including its auxiliary infrastructure do not result in any atmospheric pollutants of

⁵ The unit of measurement of gauge pressure (i.e. absolute pressure minus atmospheric pressure)

⁶ ENERTRAG (2021): Basis of Design – Doc no: 21004-ENT-PR-RPT-001

⁷ Argus (2020): Green ammonia – Opportunity knocks (URL: <https://www.argusmedia.com/en/blog/2020/may/28/green-ammonia-opportunity-knocks>)

⁸ Siemens Energy – The Green Ammonia Demonstration Programme (URL: <https://www.siemens-energy.com/uk/en/offerings-uk/green-ammonia.html>)

concern under normal operating conditions, nor are applicable to listed activity Subcategory 7.1 for which this AIR is required. As such, the process description that follows only covers activities relevant to the green NH₃ production process (i.e. the Subcategory 7.1 trigger).

A process flow diagram and a generic block layout of the proposed Green NH₃ Processing Facility is presented in **Figure 2-4** and **Figure 2-5** respectively. Process activities and anticipated atmospheric emissions are described below:

- **Water feedstock:** Water is required to produce hydrogen and for heating and cooling purposes. Feedstock water will be stored in a water reservoir. Water will be supplied via pipeline from the Komati Power Station. Other potential water sources being considered include groundwater (from borehole), direct municipal supply, or mine water decant (from surrounding mining houses). The feedstock water will be treated using reverse osmosis to remove wastes such as brine salt and sodium chloride (NaCl) to ensure the feedstock is of acceptable standards for electrolysis.
- **Electrolyser:** Purified water from the treatment plant will be fed through the electrolyser using electric current (renewable energy provided from the nearby planned wind farm) to separate water molecules (2H₂O) through a reduction-oxidation process, into hydrogen gas (2H₂ on that cathode side) and oxygen gas (O₂ on the anode side). It is proposed that 15 sets of 10 MW electrolysers (150 MW in total) be installed with the capacity to produce 20,000 tonnes per annum (tpa) of ‘green’ hydrogen and up to 40,000 tpa of ‘green’ oxygen. Oxygen will either be released to atmosphere or stored and sold as a by-product. Hydrogen will either be directed to the NH₃ production plant or sold directly to interested parties.
- **Air separation unit:** Air from the atmosphere (approximately 78% nitrogen, 21% oxygen and 1% trace gases) is separated into mainly nitrogen and oxygen using cryogenics (air compression and temperature manipulation), pressure swing adsorption (pressure control) and membrane separation. The air separation unit will have a capacity of 110,000 tpa.
- **Liquid air energy system (LAES):** The LAES will be used to store excess nitrogen collected from the air separation unit. Nitrogen will be cooled and stored in liquid form in insulated vessels at low pressure. The LAES will double as a backup energy source when needed. The system uses pressure changes from the superheating and evaporation of liquified air to turn gas turbines and generate electricity.
- **Ammonia (NH₃) synthesis:** Nitrogen from the air separation unit and hydrogen from the electrolyser will be reacted over a bed of catalyst to form NH₃ – as per the standard Haber-Bosch method. The NH₃ gas will be rapidly cooled to form anhydrous NH₃. Unreacted nitrogen and hydrogen will be recycled back to the reactor. At full capacity, the facility will produce up to 100,000 tpa of green NH₃ for market.
- **Purging:** Gas purging during the Haber-Bosch process depends on the quality of the hydrogen feedstock (i.e. from the electrolyser). ENERTRAG aim to produce hydrogen of exceptional purity and the water feedstock is purified prior to electrolysis. The hydrogen feedstock for the Haber-Bosch process will thus be free of impurities typically associated with, and purged, during conventional NH₃ production processes.

In ENERTRAG’s proposed green NH₃ production process, purging will only be required when noble gases (i.e. argon, neon and helium that naturally exist in ambient air and are not associated with human health impacts) from the air separation unit are fed in with the hydrogen from the electrolyser. Such a situation would be considered “upset conditions” and therefore purging is not anticipated as part of normal operations. It is highlighted that any noble gases purged during such a scenario would be present in the ambient air feedstock and not evolved in the Haber-Bosch process (i.e. these gases are returned to the atmosphere from where they originated). Any hydrogen and nitrogen that may be purged along with these noble gases are not recognised as having human health impacts, nor regulated as atmospheric pollutants in South Africa. All purging will be avoided (as practicable) to prevent feedstock losses.
- **Storage:** Hydrogen will be stored in pressure vessels (i.e. hydrogen bullets up to 800 tonnes in combined storage capacity). Green NH₃ will be stored as anhydrous NH₃ in bulk tanks (up to 3,750 tonnes combined storage capacity) at ambient pressure. Since NH₃ is a gas at ambient temperature, anhydrous NH₃ must be stored at temperatures below -33.34 °C to remain in liquid form.
- **Dispatch:** The facility will include three loading gantries for the filling of pressure vessels for dispatch by road or rail.

Anticipated atmospheric emissions from the proposed process include:

- Split gases from the air separation unit, including oxygen and other trace gases (e.g. carbon dioxide, neon, helium, methane, etc.), will be purged. It is highlighted that these gases are present in the ambient air feedstock and are not formed as a result of the proposed process. They are not used for NH₃ synthesis nor valuable or

naturally available in sufficient quantity to be collected as by-products, and thus are released back to atmosphere. These gases are also not regulated as atmospheric pollutants in South Africa.

- Assuming sufficient temperature control, no NH_3 evaporation during final product storage or loading activities are expected (refer to **Section 6** for more detail). NH_3 is the only regulated pollutant applicable to the proposed facility, however it is highlighted that this is not from the manufacturing process as may be expected with conventional synthetic NH_3 production methods (refer to **Section 3.1** for more detail).

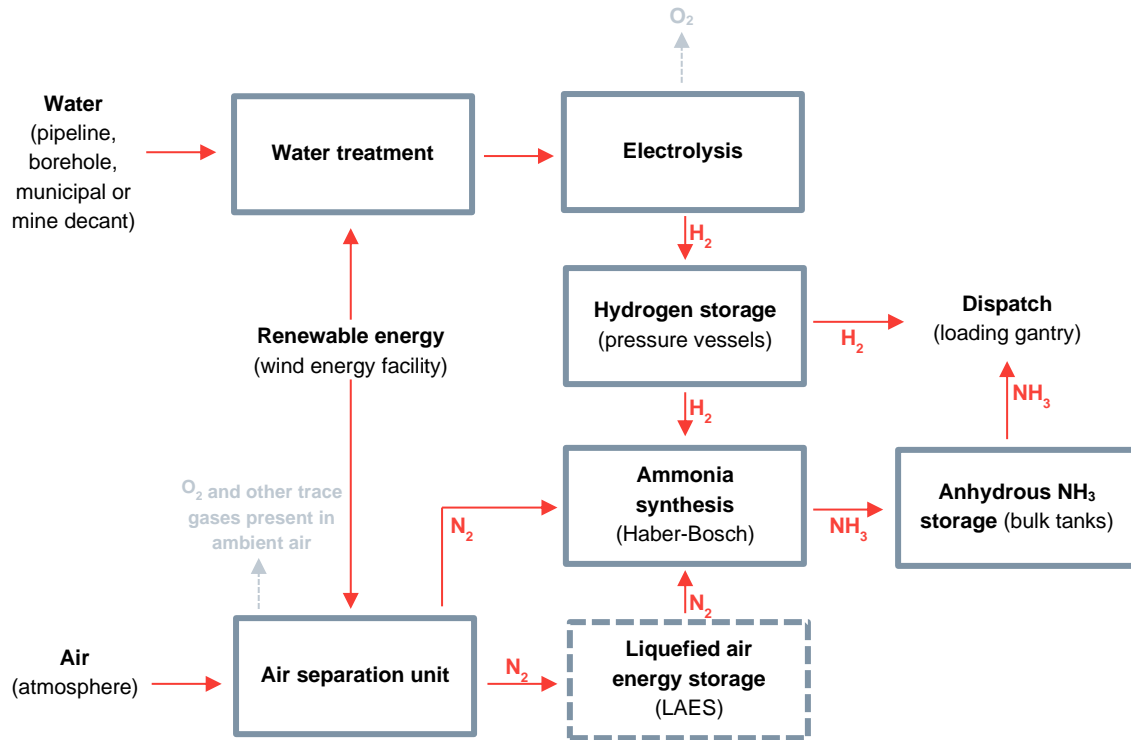


Figure 2-4: Process flow for the proposed Green NH_3 Processing Facility

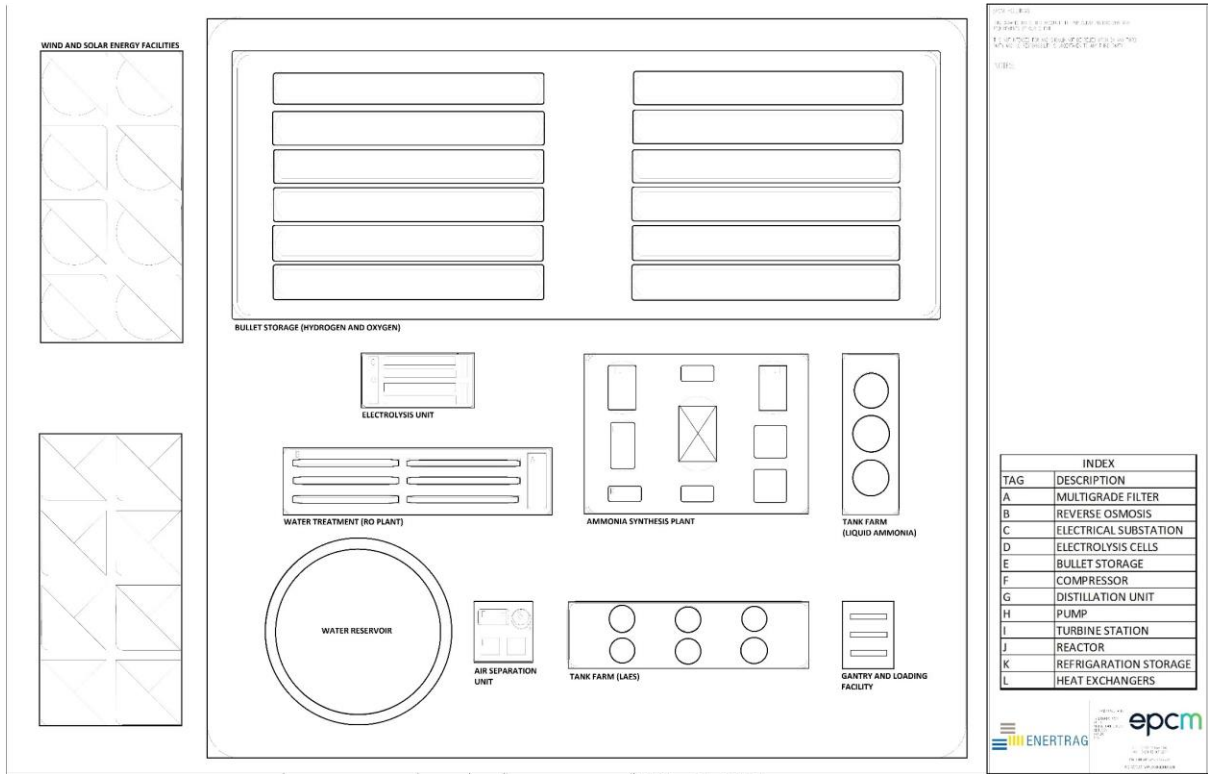


Figure 2-5: Block layout of the proposed Green NH₃ Processing Facility

3 REGULATORY FRAMEWORK

Until 2004, South Africa’s approach to air pollution control was driven by the Atmospheric Pollution Prevention Act 45 of 1965 (APPA) which was repealed with the promulgation of NEM:AQA⁹. NEM:AQA represents a shift in South Africa’s approach to air quality management, from source-based control to integrated effects-based management. The objectives of NEM:AQA are to:

- Protect the environment by providing reasonable measures for:
 - The protection and enhancement of air quality.
 - The prevention of air pollution and ecological degradation.
 - Securing ecologically sustainable development while promoting justifiable economic and social development.
 - Give effect to everyone’s right “to an environment that is not harmful to their health and well-being”¹⁰.

Significant functions detailed in NEM:AQA include:

- The National Framework for Air Quality Management¹¹.
- Institutional planning matters, including:
 - The establishment of a National Air Quality Advisory Committee.
 - The appointment of Air Quality Officers (AQOs) at each level of government.
 - The development, implementation and reporting of Air Quality Management Plans (AQMP) at national, provincial and municipal levels.
- Air quality management measures including:
 - The declaration of Priority Areas where ambient air quality standards are being, or may be, exceeded.
 - The listing of activities that result in atmospheric emissions and which have the potential to impact negatively on the environment and the licensing thereof through an AEL.
 - The declaration of Controlled Emitters.
 - The declaration of Controlled Fuels.
 - Procedures to enforce Pollution Prevention Plans or Atmospheric Impact Reporting for the control and inventory of atmospheric pollutants of concern.
 - Requirements for addressing dust and offensive odours.

3.1 MINIMUM EMISSION STANDARDS

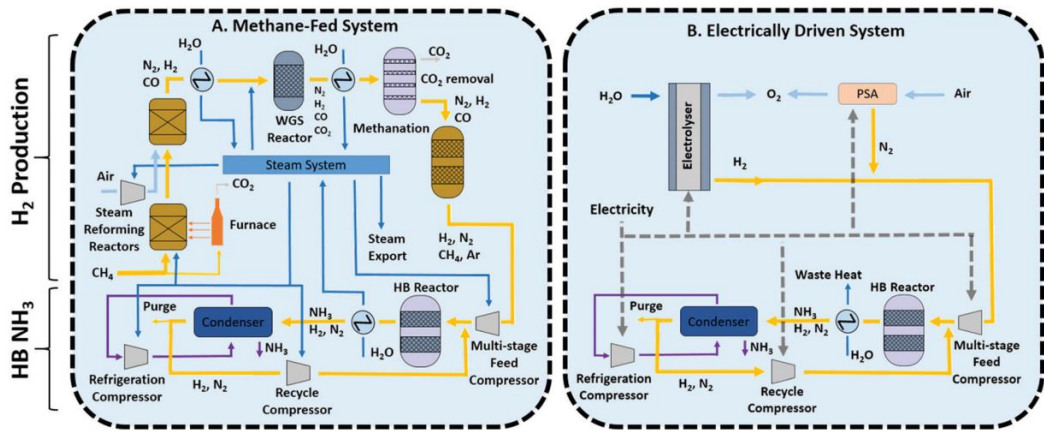
ENERTRAG propose to synthesize green NH₃ (i.e. using water electrolysis and renewable energy) as opposed to synthetic NH₃ using conventional catalytic steam reforming methods (i.e. from methane or naphtha). Conventional methods emit an array of pollutants such as sulphur oxides (SO_x), hydrogen sulphide (H₂S), hydrocarbons (HC) and carbon monoxide (CO), as well as products of combustion (e.g. oxides of nitrogen and particulates, etc.) from fuel burning appliances¹². A comparison of approaches is shown in **Figure 3-1**.

⁹ South Africa (2005): *National Environmental Management: Air Quality Act* (No. R. 39 of 2004) Government Gazette, 24 February 2005 (No. 27318)

¹⁰ South Africa (1996): *Constitution of the Republic of South Africa* (No. 108 of 1996)

¹¹ Department of Environmental Affairs (2018): *The 2017 National Framework for Air Quality Management in the Republic of South Africa* (No.R.1144 of 2018) Government Gazette, 26 October 2018 (No. 41996)

¹² US EPA (1993): AP 42, 5th ed. Vol 1. Chapter 8 - Inorganic Chemical Industry – Synthetic Ammonia (URL: https://www.epa.gov/sites/default/files/2020-09/documents/8.1_synthetic_ammonia.pdf)



	Conventional Process	Green Process
Hydrogen separation process	Catalytic steam reforming	Electrolysis
Hydrogen feedstock	Methane or naphtha	Water
Energy source	Fossil fuel combustion in a furnace	Renewable electricity (i.e. WEFs)
Emissions	SO _x , H ₂ S, HC, CO, products of combustion, greenhouse gases, and NH ₃ .	None anticipated under normal operating conditions

Figure 3-1: Schematic diagram comparing conventional methane fed NH₃ production (left) and green electrically driven NH₃ production (right)¹³

Conventional NH₃ production is listed as an air quality relevant activity, specifically *Category 7: Inorganic Chemicals Industry - Subcategory 7.1: Production and or Use in Manufacturing of Ammonia, Fluorine, Fluorine Compounds, Chlorine and Hydrogen Cyanide* under Government Notice 893 of 2013¹⁴. The threshold trigger for this subcategory is the quantity of the relevant compound being manufactured (i.e. 100 tons per annum in this case) rather than the process used to make it, regardless of process specifics or whether the regulated pollutants apply. Minimum Emission Standards (MES) associated with this subcategory are presented in **Table 3-1**.

¹³ Smith, C., K. Hill, A., Torrente-Murciano, L., (2020): Current and future role of Haber–Bosch ammonia in a carbon-free energy landscape. *Energy & Environmental Science* 13, 331–344.

¹⁴ Department of Environmental Affairs: (2013): List of Activities which result in Atmospheric Emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage (No. R. 893), Government Gazette, 22 November 2013, (No. 37054), as amended by GN 551 in 2015 and GN 1207 in 2018.

Table 3-1: Minimum emission standards for Subcategory 7.1 – Production and or Use in Manufacturing of Ammonia, Fluorine, Fluorine Compounds, Chlorine and Hydrogen Cyanide

Description:	Production and or use in manufacturing of ammonia, fluorine, fluorine compounds, hydrogen cyanide and chlorine gas (excluding metallurgical process-related activities under category 4).		
Application:	All installations producing and or using more than 100 tons per annum of the listed compound.		
Substance or mixture of substances		Plant status	mg/Nm ³ under normal conditions of 273 Kelvin and 101.3 kPa
Common name	Chemical symbol		
Hydrogen fluoride (from processes in which HF is evolved)	HF	New	5
		Existing	30
Chlorine (from processes in which Cl ₂ is evolved)	Cl ₂	New	50
		Existing	50
Ammonia (from processes in which NH ₃ is evolved)	NH ₃	New	30
		Existing	100
Hydrogen cyanide (from processes in which HCN is evolved)	HCN	New	0.5
		Existing	2

3.2 NATIONAL AMBIENT AIR QUALITY STANDARDS

Ambient air quality standards are defined as “*targets for air quality management which establish the permissible concentration of a particular substance in, or property of, discharges to air, based on what a particular receiving environment can tolerate without significant deterioration*”¹⁵. The aim of these standards is to provide a benchmark for air quality management and governance. South Africa’s National Ambient Air Quality Standards (NAAQS) are based primarily on guidance offered by two standards set by the South African National Standards (SANS):

- SANS 69:2004 Framework for implementing National ambient air quality standards.
- SANS 1929:2005 Ambient air quality – Limits for common pollutants.

SANS 69:2004 makes provision for the establishment of air quality objectives for the protection of human health and the environment as a whole. Such air quality objectives include limit values, alert thresholds and target values.

SANS 1929:2005 uses the provisions in SANS 69:2004 to establish air quality objectives for the protection of human health and the environment and stipulates that limit values are initially set to protect human health. The setting of such limit values represents the first step in a process to manage air quality and initiate a process to ultimately achieve acceptable air quality nationally.

The NAAQS presented in **Table 3-2** became applicable for air quality management from their promulgation in 2009¹⁶ and 2012¹⁷. The NAAQS generally have specific averaging periods, compliance timeframes, permissible frequencies of exceedance and measurement reference methods. It is highlighted that NH₃ is not regulated by NAAQS.

¹⁵ Department of Environmental Affairs (2000): *Integrated Pollution and Waste Management Policy for South Africa*. Government Gazette (No. R 227 of 2000), 17 March 2000 (No. 20978)

¹⁶ Department of Environmental Affairs (2009): National Ambient Air Quality Standards. Government Gazette (No. R 1210 of 2009), 24 December 2009 (No. 32816)

¹⁷ Department of Environmental Affairs (2012): National Ambient Air Quality Standard for Particulate Matter with Aerodynamic Diameter less than 2.5 Micro Metres (PM_{2.5}). Government Gazette (No. R 486 of 2012), 29 June 2012 (No. 35463)

Table 3-2: South African National Ambient Air Quality Standards

Pollutant	Averaging Period	Concentration ($\mu\text{g}/\text{m}^3$)	Permissible Frequency of Exceedance
Particulate Matter (PM_{10})	24 hours	75	4
	1 year	40	0
Particulate Matter ($\text{PM}_{2.5}$)	24 hours	40	4
		25 ^a	4
	1 year	20	0
		15 ^a	0
Benzene (C_6H_6)	1 year	5	0
Sulphur Dioxide (SO_2)	10 minutes	500	526
	1 hour	350	88
	24 hours	125	4
	1 year	50	0
Nitrogen Dioxide (NO_2)	1 hour	200	88
	1 year	40	0
Carbon Monoxide (CO)	1 hour	30000	88
	8 hours	10000	11
Ozone (O_3)	8 hours	120	11
Lead (Pb)	1 year	0.5	0

a: Effective date is 01 January 2030

3.3 INTERNATIONAL GUIDELINES

None of the pollutants regulated by NAAQS (**Section 3.2**) are relevant to ENERTRAG's proposed Green NH_3 Processing Facility and thus their associated human health impacts are not applicable to this assessment. As per the process description (**Section 2.3.2**), the only pollutant applicable to the proposed green NH_3 production process may be NH_3 , however, emissions are not expected for normal operations.

In the absence of local standards for NH_3 , international guidance is provided by the international bodies summarised below. A summary of the guidelines for health impact from exposure to NH_3 is provided in **Table 3-3**.

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

The Texas Commission on Environmental Quality (TCEQ) is the environmental agency for the state of Texas in the United States. TCEQ have developed Effects Screening Levels (ESLs) to evaluate impacts from pollutant concentrations predicted by dispersion modelling simulations. ESLs, which include both short- (1-hour) and long-term (annual) limit values, are chemical-specific concentration limits set to protect human health and welfare. They are not ambient air quality standards but rather a guideline as to whether airborne contaminants present adverse risk. Short-term ESLs are based on data concerning acute health effects, the potential for nuisance odour and effects on vegetation, while long-term ESLs are based on data concerning chronic health and vegetation effects. Welfare ESLs (i.e. odour and vegetation effects) are based on effect thresholds while health ESLs are based on toxicity factors and dose responses relevant to humans¹⁸.

CALIFORNIA OFFICE OF ENVIRONMENTAL HEALTH HAZARD ASSESSMENT

The California Office of Environmental Health Hazard Assessment (OEHHA) is the lead agency for the assessment of health risks posed by environmental contaminants in the state of California, United States. OEHHA have developed risk assessment guidelines with defined reference exposure levels (RELs) for airborne contaminants. An REL is the concentration level at or below which no adverse non-cancer health effects are

¹⁸ TCEQ (2006): Guidelines to Develop Effects Screening Levels, Reference Values and Unit Risk Factors. RG-442

anticipated for the specified exposure duration (i.e. acute 1-hour and chronic annual exposure). RELs are designed to protect the most sensitive individuals in the population by the inclusion of factors that account for uncertainties as well as individual differences in human susceptibility to chemical exposures. The factors used err on the side of public health protection to avoid underestimation of non-cancer hazards and as such, exceeding the REL does not automatically indicate an adverse health impact. Increasing concentrations above the REL value increases the likelihood that the health effect will occur¹⁹.

Table 3-3: International guidelines for NH₃

Pollutant	Averaging period	TCEQ ESL ²⁰ (µg/m ³)	OEHHA REL ²¹ (µg/m ³)
Ammonia	1-hour	180	3 200
	1-year	92	200

¹⁹ OEHHA (2015): Air Toxics Hot Spot Program Risk Assessment Guidelines – Guidance Manual for Preparation of Health Risk Assessment (URL: <https://oehha.ca.gov/media/downloads/crn/2015guidancemanual.pdf>)

²⁰ Texas Commission on Environmental Quality (2017): Effects Screening Levels using in the review of Air Permitting Data (URL: https://www.tceq.texas.gov/toxicology/esl/list_main.html)

²¹ OEHHA: Toxicity criteria on chemicals evaluated by OEHHA (URL: <https://oehha.ca.gov/chemicals/>)

4 METEOROLOGICAL CONTEXT

Seasonal and diurnal pollutant concentration levels fluctuate in response to the changing state of atmospheric stability, to concurrent variations in mixing depth and to the influence of mesoscale and macroscale wind systems on the transport of atmospheric contaminants. This section provides an overview of the atmospheric circulations influencing airflow and the subsequent dispersion and dilution of pollutant concentrations in the region while local meteorological conditions in the study area are analysed using surface meteorological data from the nearest ambient air quality monitoring station measuring meteorological parameters operated by the South African Weather Service (SAWS).

4.1 MACROSCALE ATMOSPHERIC CIRCULATION

South Africa's climate and weather is controlled by three semi-permanent, subtropical high-pressure cells that dominate the sub-continent throughout the year. These anticyclonic circulations form part of the discontinuous high-pressure belt that circles the southern hemisphere at approximately 30°S, occur above the 700 hPa level (above 3000 m above sea level)²² and are known as the South Indian Anticyclone, the continental high and the South Atlantic Anticyclone (**Figure 4-1**). Seasonal changes in the intensity and position of these high-pressure cells, together with the influence of tropical easterly lows and travelling circumpolar westerly waves drive South Africa's prevailing temperature and precipitation patterns²³.

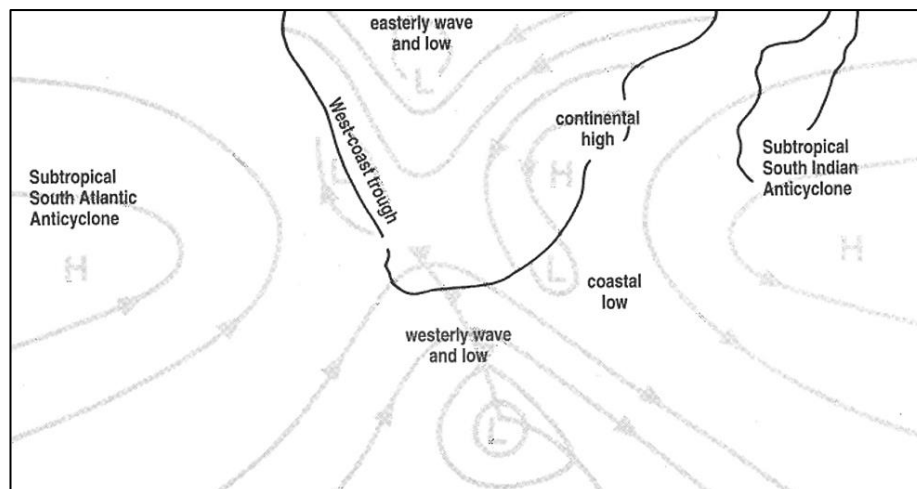


Figure 4-1 Atmospheric circulation over southern Africa (Tyson and Preston-Whyte, 2000)

Anticyclonic systems are associated with subsidence, which produce conditions of increased stability, suppressing precipitation and increasing the prevalence of dry spells. These conditions are highly favourable for the formation of both elevated and surface inversions. Elevated inversions, also known as *absolutely stable layers*, limit the vertical transport of pollution and occur over South Africa's interior plateau, at 700 hPa, 500 hPa and 300 hPa while between the escarpment and the coastline, the *absolutely stable layer* forms at 800 hPa²⁴.

Perturbations of the semi-stationary easterly waves take the form of open waves or closed lows which are associated with surface convergence and upper air divergence. This results in strong uplift, instability and sustained rainfall while surface divergence and upper air convergence on either side of the cyclonic system occurs, ensuring clear, dry conditions. These tropical disturbances are associated with copious rains if airflow has a northerly component and are mainly a summer phenomenon peaking during the months of December to February²⁵.

²² Turner, C.R., Tosen, G.R. and Lennon S.J. (1995): *Atmospheric Pollution and Climate Change Impacts in South Africa*. *Tytskrif vir Skoon Lug*. Vol. 9 - No. 4

²³ Tyson, P.D and Preston-Whyte, R.A., 2000: *The Weather and Atmosphere of Southern Africa*, Oxford University Press, Cape Town.

²⁴ Tyson, P. D., Garstang, M., Swap, R., Kallberg, P. and Edwards, M. (1996): *An air transport climatology for subtropical Southern Africa*. *Int. J. Climatol.* 16 265-291

²⁵ Tyson, P.D and Preston-Whyte, R.A., 2000: *The Weather and Atmosphere of Southern Africa*, Oxford University Press, Cape Town.

Westerly perturbations are recognised as including westerly waves, cut-off lows, southerly meridional flow, ridging anticyclones, west-coast troughs and cold fronts. Although classed as discreetly occurring phenomena, this is often not the case as they will change or merge from one into the other. These cyclonic systems are associated with surface convergence and upper-level divergence, resulting in stable conditions ahead of the system with cloud and precipitation following behind. These systems tend to follow a south-easterly trajectory as they move into the Indian Ocean. Perturbations occur most frequently in winter and bring cool weather due to airflow from the south and southwest²⁶.

4.2 LOCAL METEOROLOGY

According to the Köppen-Geiger Classification, the Hendrina area is defined as having a temperate climate with warm summers and dry winters²⁷. Meteorological variables, including hourly temperature, rainfall, humidity, wind speed and wind direction, were obtained from the nearest ambient air quality monitoring station (AQMS)²⁸. The Hendrina AQMS (approximately 17 km to the east-northeast of the study site, **Figure 4-2**) is owned and managed by SAWS and was analysed for the period January 2018 - December 2020 (i.e. three calendar years as required by the *Modelling Regulations*). Station details and data recovery for the Hendrina AQMS is given in **Table 4-1**. Although this station is at distance from the study site, the local topography is not complex and thus the meteorological data is considered representative of regional weather conditions that would prevail at the proposed development sites.

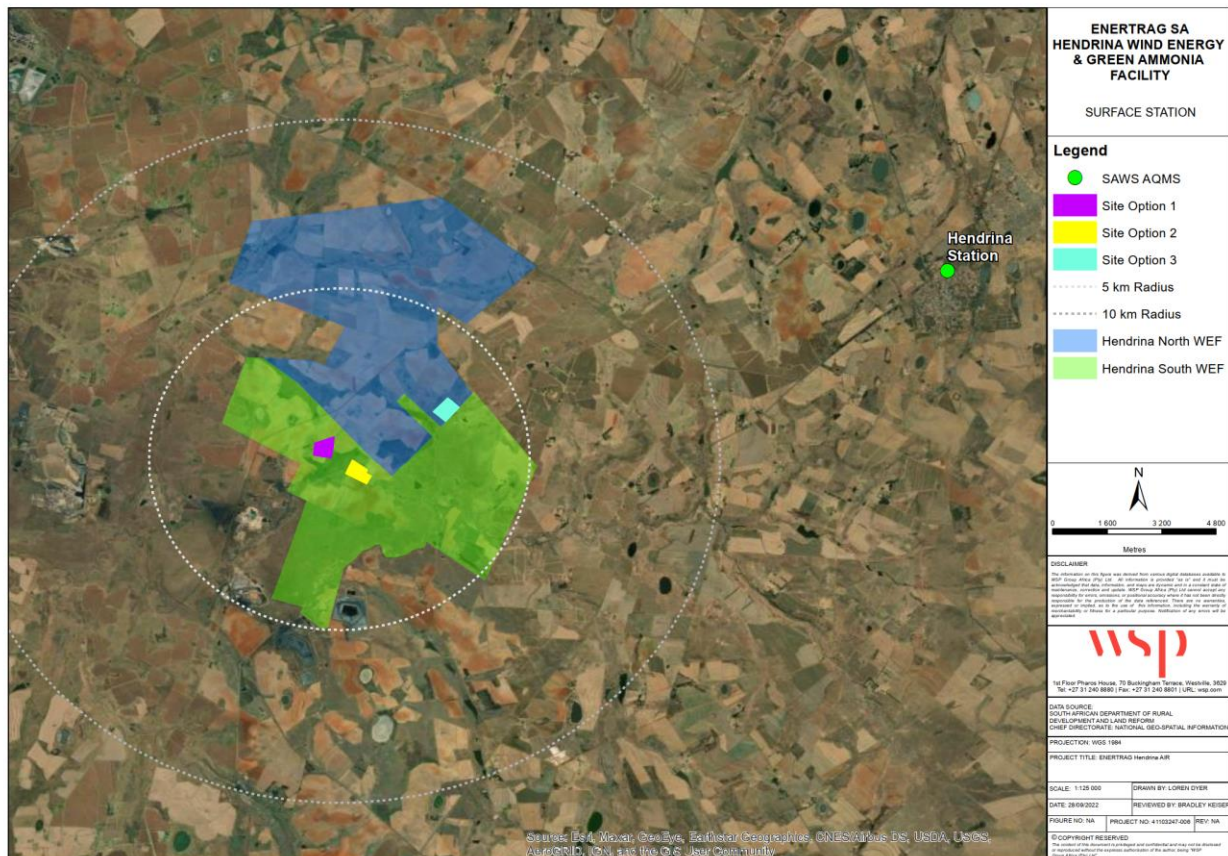


Figure 4-2: Surface station proximity to the study site

²⁶ Tyson, P.D and Preston-Whyte, R.A., 2000: *The Weather and Atmosphere of Southern Africa*, Oxford University Press, Cape Town.

²⁷ Conradie, D.C.U., (2012): *South Africa's Climatic Zones*. CSIR, Pretoria.

²⁸ This station's main function is the measurement of ambient air pollution; however, the station also measures an array of meteorological parameters. The nearest standalone SAWS meteorological station is Witbank (over 50 km to the north-northwest of the development site) and thus not considered representative of site conditions.

Table 4-1: Details of the Hendrina AQMS

Station Name	Latitude (°S)	Longitude (°E)	Altitude (m)	Data Recovery			
				Temperature	Humidity	Rainfall	Wind field
Hendrina	26.151200	29.716484	1,675	97%	97%	97%	97%

4.2.1 TEMPERATURE, HUMIDITY AND RAINFALL

Ambient air temperature influences plume buoyancy as the higher the plume temperature is above the ambient air temperature, the higher the plume will rise. Further, the rate of change of atmospheric temperature with height influences vertical stability (i.e. formation of mixing or inversion layers). Rainfall is an effective removal mechanism of atmospheric pollutants and thus also relevant in the assessment of pollution potential.

Figure 4-3 presents the average monthly temperature range, humidity and rainfall recorded at the Hendrina station. Higher rainfall occurs during the warmer, summer months (December, January and February) with drier conditions during the cooler, winter months (June, July and August). Summer temperatures for the region average at 19.5°C while winter temperatures average at 11.1°C. Hendrina received on average 570 mm of rainfall each year, with approximately 49% of that during the summer months (December, January and February) and only 3% during winter (June, July and August).

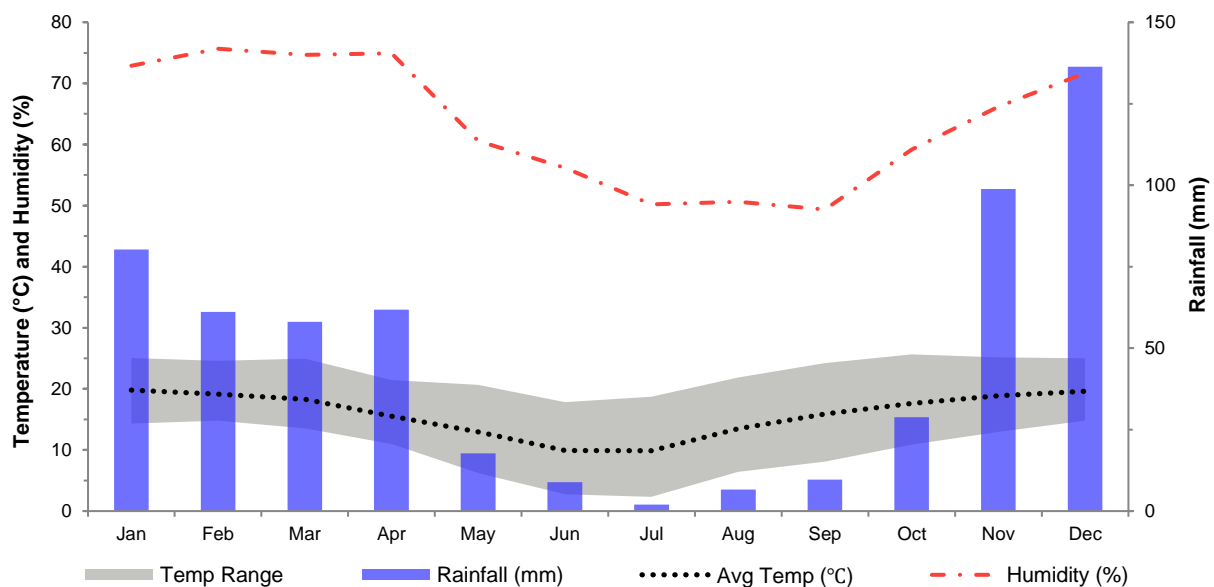


Figure 4-3: Meteorological summary for Hendrina (January 2018 - December 2020)

4.2.2 WIND FIELD

Wind roses (**Figure 4-4**) summarize wind speed and directional frequency at a location. Each directional branch on a wind rose represents wind originating from that direction. Each directional branch is divided into segments of colour, representative of different wind speeds. Calm conditions are defined by the *Beaufort Wind Force Scale*²⁹ as wind speeds less than 0.5 m/s.

Typical wind fields have been analysed using Lakes Environmental WRPlot Freeware (Version 7.0.0) for the full period (January 2018 – December 2020); diurnally for early morning (00h00 – 06h00), morning (06h00 – 12h00), afternoon (12h00 – 18h00) and night (18h00 – 00h00); and seasonally for summer (December, January and February), autumn (March, April and May), winter (June, July and August) and spring (September, October and November):

²⁹ The Beaufort wind force scale is an empirical measure that relates to observed conditions at sea or on land.

- Calm conditions (wind speeds <0.5 m/s) occurred 29.9% of the time.
- Light to fresh easterlies prevailed in the region.
- Peak wind speeds occurred from the east-northeast (11.2 m/s) and highest average wind speeds occurred from the east (3.0 m/s).
- Easterly winds prevailed during the early morning (00h00-06h00), morning (06h00-12h00) and night-time (18h00-00h00) hours.
- Winds from the west-northwest prevailed in the afternoon (12h00-18h00).
- Diurnal peak (10.3 m/s) and highest average (2.0 m/s) wind speeds occurred during the afternoon.
- Winds from the east prevailed during the spring, summer and autumn months.
- Higher directional variability in the wind field is observed during winter.
- Seasonal peak (10.4 m/s) wind speeds occur during spring and highest average (1.6 m/s) wind speeds occur during both summer and spring.

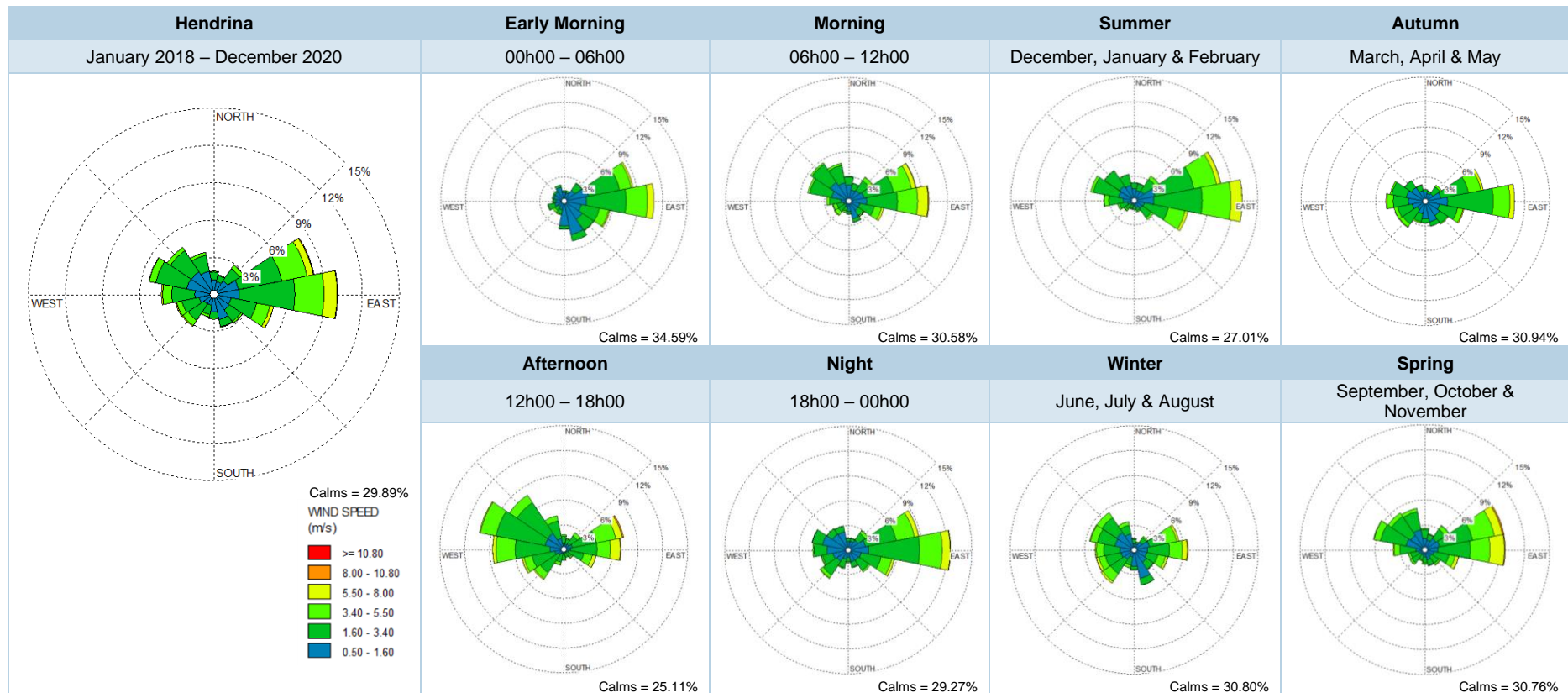


Figure 4-4: Local wind conditions at Hendrina

5 BACKGROUND AMBIENT AIR QUALITY

An evaluation of the existing air pollution situation provides an understanding of the potential risk for health impacts. The Department of Forestry, Fisheries and Environment (DFFE)³⁰ has identified District and Metropolitan Municipalities of concern with respect to air quality based on the prevalence of sources of emissions for each source category³¹. The National Framework for Air Quality Management in the Republic of South Africa³² (hereafter referred to as *The National Framework*) has rated the Nkangala District, as having “poor” air quality. The District area is thus identified as being in either the upper range of prevalence for one or more emission source categories³³ or middle range in two or more categories relative to other Districts. Municipalities that are classified as having poor air quality require priority attention in terms of air quality management planning.

The Air Quality Management Plan (AQMP) for the HPA³⁴ identifies the Steve Tshwete Local Municipality as one of the HPA’s nine air quality hot spot areas. This classification is based on atmospheric dispersion modelling outputs verified by ambient air quality monitoring data. The Hendrina area is identified in the AQMP for modelled SO₂ exceedances and measured O₃ exceedances. Elevated O₃ concentrations are attributed to secondary chemical formation resulting from the presence of NO_x and volatile organic compounds (VOC), which is noted by the assessment as being a ‘*regional scale phenomenon*’. It is highlighted that the HPA AQMP’s assessment is limited to criteria pollutants (specifically, SO₂, NO₂, PM₁₀ and O₃) none of which are relevant to the proposed ENERTRAG renewable energy complex. The only mention of NH₃ emissions in the AQMP is reference to trace amounts (not quantified) associated with biomass burning, with some agricultural burning for field clearing recognised as relevant in the Steve Tshwete area.

The nearest AQMS to the study site is the Hendrina station owned and managed by SAWS (**Figure 4-2**), approximately 17 km to the east-northeast of the study site. Pollutants measured by this station include PM₁₀, PM_{2.5}, CO, NO₂, SO₂ and O₃. None of these pollutants are relevant to the proposed ENERTRAG renewable energy complex. Since the Hendrina monitoring station does not measure NH₃ and is located too far away for ambient air quality measurements to be considered representative of ambient pollution concentrations at site, this data is not considered further.

³⁰ Known as the Department of Environmental Affairs (DEA) prior to June 2019

³¹ Source categories include listed activities, domestic fuel burning, vehicle emissions and mining emissions

³² Department of Environmental Affairs (2018): *The 2017 National Framework for Air Quality Management in the Republic of South Africa* (No.R.1144 of 2018) Government Gazette, 26 October 2018 (No. 41996).

³³ Emission source categories include listed activities, domestic fuel burning, traffic emissions and mining emissions (*The National Framework*, pg 50)

³⁴ DEA (2011): Highveld Priority Area Air Quality Management Plan (URL: https://screening.environment.gov.za/ScreeningDownloads/DevelopmentZones/HIGHVELD_PRIORITY_AREA_AQMP.pdf)

6 EMISSIONS CHARACTERISATION

An emissions inventory is a list of air pollution sources, their physical and chemical parameters, as well as the quantification of emissions. Emissions are calculated using emission factors or mass balance approaches, requiring chemical and activity data inputs.

6.1 UNIT PROCESSES AND THROUGHPUTS

Activity data (i.e. storage tank specifications, forecasted throughputs, etc.) was provided by ENERTRAG. Any errors, limitations or assumptions inherent in this data extend to this assessment. Unit processes and operating hours are presented in **Table 6-1**. Raw material throughputs, production rates and energy source consumption are presented in **Table 6-2**.

Table 6-1: Unit processes and operational times

Unit process	Function	Hours per day	Days per week	Days per year
Electrolyser	Separation of water into green hydrogen and green oxygen	24	7	365
Air separation	Separation of air into green nitrogen and green oxygen	24	7	365
Ammonia synthesis	Electrically driven Haber-Bosch synthesis of green NH ₃	24	7	365
Bulk storage	Storage of green hydrogen in pressure vessels and green anhydrous NH ₃ in bulk temperature-controlled storage tanks	24	7	365
Loading gantries	Temperature-controlled filling of pressure vessels for dispatch by road or rail	24	7	365

Table 6-2: Raw materials, products, and energy sources

Category	Item	Consumption / Production rate	Unit
Raw materials	Water	320,000	tonnes/annum
Products	Green hydrogen	20,000	tonnes/annum
	Green ammonia	100,000	tonnes/annum
Energy	Electricity	Not applicable – the Green NH ₃ Processing Facility will be powered by renewable energy supplied by the wind farm (i.e. the facility is self-sustaining)	

6.2 QUANTIFYING EMISSIONS

Emission factors are used to estimate emissions where actual emission data is not available. In most cases, these factors are averages of available data of acceptable quality and are generally assumed to be representative of long-term averages for all facilities in the source category. An emission factor is a value representing the relationship between an activity and the rate of emissions of a specified pollutant. Emission factors are always expressed as a function of the weight, volume, distance, or duration of the activity emitting the pollutant. The general equation used for the estimation of emissions is:

$$E = A \times EF \times \left(1 - \frac{ER}{100}\right)$$

Where:

- E = emission rate
 A = activity rate
 EF = emission factor
 ER = overall emission reduction efficiency (%)

The *Modelling Regulations* recommend the use of published emission factors for national consistency, e.g. United States Environmental Protection Agency (USEPA) AP-42 emission factors³⁵. As per the process description (**Section 2.3.2**), the only pollutant associated with the proposed processes that is relevant to Section 21 MES *Subcategory 7.1* is NH₃. As such, only potential sources of NH₃ are discussed in the sections that follow.

6.2.1 STORAGE TANKS

The proposed ENERTRAG facility will store synthesised anhydrous NH₃ product in bulk. Since NH₃ has a very low boiling point, NH₃ requires either temperature or pressure control to maintain a liquid phase and prevent product loss through evaporation.

PRINCIPLES OF BULK STORAGE TANK EMISSIONS

Evaporation is a natural process whereby a volatile liquid is converted into a vapour. The liquid's vapour pressure is the driving force causing evaporation. Vapour pressure is a measure of the force required to convert any volatile liquid into a gas. Molecular motion within the liquid is responsible for this force which is related to the composition of the liquid. Smaller molecule substances are more active and thus have higher vapour pressures. Higher temperatures increase molecular motion, increasing the vapour pressure with increasing temperature. As such, liquids with smaller molecular mass (i.e. g/mol) also have lower boiling points³⁶.

When vapour pressure causes the molecules of a liquid to vaporise (i.e. leave the liquid as a gas), the vapours disperse through the air space above the liquid surface, known as the 'vapour space'. Vapour molecules also condense and return to the liquid. A state of equilibrium is reached when the vapour space becomes saturated, with molecules leaving and returning to the liquid at the same rate. Due to diffusion, the composition of the vapour space becomes uniform throughout. At equilibrium, the percentage of the volatile compound (as a vapour) in the vapour space depends on the vapour pressure of the liquid³⁷.

Liquid temperature changes brought about by atmospheric conditions, can result in expansion or contraction of the tank contents. This change in the tank's vapour space causes the tank to 'breathe'. During the day, solar radiation heats the roof and walls of the tank, increasing the liquid temperature, resulting in expansion of the tank contents, as well as an increase in evaporation. The vapour within the vapour space above the liquid is also heated, increasing its volume, and resulting in an 'exhalation' of vapour through the open tank vent/s. At night, the reverse processes condense the vapour and cause an intake of ambient air into the tank³⁸.

Evaporation loss only occurs when vapours are expelled from the vapour space and released to atmosphere. Two conditions must be present for evaporation loss to occur³⁹:

- 1 Heat must be applied.
- 2 The vapour evolved must be able to escape the vapour space.

Total atmospheric emissions (i.e. the emission rate) from a tank is thus a function of the rate of evaporation and the duration that vapour is released from the vapour space. The primary factors affecting the emission rate include the vapour pressure of the liquid at the liquid storage temperature (i.e. higher vapour pressure accelerates the rate of evaporation into the vapour space), temperature changes in the tank (i.e. higher temperatures increase the liquid

³⁵ USEPA (1995): Compilation of Air Pollutant Emission Factors (AP-42)

³⁶ TI-3 Petroleum Committee (1971): Control of Atmospheric Emissions from Petroleum Storage Tanks, in Journal of the Air Pollution Control Association, 21:5, 260 – 268 (URL: <https://doi.org/10.1080/00022470.1971.10469526>)

³⁷ TI-3 Petroleum Committee (1971): Control of Atmospheric Emissions from Petroleum Storage Tanks, in Journal of the Air Pollution Control Association, 21:5, 260 – 268 (URL: <https://doi.org/10.1080/00022470.1971.10469526>)

³⁸ TI-3 Petroleum Committee (1971): Control of Atmospheric Emissions from Petroleum Storage Tanks, in Journal of the Air Pollution Control Association, 21:5, 260 – 268 (URL: <https://doi.org/10.1080/00022470.1971.10469526>)

³⁹ TI-3 Petroleum Committee (1971): Control of Atmospheric Emissions from Petroleum Storage Tanks, in Journal of the Air Pollution Control Association, 21:5, 260 – 268 (URL: <https://doi.org/10.1080/00022470.1971.10469526>)

vapour pressure and vapour volume within the vapour space), tank design and condition (i.e. mechanical conditions control the exposure of tank contents to rapid pressure changes or turbulence inside the tank), and operating schedule (i.e. the number of times a tank is filled and emptied over the assessment period)⁴⁰.

Evaporative losses can thus be classified into three categories⁴¹:

- 1 Filling losses – vapour present in the vapour space is expelled when the tank is refilled, irrespective of the mechanism by which the vapours evolve. This type of loss is applicable to all tank types except floating roof tanks and closed system pressure vessels (i.e. bullets).
- 2 Breathing losses – vapour is expelled from the tank due to thermal expansion of the vapours within the vapour space when pressure or volume changes exceed the limits of containment (e.g. due to barometric pressure changes and/or an increase in the volume of vapour in the vapour space). Tanks installed underground or fitted with reflective coatings, insulation or shading mitigate breathing losses better.
- 3 Standing losses – vapour emission resulting from causes other than breathing or changing liquid levels, such as exposure of the liquid to the atmosphere due to improper seal fitment or open vents.

Therefore, the key to reduce/limit/prevent atmospheric emissions from a storage tank includes reducing the heat applied to the liquid (i.e. sustaining the liquid temperature below the boiling point of the compound) and containing evolved vapours within the vapour space (i.e. prevent the release of vapours to atmosphere)

PROPOSED NH₃ STORAGE

ENERTRAG propose an insulated, temperature-controlled (i.e. -33.34°C) storage tank solution. The temperature of the liquid will be maintained below boiling point to prevent evaporation of the product. The liquid vapour pressure of NH₃ at a temperature of -33.34 °C is zero⁴². Storage tank vents will remain closed to sustain this low liquid temperature and prevent any mechanically induced turbulence inside the tanks. Given that the vapour pressure is zero at the intended storage temperature, evaporation of the product will not occur. Therefore, emissions from the bulk storage of NH₃ at the proposed ENERTRAG facility are not anticipated under normal operating conditions.

Two tank storage scenarios are being considered by ENERTRAG with the final design pending. Tank specifications provided by ENERTRAG are presented in **Table 6-3**.

⁴⁰ TI-3 Petroleum Committee (1971): Control of Atmospheric Emissions from Petroleum Storage Tanks, in Journal of the Air Pollution Control Association, 21:5, 260 – 268 (URL: <https://doi.org/10.1080/00022470.1971.10469526>)

⁴¹ TI-3 Petroleum Committee (1971): Control of Atmospheric Emissions from Petroleum Storage Tanks, in Journal of the Air Pollution Control Association, 21:5, 260 – 268 (URL: <https://doi.org/10.1080/00022470.1971.10469526>)

⁴² Tanner Industries (1998): Customer Manual – Anhydrous Ammonia (URL: <https://www.tannerind.com/PDF/blue-anhy-amm.pdf>)

Table 6-3: Storage tank specifications

	Scenario 1	Scenario 2
Tank ID	NH ₃ Tank	NH ₃ Tank
Chemical Name	Anhydrous NH ₃	Anhydrous NH ₃
Number of duplicate tanks	3	1
Latitude (S)	TBC	TBC
Longitude (E)	TBC	TBC
Horizontal / Vertical	Horizontal	Horizontal
Floating or Fixed Roof	NA	NA
Height / Length (m)	15	20
Diameter (m)	14	20
Maximum Liquid Height (m)	11.90 ^(a)	17.00 ^(a)
Average Liquid Height (m)	5.95 ^(b)	8.50 ^(b)
Working Volume (m³)	915.9 ^(c)	2 670.4 ^(c)
Turnovers per tank per year	54.0	55.6
Net Throughput per tank (m³/yr)	49 456 ^{(d) (e)}	148 368 ^(e)
Heated	Refrigerated to -33.4°C	Refrigerated to -33.4°C
Colour of tank	Stainless steel	Stainless steel

a: Maximum liquid height is assumed to be 85% of the tank's vertical dimension

b: Average liquid height is assumed to be 50% of the maximum liquid height

c: Working volume is calculated using the tank dimensions provided

d: For Scenario 1, it is assumed that all throughput is split equally between the number of duplicate tanks

e: Net throughput is calculated using a liquid density of 0.674 g/ml⁴³

EMISSION RATE MODELLING

South Africa's *Modelling Regulations* recommend the use of the US EPA and American Petroleum Industry (API) TANKS 4.0.9d model for estimating emissions from bulk liquid storage tanks. TANKS is Windows-based software created on the emission estimation procedures from the US EPA's AP-42 emission estimation manual. TANKS uses chemical, meteorological, roof fitting and rim seal data to generate breathing and working loss estimates for various types of storage tanks.

While the US EPA considers the use of TANKS 4.0.9d to be appropriate for quantifying NH₃ emissions from bulk storage (if the proper constants are applied)⁴⁴, the software is inherently flawed in its ability to simulate liquid temperatures below 0°F (i.e. -28.12°C). As such, TANKS could not be used in this case to demonstrate the null emissions associated with ENERTRAG's proposed refrigerated storage design.

6.2.2 MATERIAL LOADING

Anhydrous NH₃ will be loaded from the onsite temperature-controlled bulk storage tanks to pressure vessels for dispatch by road and rail. Emission factors for material loading/offloading operations have been established by the US EPA and Australian National Pollutant Inventory (NPI). These are however, flagged by both organisations as only applicable to organic liquids and specifically stated as "*not suitable for estimating emissions from ammonia, mineral acids or other inorganic compounds...*"⁴⁵. No other emission factors for the loading of ammonia were found in a review of available literature. As such, emissions from loading activities cannot be quantified.

It is highlighted that the loading process will also be temperature and pressure controlled to prevent the evaporation of NH₃ as described in **Section 6.2.1** and therefore no emissions are expected under normal operating conditions.

⁴³ URL: https://www.concoa.com/ammonia_properties.html

⁴⁴ USEPA (1994): Development and Selection of Ammonia Emission Factors – Final Report (URL: <https://nepis.epa.gov/Exe/ZyPDF.cgi/P100ERTR.PDF?Dockkey=P100ERTR.PDF>)

⁴⁵ NPI (2004): Inorganic Chemicals Manufacturing 2.0, pg 38 (URL: <http://www.npi.gov.au/system/files/resources/5a02d47b-2130-ea94-a59b-e85965eae307/files/inorganic-chemical.pdf>)

6.2.3 DISPERSION MODELLING

Atmospheric dispersion modelling mathematically simulates the transport and fate of pollutants emitted from a source to the atmosphere. Algorithms incorporate source criteria, surface topography, land use and meteorology to predict the downwind concentrations of these pollutants. These provide a useful tool to ascertain the spatial and temporal patterns of ground level pollutant concentrations arising from various point, line, area and volume sources. These outputs are primarily used in environmental and health impact assessments, risk assessments and to determine monitoring requirements, including spatial and temporal resolution.

As per the Regulations Prescribing the Format of the AIR (hereafter referred to as the '*AIR Regulations*')⁴⁶ an AIR typically must include an assessment of impacts on human health and the environment using dispersion modelling. However, as explained in **Section 6.2.1** and **Section 6.2.2**, no evaporative losses are anticipated from the bulk storage of NH₃ (under normal operating conditions), and no suitable methodology for estimating emission rate inputs required for dispersion modelling, is currently available. As such, emissions cannot be quantified ahead of the proposed facility's operational phase and thus a dispersion modelling assessment cannot be conducted at this time.

The licensing authority agreed on 11 March 2022 that this AIR must comprise a qualitative impact assessment with further quantitative assessment conducted when operational information and site monitoring data is available and will form part of the facility's PAEL review process. Recommendations in this regard are provided in **Section 8**.

⁴⁶ Department of Environmental Affairs (2013): Regulations prescribing the format of the atmospheric impact report.

7 IMPACT ASSESSMENT

7.1 IMPACTS ON THE RECEIVING ENVIRONMENT

7.1.1 CONSTRUCTION PHASE

Emissions during construction are associated with land clearing, drilling, and blasting, ground excavation, cut and fill operations and the movement of heavy construction vehicles on temporary roads. Pollutants associated with construction activities are typically Total Suspended Particulates (TSP), PM₁₀ and PM_{2.5} with lesser contributions of CO, NO₂, SO₂ and C₆H₆ from vehicle exhausts.

PM refers to solid or liquid particles suspended in the air. PM varies in size from particles that are only visible under an electron microscope to soot or smoke particles that are visible to the human eye. Particles can be classified by their aerodynamic properties into coarse particles, PM₁₀ (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, PM_{2.5} (particulate matter with an aerodynamic diameter of less than 2.5 µm)⁴⁷. In addition to reduced visibility, particulate air pollution poses health risks associated with the respiratory system⁴⁸. Particle size controls how far into the respiratory system particles can permeate. Fine particles have been found to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs compared to smaller particles⁴⁹. PM_{2.5} can enter the bloodstream via capillaries in the lungs with the potential to be laid down as plaques in the cardiovascular system or brain⁵⁰. Reported health effects to PM include eye, nose, and throat irritation, coughing, reduced lung function, inflammation of the lungs, angina, myocardial infarction, and bronchitis.

Heavy construction activity is a source of dust emissions that can have a significant but transient impact on local air quality. The amount of dust emitted from construction operations depends on the area of land being worked, the proportion of land lying exposed at any time, the clearing and dozing equipment used, the number and type of vehicles on temporary roads, and the duration of the construction phase. The majority proportion of dust emissions result from heavy vehicle traffic movement on temporary gravel roads at the construction site.

Considering the proposed site extent is small (0.25 km²) and sensitive receptors are more than 1.4 km from either of the proposed development sites (refer to **Table 2-2**), atmospheric impacts from dust emissions during the temporary construction phase are anticipated to be low. With the implementation of appropriate control measures, the impact on neighbouring sensitive receptors will be reduced further and assessed to be very low (refer to **Section 7.2**)

7.1.2 OPERATIONAL PHASE

The only atmospheric pollutant applicable to the operational phase of ENERTRAG's proposed Green NH₃ Processing Facility is NH₃. Potential impacts on human health and vegetation from exposure to NH₃ are discussed below.

HUMAN HEALTH IMPACTS

NH₃ is an alkaline chemical widely used in industrial applications as a feedstock for fertilizers, plastics, and explosives. It is a colourless, water-soluble gas with an unpleasant, sharp, and pungent odour.

NH₃ vapour causes irritation to the eyes and respiratory tract with high concentrations causing conjunctivitis, laryngitis, and pulmonary oedema. NH₃ can combine with moisture in the eyes and mucous membranes to form

⁴⁷ Harrison, R.M. and R.E. van Grieken, (1998): *Atmospheric Aerosols*. John Wiley: Great Britain

⁴⁸ World Health Organization (2000): *Air Quality Guidelines for Europe* (2nd edition), Copenhagen, Denmark. (WHO Regional Publications, European Series, No 91)

⁴⁹ Manahan, E. (1991): *Environmental Chemistry*.

⁵⁰ US EPA (2011): *Emissions Factors & AP 42, Compilation of Air Pollutant Emission Factors*. URL: <http://www.epa.gov/ttn/chief/ap42/index.html#toc>.

ammonium hydroxide. Ammonium hydroxide causes saponification and liquefaction of the exposed, moist epithelial surfaces of the eye and can easily penetrate the cornea and damage the iris and the lens. Damage to the iris may eventually lead to cataracts.

Inhalation exposure may result in an increase in systemic arterial blood pressure. Documented odour thresholds for NH₃ vary from 30 to 73,000 µg/m³ causing annoyance and potentially exacerbating pre-existing asthma. Reported health effects due to NH₃ gas exposure include eye, nose, and throat irritation, coughing, dermal irritation, and respiratory failure⁵¹.

Generally, emissions from bulk storage and loading activities typically occur near ground-level and ambient concentrations peaking within the operational boundary of a facility. It is unlikely that NH₃ emissions from a low-level emission source would reach sensitive receptors more than 1.4 km from any of the proposed development sites (refer to **Table 2-2**), especially at the concentrations required to induce health impacts or create an odour nuisance. As such, any potential NH₃ emissions from the proposed development will have a very low impact (if any) on human health. It is highlighted that, with the intended temperature-controlled storage and loading solutions proposed, emissions under a normal operating scenario are not anticipated (refer to **Section 6.2**).

EFFECTS ON VEGETATION

Air pollution in South Africa was first identified as a potential threat to vegetation in 1988 by Tyson *et al*⁵². The commercial forests of the eastern escarpment were highlighted as a threatened resource due to their proximity to the heavily industrialised Highveld. Marshal *et al.*, (1998)⁵³ also identified concerns around the potential impacts on crop yields on the Highveld however specifically linked impacts to PM, SO₂, O₃, NO_x and hydrogen fluoride (HF).

According to Krupa (2003)⁵⁴ acute exposure to NH₃ can result in visible foliar injury on vegetation. NH₃ is deposited rapidly within 4 – 5 km from its source but may also transform into fine particle ammonium (NH₄⁺) aerosols with increased potential for longer range transport. While it is common practise to use NH₃ as an agricultural fertilizer, adverse effects on vegetation can occur when the rate of foliar uptake of NH₃ is greater than the rate and capacity for in vivo detoxification by the plant species. Studies on European vegetation found that indigenous vegetation is most sensitive to NH₃ with agricultural crops being least sensitive⁵⁵.

In the South African context, increased rates of nitrogen deposition and nutrient accumulation in the soil during high pollution episodes may threaten plant species that are accustomed to nutrient poor soils. While plant species from high nutrient environments can tolerate nutrient accumulations, nutrients can easily accumulate to toxic concentrations for more sensitive species such as fynbos⁵⁶.

Although high pollution episodes are common in the HPA, the land surrounding the proposed development site is used for mining, crop cultivation or is vacant open veld earmarked for future mining ventures and is not considered to be sensitive. As such, any ambient NH₃ contributions from the proposed development will have a very low impact (if any) on neighbouring grasslands and crop production. It is highlighted that, with the intended temperature-controlled storage and loading solutions proposed, emissions under a normal operating scenario are not anticipated (refer to **Section 6.2**).

7.1.3 CUMULATIVE ASSESSMENT

It is noted that there are no other green NH₃ facilities or industrial sources producing NH₃ within a 30 km radius of the proposed ENERTRAG site. With NH₃ being the only atmospheric pollutant applicable to the operational phase (although null emissions expected with the proposed temperature-controlled storage in place), the cumulative NH₃ emissions in the area will also be null, as there are no other NH₃ sources surrounding the site.

⁵¹ OEHHA (1999): Appendix D.2 Acute RELs and toxicity summaries (URL: <https://oehha.ca.gov/media/downloads/cmr/appendixd2final.pdf>)

⁵² Tyson, P. D., Kruger, F. J., and Louw, C. W. (1988). *Atmospheric pollution and its implications in the Eastern Transvaal Highveld*. National Scientific Programmes Unit: CSIR.

⁵³ Marshall, F. M., Ashmore, M. R., Bell, J. N. B., and Milne, E. (1998, September). Air pollution impacts on crop yield in developing countries—a serious but poorly recognised problem. In *Proc. 11th World Clean Air and Environment Congress*.

⁵⁴ Krupa, S.V. (2003): Effects of atmospheric ammonia on terrestrial vegetation: a review. In *Environmental Pollution* vol 124(2): 179 – 221. (DOI: 10.1016/s0269-7491(02)00434-7)

⁵⁵ Krupa, S.V. (2003): Effects of atmospheric ammonia on terrestrial vegetation: a review. In *Environmental Pollution* vol 124(2): 179 – 221. (DOI: 10.1016/s0269-7491(02)00434-7)

⁵⁶ Wilson, D., Stock, W.D. and Hedderson, T. 2009. Historical nitrogen content of bryophyte tissue as an indicator of increased nitrogen deposition in the Cape Metropolitan Area, South. *Environmental Pollution* 157 938–945

Dominant emission sources surrounding the proposed site include numerous collieries (refer to **Section 2.2**) which are responsible for generating large amounts of dust and particulate matter. These pollutants are not associated with the operational phase of the ENERTRAG facility, however, will be produced during the construction and decommissioning phases. Based on the small site footprint (0.25 km²) and the transient nature of construction and decommissioning activities, the cumulative impact of dust and particulate matter during these phases are envisaged to be negligible.

7.1.4 DECOMMISSIONING PHASE

Activities and emissions associated with the decommissioning phase are considered to be similar to those of the construction phase discussed in **Section 7.1.1**.

Considering the proposed site extent is small (0.25 km²) and sensitive receptors are more than 1.4 km from either of the proposed development sites (refer to **Table 2-2**), atmospheric impacts from dust emissions during the temporary decommissioning phase are anticipated to be low. With the implementation of appropriate control measures, the impact on neighbouring sensitive receptors will be reduced further and assessed to be very low (refer to **Section 7.2**).

7.1.5 POST-CLOSURE PHASE

Once decommissioning activities cease, the only associated emissions may include wind-blown dust from exposed land on the site footprint. Post closure, the site should revegetate relatively quickly limiting this wind-blown dust and creating no permanent air quality issues going forward. Atmospheric impacts from dust emissions during the post-closure phase are therefore anticipated to be very low (refer to **Section 7.2**).

7.2 IMPACT SIGNIFICANCE RATING

From a technical, conceptual, or philosophical perspective the focus of impact assessment ultimately narrows down to a judgment on whether the predicted impacts are significant or not. The concept of significance is at the core of impact identification, prediction, evaluation, and decision-making (DEAT, 2002)⁵⁷.

The purpose of this air quality assessment is to identify the potential impacts and associated risks posed by the operation of the proposed ENERTRAG Green NH₃ Processing Facility on the surrounding air quality of the area. The outcomes of the impact assessment will provide a basis to identify the key risk drivers and make informed decisions on the way forward in order to ensure that these risks do not result in unacceptable social or environmental risk.

All impacts of the proposed Project were evaluated using a risk matrix, which is a semi-quantitative risk assessment methodology. This system derives an environmental impact level on the basis of the magnitude, extent, reversibility, duration and probability of occurrence. The overall risk level is determined using professional judgement based on a clear understanding of the nature of the impact, potential mitigatory measures that can be implemented and changes in risk profile as a result of implementation of these mitigatory measures. A full description of the risk rating methodology is presented in **Appendix A**. Key localised air quality impacts associated with the ENERTRAG Green NH₃ Processing Facility include:

- 1 Construction phase impacts on ambient air quality.
- 2 Operational phase impacts on ambient air quality.
- 3 Decommissioning phase impacts on ambient air quality.
- 4 Post-closure phase impacts on ambient air quality.

Outcomes of the air quality impact assessment are contained within **Table 7-1** outlining the impact of each parameter and the resulting risk level. The resultant air quality risks for residential receptors were ranked “low” for the construction and decommissioning phases and “very low” for the operational and post-closure phases.

⁵⁷ Department of Environmental Affairs and Tourism (2002): Impact Significance, Integrated Environmental Management, Information Series 5, Department of Environmental Affairs and Tourism (DEAT), Pretoria.

Table 7-1: Impact assessment of risks associated with the operation of the Hendrina Green NH₃ Processing Facility

Description	Without Mitigation							With Mitigation						
	Magnitude	Extent	Reversibility	Duration	Probability of Occurrence	Significance	Risk Level	Magnitude	Extent	Reversibility	Duration	Probability of Occurrence	Significance	Risk Level
Construction phase - Degradation of ambient air quality due to dust emissions	1	2	1	2	4	24	Low	1	1	1	2	3	15	Very Low
Operational phase - Potential degradation of ambient air quality due to NH ₃ emissions	1	1	1	4	1	7	Very Low	NA	NA	NA	NA	NA	NA	NA
Decommissioning phase - Degradation of ambient air quality due to dust emissions	1	2	1	2	4	24	Low	1	1	1	2	3	15	Very Low
Post-closure phase - Degradation of ambient air quality due to dust emissions	1	1	1	2	2	10	Very Low	1	1	1	2	1	5	Very Low

Note: A post-mitigation scenario is not applicable for the control of NH₃ emissions during the operational phase. All emission controls are considered standard operating procedure and thus the pre-mitigation scenario is representative of normal operations as the proposed facility is designed to function.

8 RECOMMENDATIONS

Although atmospheric impacts from the proposed Green NH₃ Processing Facility (including the construction thereof) are qualitatively assessed to be very low (or low), the mitigation and data management measures recommended in **Table 8-1** should be considered to minimize impacts and facilitate a quantitative impact assessment going forward.

Table 8-1: Recommended mitigation and data management measures

Impact	Mitigation and data management measures
Degradation of ambient air quality due to dust emissions associated with the construction and decommissioning phases	<ul style="list-style-type: none"> – Limit the duration of the construction phase to as short a timeframe as possible. – Where possible, minimise the area under construction. – Make use of wet suppression techniques to minimise dust entrainment along unpaved roads and during periods of high wind speeds. – Where possible, minimise speed limits, vehicle weights and the number of vehicles using unpaved roads. – Once construction is complete, initiate rehabilitation (e.g. re-vegetation) procedures to reduce wind speed across exposed surfaces.
Potential degradation of ambient air quality due to NH ₃ emissions associated with the operational phase.	<ul style="list-style-type: none"> – Maintain appropriate operational controls (e.g. appropriate temperature and pressure settings for storage vessels and loading gantries). – Conduct regular equipment inspections for visible/audible/odorous leaks. – Conduct regular checks and periodic replacement of components including pump seals, compressor seals, pipeline valves, open-ended valves, flanges, and other connections (as applicable) in line with manufacturer specifications. – Conduct training of the workforce at all levels (i.e. workers, foremen, managers) in awareness of air emissions. This can be included in site induction courses and should focus on promoting understanding as to why operational controls are in place and should be adhered to. – Complaints and any actions arising from a complaint must be recorded in a complaints register maintained by site management. – Undertake passive monitoring of NH₃ along the facility's fenceline and at proximate receptors. A monthly monitoring frequency for a period of twelve months is recommended to provide sufficient data for follow up quantitative assessment of impacts. Monitoring requirements and the frequency thereof can be revised during the PAEL review process. – Maintain meticulous record keeping of all inputs, throughputs and production rates, including loading and dispatch quantities to enable a mass balance quantification of facility wide evaporative losses (if any) over time. – Assess and revise impacts when sufficient operational information is available to do so.
Degradation of ambient air quality due to dust emissions associated with the post-closure phase	<ul style="list-style-type: none"> – Revegetate the site footprint on completion of decommissioning as soon as possible to minimise dust entrainment from exposed land.

9 CONCLUSION

ENERTRAG is proposing the development of a renewable energy complex for the generation of renewable electricity using wind turbines. A Green NH₃ Processing Facility is also proposed as part of the proposed development with an intended production capacity of 100,000 tpa. NH₃ production in excess of 100 tons per annum triggers listed activity *Subcategory 7.1: Production and or use in Manufacturing of Ammonia, Fluorine, Fluorine Compounds, Chlorine and Hydrogen Cyanide* of the Listed Activities⁵⁸, promulgated in line with Section 21 of NEM:AQA, and thus an AEL is required.

In the absence of appropriate methodologies to quantify emission rates using the available activity data, this study qualitatively assessed potential air quality impacts from the proposed site activities. The assessment relied on the intended operational design data provided by ENERTRAG and well understood principles of bulk liquid storage and compound properties. Assessment findings are summarised as follows:

CONSTRUCTION PHASE

- Dust (TSP, PM₁₀ and PM_{2.5}) emissions typical of construction activities are expected during the construction of the Green NH₃ Processing Facility. Considering the small extent of the proposed site, the site's distance from proximate receptors, and the transient nature of the construction phase, impacts are expected to be low. Appropriate control measures can be applied to further reduce impacts.
- The impact significance of the construction phase is assessed to be low (without mitigation) to very low (with mitigation).

OPERATIONAL PHASE

- Hydrogen and nitrogen feedstock for the Haber-Bosch process will be of exceptional purity negating the need for impurity purging. As such, NH₃ emissions from the Haber-Bosch process are not anticipated under normal operating conditions. The purging of noble gases may be required under upset conditions (refer to **Section 2.3.2**).
- Synthesised anhydrous NH₃ will be stored in temperature-controlled bulk storage tanks at -33.4°C, sufficiently low to prevent product evaporation. Storage tank vents will remain closed to sustain this low liquid temperature and prevent any mechanically induced turbulence inside the tank/s. As such, NH₃ emissions from bulk storage vessels are not anticipated as the liquid cannot vaporise and cannot escape containment.
- Product loading to pressure vessels for dispatch will occur under temperature and pressure-controlled conditions to prevent evaporation during dispatch.
- In a scenario where NH₃ is emitted, emissions will occur at a low-level and are therefore unlikely to reach proximate receptors at concentrations required to induce health or nuisance impacts. Surrounding vegetation is not considered sensitive to nutrient accumulation and impacts on neighbouring grasslands and crop production are also not anticipated.
- The impact significance of the operational phase (under normal operating conditions) is assessed to be very low (NH₃ will be stored in temperature-controlled bulk storage tanks as the norm, so no further mitigation is applicable).

As agreed with the licensing authority, further quantitative assessment should be conducted when operational information and site monitoring data is available to do so and must form part of the facility's PAEL review process. Therefore, in addition emissions control measures, it is recommended that:

- Complaints and any actions arising from a complaint must be recorded in a complaints register maintained by site management.
- Passive monitoring of NH₃ along the facility's fenceline and at proximate receptors be conducted to provide context in terms of actual impact (if any). A monthly monitoring frequency for a period of twelve months is

⁵⁸ Department of Environmental Affairs: (2013): List of Activities which result in Atmospheric Emissions which have or may have a significant detrimental effect on the environment, including health, social conditions, economic conditions, ecological conditions or cultural heritage (No. R. 893), Government Gazette, 22 November 2013, (No. 37054), as amended by GN 551 in 2015 and GN 1207 in 2018.

recommended to provide sufficient data for follow up quantitative assessment of impacts. Monitoring requirements and the frequency thereof can be revised during at the PAEL review process.

- Site management maintain meticulous record keeping of all inputs, throughputs and production rates, including loading and dispatch quantities to enable a mass balance quantification of facility wide evaporative losses (if any) over time.

DECOMMISSIONING PHASE

- Dust (TSP, PM₁₀ and PM_{2.5}) emissions typical of decommissioning activities are expected during the decommissioning of the Green NH₃ Processing Facility. Considering the small extent of the proposed site, the site's distance from proximate receptors, and the transient nature of the decommissioning phase, impacts are expected to be low. Appropriate control measures can be applied to further reduce impacts.
- The impact significance of the decommissioning phase is assessed to be low (without mitigation) to very low (with mitigation).

POST-CLOSURE PHASE

Once decommissioning activities cease, the only associated emissions may include wind-blown dust from exposed land on the site footprint. Post closure, the site should revegetate relatively quickly limiting this wind-blown dust and creating no permanent air quality issues going forward. Atmospheric impacts from dust emissions during the post-closure phase are therefore anticipated to be very low (with and without mitigation).

10 FORMAL DECLARATIONS

10.1 DECLARATION OF ACCURACY OF INFORMATION

DECLARATION OF ACCURACY OF INFORMATION - APPLICANT

Name of Enterprise: _____

Declaration of accuracy of information provided:

Atmospheric Impact Report in terms of section 30 of the Act.

I, _____ (duly authorised), declare that the information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1) (g) of this Act.

Signed at _____ on this _____ day of _____

SIGNATURE

CAPACITY OF SIGNATORY

10.2 DECLARATION OF INDEPENDENCE

DECLARATION OF INDEPENDENCE - PRACTITIONER

Name of Practitioner: Kirsten Collett

Name of Registration Body: South African Council for Natural Scientific Professions (SACNASP)

Professional Registration No: 115870

Declaration of independence and accuracy of information provided:

Atmospheric Impact Report in terms of Section 30 of the Act.

I, Kirsten Collett, declare that I am independent of the applicant. I have the necessary expertise to conduct the assessments required for the report and will perform the work relating the application in an objective manner, even if this results in views and findings that are not favourable to the applicant. I will disclose to the applicant and the air quality officer all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the air quality officer. The information provided in this atmospheric impact report is, to the best of my knowledge, in all respects factually true and correct. I am aware that the supply of false or misleading information to an air quality officer is a criminal offence in terms of section 51(1) (g) of this Act.

Signed at Waterfall on this 08th day of February 2023

SIGNATURE

Principal Consultant at WSP

CAPACITY OF SIGNATORY

APPENDIX

A IMPACT ASSESSMENT METHODOLOGY



APPENDIX

The assessment of impacts and mitigation evaluates the likely extent and significance of the potential impacts on identified receptors and resources against defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise or compensate for any adverse environmental impacts, to enhance positive impacts, and to report the significance of residual impacts that occur following mitigation.

The key objectives of the risk assessment methodology are to identify any additional potential environmental issues and associated impacts likely to arise from the proposed Project, and to propose a significance ranking. Issues / aspects will be reviewed and ranked against a series of significance criteria to identify and record interactions between activities and aspects, and resources and receptors to provide a detailed discussion of impacts. The assessment considers direct⁵⁹, indirect⁶⁰, secondary⁶¹ as well as cumulative⁶² impacts.

A standard risk assessment methodology is used for the ranking of the identified environmental impacts pre-and post-mitigation (i.e. residual impact). The significance of environmental aspects is determined and ranked by considering the criteria⁶³ presented in **Table 10-1**.

Table 10-1: Impact Assessment Criteria and Scoring System

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Magnitude (M) The degree of alteration of the affected environmental receptor	Very low: No impact on processes	Low: Slight impact on processes	Medium: Processes continue but in a modified way	High: Processes temporarily cease	Very High: Permanent cessation of processes
Impact Extent (E) The geographical extent of the impact on a given environmental receptor	Site: Site only	Local: Inside activity area	Regional: Outside activity area	National: National scope or level	International: Across borders or boundaries
Impact Reversibility (R) The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change	Reversible: Recovery without rehabilitation		Recoverable: Recovery with rehabilitation		Irreversible: Not possible despite action
Impact Duration (D) The length of permanence of the impact on the environmental receptor	Immediate: On impact	Short term: 0-5 years	Medium term: 5-15 years	Long term: Project life	Permanent: Indefinite
Probability of Occurrence (P) The likelihood of an impact occurring in the absence of pertinent environmental management measures or mitigation	Improbable	Low Probability	Probable	Highly Probability	Definite
Significance (S) is determined by combining the above criteria in the following formula:	$[S = (E + D + R + M) \times P]$ $Significance = (Extent + Duration + Reversibility + Magnitude) \times Probability$				
IMPACT SIGNIFICANCE RATING					
Total Score	4 to 15	16 to 30	31 to 60	61 to 80	81 to 100
Environmental Significance Rating (Negative (-))	Very low	Low	Moderate	High	Very High

⁵⁹ Impacts that arise directly from activities that form an integral part of the Project.

⁶⁰ Impacts that arise indirectly from activities not explicitly forming part of the Project.

⁶¹ Secondary or induced impacts caused by a change in the Project environment.

⁶² Impacts are those impacts arising from the combination of multiple impacts from existing projects, the Project and/or future projects.

⁶³ The definitions given are for guidance only, and not all the definitions will apply to all the environmental receptors and resources being assessed. Impact significance was assessed with and without mitigation measures in place.

APPENDIX

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Environmental Significance Rating (Positive (+))	Very low	Low	Moderate	High	Very High

10.2.1 IMPACT MITIGATION

The impact significance without mitigation measures will be assessed with the design controls in place. Impacts without mitigation measures in place are not representative of the proposed development’s actual extent of impact and are included to facilitate understanding of how and why mitigation measures were identified. The residual impact is what remains following the application of mitigation and management measures and is thus the final level of impact associated with the development. Residual impacts also serve as the focus of management and monitoring activities during Project implementation to verify that actual impacts are the same as those predicted in this report.

The mitigation measures chosen are based on the mitigation sequence/hierarchy which allows for consideration of five (5) different levels, which include avoid/prevent, minimise, rehabilitate/restore, offset and no-go in that order. The idea is that when project impacts are considered, the first option should be to avoid or prevent the impacts from occurring in the first place if possible, however, this is not always feasible. If this is not attainable, the impacts can be allowed, however they must be minimised as far as possible by considering reducing the footprint of the development for example so that little damage is encountered. If impacts are unavoidable, the next goal is to rehabilitate or restore the areas impacted back to their original form after project completion. Offsets are then considered if all the other measures described above fail to remedy high/significant residual negative impacts. If no offsets can be achieved on a potential impact, which results in full destruction of any ecosystem for example, the no-go option is considered so that another activity or location is considered in place of the original plan.

The mitigation sequence/hierarchy is shown in **Figure 10-1** below.

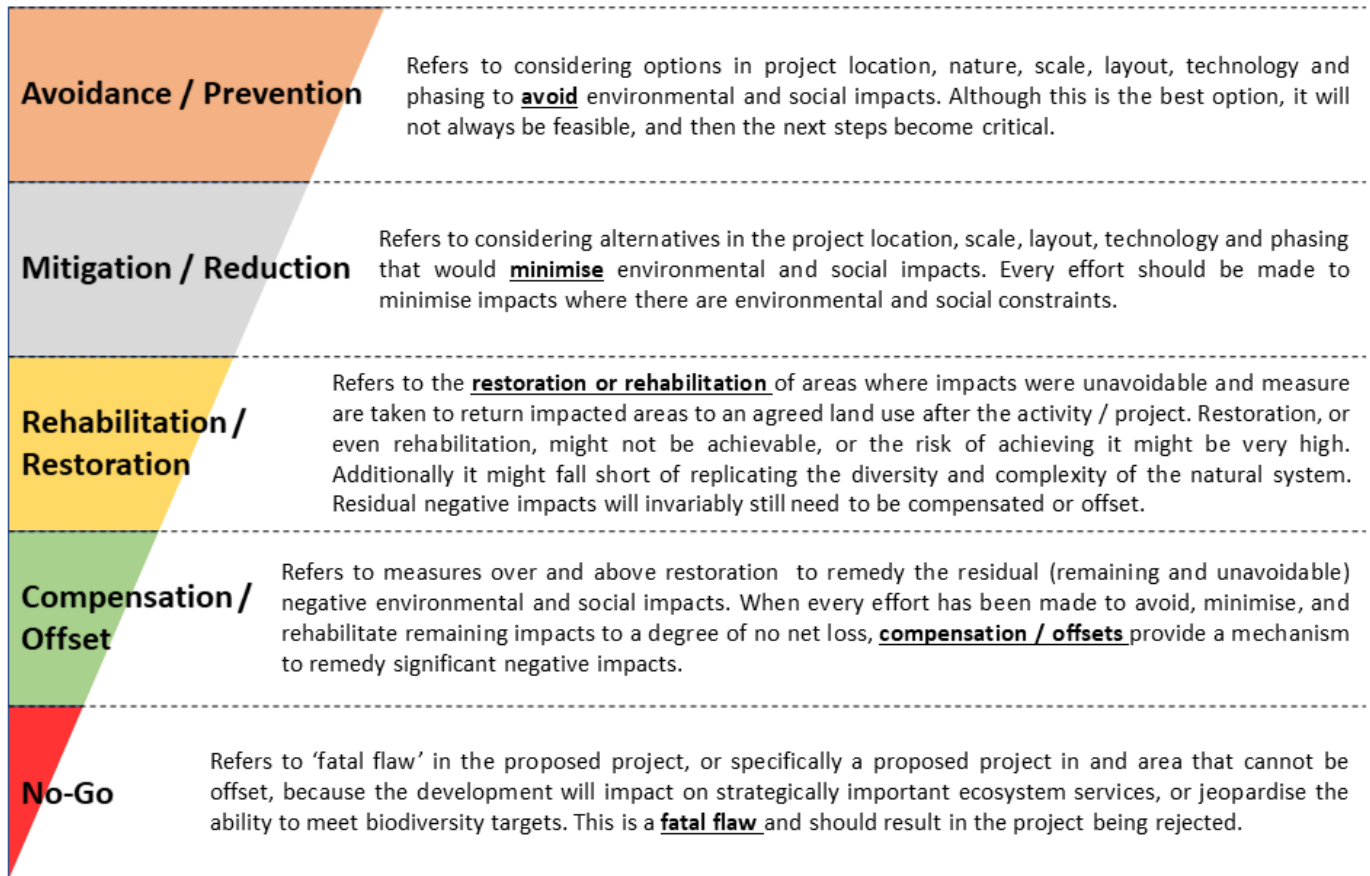


Figure 10-1: Mitigation Sequence/Hierarchy