Technical Report C

Supplementary air quality impact assessment

Viva Energy Gas Terminal Project

Prepared for
Viva Energy Gas Australia Pty Ltd
ABN: 645 450 059

Technical Report C: Supplementary air quality impact assessment

Viva Energy Gas Terminal Project Supplementary Statement

03-Sep-2024
Viva Energy Gas Terminal Project

Technical Report C: Supplementary air quality impact assessment

Viva Energy Gas Terminal Project Supplementary Statement

Client: Viva Energy Gas Australia Pty Ltd

ABN: 645 450 059

Prepared by

AECOM Australia Pty Ltd
Wurundjeri and Bunurong Country, Tower 2, Level 10, 727 Collins Street, Melbourne VIC 3008, Australia
T +61 1800 868 654 www.aecom.com
ABN 20 093 846 925

03-Sep-2024

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 and ISO45001.

Table of Contents

Executive summary

This technical report provides a supplementary air quality study in response to Recommendation 11 in Table 1 of the Minister's Directions for the Viva Energy Gas Terminal Project (the project) Supplementary Statement.

In March 2023, the Victorian Minister for Planning determined that the project Environment Effects Statement (EES) requires a Supplementary Statement to be prepared by Viva Energy Gas Australia Pty Ltd (Viva Energy), in accordance with sections 5 and 8C(2) of the *Environment Effects Act 1978 (Vic)*. The Supplementary Statement is required to provide some additional information to inform the Minister for Planning's final assessment of the project's environmental effects on the marine environment, noise, air quality and Aboriginal cultural heritage in accordance with the Minister's Directions.

Overview

Viva Energy is planning to develop a gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate a secure and flexible supply of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years. This project would support the community's energy needs as the energy market transitions to lower emissions alternatives.

The FSRU would store liquefied natural gas (LNG) received from visiting LNG carriers (that would moor directly adjacent to the FSRU), and regasify the LNG as required to meet industrial, commercial, and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The gas terminal would be located adjacent to, and on Viva Energy's Geelong Refinery in a heavily industrialised setting. It would benefit from Viva Energy's experience and capability as an existing Major Hazard Facility (MHF) operator, and potential synergies between the two facilities, such as reuse of the FSRU seawater discharge within the refinery operations.

Methodology

The modelling undertaken in original EES study Technical Report H: *Air quality impact assessment* (AECOM, 2022) (hereafter referred to as "AQ EES study") showed no exceedances of adopted air quality criteria at any of the sensitive receptors in the study area. The AQ EES study concluded that air quality impacts from FSRU operations would be low, would not exceed adopted regulatory air quality criteria and would be localised in the vicinity of Refinery Pier and the Refinery.

The Inquiry and Advisory Committee (IAC) considered the air quality criteria adopted in the EES was appropriate and noted that EPA supported the adopted criteria. The IAC also agreed that the modelling demonstrated that, if the project was implemented in accordance with all the assumptions in the modelled scenarios, the impacts on air quality would be acceptable (IAC Report No. 1, section 13.3 (iii)).

Three items of further work were identified under Recommendation 11 in Table 1 of the Minister's Directions and are summarised below along with the methodology adopted to address each task:

a. Conduct sensitivity testing on the air quality modelling to confirm that operational impacts on air quality would be acceptable considering the significance of the wake effects of the FSRU (Recommendation 11a)
    - Document and summarise differences between general arrangement of Hoegh, Bergesen Worldwide (BW) and Golar FSRUs
    - Model emissions using AERMOD to compare wake effects for:
        - the FSRU discharge points with no wake effects
        - three different FSRU configurations (based on general arrangements of Hoegh, BW and Golar FSRUs)
        - two different FSRU orientations (bow facing southeast (proposed) and northwest)
        - with and without an LNG carrier alongside the FSRU.

b. Conduct sensitivity testing on the air quality modelling to confirm that operational impacts on air quality would be acceptable considering a ‘worst-case’ scenario for air emissions (but based on the use of best available technology (BAT)) (Recommendation 11b)
   - Demonstrate the ‘worst-case’ scenario for air emissions by comparing the sensitivity testing results for different configurations and orientations of the FSRU.
   - Provide further discussion and analysis for the ‘worst-case’ scenario air quality impacts, such as frequency of occurrence analysis and time varying background.

c. Conduct sensitivity testing on the air quality modelling to confirm that operational impacts on air quality would be acceptable considering the implications of bubble limits and stack specific limits for sensitive receptors (Recommendation 11c)
   - Provide proposed project gas production profiles to demonstrate the gas demand trend over a year and establish the basis for calculating bubble limits.
   - Present the proposed stack specific limits and bubble limits.
   - Compare long-term (annual) air emissions and air quality impacts on sensitive receptors for stack specific limits only, and a combination of stack and bubble limits.

The IAC accepted the use of the Hoegh Esperanza FSRU air emissions data which represents current best available technology and did not consider that further sensitivity testing is required in this regard (IAC Report No. 1, section 13.3 (iii)).

Outcomes of Supplementary Study

a. The significance of the wake effects of the FSRU (Recommendation 11a)

The following statement was made in the AQ EES study:

“*Sensitivity analysis showed that dispersion patterns from the FSRU are highly dependent on wake effects.*”

The intent of this statement was to highlight the difference in predicted pollutant concentrations between modelled scenarios when wake effects were included or excluded in the model. When wake effects are enabled in the model, variations in the dimensions of the same building are not expected to have a significant impact on the modelled results.

Sensitivity testing with wake effects enabled and disabled in the model demonstrated that ground level concentrations with no wake effects are predicted to be much lower compared to ground level concentrations with wake effects enabled. Based on the dimensions of the Esperanza FSRU and the stack heights, wake effects from the FSRU should be considered in the dispersion modelling, which was the approach adopted in the AQ EES study.

When the orientation of the FSRU changes, the distance and relative location between the stack, the land and sensitive receptors change. Wake effects influence how the plume would travel from stacks to sensitive receptors and as a result, the ground level concentrations at sensitive receptors are influenced by distance and relative location.

To understand how the configurations and orientations of the FSRU may influence wake effects and associated predicted pollutant ground level concentrations at sensitive receptors, sensitivity testing for the following scenarios was conducted as part of the supplementary study:

- FSRU plus LNG carrier
   - Esperanza: bow facing southeast (modelled in the AQ EES study)
   - Esperanza: bow facing northwest
   - Golar: bow facing southeast
   - Golar: bow facing northwest
- FSRU only
   - Esperanza: bow facing southeast (modelled in the AQ EES study)

- Esperanza: bow facing northwest
- Golar: bow facing southeast
- Golar: bow facing northwest

The sensitivity testing found that predicted air quality impacts for the Esperanza and Golar FSRUs only vary slightly. However, lower ground level concentrations at onshore sensitive receptors are predicted when the bow is facing northwest compared to facing southeast.

Overall, the Esperanza with its bow facing southeast alongside an LNG carrier (modelled in the AQ EES study) is predicted to be the worst-case scenario among all configurations and orientations assessed. As demonstrated in the AQ EES study, all modelled pollutants were predicted to comply with relevant criteria at all sensitive, industrial, and gridded receptor locations for this scenario. Further analysis of the results is presented under task b. It is noted that this is the preferred orientation for the FSRU due to maritime and port operations safety reasons.

The findings of this item of further work are consistent with the findings of the air quality impact assessment completed as part of the original EES (AQ EES study) and has confirmed that operational impacts of the FSRU on air quality would be acceptable considering the significance of the wake effects of the FSRU.

b. A ‘worst-case’ scenario for air emissions (but based on the use of BAT) (Recommendation 11b)

Air emissions from the FSRU are directly proportional to the number of engines and boilers required to meet market demand (i.e., air emissions increase as the number of engines and boilers that are being used increases). A higher production rate requires the use of more engines and therefore will result in higher air emissions.

The emission inventory and modelling results in the AQ EES study have shown that the highest air emissions for the same FSRU configuration are expected to occur during the peak load scenario, when all four engines and two boilers are running at 100 percent load.

In consideration of different FSRU configurations and orientations, the sensitivity testing results from task a demonstrated that the worst-case scenario among all assessed configurations is the Esperanza FSRU with its bow facing southeast, with an LNG carrier alongside. This scenario was modelled in the AQ EES study.

Time-series concentrations analysis for the worst-case scenario demonstrates that pollutant concentrations resulting from operation of the FSRU would be well below the relevant criteria and would not be discernible from background concentrations. Potential air quality impacts associated with the project would be minor and emissions would be unlikely to cause significant adverse impacts on the surrounding environment.

The findings of this item of further work are consistent with the findings of the air quality impact assessment completed as part of the original EES (AQ EES study) and have confirmed that operational impacts on air quality would be acceptable considering a worst-case scenario for air emissions.

c. The implications of bubble limits and stack specific limits for sensitive receptors (Recommendation 11c)

The IAC recommended that Viva Energy should continue to work with the Victorian Environment Protection Authority (EPA Victoria) to compare the effects of bubble limits and stack specific limits in relation to air quality impacts on sensitive receptors. This study assessed the potential air emissions and impacts on sensitive receptors for two scenarios: one with stack specific limits only and another with a combination of stack specific emission limits and annual bubble limits.

For stack specific limits, emission rates calculated based on 100 percent load of each engine and boiler in the AQ EES study are proposed to be the emission limit for each stack. As gas demand increases, more engines would be turned on, but air emissions from the corresponding stacks would need to meet the proposed emission limits.

According to the gas production profile (please refer to Table 4-1 of Chapter 4: *Project description* of the original EES), annual bubble limits were calculated based on the following operating scenario:

- 90 days summer open loop (~3 months)
- 179 days spring/autumn open loop (~6 months)
- 90 days winter open loop (~3 months)
- 6 days peak load (2 days per winter month)

An impact analysis for stack specific limits only and a combination of stack and bubble limits scenarios was conducted. The analysis showed that the combination limits scenario would result in lower annual emissions and lower ground level annual average concentrations at sensitive receptors. Therefore, a combination of stack specific limits and annual bubble limits is considered most appropriate for this project.

A bubble limit was proposed in the development licence application that was submitted as part of the original EES (Attachment V: Development Licence Applications). A combination of stack specific limits and bubble limits has been proposed which provides an emissions limit based on the use of best available technology.

The applicability of bubble limits is subject to the development licence statutory approval process. EPA Victoria will ultimately determine the stack specific limits and/or annual bubble limits which would form part of the operating licence conditions for the FSRU following approval.

Integrated Assessment

The original AQ EES study concluded that:

- *All modelled operating scenarios demonstrated there are no exceedances of criteria at any of the sensitive, industrial or gridded receptor locations.*
- *The air modelling assessment demonstrates that air quality impacts from the FSRU operations would be minor and emissions are unlikely to have regionally or State significant effects on the air environment.*

The findings of this supplementary air quality study for the project are consistent with the findings of the original AQ EES study. In addition, this supplementary study also found that:

- Predicted air quality impacts for the Esperanza and Golar FSRUs only vary slightly. Sensitivity testing results demonstrate that Esperanza with its bow facing southeast alongside an LNG carrier (modelled in the AQ EES study) is the worst-case scenario among all configurations and orientations assessed.
- Time-series concentrations analysis for the worst-case scenario demonstrates that pollutant concentrations resulting from operation of the FSRU would not be discernible from background concentrations most of time.
- A combination of stack specific limits and annual bubble limits would result in lower annual emissions, and lower ground level annual average concentrations, at sensitive receptors compared to stack specific limits only. As such, it is considered most appropriate to adopt a combination of stack specific limits and annual bubble limits for this project.

Recommended Mitigation Measures

There are no changes to the overall conclusion of the original AQ EES study. Therefore, no additional mitigation measures have been proposed and the original recommended mitigation measures are considered both appropriate and adequate.

The original mitigation measures recommended to avoid, minimise, and mitigate potential adverse effects on air quality are listed in section 9 of AQ EES study.

Abbreviation

Abbreviation	Definition
AECOM	AECOM Australia Pty Ltd
AEMO	Australian Energy Market Operator
AQ EES study	Technical Report H: *Air quality impact assessment* (AECOM, 2022)
BAT	Best Available Techniques
BW	Bergesen Worldwide
CO	Carbon monoxide
DMG	Dredged material ground
DWGM	Declared wholesale gas market
EES	Environment Effects Statement
EPA Victoria	Victorian Environment Protection Authority
ERS	Environment Reference Standard
FSRU	Floating storage and regasification unit
g/s	Gram per second
g/min	Gram per minute
HDD	Horizontal directional drilling
km	Kilometre
km^2	Square kilometre
kW	Kilowatt
LNG	Liquified natural gas
MHF	Major Hazard Facility
MLA	Marine loading arms
m^3	Cubic metre
MW	Megawatt
NO_2	Nitrogen dioxide
PM_{10}	Particulate matter 10 micrometres or less in diameter
ppm	Part per million
ROW	Right of way
SO_2	Sulfur dioxide
SWP	South-West Pipeline

Abbreviation	Definition
SWI	Seawater intake
TJ/d	Terajoules per day
TRG	Technical reference group
t/yr	Tonne per year
$\mu g/m^3$	Micrograms per cubic metre
VIC	Victoria
Viva Energy	Viva Energy Gas Australia Pty Ltd
VOC	Volatile organic compound
VTS	Victorian Transmission System

Glossary of terms

Term	Definition
AERMOD	A steady-state plume model that incorporates air dispersion based on planetary boundary layer turbulence structure and scaling concepts
Bubble limit	Bubble limit is the maximum amount of air emissions that are allowed to be discharged from the whole site (EPA Victoria, 2017)
Stack specific limit	Stack specific limit is the maximum amount of air emissions that are allowed to be discharged from each discharge point.
Wake effect	Wake effect *is the effect on plume dispersion caused by the presence of buildings near a stack, usually resulting in increased ground-level concentrations of pollutants* (NSW EPA, 2022)

1.0 Introduction

This technical report provides a supplementary air quality study in response to Recommendation 11 in Table 1 of the Minister's Directions for the Viva Energy Gas Terminal Project (the project) Supplementary Statement.

Viva Energy Gas Australia Pty Ltd (Viva Energy) is planning to develop a gas terminal using a ship known as a floating storage and regasification unit (FSRU), which would be continuously moored at Refinery Pier in Corio Bay, Geelong. The key objective of the project is to facilitate a secure and flexible supply of gas for the south-east Australian gas market where there is a projected supply shortfall in coming years. This project would support the community's energy needs as the energy market transitions to lower emissions alternatives.

The FSRU would store liquefied natural gas (LNG) received from visiting LNG carriers (that would moor directly adjacent to the FSRU) and would convert LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification) as required to meet industrial, commercial, and residential customer demand. A 7-kilometre gas transmission pipeline would transfer the gas from the FSRU to the Victorian Transmission System (VTS) at Lara.

The project would be situated adjacent to, and on, Viva Energy's Geelong Refinery, within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. Co-locating the project with the existing Geelong Refinery and within the Port of Geelong offers significant opportunity to minimise potential environmental effects and utilise a number of attributes that come with the port and industrial setting.

In March 2023, the Victorian Minister for Planning determined that the project Environment Effects Statement (EES) requires a Supplementary Statement to be prepared by Viva Energy Gas Australia Pty Ltd (Viva Energy), in accordance with sections 5 and 8C(2) of the *Environment Effects Act 1978 (Vic)*. The Supplementary Statement is required to complete the assessment of the project's environmental effects on the marine environment, noise, air quality and Aboriginal cultural heritage in accordance with the Minister's Directions and inform decision making.

1.1 Purpose

This supplementary air quality study provides a technical response to Recommendation 11 in Table 1 of the Minister's Directions, integrates the findings of the study with key outcomes of the original EES air quality impact assessment and provides an update to the air quality mitigation measures recommended in the original EES where necessary.

The objective of this study is to provide sensitivity analysis on the air quality modelling to confirm that the operational impacts from the proposal are acceptable, supplementary to the original air quality impact assessment.

The sensitivity analysis included the investigation of the potential significance of wake effects of the FSRU, the potential worst-case scenario for emissions and the implication of bubble limits and stack specific limits for sensitive receptors, to meet the requirements of Recommendation 11 in Table 1 of the Minister's Directions as detailed in section 2.0.

1.2 Project area

The project would be located adjacent to, and on, the Geelong Refinery and Refinery Pier in the City of Greater Geelong, 75 kilometres (km) south-west of Melbourne. The project area is within a heavily developed port and industrial area on the western shores of Corio Bay between the Geelong suburbs of Corio and North Shore. The Geelong central business district is located approximately 7 km south of the project. The project area is shown in Figure 1.Corio Bay is the largest bay in the south-west corner of Port Phillip Bay and is a sheltered, shallow basin at the western end of the Geelong Arm, with an area of 44 square kilometres (km^2). The Point Wilson/Limeburners Bay section of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar site is located along the northern shoreline of Corio Bay, approximately one kilometre to the north-east of the project.

The Port of Geelong has been in operation for over 150 years and is the largest industrial bulk cargo port in Victoria, attracting over 600 ship visits and handling more than 14 million tonnes of product annually. Geelong's shipping channels extend 18 nautical miles through Corio Bay from Point Richards through to Refinery Pier. Ports Victoria manages commercial navigation in the port waters in and around Geelong and is responsible for the safe and efficient movement of shipping, and for maintaining shipping channels and navigation aids. The channels are man-made having been deepened and widened through periodic dredging to support port trade development.

Refinery Pier is the primary location within the Port of Geelong for movement of bulk liquids. Vessels up to 265 metres in length currently utilise the four berths at Refinery Pier which service Viva Energy refinery operations. The majority of ship visits to the port are to Refinery Pier, with Viva Energy accounting for over half of the trade through the Port of Geelong.

The Geelong Refinery has been operating since 1954 with both the refinery and the co-located Lyondell Bassell plant being licensed Major Hazard Facilities (MHFs). A range of industrial activities are situated in the Port environs including wood fibre processing and chemical, fertiliser and cement manufacturing.

To the north of the Geelong Refinery, along the proposed underground pipeline corridor, the area is predominantly rural. There are several other existing Viva Energy-owned underground pipelines running between the refinery and the connection point to the South-West Pipeline (SWP) at Lara. The proposed pipeline route follows already disturbed pipeline corridors, where possible, through a mix of land uses.

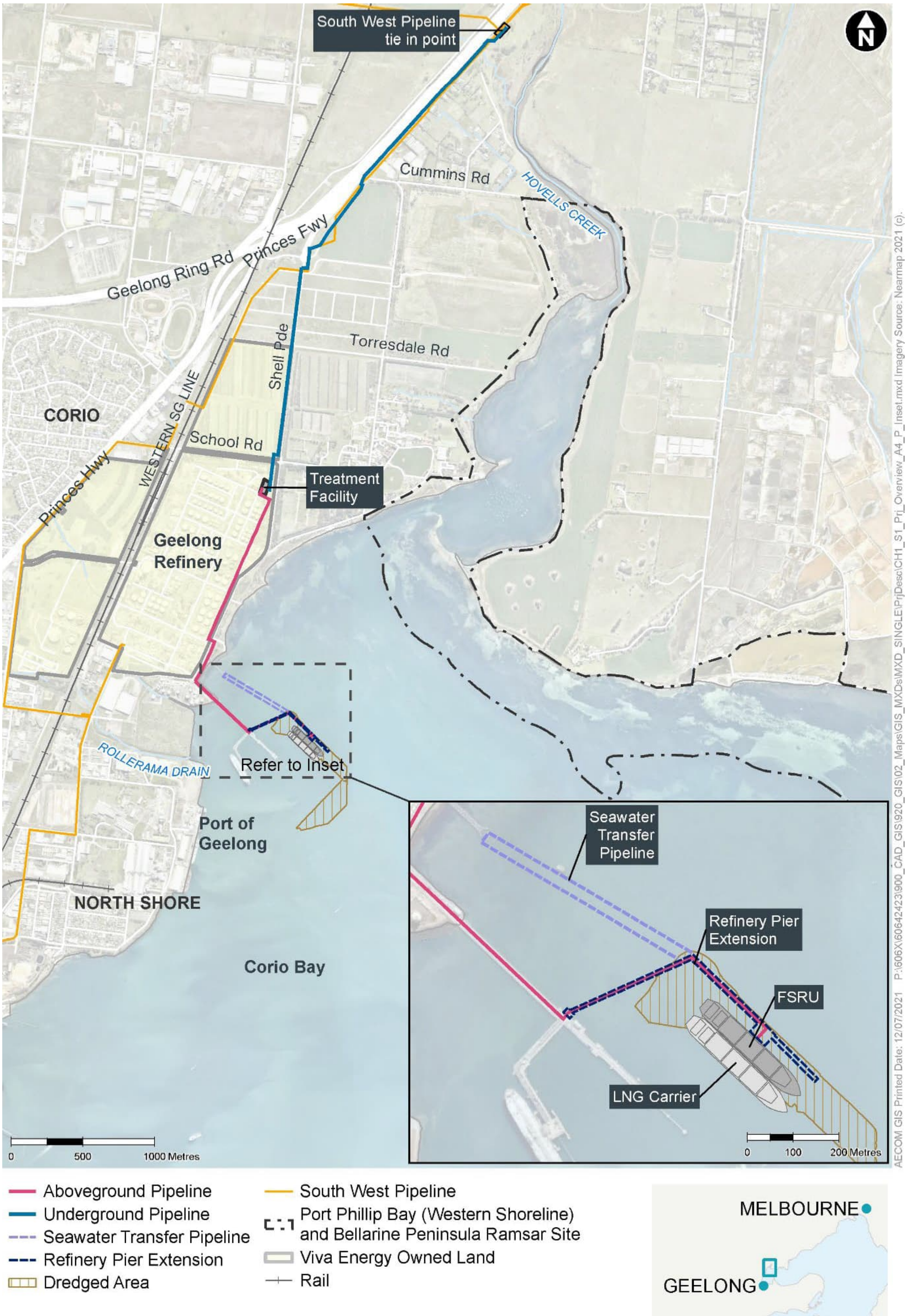


Figure 1 Project overview

1.3 Project description

Key components of the project include:

- extension of the existing Refinery Pier with an approximately 570 metre (m) long angled pier arm, new berth and ancillary pier infrastructure including high pressure gas marine loading arms (MLAs) and a transfer line connecting the seawater discharge points on the FSRU to the refinery seawater intake.
- continuous mooring of an FSRU at the new Refinery Pier berth to store and convert LNG into natural gas. LNG carriers would moor alongside the FSRU and unload the LNG.
- construction and operation of approximately 3km of aboveground gas pipeline on the pier and within the refinery site connecting the FSRU to the new treatment facility.
- construction and operation of a treatment facility on refinery premises including injection of nitrogen and odorant (if required).
- construction and operation of an underground gas transmission pipeline, approximately 4km in length, connecting to the SWP at Lara.

The Refinery Pier extension would be located to the north-east of Refinery Pier No. 1. The new pier arm would be positioned to allow for sufficient clearance between an LNG carrier berthed alongside the FSRU and a vessel berthed at the existing Refinery Pier berth No. 1. Dredging of approximately 490,000 cubic metres of seabed sediment would be required to allow for the new berth pocket and swing basin.

The FSRU vessel would be up to 300 m in length and 50 m in breadth, with the capacity to store approximately 170,000 cubic metres (m^3) of LNG. The FSRU would receive LNG from visiting LNG carriers and store it onboard in cryogenic storage tanks at about -160 °C.

The FSRU would receive up to 160 PJ per annum (approximately 45 LNG carriers) depending on demand. The number of LNG carriers would also depend on their storage capacity, which could vary from 140,000 to 170,000 m^3.

When gas is needed, the FSRU would convert the LNG back into a gaseous state by heating the LNG using seawater (a process known as regasification). The natural gas would then be transferred through the aboveground pipeline from the FSRU to the treatment facility where odorant and nitrogen would be added, where required, to meet Victorian Transmission System (VTS) gas quality specifications. Nitrogen injection would occur when any given gas cargo needs to be adjusted (diluted) to meet local specifications. Odorant (mercaptan) is added as a safety requirement so that the normally odourless gas can be smelt when in use. From the treatment facility, the underground section of the pipeline would transfer the natural gas to the tie-in point to the SWP at Lara.

1.3.1 Key construction activities

Construction of the project would occur over a period of up to 18 months. The key construction activities relate to:

- localised dredging of seabed sediments to enable the FSRU and LNG carriers to berth at Refinery Pier and excavation of a shallow trench for the seawater transfer pipe
- construction of a temporary loadout facility at Lascelles Wharf
- construction of the new pier arm and berthing infrastructure, and aboveground pipeline along Refinery Pier and through the refinery
- construction of the treatment facility on a laydown area at the northern boundary of the refinery site
- construction of the buried pipeline
- construction at the tie-in point to the SWP at Lara.

There are no construction activities required for the FSRU component of the project. The vessel would be built, commissioned and all production and safety systems verified prior to being brought to site.

An estimated 490,000 cubic metres (m^3) of dredging would be required, over an area of approximately 12 hectares (ha), adjacent to the existing shipping channel to provide sufficient water depth at the new berth and within the swing basin for visiting LNG carriers to turn. Dredging within the new berth would be undertaken to a depth of 13.1 metres and the swing basin would be dredged to a depth of 12.7 metres. The dredging footprint is shown in Figure 1. It is planned to deposit the dredged material within Ports Victoria's existing dredged material ground (DMG) in Port Phillip Bay to the east of Point Wilson, approximately 26 km from Refinery Pier.

The temporary loadout facility at Lascelles Wharf would be the first construction activity to take place in order to facilitate the Refinery Pier extension. This would involve the installation of 10 piles using hydraulic hammers.

Construction of the pier arm would be carried out once dredging was complete, primarily from the water using barge-mounted cranes. Steel piles would be driven into the seabed by cranes mounted on floating barges and pre-cast concrete and pre-fabricated steel components would be transported to site by barge and lifted into position. The installation of pier infrastructure such as the marine loading arms (MLAs), piping from the FSRU to the existing refinery seawater intake (SWI) and aboveground pipeline would also be undertaken from the water using barge-mounted cranes.

Installation of the 3km above ground pipeline along the pier and through the refinery is anticipated to take 3.5 months to complete. The above ground pipeline would run along the pier to the existing pipe track east of Shell Parade within the pier foreshore compound. It would then pass through a road under-crossing to the existing refinery pipe track. The pipeline would then run north along the existing refinery pipe track to an existing laydown area where the treatment facility would be located.

The treatment facility would be located within an existing laydown area in the refinery site and cover an area of approximately 80m x 120m. Construction of the treatment facility would take approximately 6 months and would be undertaken by specialist crews across distinct phases of work. These would include initial earthworks and civil construction, mechanical installation and electrical and instrumentation works.

The 4km underground pipeline would be installed in stages over an approximate 4-month period within a corridor which has been selected so as to avoid the need for trenchless construction beneath watercourses or other environmental sensitivities. Firstly, a construction right of way (ROW) would be established, clearly identified and fenced off where required. Typically, this would be between 25 and 30m wide, and minimised where possible to reduce disturbance. Once the construction ROW is established, vegetation would be removed, and a trench excavated to a maximum depth of 2m and a maximum width of 1m for the pipeline to be placed. Following the placement of the pipeline, the construction ROW would be rehabilitated to its pre-existing condition as far as practicable for the purposes for which it was used immediately before the construction of that part of the pipeline.

Trenchless construction (including boring or horizontal directional drilling (HDD)) would be used to install the underground pipeline in areas that are not suited to open trenching techniques, such as at intersections with major roads, which would be confirmed during detailed design. Trenchless construction would involve boring or drilling a hole beneath the ground surface at a shallow angle and then pushing or pulling a welded length of pipe through the hole without disturbing the surface. It is anticipated that the maximum depth of the trenchless section would be 25m.

Construction at the tie-in point to the SWP at Lara would be undertaken by specialist crews across the distinct phases of works, as with the treatment facility.

1.3.2 Key operation activities

The project is expected to be in operation for approximately 20 years. Key activities relating to project operation include:

- receipt of up to 45 LNG carriers each year at Refinery Pier – the number and frequency of LNG carriers arriving each year would depend on their storage capacity and gas demand
- regasification of LNG onboard the FSRU using seawater as a heat source, which would then be reused within the refinery as cooling water
- injection of nitrogen and odorant into the gas prior to distribution via the VTS
- monitoring and maintenance of the pipeline easement.

1.3.3 Key decommissioning activities

The FSRU, which continues to be an ocean-going vessel throughout the operation of the project, would leave Corio Bay on completion of the project life to be used elsewhere.

It is anticipated that the Refinery Pier berth and facilities would be retained for other port related uses. The underground pipeline would likely remain in situ subject to landholder agreements and either decommissioned completely or placed into care and maintenance arrangements.

Decommissioning activities may be subject to change, subject to legislative requirements at the time and potential repurposing of the infrastructure at the end of the project.

1.3.4 Project activities relevant to the supplementary study

In accordance with Recommendation 11 in Table 1 of the Minister's Directions the focus of the supplementary air quality study was to conduct a sensitivity analysis of the air quality modelling and confirm the acceptability of the air quality impact associated with the operation of the FSRU.

2.0 Minister's Directions

The modelling undertaken in original EES study Technical Report H: Air quality impact assessment (AECOM, 2022) (hereafter referred to as "AQ EES study") showed no exceedances of adopted air quality criteria at any of the sensitive receptors in the study area. The AQ EES study concluded that air quality impacts from FSRU operations would be low, would not exceed adopted regulatory air quality criteria and would be localised in the vicinity of Refinery Pier and the Refinery.

The Inquiry and Advisory Committee (IAC) considered the air quality criteria adopted in the EES are appropriate and noted that EPA supported the adopted criteria. The IAC also agreed that the modelling demonstrates that if the project is implemented in accordance with all the assumptions in the modelled scenarios, the impacts on air quality would be acceptable (IAC Report No. 1, section 13.3 (iii)).

In addition, The IAC accepted the use of the Hoegh Esperanza FSRU air emissions data which represents current best available technology and did not consider that further sensitivity testing is required in this regard (IAC Report No. 1, section 13.3 (iii))

The IAC also recommended that Viva Energy continues to work with the Victorian Environment Protection Authority (EPA Victoria) to compare the effects of bubble limits and stack specific limits in relation to air quality impacts on sensitive receptors.

The Minister's Directions require Viva Energy to prepare a Supplementary Statement to provide an assessment of the environmental effects of the project on the marine environment, noise, air quality and Aboriginal cultural heritage with respect to the consolidated recommendations of the IAC for further work. Table 1 of the Minister's Directions presents the IAC's consolidated recommendations for further work.

Three items of further work were identified under Recommendation 11 in Table 1 of the Minister's Directions which relates to air quality. Recommendation 11 is presented in Table 1 below.

Table 1 Recommendation for further work relevant to this supplementary air quality study

Recommendation	Further work to be undertaken	Supplementary study section
Recommendation 11	Undertake sensitivity testing on the air quality modelling to confirm that operational impacts on air quality would be acceptable. Consider:	
	a) the significance of the wake effects of the floating storage and regasification unit (FSRU)	Section 4.1
	b) a 'worst-case' scenario for air emissions (but based on the use of best available technology [BAT])	Section 4.2
	c) the implication of bubble limits and stack specific limits for sensitive receptors.	Section 4.3

3.0 Methodology

This section describes how the supplementary air quality study was conducted to address the Minister's Directions related to air quality (Recommendation 11). The following sections outline the study methodology.

3.1 Proposed tasks to address Minister's Directions

A description of the proposed tasks to address Recommendation 11, as well as a summary of the expected outcome of each task is provided in Table 2 below.

Table 2 Air quality methodology

Task objective	Task description	Outcomes
Confirm that operational impacts on air quality would be acceptable to address Recommendation 11	Conduct sensitivity testing on the air quality modelling to confirm that operational impacts on air quality would be acceptable considering: a. The wake effects of the FSRU (Recommendation 11a) - Document and summarise differences between general arrangement of Hoegh, Bergesen Worldwide (BW) and Golar FSRUs - Model emissions using AERMOD to compare wake effects for: ▪ the FSRU discharge points with no wake effects ▪ different FSRU configurations (based on general arrangements of Hoegh, BW and Golar FSRUs) ▪ two different FSRU orientations (bow facing south-east (proposed) and north-west) ▪ with and without an LNG carrier alongside the FSRU. b. A 'worst-case' scenario for air emissions (but based on the use of BAT) (Recommendation 11b) - Compare the sensitivity testing results for different configurations and orientations of the FSRU. - Provide further discussion and analysis for the 'worst-case' scenario air quality impacts, such as frequency of occurrence analysis and time varying background. c. The implications of bubble limits and stack specific limits for sensitive receptors (Recommendation 11c) - Provide proposed project gas production profiles to demonstrate the gas demand trend over a year and establish the basis for calculating bubble limits. - Present the proposed stack specific limits and bubble limits. - Compare long-term (annual) air emissions and air quality impacts on sensitive receptors for stack specific limits only, and a combination of stack and bubble limits. The Inquiry and Advisory Committee (IAC) accepted the use of the Hoegh FSRU (Esperanza) data which represents current best available technology and did not consider that further sensitivity testing is required in this regard.	**Task a:** An understanding of the significance of wake effects on ground level concentrations due to different FSRU orientations and configurations. **Task b:** Determine the 'worst-case' scenario for air emissions and show the potential air quality impacts from the project for the 'worst-case' scenario. **Task c:** Identification of the most appropriate limits for the environment while meeting operational requirements. 1.

3.2 Study area and sensitive receptors

3.2.1 Study area

The study area for this supplementary air quality study is consistent with AQ EES study, which is a 10 square kilometre grid surrounding the FSRU.

For sensitivity testing, ground level concentrations at a 10 by 10 kilometres multi-tier receptor grid were assessed for the study area:

- A 100 m resolution inner tier grid extending to 5 x 5 km (i.e., 51 x 51 points).
- A 500 m resolution outer tier grid extending to 10 x 10 km (i.e., 21 x 21 points).

Sensitive receptors assessed within the study area are further discussed in section 3.2.2. Figure 2 shows the study area and the locations of assessed receptors.

3.2.2 Sensitive receptors

This section provides a summary of nearby sensitive receptors, which were detailed in section 5.2 of the AQ EES study.

The area surrounding the FSRU is characterised by a mixture of industrial uses, commercial areas and residential dwellings. A sensitive land use is one where it is plausible for people to be exposed over extended durations (EPA, 2022). Sensitive land uses include, but are not limited to:

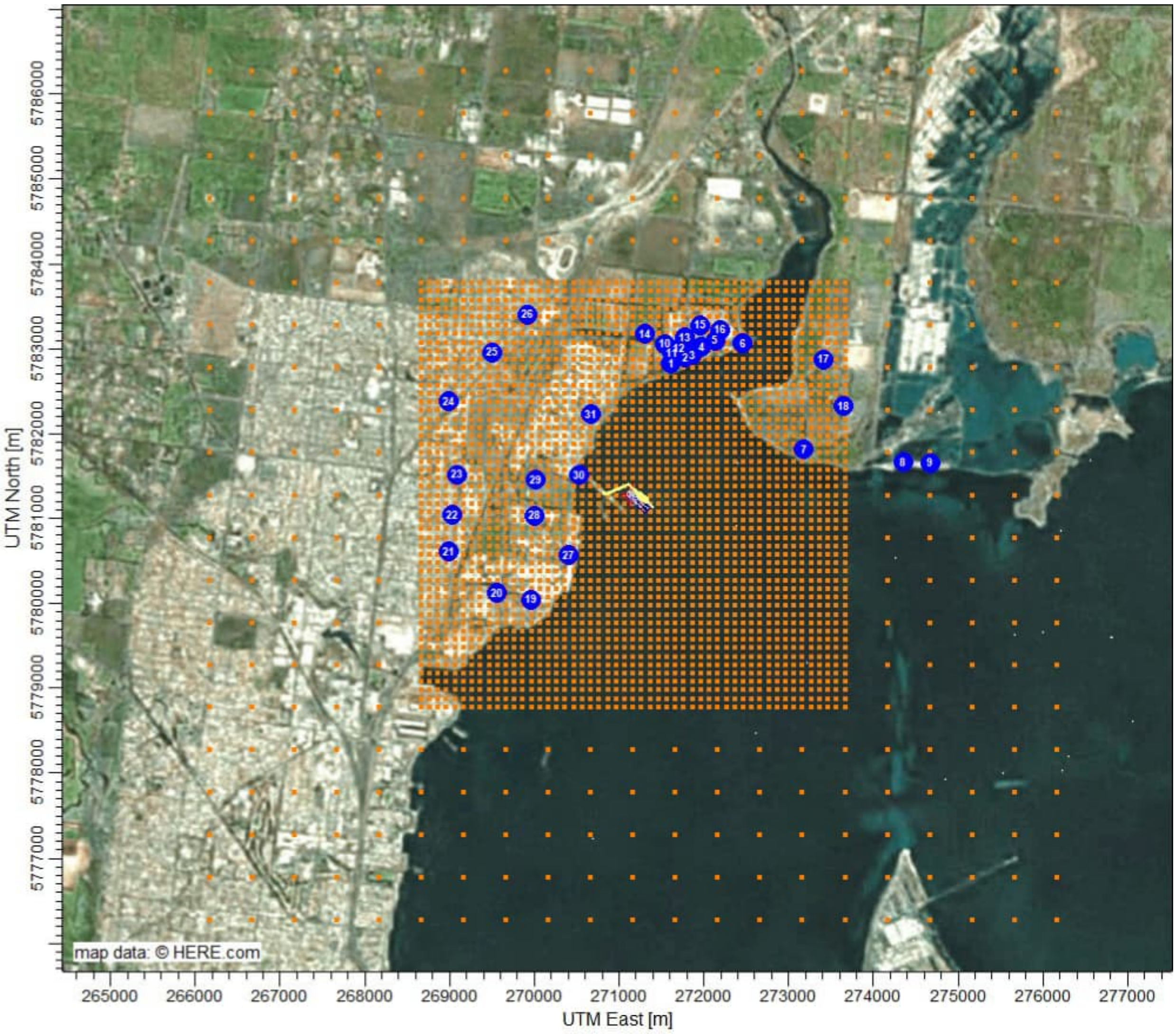
- residential premises
- educational and childcare facilities
- nursing homes
- retirement villages
- hospitals
- ecological significance (e.g. national parks or other areas of ecological significance)

The nearest sensitive receptors are located 1.5 kilometres from the FSRU, and the nearest industrial receptor is located 600m west of the FSRU. Modelling results show that pollutant concentrations are greatest near the FSRU and decrease over distance. Therefore, the nearest 31 receptors from the FSRU were modelled in the AQ EES study and this supplementary study:

- 26 Sensitive receptors: Receptors 1 to 26
- 5 Industrial receptors: Receptors 27 to 31.

The locations of these receptors are presented in Figure 2.

Australian Bureau of Statistics (ABS) information shows that the study area has low population density (generally less than 500 people per square kilometre) with ‘most disadvantaged’ areas located at least 1.5 kilometres from the proposed project location. The combination of low population density and large buffer to vulnerable populations indicates that increased impacts on health from air pollution are unlikely in the study area.



Note: Orange squares represent gridded receptors, and blue circles represent sensitive and industrial receptors

Figure 2 Study area and modelled grided and discrete receptors

3.3 Stakeholder and community engagement

In accordance with the Minister's Directions, a Technical Reference Group (TRG) has been convened and is chaired by Department of Transport and Planning, Impact Assessment Unit on behalf of the Minister for Planning. The TRG has provided input to Viva Energy's Study Program required to inform the Supplementary Statement and throughout the Supplementary Statement extended assessment process.

Engagement and consultation to support the assessment of the environmental effects of the project on air quality, with respect to the recommendations in Table 1 of the Minister's Directions, is being undertaken in accordance with Viva Energy's Supplementary Statement Consultation Activities Plan. The approach, as described in the Supplementary Statement Consultation Activities Plan, has been updated taking on board feedback from stakeholders and the IAC. Activities are focused on facilitating meaningful stakeholder involvement in the extended assessment process and providing opportunities for genuine engagement on the further work required by the Minister's Directions.

3.4 Assumptions and limitations

This supplementary air quality study was completed based on the following assumptions and limitations:

- For the purpose of testing the significance of wake effects:
  - the Hoegh Esperanza discharge parameters, including emission rate, flow rate, temperature, and stack diameter, was assumed for the Golar FSRU
  - stack height and location were adjusted to align with the design arrangement drawing of the Golar FSRU.

  When a specific FSRU is confirmed for the project, air dispersion modelling for the selected FSRU will be conducted to refine the predicted impacts.
- The liquid-fuelled scenario is not expected to occur during normal operations, and would only occur during maintenance, start-up, and emergency situations, therefore not further discussed in this sensitivity testing.
- The peak load scenario would be infrequent (i.e., two days per winter month) according to market demand. However, to capture the possible worst impact, the peak load scenario was modelled for every hour over the five-year modelling period (43,848 hours). The peak load scenario modelled is in the closed loop mode since it would result in higher emissions than the preferred open loop mode, representing a conservative worst-case scenario.
- The proposed stack specific limits and annual bubble limits were based on current design of the project. Following the confirmation of a specific FSRU for the project, a variation to the proposed limits may be required where the selected FSRU has different engine sizes and exhaust parameters. Viva Energy will select an FSRU with emissions that will not vary significantly from those of the Hoegh Esperanza and uses best available technology.
- To determine the potential annual average ground level concentrations at sensitive receptors under a combination of stack specific and bubble limits, dispersion modelling was conducted assuming the FSRU would run at peak load on the first two days of each winter month. In reality, the peak load may occur on any winter day. However, the difference in annual average concentration is considered negligible if the peak load occurs on a different day.

3.4.1 Linkages to EES studies and other supplementary studies

This air quality supplementary study references sections of the original EES study Technical Report H: *Air quality impact assessment* (AECOM, 2022) (hereafter referred to as “AQ EES study”) where relevant.

4.0 Results of Supplementary Study Tasks

4.1 The significance of the wake effects of the FSRU

4.1.1 Wake effects

Building wake effect is *the effect on plume dispersion caused by the presence of buildings near a stack, usually resulting in increased ground-level concentrations of pollutants* (NSW EPA, 2022). Wake effects can occur if:

$$H_s < Hb + 1.5L$$

Where:

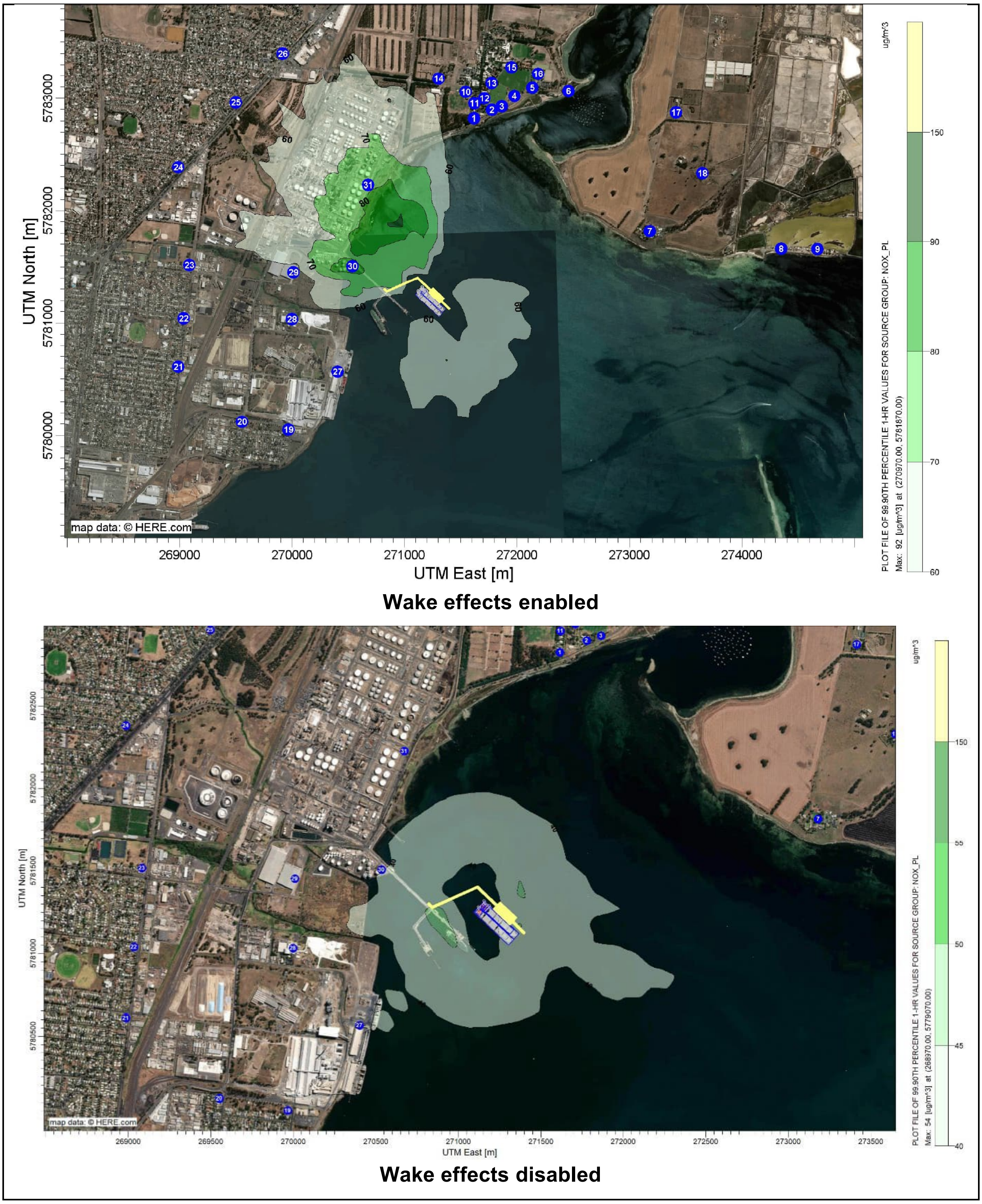
- Hs = Stack Height
- Hb = Building Height
- L = Less of Hb or the Project Building Width (PBW)
- PBW = Maximum length of a building that could affect air flow around and over a building or other obstacle.

If the distance between the stack and a building is less than 5L, wake effects need to be considered. Based on the dimensions of the Esperanza FSRU and the stack heights, wake effects from the FSRU should be considered in the dispersion modelling.

It is noted that the intent of the AQ EES study statement, "*Sensitivity analysis showed that dispersion patterns from the FSRU are highly dependent on wake effects*" was to highlight the difference in predicted pollutant concentrations between modelled scenarios when wake effects were included or excluded in the model. When wake effects are enabled in the model, variations in the dimensions of the same building are not expected to have a significant impact on the modelled results.

Figure 3 shows the contour plots that were developed as part of the AQ EES study for the 1-hour average NO_2 cumulative concentrations for the peak load scenario plus an LNG carrier, with wake effects enabled and disabled. Ground level concentrations predicted with no wake effects in the model are much lower.

Sensitivity testing regarding the impact of different configurations and orientations of the FSRU on ground level concentrations is further discussed in section 4.1.2 and 4.1.3.



Note: FSRU peak load scenario plus LNG carrier, with wake effects enabled and disabled.

Figure 3 Contour plots of 1-hour average 99.9th percentile cumulative NO_2

4.1.2 Sensitivity testing scenarios

To assess the significance of the wake effects of the FSRU, configurations of the following four 170,000 m^3 FSRUs were reviewed:

- Hoegh Esperanza
- Golar Tundra
- Golar Igloo
- BW Integrity

Table 3 presents the detailed dimensions of the four FSRUs, and the data shows that the dimensions of Golar Tundra, Golar Igloo and BW Integrity are the same. Therefore, a Golar FSRU was selected to compare the predicted air quality impacts against those modelled for the Esperanza. There are slight dimensional variations between the Golar and Esperanza FSRUs, but they are not significantly different.

Table 3 Configuration of different FSRU (meter)

Dimension	Hoegh Esperanza	Golar Tundra	Golar Igloo	BW Integrity
Length O. A.	294	293	293	293
Length B. P.	282	281	281	281
Breadth (moulded)	46	43	43	43
Depth (moulded)	26	27	27	27
Designed draught (moulded)	12	12	12	12
Scantling draught (moulded)	13	13	13	13
A Deck (height x length x breadth)	19x44x32	20x40x37	20x40x37	20x40x37
B Deck (height x length x breadth)	22x44x32	23x40x34	23x40x34	23x40x34
C Deck (height x length x breadth)	25x44x32	26x40x34	26x40x34	26x40x34
D Deck (height x length x breadth)	29x44x32	30x40x30	30x40x30	30x40x30
Navigation Bridge Deck (height x length x breadth)	32x42x46	33x39x43	33x39x43	33x39x43
W/H Top (height x length x breadth)	35x43x46	36x39x24	36x39x24	36x39x24
Exhaust emission height (above designed draught)	50	41	41	41
Funnel top (height x length x breadth)	48x12x12	38x8x9	38x8x9	38x8x9

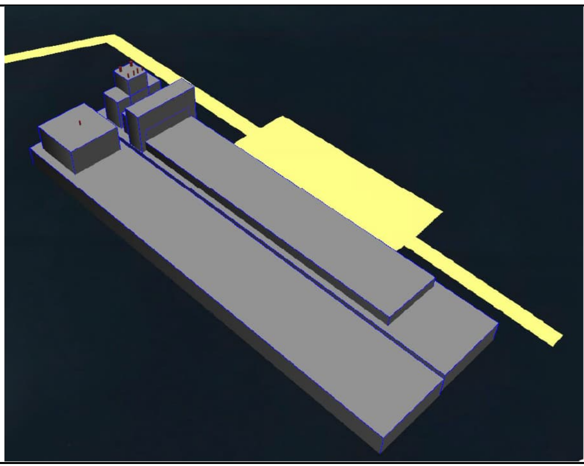
Note: All the heights were measured from the designed draught.

In addition to different configurations of FSRUs, the orientations of the FSRUs were also considered for sensitivity testing to understand how the orientation may influence wake effects and associated predicted pollutant ground level concentrations at sensitive receptors.

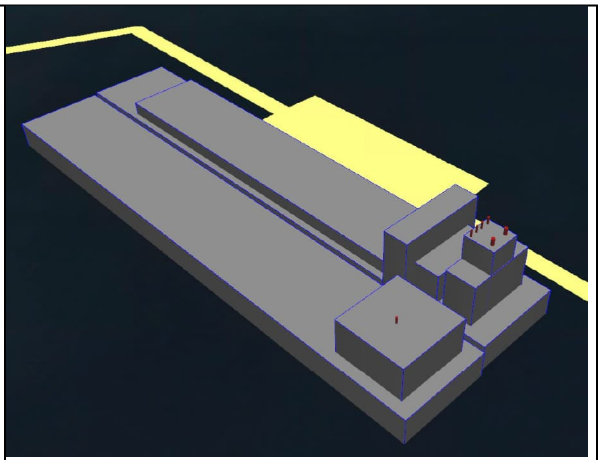
To understand how FSRU configurations and orientations may influence plume dispersal the following scenarios were assessed:

- FSRU plus LNG carrier
  - Esperanza: bow facing southeast (modelled in the AQ EES study)
  - Esperanza: bow facing northwest
  - Golar: bow facing southeast
  - Golar: bow facing northwest
- FSRU only
  - Esperanza: bow facing southeast (modelled in the AQ EES study)
  - Esperanza: bow facing northwest
  - Golar: bow facing southeast
  - Golar: bow facing northwest

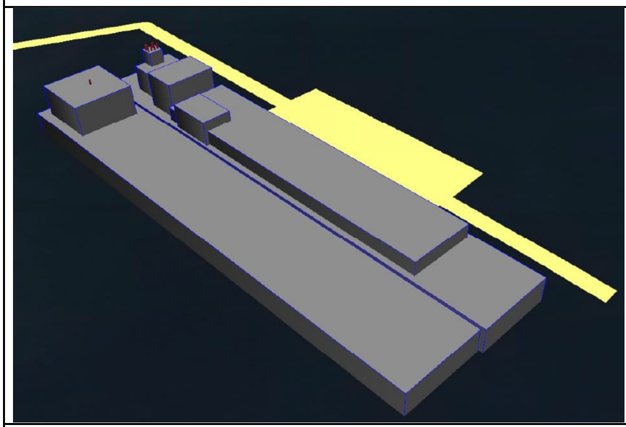
Figure 4 shows the 3D view of the modelled configurations for the FSRU plus LNG carrier scenarios. For the sensitivity analysis of wake effects, the same emission inventory, including emission rate, flow rate, temperature, and stack diameter, was assumed for the Golar FSRU, while the stack height and location were adjusted to align with the design of a Golar FSRU. When a specific FSRU has been ultimately confirmed, air dispersion modelling for the selected FSRU will be conducted to refine the predicted impacts.



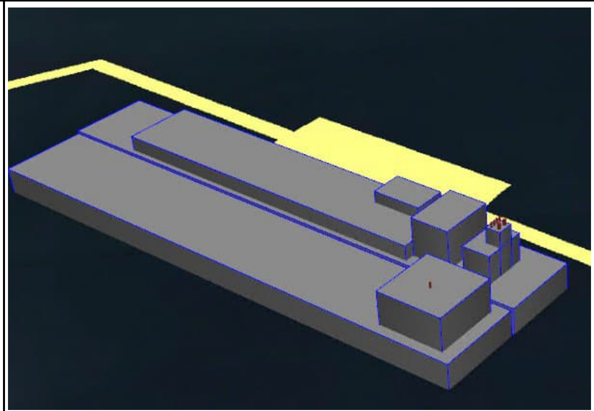
Esperanza – Bow facing southeast (previously modelled)



Esperanza – Bow facing northwest



Golar– Bow facing southeast



Golar – Bow facing northwest

Figure 4 Modelled configurations for FSRU and LNG carrier

The modelled scenarios in the AQ EES study for the Esperanza with its bow facing southeast are presented in Table 4. It is noted that the liquid-fuelled scenario is not expected to occur during normal operations, and would only occur during maintenance, start-up and emergency situations, therefore this scenario is not discussed in this sensitivity testing. In addition, the AQ EES study predicted that air emissions generated during peak load have the highest impacts during normal operations.

To compare the highest impacts of different FSRU configurations, this sensitivity testing was conducted for the peak load scenario (gas-fuelled, closed loop) as shown in Table 4. Note that closed loop is not preferred as the usual operating mode as it uses up to 2.5% of the LNG cargo to heat the LNG and has higher greenhouse gas emissions than open loop operation. Closed loop operating mode would only be utilised in the unlikely event that the FSRU was unable to discharge water through the seawater transfer pipe to the refinery, for example, during FSRU maintenance or due to a pump or pipe failure. Notwithstanding this, the closed loop mode has been used in the sensitivity testing as a worst-case scenario and compare the highest potential impacts of different FSRU configurations and orientations.

As discussed in the AQ EES Study, a $PM_{2.5}$/PM_{10} ratio of 83.7 percent was used to calculate $PM_{2.5}$ concentrations based on NPI emission factors for auxiliary engines (weighted average burn) (Australian Government, 2012). The modelling results of the AQ EES Study show that, during normal operation, the predicted maximum cumulative 24-hour PM_{10} concentrations accounted for 65% of its daily criterion at receptors, while the predicted concentration for 24-hour $PM_{2.5}$ accounted for 63% of its daily criterion. Therefore, the 24-hour average PM_{10} was chosen as an air quality indicator alongside the 1-hour average NO_2 due to their relatively high predicted cumulative concentrations in the AQ EES study.

Table 4 Summary of modelled scenarios in the AQ EES study

Modelling scenario	Description
Gas-fuelled, Summer, Open loop	Open loop, gas production rate of 250 TJ/day 2 engines operating at 5,250kW
Gas-fuelled, Summer, Closed loop	Closed loop, gas production rate of 250 TJ/day 2 engines operating at 5,250kW, 1 boiler operating at 100 percent load
Gas-fuelled, Winter, Open loop	Open loop, gas production rate of 500 TJ/day 3 engines operating at 5,250kW
Gas-fuelled, Winter, Closed loop	Closed loop, gas production rate of 500 TJ/day 3 engines operating at 5,250kW, 2 boilers operating at 100 percent load
Gas-fuelled, Peak load, Closed loop	Four natural gas-fuelled engines and two natural gas-fuelled boilers operating at 100 percent load, 620TJ/day
Liquid-fuelled	Two liquid-fuelled engines operating at 1776kW (~25% load), total fuel usage 14.6t/d

4.1.3 Sensitivity testing results

Table 5 presents the summary of sensitivity testing results. Figure 5 and Figure 6 show the predicted 1-hour 99.9th percentile NO_2 and 24-hour average PM_{10} ground level incremental concentrations at industrial and sensitive receptors for different configurations of FSRU alongside LNG carrier, and Figure 7 and Figure 8 present predicted results for the FSRU only scenario. Detailed results in tabular format are presented in Appendix A.

Figure 9 and Figure 10 show the contour plots for 1-hour average 99.9th percentile NO_2 cumulative concentrations (project contribution plus background of 28.2 µg/m^3) for the with and without the LNG carrier scenarios.

For both with and without the LNG carrier scenarios, the sensitivity results for peak load indicate that:

- The 1-hour 99.9th percentile NO_2 and maximum 24-hour PM_{10} are predicted to comply with the Environment Reference Standard (ERS) criteria at all modelled receptors for all configurations and orientations of the FSRU.
- For both Esperanza and Golar FSRUs, higher maximum cumulative concentrations at discrete receptors (both sensitive and industrial) are predicted when the bow is facing southeast (the orientation modelled in the EES) as compared to when it is facing northwest. It is also noted that some receptors are predicted to experience higher concentrations when the bow is facing northwest due to their relative locations to the FSRU.
- For both Esperanza and Golar FSRUs, the maximum cumulative 1-hour 99.9th percentile NO_2 at all modelled locations (both discrete and gridded receptors) are predicted to be higher when the bows are facing northwest. However, these worst-affected areas are located southeast of the FSRU, further away from the coast, resulting in lower concentrations at sensitive receptors onshore.
- When the bows face southeast or northwest, Esperanza is predicted to have slightly higher maximum cumulative concentrations at sensitive receptors compared to Golar. It is also noted that some receptors are predicted to experience slightly higher concentrations for Golar due to their relative locations to the FSRU.
- FSRU plus LNG carrier scenario is predicted to have higher concentrations at modelled receptors compared to the without LNG carrier scenario.

In summary, predicted air quality impacts for the Esperanza and Golar FSRUs only vary slightly. However, lower ground level concentrations at onshore sensitive receptors are predicted when the bow is facing northwest compared to facing southeast.

Overall, the Esperanza with its bow facing southeast alongside an LNG carrier (modelled in the AQ EES study) is predicted to be the worst-case scenario among all configurations and orientations assessed. As demonstrated in the AQ EES study, all modelled pollutants were predicted to comply with relevant criteria at all sensitive, industrial and gridded receptor locations for the worst-case scenario. Further analysis of the results is presented in section 4.2.2. It is noted that this is the preferred orientation for the FSRU due to maritime and port operations safety reasons.

The finding of this item of further work is consistent with the scenario modelled in the original air quality technical study completed as part of the original EES (AQ EES study) and has confirmed that operational impacts on air quality would be acceptable considering the significance of wake effects of the FSRU.

Table 5 Summary of sensitivity testing results

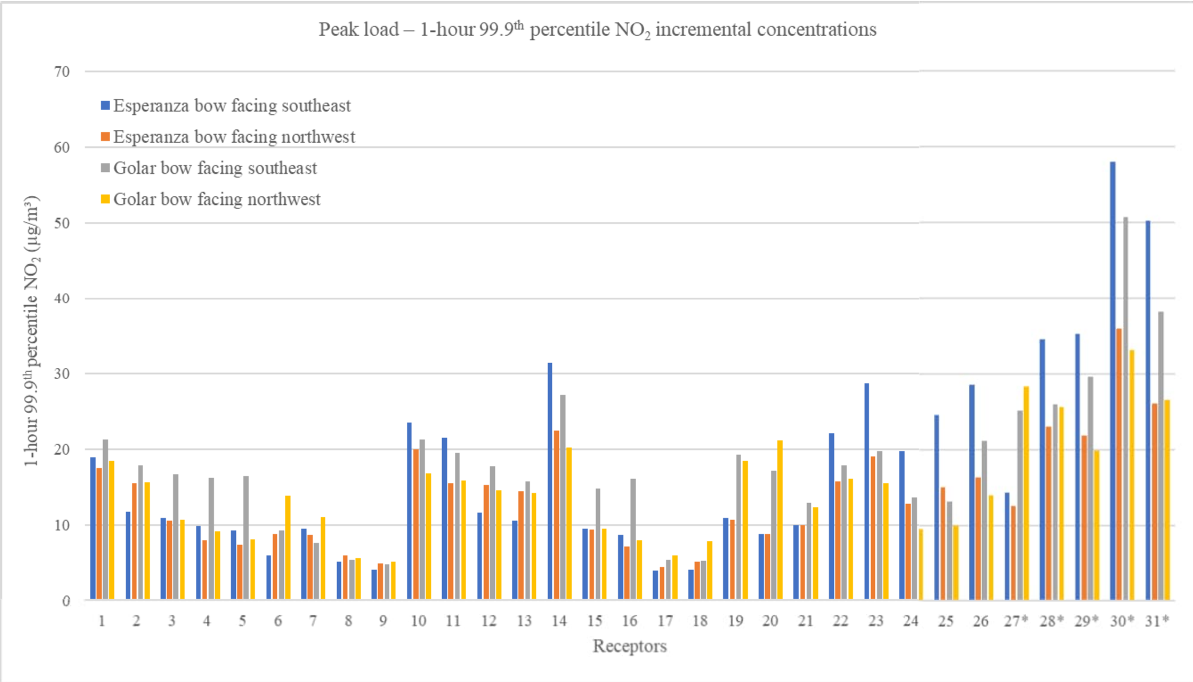
Sensitivity testing scenarios		Peak load - 1-hour 99.9th percentile NO_2 (µg/m³)				Peak load – Maximum 24-hour PM_{10} (µg/m³)			
		Esperanza		Golar		Esperanza		Golar	
		Bow facing SE[1]	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE[1]	Bow facing NW	Bow facing SE	Bow facing NW
Maximum at sensitive receptors									
FSRU and LNG carrier	Incremental	31.4	22.4	27.1	21.2	1.1	0.9	0.9	0.8
	Cumulative	59.6	50.6	55.3	49.4	28.6	28.4	28.4	28.3
FSRU	Incremental	27.5	17.2	20.9	15.1	1.1	0.8	0.8	0.7
	Cumulative	55.7	45.4	49.1	43.3	28.6	28.3	28.3	28.2
Maximum at industrial receptors									
FSRU and LNG carrier	Incremental	58.0	36.0	50.7	33.2	5.19	3.5	5.23	3.3
	Cumulative	86.2	64.2	78.9	61.4	32.7	31.0	32.7	30.8
FSRU	Incremental	49.6	29.7	46.7	29.4	5.0	3.3	5.1	3.0
	Cumulative	77.8	57.9	74.9	57.6	32.5	30.8	32.6	30.5
Maximum at gridded receptors									
FSRU and LNG carrier	Incremental	63.7	65	67.7	73.7	Not applicable[2]			
	Cumulative	91.9	93.2	95.9	101.9				
FSRU	Incremental	53.9	73.8	65.7	69.1				
	Cumulative	82.1	102	93.9	97.3				
Criteria		150[3]				50			

Note: 1. Previously modelled scenario in the AQ EES study.

2. Maximum cumulative concentrations at gridded receptors were not reported for 24-hour PM_{10} because the 24-hour PM_{10} criterion only applies at sensitive receptors (EPA Victoria, 2022).

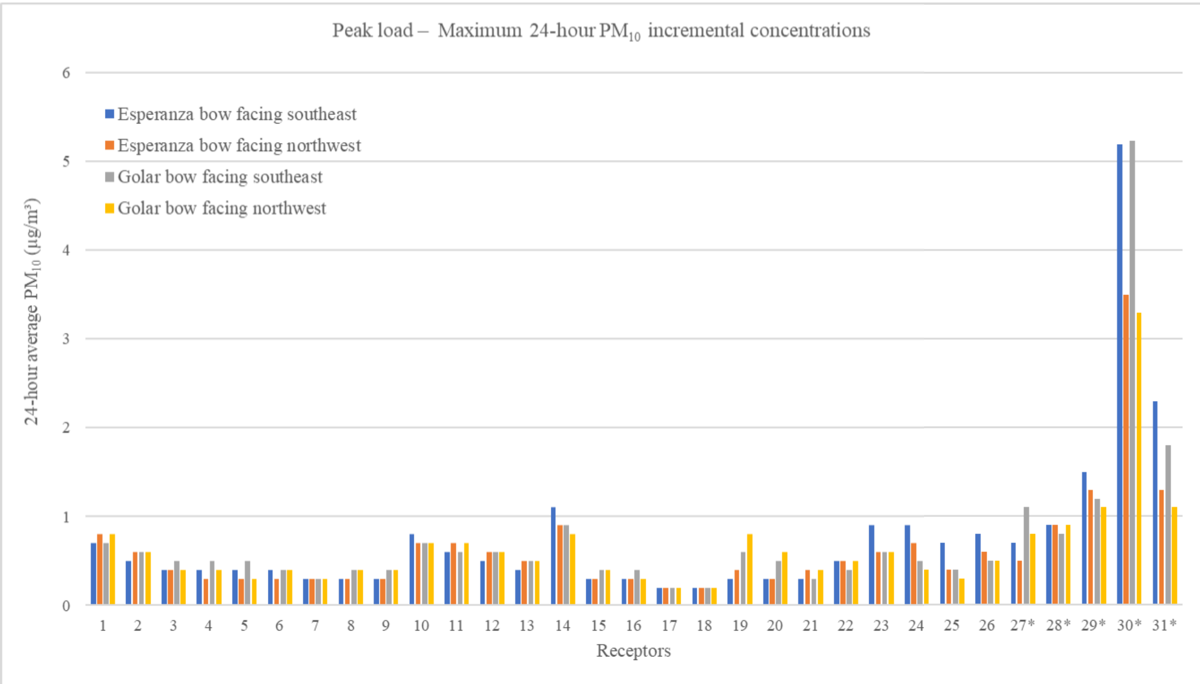
3. The 1-hour average NO_2 criterion in the Environment Reference Standard (ERS) is 0.08 parts per million (ppm). An equivalent criterion of 150 µg/m³ was adopted in the AQ EES study and this supplementary study, and predicted concentrations were also reported in µg/m³ reflecting the unit used in the dispersion model.

4.The highest predicted concentration for each configuration is highlighted in blue.



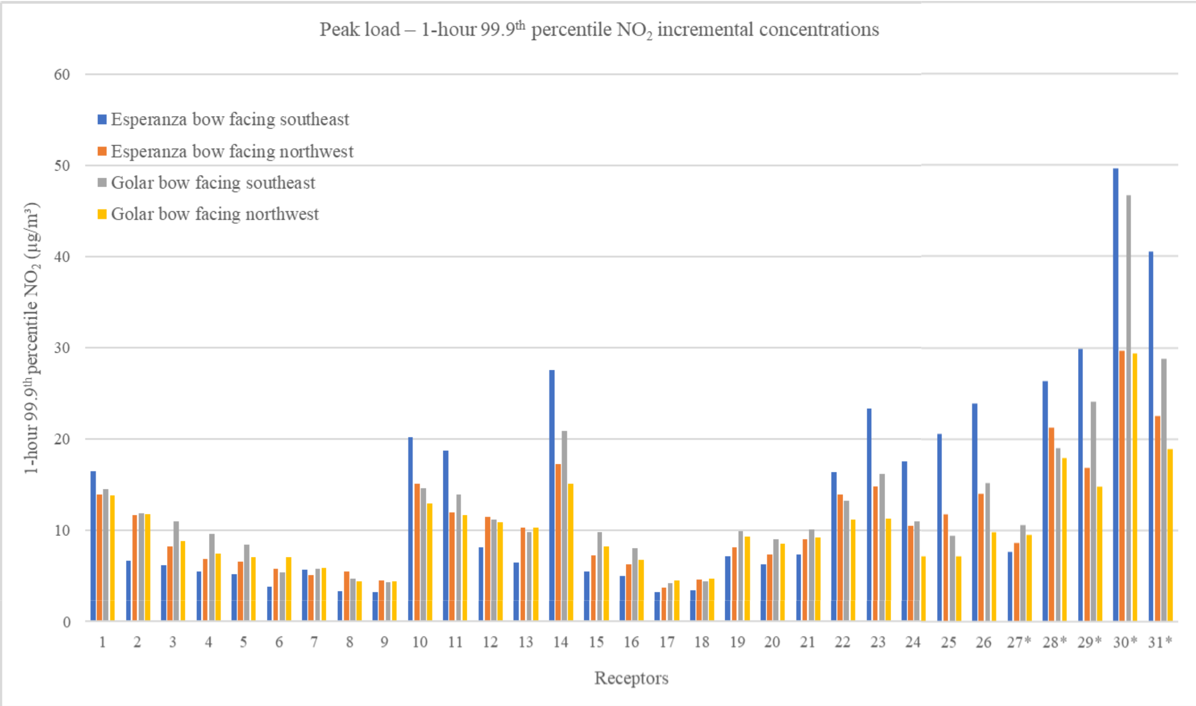
*Note: * means industrial receptors.*

Figure 5 **1-hour 99.9th percentile NO_2 incremental concentrations at industrial and sensitive receptors, FSRU at peak load alongside LNG carrier (2016-2020)**



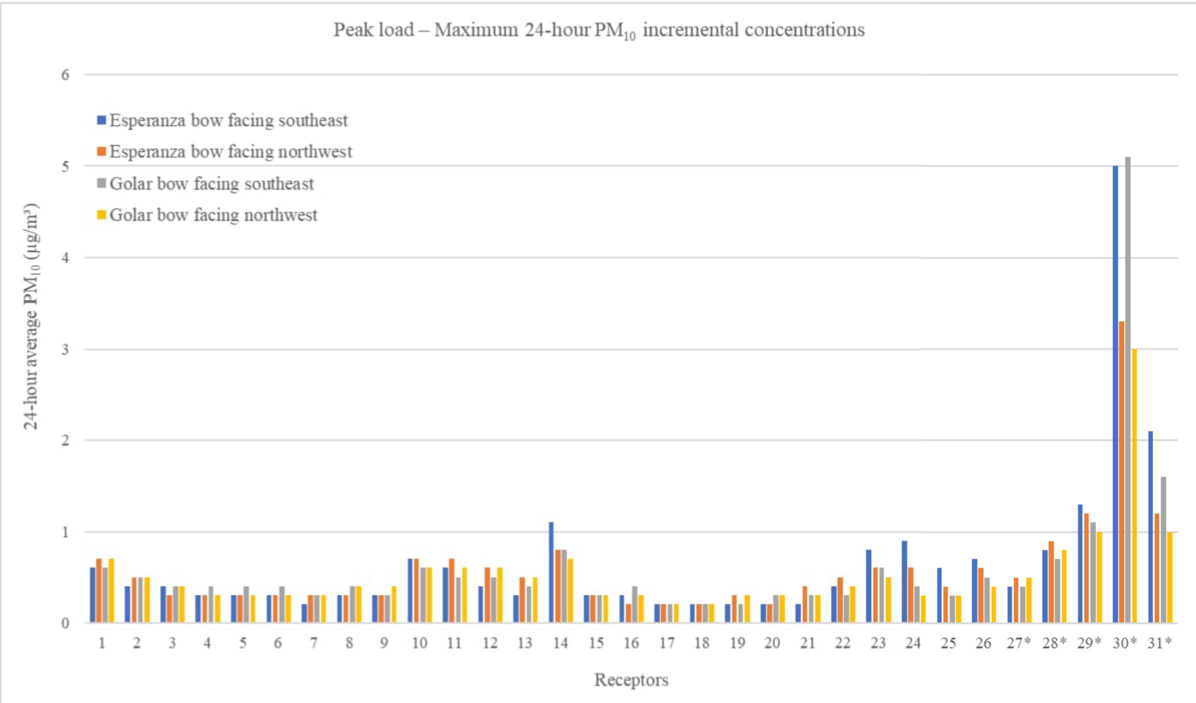
*Note: * means industrial receptors.*

Figure 6 **Maximum 24-hour PM_{10} incremental concentrations at industrial and sensitive receptors, FSRU at peak load alongside plus LNG carrier (2016-2020)**



*Note: * means industrial receptors.*

Figure 7 1-hour 99.9th percentile NO_2 incremental concentrations at industrial and sensitive receptors, FSRU only at peak load (2016-2020)



*Note: * means industrial receptors.*

Figure 8 Maximum 24-hour PM_{10} incremental concentrations at industrial and sensitive receptors, FSRU only at peak load (2016-2020)

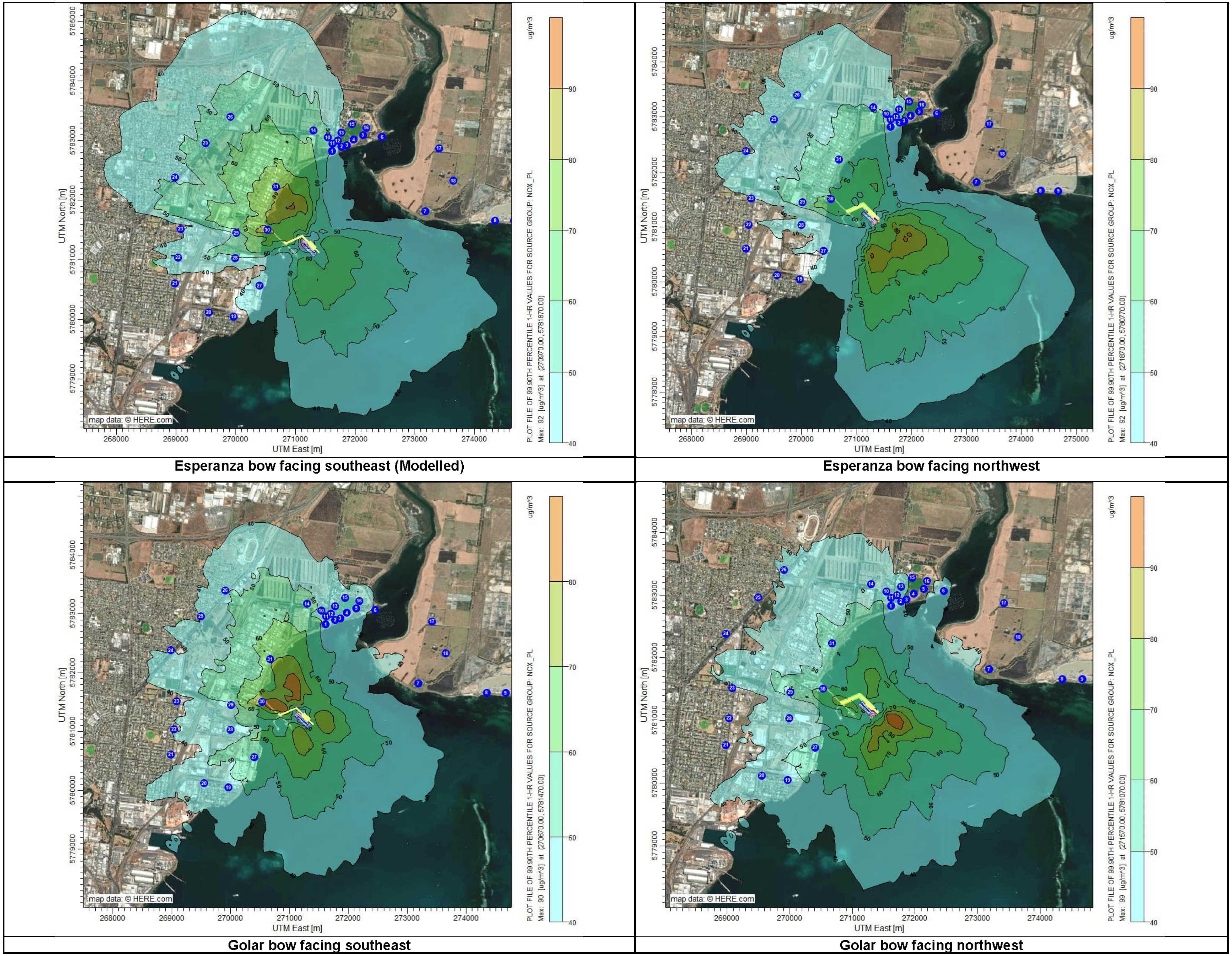


Figure 9 Contour plots for cumulative 1-hour average 99.9th percentile NO_2 concentrations for different configurations of the FSRU plus LNG carrier, 2020 MET (including background of 28.2 µg/m^3)

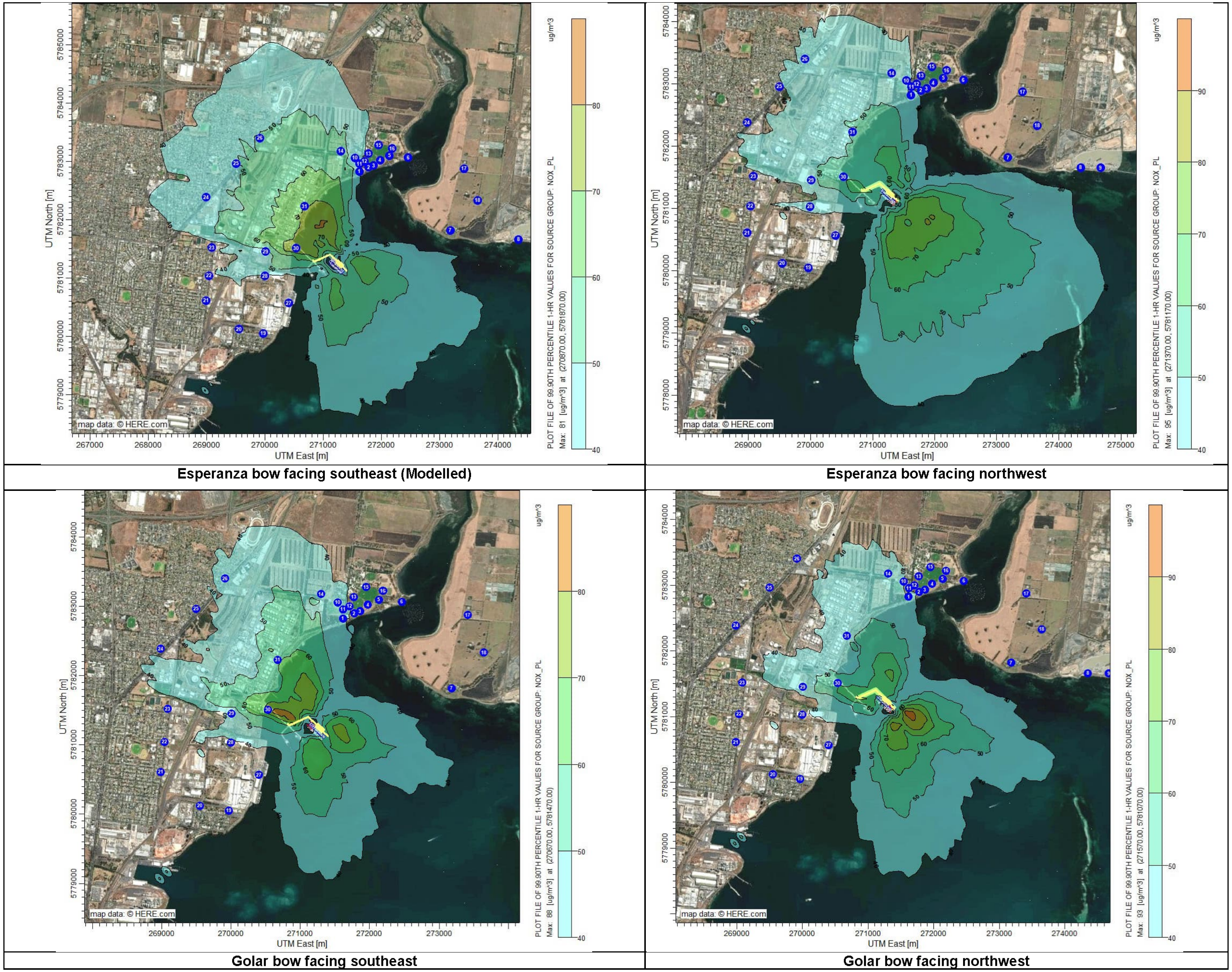


Figure 10 Contour plots for cumulative 1-hour average 99.9th percentile NO_2 concentrations for different configurations of the FSRU, 2020 MET (including background of 28.2 µg/m³)

4.2 A 'worst-case' scenario for air emissions (but based on the use of BAT)

4.2.1 Worst-case scenario

Air emissions from the FSRU are directly proportional to the number of engines and boilers required to meet market demand (i.e., air emissions increase as the number of engines and boilers that are being used increases). A higher production rate requires the use of more engines and therefore will result in higher air emissions.

The emission inventory and modelling results in the AQ EES study have shown that the highest air emissions for the same FSRU configuration are expected to occur during the peak load scenario, when all four engines and two boilers are running at 100 percent load.

To demonstrate the worst-case scenario in consideration of FSRU configurations, sensitivity testing results for all assessed configurations and orientations of the FSRU at sensitive and industrial receptors are summarised in Table 6.

The results indicate that the Esperanza FSRU, with its bow facing southeast, is predicted to have the highest impacts on sensitive and industrial receptors for both NO_2 and PM_{10}, except for 24-hour average PM_{10} at industrial receptors with a small variation of less than 0.1 µg/m³. The Inquiry and Advisory Committee (IAC) accepted the use of the Hoegh Esperanza FSRU air emissions data which represents current best available technology and did not consider that further sensitivity testing is required in this regard (IAC Report No. 1, section 13.3 (iii)).

Overall, the worst-case scenario among all assessed configurations is the Esperanza with its bow facing southeast, along with the LNG carrier (AQ EES modelled). Among all operational scenarios modelled (refer to Table 4) for the Esperanza in the EES, the highest air emissions during normal operations occur during peak load.

Table 6 Summary of sensitivity testing results at receptors

Sensitivity testing scenarios		Peak load - 1-hour 99.9th percentile NO_2 (µg/m³)				Peak load – Maximum 24-hour PM_{10} (µg/m³)			
		Esperanza		Golar		Esperanza		Golar	
		Bow facing SE[1]	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE[1]	Bow facing NW	Bow facing SE	Bow facing NW
Maximum at sensitive receptors									
FSRU and LNG carrier	Incremental	31.4	22.4	27.1	21.2	1.1	0.9	0.9	0.8
	Cumulative	59.6	50.6	55.3	49.4	28.6	28.4	28.4	28.3
FSRU	Incremental	27.5	17.2	20.9	15.1	1.1	0.8	0.8	0.7
	Cumulative	55.7	45.4	49.1	43.3	28.6	28.3	28.3	28.2
Maximum at industrial receptors									
FSRU and LNG carrier	Incremental	58.0	36.0	50.7	33.2	5.19	3.5	5.23	3.3
	Cumulative	86.2	64.2	78.9	61.4	32.7	31.0	32.7	30.8
FSRU	Incremental	49.6	29.7	46.7	29.4	5.0	3.3	5.1	3.0
	Cumulative	77.8	57.9	74.9	57.6	32.5	30.8	32.6	30.5

Note: 1. Previously modelled scenario in the AQ EES study.
2.The highest predicted concentration for each configuration is highlighted in blue.

4.2.2 Worst-case scenario impacts analysis

Section 13 (iii) of IAC Report No. 1 states that modelling results indicate that although air emissions from the FSRU are not expected to exceed adopted criteria "…*would cause significant increases in some pollutants compared to background concentrations (all in micrograms per cubic metre):*

- *nitrogen dioxide would increase from a background concentration of 28.2 to a maximum of 86.2, compared to a criterion level of 150*
- *small particulates ($PM_{2.5}$) would increase from a background concentration of 11.5 to a maximum of 19.5, compared to a criterion level of 25*
- *large particulates (PM_{10}) would increase from a background concentration of 27.5 to a maximum of 37.0, compared to a criterion level of 50*
- *formaldehyde would increase from a background concentration of 6.7 to a maximum of 57.3, compared to a criterion level of 100."*

To address the concerns regarding the significant increases of some pollutants' concentrations, further analysis was conducted as described below.

Firstly, the maximum cumulative daily average $PM_{2.5}$ of 19.5 µg/m^3 and daily average PM_{10} of 37.0 µg/m^3 (referenced by the IAC) were predicted to occur in the liquid-fuelled scenario, which would only occur during maintenance, start-up and emergency situations. The liquid-fuelled scenario should therefore be considered a transitory scenario and is not considered representative of normal operating conditions. The worst case during normal operation is the peak load scenario, which is further analysed in this section.

Secondly, the concentrations referenced by the IAC were the maximum concentration over the five years of modelling for each pollutant at industrial receptor 30. To further demonstrate the potential impacts of air emissions from the FSRU, frequency of occurrence analysis using time-series incremental concentrations (project contribution) was undertaken at sensitive receptors 1, 10, 14, 23 and 26, and industrial receptors 29, 30 and 31.

Table 7 and Table 8 present the occurrence frequency of 1-hour average NO_2 and 24-hour average PM_{10} concentrations, respectively, for FSRU at peak load with LNG carrier alongside over five years (2016 to 2020). The results indicate that:

<u>NO_2</u>

- For more than 96 percent of the time, increases in 1-hour average NO_2 concentration as a result of the FSRU are less than 5 µg/m^3 at any receptor and will not be discernible from background concentrations.
- Only 0.08 percent of the hours (I.e., 34 out of 43848 hours modelled) at industrial receptor 30 are predicted to experience 1-hour average NO_2 concentrations greater than 55 µg/m^3 (the IAC referenced the maximum 99.9th percentile 1-hour average NO_2 of 58 µg/m^3).

<u>PM_{10}</u>

- For over 98 percent of the time, predicted increases in the daily average PM_{10} concentration as a result of the FSRU are less than 1 µg/m^3 at any receptor and will not be discernible from background concentrations.
- Only 0.1 percent of days (I.e.,2 out of 1827 days modelled) at industrial receptor 30 are predicted to experience a daily increase in PM_{10} concentration greater than 5 µg/m^3 with a maximum increase of 5.2 µg/m^3.

In addition, time-varying background data for 1-hour NO_2 and 24-hour PM_{10} was also reviewed to calculate time-varying cumulative concentrations for the peak load scenario. Figure 11 and Figure 12 show the ranked project contribution at receptor 30 (most affected receptor) with corresponding background concentrations for 1-hour NO_2 and 24-hour PM_{10} respectively. The figures indicate that:

- Cumulative 1-hour NO_2 concentrations are predicted to be below the ERS criterion for all the hours modelled, and project contributions would not be discernible from the background pollutant levels for most of the time.

- Incremental increases in daily average PM_{10} from the FSRU plus LNG carrier at peak load scenario are negligible and would not result in additional exceedances of the ERS criterion (beyond those attributable to background concentrations).

It is important to note that peak load scenario would be infrequent (i.e., two days per winter month) according to market demand. The peak load scenario modelled is in the closed loop mode since it would result in higher emissions than the preferred open loop mode, representing a conservative worst-case scenario. In summary, impact analysis for the worst-case scenario demonstrates that pollutant concentrations resulting from operation of the FSRU will not be discernible from background concentrations most of time. Potential air quality impacts associated with the project would be minor and emissions are unlikely to cause significant adverse impacts on the surrounding environment.

The findings of this item of further work is consistent with the findings of the air quality technical study completed as part of the original EES (AQ EES study) and has confirmed that operational impacts on air quality would be acceptable considering a worst-case scenario for air emissions.

Table 7 Frequency of NO_2 hourly averages, FSRU with LNG carrier, peak load scenario (2016 to 2020)

Location	R01	R10	R14	R23	R25	R26	R29	R30	R31
NO_2 concentration (µg/m³)	Total Number of Hours in Five Years								
Less than 5	43047	43271	43127	43497	43493	43432	43069	42502	42301
5 – 15	738	421	468	273	256	219	640	649	1039
15 – 25	57	140	165	46	77	136	49	332	163
25 – 35	6	16	88	30	22	61	60	135	137
35 – 45	0	0	0	2	0	0	30	120	135
45 – 55	0	0	0	0	0	0	0	76	73
55 – 65	0	0	0	0	0	0	0	33	0
65 – 75	0	0	0	0	0	0	0	1	0
Greater than 75	0	0	0	0	0	0	0	0	0
NO_2 concentration (µg/m³)	Percentage of hours								
Less than 5	98.2%	98.7%	98.4%	99.2%	99.2%	99.1%	98.2%	96.9%	96.5%
5 – 15	1.68%	0.96%	1.07%	0.62%	0.58%	0.50%	1.46%	1.48%	2.37%
15 – 25	0.13%	0.32%	0.38%	0.10%	0.18%	0.31%	0.11%	0.76%	0.37%
25 – 35	0.01%	0.04%	0.20%	0.07%	0.05%	0.14%	0.14%	0.31%	0.31%
35 – 45	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.07%	0.27%	0.31%
45 – 55	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.17%
55 – 65	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%	0.00%
65 – 75	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.002%	0.00%
Greater than 75	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table 8 Frequency of 24-hour averages PM_{10}, FSRU with LNG carrier, peak load scenario (2016 to 2020)

Location	R01	R10	R14	R23	R25	R26	R29	R30	R31
Concentration (µg/m³)	Total Number of days in Five Years								
Less than 1	1827	1827	1826	1827	1827	1827	1823	1788	1793
1 – 2	0	0	1	0	0	0	4	24	33
2 – 3	0	0	0	0	0	0	0	7	1
3 – 4	0	0	0	0	0	0	0	3	0
4 – 5	0	0	0	0	0	0	0	3	0
5 – 6	0	0	0	0	0	0	0	2	0
Greater than 6	0	0	0	0	0	0	0	0	0
Concentration (µg/m³)	Percentage of days								
Less than 1	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	99.8%	97.9%	98.1%
1 – 2	0.00%	0.00%	0.05%	0.00%	0.00%	0.00%	0.22%	1.31%	1.81%
2 – 3	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.38%	0.05%
3 – 4	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.16%	0.00%
4 – 5	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.16%	0.00%
5 – 6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%
Greater than 6	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

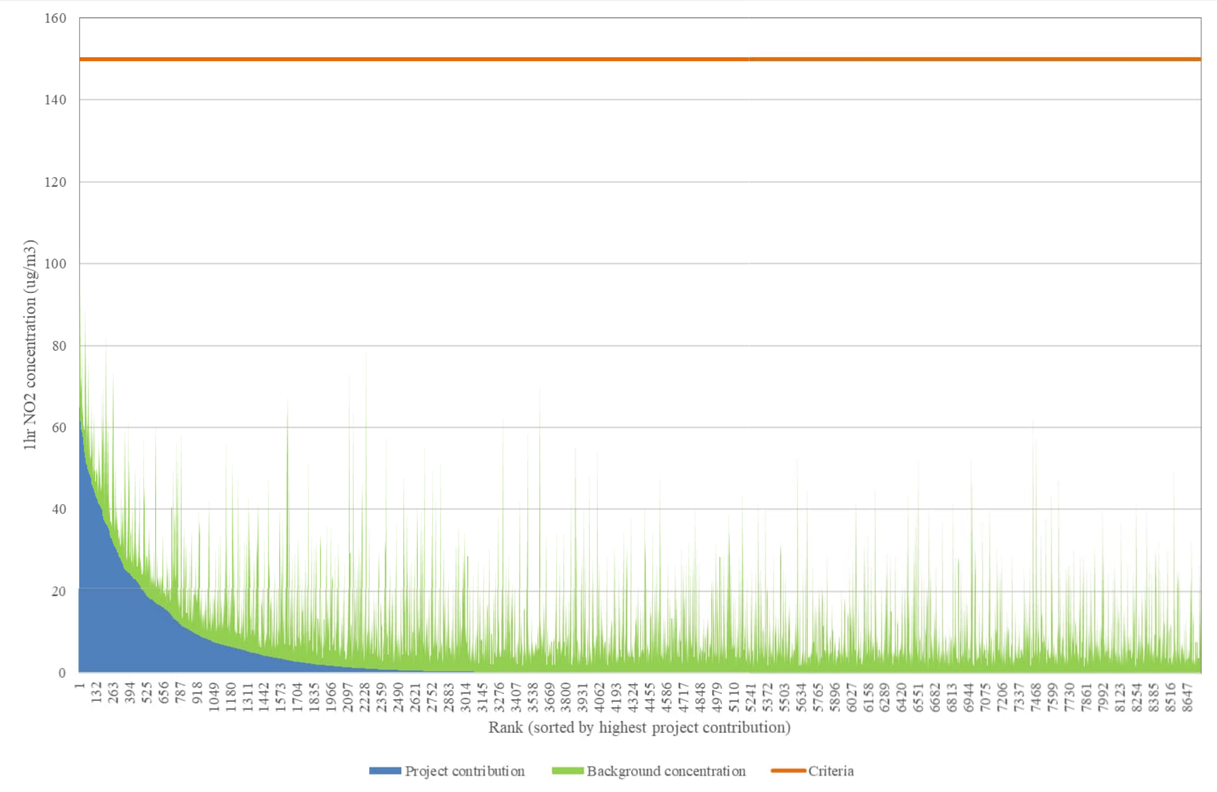


Figure 11 **1-hour average NO_2 ranked project contribution (Top 8760 out of 43848) at receptor 30 and corresponding background**

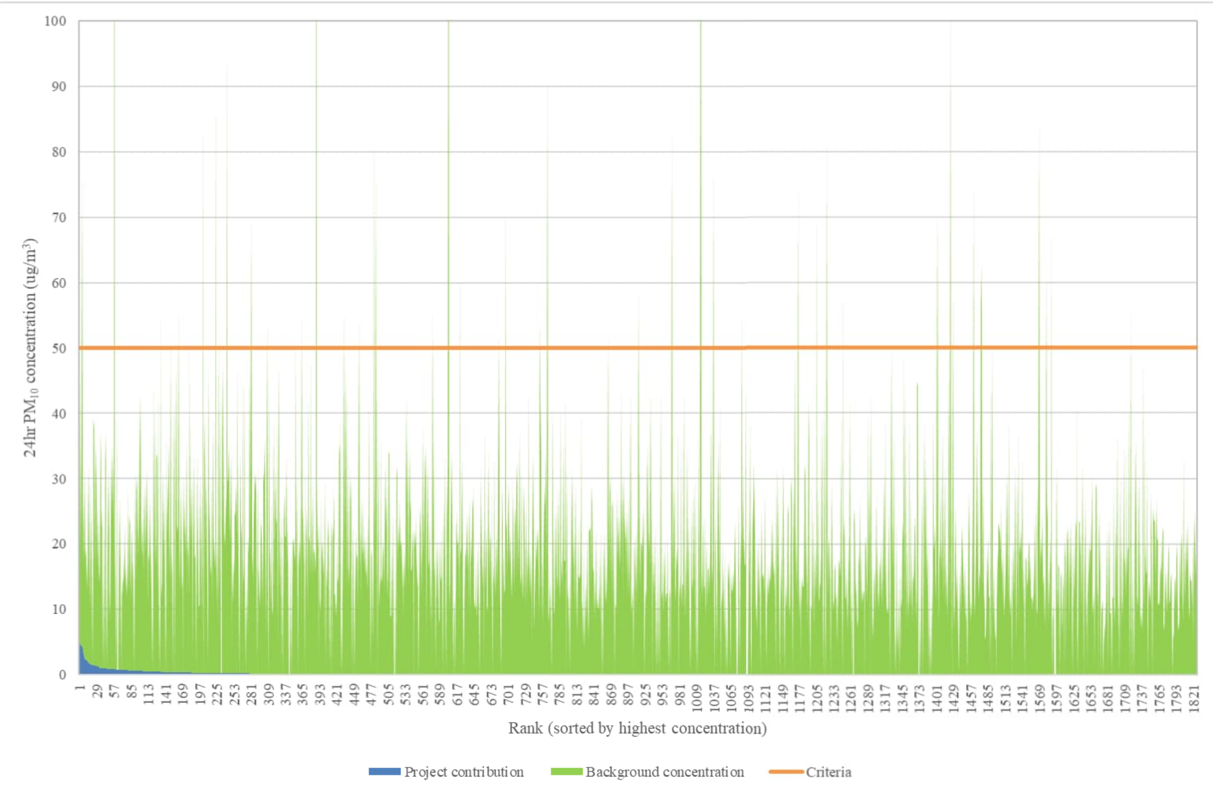


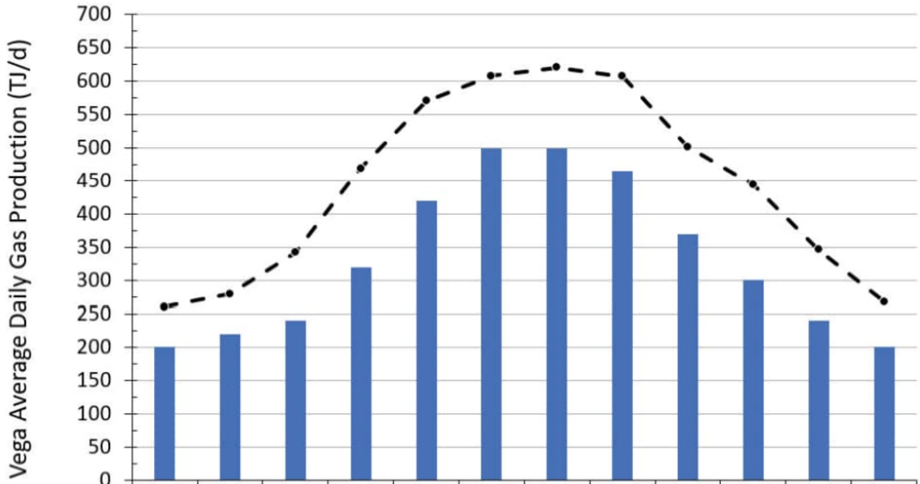
Figure 12 **24-hour average PM_{10} ranked project contribution (1827 days in five years) at receptor 30 and corresponding background**

4.3 The implication of bubble limits and stack specific limits for sensitive receptors

4.3.1 Gas demand

As described in the EES, there would be periods of time when there is reduced demand for gas as well as periods of time when there is high demand for gas, and this depends on a variety of factors. Typically, there is higher demand in winter and lower demand in summer.

The design basis gas production profile provided by the proponent is presented in Figure 13. This profile was based on 12 months of Victorian declared wholesale gas market (DWGM) total injection data (to November 2020) and the Australian Energy Market Operator (AEMO) Victorian gas demand profile from the Victorian Gas Planning Report Update 2020 (Worley, 2021).



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vega Avg Daily Gas Production (TJ/d)	200	220	240	320	420	500	500	466	369	300	240	200
Vega Peak Day Production (TJ/d)	261	280	342	469	570	608	620	607	502	445	346	268

Source: PR-MEM-001 VEGA Gas Production Profile, Worley 2021

Figure 13 Design basis gas production profile

4.3.2 Proposed limits

Air emissions from the FSRU are directly proportional to the number of engines and boilers required to meet market demand (i.e., air emissions increase as the number of engines and boilers that are being used increases). A higher production rate requires the use of more engines and therefore will result in higher air emissions.

To minimise air emissions associated with the project while providing flexibility to operate at 100 percent load when required, a combination of stack specific emission limits and annual bubble limits is proposed.

Stack specific limits

The reference design FSRU chosen for the air quality impact assessment was the Höegh Esperanza which represents current best available technology. The pollutant emissions estimates (grams per second (g/s)) for each exhaust were based on the manufacturer's emissions specifications as set out in Table 4-11 to Table 4-13 of the original AQ EES study.

Emission rates calculated based on 100 percent load of each engine and boiler are proposed to be the emission limit for each stack. Internal combustion engines are often designed to operate most efficiently at or near their maximum load. Running an engine at higher loads is more fuel-efficient and results in lower air emissions per unit of power generated (g/kWh), compared to running the same engine at lower loads. This can be seen from the emission rates design specification data in Table 4-11, Table 4-12 and Appendix B of the AQ EES study. For example, delivering the same amount of gas, on one engine running at 100 percent load would generate less air emissions than two engines running at 50 percent load. It is therefore not practicable to restrict the FSRU operating scenario to less than its rated load (100 percent load).

The original AQ EES study demonstrated that during a peak load scenario, air quality impacts are negligible and would not result in additional exceedances of the criteria (beyond those attributable to background concentrations) and, in most cases, would not be discernible from the background pollutant levels.

Table 9 lists the specific emission rates and proposed emission limits for each stack. As gas demand increases, more engines will be turned on, but air emissions from the corresponding stacks will need to meet the proposed emission limits.

The typical engine operating load ranges from 60% to 100%.

Gas-fuelled Particulate matter (PM_{10} and $PM_{2.5}$) and SO_2 emissions are expected to be negligible and should therefore not require a licence limit.

Table 9 Stack specific limits

Stacks	Engine/boiler power rating	Emission rates (g/s)			Proposed emission limits (g/min)		
		NOx (as NO_2)	CO	VOC	NOx (as NO_2)	CO	VOC
Exhaust 1	5850 kW	1.95	1.46	0.796	117	88	48
Exhaust 2	7800 kW	2.6	1.95	1.06	156	117	64
Exhaust 3	7800 kW	2.6	1.95	1.06	156	117	64
Exhaust 4	7800 kW	2.6	1.95	1.06	156	117	64
Boiler 1	60 MW steam heating capacity	2.86	2.41	0.157	172	145	9
Boiler 2	60 MW steam heating capacity	2.86	2.41	0.157	172	145	9
Total		15.5	12.1	4.3	928	728	257

Bubble limits

While the stack specific limits set emission limits for each stack, bubble limits define the maximum amount allowed to be discharged from the whole site. The bubble limits would prevent the engines and boilers from being operated unnecessarily.

Section 4.4 of the AQ EES study provides emission rates for six operational scenarios. A summary of the six scenarios is presented in Table 4.

Open loop, which does not require boilers, is the preferred mode of operation and results in lower emissions than when operating in closed loop mode. Therefore, the bubble limits were calculated based on open loop operation for the four seasons, and closed loop for peak load to cover the potential need for the boilers. It is noted that the peak load production rate (620TJ/d) would be infrequent, approximately two days per winter month on average as shown in Figure 13.

Emission rates for the operating scenarios used to determine bubble limits are summarised in Table 10. Autumn and spring (350TJ/d) emission rates were not presented in the AQ EES study, so have been calculated using the average of summer (250TJ/d) and winter (500TJ/d) scenarios.

Gas-fuelled particulate matter (PM_{10} and $PM_{2.5}$) and SO_2 emissions are expected to be negligible and should therefore not require a licence limit.

Table 10 Summary of air emission rates

Substance	Operating Scenario	Total emissions		
		g/s	Kg/day	t/yr
NO_x (as NO_2)	Summer, open loop, 250TJ/d	3.5	302	110
CO		3.2	277	101
VOC		1.4	123	45
NO_x (as NO_2)	Autumn and spring, open loop, 350TJ/d*	4.4	378	138
CO		4.0	347	126
VOC		1.8	154	56
NO_x (as NO_2)	Winter, open loop, 500TJ/d	5.3	454	166
CO		4.8	416	152
VOC		2.1	185	68
NO_x (as NO_2)	Peak Load, 4 Engines and 2 Boilers (closed loop) at 100% load, 620TJ/d	15.5	1336	488
CO		12.1	1048	382
VOC		4.3	371	135

Note* – Autumn and spring (350TJ/d) emission rates were estimated using the average of summer (250TJ/d) and winter (500TJ/d).

Table 11 Proposed bubble limits

Substance	Operating Scenario for bubble licence	Annual emissions (t/yr)
NO_x (as NO_2)	Proposed annual bubble limit (365 days): • 90 days summer open loop (~3 months) • 179 days spring/autumn open loop (~6 months) • 90 days winter open loop (~3 months) • 6 days peak load closed loop (2 days per winter month)	145
CO		130
VOC		57

4.3.3 Impacts analysis for proposed emission limits

This section further discusses potential air emissions based on the proposed emission limits and demonstrates the environmental benefit of the proposed combination of stack specific and bubble limits through sensitivity testing.

For the stack specific emission limits only scenario, it would be possible to run all the engines and boilers on 100 percent load all year long (although this is extremely unlikely to occur based on gas demand), as long as the stack specific emission limits are met.

If a combination of stack specific and bubble limits is included as a condition of operation, Viva Energy would need to meet not only the stack specific limits during normal operations but also the annual bubble limits, which were calculated based on the predicted gas demand/production profile over a year. This allows for implementation of a more stringent annual emissions pollutant load while meeting operational requirements specifically to account for peak gas demand.

The maximum short-term impacts (less than or equal to 24 hours average) would be the same for the two scenarios as they both allow the FSRU to run on peak load for a whole day. However, the long-term impacts (annual average) are expected to be lower if a combination of stack specific and bubble limits is selected.

Table 12 presents the annual emission limits for the stack specific limits only and combination scenarios.

Table 13 presents the maximum annual average pollutant concentrations at sensitive receptors for the two scenarios.

Table 12 Annual emission limits

Substance	Stack specific limits only (t/yr)	Combination – Stack specific plus bubble limits (t/yr)
NO_x (as NO_2)	488	145
CO	382	130
VOC	135	57

Table 13 Maximum annual average concentrations at sensitive receptors (µg/m³)

Concentration (µg/m³)	Stack specific limits only scenario (Peak load)			Combination – Stack specific plus bubble limits[3] (Bubble limits scenario in Table 11)		
	NO_2	CO	VOC	NO_2	CO	VOC
Maximum incremental concentration at sensitive receptors	0.5	1.1	0.5	0.2	0.5	0.2
Maximum incremental concentration at industrial receptors	0.9	2.2	0.9	0.4	1.1	0.4
Background	12.1[1]	/[2]	/[2]	12.1[1]	/[2]	/[2]
Maximum cumulative concentration	13.0	/[2]	/[2]	12.5	/[2]	/[2]
Criteria	28	/[2]	/[2]	28	/[2]	/[2]

Note: 1. The maximum measured annual average NO_2 concentrations at the Geelong South station for the period 2016 to 2020.
2. /: no background data or criteria available.
3. The stack specific plus bubble limit scenario was modelled assuming that the FSRU would run at peak load on the first two days of each winter month.

The results of the modelling show that the combination limits scenario would result in lower annual emissions and lower ground level annual average concentrations at sensitive receptors. Therefore, a combination of stack specific limits and annual bubble limits is considered most appropriate for this project.

A bubble limit was proposed in the development licence application that was submitted as part of the original EES (Attachment V: Development Licence Applications). A combination of stack specific limits and bubble limits has been proposed which provides an emissions limit based on the use of best available technology.

The applicability of bubble limits is subject to the development licence statutory approval process. EPA Victoria will ultimately determine the stack specific limits and/or annual bubble limits which would form part of the operating licence conditions for the FSRU following approval.

5.0 Integrated Assessment

This section integrates the key outcomes of the original AQ EES study with the findings of this supplementary EES study.

The original AQ EES study concluded that:

- *All modelled operating scenarios demonstrated there are no exceedances of criteria at any of the sensitive, industrial or gridded receptor locations.*
- *The air modelling assessment demonstrates that air quality impacts from the FSRU operations would be minor and emissions are unlikely to have regionally or State significant effects on the air environment.*

The findings of this supplementary air quality study regarding potential air quality impacts associated with the project are consistent with the findings of the original AQ EES study. In addition, this study also found that:

- Predicted air quality impacts for the Esperanza and Golar FSRUs only vary slightly. However, lower ground level concentrations at onshore sensitive receptors are predicted when the bow is facing northwest compared to facing southeast.
- Esperanza with its bow facing southeast alongside an LNG carrier (modelled in the AQ EES study) is predicted to be the worst-case scenario among all configurations and orientations assessed. As demonstrated in the AQ EES study, all modelled pollutants were predicted to comply with relevant criteria at all sensitive, industrial and gridded receptor locations for the worst-case scenario.
- Time-series concentrations analysis for the worst-case scenario demonstrates that pollutant concentrations resulting from operation of the FSRU will not be discernible from background concentrations most of time. Potential air quality impacts associated with the project would be minor and emissions are unlikely to cause significant adverse impacts on the surrounding environment.
- A combination of stack specific limits and annual bubble limits would result in lower annual emissions, and lower ground level annual average concentrations at sensitive receptors compared to stack specific limits only. As such, it is considered most appropriate to adopt a combination of stack specific limits and annual bubble limits for this project.

6.0 Mitigation Measures

There are no changes to the overall conclusion of the original AQ EES study. Therefore, no additional mitigation measures have been proposed and the original mitigation measures are considered both appropriate and adequate.

The original mitigation measures recommended to avoid, minimise, and mitigate potential adverse effects on air quality are listed in section 9 of AQ EES study.

7.0 Conclusion

This supplementary air quality study found that:

- Predicted air quality impacts for the Esperanza and Golar FSRUs only vary slightly. However, lower ground level concentrations at onshore sensitive receptors are predicted when the bow is facing northwest compared to facing southeast.
- Esperanza with its bow facing southeast alongside an LNG carrier (modelled in the AQ EES study) is predicted to be the worst-case scenario among all configurations and orientations assessed. As demonstrated in the AQ EES study, all modelled pollutants were predicted to comply with relevant criteria at all sensitive, industrial and gridded receptor locations for the worst-case scenario.
- Time-series concentrations analysis for the worst-case scenario demonstrates that pollutant concentrations resulting from operation of the FSRU will not be discernible from background concentrations most of time.
- A combination of stack specific limits and annual bubble limits would result in lower annual emissions, and lower ground level annual average concentrations at sensitive receptors compared to stack specific limits only. As such, it is considered most appropriate to adopt a combination of stack specific limits and annual bubble limits for the project.

In conclusion, the findings of the items of further work were found to be consistent with the findings of the air quality impact assessment completed as part of the original EES (AQ EES study) and confirmed that operational impacts on air quality would be acceptable considering the significance of the wake effects of the FSRU and a worst-case scenario for air emissions. In addition, a combination of stack specific limits and a bubble limit which provides an emissions limit based on the use of best available technology. The applicability of bubble limits is subject to the development licence statutory approval process. EPA Victoria will ultimately determine the stack specific limits and/or annual bubble limits which would form part of the operating licence conditions for the FSRU following approval.

8.0 References

AECOM. (2022). *Technical Report H: Air quality impact assessment.*

EPA. (2022). *EPA Publication 1961: Guideline for Assessing and Minimising Air Pollution in Victoria.*

EPA Victoria. (2017). *EPA Publication 1322.9 - Licence Management.*

EPA Victoria. (2022). *Environment Reference Standard.*

EPA Victoria. (2022). *EPA Publication 1961: Guideline for Assessing and Minimising Air Pollution in Victoria.*

NSW EPA. (2022). *Approved Methods for the Modelling and Assessment of Air Pollutants in New South Wales.* Environment Protection Authority.

Planning Panels Victoria. (October 2022). *Viva Geelong Gas Import Terminal - Inquiry and Advisory Committee Report No. 1.*

Worley. (2021). *Vega Gas Production Profile.*

Appendix A

Sensitivity Testing Results

Appendix A Sensitivity Testing Results

Table 14 Predicted ground level concentrations for different configurations of FSRU plus LNG carrier (2016-2020)

Receptor	Peak load – 1-hour 99.9th percentile NO_2 (µg/m³)				Peak load – Maximum 24-hour PM_{10} (µg/m³)			
	Esperanza		Golar		Esperanza		Golar	
	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW
1	18.9	17.5	21.3	18.4	0.7	0.8	0.7	0.8
2	11.7	15.5	17.8	15.6	0.5	0.6	0.6	0.6
3	10.9	10.6	16.7	10.7	0.4	0.4	0.5	0.4
4	9.8	7.9	16.2	9.1	0.4	0.3	0.5	0.4
5	9.2	7.4	16.4	8.1	0.4	0.3	0.5	0.3
6	5.9	8.8	9.3	13.8	0.4	0.3	0.4	0.4
7	9.5	8.6	7.6	11.0	0.3	0.3	0.3	0.3
8	5.1	5.9	5.3	5.6	0.3	0.3	0.4	0.4
9	4.1	4.9	4.8	5.1	0.3	0.3	0.4	0.4
10	23.5	20.0	21.3	16.8	0.8	0.7	0.7	0.7
11	21.5	15.5	19.5	15.8	0.6	0.7	0.6	0.7
12	11.6	15.2	17.7	14.6	0.5	0.6	0.6	0.6
13	10.5	14.4	15.7	14.2	0.4	0.5	0.5	0.5
14	31.4	22.4	27.1	20.2	1.1	0.9	0.9	0.8
15	9.5	9.4	14.8	9.5	0.3	0.3	0.4	0.4
16	8.6	7.1	16.1	7.9	0.3	0.3	0.4	0.3
17	3.9	4.4	5.4	6.0	0.2	0.2	0.2	0.2
18	4.1	5.1	5.2	7.8	0.2	0.2	0.2	0.2
19	10.9	10.7	19.3	18.4	0.3	0.4	0.6	0.8
20	8.8	8.8	17.1	21.2	0.3	0.3	0.5	0.6
21	10.0	10.0	12.9	12.3	0.3	0.4	0.3	0.4
22	22.1	15.7	17.8	16.1	0.5	0.5	0.4	0.5
23	28.7	19.0	19.7	15.5	0.9	0.6	0.6	0.6
24	19.7	12.8	13.6	9.5	0.9	0.7	0.5	0.4
25	24.5	15.0	13.1	10.0	0.7	0.4	0.4	0.3
26	28.6	16.3	21.2	13.9	0.8	0.6	0.5	0.5
27*	14.3	12.6	25.2	28.3	0.7	0.5	1.1	0.8
28*	34.6	23.0	26.0	25.6	0.9	0.9	0.8	0.9
29*	35.3	21.8	29.6	19.8	1.5	1.3	1.2	1.1
30*	58.0	36.0	50.7	33.2	5.19	3.5	5.23	3.3

Receptor	Peak load – 1-hour 99.9th percentile NO_2 (µg/m³)				Peak load – Maximum 24-hour PM_{10} (µg/m³)			
	Esperanza		Golar		Esperanza		Golar	
	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW
31*	50.2	26.1	38.2	26.6	2.3	1.3	1.8	1.1
Max Incremental at discrete receptors	58.0	36.0	50.7	33.2	5.19	3.5	5.23	3.3
Max Cumulative at discrete receptors	86.2	64.2	78.9	61.4	32.7	31.0	32.7	30.8
Max Cumulative at gridded receptors	91.9	93.2	95.9	101.9	Not applicable**	Not applicable**	Not applicable**	Not applicable**
Background	28.2				27.5			
Criteria	150				50			

*Note:1. * means industrial receptors.*

2. Highest predicted concentration for each scenario at sensitive receptors is highlighted in blue, and the highest at industrial receptors is highlighted in purple.

*3. **: Maximum cumulative concentrations at gridded receptors were not reported for 24-hour PM_{10} because the 24-hour PM_{10} criterion only applies at sensitive receptors* (EPA Victoria, 2022)

Table 15 Predicted ground level concentrations for different configurations of FSRU only (2016-2020)

Receptor	Peak load - 1-hour 99.9th percentile NO_2 (µg/m³)				Peak load – Maximum 24-hour PM_{10} (µg/m³)			
	Esperanza		Golar		Esperanza		Golar	
	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW
1	16.5	13.9	14.5	13.8	0.6	0.7	0.6	0.7
2	6.7	11.7	11.9	11.8	0.4	0.5	0.5	0.5
3	6.2	8.3	11.0	8.8	0.4	0.3	0.4	0.4
4	5.5	6.9	9.6	7.5	0.3	0.3	0.4	0.3
5	5.2	6.6	8.4	7.1	0.3	0.3	0.4	0.3
6	3.9	5.8	5.4	7.1	0.3	0.3	0.4	0.3
7	5.7	5.1	5.8	5.9	0.2	0.3	0.3	0.3
8	3.4	5.5	4.7	4.4	0.3	0.3	0.4	0.4
9	3.3	4.5	4.3	4.4	0.3	0.3	0.3	0.4
10	20.2	15.1	14.6	12.9	0.7	0.7	0.6	0.6
11	18.7	12.0	13.9	11.7	0.6	0.7	0.5	0.6
12	8.2	11.5	11.2	10.9	0.4	0.6	0.5	0.6
13	6.5	10.3	9.8	10.3	0.3	0.5	0.4	0.5
14	27.5	17.2	20.9	15.1	1.1	0.8	0.8	0.7
15	5.5	7.3	9.8	8.3	0.3	0.3	0.3	0.3
16	5.0	6.3	8.1	6.8	0.3	0.2	0.4	0.3
17	3.3	3.8	4.2	4.5	0.2	0.2	0.2	0.2
18	3.5	4.6	4.4	4.7	0.2	0.2	0.2	0.2
19	7.2	8.2	9.9	9.3	0.2	0.3	0.2	0.3
20	6.3	7.4	9.0	8.5	0.2	0.2	0.3	0.3
21	7.4	9.0	10.1	9.2	0.2	0.4	0.3	0.3
22	16.4	13.9	13.2	11.2	0.4	0.5	0.3	0.4
23	23.3	14.8	16.2	11.3	0.8	0.6	0.6	0.5
24	17.5	10.5	11.0	7.2	0.9	0.6	0.4	0.3
25	20.6	11.8	9.4	7.2	0.6	0.4	0.3	0.3
26	23.9	14.0	15.2	9.8	0.7	0.6	0.5	0.4
27*	7.7	8.6	10.6	9.5	0.4	0.5	0.4	0.5
28*	26.3	21.3	19.0	17.9	0.8	0.9	0.7	0.8
29*	29.9	16.9	24.1	14.8	1.3	1.2	1.1	1.0

Receptor	Peak load - 1-hour 99.9th percentile NO_2 (µg/m³)				Peak load – Maximum 24-hour PM_{10} (µg/m³)			
	Esperanza		Golar		Esperanza		Golar	
	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW	Bow facing SE	Bow facing NW
30*	49.6	29.7	46.7	29.4	5.0	3.3	5.1	3.0
31*	40.5	22.5	28.8	18.9	2.1	1.2	1.6	1.0
Max Incremental at discrete receptors	49.6	29.7	46.7	29.4	5.0	3.3	5.1	3.0
Max Cumulative at discrete receptors	77.8	57.9	74.9	57.6	32.5	30.8	32.6	30.5
Max Cumulative at gridded receptors	82.1	102.0	93.9	97.3	Not applicable**	Not applicable**	Not applicable**	Not applicable**
Background	28.2				27.5			
Criterion	150				50			

*Note:1. * means industrial receptors.*

2. The highest predicted concentration for each scenario at sensitive receptors is highlighted in blue, and the highest at industrial receptors is highlighted in purple.

*3. **: Maximum cumulative concentrations at gridded receptors were not reported for 24-hour PM_{10} because the 24-hour PM_{10} criterion only applies at sensitive receptors* (EPA Victoria, 2022) .

VIVA
Energy Australia