

Alcoa Wagerup Refinery Efficiency Project Current, Planned and Potential Future Volatile Organic Compounds (VOC) and Odour Emissions Control Measures

Overview Design Report Supporting Ministerial
Statement 728 Section 46 Application

August 2019

EXECUTIVE SUMMARY

This report is an overview of the proposed Volatile Organic Compound (VOC) and odour abatement path for the Wagerup Alumina Refinery Efficiency Project (the Project) for the purposes of informing an application under section 46 of the *Environmental Protection Act 1986 (WA)* (EP Act) to change conditions under Ministerial Statement 728 (MS 728).

The aim of the Project is to enable the two existing refinery production units to achieve an alumina output of approximately 3.3 million tonnes per annum (Mtpa). The current licenced capacity for the refinery is 2.85 Mtpa.

The project scope will increase production by addressing reliability and availability issues with a small number of major equipment additions. In general, the Project is focussed on upgrades that remove of circuit limitations (“de-bottlenecking”), as well as improving process and energy efficiencies.

The emissions reduction associated with the Project is to address VOC and odour emission as defined in the 2018 Wagerup Refinery Emissions Inventory, with a focus on a major low-level source of VOC and odour emissions in the refinery identified in the relevant condition of the Wagerup Ministerial Statement.

The proposed abatement solution addresses Building 25A slurry storage emissions, identified as the second highest VOC emitter and third largest odour emitter in the 2018 Emissions Inventory. The solution incorporates capture of the Building 25A slurry storage tank emissions with subsequent destruction of contained VOC and odorous compounds in a Regenerative Thermal Oxidiser (RTO).

The abatement proposal addresses six low elevation point sources of VOC and odour emissions within the refinery, while satisfying Ministerial Statement condition 8-1.1 regarding refinery VOC and odour and is based on existing proven and familiar site technology which meets best practice criteria.

In addition, the solution achieves a reduction from the equivalent VOC emission rate for the Project production of 3.3 Mtpa to below the estimated refinery emission rate for the current 2.85 Mtpa licence.

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1 WAGERUP REFINERY BACKGROUND

The Alcoa Wagerup Alumina Refinery processes raw bauxite into a calcined smelter grade alumina product.

- Licence L6217/1983/15 includes a production limit of 2.85 Mt alumina per licence year. There is an additional daily calcination licence limit of 8,400 tonnes of alumina.
- Wagerup Alumina Refinery has prior ministerial approvals dating from 2006 to produce up to 4.7 Mtpa calcined alumina subject to the conditions and procedures contained in MS 728.
- The MS 728 approval was initially associated with a Third Production Unit which would be in addition to the existing two operating units to achieve a major production increase.
- MS 728 has since been amended by MS 1069 with conditions remaining based on a refinery expansion occurring in one stage to 4.7 Mtpa through a Third Production Unit.

The Project and associated s.46 application now seeks to gain approval to increase the production licence to 3.3 Mtpa within the existing 4.7 Mtpa overall approval.

1.1 Production Licence L6217/1983/15

The Alcoa Wagerup alumina refinery production licence L6217/1983/15 commenced on 13 November 2013 and was due for expiry on 12 November 2015. In October 2015 an amendment was made to extend the licence to November 2016, and subsequently, effective 29 April 2016, this licence was amended to expire on 12 October 2035.

In addition to the 2.85 Mtpa annual and 8,400 tonnes daily alumina production limits, there is a Volatile Organic Compound (VOC) emission-linked production limit referencing calcination throughput.

- The production licence limits are reflective of Priority VOC emissions limits assigned to the calcination area of a total of 29,501 kg per licence year.
- This total represents the combined emissions of five Priority VOCs of Acetaldehyde, Acetone, 2-butanone, Formaldehyde and Benzene.
- There additionally exists a 90-day Priority VOC limit which is approximately a days-adjusted quarter of the total calciner area emissions.

The 2015 production licence increase from the limit of 2.65 Mtpa to 2.85 Mtpa was achieved by the successful abatement of VOC emissions. This was done by capture and destruction of VOCs previously released to atmosphere, permitting an approved increase in production. The magnitude of VOC abatement was determined with reference to the baseline of the Wagerup Alumina Refinery 2014 Emissions Inventory.

1.2 Production Situation

Successful developments and implementation of technology and processes have seen the existing two Wagerup production units have the capability to achieve the 2.85 Mtpa licence production limit without the need to construct a Third Production Unit as originally conceived.

Further development has seen the Project team formed to identify and engineer solutions to remove production restrictions in the existing two units to fully utilise their remaining capacity. The current scope removes process bottlenecks and incorporates selective addition of new equipment in the existing Bayer circuits to achieve approximately 3.3 Mtpa production rate.

1.3 Wagerup Project Conditions

As part of the Project strategy, Alcoa is currently in negotiations with the Environmental Protection Authority (EPA) to amend the MS 728 conditions which were defined in 2006. MS 728 conditions allow a 4.7 Mtpa production limit and a Third Production Unit if defined conditions were to be satisfied.

The amendment will seek to update the MS 728 conditions with fulfillment, interim actions, data collected, and modelling undertaken at Wagerup in the 2004-2018 period, as well as current refinery operation. The major focus of both the original MS 728, and the proposed amendments will be on air emissions conditions. These are stipulated in Condition 8 (specifically around VOC and odour emissions) and Condition 9 (Air Dispersion Modelling of emissions and resulting ground level concentrations).

A successful s.46 outcome will permit the submission of a project Part V Works Approval application to maximise production of the current two operating units via the Wagerup Efficiency Project, prior to any Third Production Unit project being progressed.

2 WAGERUP EFFICIENCY PROJECT

2.1 Production Increase

The design basis of the Project is to achieve an increase in production to approximately 3.3 Mtpa utilising proven and successful process design. Proven and successful process design refers to technology operating in an Alcoa refinery operation globally and preferably in Western Australian operations, which meets safety, efficiency and production standards, and achieves emissions and other regulatory compliances. This reduces the risks of the project options with respect to the refinery operation, inclusive of emissions impacts.

With the current refinery production licence limit of 2.85 Mtpa linked to VOC production of 29,501 kg/year from calcination, operating licence L6217/1983/15 would require amendment to modify or eliminate the calciner linkage of Priority VOC emissions to production.

If there continues to be a limitation on calciner VOCs, there are no suitable or practical VOC abatement options available within the calcination area that meet the magnitude of the abatement requirements. Potential abatement of other VOC emissions sources within refinery areas outside calcination would need to be addressed.

Recognition of the importance of VOC capture and destruction in these other refinery areas in maintaining existing refinery VOC emission levels is anticipated to support increases in production limit. This will encourage selection of the best and most appropriate VOC abatement outcome where suitable capture and technology can be applied.

2.2 Project Scope

The aim of the proposed project is to maximise production and minimise emissions while promoting efficiencies in energy and raw material use. Key areas of focus include:

- Production availability of existing plant by specific focus to events/scenarios (both planned and unplanned) that reduce current production capability, and by assessment of the impact of additional key infrastructure.
- Improving existing plant operational stability.
- Yield opportunities in the production of alumina hydrate.
- Flow opportunities based on limitations of major plant circuits.

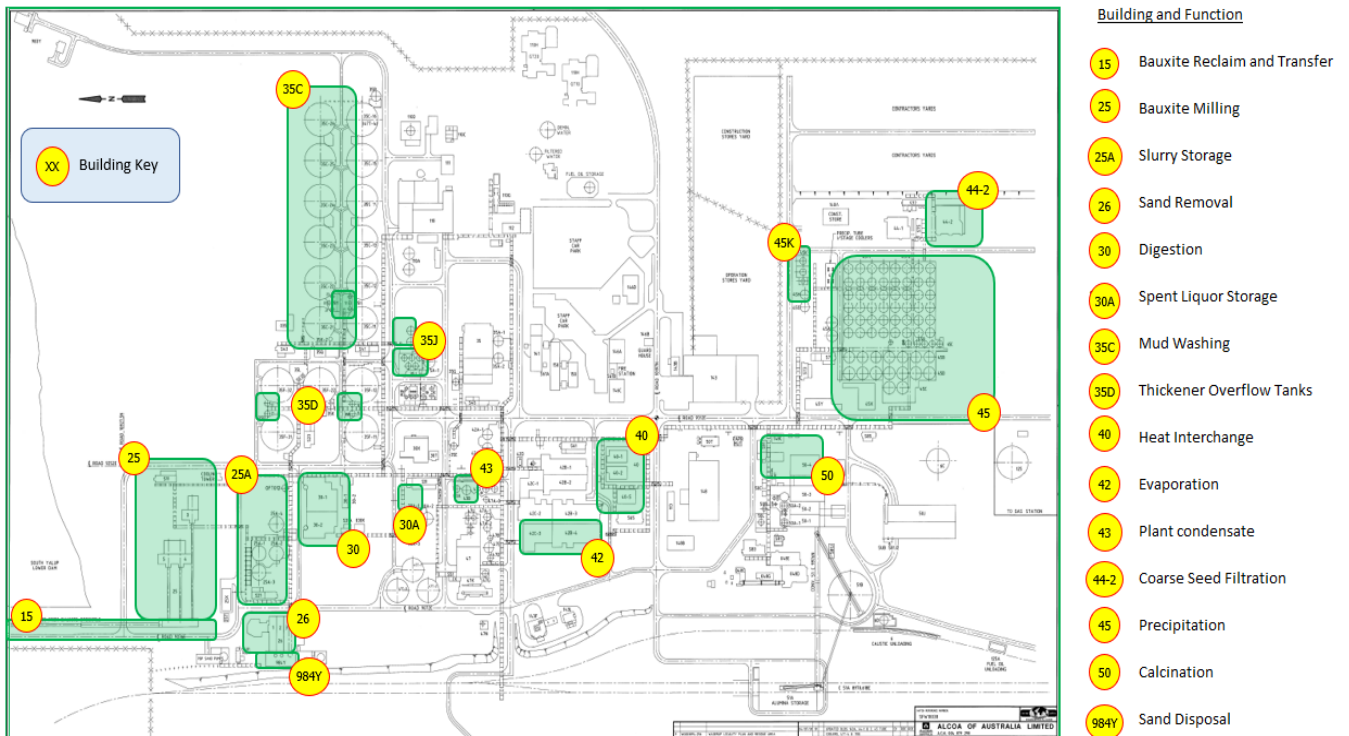
2.2.1 Major Areas Identified for Project Scope

Proposed installation and modification of major equipment in the Project is discussed in detail in individual building Project Design Criteria documents held within the project, with a summary in the following sections.

Table 1 Refinery Area Project Scope

Area	Upgraded	New
15	<ul style="list-style-type: none"> C100 conveyor and shuttle (extension to new mill feed bin) 	<ul style="list-style-type: none"> C200 Conveyor and shuttle (redundancy)
25		<ul style="list-style-type: none"> Bauxite bin Semi-autogenous grinding (SAG) mill
25A	<ul style="list-style-type: none"> Contact Heaters in 25A to improve energy efficiency 	<ul style="list-style-type: none"> Contact heaters for new mill discharge line
26		<ul style="list-style-type: none"> New sand rake washing unit Transfer tank and pumping
30	<ul style="list-style-type: none"> CRD Heaters associated with Digestion Unit 2 for energy recovery and emissions reduction Blow off tank piping and internals to improve operational stability and availability 	<ul style="list-style-type: none"> 30A Liquor to Mill pump and line Digestion WOF additional heater shells (1 per Digestion unit) for energy recovery and reduction in blow-off emissions
35	<ul style="list-style-type: none"> Slurry pumping in washers (Bank 2) Overflow liquor pumping in washers (Bank 2) 35A and 35D pumping and piping 35J Causticisation pumping and piping 	
984	<ul style="list-style-type: none"> Sand to lake piping and pumping 	
259	<ul style="list-style-type: none"> Mud pumping at the super thickener 	
40	<ul style="list-style-type: none"> Heat Interchange Unit 1 and 2 piping for energy recovery Replacement of undersize plate heat exchange pack for energy recovery and utilisation 	
44	<ul style="list-style-type: none"> Green Liquor to Coarse Seed Re-slurry Seed Filtration tankage and pumping 	<ul style="list-style-type: none"> New coarse seed filter in existing building and new filtrate tanks, pumps and piping New coarse seed pumping and piping to existing coarse seed facility
45	<ul style="list-style-type: none"> Hydrate Export pumping Cooling tower water pumping 	<ul style="list-style-type: none"> Eight additional precipitation tanks in agglomerator duty at the head of existing trains to improve yield PISC area changes to improve energy efficiency
50		<ul style="list-style-type: none"> New calciner and associated facilities
Electrical	<ul style="list-style-type: none"> Modification to some substations, yard piping and electrical distribution 	<ul style="list-style-type: none"> New substations and electrical distribution Additional electrical tie to Western Power
Utilities	<ul style="list-style-type: none"> Extension of utility systems to support new equipment Debottleneck of steam, air piping to improve capability using existing generation capability 	

Figure 1: Refinery Areas Affected by Scope Addition/ Modification



2.2.2 Specific Areas Excluded from the Project Scope

The Project will not be making any modifications to:

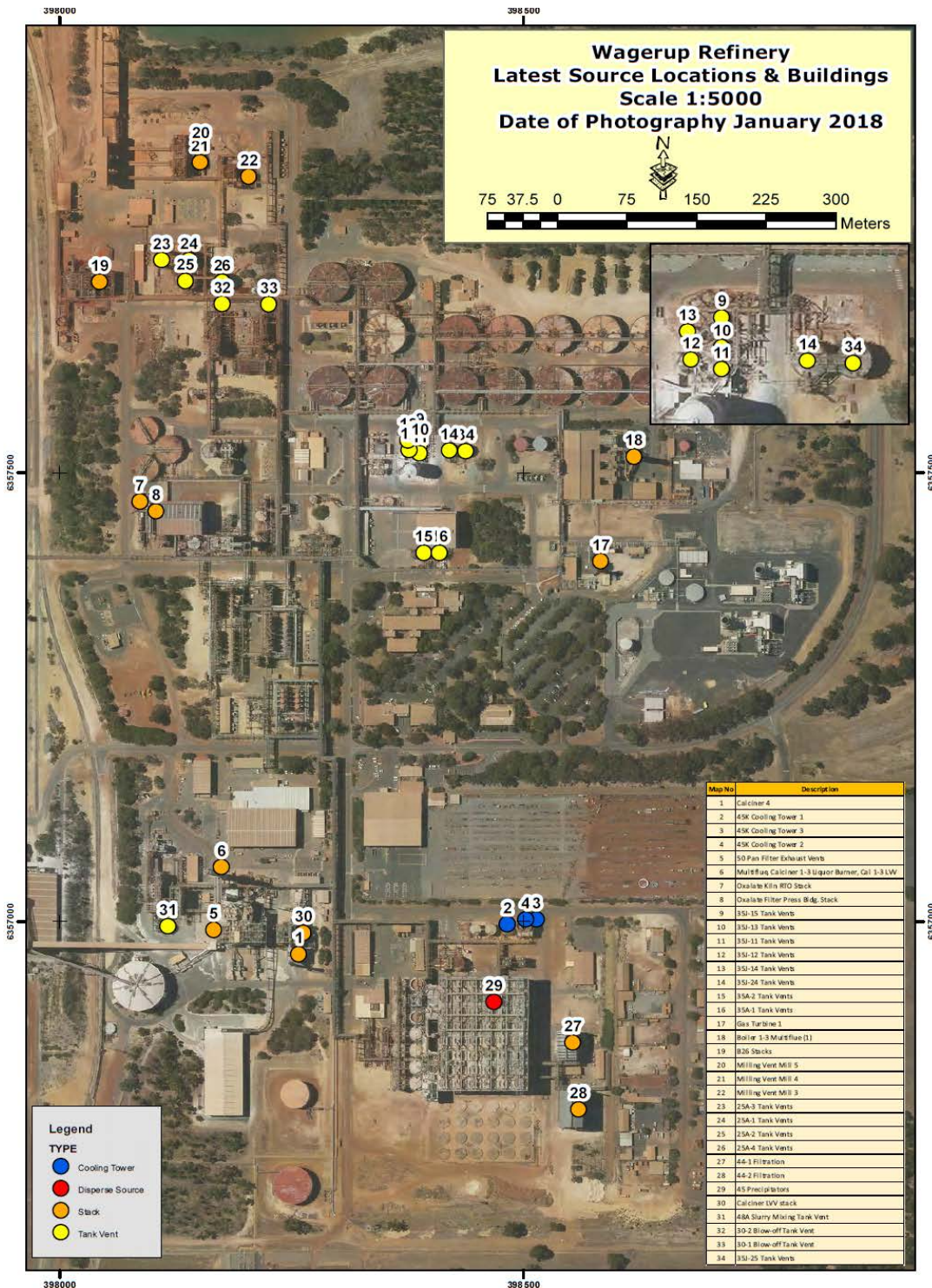
- Liquor burning
- Oxalate precipitation
- Biological oxalate destruction
- Boilers and Gas Turbine-HRSG
- Residue storage
- Water storage.

3 WAGERUP EMISSIONS

Alcoa's application for an amendment under s.46 of the EP Act focusses on air emissions, and specifically VOC and odour emissions. Air emissions quantification is used as an input to an Air Dispersion Model to identify any potential health risk from emissions.

Figure 2 shows the locations of key air emissions quantification points within the Wagerup refinery that are included in the reference Emissions Inventory.

Figure 2: Overview of Wagerup Refinery Emissions Points included in EI



3.1 Emissions Inventory (EI)

The refinery Emissions Inventory records point source and fugitive source contributions to the total refinery emissions profile for a range of emissions including volatile organic compounds (VOCs) and odour. The primary VOC compounds considered and their emission rates, including the Priority VOC compounds for calciner licence conditions (acetaldehyde, acetone, benzene, 2-butanone, and formaldehyde), can be found in the 2018 Emissions Inventory document.

As part of baseline inputs to any Works Approval process, the Alcoa Wagerup Alumina Refinery has periodically revised its emissions inventory. The 2018 Wagerup Emissions Inventory extends the 2014 Emissions Inventory by updating the inventory with measurement data collected to the end of 2018, and further flow studies.

As an amenity issue rather than health risk, odour is included in the 2018 Emissions Inventory. While a weak correlation has previously been determined between VOCs and odour emission, measured odour determined by dynamic olfactometry testing is the basis of the 2018 Emissions Inventory measure for odour.

3.2 Emissions Forecast Methodology

The emission rates for increased production are forecast using a consistent methodology which is applied to the current reference emissions inventory sources and using an identified equipment and process scope.

Emissions changes are predicted using a defined methodology developed based on refinery area and aspects of tank surface area changes, flow changes and equipment addition or subtraction.

3.3 Emissions Measurement Development

The Alcoa Centre of Excellence (CoE) supports Alcoa's global refining practices and has undertaken various trials for improving emission measurement and quantification using alternative measurement and analytical techniques.

These have been trialled for possible replacement of standard sampling and analysis practises and provide an opportunity to collect improved data for those sources which prove problematic for application of standard methodologies (e.g. saturated sources, diffuse sources and sources with high volume, low concentration flows). The aim is to continually improve the understanding and representation of emissions and provide an inventory on which abatement options can be chosen based on confidence in source emitter characteristics.

Recent validation work by the CoE with Open Path–Fourier Transform Infrared Spectroscopy (OP-FTIR) has provided a prospective means of addressing this for Cooling Tower sources.

3.4 Air Dispersion Modelling

Air dispersion modelling uses emission rates from point and diffuse sources to estimate ground level concentrations of emissions in areas surrounding the refinery. These ground level concentrations can then be used to determine health risk levels for chronic and acute health impacts as well as any incremental cancer risk. Previous studies have shown these risks to be very low.

3.5 Current VOC Emissions Control Measures

Volatile organic compounds can volatilise and become an emission at Bayer liquor temperatures in tank vents with vapour, or under vacuum through vacuum pump exhausts. In the period 2002 to 2018, projects have been put in place at the Wagerup alumina refinery to capture and destroy VOC and odour emissions from refinery emission points. These installations have been positioned to address point sources that have higher confidence of capture and destruction of VOC and odorous compounds and have addressed a number of MS 728 Condition 8-1 sources.

In the process of addressing these emissions in proportion to their health risk or amenity impacts, application of best practice using Best Available Technology (BAT) is considered. This covers the availability of proven technology, its reliability, cost and operation that provide the most effective emissions management under economically viable conditions.

The existing VOC and odour abatement technologies and utilisation at the Wagerup alumina refinery are indicated in the next sections.

3.5.1 Regenerative Thermal Oxidiser (RTO) Technology

The installation of regenerative thermal oxidisers (RTO) allows combustion of gas streams containing organics or odorous compounds at a high temperature sufficient to achieve complete combustion of these to carbon dioxide and water. Combustion is provided by natural gas burners with residence time at temperature achieved by passing gases through permeable refractory beds maintained at temperature.

a) Liquor Burner (Building 48)

VOC and odour emissions from the liquor burner kiln off-gas in Building 48 are captured and treated in a Regenerative Thermal Oxidiser (RTO). This was installed in 2006 and improved upon the previous practices of discharging to atmosphere, using a scrubber alone or passing the exhaust through a catalytic thermal oxidiser (CTO) and dehumidifier. The RTO reduces VOC and odorous emissions to negligible during operation.

b) Oxalate Precipitation and Kiln (Building 47)

VOC and odour emissions from the vacuum pump exhausts and the oxalate kiln off-gas in Building 47 are captured and treated in a Regenerative Thermal Oxidiser (RTO). This was installed in 2012 and provides treatment of emissions that were previously discharged to atmosphere. The RTO reduces VOC and odorous emissions to negligible during operation.

3.5.2 Post-Combustion Treatment in Calciners

Calcination of alumina requires high temperatures within the calciner unit. There are three zones within calciners which maximise combustion and conversion processes: pre-heater, firing zone and holding vessel. Any air supplied into the calciner will pass through these three zones and be subject to an extended period of high temperature and ignition sources. As such, providing a stream of VOC or odour rich gases into this air flow is an effective method of fully combusting these compounds.

a) Vacuum Pump Vent Redirection of Calciners 1,2,3 (Building 50)

Of the four calciners, the vacuum pumps on Calciners 1, 2 and 3 were suitably co-located to enable effective capture of vacuum pump exhaust gases in an integrated project. These were the basis of a project commissioned in 2015 to capture and re-direct into the calciner combustion zones for destruction.

This has addressed a significant part of the original 2006 Condition 8.1.5 for reduction of VOC and odour from calciner low volume vent sources, being three of the four calciners vacuum discharges.

3.5.3 Post-combustion Treatment in Power Station (Building 35N)

The purpose of thermal power stations in alumina refineries is to burn fuel and convert that heat to steam which drives generation of electricity or supplies high-pressure steam for processing. At the Wagerup alumina refinery, the high temperatures achieved by burning natural gas as fuel within the burner and combustion chamber sections are effective in destroying the VOC and odorous compounds.

A power-station destruction system for vent gases comprising VOC and odorous compounds - the capture network referred to as Building 35N - was put into service in 2002. This addressed emissions from numerous site point sources as below:

a) Digestion Condensers and Blow-off (Building 30C)

Excess heat that was not recovered from heat exchangers in digestion is let down to atmospheric pressure in the blow-off vessels in Area 30. This flashed vapour contains VOC emitted from the digestion liquor and was emitted direct to air.

A project to reduce the blow-off streams and condense the vapour previously emitted to air in condensers enabled capture of the non-condensed VOC and odorous gases. After water vapour is condensed in 30C, un-condensed VOC and odorous compounds are extracted as non-condensables by vacuum pump and discharged into the 35N powerhouse destruction system.

b) Heat Interchange Units (Building 40)

The barometric vessel in Heat Interchange Building 40 uses vacuum pumps to assist in maintaining a flashing profile in the strong liquor flash vessel trains.

The vacuum pump discharge containing volatilised VOC and odour compounds is directed into the 35N powerhouse destruction system.

c) Evaporation Units (Buildings 42B and 42C)

Flashing profiles in the evaporators are maintained by a vacuum pump to extract non-condensable gases from the online heaters from both hot (42B) and cold chain (42C) sections.

42C1 and 42C3 non-condensables are directed to the 35N system. The 42C2 system takes all 42B units non-condensables as well as the 42C2 non condensables, condenses these to remove water vapour and mercury, and then directs the remaining non-condensables to the 35N powerhouse destruction system.

d) Filtrate Tanks (Building 35A)

The green liquor from the thickeners is filtered and discharged into the 35A filtrate tank.

The 35A tank vents, discharging vapour from the hot strong Bayer liquor, is captured by the 35N system using the suction produced by the induced draft fan in the 35N system. This captures VOC and odour released with the steam vapour venting of this tank and destroys them in the power-station combustion zone.

This integration addressed the MS 728 Condition 8.1.2 for reduction of VOC and odour from clarification tanks - 35A green liquor.

e) Causticisation Tanks (Building 35J)

Heated wash liquor is directed from second washers into the 35J Building where liquor temperatures are increased to >95°C and lime added to causticize the liquor.

The 35J tank vents, discharging vapour from the hot Bayer liquor, is tied in to the 35N system using the suction produced by the induced draft fan in the system. This captures VOC and odour released with the steam vapour and destroys them in the power-station combustion zone.

This integration addressed the MS 728 Condition 8.1.3 for reduction of VOC and odour from clarification tanks - 35J causticisation.

f) Refinery Waste Disposal (Building 984Y)

The 984Y reaction tanks are used to treat two specific condensate sources from Area 30 and Area 42C. These condensates have been produced from low temperature condensers in the areas used on non-condensable streams. Due to the low temperature these condensates have noticeable VOC and odorous components that were emitted from the 984Y tank vents.

These vent streams are captured by the 35N system using the suction produced by the induced draft fan in the system and VOC and odour destroyed in the power-station combustion zone.

4 PROJECT VOC EMISSIONS

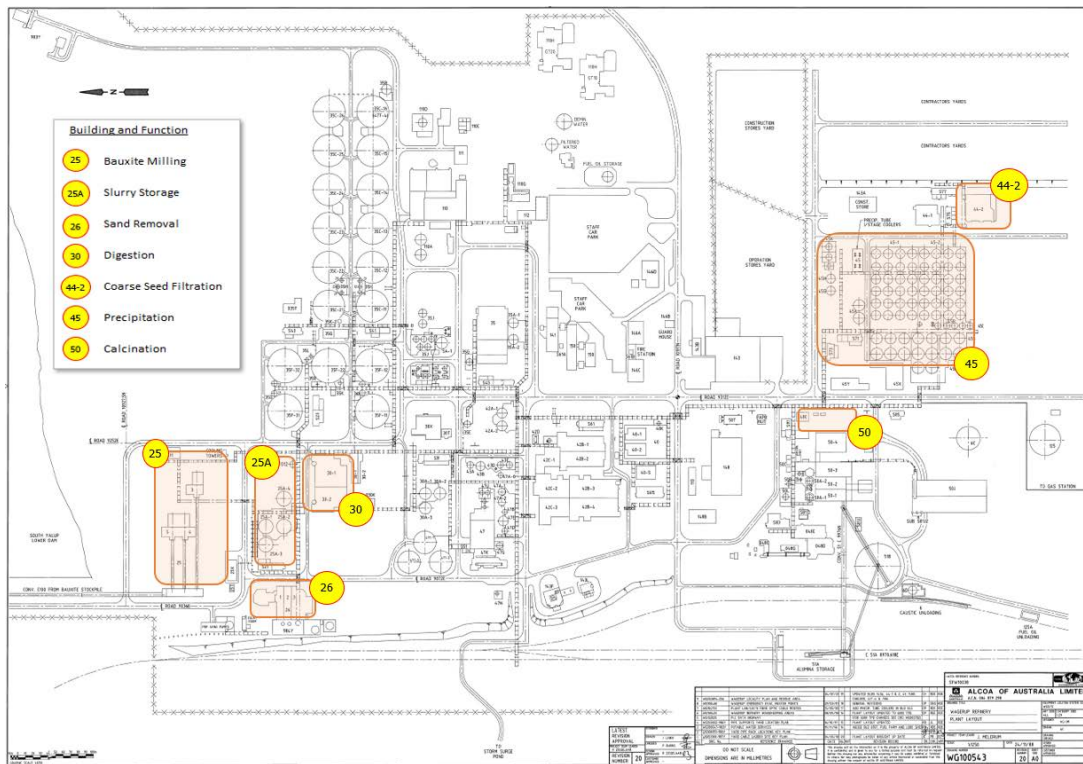
The VOC and odour baseline for analysis is the forecast for 2.85 Mtpa licence using the 2018 Emissions Inventory and reported licence period (13 November 2017 to 12 November 2018) production level. The refinery production rate achieved in 2018 licence year was 2.659 Mt alumina with 2018 calendar year production of 2.633 Mt.

A full overview of the individual point and fugitive source emission values is included in the 2018 Wagerup Refinery Emissions Inventory. The forecast VOC and odour average emission rates for the Project production rate (3.3 Mtpa) compared with current licence (2.85 Mtpa) are included in Appendix A. Table 2 shows a summary of the estimated impact on emissions from the Project scope.

Table 2 VOC and Odour Emission Impacts by Refinery Area from Proposed Project Scope.

Area	VOC and Odour Change	2.85Mtpa Average contribution to site total		Indicative Growth impact above 2.85 Mtpa
		VOC	Odour	
50 Calciners	Additional calciner. Emissions proportional to production and calciners.	35%	36%	VOC +6% Odour +6%
25A Slurry storage	No tankage increase, new RTO treating emissions. Project scope includes capture and destruction of VOC and odorous emissions with RTO.	20%	16%	VOC -16% Odour -12%
45K Cooling towers	No scope change. Emissions proportional to production.	13%	25%	VOC +2%* Odour +4%*
25 Milling	Typical operation (3 mills) same as 2018. Emissions proportional to equipment operation/production.	11%	2%	VOC +2% Odour 0%
44 Seed filtration	Increase in units operating. Emissions in line with extra tankage and equipment.	3%	1%	VOC +2% Odour +1%
26 Sand separation	Increase in units operating. Emissions proportional to equipment in operation.	1%	5%	VOC +1% Odour +3%
45 Precipitation	Increased tankage. Expect a small increase related to surface area.	0%	0%	-
30 Digestion	Improved heat recovery with additional and upgraded heaters and blow off tank modifications. Improved blow off vapour recovery reduces typical and peak emissions.	0%	0%	-
110 Powerhouse	Incremental change but limited by additional steam efficiencies and 3 rd party energy. <i>Conservatively ratio to production.</i>	6%	7%	VOC +1% Odour +1%
42 Evaporation 44 Heat Interchange	No change anticipated. Improvements in energy recovery.	0%	0%	-
47 Oxalate removal 48 Liquor burning	No change anticipated. Post-kiln RTO already fitted. No change anticipated. Post-kiln RTO already fitted.	1%	4%	-
35 Clarification, causticisation, filtration	No change anticipated.	1 % (35A) 3 % (35J)	1 % (35A) 1 % (35J)	-
15 Stockyard	No impact on VOC or odour.	-	-	-
984Y Sand and Mud to Lake 259 Residue Disposal Area	No change anticipated.	-	-	-

Figure 3 Wagerup refinery project areas contributing to emissions

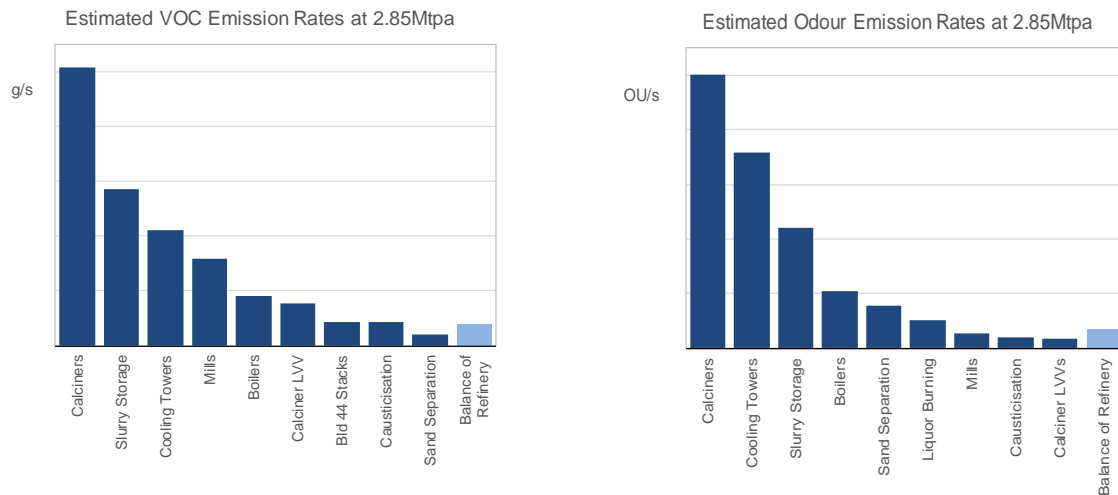


4.1 Project VOC and Odour Abatement

Alcoa screens options for implementation using their procedure for Specific Solutions Analysis. This process includes ranking technical feasibility, confidence in outcome, construction, operation, impact on costs and impact on emissions to produce a decision score. A high project score indicates the likelihood of the option achieving its design aim.

With the reduction in community complaints about odour, the project has prioritised addressing VOC emission reduction which can affect health risk levels over the amenity issue of odour. In that context, it is an expectation that capture and destruction of VOC compounds will, by association, result in a corresponding odour reduction.

Figure 3 Estimated Wagerup refinery VOC and odour emissions ranked contributions at 2.85 Mtpa



4.1.1 Area Abatement Options

a) Calcination Operation (Building 50)

The calciner exhausts are the largest VOC and odour source at the refinery. Improvements in calciner emissions are part of ongoing studies and represent a complex set of interactions within the calcination process. On that basis, methods to address calciner VOC emissions as an option for VOC abatement are excluded from the Project scope.

b) Cooling Towers (Building 45K)

The 45K cooling towers are a non-Bayer source of emissions within the refinery and have been characterised as the third largest VOC and second largest odour emitter.

The magnitude of the emissions outcome is heavily biased by historical values obtained 2002-2007. Ongoing work is occurring as high emissions historically characterised are not supported by recent years analyses of both water balances and air sampling of the cooling towers. No abatement in the area is considered for this project due to the characterisation work in progress that indicates cooling towers are a low emission source, with VOC emissions associated with the evaporative loss from these units - if present - returning concentration values near or below concentration detection limits.

c) Bauxite Milling (Building 25)

The bauxite milling process has a number of vents associated with each mill, including discharge trommel, screens and product tanks. The capture efficiency due to number of vents and open sections in this area is expected to be relatively low. In achieving a suitable abatement level the capture was estimated to be insufficient to warrant further analysis as a standalone solution.

d) Boilers and Gas Turbine (Building 110)

Boilers and Gas Turbine provide steam and electricity to the refinery by combustion of natural gas, with the use of this fuel itself considered low emission and a Best Available Technology.

Understanding of combustion arrangements is required for reducing any VOC emission identified from the power-house while also minimising NOx. This occurs as NOx reduction and VOC reduction are potentially contradictory due to conflicting temperature and residence time requirements for their control. As this requires an area specific characterisation and investigation program, VOC reduction optimisation in the power-station is considered outside the domain of the Project.

e) Calcination Area Low Volume Venting (Building 50)

In the past, the capture and combustion of the vacuum pump exhausts in three of the four calciners has been successfully achieved. However, the scope of installing a similarly complex facility to undertake capture of a single vacuum pumps exhaust for the remaining Calciner 4 is a less economically effective option than other identified larger, lower risk abatements in other refinery areas.

Any new calciner option is anticipated to integrate the vacuum pump exhaust redirection into the furnace zones for destruction.

The fugitive emissions from scroll hoods, Dorrco and filter hoods of the installed calciners make capture of the variety of low volume emissions less economically attractive than capturing fewer and larger point sources as identified in other refinery areas.

f) Seed Filtration (Building 44)

Building 44 Seed filtration has vacuum pumps and tank extraction fan point sources that can be addressed by capture, however Seed Filtration is a discrete area some distance from the main plant infrastructure and is a minor emissions source. This adds additional implementation costs for a comparatively small emission reduction.

g) Alumina Hydrate Soda (Building 45)

The relation between calciner VOC emissions and alumina hydrate soda and organic carbon level has been the subject of many past investigations and trials and was reviewed for this project. The ability to reduce Calciner VOC emissions relies on the ability to reduce the overall refinery liquor stream Total Organic Carbon (TOC) concentration. The liquor burning facility is currently utilised at maximum capacity in order to reduce liquor TOC levels and further reduction is not economically feasible at this point in time.

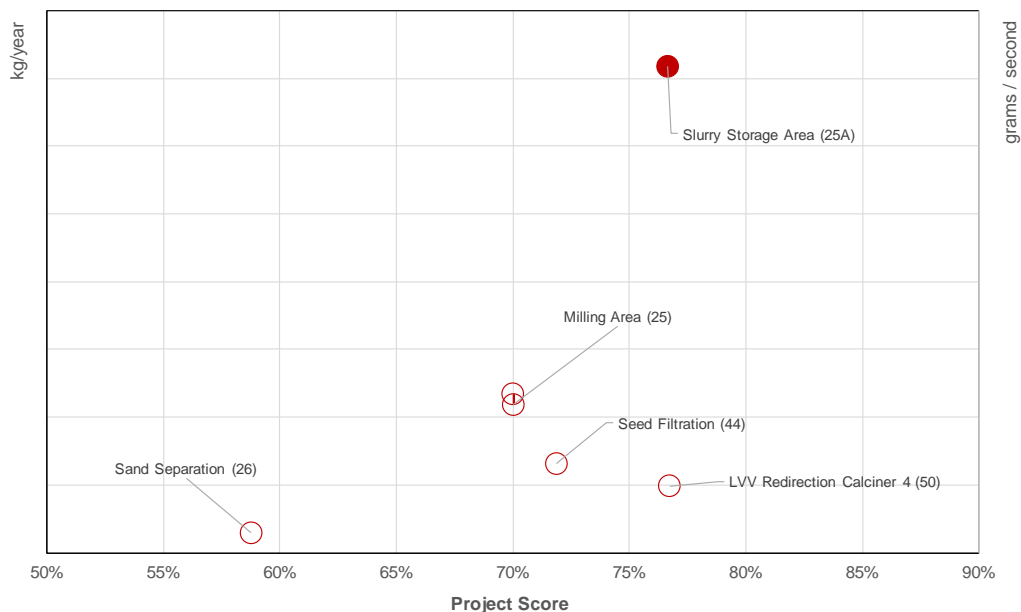
h) Sand Separation (Building 26)

The digested slurry direct from letdown after the digestion stage is processed firstly by removing the sand component. The sand removal area is a smaller emissions source with multiple vapour sources from equipment and process in the building making capture of emissions difficult and ineffective. As such the benefit is small and other options present a better magnitude and project score for abatement.

4.1.2 VOC Abatement Selection

This decision score for VOC abatement was charted against the magnitude of VOC abated for each solution to identify likely candidate solutions. This followed the Alcoa Specific Solutions Analysis (SSA) template based on preliminary project scope and emissions estimates. The outcome of the review of options gave clarity in the choice of abatement direction.

Figure 4 Indicative Net reduction in VOC emissions below forecast 2.85Mtpa baseline (Project SSA analysis)



4.1.3 Selected VOC Abatement Option

The identified option for the Project VOC abatement is the selection of the option to capture the vent emissions from the Building 25A Slurry Storage tanks and destroy VOC and odorous compounds from these in a new Regenerative Thermal Oxidiser (RTO).

The slurry storage tanks in Area 25A contain milled slurry which is heated in contact heaters by tertiary export vapour from digestion flash vessels. The emissions from these tank vents comprise the second largest recorded site VOC emission and third largest odour emitter.

The choice of addressing 25A as a large emitter of VOC and odour from the SSA analysis corresponded with the satisfying of Condition 8.1.1 of MS 728.

a) Summary of Option

The 25A Slurry Storage RTO option has both a high project score and a high VOC and odour reduction benefit. The table below summarises the option based on the 2018 Emissions Inventory data (June 2019).

Option	25A Slurry Storage Tank Vents Capture
MS728 Commitment	Pre-existing Condition 8-1.1. “At least a 75% reduction in peak and average emission rates of Volatile Organic Compounds (VOCs) and odour from the 25A slurry tank vents.”
Existing	Tank stacks to atmosphere, some tertiary digestion vapour venting from first tank. Second largest VOC emitter and third largest odour emitter in 2018 Wagerup Refinery Emissions Inventory.
Project Abatement Strategy	Capture tank stacks in pipe network and ducted to Regenerative Thermal Oxidiser (RTO) for combustion.
Destruction method	High temperature combustion of VOC and odour compounds. Duty: Regenerative Thermal Oxidiser (RTO) using natural gas Partial backup: 35N Powerhouse combustion using natural gas
Applied VOC capture and destruction efficacy	80% estimated to be captured for project criteria. Noted is RTO availability of Pinjarra ~95% over 5 years in similar duty plus de-rating for capture efficiency of tank stack flow and RTO destruction efficiency.
Benefits	Capture and destruction solution is based on an operating process at Pinjarra in the same duty. Not new technology - two RTOs are in service at Pinjarra refinery and two at Wagerup refinery. The capture will address six point-sources of VOC emissions (six stacks on four tanks). The process will destroy non-VOC odour components within the combustion processes (such as ammonia). The capture removes disperse low elevation odour and VOC source affecting the adjacent refinery production areas. Proposed 30C non-condensables re-directed to the RTO for definite destruction and odour removal from power station air heaters when RTO online. Proposed partial back-up from 35N system for periods when RTO is offline.
Est. VOC reduction	0.46 g/s (~14,370 kg/year) Equivalent to 110% of total reduction required to reduce total refinery VOC emissions at 3.3 Mtpa to be below or equal to 2.85 Mtpa emission rates.
Approximate Odour reduction	177,000 OU/s Equivalent to ~11% reduction in total refinery odour emissions rates compared with 3.3Mtpa without abatement.
Outcome for Project Scope	Satisfies existing Condition 8-1.1 for VOC and odour VOC emission rate for 3.3 Mtpa with 25A abatement achieves the estimate of VOC emission rate at 2.85Mtpa for EI sources. Likelihood that odour will achieve 2.85Mtpa emission rate due to measurement variability and source intensity variations.

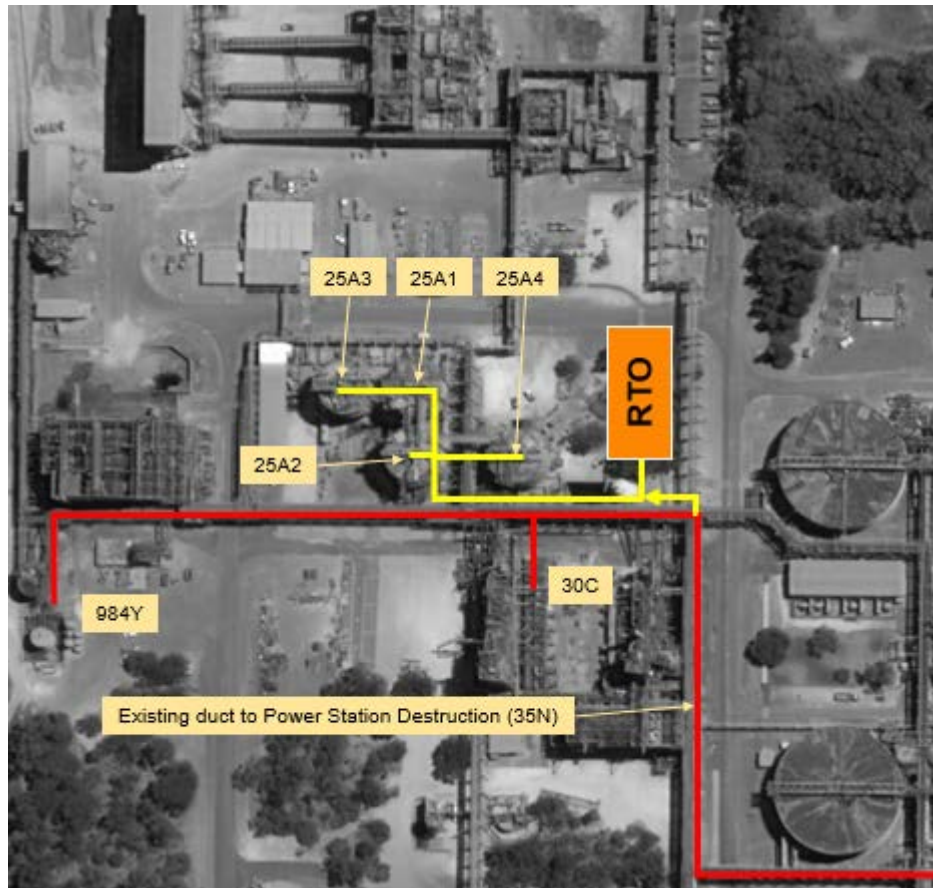
b) Estimates of peak emission rate

It is anticipated that peak emission rates during operation of the RTO, will see capture and abatement of VOC and odour emissions peaks as for the average operation.

The proposal to tie-in to use residual 35N system capacity when the RTO is off-line will additionally maintain lower emissions when the RTO is offline.

c) Preliminary Schematic of RTO collection in 25A

Figure 5 Potential Layout of 25A RTO unit and tie-in to 35N



d) Operational guidelines during stable and unstable operation

The operation of the RTO in the 25A area will follow guidelines that are in use for the existing RTO units in operation at both the Pinjarra and Wagerup refineries.

Proven and established practices will be applied to general operation as well as minimising emissions during unstable operating conditions such as during shut-downs, start-up, and equipment failure. These procedures will be developed during the project phase and will be adapted from guidelines in use at RTO units in existing service at Pinjarra (2 units) and Wagerup (2 units).

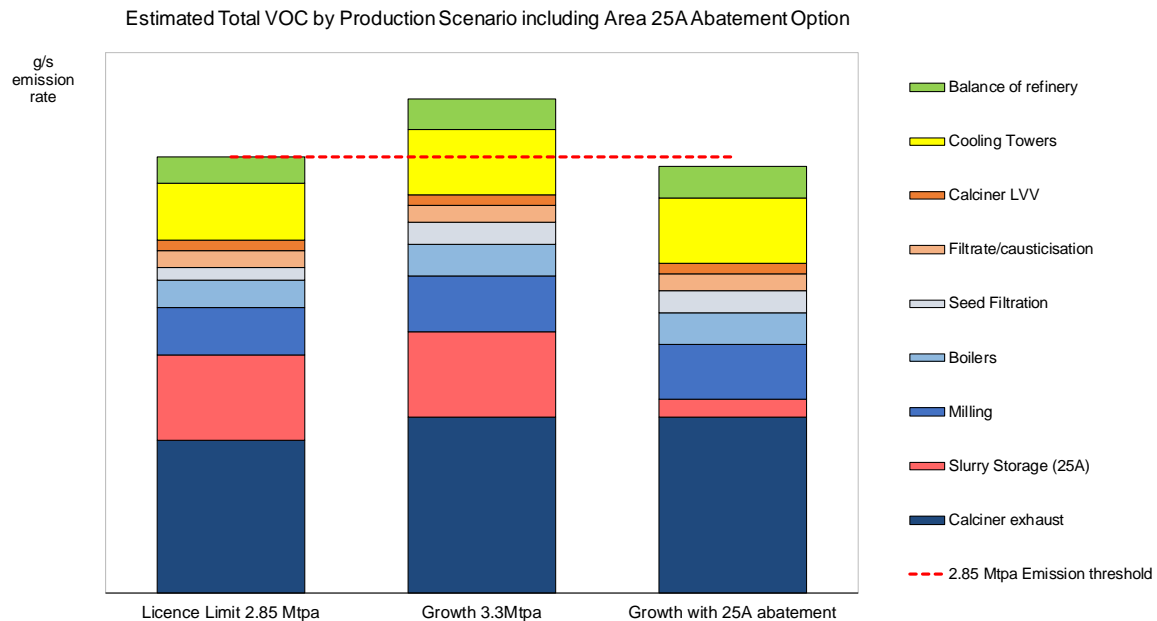
Specific operational experience from the Pinjarra Area 30 RTO in similar duty will directly inform the procedures for the new Area 25A RTO at Wagerup.

4.1.4 Refinery Outcome for VOC

The selection of the abatement option to capture 25A Slurry Storage tank vents and destroy the vapours using RTO technology as part of the Project is anticipated to satisfy the pre-existing MS 728 Condition 8-1.1 for the refinery.

Overall VOC emission estimates with 80% capture of the 25A tank vents is shown below, with an availability from the RTO expected to be 95% but de-rated by estimates for vent capture and VOC destruction efficiencies.

Figure 6 Refinery VOC Emissions Breakdown with Project Scope



4.1.5 Refinery Outcome for Odour

The Wagerup alumina refinery has had an historical amenity issue related to Bayer process odour emissions.

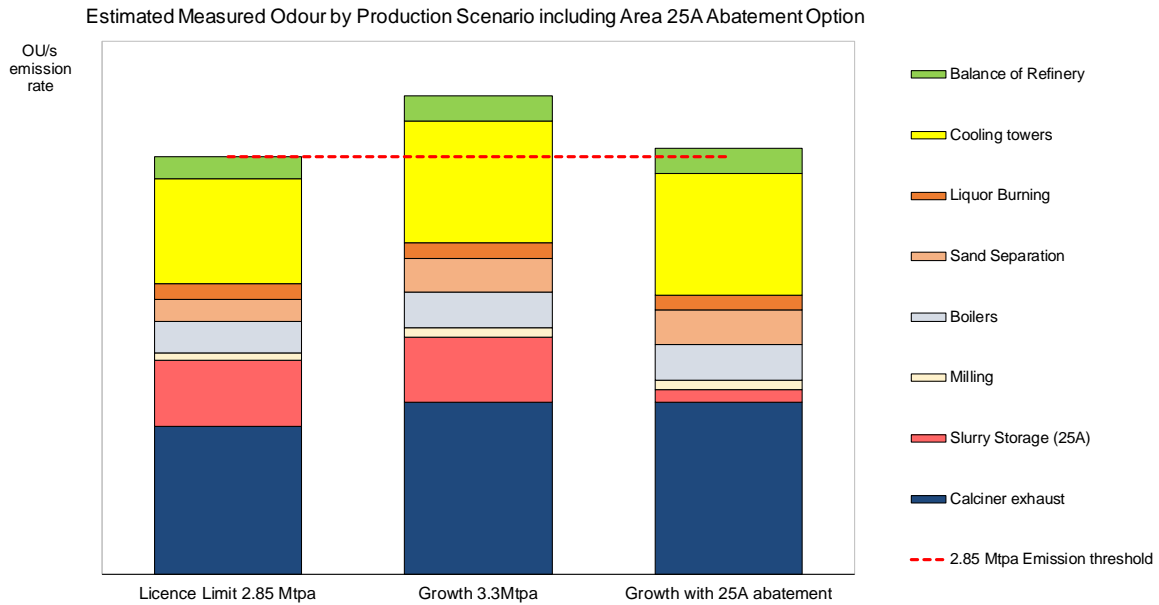
Odour emissions can be highly distinctive between sources of emissions differing in both intensity and magnitude between production areas. Odour emissions from individual process areas also have a high variability based on dynamic olfactometry testing results. Both of these factors complicate direct comparison between particular abatement approaches.

The refinery Bayer odour emissions have been progressively improved as a consequence of VOC focussed destruction projects at the refinery reducing emission rates of both VOC and non-VOC odorous compounds. The 45K Cooling Towers - currently estimated to be the second largest source of odour emissions from the refinery - are a non-Bayer liquor related source.

As a result of the review of VOC emissions from 45K Cooling Towers which indicated that the cooling towers are not a key source of VOC emissions for the refinery, further measurement of odour from the 45K Cooling Towers is to be undertaken to assess whether odour emission rate reductions mirror the VOC emission reductions.

With the reduction in community complaints around odour, the Project focus is on the reduction of VOC levels due to this being a contributor to any health risk assessment undertaken, rather than directly on the amenity issue of odour for affected locations. Destruction of VOC emissions streams is likely to result in a reduction of odour by removal of both VOC and non-VOC odorous compounds. The selection of the abatement option to capture 25A Slurry Storage tank vents and destroy the vapours using RTO technology as part of the Project, is anticipated to satisfy the pre-existing MS 728 Condition 8-1.1.

Figure 7 Refinery Measured Odour Emissions estimates with the Project Scope



5 FULL 4.7 MTPA REFINERY VOC AND ODOUR OUTLOOKS

The increase to 4.7 Mtpa production rate is expected to produce an increase in VOC and odour emissions. The magnitude of any increases or decreases associated with the production level is entirely dependent on the scope chosen to achieve the production rate. This scope for future achievement of the 4.7Mtpa approval currently remains undefined, with the forecasts indicated below reflecting specific scenarios to identify large contributors and paths for pursuing abatement.

Achieving any offset of emissions increases for both VOC and odour for such future increases in production presents specific challenges and requires detailed investigation of large refinery sources, such as calciners and power station operation, as well as selection of future production and abatement scopes. A risk-based assessment is likely to be more appropriate to evaluate whether abatement is required rather than prescriptive reductions.

The following graphics show the impact of the increase of emissions to 4.7 Mtpa with no abatement applied, followed by the reduction if the 25A slurry storage tank vents were addressed at that production level, and then the indicative reduction magnitudes that would be required to achieve no increase in VOC emissions based on the indicative scope selected to achieve 4.7 Mtpa.

Figure 8 Indicative Refinery VOC Emissions forecast and generic abatement at 4.7Mtpa

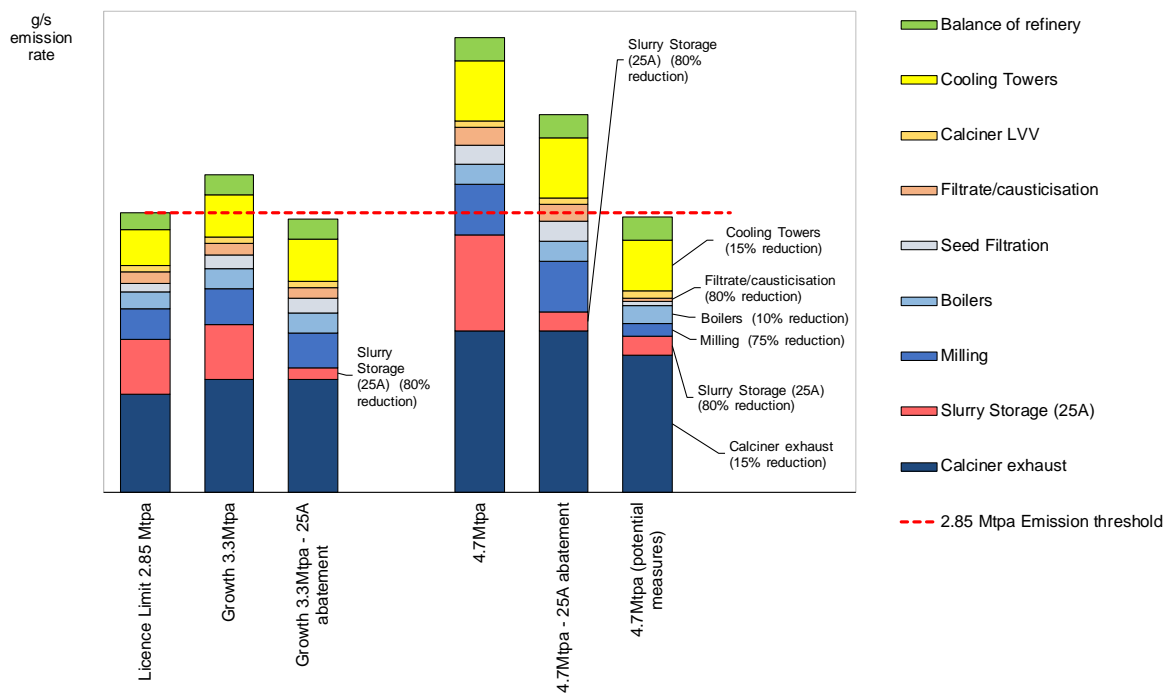
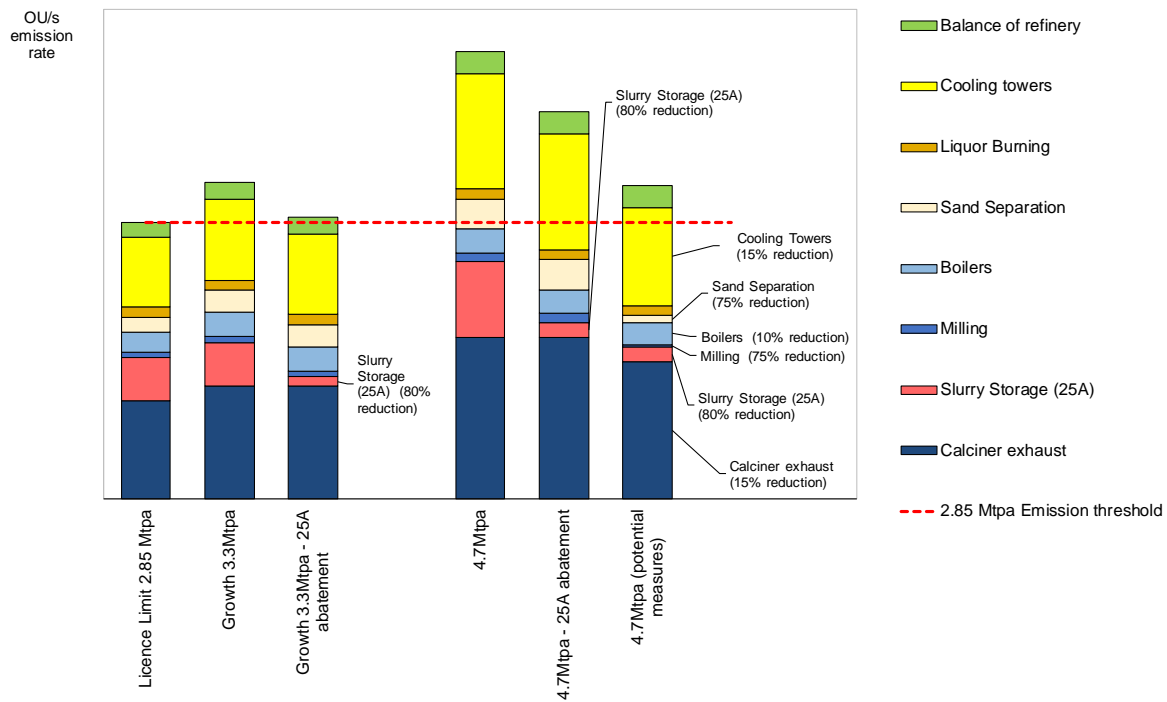


Figure 9 Indicative Refinery Odour Emissions forecast and generic abatement at 4.7Mtpa



6 PROJECT VOC AND ODOUR ABATEMENT CONCLUSION

Existing Ministerial Conditions for the refinery itemise a number of priority emissions sources to address to facilitate an increase in production to the approved licence limit of 4.7 Mtpa.

The increase in production attributable to the efficiency project for the existing Bayer process Units 1 and 2 at Wagerup Refinery without abatement increases VOC and odorous emissions from various refinery sources.

To offset this increase, the Project includes scope to address the high emissions source of Building 25A Slurry Storage in achieving the increase to 3.3 Mtpa alumina production without increasing overall refinery VOC and odour emission. This is to be achieved by capture and destruction of these VOC and odorous compounds emissions by installing a new Regenerative Thermal Oxidiser.

The RTO is an effective technology for destroying these compounds with a high efficiency and availability and is known technology currently in use at both the Pinjarra and Wagerup refineries. The successful application of RTO technology in Area 30 at Pinjarra has been in service with duty equivalent to the 25A RTO at Wagerup proposed to be installed in this project.

The outcome of the VOC and odour abatement direction is to satisfy the Ministerial Statement condition to reduce the emissions at the low elevation 25A tank vents, which are the second largest VOC emitter and third largest odour emitter recorded in the emissions inventory data.

Successful implementation of this option has the expectation to reduce refinery VOC emissions at 3.3 Mtpa to below the existing forecast for the approved licence level of 2.85 Mtpa and see the reduction level for refinery odour emissions.

APPENDIX A. SUMMARY ESTIMATES OF AVERAGE REFINERY VOC AND ODOUR EMISSIONS

Average VOC ¹ and Odour Estimated forecast emissions		2.85 Mt/a Current Licence Forecast		3.3 Mt/a			
Source	Forecast Basis:	Odour	Total VOCs	Growth Project Forecast		with abatement Estimated	
	Emissions Proportional to Production? ²	MOU/s	g/s	Odour	Total VOCs	Odour	Total VOCs
		MOU/s	g/s	MOU/s	g/s	MOU/s	g/s
Combustion Equipment Point Sources:							
B47 Oxalate Kiln Stack	No	8,509	0.01	8,509	0.01	8,509	0.01
B48 Liquor Burning	No	49,668	0.02	49,668	0.02	49,668	0.02
B50 Calciners	Yes	501,588	1.02	580,786	1.18	580,786	1.18
B110 Boilers	Yes	104,658	0.18	121,183	0.21	121,183	0.21
Non-Combustion Equipment Point Sources:							
B47 Oxalate Filter Building Stack	No	1,414	0.01	1,414	0.01	1,414	0.01
B50 Calciner LVV, vents, hoods	No	17,030	0.15	20,997	0.18	20,997	0.18
B45K Cooling Towers	Yes	356,629	0.38	412,939	0.44	412,939	0.44
B50 Cooling Towers	Yes	521	0.00	604	0.00	604	0.00
B50 Calciner 4 Extraction Hoods	No	721	0.00	721	0.00	721	0.00
B48A Tank exhaust	No	697	0.00	697	0.00	697	0.00
Grouped Sources:							
B25 Mill Trommel Vents	Yes ²	26,787	0.32	31,017	0.37	31,017	0.37
B25A Tank Vents	No	220,919	0.57	220,919	0.57	44,184	0.11
B26 Stacks	No ²	77,124	0.04	115,686	0.04	115,686	0.04
B35A Tank Vents	No	10,828	0.03	10,828	0.03	10,828	0.03
B35J Tank Vents	No	19,340	0.09	19,340	0.09	19,340	0.09
B30 Blow-off stacks	No	0	0.00	0	0.00	0	0.00
B45 Precipitators	No ²	0	0.01	0	0.01	0	0.01
B44 Seed Filtration Stacks	No ²	13,959	0.09	23,265	0.15	23,265	0.15

1. Estimates to two decimal places - may be present but non-zero.

2. Related to equipment units online to improve efficiency, availability or reliability.