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Title of Paper: **Investigation of the National Pollutant Inventory (NPI) as a Sustainability Tool**

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Abstract

The National Pollutant Inventory [NPI] was established in the late 1990's, requiring all facilities across Australia to publicly report listed pollutants if they exceed an estimated threshold. Combined with an online database, the NPI provides an important mechanism to track pollution by facility, industry or geographic region.

There remains, however, surprisingly little published analyses of NPI data – especially with respect to performance of facilities or industry sectors over time. Are pollutant loads from industries declining over time with the introduction of better technologies and more efficient processes, or are efficiencies being over-whelmed by growth in industrial production?

This paper will present analyses on the coal industry (both mining and power generation operations) and their reported NPI data, show trends within the data (in terms of five key-indicating pollutants – NO_x, SO_2, PM_{10}, VOCs, CO) and provide a comparison of the different operations using common metrics to ascertain the use of the NPI as a sustainability tool.

1 Introduction

A Pollutant Release and Transfer Register [PRTR] (Wexler 2005), is a database containing estimated pollutant release data submitted by companies to government and the public. The concept of a PRTR was first developed in the USA and Canada after events such as the Bhopal disaster in 1984 and large toxic chemical releases in the USA saw thousands of industrial workers die (USEPA 2010). Other national PRTRs include the USA Toxics Release Inventory [TRI] Program established in 1990 and the Canadian National Pollutant Release Inventory [NPRI] formed in 1994.

Following in the steps of America and Canada, Australia developed their own PRTR by forming the National Pollutant Inventory [NPI] in 1998. The NPI uses facility emissions, facility transfers and diffuse emissions to identify and calculate land, water and air emissions generated by industry practices (NPI 2010).

A key sustainability challenge is to reduce both pollution loads and pollution intensity. For example, sulfur dioxide (SO_2) emissions from coal-fired electricity leads to acid rain problems – as electricity generation grows there is a need to significantly reduce the intensity of SO_2 emissions to ensure that total emissions plateau or possibly decline. Since the 1970s and the rise of environmental legislation and controls in countries such as the USA and Australia, this has been achieved with power stations installing pollution control equipment such as scrubbers and electrostatic precipitators (e.g. MIT 2007). However, given the continuing growth in population, industry and consumption, especially in rapidly developing countries like China, the problem of pollution burdens remain a major sustainability challenge (e.g. air quality issues in urban or industrial areas).

Data from PRTR programs are intended to provide the basis to examine pollution burdens and trends over time. Although the TRI and NPRI programs have been running for almost 20 years, very few rigorous studies of PRTR data, especially trends over time, appear to have been published. Studies investigating the efficacy or use of NPI data also remain scarce. With respect to sustainability, PRTR data is therefore crucial and should help inform progress on problems such as pollution burdens.

The NPI calculates emission data based on inputs and calculation manuals for particular industries, including some actual monitoring where available. Therefore it is not necessarily measuring the amount of emissions produced, but rather a calculation on what would possibly be released based on the amount of inputs and the type of industry practice (NPI 2010). Some measurements are required for industries in which it can be economically implemented (e.g. dust monitoring stations). Manuals have been produced by the NPI to help industries estimate their emissions within the scope of NPI reporting procedures.

This paper will review and present analyses of NPI data for some parts of the coal industry in Australia, including mines and power stations. The usefulness of the NPI as a foundation sustainability tool in understanding pollution challenges is then discussed.

2 Methodology

The Hunter Valley in New South Wales and the Latrobe Valley in Victoria are renowned for their significance in both economical and environmental terms. The Latrobe Valley has vast brown coal seams running through the region, and, due its high moisture, is almost exclusively used for electricity generation in adjacent coal-fired power stations. The Hunter Valley has large seams of black coal mined for electricity generation in NSW, coking coals for steel production, or export thermal or coking coals.

There are significant pollution issues and health concerns associated with coal mining and electricity generation for local communities (Higginbotham et al 2010 and Nelson et al 2010). Furthermore, as a finite resource it is important to understand the impacts of different coal quality on pollution intensity (Mudd 2010; Diniz da Costa and Pagan 2006). Of the 93 listed substances believed by the NPI to have a significant impact on human health and the environment (NPI 2010), the five selected were:

- PM_{10} – Particulate matter less than 10μm in diameter; respiratory illnesses (Thishan Dharshana and Coowanitwong 2008),
- NO_x – Oxides of nitrogen; photochemical smog (McMurray 1980, Nelson et al. 2010) and blasting techniques in mining operations (Attalla 2007),
- CO – Carbon monoxide; incomplete combustion in underground mining operations and coal-fired power plant operations (Chilton 1989)
- VOCs – Volatile organic compounds; respiratory illnesses (Rothweiler 1993), and
- SO_2 – Sulfur dioxide; acid rain (Gimeno 2001) and respiratory illnesses (Highton 1980).

Within the Hunter Valley and the Latrobe Valley, many coal mines and coal-fired power plants were identified and investigated for availability of production data. Annual coal production (Mt/yr) and annual electricity generation (MWh/yr) data was combined with NPI data. This information was gathered from annual corporate or sustainability reports made publically available on company websites or in government publications. In some cases, all data was not publically available and therefore not analysed. Eight coal mines (Table 1) and eleven coal-fired power plants (Table 2) were selected for investigation.

Using the NPI data, magnitudes of annual emissions in tonnes were produced for individual site analysis. To allow for a comparison between mines and power stations, whether in the Hunter Valley or the Latrobe Valley, the NPI data was used with production data to produce a metric for comparison. Therefore, coal mines and power stations were also analysed using common metrics such as kilograms of pollutant per mega (10^6) tonne of coal (kg/Mt) and kilograms of pollutant per megawatt hour (kg/MWh) respectively. This provides the ability to compare different operations irrespective of the site.

Table 1: Summary of coal mines in the Hunter Valley and Latrobe Valley

	Coal Mine	Operator	Location	Mine type^
Hunter Valley	Mount Arthur	BHP Billiton	Muswellbrook, NSW	O/C
	Bengalla	Coal and Allied	Muswellbrook, NSW	O/C, U/G
	Hunter Valley	Coal and Allied	Lemington, NSW	O/C, U/G
	Mount Thorley*	Coal and Allied	Mount Thorley, NSW	O/C, U/G
	Warkworth*	Coal and Allied	Mount Thorley, NSW	O/C, U/G
Latrobe Valley	Loy Yang A#	Loy Yang Power	Traralgon, VIC	O/C
	Hazelwood#	International Power	Morwell, VIC	O/C
	Yallourn#	TRUenergy	Yallourn, VIC	O/C

^ O/C = Open cut mining, U/G = Underground mining
* Reported together on the NPI database
# Production data not publically available

Table 2: Summary of coal-fired power plants in the Hunter Valley and Latrobe Valley

	Power station	Operator	Location	Capacity (MW)
Hunter Valley	Eraring	Eraring Energy	Eraring, NSW	2640
	Liddell	Macquarie Generation	Muswellbrook, NSW	2640
	Bayswater	Macquarie Generation	Muswellbrook, NSW	2000
	Mount Piper*	Delta Energy	Portland, NSW	1400
	Vales Point*	Delta Energy	Mannering Park, NSW	1320
	Wallerawang*	Delta Energy	Wallerawang, NSW	1000
	Munmorah*	Delta Energy	Doyalson, NSW	600
Latrobe Valley	Loy Yang A^	Loy Yang Power	Traralgon, VIC	2100
	Hazelwood^,#	International Power	Morwell, VIC	1600
	Yallourn^	TRUenergy	Yallourn, VIC	1480
	Loy Yang B#	International Power	Traralgon, VIC	1050

^ NPI data reporting combined mining and energy generation operations
* Annual electricity generation data combined for total Delta Electricity coal-fired operations
# Electricity generation data not publically available

3 NPI data analysis

All figures are represented with a primary axis and secondary axis, both with units of tonnes of pollutant emitted per year. A solid line represents data on the primary axis (larger values) and a dashed line for the secondary axis (smaller values). All NPI data is reported on a financial year basis for consistency with NPI data, with the year representing data up to the end of the financial year period.

3.1 Coal mining operations

Eight coal mines were investigated on the five selected key indicator pollutants. NPI data was found for five coal mines in the Hunter Valley. NPI data for coal mines for the Latrobe valley were harder to obtain, as they operated on the same site as a coal-fired power plant. Therefore the emission data was combined with the data for the power plant, making the data unavailable for coal mine comparison. An example of NPI analysis on a coal mining operation is shown below for the Mount Thorley and Warkworth operation (Figure 1).

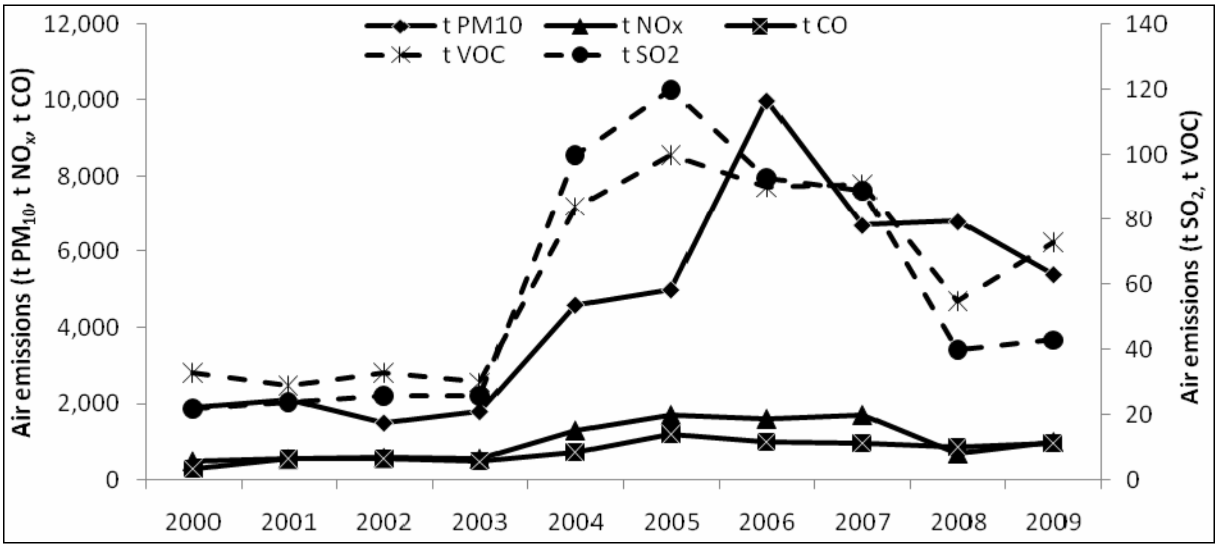

Figure 1: NPI data for Mount Thorley and Warkworth mining operations (1999-2009).

3.2 Coal-fired power plant operations

Eleven coal-fired power plants were investigated in the Hunter Valley and Latrobe Valley. NPI data was found for all seven sites in the Hunter Valley, but only for one of the four in the Latrobe Valley. Given that the majority of brown coal is not sold internationally, but used on-site in coal-fired power plants, Emissions from burning coal and operating the mine are not distinguishable. However, Loy Yang B power station is the only exception, which receives coal from Loy Yang A, and could be analysed along with the Hunter Valley NPI data. An example of NPI power plant analysis is shown in Figure 2.

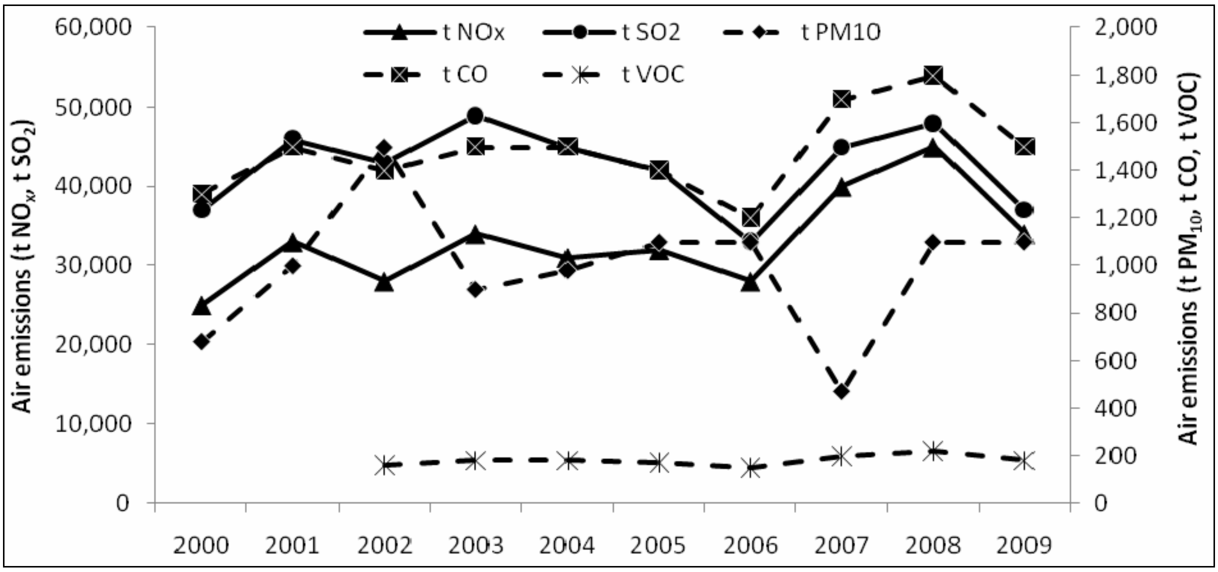

Figure 2: NPI data for Eraring power station operations (1999-2009).

4 Result of metric comparisons

4.1 Coal mining comparison

Coal mining production data from industry operators was obtained from annual reports and other documentation provided for community or general public information (Table 3). Of the five key indicator pollutants, the top three pollutants in terms of magnitude were compared between the five coal mines. This is due to the magnitude of VOCs and SO_2 values being smaller by a factor of 10.

Table 3: Available production data used for the listed coal mines in Mt/yr

	Annual Coal Production (Mt)								
Coal Mine	2001	2002	2003	2004	2005	2006	2007	2008	2009
Bengalla	4.9	5.4	6.2	5.3	6.0	5.5	5.2	5.4	5.5
Hunter Valley ops.	12.2	12.6	12.0	13.3	12.4	12.0	10.1	10.8	11.2
Warkworth^	5.7	6.9	5.9	6.3	7.0	7.3	5.8	6.0	5.2
Mount Thorley^	4.5	5.4	6.2	3.5	4.0	3.9	2.9	2.9	3.3
Mount Arthur				8.7	9.9	9.1	10.9	11.8	11.8
Total (Mt)				**37.1**	**39.3**	**37.8**	**34.9**	**36.9**	**37.0**

^ Reported as a single mining operation in NPI data – Mount Thorley and Warkworth

4.1.1 PM_{10} comparison

Figure 3 below shows comparison data for the investigated mines in the Hunter Valley region. All four mines show similar PM_{10} loads generated from the production of one tonne of coal, ranging from 0.1 kg/t to 1.2 kg/t. All mines show a general trend for increasing PM_{10} emissions, from an average of 0.33 kg/t in 1999 to 0.71 kg/t in 2009.

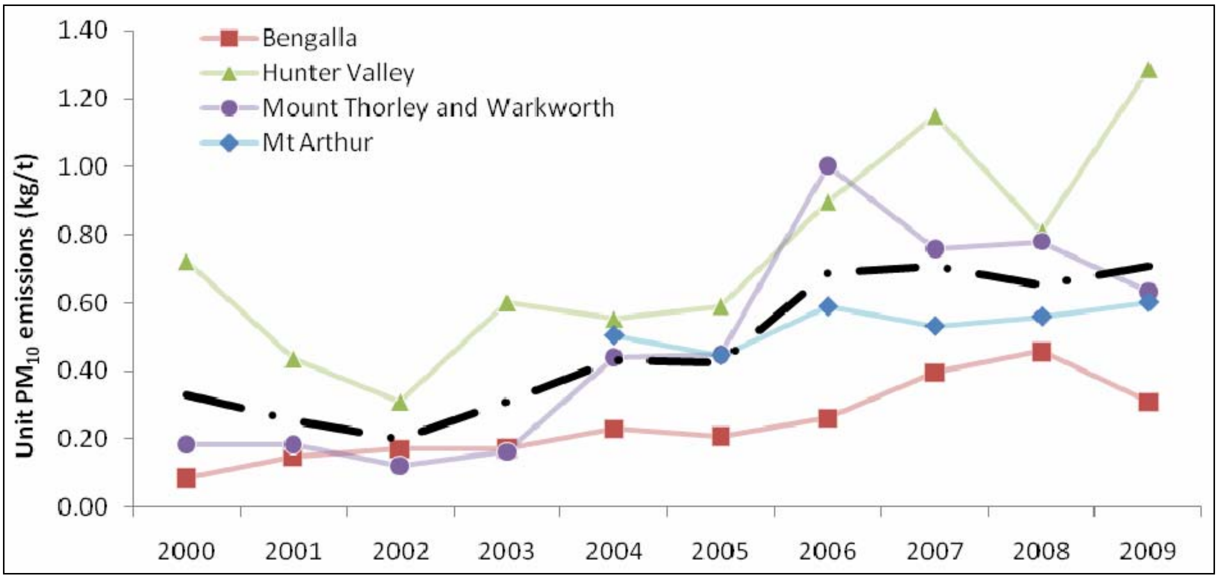

Figure 3: Comparison graph of the Hunter Valley mines for PM_{10} emissions produced per tonne of coal produced. The average kg/t value for PM_{10} emissions of all mines is represented by the black dash-and-dot line.

4.1.2 NO_x comparison

The second comparison on mine data was NO_x emissions produced per tonne of coal production. Again a general trend for increasing NO_x emissions can be seen by the black dash-and-dot line in Figure 4. A large increase is noticed in the final year of analysis (financial year of 2009) for all the mines, especially in the Mount Arthur mine.

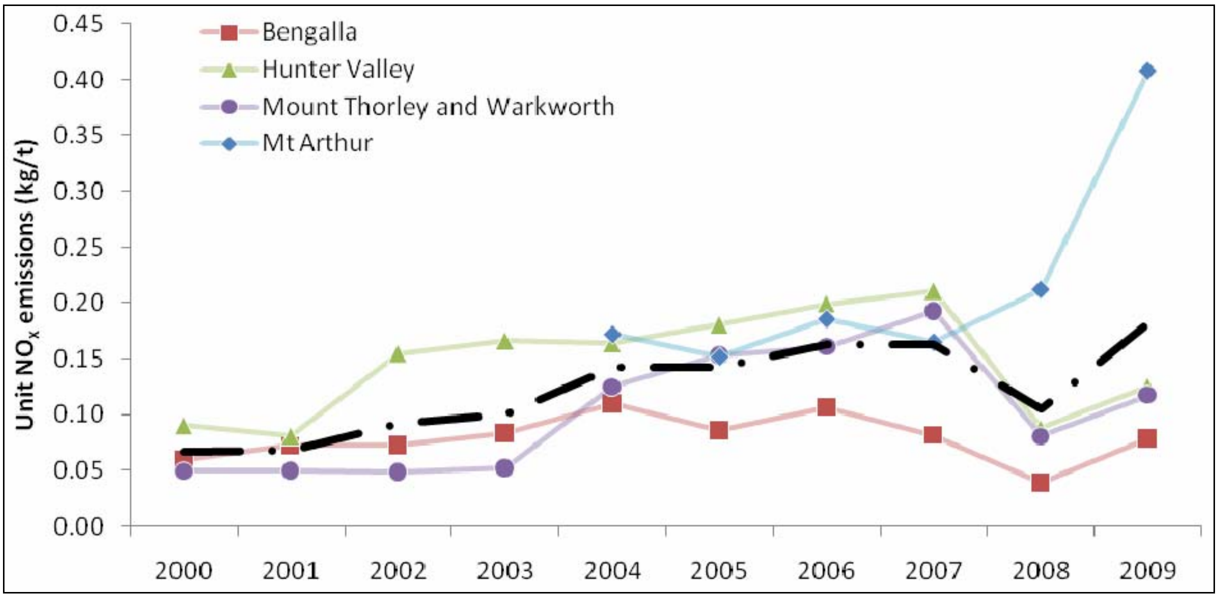

Figure 4: Comparison graph of the Hunter Valley mines for NO_x emissions produced per tonne of coal produced. The average kg/t value for NO_x emissions of all mines is represented by the black dash-and-dot line.

4.1.3 CO comparison

Carbon monoxide was the third pollutant analysed by comparison with Hunter Valley mining operations. All operations showed low variability with a general increase in pollutant emissions from 1999 to 2009. Mount Arthur mining operations again showed higher individual site intensity of CO emissions compared to the other mines (Figure 5).

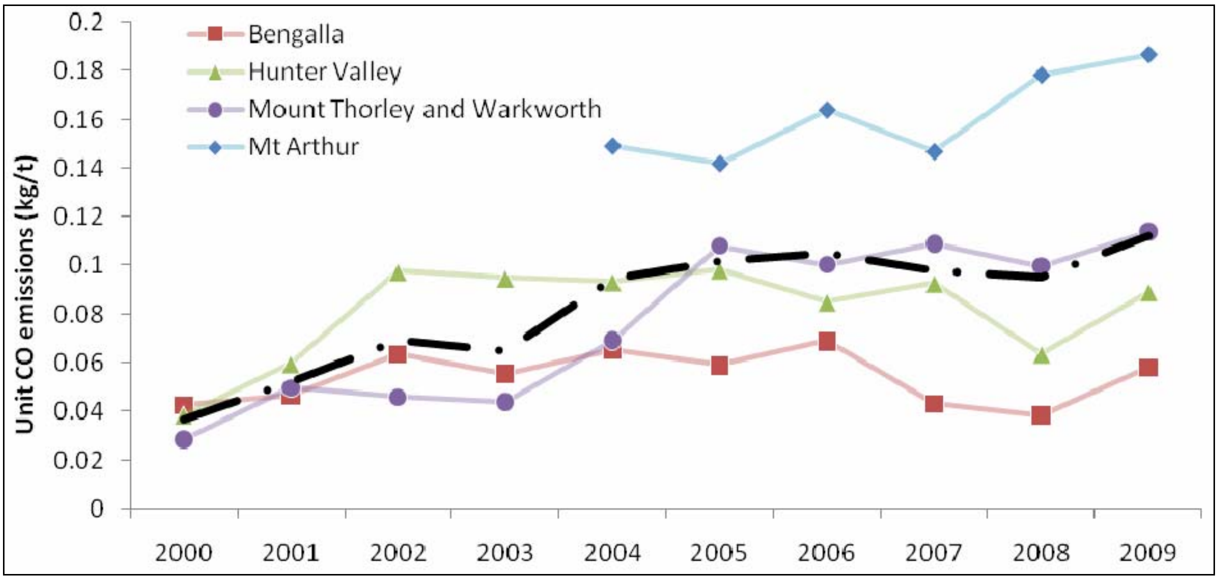

Figure 5: Comparison graph of the Hunter Valley mines for CO emissions produced per tonne of coal produced. The average kg/t value for CO emissions of all mines is represented by the black dash-and-dot line.

4.2 Coal-fired power plant comparison

As with the coal mining comparison, annual electricity generation was compiled from annual reports. Careful consideration of the presented information was necessary to obtain total produced electricity, rather than electricity sent to grid, as the emissions are attributed to total electricity generation (including on-site electricity use). These can be seen in Table 4 below.

Table 4: Total electricity production data used for the listed companies in TWh/yr

Power Station	Annual Electricity Generation (TWh)^									
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Eraring		13.1	14.0	14.9	14.8	12.7	14.2	17.5	17.3	15.4
Liddell			16.8	15.7	16.6	16.9	16.5	14.3	15.4	15.9
Bayswater			7.8	7.3	9.0	9.7	10.1	10.8	10.9	11.1
Delta Electricity*	20.5	21.2	20.8	20.4	21.3	21.7	21.9	22.0	24.1	23.8
Total (TWh)			**59.4**	**58.3**	**61.7**	**61.0**	**62.7**	**64.6**	**67.7**	**66.2**

^ 1 TWh is 1,000,000 MWh; *Electricity generation for Delta Electricity coal-fired power stations listed as a single value (Delta Electricity various).

The top two key indicator pollutants, in terms of magnitude of emissions, are compared between the different coal-fired power plants in the Hunter Valley. Again, these were chosen as the magnitudes of the other three pollutants were found to be a factor of 10 less than the other two pollutant emissions.

4.2.1 SO_2 comparison

Figure 6 shows the comparison graph of all Hunter Valley power plant operations in regards to SO_2 emissions. A steady trend was identified for SO_2 generation across all coal-fired power plants from the start of reporting in 1999 to the most recent information from 2009. Munmorah was the only power station to have a visible SO_2 increase since 1999, which may be attributed to the increased generation capacity installed in 2007 as noted in the NPI datasheets (NPI 2010).

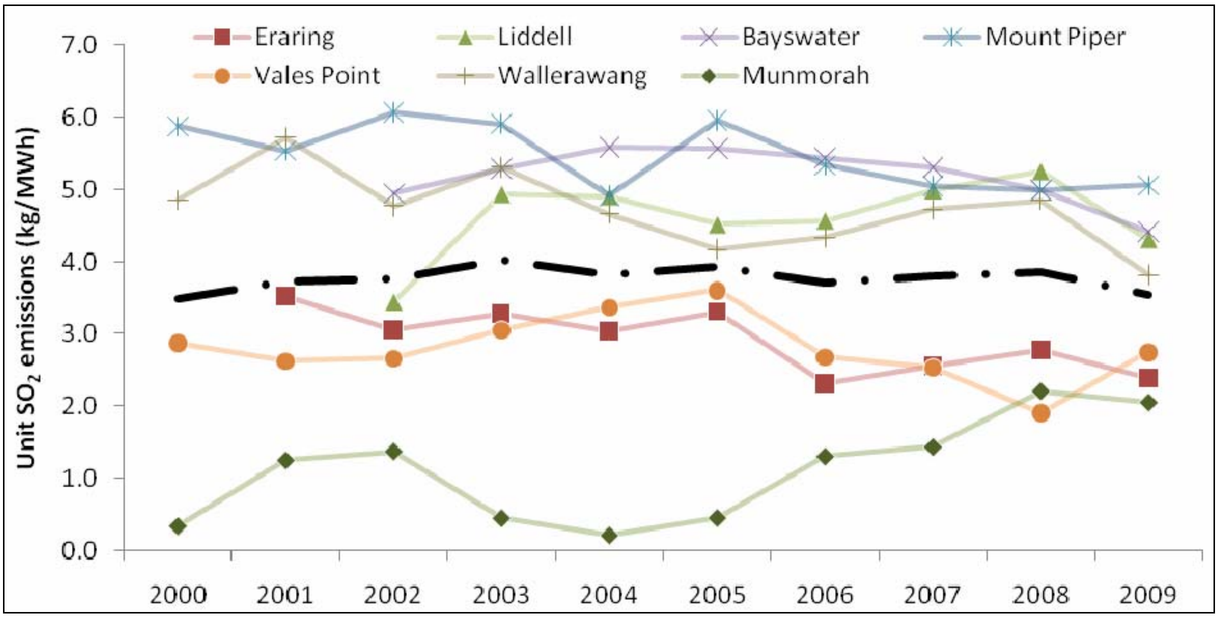

Figure 6: Comparison graph of the Hunter Valley power stations for SO_2 emissions produced per tonne of coal produced. The average kg/t value for SO_2 emissions of all power stations is represented by the black dash-and-dot line.

4.2.2 NO_x comparison

Figure 7 shows a NO_x emission analysis of the investigated power stations in the Hunter Valley. A similar trend is visible for NO_x emissions, as seen in Figure 6, with all power stations except Munmorah showing an increasing trend in NO_x generation. Mount Piper had the largest NO_x intensity of the analysed power stations since reporting began in 1999.

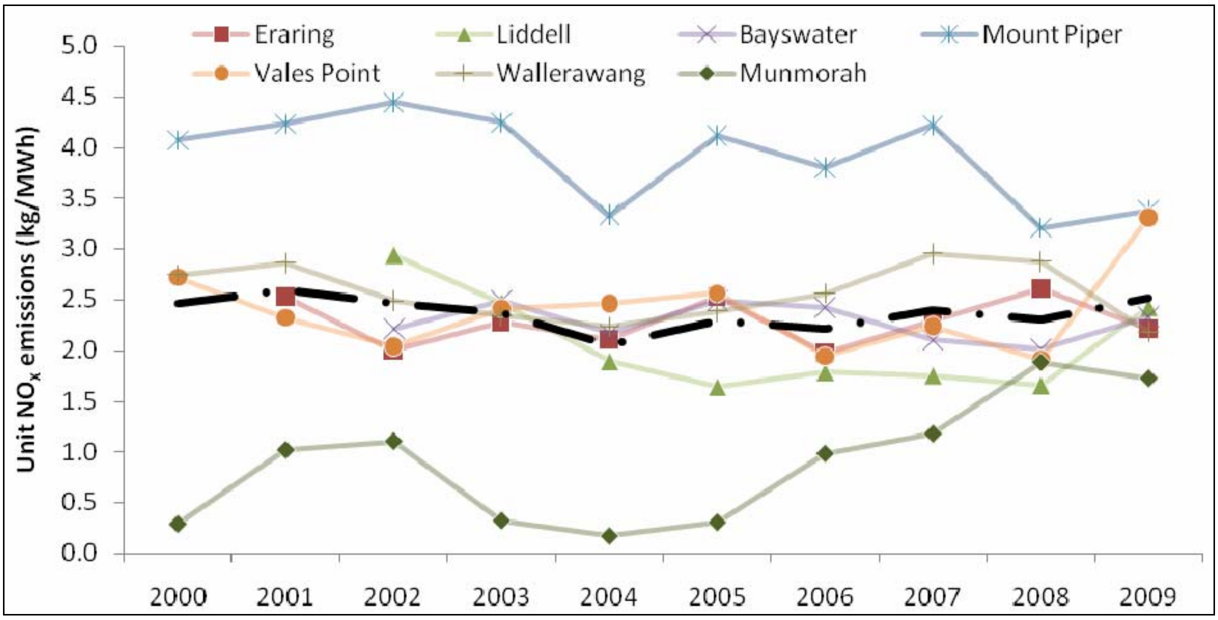

Figure 7: Comparison graph of the Hunter Valley power stations for NO_x emissions produced per tonne of coal produced. The average kg/t value for NO_x emissions of all power stations is represented by the black dash-and-dot line.

5 Discussion

Access of company production data

The largest mining and coal-fired power plant operations were chosen for analysis due to their high economical value to the Australian economy and high environmental burden. Although most of the large operators provided production data for their mining and electricity generation operations, some companies such as Xstrata were unwilling to provide individual site data. Also, access to data in the preferred format is not always available. Most data was provided in financial year format along with the financial information in annual reports. BHP Billiton reported coal data for the Mount Arthur coal mine by calendar year which meant half-yearly productions from two separate years were added to gain financial-year. Also, International Power, which operates Loy Yang B and Hazelwood power stations, did not provide annual electricity generation, therefore preventing a metric comparison of these stations.

5.1 NPI datasheets and comments

The NPI provides space for basic comments on datasheets to assist the public in identifying reasons for changing pollutant measures observed in the results. As part of entering data into the NPI database, comments on actions taken during the year to reduce annual pollutant loads are logged and the date posted. Examples were seen for many sites that scrubbers and electrostatic precipitators were installed around the time when pollutant levels were falling. These were very useful in understanding the trends seen in some years, such as that shown in section 3.1, where Mount Thorley and Warkworth operations are explained by installation of real-time PM_{10} monitoring controls and use of dust suppression by water and chemicals (NPI 2010). Although the public may not go to great lengths to analyse long trends in the data set, they will see that measures are being implemented to reduce the impact a specific operation is having on their environment.

5.2 Mining comparisons

The largest pollutant emissions from mining operations was observed to be PM_{10}, most likely due to the moving of overburden and during the transport of coal back for handling by large trucks (Mudd 2010). As mentioned above, it was noted in most NPI datasheets that dust suppressant measures were being used to limit PM_{10} generation. Unfortunately, the use of chemicals was listed as a measure, which is not expressed in the data. This means that not all of the environmental impacts are being captured by the analysis of NPI data.

A worrying trend found in the data was the increase of PM_{10} emissions from mining operations. Since the NPI started gathering data, PM_{10} emissions have increased across the board. Although the final years of data have shown downward trends in pollutant generation, in a strong mining economy like Australia strategies need to be drawn to further reduce particulate emissions produced by mining operations. Worries of rising emissions in the Upper Hunter Valley region have been raised in a study by Higginbotham et al (2010), including the rising particulate emissions from mining activities. $PM_{2.5}$ emissions, associated with health problems due to their ability to stay within the lung after inhalation (Dagher et al. 2006), have also been of worry to surrounding communities. Industry has started reporting $PM_{2.5}$ emissions separately to PM_{10} since 2008 and further studies incorporating both $PM_{2.5}$ and PM_{10} are recommended.

An investigation into underground and open-cut mining operations is also recommended for further studies. Analysis on different mining operations was attempted, but lack of available data restricted this study from undertaking an in-depth analysis.

5.3 Electricity generation comparisons

Coal-fired power plants were seen to have stable outputs of the two chosen key indicator pollutants; SO_2 and NO_x emissions. Large quantities of SO_2 were reported to the NPI by Liddell and Bayswater power stations, averaging 43,000 t/yr and 82,000 t/yr respectively. A significant finding was that pollutant intensity is not proportional to the capacity of the power plant. In fact, Mount Piper power station was found to have the largest intensity of SO_2 and NO_x of all the power stations investigated.

However, when analysed by the applied metric for comparison of kg/MWh, they appeared within the average of all Hunter Valley electricity generation operations inspected. But is this a respectable level of these emissions? Is 82,000 t/yr acceptable? This is just one power station, what about the sum of all the power stations in the Hunter Valley, the Latrobe Valley or all of Australia? A recent study on the future of coal by MIT (2007) mentions that America is already putting measures in place to reduce large pollutant emissions associated with coal-fired power generation. The U.S. EPA enacted a legal framework to reduce SO_2 and NO_x emissions, titled the Clean Air Institute Rule [CAIR]. Projected reductions of SO_2 and NO_x emissions with projected electricity requirements up to 2020 are shown in Figure 8.

This study shows that Australia is falling behind other countries in terms of air quality strategies and public health issues with regards to the coal industry in Australia. It is recommended that further studies be done investigating trends between data of different PRTRs (e.g. NPI, TRI and NPRI) around the world and trends of pollutant metrics. This would enable the ranking of countries in terms of a set metric, kg/t and kg/MWh, as stated in this report and provide a comparison of treatment measures being used around the world.

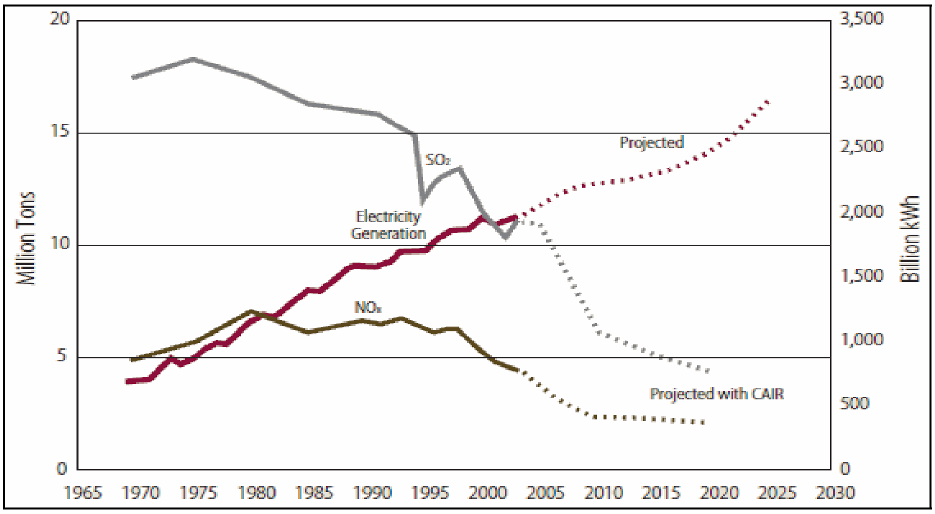

Figure 8: U.S. plan to reduce SO_2 and NO_x emissions as projected with the CAIR model until 2020 (MIT 2007, p. 137).

6 Conclusions and Recommendations

An analysis of NPI data revealed that the mining and electricity generating industries are installing technologies and improving practices in order to mitigate the toxic emissions investigated in this report. The NPI database has provided comments and updates on every financial-year datasheet that allows the public to understand why some changes in pollutant loads change. However, the continued rising of total annual emissions indicates that improvements to operation processes and technology are being overwhelmed by production.

Comparisons between the individual mines and individual coal-fired power plants show that the capacity is not proportional to the intensity of emissions released; Mount Piper power station, having a capacity of half the Eraring and Liddell power stations, had the greatest SO_2 and NO_x emission intensity of the investigated power stations. Therefore, bigger is not necessarily more polluting per MWh, nor is it automatically more efficient.

Overall, the NPI is seen as a suitable tool for assessing pollution burdens and intensities from various industries, in this case coal mining and electricity generation. It provides an important tool to inform progress on sustainability. Further studies are recommended on NPI data for different industries and comparing multiple PRTRs around the world. Also, an analysis with focus on different mining techniques is suggested for future investigation.

7 References

Attalla M., 2007. “NO_x emissions from blasting operations in open-cut mining in the Hunter Valley”, Proc. 14th International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) World Congress 2007, 18th Clean Air Society of Australia and New Zealand (CASANZ) Conf.

BHP Billiton, various. BHP Billiton Annual Reports, yrs 2006-2009, www.bhpbilliton.com.

Burnup C., 1995. “National pollutant inventory - implications for industry”, *Managing environmental impacts - policy and practice; Twentieth annual environmental workshop 1995*, pp37-46.

Burritt R. and Saka C., 2006. “Quality of Physical Environmental Management Accounting Information”, in *Sustainability Accounting and Reporting*. SPRINGER: The Netherlands, ch. 17

Coal and Allied, various. Publications and reports, yrs 2002-2009, www.coaland allied.com.au

Chilton J., 1989. "Miner's personal carbon monoxide alarm." *IEEE Transactions on Industry Applications*, Vol 25:3 pp 503-508.

Dagher Z., Garçon G., et al., 2006. "Activation of different pathways of apoptosis by air pollution particulate matter ($PM_{2.5}$) in human epithelial lung cells (L132) in culture." *Toxicology*, Vol. 225:1 pp12-24.

Delta Electricity, various. Annual Reports, yrs 2002-2009, www.de.com.au

Diniz da Costa J. and Pagan, R., 2006. "Sustainability Metrics for Coal Power Generation in Australia", *Process Safety and Environmental Protection*, Vol. 84:B2 pp143-149.

Environment Canada, 2010. "National Pollutant Release Inventory: Tracking Pollution in Canada", www.ec.gc.ca/inrp-npri/default.asp?lang=en [Accessed 04/06/2010]

Eraring, various. Annual Reports, yrs 2001-2009, www.eraring-energy.com.au

Farnell G., 1994. "National pollutant inventory - what does it mean for industry?", *Nineteenth annual environmental workshop 1994*, pp11-20.

Google Earth, 2010. Google Earth images – Hunter Valley, NSW, and Latrobe Valley, VIC. earth.google.com [Accessed 06/06/2010]

Gimeno L., Marín E., et al., 2001. "How effective has been the reduction of SO2 emissions on the effect of acid rain on ecosystems?", *The Science of The Total Environment*, Vol. 275:1-3 pp63-70.

Highton N. H., 1980. "Sulfur dioxide from electricity generation: Policy options for pollution control", *Energy policy*, Vol. 8:1 pp61-76

Higginbotham N., Freeman S., et al., 2010. "Environmental injustice and air pollution in coal affected communities, Hunter Valley, Australia", *Health and Place*, Vol 16. pp259-266

International Power, various. Publications and Reports, yrs 2007-2009. www.ipplc.com.au

Loy Yang Power, various. Sustainability Reports, yrs 2004-2008. www.loyyangpower.com.au

Macquarie Generation, various. Macquarie Generation Annual Reports, 2002-2008. www.macgen.com.au

McMurry P. H., 1980. "Photochemical aerosol formation from SO2: A theoretical analysis of smog chamber data", *Journal of Colloid and Interface Science*, Vol. 78:2 pp513-527

MIT (Massachusetts Institute of Technology) 2007, "The Future of Coal: Options for a Carbon-Constrained World", *MIT*: Cambridge, MA, USA, www.web.mit.edu/coal/

Mudd G. M., 2010. "The Environmental sustainability of mining in Australia: key mega-trends and looming constraints", *Resources Policy*, Vol. 35:2 pp98-115

Nelson P., Shah P., et al., 2010. "Environmental impacts of coal combustion: A risk approach to assessment of emissions", *Fuel*, Vol. 89 pp810-816

NPI (National Pollutant Inventory) 2010. NPI database. www.npi.gov.au

Rothweiler H., 1993. "Human exposure to volatile organic compounds in indoor air - a health risk?", *Toxicological and environmental chemistry*, Vol. 40:1 pp93-102

TRUenergy, various. Sustainability and Environment Reports, yrs 2005-2009. www.truenergy.com.au

Thishan Dharshana K. G. and Coowanitwong N., 2008. "Ambient PM_{10} and respiratory illnesses in Colombo City, Sri Lanka", *Journal of Environmental Science and Health*, Part A: Toxic/Hazardous Substances and Environmental Engineering, Vol 43:9 pp1064-1070

USEPA (United States Environmental Protection Agency) 2010. Toxics Release Inventory Program, www.epa.gov/tri/triprogram/whatis.htm [Accessed 04/06/2010]

Wexler P., Harjula H., et al., 2005. "Pollutant Release and Transfer Registers (PRTRs)", *Encyclopaedia of Toxicology*, New York. Elsevier**:** 463-467.