NSW Environment Protection Authority Review of Coal Fired Power Stations Air Emissions and Monitoring

Attachment D:

Representativeness of Sampling Data

EPA 2018P0703

Contents

Purpose

This appendix provides an overview of the analysis used by the EPA to inform the review of representativeness of air emission monitoring conducted by the NSW coal fired power stations. A subset of tables and graphs which inform the *NSW EPA Review of Coal Fired Power Stations Air Emissions and Monitoring (March 2018)* report have been compiled in the appendix, along with additional discussion.

The EPA reviewed and analysed power station data for the five-year period 2011 to 2016, including:

- hourly continuous emission monitoring (CEM) data for nitrogen Oxides (NOx), sulfur dioxide (SO_2), opacity
- daily coal quality analysis reports for calorific value, sulfur and ash content
- hourly boiler loads (MW) and coal usage (t/hr)
- periodic (stack test) reports

This document comprises of the following sections:

Section 1: Periodic particulate sampling

Section 2: Continuous opacity monitoring

Section 3: Sulfur dioxide and nitrogen oxides sampling

Section 4: Coal quality burnt during test periods

1) Periodic Sampling - Solid Particles

Periodic stack test reports – totalling 108 reports and spanning 2011-3016 – were reviewed to inform the representativeness of solid particle (TSP) sampling conducted at NSW power stations.

This section discusses:

- solid particle monitoring requirements
- boiler load during periodic sampling
- approach used to collect periodic solid particle samples

1.1. Solid Particle Monitoring Requirements

Each coal fired power station is required to monitor, by sampling and obtaining results by analysis, the concentration of each pollutant specified in their EPL. Sampling frequency and units of measure are also prescribed. The EPL requirements for solid particle[1] sampling are summarised in Table 1 below. Each power station is required to collect, analyse and report a solid particle sample from each boiler, once per year.

Table 1: NSW Coal fired power stations - EPL Solid particle sampling requirements.

Station	EPA Sampling Point ID and Description	Pollutant	Frequency	Sampling Method	Units of Measure	Reference Basis
Bayswater Power Station	*10: Boiler 1* *11: Boiler 2* *12: Boiler 3* *13: Boiler 4*	Solid Particles	Yearly	TM-15	mg/m^3	Dry, 273 K, 101.3 kPa,12 % CO_2 or eq. % O_2
Eraring Power Station	*11: Boiler 1* *12: Boiler 2* *13: Boiler 3* *14: Boiler 4*	Solid Particles	Yearly	TM-15	mg/m^3	Dry, 273 K, 101.3 kPa, 7% O_2
Liddell Power Station	*1: Unit 1 / Boiler 1-2* *2: Unit 2 / Boiler 1-2* *3: Unit 3 / Boiler 3-4* *4: Unit 4 / Boiler 3-4*	Solid Particles	Yearly	TM-15	mg/m^3	Dry, 273 K, 101.3 kPa, 7% O_2
Mount Piper Power Station	*2: Boiler 1* *3: Boiler 2*	Solid Particles	Yearly	TM-15	mg/m^3	Dry, 273 K, 101.3 kPa, 7% O_2
Vales Point Power Station	*11: Boiler 5* *12: Boiler 6*	Total Solid Particles	Yearly	TM-15	mg/m^3	Dry, 273 K, 101.3 kPa, 7% O_2

1.2. Boiler load during periodic sampling

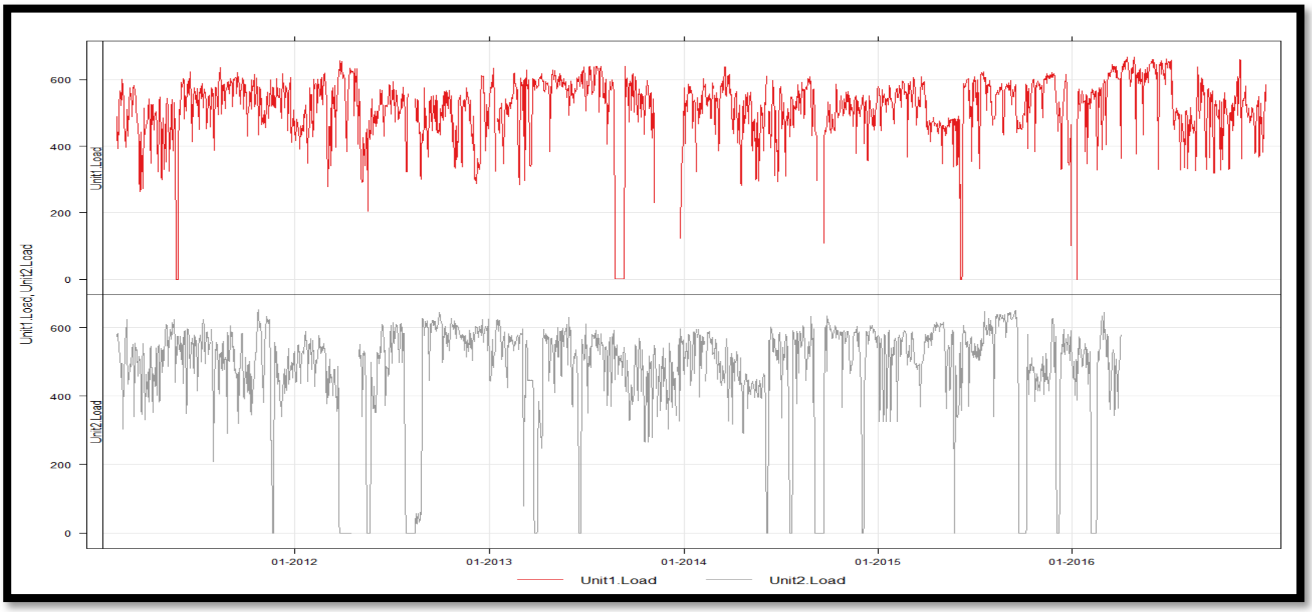
The EPA reviewed power generation and boiler load data to investigate if periodic solid particle emission testing was undertaken at times considered representative of normal boiler operations. Power generation data was sourced from each of the power stations and the Australian Energy Market Operator (AEMO).

The boiler load at the time of emission testing was compared with monthly and annual average boiler loads. The comparison was used to determine if boiler load conditions were normal at the time emission testing was being conducted.

Boiler load varies as a function of time, season and consumer demand. Most power stations operate each boiler between 300 to 650 megawatts (MW). Typical boiler load variation can be seen in Figure 1 below.

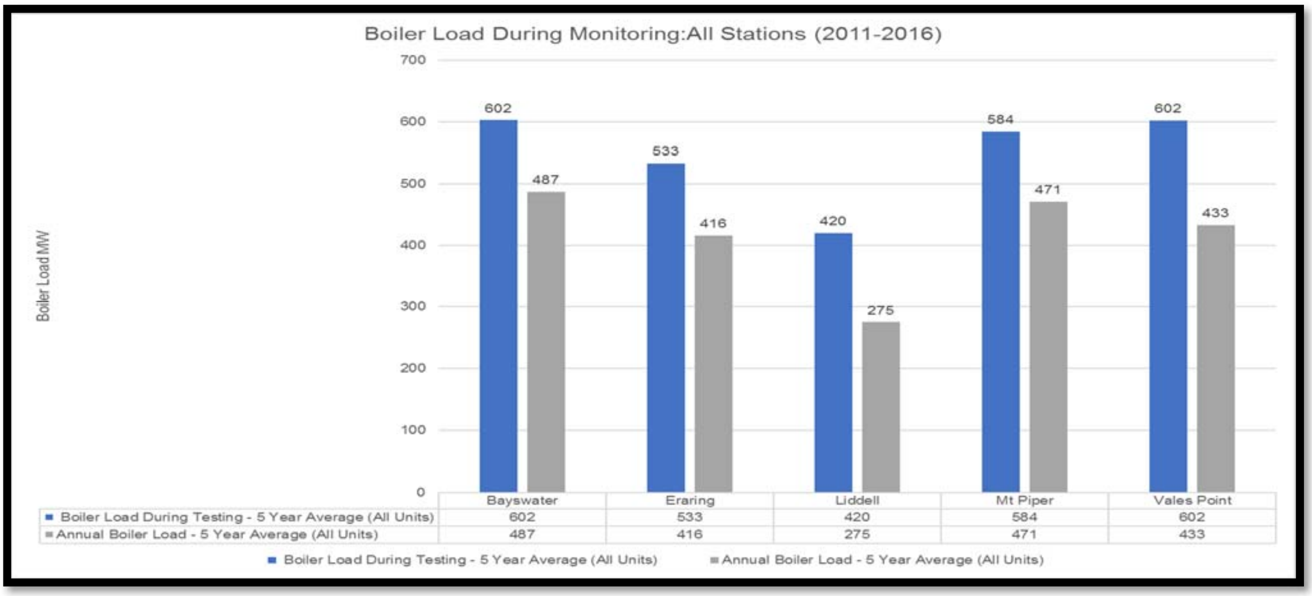
[1] For this review, 'particles', 'solid particles', total solid particles' (TSP), 'particulate' and 'particulate matter' are considered synonymous.

Figure 1: Bayswater Boiler Unit 1 and Boiler Unit 2 load variation averaged daily (2011-2016).



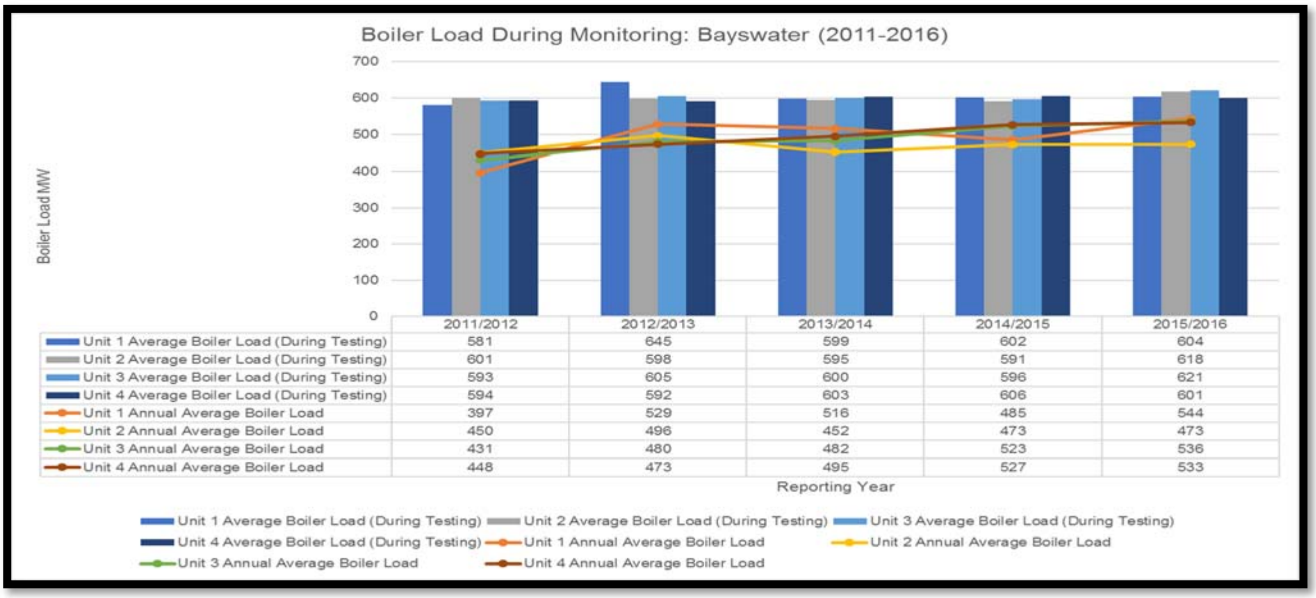
The EPA compared the boiler load at the time periodic sampling was being undertaken, with the average annual boiler load – specific to the unit being tested. The review found periodic testing is typically conducted when boiler loads are above the annual average load. In Figure 2 the 5-year average boiler load during periodic sampling compared with the 5-year average boiler load for each power station.

Figure 2: Average boiler load during periodic monitoring - All power stations (2011-2016).



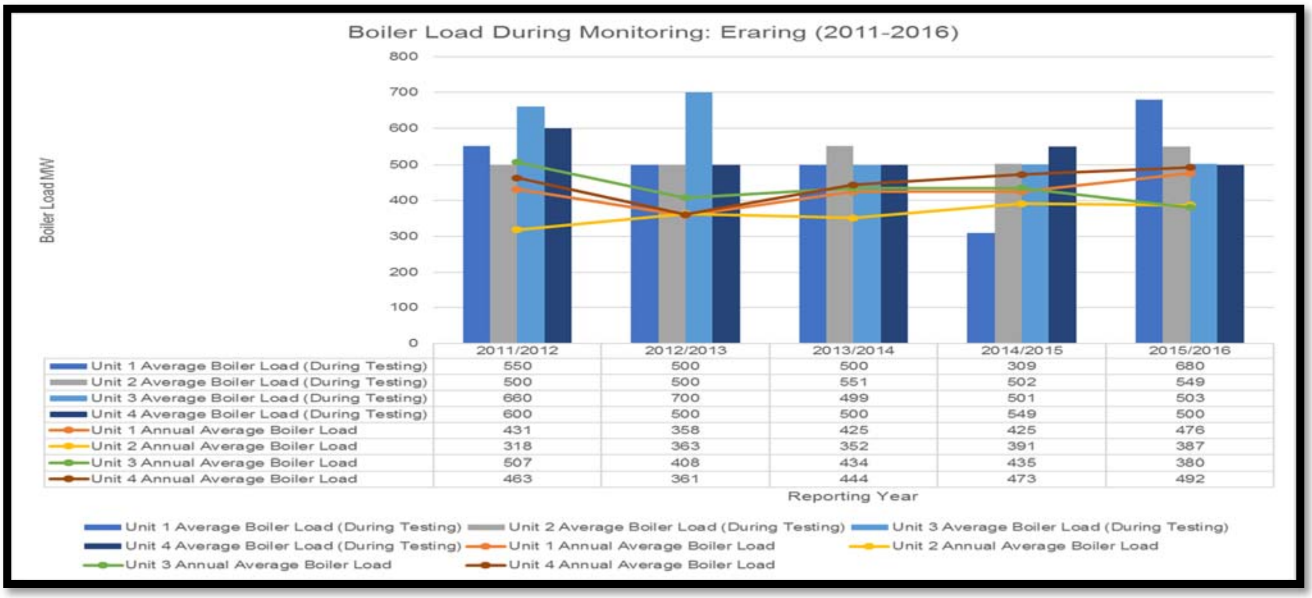
Figures 3 to 7 provide annual comparisons for each power station and individual boiler. The columns represent the average boiler load at the time periodic particle sampling was undertaken, the trendlines are the annual boiler load, for each unit.

Figure 3: Average boiler load during periodic monitoring - All Units - Bayswater Power Station (2011-2016).



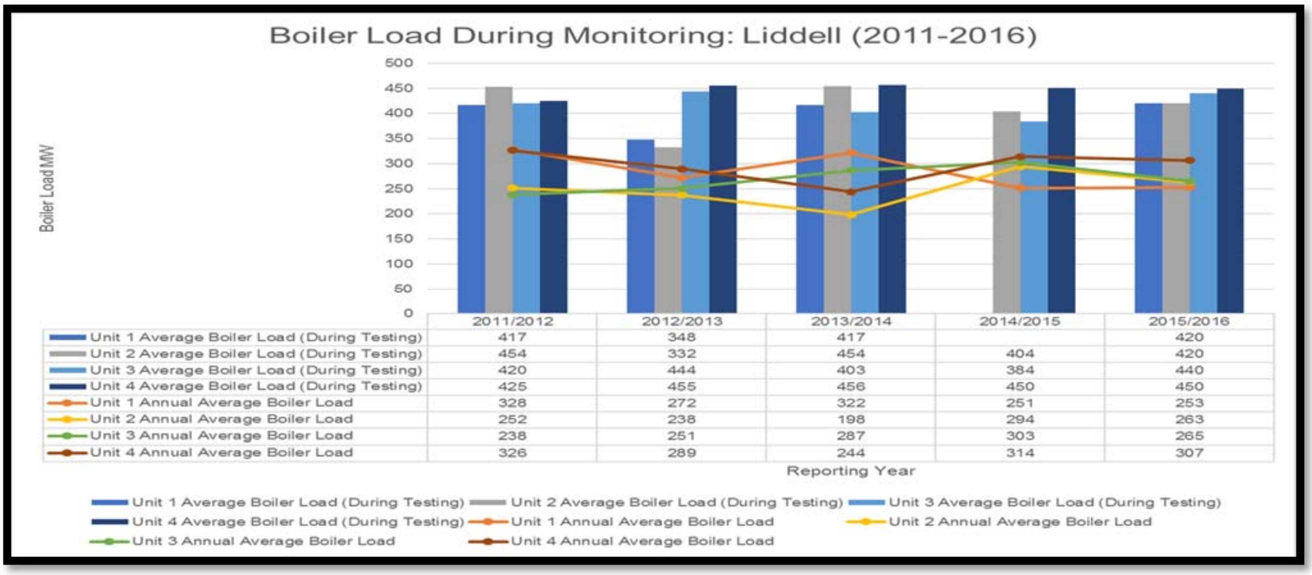
	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Unit 1 Average Boiler Load (During Testing)	581	645	599	602	604
Unit 2 Average Boiler Load (During Testing)	601	598	595	591	618
Unit 3 Average Boiler Load (During Testing)	593	605	600	596	621
Unit 4 Average Boiler Load (During Testing)	594	592	603	606	601
Unit 1 Annual Average Boiler Load	397	529	516	485	544
Unit 2 Annual Average Boiler Load	450	496	452	473	473
Unit 3 Annual Average Boiler Load	431	480	482	523	536
Unit 4 Annual Average Boiler Load	448	473	495	527	533

Figure 4: Average boiler load during periodic monitoring - All Units - Eraring Power Station (2011-2016).



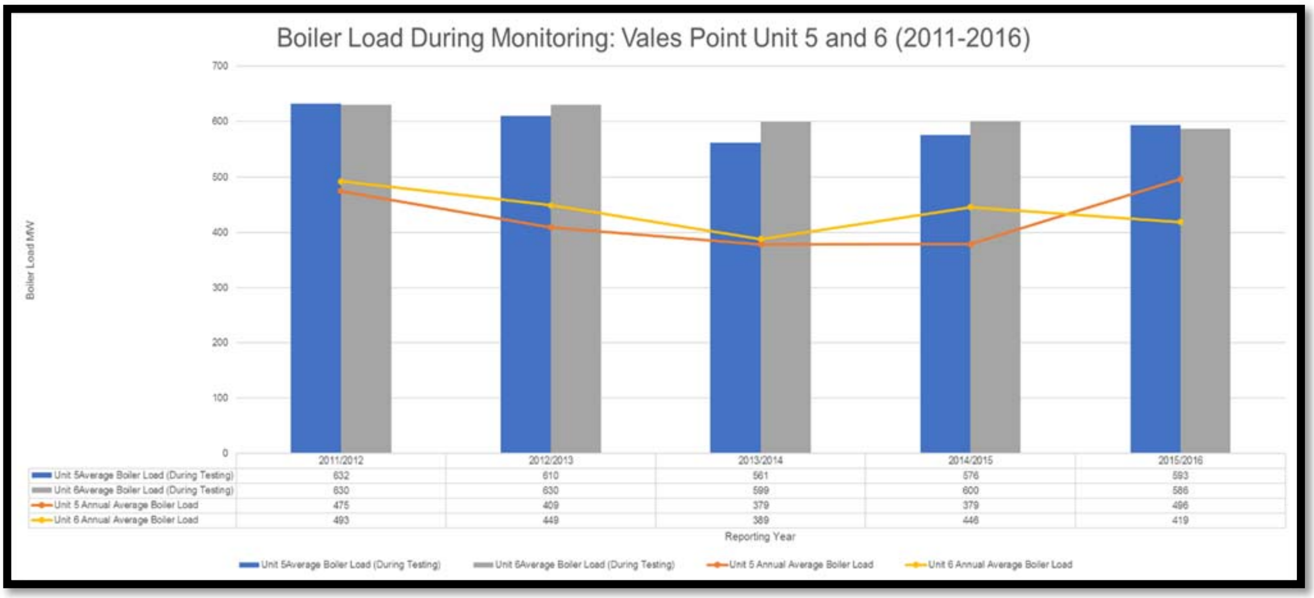
	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Unit 1 Average Boiler Load (During Testing)	550	500	500	309	680
Unit 2 Average Boiler Load (During Testing)	500	500	551	502	549
Unit 3 Average Boiler Load (During Testing)	660	700	499	501	503
Unit 4 Average Boiler Load (During Testing)	600	500	500	549	500
Unit 1 Annual Average Boiler Load	431	358	425	425	476
Unit 2 Annual Average Boiler Load	318	363	352	391	387
Unit 3 Annual Average Boiler Load	507	408	434	435	380
Unit 4 Annual Average Boiler Load	463	361	444	473	492

Figure 5: Average boiler load during periodic monitoring - All Units - Liddell Power Station (2011-2016).



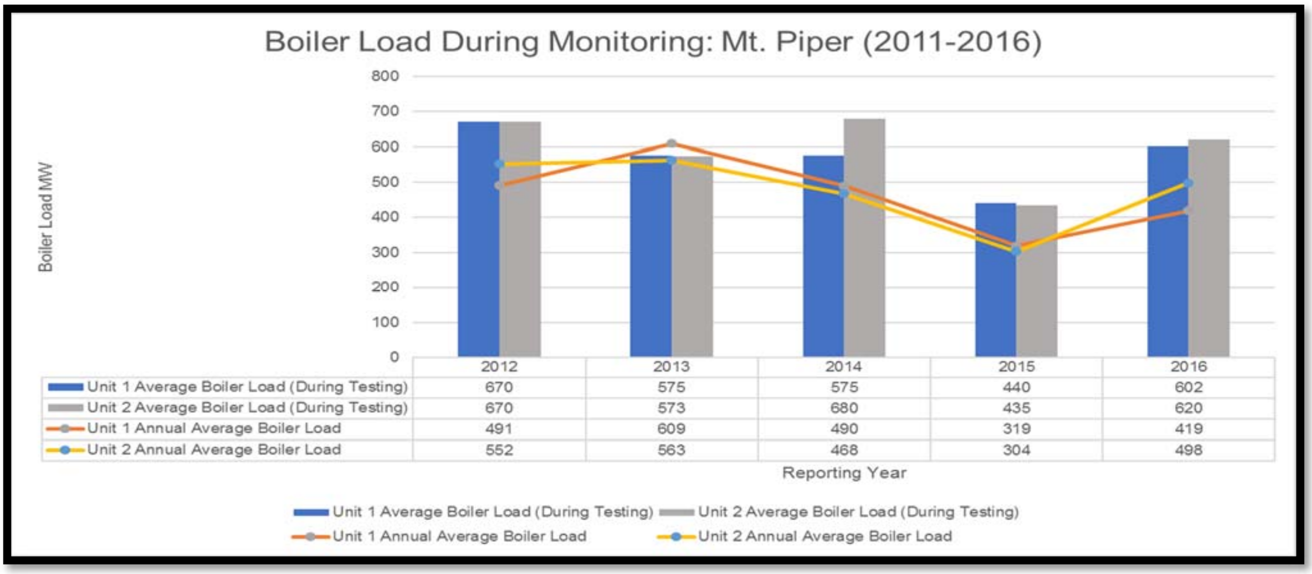
	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Unit 1 Average Boiler Load (During Testing)	417	348	417		420
Unit 2 Average Boiler Load (During Testing)	454	332	454	404	420
Unit 3 Average Boiler Load (During Testing)	420	444	403	384	440
Unit 4 Average Boiler Load (During Testing)	425	455	456	450	450
Unit 1 Annual Average Boiler Load	328	272	322	251	253
Unit 2 Annual Average Boiler Load	252	238	198	294	263
Unit 3 Annual Average Boiler Load	238	251	287	303	265
Unit 4 Annual Average Boiler Load	326	289	244	314	307

Figure 6: Average boiler load during periodic monitoring - All Units – Vales Point Power Station (2011-2016)



	2011/2012	2012/2013	2013/2014	2014/2015	2015/2016
Unit 5Average Boiler Load (During Testing)	632	610	561	576	593
Unit 6Average Boiler Load (During Testing)	630	630	599	600	586
Unit 5 Annual Average Boiler Load	475	409	379	379	496
Unit 6 Annual Average Boiler Load	493	449	389	446	419

Figure 7: Average boiler load during periodic monitoring - All Units – Mount Piper Power Station (2011-2016)



	2012	2013	2014	2015	2016
Unit 1 Average Boiler Load (During Testing)	670	575	575	440	602
Unit 2 Average Boiler Load (During Testing)	670	573	680	435	620
Unit 1 Annual Average Boiler Load	491	609	490	319	419
Unit 2 Annual Average Boiler Load	552	563	468	304	498

Solid Particle Sampling Method

Each of the power stations are required to sample solid particle emissions in accordance with the *Approved Methods for the Sampling and Analysis of Air Pollutants in NSW (2007)* (Approved Methods Sampling)[2].
- Test Method 15 (TM-15). The method is used to collect a representative sample of particulate matter in a gas stream of a stack or duct. A representative sample is a quantity of collected gas which has the same characteristics as the flue gas being investigated.

The reference method for TM-15 is Australian Standard (AS) 4323.2-1995 or USEPA (2000) Method 5 under approved circumstances. AS4323.2 (Method 2: *Determination of total particulate matter—Isokinetic manual sampling—Gravimetric method),* is an isokinetic sampling method for determination of particulate matter emitted from stationary sources.

Source samples are collected by drawing stack gas, at an isokinetic sampling rate, through a nozzle, probe and filter. Solid particles are collected on a pre-weighed filter. The mass of the particulate matter is determined gravimetrically and related to the volume of gas sampled. The method provides a measure of the concentration and mass flowrate (and collectively mass emission rate).

Solid particle samples collected in accordance with the approved sampling method are deemed to be representative of the in-stack concentration of solid particles for the sampling period.

Stack testing reports reviewed for each power stations report total solid particle sampling was conducted in accordance with TM-15 between 2011-2016. Sample analysis was conducted by NATA accredited laboratories (refer to Attachment C, Section 2).

Sampling Solid Particles from Multiple Ducts

Particle samples are required to be collected from EPA identified discharge/monitoring points, as per the EPLs. The location of the EPA sampling point described in the EPL is typically the boiler stack. Due to the size of boiler stacks, sampling is often conducted in the boiler exhaust ducts leading to the stack.

Boiler exhaust ducts may comprise multiple ducts. Each duct directs boiler flue exhaust gases through parallel pollution control systems i.e. baghouses. The exhaust ducts are then either a) re-combined before entering the boiler exhaust stack, or b) enter directly into the stack.

The approach used at each power station to collect solid particle samples differs as per Table 2. For example, Bayswater, Liddell and Eraring collect and report solid particle emission concentrations from a single duct only.

Variation in sampling approach may be due to ambiguity of EPL listed monitoring locations and sampling requirements (see Section 4, Attachment B_Coal fired power stations licence consistency review).

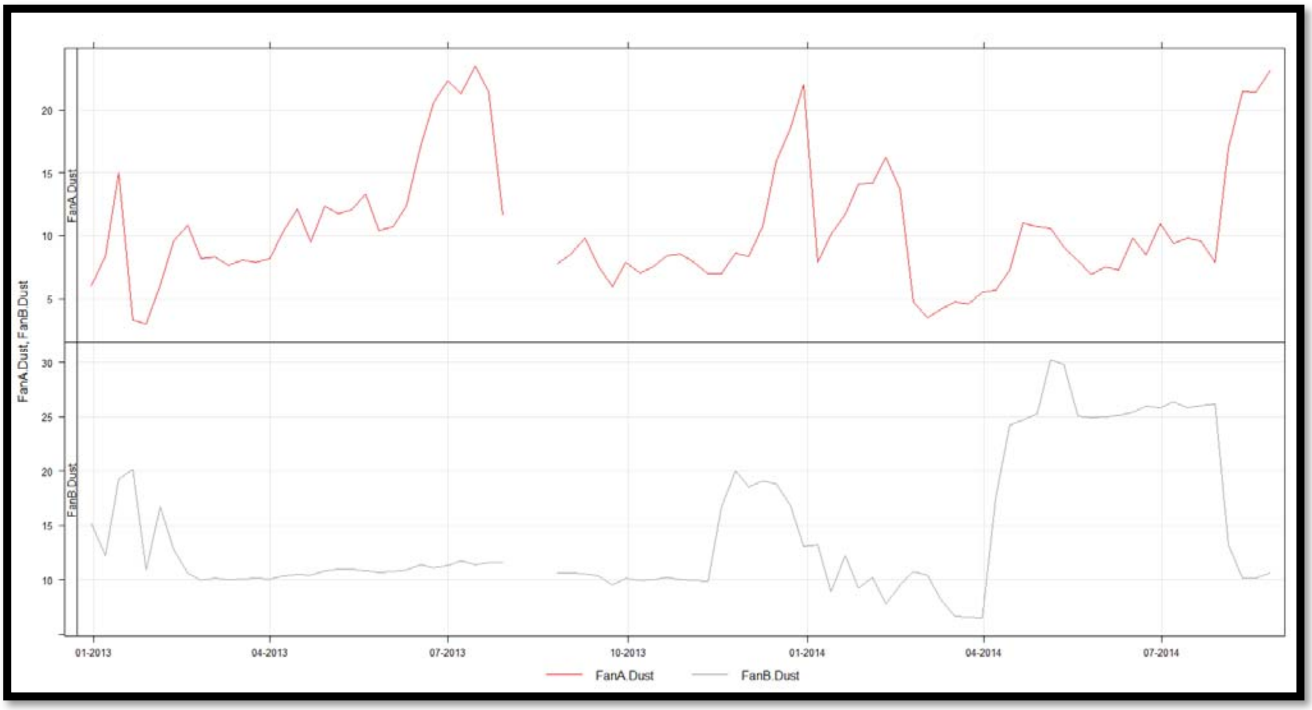
[2] *http://www.environment.nsw.gov.au/resources/air/07001amsaap.pdf*

Table 2: Approach used to measure TSP at NSW coal fired power stations.

Station	EPA ID no.	Location Description	Number of duct ducts	Approach to sampling TSP
Bayswater	10	Boiler 1 stack	2 (1A, 1B)	Each boiler is sampled once per year, spaced evenly across the year. Each boiler stack is comprised of 2 separate ducts, A and B duct. Bayswater sample from either duct A or B only.
	11	Boiler 2 stack	2 (2A, 2B)	
	12	Boiler 3 stack	2 (3A, 3B)	
	13	Boiler 4 stack	2 (4A, 4B)	
Liddell	1 and 7	Unit 1 Boiler	2 (1A, 1B)	Each boiler is sampled once per year, spaced evenly across the year. Each boiler stack is comprised of 2 separate ducts, A and B duct. Liddell sample from either duct A or B only.
	2 and 8	Unit 2 Boiler	2 (2A, 2B)	
	3 and 9	Unit 3 Boiler	2 (3A, 3B)	
	4 and 10	Unit 4 Boiler	2 (4A, 4B)	
Mount Piper	2	Boiler 1	2 (1A, 1B)	Each boiler is sampled once per year, spaced evenly across the year. Each boiler stack is comprised of 2 separate ducts, A and B duct. Both ducts are sampled and an average result is used.
	3	Boiler 2	2 (2A, 2B)	
Eraring	11	Boiler No. 1	2 (1A, 1B)	Each boiler is sampled once per year, spaced evenly across the year. Each boiler stack is comprised of 2 separate ducts, A and B duct. Eraring sample from either duct A (Top Pass) or B (Bottom Pass) only.
	12	Boiler No. 2	2 (2A, 2B)	
	13	Boiler No. 3	2 (3A, 3B)	
	14	Boiler No. 4	2 (4A, 4B)	
Vales Point	11	Boiler Unit No. 5	4 (5A,5B,5C,5D)	Each boiler is sampled once per year, generally at approximately the same time of year. Each boiler stack is comprised of 4 separate ducts, A to D. All ducts are sampled for TSP and flow rate and an average result is used.
	12	Boiler Unit No. 6	4 (6A,6B,6C,6D)	

Particulate based pollution concentrations (i.e. dust, metals) may vary between two exhaust ducts, originating from a single boiler, due to passing through separate pollution control systems. Solid particle samples collected from a single duct, of a multiple duct exhaust system, may be less representative than samples collected from all ducts, originating from a single boiler. An example of this variation can be seen in Figure 8.

Figure 8: CEM measured dust concentrations at Eraring PS-Unit 2 Fan Duct A and B.



In Figure 8, Fan B (the bottom data trend) shows periods of stable opacity readings while, during the same period of time, Fan A has peaks indicating periods when Fan A dust concentration were likely to be higher than Fan B.

Due to the large diameter of boiler exhaust ducts and site specific infrastructure constraints, the sampling locations for all power stations have been identified as 'non-ideal' - in accordance with Australian Standards 4323.1. As the sampling planes are non-ideal, all power stations measure stack gas flow rates using USEPA Method 1, in place of AS4323.1, as per the approved circumstances detailed in section 2 of the Approved Methods Sampling.

Procedures are incorporated into the approved test methods to improve measurement uncertainty at non-ideal sampling locations. However, the boiler exhaust duct orientation and distance of the sampling plane to flow disturbances may affect flow characteristics within the ducts, causing variation in particle distribution and measured particle based pollutant concentrations.

While the precision of the sampling method may vary according to the parameters listed above, measurement uncertainty of ±15 % is typically reported for sampling method AS4323.2 within stack testing reports.

It is noted through review of the reported emission concentrations that reported particle emissions are typically less than 20 mg/m^3, which leaves significantly more than a 15% margin to the EPL compliance limit.

1.3. Representativeness of Periodic Particle Samples

Opacity trends were used to investigate if periodic particle sampling was conducted at times when particulate emissions were representative. Data collected from all power station opacity meters was graphed and reviewed.

Continuous opacity monitoring conducted at the power stations is used to provide an indicative measure of dust levels at the outlets of the baghouse filters. As manual particulate sampling, with gravimetric analysis is a more accurate way to determine the mass concentration of particle emissions (see discussion in Section 2), this review does not evaluate the accuracy of periodic particle sampling results to measurements from continuous opacity monitors.

The review found periodic monitoring for TSP was generally conducted at times representative of normal dust (opacity) concentrations, as indicated by CEM opacity monitor trends.

Figures 9 to 12 below are a sample of the comparison trends used to determine representativeness of periodic sampling. They are typical of power station opacity trends observed for the 5-year period reviewed. Periodic tests are indicated by the red dots.

Although this review does not evaluate the accuracy of the periodic testing results against the opacity trend, it is noted that the two sets of measured results are still within a reasonable range of each other – when measurement uncertainty, difference in measurement method and averaging periods are considered. Importantly, both measurements indicate the power stations are compliant with EPL total solid particle emission limits.

Figure 9: Bayswater Unit 4, Fan A daily average opacity trend, as undifferentiated particulates and stack test TSP (mg/m^3).

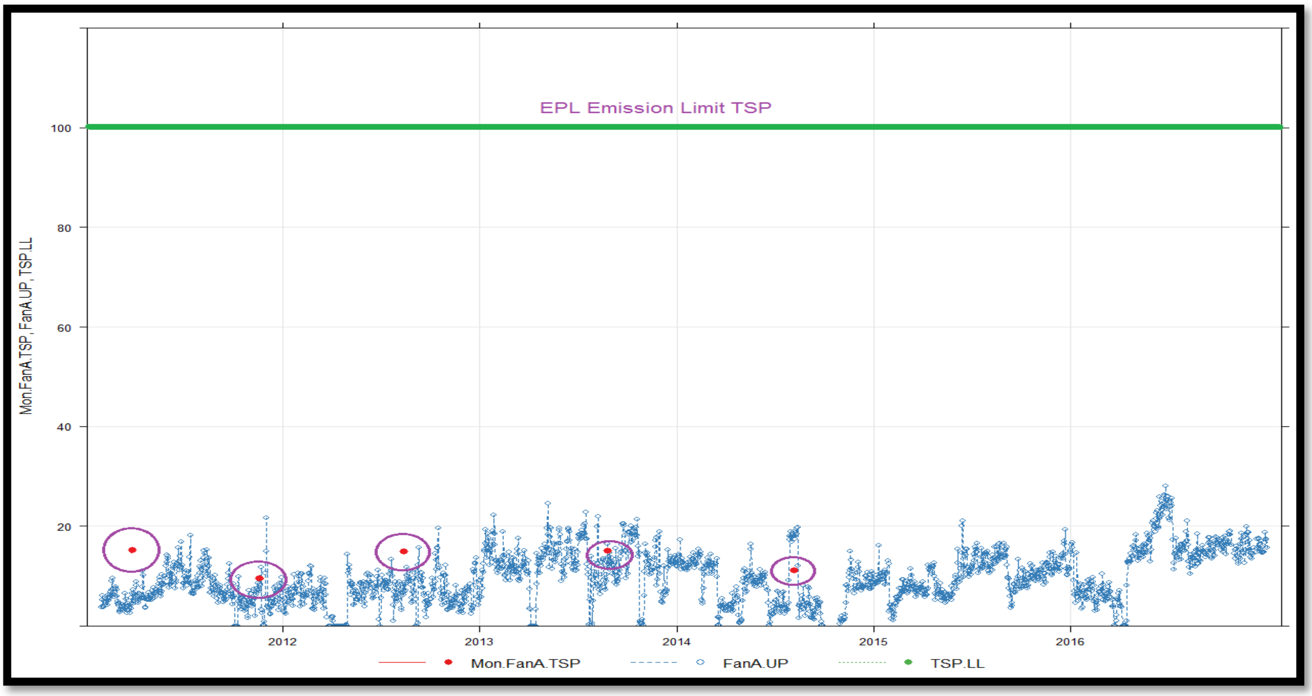
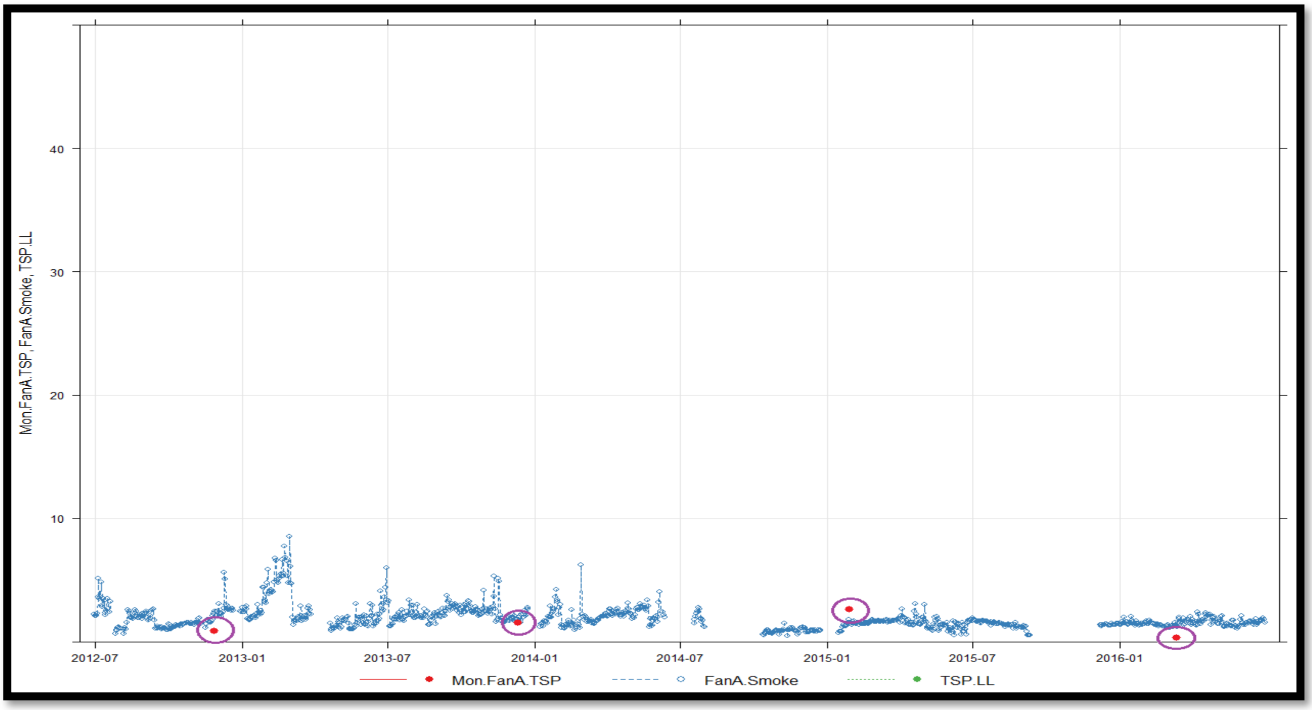


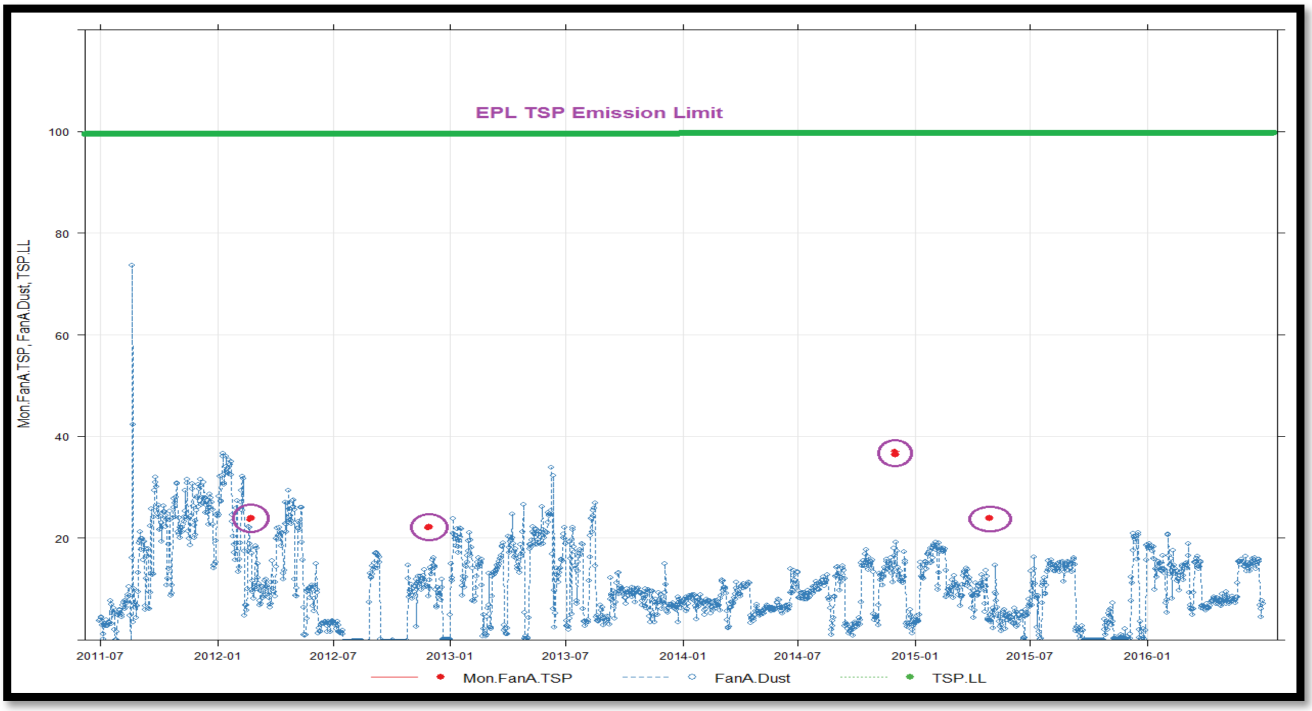
Figure 10: Eraring Unit 1, Duct A - Daily average of Opacity CEM, as undifferentiated particulates and stack test TSP (mg/m^3)

Figure 11: Vales Point Unit 5, Duct A - Daily average of Opacity CEM, as undifferentiated particulates and stack test TSP (mg/m^3).



 # The licence limit is not displayed on the graph due to the low range of opacity measurements and periodic test results.

Figure 12:Liddel Unit 3, Duct A - Daily average of Opacity CEM, as undifferentiated particulates and stack test TSP (mg/m³)



2) Continuous Opacity Monitoring

With the exception of Mount Piper, each of the NSW coal fired power stations have an EPL requirement to monitor undifferentiated particulates, as per Table 3.

Table 3: NSW coal fired power stations - undifferentiated particulates monitoring requirements

Station	EPA Sampling Point ID and Description	Pollutant	Frequency	Sampling Method	Units of Measure
Bayswater Power Station	*10: Boiler 1* *11: Boiler 2* *12: Boiler 3* *13: Boiler 4*	Undifferentiated Particulates[1]	Continuous	CEM-1	Percent Opacity
Eraring Power Station	*11: Boiler 1* *12: Boiler 2* *13: Boiler 3* *14: Boiler 4*	Undifferentiated Particulates[1]	Continuous	CEM-1	mg/m^3
Liddell Power Station	*1: Unit 1 / Boiler 1-2* *2: Unit 2 / Boiler 1-2* *3: Unit 3 / Boiler 3-4* *4: Unit 4 / Boiler 3-4*	Undifferentiated Particulates[1]	Continuous[2]	CEM-1	Percent Opacity
Mount Piper Power Station	No Requirement				
Vales Point Power Station	*11: Boiler 5* *12: Boiler 6*	Undifferentiated Particulates[1]	Continuous	In line instrumentation[3]	mg/m^3

1: Undifferentiated Particulates - The term 'undifferentiated particulates' is not a term defined in NSW regulatory instruments, including EPL's. For the purpose of this discussion, undifferentiated particulates are particles calculated using the response of an opacity meter and a calibration factor, unique to that specific installation.
2: As per EPL condition M2.4: Liddell power station must ensure that at least two (2) continuous monitors are operating and accurately measuring opacity in flue gases during the reporting period.
3: Vales Point licence specifies In-Line instrumentation as the sampling method. This is not a recognised NSW Approved Sampling method.

2.1. Opacity Monitoring Method

Continuous Emission Monitoring method 1 (CEM-1) is the NSW approved monitoring method to determine smoke emission *(if determining whether a specified standard of concentration of opacity has been exceeded).*

The Approved Methods Sampling, lists the reference method for CEM-1 as United States Environmental Protection Agency (USEPA) Performance Specification 1 (PS-1) - *Specifications and test procedures for continuous opacity monitoring systems in stationary sources*. PS-1 covers the instrumental measurement of opacity caused by attenuation of projected light through an effluent gas stream.

Opacity is expressed in scales of opacity %, and calculated from basic measurement of light transmittance. Opacity meters measure the decrease in light intensity due to absorption and scatter. Opacity measurements are dependent on particle size, composition, shape, colour and refractive index. These properties may change with fuel type and other gas stream factors, thus calibration is necessary with variation of process conditions.

The EPA does not have published a guidance document on how to determine undifferentiated particulates or mass based particle emissions from continuous opacity monitoring. CEM-1 does not include guidance on this procedure either, therefore, to meet EPL requirements, each of the NSW power stations have adopted their own approach for reporting opacity as a mass based concentration of particulate emissions, expressed as undifferentiated particulates.

To report particle concentrations (mg/m^3) from an opacity measurement, the instrument response of the opacity monitor must be correlated to a determined mass concentration obtained through gravimetric analysis. Guidance on this procedure is given in USEPA Performance Specification 11 (PS-11).

The purpose of PS-11 is to establish the initial installation and performance procedures that are required for evaluating the acceptability of a particulate matter (PM) continuous emission monitoring system (CEMS).

In the United States, following initial installation of a PM CEMS, the ongoing QA/QC requirements are established using USEPA Procedure 2—*Quality assurance requirements for particulate matter continuous emission monitoring systems at stationary sources* and USEPA Procedure 3 is used to demonstrate continuous compliance with opacity standards.

2.2. Opacity Monitoring Equipment

The continuous monitors currently installed at the power stations are designed to measure opacity. Table 4 provides a summary of the monitor type, number and installation date for equipment currently installed at each of the power stations to monitor opacity.

Table 4: Summary of installed opacity monitoring equipment at NSW power stations.

Station	No. Monitors	Installation date	Manufacturer/ Model type	Monitor Type
Bayswater	4	Between 2012 and 2014	3 x SICK Dusthunters. 1 x SICK model OMD41	opacity monitors
Liddell	8	2008/2009[1]	Opal	opacity monitors
Mount Piper	No requirement to monitor Opacity			
Eraring	8	2013	Durag DR290	opacity monitors
Vales Point	8	Between September 2005 and April 2006	Durag DR290	opacity monitors

1: The installation dates for the opacity monitors at Liddell PS were not provided. NPI website records indicate the opacity monitors were installed between 2008-2009.

2.3. CEMS Calibration and Maintenance

Each of the power stations perform routine maintenance and calibrations on the installed opacity monitoring equipment. Historical maintenance/ inspection records, calibration sheets and purchasing records were provided by each of the power stations to demonstrate proper and efficient operation of the monitoring equipment. A brief overview of the schedules and record keeping is provided below.

Bayswater

Bayswater perform routine 6 monthly, multipoint calibrations on opacity monitors. The calibration and maintenance is scheduled using an automated management (SAP) system. Calibrations are performed by SICK P/L as per a service agreement with Bayswater. Maintenance records are logged using a database, and PDF copies of records are retained on file. Table 5 presents sample maintenance record entries from SAP.

Table 5: Example of Bayswater SAP records used for planning maintenance and calibrations.

Basic fin. date	Order Type	Description
04/05/2012	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
02/11/2012	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
03/05/2013	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
01/11/2013	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
02/05/2014	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
01/07/2015	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
02/11/2015	PM01	SDM "A" MULTIPOINT CALIBRATION DHT-100
04/05/2012	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
02/11/2012	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
03/05/2013	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
01/11/2013	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
02/05/2014	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
17/11/2014	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
25/06/2015	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
19/10/2015	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41
02/05/2016	PM01	SDM "A" MULTIPOINT CALIBRATION OMD-41

Liddell

Liddell perform routine 6 monthly, multipoint calibrations on opacity monitors. The calibration and maintenance is scheduled using a SAP system. Calibrations are performed by external contractors, various companies were used over the period 2011-2016, the most current service reports were completed by Phoenix Instruments. PDF copies of maintenance records are retained on file.

- opacity monitor filter change – every 6 months
- opacity monitor lens cleaning - monthly
- opacity monitors span cal. check – every 6 months
- opacity monitor checks – every quarter (4 per year)

Vales Point

Delta utilises a Work-order Management System (WMS) to plan, track and complete routine and breakdown maintenance at Vales Point. A summary of the completed work orders was provided for the opacity monitors.

Calibration and routine maintenance of the Durag CEMS system is completed internally by Delta staff. The calibration program has included:

- Six (6) monthly multipoint calibration; and
- Comparison of dust burden calculation from opacity readings with physical (isokinetic) test results for the same periods.

Eraring

Eraring use a work order database to schedule ongoing routine maintenance and record monitor faults Opacity monitor inspections and maintenance is performed in accordance with Standard Operating Procedure (SOP) P049 - *Opacity Monitor Maintenance Routine.* Work is undertaken by Origin Energy technicians. Completed inspection reports are scanned, and saved as in PDF format.

3) Gases - NOx and SO_2

To investigate the representativeness of periodic and continuous NOx and SO_2 sampling the following was considered:

- Environment Protection Licence (EPL) requirements
- Continuous Emission Monitoring Systems (CEMS) equipment
- Stack test results compared to Continuous Emission Monitoring (CEM) data

3.1. Environment Protection Licence requirements

With the exception of Mount Piper, each of the power stations are required to continuously monitor SO_2 and NOx. The continuous measurement of NOx and SO_2 must be performed in accordance with NSW Approved Methods Sampling.

The approved test method is CEM-2. The reference method is United States Environmental Protection Agency (USEPA) Performance Specification 2 (PS-2). PS-2 is used for evaluating the acceptability of SO_2 and NOx continuous emission monitoring systems (CEMS) at the time of installation or soon after. The licensee has a responsibility to calibrate, maintain, and operate installed CEMS properly.

NSW EPA does not currently have published guidance for operating and maintaining CEMS. As such, each operator has adopted their own approach for demonstrating proper and efficient operation of monitoring systems.

Tables 6 and 7 provide a summary of monitoring frequency, sampling methods and units of measure prescribed by the power stations EPLs for monitoring emissions of NOx and SO_2.

Table 6: NSW Power Station EPL required SO_2 and NOx monitoring frequency.

Pollutant	Sampling Frequency	Bayswater	Eraring	Liddell	Mount Piper	Vales Point
Nitrogen Oxides (NOx)	Periodic	Yearly [1]	-	Yearly	Quarterly	-
	Continuous	Boiler 1	All Boilers	All Boilers		All Boilers
Sulfur dioxide (SO_2)	Periodic	Yearly [1]	-	Yearly	Quarterly	-
	Continuous	Boiler 1	All Boilers	All Boilers		All Boilers

1. *Yearly sampling on Bayswater boilers 2,3 and 4.*

Table 7: NSW Power Station EPL SO_2 and NOx monitoring requirements.

Station	Pollutant	Frequency	Sampling Method	Units of Measure
Bayswater Power Station	Nitrogen Oxides (NOx)	Continuous	CEM-2	mg/m^3
		Periodic	TM-11	mg/m^3
	Sulfur Dioxide (SO_2)	Continuous	CEM-2	mg/m^3
		Periodic	TM-4	mg/m^3
Eraring Power Station	Nitrogen Oxides (NOx)	Continuous	CEM-2	mg/m^3
		Periodic	-	-
	Sulfur Dioxide (SO_2)	Continuous	CEM-2	mg/m^3
		Periodic	-	-
Liddell Power Station	Nitrogen Oxides (NOx)	Continuous	CEM-2	mg/m^3
		Periodic	TM-11	mg/m^3
	Sulfur Dioxide (SO_2)	Continuous	CEM-2	mg/m^3
		Periodic	TM-4	mg/m^3
Mount Piper Power Station	Nitrogen Oxides (NOx)	Continuous	-	-
		Periodic	TM-11	mg/m^3
	Sulfur Dioxide (SO_2)	Continuous	-	-
		Periodic	TM-4	mg/m^3
Vales Point Power Station	Nitrogen Oxides (NOx)	Continuous	In line instrumentation	mg/m^3
		Periodic	-	-
	Sulfur Dioxide (SO_2)	Continuous	In line instrumentation	ppm
		Periodic	-	-

3.2. Gases CEMS Equipment

Table 8 lists the current analyser equipment installed at each station.

Table 8: Gases CEM monitoring equipment installed at power stations.

Station	No. Monitors	Installation date	Manufacturer/ Model type	Monitor Type
Bayswater	4	2002 and 2005	2 x SICK GM31 SO_2, NOx.	In-situ, UV - Differential Optical Absorption Spectroscopy (DOAS)
		December 2014	2 x SICK GM32 SO_2, NOx.	In-situ, UV - Differential Optical Absorption Spectroscopy (DOAS)
Liddell	4	2003 - 2004	Procal Analytics - P200	Infra-Red (IR) detector
Mount Piper	No NOx or SO_2 CEMS			
Eraring	4	2002	Ecotech EC9850 SO_2 Analyser	fluorescence spectroscopy
	8	2013[1]	Ecotech EC9841 NOx Analyser	chemiluminescence detection
Vales Point	4	2012	Procal Analytics - P2000	Infra Red (IR) detector

1: Exact installation date could not be determined from the information provided under s191 notice. Data was sourced from the NPI website.

The monitors are installed on each unit in large flue gas ducts, between ID fans and the stack. From Table 8, the age of the current monitors, from date of installation, ranges from 3 to 15 years old. Monitors installed before 2005 may be considered to be approaching end-of-life.

3.3. Monitor Calibration and Maintenance

As per the Approved Methods Sampling, during the installation of a CEMS system, a Relative Accuracy Audit (RAA) should be conducted.

A best practice approach, for the ongoing evaluation of CEMS, should include well defined, rigorous quality assurance procedures coupled with regular Relative Accuracy Audits (RAAs). *Relative Accuracy (RA)* means the absolute mean difference between the gas concentration or emission rate determined by the CEMS and the value determined by the discrete reference method (RM) sampling.

Vales Point provided evidence of CEMS Relative Accuracy Audit conducted in 2012 on SO_2 and NOx monitors installed on Units 5A, 5B, 6A and 6B. Relative Accuracy Audit records were not provided by Bayswater, Liddell or Eraring power stations.

NSW regulation requires power stations to operate plant and equipment in a proper and efficient manner. Proper and efficient operation of the installed CEMS was demonstrated by the power stations based on the following:

- maintenance records
- calibration records
- equipment fault logs
- equipment manuals
- standard operating procedures

A brief overview of the schedules and record keeping is provided below.

Bayswater

For the installed GM31 and GM32 SO_2/NOx monitors at Bayswater Power Station, annual service and linearity checks are performed by Sick Pty Ltd, as per a service agreement with Bayswater. Filter maintenance is performed every 6 months. Maintenance records are logged using a database, and PDF and excel copies of records are retained on file. Figures 13 and 14 are clips taken from the maintenance database.

Figure 13: Bayswater SAP purchase history for CEM servicing and linearity checks.

Purchasing Document	Document Date	Material	Short Text	Order Quantity	Plant	Order Unit	Name of Vendor
4500266807	22/01/2014		Commission SOX/NOX and HF	1.000	BAYS	PU	102218 SICK PTY LTD
4500266519	17/01/2014		Service Agreement for Bayswater SICK EMS	1.000	BAYS	PU	102218 SICK PTY LTD
4500258782	16/08/2013		GM700-0211	1	BAYS	EA	102218 SICK PTY LTD
4500258782	16/08/2013		GMP-700-1342	1	BAYS	EA	102218 SICK PTY LTD
4500248735	21/01/2013		BW 1B GM31 onsite repairs by SICK:	1.000	BAYS	PU	102218 SICK PTY LTD
4500246260	21/11/2012		GM31 onsite service+linearity test:	1.000	BAYS	PU	102218 SICK PTY LTD
4500222165	10/08/2011		SO2/NOx-onsite service+linearity test:	1.000	BAYS	PU	102218 SICK PTY LTD

Figure 14: Bayswater routine monitor filter maintenance schedules

Main WorkC	Assembly des	Priorit	Revision	Bas. start da	Basic fin. da	Order Typ	User stat	Description	Functional Loc.
PSTA		3		26/09/2011	26/09/2011	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
PSTA		3		26/03/2012	26/03/2012	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
PSTA		3		24/09/2012	24/09/2012	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
PSTA		3		25/03/2013	25/03/2013	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
PSTA		3		23/09/2013	23/09/2013	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
PSTA		3		24/03/2014	24/03/2014	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
PSTA		3		22/09/2014	22/09/2014	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
T1TECHA		3		23/03/2015	23/03/2015	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
T1TECHA		3		15/08/2015	15/08/2015	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_
T1TECHA		3		03/04/2016	03/04/2016	PM01	PLND	Nox Sox Analyser Filter Routine	B.1.BLR_.GAS_.INST_

Liddell

Calibrations on NOx and SO_2 monitors are conducted every 6 months by an external contractor – Phoenix Instrumentation. Following a full-service, a calibration certificate is provided to Liddell to confirm the monitor has completed a successful calibration. The PDF records from 2011-2016 have been provided to EPA, and form part of this review.

Each instrument carries out a zero check every 6 hours. During a zero check it pressurizes the unit with zero instrument air and checks / resets the zero point. The units do not check span automatically, only when challenged manually with calibration, typically during a service. Figure 15 is a clip from Liddell's maintenance scheduling system.

Figure 15: Example data from Liddell's maintenance scheduling system.

Scheduling overview list form: Maintenance Scheduling Overview List

Maintenance item   Maintenance plans

S	Order	Maintenance item description	Plnd. date	Start date	Completion	Functional Location	FunctLocDescrip.	MntItem	MntPlan	Group
	1878513	SOx/NOx Monitor 6MTH Tech Serv	21.05.2015	21.05.2015	04.01.2017	L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
	1913630	SOx/NOx Monitor 6MTH Tech Serv	17.11.2015	31.12.2015		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
	1946222	SOx/NOx Monitor 6MTH Tech Serv	15.05.2016	15.05.2016	26.05.2016	L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
	1978608	SOx/NOx Monitor 6MTH Tech Serv	11.11.2016	11.11.2016		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
	2010935	SOx/NOx Monitor 6MTH Tech Serv	10.05.2017	10.05.2017		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
		SOx/NOx Monitor 6MTH Tech Serv	06.11.2017	06.11.2017		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
		SOx/NOx Monitor 6MTH Tech Serv	05.05.2018	05.05.2018		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
		SOx/NOx Monitor 6MTH Tech Serv	01.11.2018	01.11.2018		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST
		SOx/NOx Monitor 6MTH Tech Serv	30.04.2019	30.04.2019		L.CS.DCS_.INSTR.CHEM...	SOX/NOX Instrumentati...	18096	16142	LBINST

Vales Point

Calibration and routine maintenance of the Procal CEMS system is completed by an external (non-Delta) contractor. Six (6) monthly calibrations and scheduled services were completed Nov 2012 – Feb 2017. Note that annual calibrations were scheduled in 2014 but have been completed 6-monthly at all other times.

Relative accuracy test audit (RATA) was completed on the four CEMS units to ensure compliance with USEPA Performance Specification 2 (2000). An excerpt from the AECOM report is provided in Figure 16.

Figure 16: Excerpt from AECOM report #122056 - RATA testing of Continuous Emission Monitoring Systems Delta Electricity Vales Point Power Station (August 2012).

RATA Testing of Continuous Emission Monitoring Systems
Delta Electricity Vales Point Power Station

1.0 Introduction

AECOM was appointed by Phoenix Instrumentation to conduct a Relative Accuracy Test Audit (RATA) on four new Continuous Emission Monitoring Systems (CEMS)[1] for Delta Electricity at Vales Point Power Station, to ensure compliance with *USEPA Performance Specification 2 (2000) – Specifications and Test Procedures for SO_2 and NO_x Continuous Emission Monitoring Systems in Stationary Sources, Section 13.2.*

The approved Reference Methods (RM) selected for the RATA were:

- Nitrogen Oxides (NOx) - US EPA Method 7(E); and
- Sulphur Dioxide (SO_2) - US EPA Method 6(C).

Testing was conducted on 24, 25, 31 July 2012, and 1 August 2012, to determine the Relative Accuracy (RA) of the SO_2 and NO_x results for the CEMS installed on:

- Unit 5 Duct A;
- Unit 5 Duct B;
- Unit 6 Duct A; and
- Unit 6 Duct B.

Testing was carried out in accordance with *USEPA Performance Specification 2 (2000), Section 8.4* – Relative Accuracy Test Procedure, with 12 tests carried out at each location.

Delta utilises a Workorder Management System (WMS) to plan, track and complete routine and breakdown maintenance at Vales Point. Table 9 provides a summary of the Procal CEMS maintenance and service record 2012-2017.

Table 9: Vales point - Procal Service and Maintenance History

March 2013	Repair O_2 Probes
May 2013	Procal Standard Service
September 2013	Servicing of sensors, replacing filters & heater and equipment assessment
November 2013	Procal Standard Service
February 2014	NOx and SOx calibration and reading confirmation
July 2014	Procal Process Mirror, Donaldson Auto Condensate Drain and Novatech reference air pump replacement
July 2014	Procal Standard Service
August 2014	Procal heater repair
September 2014	Novatech O_2 probes service, filter replacement and repair
October 2014	CEMS output card replacement
October 2014	Novatech O_2 Probe repair
December 2014	NOx reading check
February 2015	Procal Standard Service
August 2015	Procal Standard Service
October 2015	Novatech O_2 Probes repairs
April 2016	Novatech O_2 Probes Repairs
May 2016	Procal heater service and SOx/NOx analyser check
August 2016	Procal Standard Service, Replacement of Procal P200 Mirror and sample/process lens, and replacement of MP24 reference air pump.
November 2016	Repair and Service of Novatech O_2 Probes
February 2017	Procal Standard Service
March 2017	Novatech O_2 probe service and repair

Eraring

CEMS instrumentation is managed through an external contractor, through which the following monthly service activities are undertaken:

- Mechanical overhauls of pumps and compressors
- Inspection of dynamic equipment
- Cleaning of probes
- Single and Multipoint calibrations
- Service of gas and pneumatic systems
- Telemetry checks
- Replacement of scrubbing materials.

- Maintenance is carried out in accordance with a set of Standard Operating Procedures (SOPs)
- Span and Zero checks are completed daily and logged into an excel tracking sheet. Spreadsheets from 2011-2016 were provided by Eraring for this review.
- On a monthly basis, technicians undertake single point calibrations for CEMS instrumentation.
- Every 6 months, a full linearity multi point calibration is undertaken.

3.4. Representativeness of Gases CEMS

To help investigate the representativeness of continuous SO_2 and NOx monitoring, hourly CEMS data was compared with periodic emission test results for the corresponding time period. Periodic test measurements are typically conducted over a 60-minute period. The mean difference between the gas concentration determined by the CEMS and the value determined by the nearest reference method test (RM) was calculated.

The EPA used three categories to group the results of the data analysis.

i. <80% - means periodic tests measured concentrations less than 80% (100-20) of CEMS.
ii. 100% (±20%) - means periodic tests measured concentrations between 80% and 120% of the CEMS.
iii. >120% - means periodic tests measured concentrations greater than 120% (100+20) of CEMS.

The 20% criteria was adopted based on acceptance criteria as per Performance Specification 2 (PS-2)[3]. A summary of the results is provided in Table 10.

Table 10: Time Paired CEMS concentrations of SO_2(ppm) and NOx (ppm) and reported stack test results (2011-2016)

	Sulfur Dioxide (SO_2)			Nitrogen Oxides (NO_2)		
	Test <80% of CEMS	Test ± 20% of CEMS	Test >120% of CEMS	Test <80% of CEMS	Test ± 20% of CEMS	Test > 120% of CEMS
Bayswater	0%	100%	0%	0%	75%	25%
Liddell	11%	84%	5%	5%	67%	28%
Vales Point	0%	33%	67%	25%	67%	8%
Eraring[#]	5%	28%	67%	12%	13%	75%
Average	4%	35%	61%	34%	55%	11%

 # Eraring, stack test results for SO_2 are reported as an SO_3 equivalent. When the periodic test results were converted to an SO_2 equivalent concentration (based on molecular weight), the difference was reduced.

3.5. NOx and SO_2 Stack Test and CEMS Monthly Comparison

Periodic testing at Bayswater, Eraring, Vales Point and Liddell, is typically conducted once per year/per boiler. To investigate periodic testing is representative of longer term emission trends, the measured concentrations of SO_2 and NOx from RM stack tests (typically 60 minute samples) were compared with corresponding CEMS measurements (monthly average from hourly measurements). The comparison is presented in Table 11 over page.

[3] *The method applied by in the review to calculate the measurement difference is not intended to determine measurement accuracy or a correlation curve in accordance with PS-2. PS-2 has specific requirements including numerous time paired test runs.*

Table 11 shows that the measured concentrations of SO_2 and NOx, from periodic tests, tended to be greater than the CEMS monthly average. This is likely contributed to due to periodic testing typically being conducted when boiler loads are above average - as discussed in section 1.2. Samples collected under high boiler load conditions are expected to be representative of peak emissions.

Table 11 – Monthly average CEM concentrations of SO_2(ppm) and NOx (ppm) compared with reported stack test results

	Sulfur Dioxide (SO_2)			Nitrogen Oxides (NO_2)		
	Test <80% of CEMS	Test ± 20% of CEMS	Test >120% of CEMS	Test <80% of CEMS	Test ± 20% of CEMS	Test >120% of CEMS
Bayswater	0%	100%	0%	0%	67%	33%
Liddell	16%	42%	42%	0%	26%	74%
Vales Point	0%	0%	100%	29%	14%	57%
Eraring	10%	20%	70%	12%	13%	75%
Average	6%	41%	53%	10%	30%	60%

Periodic test results were also graphed in comparison with SO_2 and NOx CEMS trends. A sample of the typical graphs prepared and inspected for the review is presented in Figures 17 and 18. Periodic samples are indicated by the red dots. The graphs indicate that periodic testing was conducted at times considered broadly representative of average CEMS (emission) trends. Importantly, the trends do not indicate that sampling was conducted when emissions of SO_2 and NOx were lower than average.

Although some of the periodic tests (red dots) do not match exactly with the theoretical CEMS trend line, the measured results are within a reasonable range of each other – when measurement uncertainty, difference in measurement principal and averaging periods are taken into consideration. Importantly, both measurement types indicate the in-stack concentrations are considerably below the reporting limit of 600ppm.

Figures 19 and 20 are examples of periodic stack tests reporting concentrations greater than 120% of the concentrations measured by the CEMS. Retrospectively investigating a discrepancy between measured values makes it difficult to identify the cause of the difference. Improved reporting and quality assurance/ quality control procedures should identify inconsistencies between periodic and CEMS measurement values earlier. Improved QA/QC procedures could inform best practice management and maintenance practices and improve the representativeness of continuous monitoring.

Figure 21 shows that, the manual stack samples, indicated by the red dots, appear to be representative of the NOx concentrations at the time of sampling (accounting for boiler outages).

Figure 17: Liddell Unit 1_Daily average of CEMS SO_2 (ppm) and monitored SO_2 (ppm)

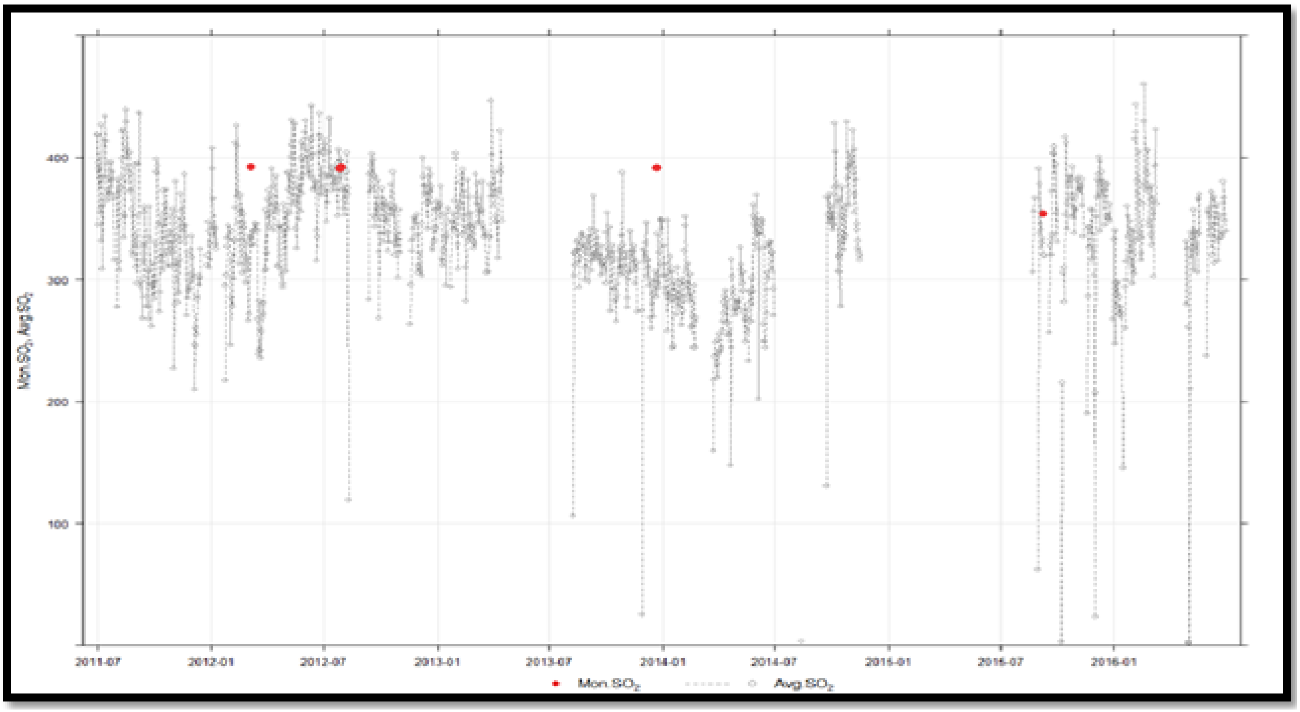


Figure 18: Bayswater Unit 1_Daily average of CEMS NOx (ppm) and monitored NOx (ppm).

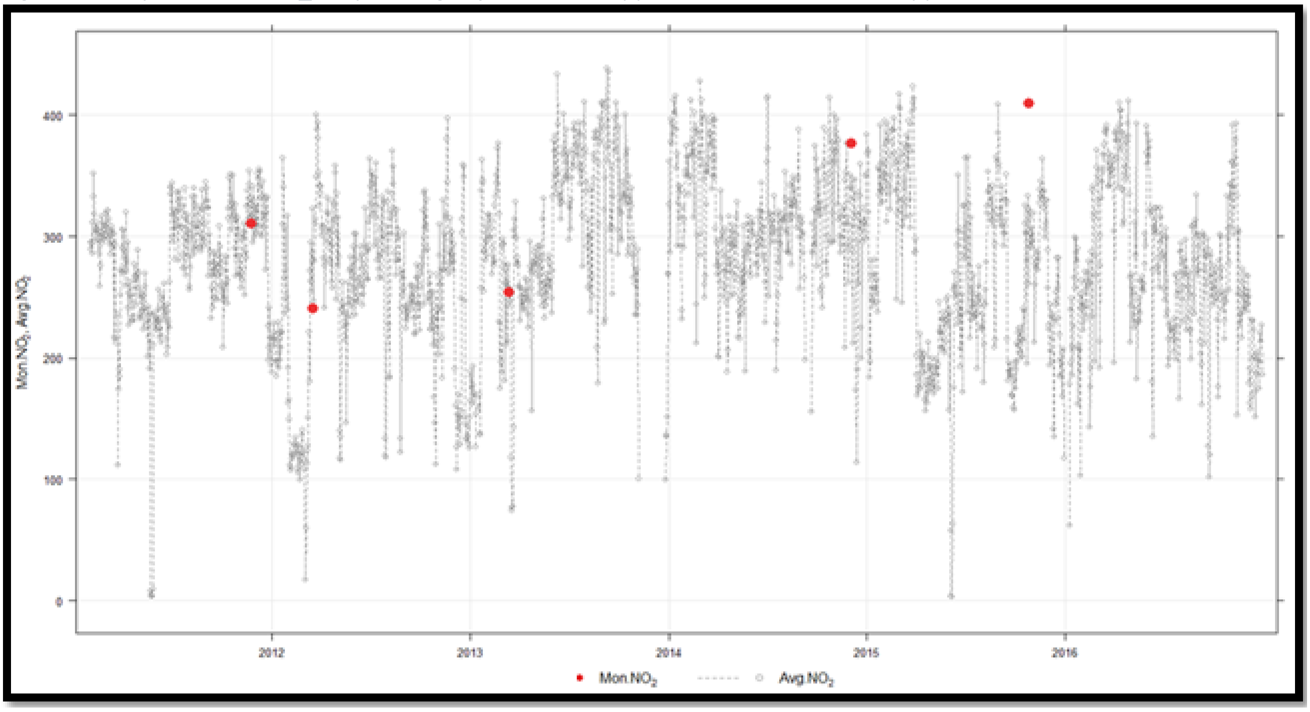


Figure 19: Eraring PS, Unit 4_Daily average of CEMS SO_2 (ppm) and monitored SO_2 (ppm). Points circled in purple are periodic sample results greater than 120% of the CEMS trend line.

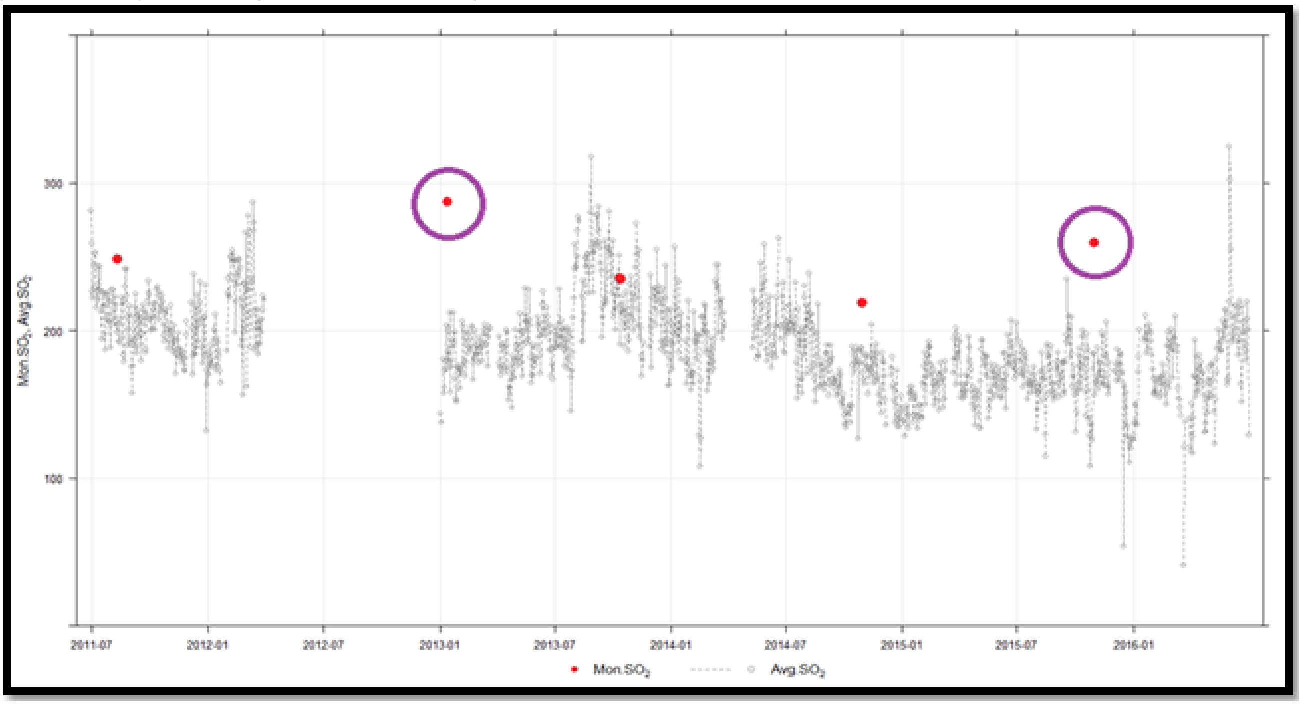


Figure 20: Vales Point PS Unit 6 Duct A and B_ Daily average of CEMS SO_2 (ppm) and monitored SO_2 (ppm)

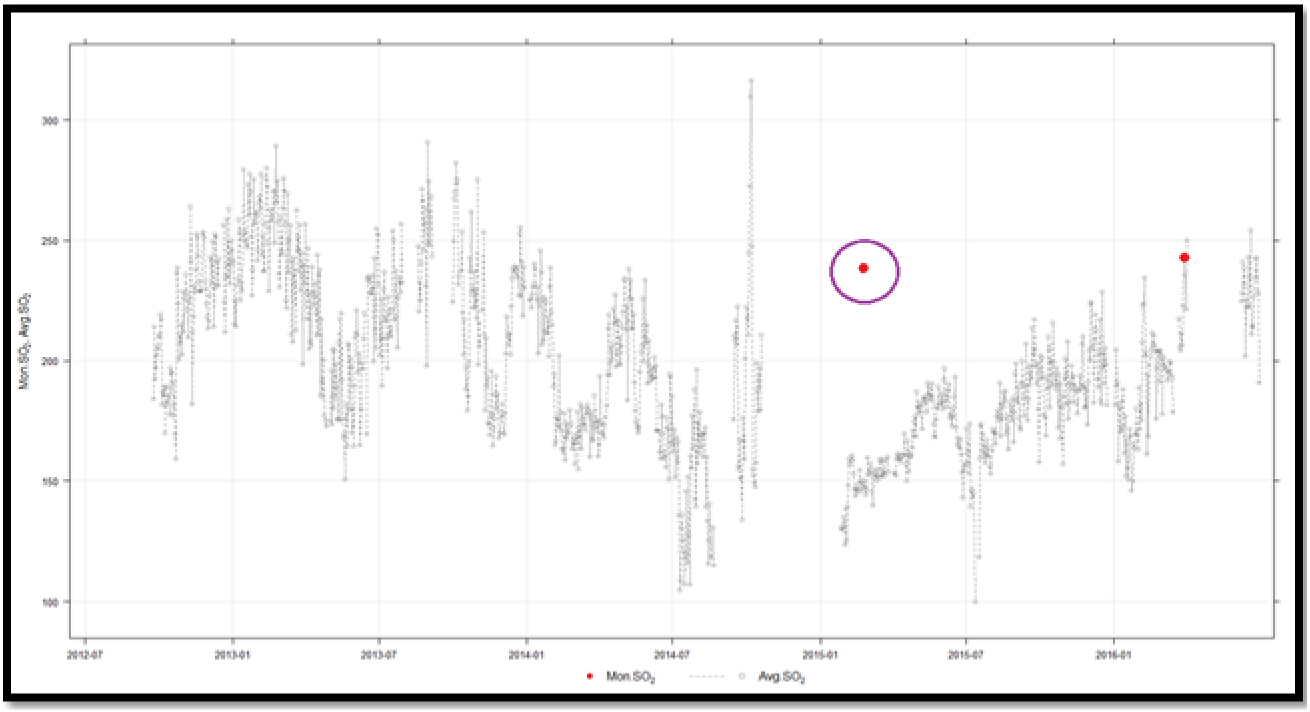
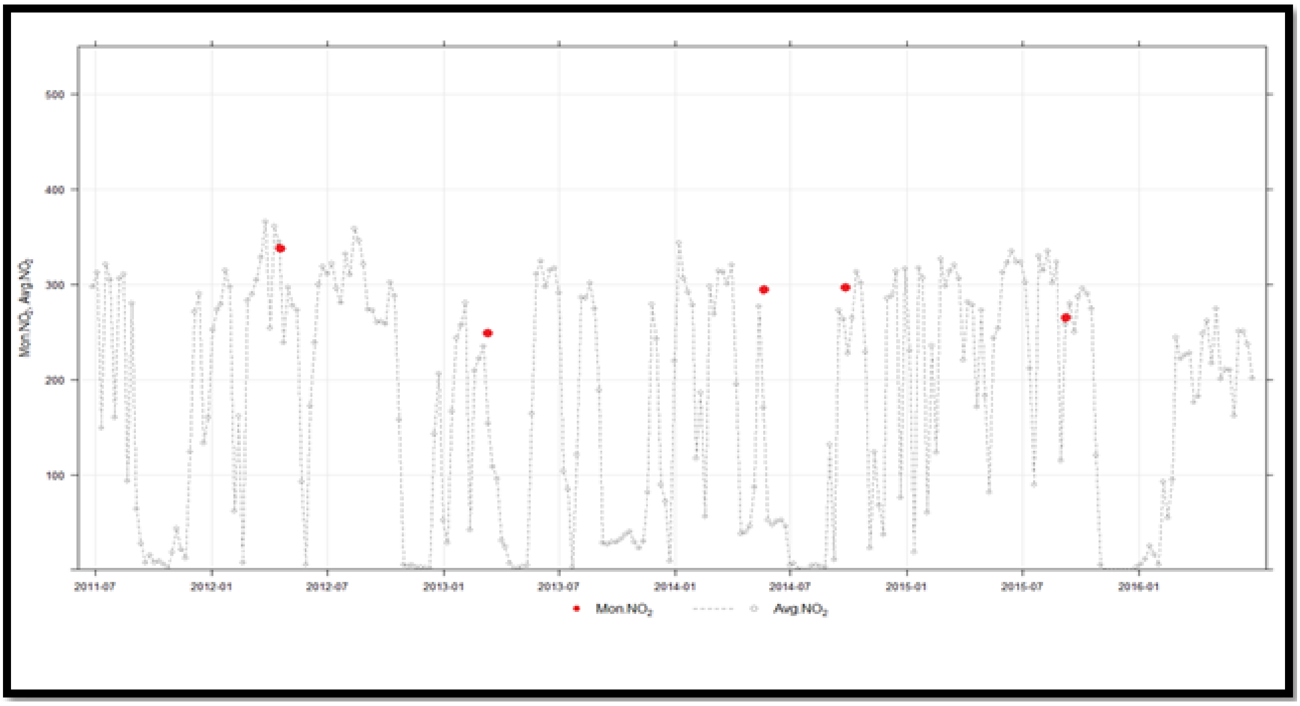


Figure 21: Liddell PS Unit 2_Weekly average of CEMS NO_x (ppm) and monitored NO_x (ppm)



3.6. Bayswater SO_2 Review

Bayswater power station is comprised of four boiler units. The EPL for Bayswater includes a requirement to continuously monitor SO_2 concentrations on Unit 1 exhaust only[4]. To determine if the monitoring being conducted on Unit 1 boiler exhaust is representative of all boilers, the reviewed compared periodic SO_2 sampling across all 4 boiler exhausts, for the period 2011-2016.

Table 12 provides a summary of yearly average SO_2 concentrations. During 2013, the Unit 1 average SO_2 concentration is lower than all other boilers. For all other years (2011, 2012, 2014 and 2015) Unit 1 concentrations were similar to or greater than the average for all units.

Table 12: Summary of Bayswater Power Station SO_2 emissions (2011-2016)

Year	Average SO_2 Concentration (Unit 1 Only)	Average SO_2 Concentration (All four Units)	Average SO_2 Concentration (Units 2, 3 and 4)
2011	823	853	863
2012	1100	1025	1000
2013	970	1167	1233
2014	1000	960	947
2015	1100	950	900

Graphs were used to compare the measured SO_2 concentrations, from periodic sampling test reports, for all four boiler units for the period 2011-2016. Figures 22 and 23, plot the periodic SO_2 measurements for all four boilers for the period 2011-2016. The measurements from Unit 1 are comparable to the measurements taken from the other three boilers.

Figure 24 shows the average SO_2 concentrations across all boilers, for the 5-year period was 991 mg/m^3 (corrected to 12% CO_2). The average concentrations ranged from 940 – 1082 mg/m^3. The average SO_2 concentration for Unit 1 was 998 mg/m^3. Of the four outlets monitored, Unit 1 was nearest to the average of all four ducts for the 5-year period.

[4] *In 2017 Bayswater installed SO_2 CEMS on all units.*

Figure 22: Stack test SO_2 concentrations for Bayswater power station (2011-2016)

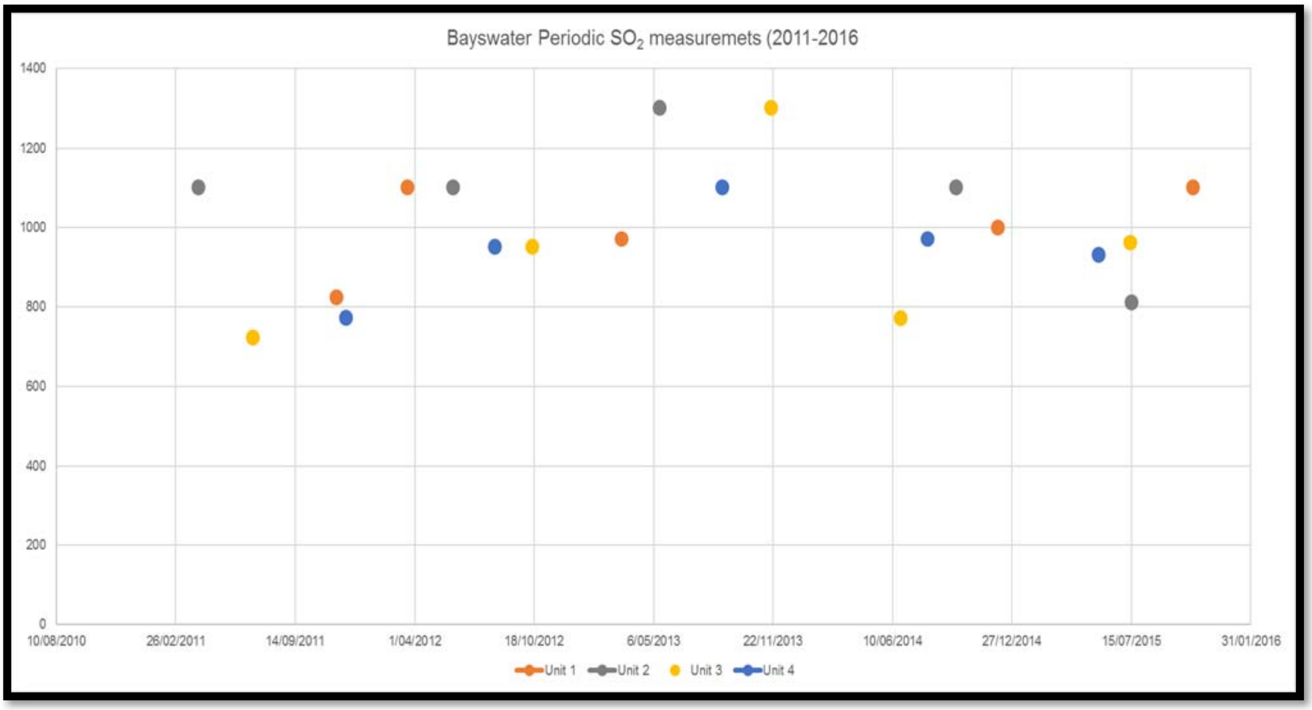


Figure 23: Bayswater periodic SO_2 measurements - compared by year (2011-2016).

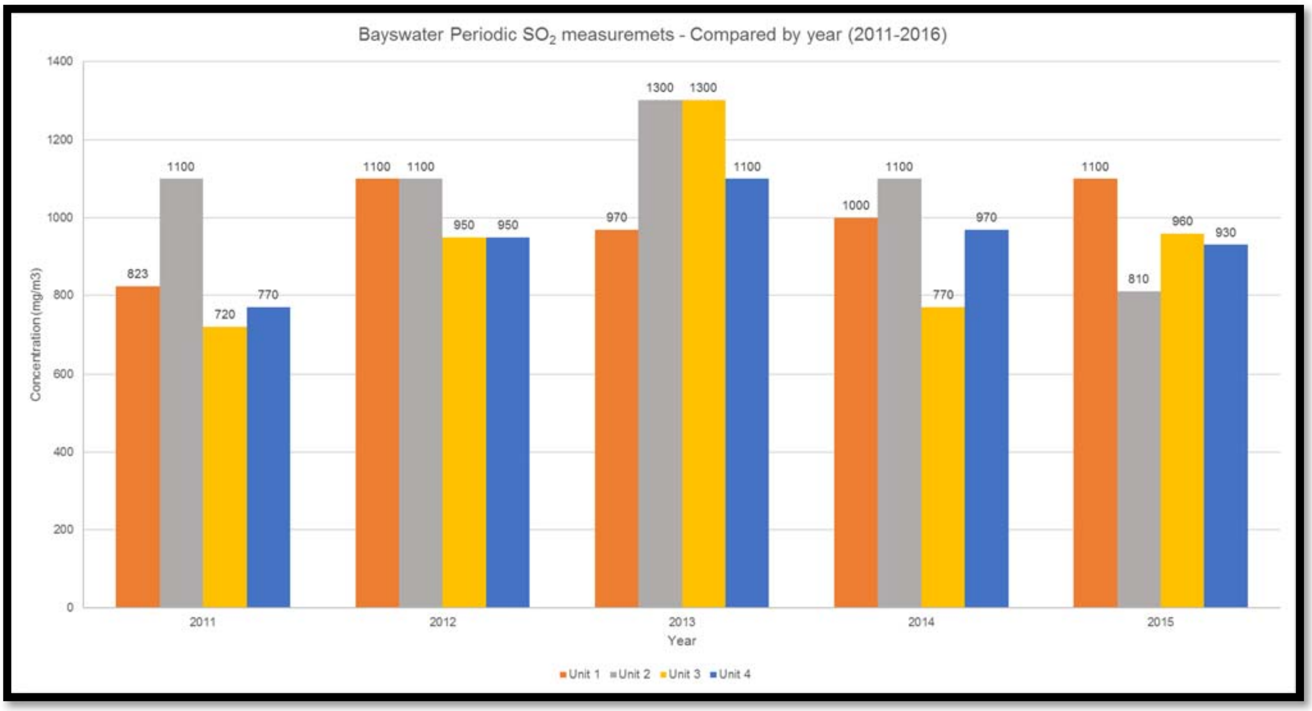


Figure 24: Bayswater periodic SO2 measurements - 5 yearly average

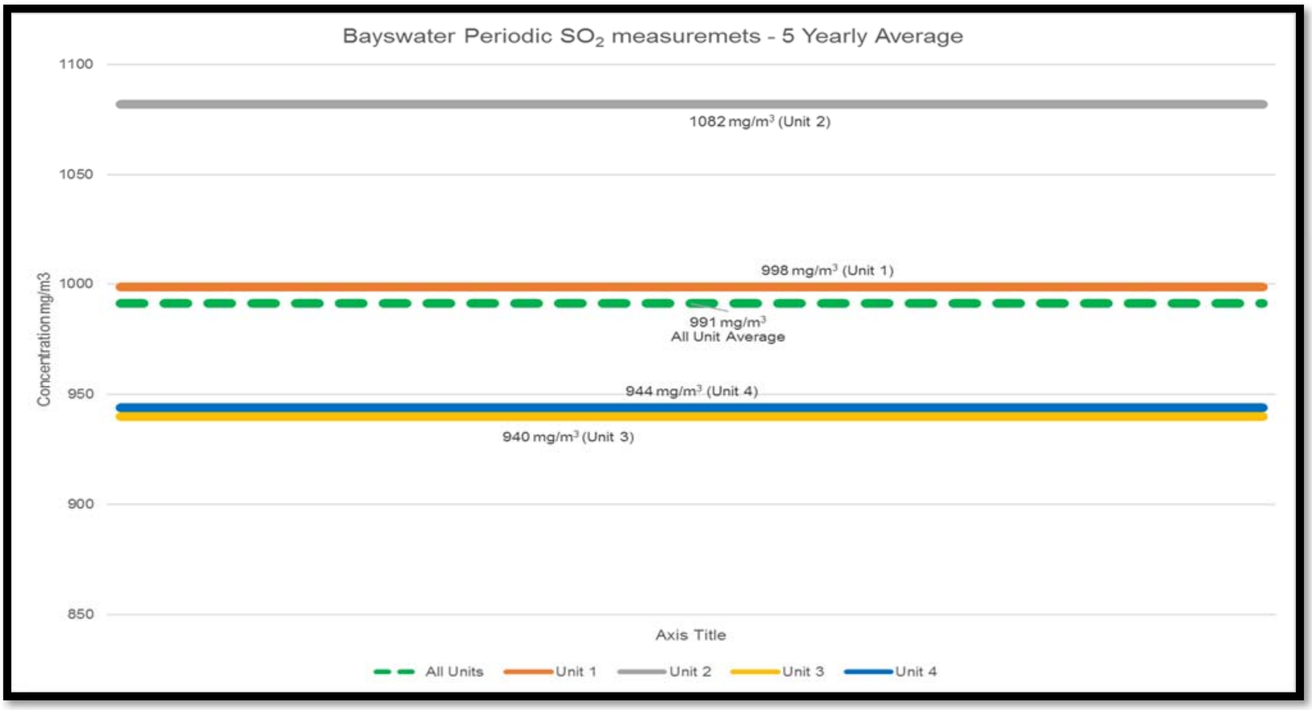


Figure 25 and Figure 26 plot Bayswater Unit 1 periodic SO_2 measurements against daily and monthly CEMs monitoring data trendlines for 2011 – 2016. The plotted sampling points generally match the CEMs SO_2 trend. There is no appreciable difference in the CEMs data trend, for the time periods when stack testing was conducted, that would indicate a significant change in process or fuel quality. It is therefore unlikely coal quality or boiler settings are being changed to lower emissions from Unit 1 boiler.

Figure: 25 - - Bayswater Unit 1 (Daily) CEMs SO_2 (ppm) and monitored (Reference Method test) SO_2 (ppm)

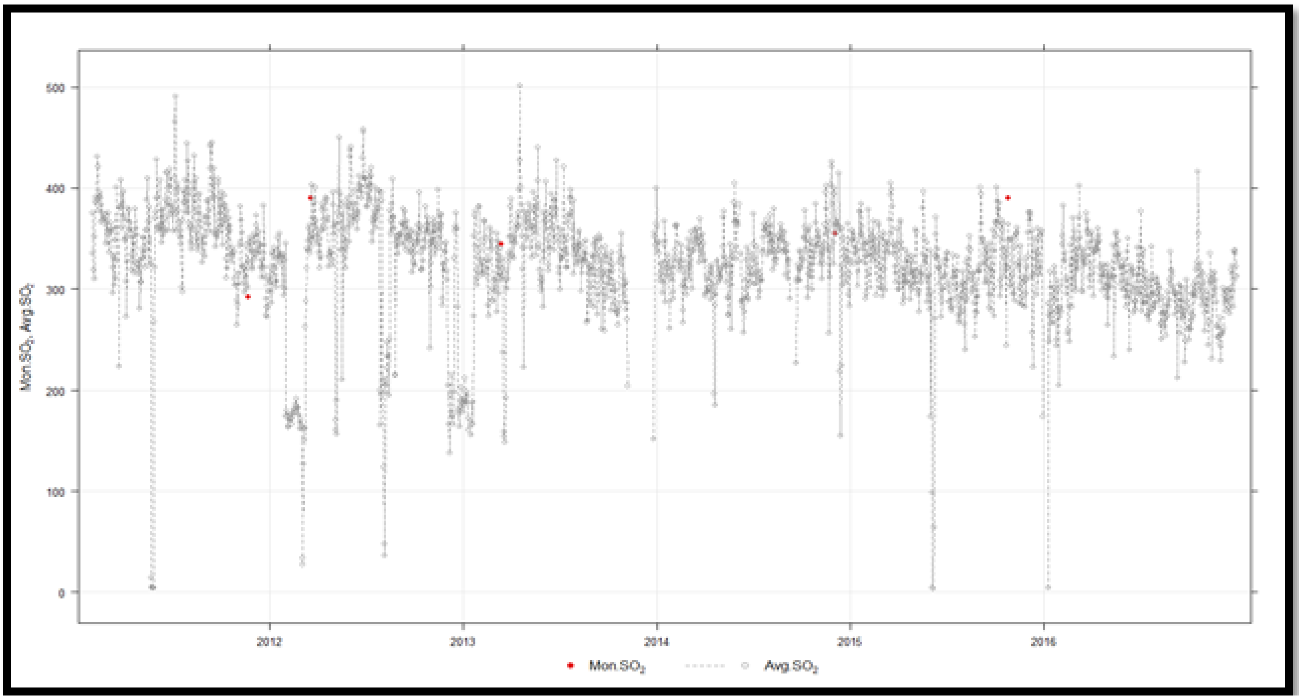
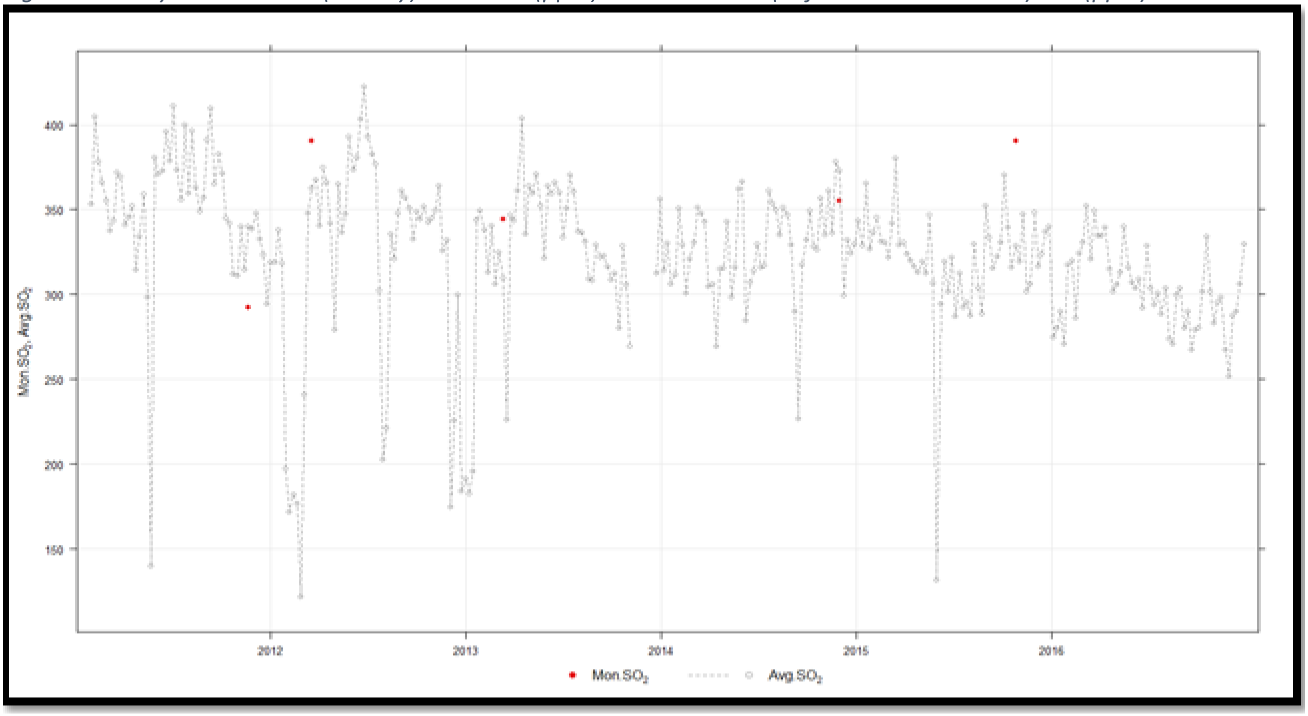


Figure: 26 - Bayswater Unit 1 (Weekly) CEMs SO_2 (ppm) and monitored (Reference Method test) SO_2 (ppm)



4) Coal Data Analysis

Overview

Fuel quality consistency was reviewed to help determine if periodic emission sampling is being conducted when emissions are considered representative of normal operations. Daily, 'as fired' coal quality data was compared for periods during stack emission testing and all other periods to identify if specific coal blends have been used for sampling periods.

Coal consistency and preparation practices

Fuel (coal) combusted by the power stations is usually sourced from near-by coal mines. Coal is delivered by train, truck or conveyor to coal handling and processing areas. It is common to have a number of coal mines supplying a single power station. To ensure consistency of fuel quality and meet regulatory requirements, regular analysis is conducted.

Coal burnt at the power stations is required to meet fuel specifications. Vales Point and Eraring have EPL conditions limiting the sulfur content of coal fuel to not exceed 0.5% by weight. The licence for Liddell requires that the sulfur content of coal as fired in the boilers must not exceed 1% by weight. The Bayswater and Mount Piper EPLs do not list any limits for sulfur in coal.

Coal may be blended to ensure consistency and to meet required specifications. Blending is usually undertaken by the supplying mine. The power stations do not use specific blending infrastructure, but coal can be blended onsite using bulk handling/earth moving equipment.

Once the coal quality meets the power stations requirements, it is usually prepared by washing, crushing and milling to produce pulverised coal fuel. The pulverised coal is then directed to the boiler and fired or sent to a storage area for later use.

Fuel quality testing regimes and responsibilities

The power stations perform fuel quality analysis in accordance with EPL requirements. Mines supplying coal are generally required to provide a certificate of analysis for each load of coal delivered. Each power station then tests the coal, just prior to being fired in the boilers.

The EPLs for Eraring and Liddell require the sampling and analysis of fuel received on the premises. The fuel analysis performed by the coal supply companies is referred to as "as supplied coal". The testing done prior to entering the boilers is referred to as "as fired/burnt"

The EPL for Liddell refers specifically to blending of coal to minimise any exceedance of SO_2 trigger value of 600 ppm. Bayswater and Mount Piper do not have specific EPL requirements for coal fuel monitoring but the review found that fuel analysis is routinely undertaken by these power stations.

Data Analysis

Figures 27 to 39, on the following pages, were used to compare the daily 'as fired' coal quality data for periods during stack emission testing with all other periods. Ash content, sulfur content and calorific value were used as identity markers to determine the variability of coal composition.

Figure 27: Bayswater Daily Coal Composition as Fired (2011-2016). The average calorific value, sulfur content and ash content are comparable comparable for testing and non-testing periods

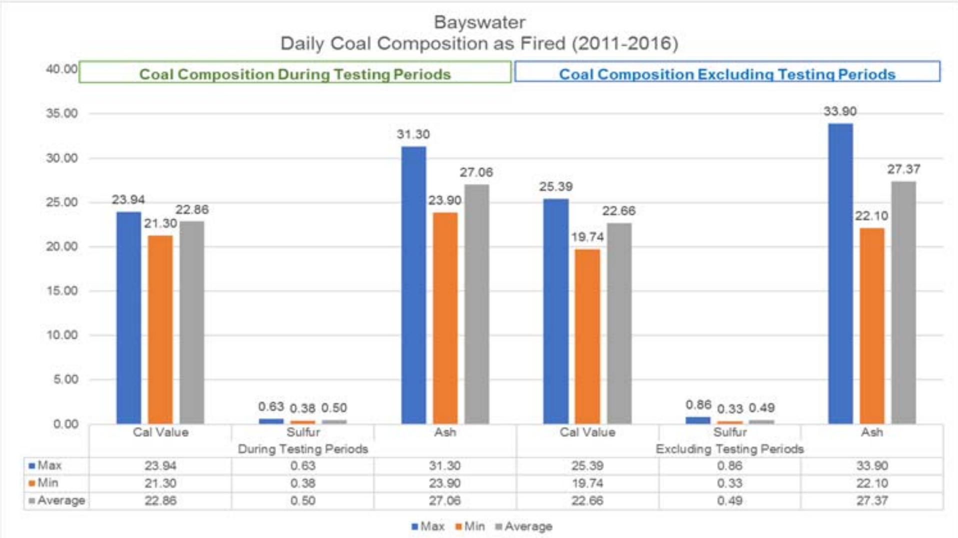


Figure 28: Bayswater Daily Coal Composition as Fired (2014) showing the average calorific value, sulfur content and ash content are comparable for testing and non-testing periods.

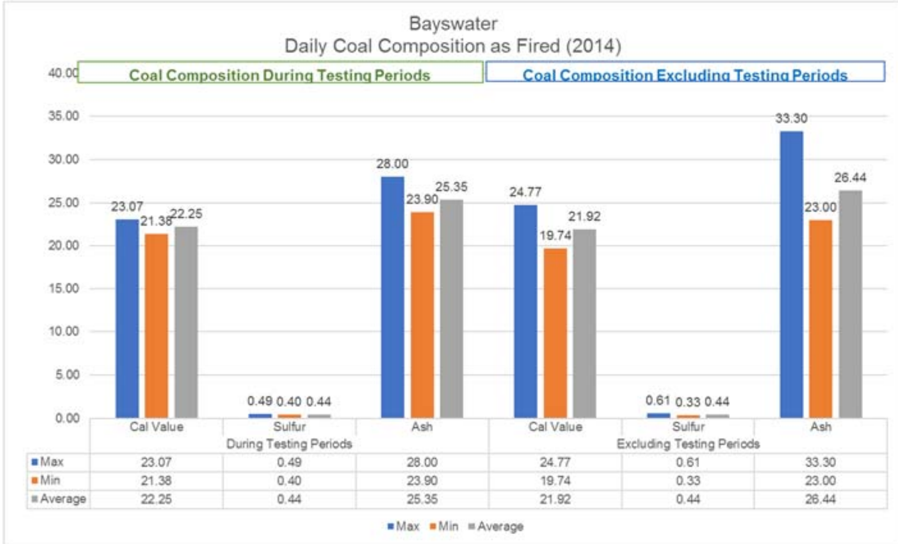


Figure 29: Bayswater Daily Coal Composition as Fired (2015) showing the average calorific value and ash content are comparable for testing and non-testing periods. Average Sulfur content during testing periods is slightly above the non-testing periods.

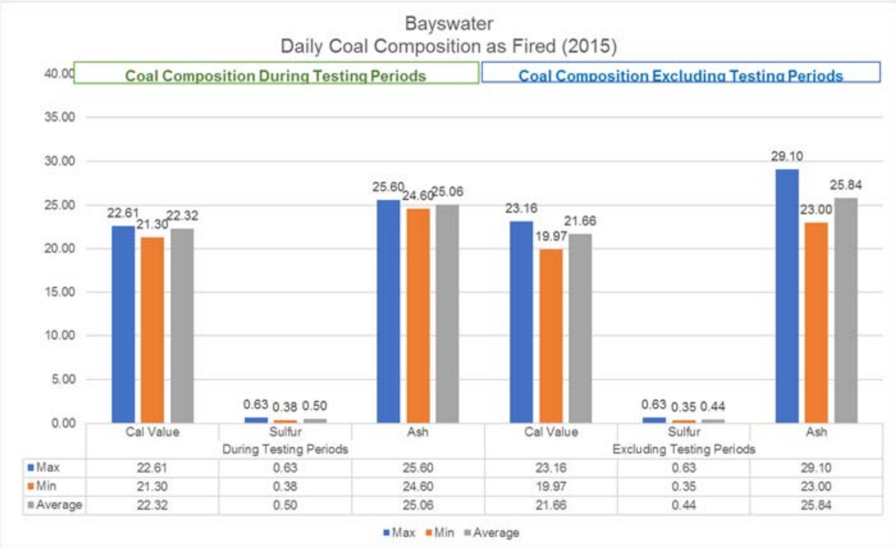


Figure 30: Vales Point Daily Coal Composition as Fired (2015) showing the average calorific value and ash content are comparable for testing and non-testing periods.

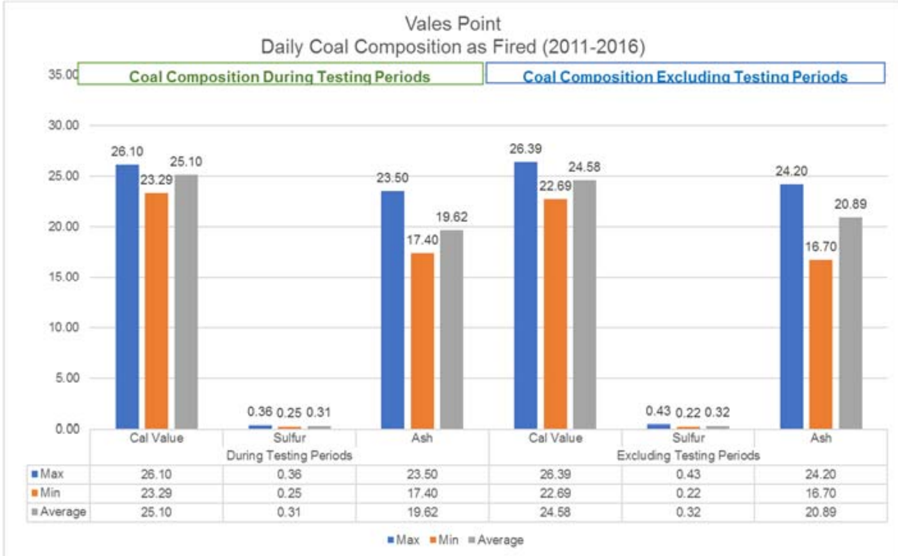
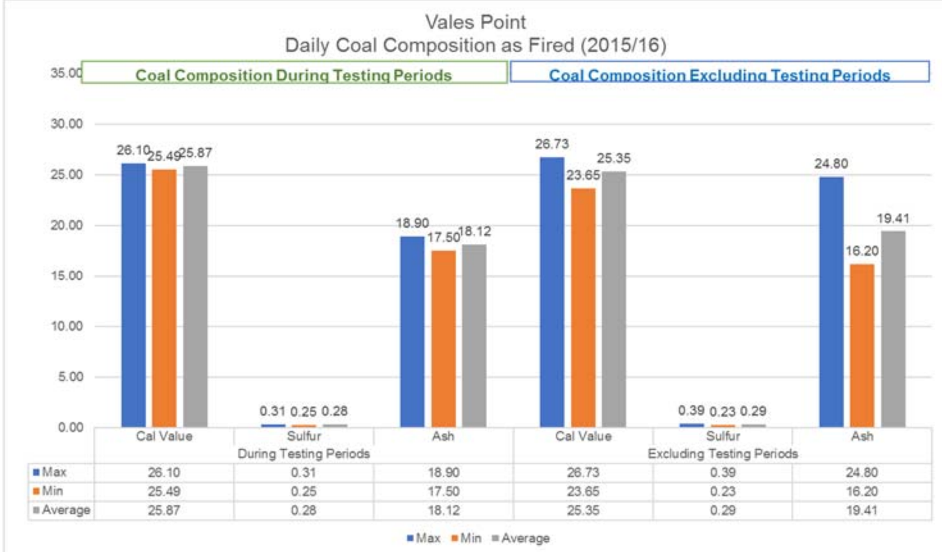


Figure 31: Vales Point Daily Coal Composition as Fired (2014/15) showing the average calorific value, sulfur and ash content are comparable for testing and non-testing periods.

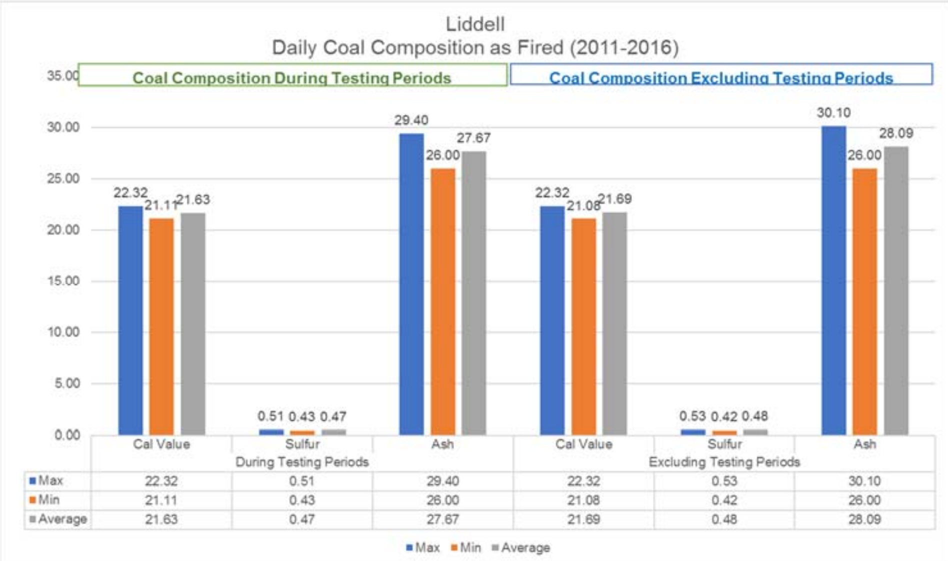
	Cal Value (During Testing Periods)	Sulfur (During Testing Periods)	Ash (During Testing Periods)	Cal Value (Excluding Testing Periods)	Sulfur (Excluding Testing Periods)	Ash (Excluding Testing Periods)
Max	25.77	0.33	20.10	26.48	0.86	22.10
Min	24.54	0.31	17.40	23.77	0.21	15.60
Average	25.35	0.32	18.54	25.20	0.32	18.98

Figure 32: Vales Point Daily Coal Composition as Fired (2015/16) showing the average calorific value and sulfur content are comparable for testing and non-testing periods. Average ash content is slightly higher for the testing periods.



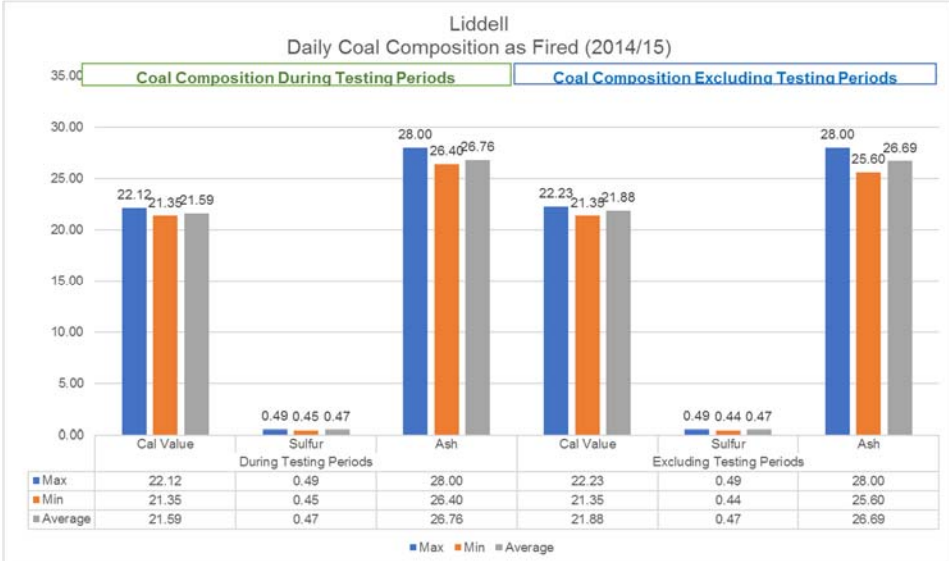
	Cal Value (During Testing Periods)	Sulfur (During Testing Periods)	Ash (During Testing Periods)	Cal Value (Excluding Testing Periods)	Sulfur (Excluding Testing Periods)	Ash (Excluding Testing Periods)
Max	26.10	0.31	18.90	26.73	0.39	24.80
Min	25.49	0.25	17.50	23.65	0.23	16.20
Average	25.87	0.28	18.12	25.35	0.29	19.41

Figure 33: Liddell Daily Coal Composition as Fired (2011-2016) showing the average calorific value, sulfur and ash content are comparable for testing and non-testing periods.



	Cal Value (During Testing Periods)	Sulfur (During Testing Periods)	Ash (During Testing Periods)	Cal Value (Excluding Testing Periods)	Sulfur (Excluding Testing Periods)	Ash (Excluding Testing Periods)
Max	22.32	0.51	29.40	22.32	0.53	30.10
Min	21.11	0.43	26.00	21.08	0.42	26.00
Average	21.63	0.47	27.67	21.69	0.48	28.09

Figure 34: Liddell Daily Coal Composition as Fired (2014/15) showing the average calorific value, sulfur and ash content are comparable for testing and non-testing periods.



	Cal Value (During Testing Periods)	Sulfur (During Testing Periods)	Ash (During Testing Periods)	Cal Value (Excluding Testing Periods)	Sulfur (Excluding Testing Periods)	Ash (Excluding Testing Periods)
Max	22.12	0.49	28.00	22.23	0.49	28.00
Min	21.35	0.45	26.40	21.35	0.44	25.60
Average	21.59	0.47	26.76	21.88	0.47	26.69

Figure 35: Liddell Daily Coal Composition as Fired (2015/16) showing the average calorific value, sulfur and ash content are comparable for testing and non-testing periods.

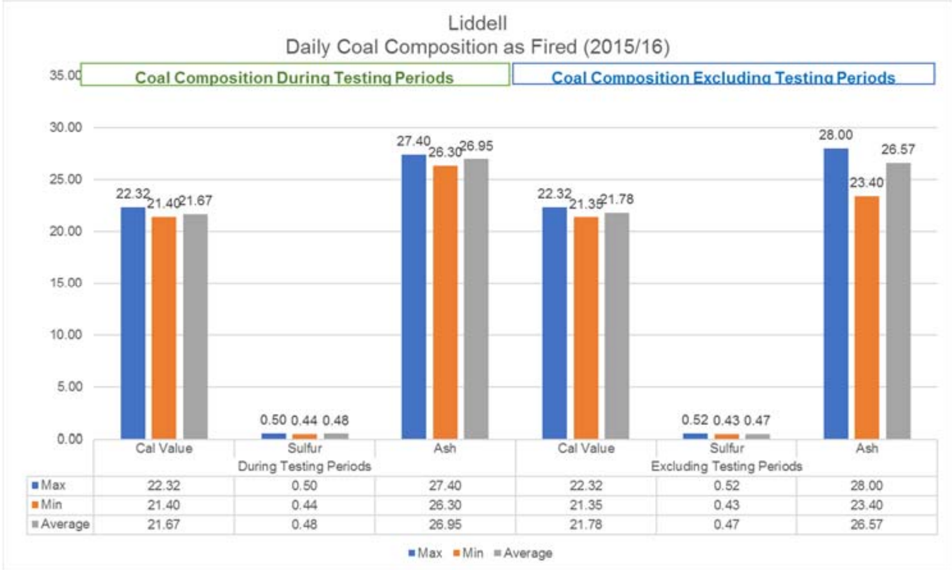


Figure 36: Mt. Piper Daily Coal Composition as Fired (2011-2016) showing the average calorific value, sulfur and ash content are comparable for testing and non-testing periods.

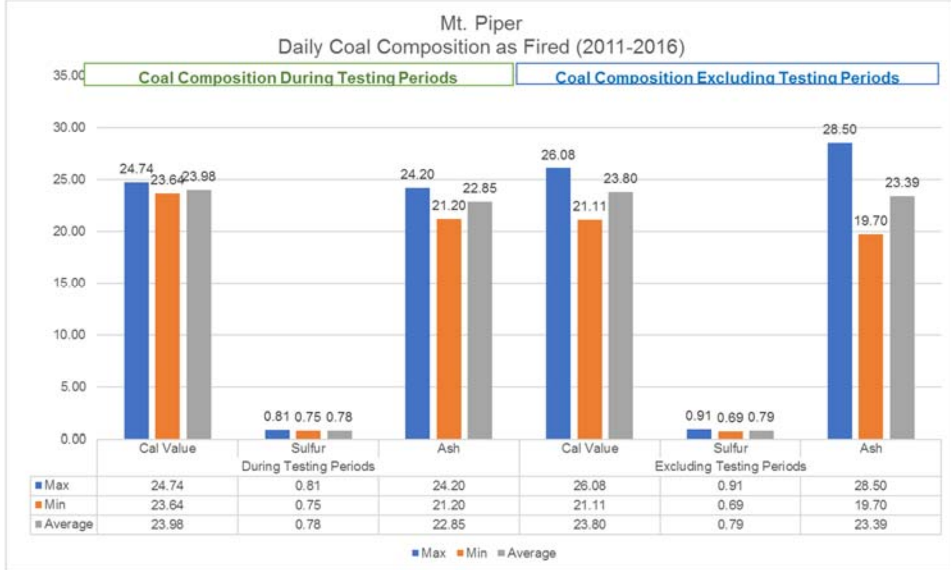


Figure 37: Mt. Piper Daily Coal Composition as Fired (2015) showing the average calorific value and ash content are comparable for testing and non-testing periods

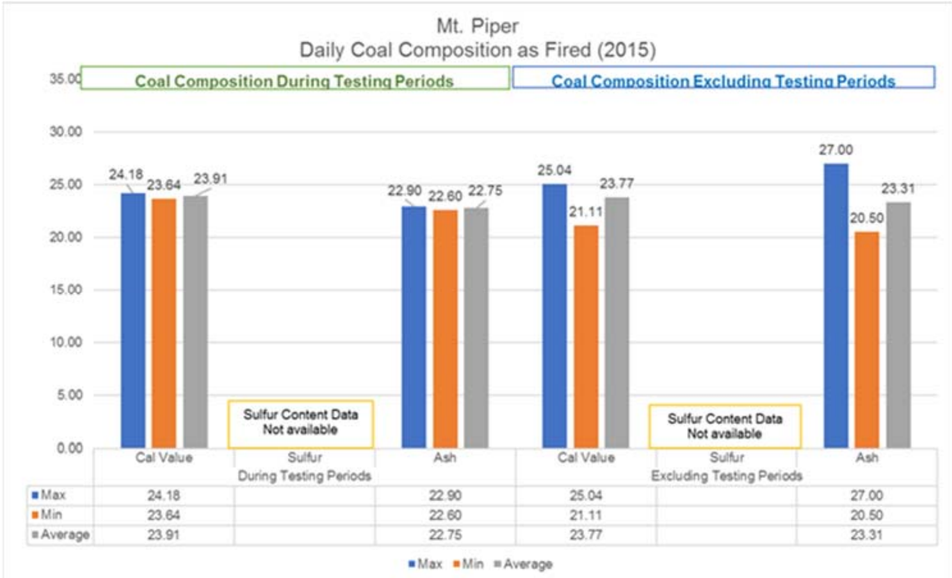


Figure 38: Mt. Piper Daily Coal Composition as Fired (2016) showing the average calorific value and ash content are comparable for testing and non-testing periods.

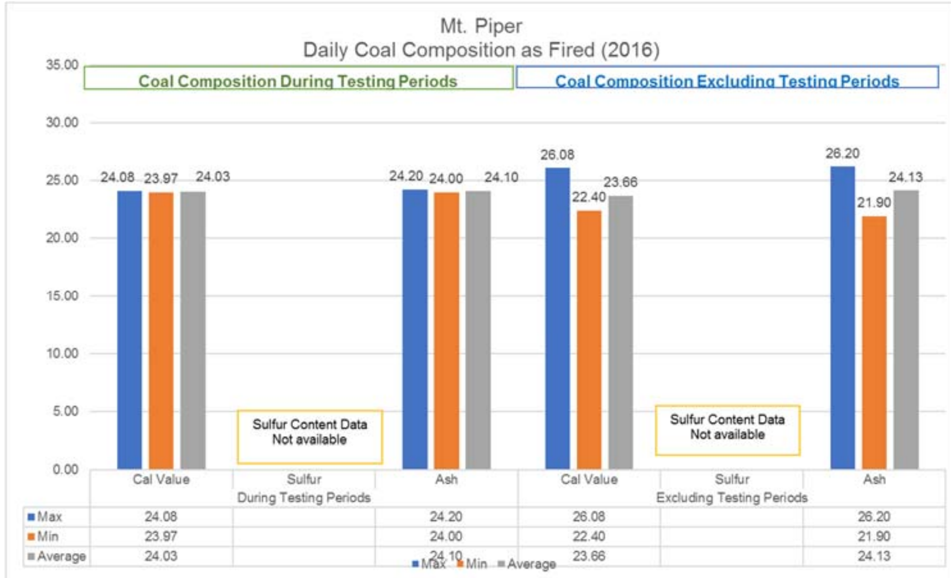


Figure 39: Eraring Monthly Coal Composition as Fired (2011-2016) showing the average calorific value, sulfur and ash content are comparable for testing and non-testing periods. Note: Coal Analysis data is only available on a monthly basis. Coal composition data is only representative of one sampling period.

	Cal Value (During Testing Periods)	Sulfur (During Testing Periods)	Ash (During Testing Periods)	Cal Value (Excluding Testing Periods)	Sulfur (Excluding Testing Periods)	Ash (Excluding Testing Periods)
Max	23.22	0.40	24.08	25.06	0.56	25.83
Min	23.22	0.40	24.08	22.40	0.30	19.19
Average	23.22	0.40	24.08	23.71	0.43	22.77