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Coal: Production Trends, Sustainability Issues and Future Prospects

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For

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CONTENTS

EXECUTIVE SUMMARY

This case study presents a data compilation relating to black coal at global and national scale. The study was undertaken as part of a broader research program focused on “peak minerals” and implications for commodity futures in Australia.

Reserves and historical production data, at the national and global scales, are compiled from a range of sources to provide a comprehensive basis for understanding the opportunities and consequences of developing these coal resources. Data at a sub-national scale (NSW) is then used to present a more detailed review of reserves, production and overburden, consumption, employment and export–related issues.

This data is then used to model future global black coal production. The modelling projects a global peak in black coal production within a decade. This is heavily influenced by consumption in China which itself has transitioned from being a significant coal exporter to coal importer. Australian production is projected to peak by the middle of the present century.

The report concludes with an overview of coal mining methods and alternatives for using coal.

1. BACKGROUND

This case study is part of the peak minerals component of work within the commodity futures stream of the CSIRO Mineral Futures Collaboration Cluster.

1.1. Aim

The aim of this report is to evaluate the extent of Australia's potential to derive economic, social and environmental benefit from coal resources over the long term. This chapter will provide a case study that demonstrates the potential opportunities and consequences of developing the coal resources. Further the case study provides an overview of the strategies (including policy interventions) that could guide the sustainable development of such resources.

2. INTRODUCTION

Coal is a readily combustible rock that contains mostly carbonaceous material (EIA, 2009). Throughout this case study black coal will refer to all coal that is not lignite, with black coal often referred to commonly as hard coal (this report will only use black coal). Coal is primarily used for electricity generation, and in the iron / steelmaking industries. Coal is also used in the cement industry and to a lesser extent in the production of activated carbon and carbon fibre WCA (2010). Australia is the largest exporter of coal in the world, exporting 125 Mt of metallurgical coal and 136 Mt of thermal coal in 2008-09, earning Australia just under A$55 billion (ABARE, 2010; ACA, 2010). Most of Australia's black coal production occurs in NSW and Queensland, with only modest production from Tasmania, South Australia and Western Australia.

2.1. Global Distribution

The world's black coal reserves are estimated to be around 700 Gt. As shown in Table 1 (below), six countries dominate coal reserves, specifically: USA, China, Russia, India, Australia and South Africa. These continents contain ~85% of the world's coal reserves and Australia is ranked fifth in terms of coal reserves.

Table 1: World black coal reserves (Gt)

Country	Rempel et al. (2009)	World Energy Council (2010)
USA	231.9	207.1
China	180.6	95.9
Russia	69.9	146.6
India	76.4	56.1
Australia	39.6	39.2
South Africa	31.0	30.2
Others	99.0	90.5
Total	**728.4**	**665.6**

2.1.1. Distribution of coal in Australia

Australia's black coal resources are predominantly in NSW and Queensland as shown in Table 2.

Table 2: Australian black coal resources (Gt) (Sait, 2009)

State	Economic	Paramarginal	Submarginal	Inferred	Total
Queensland	22.1	0.5	0.4	17.2	40.2
NSW	15.6	0.6	2.4	32.6	51.2
Tasmania	0.3				0.3
South Australia	-	0.1	3.9	14.1	18.2
Western Australia	1.3	0.3		2.8	4.4
Australia	**39.2**	**1.5**	**6.7**	**66.7**	**114.2**

2.2. Global Production

World black coal production is believed to have begun in Europe. By 1900, 59% of black coal was produced in Europe, 35% in the United States, 1% in Australia and 5% in the rest of the world. Today world black coal production is dominated China (47%) and the United States (17%) with Australia contributing around 5.6%. World coal production for the big 6 producers is shown in Figure 1.

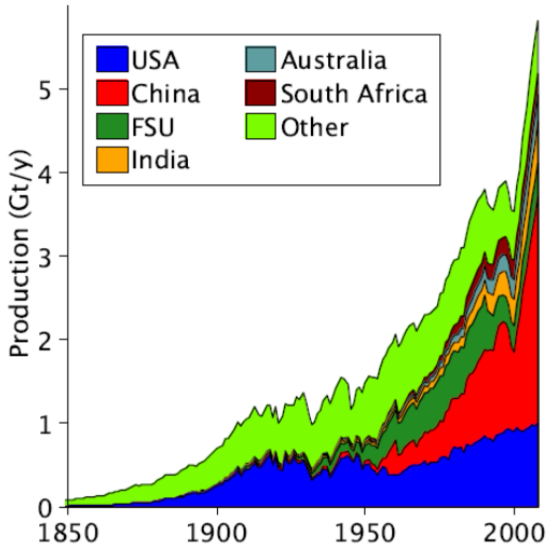


Figure 1: Annual production of black coal by country (Mohr and Evans, 2009; World Energy Council, 2010; Minerals UK, var.)

2.2.1. Production of black coal in Australia

Australian black coal production has been dominated by NSW and Queensland since production began, see Figure 2. From the late 1960's onwards Queensland coal production has been increasing rapidly to point where it is now producing more than 55% of Australia's black coal production, see Figure 2.

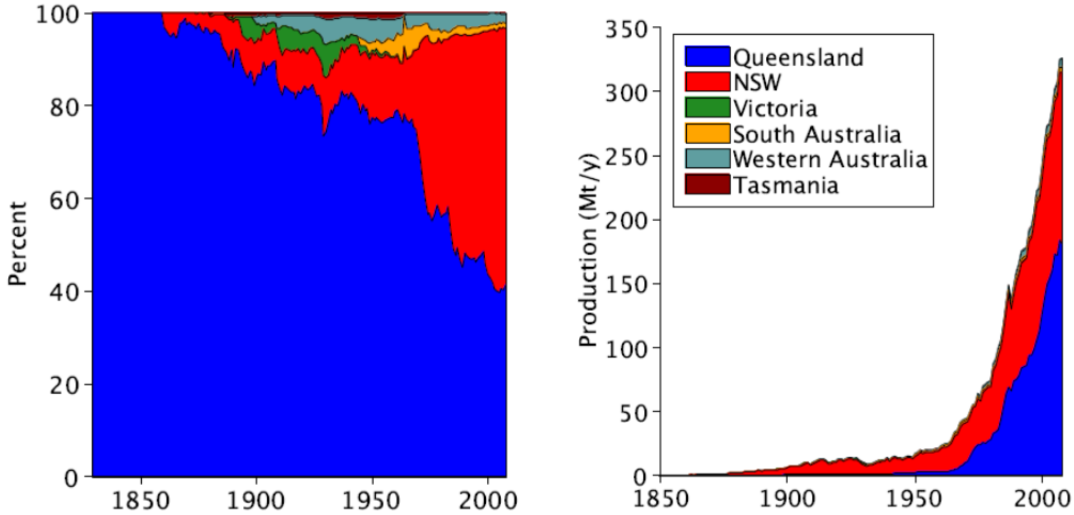


Figure 2: Annual production of black coal in Australia percentage (Australian Bureau of Statistcs, 2008; DEEDI, 2010; Davidson et al, 1930; ABARE, 2010; NSW DPI, 2009)

3. Case Study – New South Wales, Australia

NSW was selected as the region to study for the case study as NSW and Queensland dominate Australia's production and NSW was the main producer of black coal in Australia, and even though Queensland has recently overtaken it, is still a major producer. Further, NSW has the largest amount of black coal recoverable resources.

3.1. Introduction

Information on the NSW black coal will now be presented. First general background and location information will be presented in sub-section 3.2. Next the mines and deposits will be examined in detail in sub-section 3.3. Following this mining, production and processing information, such as raw to saleable coal production, average mine size and overburden ratios, etc., will be discussed in sub-section 3.4. Finally sub-section 3.5 will briefly review domestic consumption, while sub-section 3.6 details exports and sub-section 3.7 examines financial and socio-economic information of NSW coal.

3.2. Background

3.2.1. History

Coal was well known to the Aboriginal people in Newcastle and Lake Macquarie and was used as a cooking fuel and for releasing spirits (NSW Minerals Council, 2010b), but was first discovered by European settlers in NSW (and Australia) at the entrance to the Hunter River in Newcastle, New South Wales by William Bryant (ACA, 2008b). Unfortunately, William Bryant was an escaped convict and decided not to notify authorities (NSW Minerals Council, 2010b). Hence it was left to Lieutenant John Shortland to make the official discovery in 1797 (NSW Minerals Council, 2010b). In 1797 coal was also discovered by shipwreck survivors, on the South Coast, near Coalcliff in NSW (NSW Minerals Council, 2010b; DM, 1925). Coal mining in NSW (and Australia) first began in 1799 in Newcastle, and 150 tonnes of coal was exported to India in 1801 (Huleatt, 1981). Initially the Australian Agricultural Company (AA) had a monopoly on coal production, which ultimately ended in 1847 (NSW Minerals Council, 2010b). Coal production in the South Coast at Mount Keira commenced the following year after AA's monopoly ended (NSW Minerals Council, 2010b). Subsequently other regions of NSW commenced coal production, firstly in the Western region near Lithgow around 1865 (although local landowner knew about the existence of coal before this time and are believed to have produced coal unofficially) (NSW Minerals Council, 2010b). Coal production in the Hunter Coalfields also started in 1865 with the Rix Creek coal mine Schmitz (1988). Next, coal in Gunnedah was discovered in 1877 by farmers boring for water, and in 1895 the first mine Gunnedah Colliery began operations (NSW Minerals Council, 2010b). Finally, coal was discovered in Sydney in 1892 in Balmain (in the heart of Sydney) and production occurred between 1897 and 1931 (DPI, 2007).

3.2.2. Sites and situation

The principle coal basin in NSW is the Sydney-Gunnedah Basin, stretching from Wollongong in the south of the state up past Gunnedah near the border with Queensland. Currently, there are two coal ports namely Port Kembla (Wollongong) and Port Waratah (Newcastle) however coal historically was also exported from Sydney and Catherine Hill bay (near Lake Macquarie). The New England, Pacific, Kamilaroi, Castlereagh and Hume Highways run through the basin, with the New England Highway connecting Hunter coalfields to Newcastle, the Pacific Highway connecting Sydney to Newcastle allowing Newcastle coalfield mines access to Port Waratah, the Kamilaroi Highway linking the Gunnedah Coalfield with Scone, the Castlereagh Highway connecting Western coalfield mines to Sydney. The Sydney-Gunnedah basin is also well serviced by rail infrastructure, as shown in Figure 3.

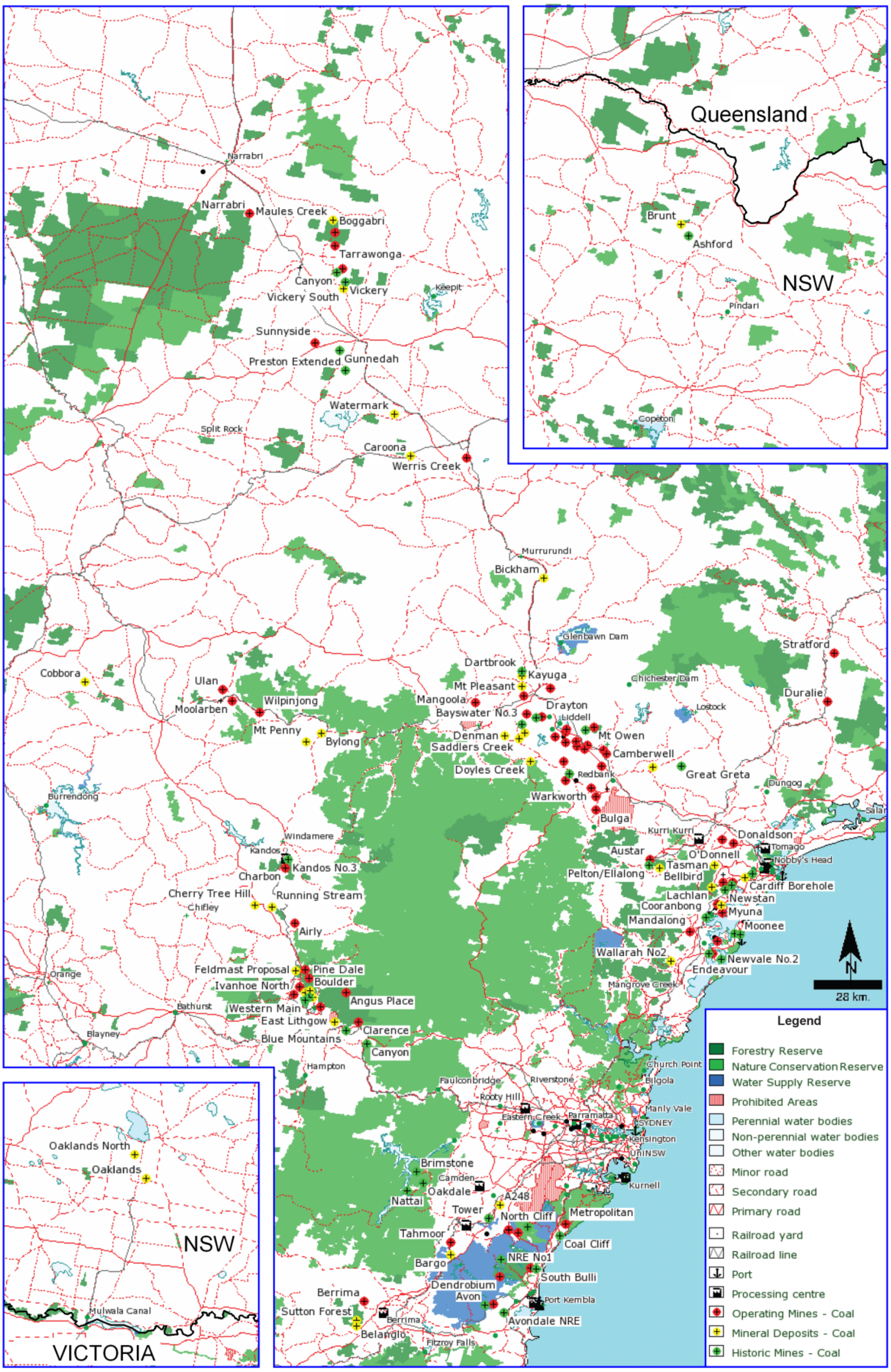


Figure 3: The location of the NSW coal deposits relative to railways and roads (AMA 2011)

3.3. Deposits

3.3.1. Mines

The coal deposits in New South Wales are split into a number of regions. The main regions are: Southern, Central, Western, Newcastle, Hunter and Gunnedah basins, with smaller mining basins at Oaklands, Gloucester as shown in Figure 4. In addition, there has been coal mining in the Ashford Basin (near Inverell) of north-eastern NSW. There have been around 450 active or historic coal mines in NSW, with active mines shown in Figure 3.

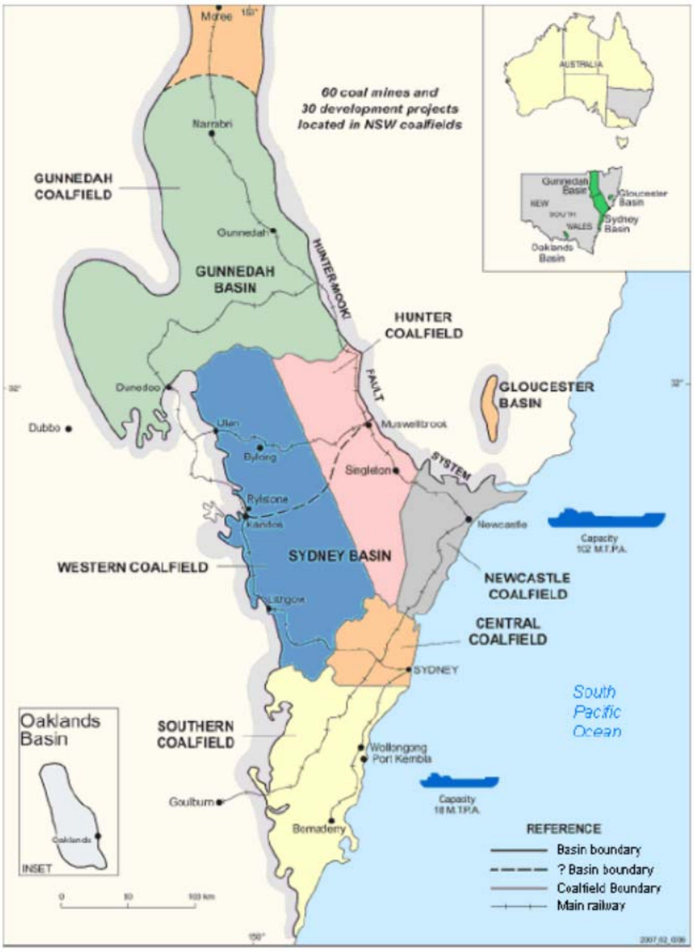


Figure 4: The various basins of NSW (DPI, 2005)

3.3.2. Historic Resources

Historical estimates of NSW resources by quality and region are shown in Tables 3 and 4. The historical resources have only changed significantly once, with an increase in the Assumed and Inferred coal resources for the Southern Coalfields (NSW DPI, 2009). The lack of change in the statistics could indicate that resources are very well known implying that further discoveries are unlikely or indicates that resources are sufficient for a considerable amount of time in the future and hence finding more resources is of little importance.

Table 3: Coal resources by mineral resource category (Gt) (NSW DPI, 2009)

Year	Measured + Indicated	Inferred	Total
1986	33.44	46.62	80.06
1989	33.44	46.62	80.06
1991	33.44	46.62	80.06
1992	34.36	54.28	88.64
1993	34.36	54.28	88.64

Table 4: Coal resources by region (Gt) (NSW DPI, 2009)

Year	Gunnedah	Hunter	Southern	Newcastle	Oaklands	Western	Gloucester	Total
1986	32.010	22.648	8.216	7.991	4.648	4.340	0.203	80.056
1989	32.010	22.648	8.216	7.991	4.648	4.340	0.203	80.056
1991	32.01	22.648	8.216	7.991	4.468	4.340	0.203	80.056
1992	31.760	22.648	17.047	7.991	4.648	4.340	0.203	88.637
1993	31.760	22.648	17.047	7.991	4.648	4.340	0.203	88.637

3.3.3. Historic Reserves

The NSW recoverable reserve estimates by region are shown in Table 5. The total reserve estimates have been relatively stable with only a slight increase in the estimates. Although the Gunnedah Basin has the largest resources, the Hunter Basin has the largest reserves, which is due to the Hunter coalfields having been further developed than the Gunnedah Basin due to the shorter transport distances to the Port of Newcastle and coal fired power stations.

Table 5: Coal reserves by region (Gt) (NSW DPI, 2009)

Year	Hunter	Western	Newcastle	Gunnedah	Oaklands	Southern	Gloucester	Total
1989-90	3.43	0.90	1.13	0.45	1.12	1.31	0.00	8.35
1990-91	4.88	1.06	1.10	0.45	1.12	1.34	0.04	10.00
1991-92	4.56	1.05	1.17	1.11	1.12	1.10	0.05	10.16
1992-93	4.89	1.43	1.05	1.14	1.12	1.19	0.05	10.88
1993-94	4.42	1.01	1.01	1.14	1.12	1.09	0.04	9.83
1994-95	6.23	0.87	0.83	1.14	1.12	1.17	0.04	11.40
1995-96	4.19	1.01	2.41	0.45	1.12	1.12	0.05	10.35
1997-98	6.67	1.00	2.47	0.75	1.12	1.05	0.07	13.13
1999-00	4.97	1.11	2.32	0.75	1.12	0.98	0.05	11.29
2000-01	5.10	1.11	1.93	0.74	1.12	0.97	0.02	10.99
2001-02	4.26	1.25	1.79	0.76	1.12	0.87	0.02	10.07
2002-03	4.27	1.15	1.72	0.76	1.12	0.81	0.02	9.85
2003-04	4.09	1.08	1.64	0.77	0.40	0.74	0.02	8.73
2004-05	3.57	1.00	1.60	0.77	0.40	0.66	0.02	8.01
2006-07	4.05	1.56	1.60	1.29	1.28	0.81	0.02	10.61
2007-08	4.33	1.76	1.44	1.29	1.28	0.67	0.02	10.79
Cum. Prod.	1.44	0.49	1.13	0.04	<<0.01	0.74	0.02	3.87

3.3.4. Current Resources and Reserves and URR estimate

A detailed compilation of NSW coal resources and reserves has been compiled using Coal Industry Profile data and JORC estimates from individual company reports. The compiled data is found in appendix A, with summary tables presented in Tables 6 and 7.

The resources have been collated to be 36 Gt which when combined with 4 Gt of cumulative production gives an estimated URR of 40 Gt for NSW. The predominant basin is the Hunter basin with resources of almost 19 Gt. Although the Gunnedah basin currently only have 3 Gt of resources, it is likely that this basin's resources will grow as more deposits are explored in detail. Approximately 60% of the resources exist in the three main resource companies Xstrata, Rio Tinto and BHP.

The URR is the Ultimately Recoverable Resources (URR) and is determined by combining cumulative production of 4 Gt with the resource estimate of 36 Gt a URR of 40 Gt was determined. The URR value is the key input needed to determine the future production of black coal resources for NSW, Australia and the World.

Table 6: The NSW coal resources and reserves by basin.

		Production		Emp.		Reserves	Marketable Reserves	Resources		
		Raw	Sal.							
Hunter	LW	19.5	12.5	8277	J	3583	2490	16663	Prod	80.4
	BP	0.0	0.0		NJ	392	215	1974	CP	1440.4
	OC	93.0	67.9		Total	3975	2705	18637	URR	20077.3
Newcastle	LW	11.1	9.7	1968	J	241	217	1663	Prod	16.1
	BP	3.9	3.7		NJ	152	66	1683	CP	1126.3
	OC	3.9	2.7		Total	394	283	3346	URR	4472.3
Gloucester	LW	0.0	0.0	152	J	38	0	207.9	Prod	1.9
	BP	0.0	0.0		NJ	0	0	0.0	CP	24.5
	OC	2.8	1.9		Total	38	0	207.9	URR	232.4
Southern	LW	12.3	9.6	2636	J	157	125	1668.2	Prod	10.4
	BP	0.8	0.8		NJ	203	40	664.6	CP	740.9
	OC	0.0	0.0		Total	359	165	2332.8	URR	3073.7
Oaklands	LW	0.0	0.0	0	J	0	0	2102.0	Prod	0.0
	BP	0.0	0.0		NJ	0	0	0.0	CP	0.2
	OC	0.0	0.0		Total	0	0	2102.0	URR	2102.2
Western	LW	11.5	10.7	1717	J	774	400	5887.8	Prod	22.2
	BP	2.3	2.0		NJ	291	25	921.2	CP	494.2
	OC	11.9	9.6		Total	1065	425	6809.0	URR	7303.2
Gunnedah	LW	0.0	0.0	325	J	702	321	2144.1	Prod	4.0
	BP	0.0	0.0		NJ	0	0	576.1	CP	44.4
	OC	4.3	4.0		Total	702	321	2720.2	URR	2764.6
Ashford	LW	0.0	0.0	0	J	0	0	4.6	Prod	0.0
	BP	0.0	0.0		NJ	0	0	0.0	CP	3.3
	OC	0.0	0.0		Total	0	0	4.6	URR	7.9
Central	LW	0.0	0.0	0	J				Prod	0.0
	BP	0.0	0.0		NJ	0	0	0.0	CP	0.7
	OC	0.0	0.0		Total	0	0	0.0	URR	0.7
Total	LW	54.3	42.5	15075	J	5496	3553	30341.3	Prod	135.1
	BP	7.0	6.5		NJ	1038	346	5819.0	CP	3874.8
	OC	115.9	86.2		Total	6534	3900	36159.4	URR	40034.3

LW = Longwall, BP = Bord and Pillar, OC = Open Cut, J = JORC, NJ = Not JORC, Prod = Annual production, CP = Cumulative Production, URR = Ultimately Recoverable Resources (CP + Total Resources).

Table 7: The NSW coal resources and reserves by company.

Company	Production	Employees	Reserves	Marketable Reserves	Resources	JORC	%Total
Xstrata	36.56389	3869	1217.3	889.8	10753.6	Y	29.7
Rio Tinto	24.83915	3004	1478	1048	5699	Y	15.8
BHP	18.76795	2300	1138	843	5046	Y	14.0
Centennial	18.45048	1819	428.4	412.8	2483.0	Y	6.9
Whitehaven	2.748017	231	346.29	321.04	1496.7	Y	4.1
Kores Australia	0				1209	N	3.3
Coalworks	0				1194	P	3.3
Felix Resources	2.956623	350	453.2		1148	Y	3.2
Peabody	11.61165	1106	546.3	208.3	1126.6	N	3.1
Anglo	4.613432	328	40.9	38.8	822.8	Y	2.3
Other	0				628	N	1.7
Aston Resources	0		356		610	Y	1.7
Idemitsu Australia	2.51825	219	27.5	26	607	N	1.7
Gujarat NRE	0.588797	407	158.8		572.9	P	1.6
Cockatoo Coal	0				538	Y	1.5
Nucoal	0				497.7	Y	1.4
NSW Government	0				400	N	1.1
Noble Group	1.777483	276	61	5	237.46	N	0.7
Big Ben Holding	1.757783	178	81.9		229.5	N	0.6
White Energy	0				223.7	P	0.6
Vale	3.829641	558	71.44	38.5	217.36	N	0.6
Gloucester Coal	1.890523	152	38		207.9	Y	0.6
Yanzhou	1.237098	190	51	42.7	113	N	0.3
CET resources	0.758811	77	15.8	5.8	73.8	N	0.2
Enhance Place	0.239231	11	20	20	20	N	0.1
7MQ	0		4.2		4.4	N	<0.1
Total	135.1488	15075	6534	3900	36159.4		100.0

Y = Yes, N = No, P = Partial: Coalworks all JORC resources excluding Ferndale, Gujarate NRE Non JORC potential reserves included, White Energy all JOCR resources excluding Glendon Brook.

3.4. Processing information

3.4.1. Coal production by coalfields

The NSW coal production by coalfields is shown in Figure 5. As shown, the Newcastle Coalfields dominated production up to 1950, with more than 60% of the production. Between 1950 and 1970 approximately 80% of the coal was produced by Newcastle and Southern Coalfields. Since 1970 the Hunter Coalfield has been the principle source of growth in coal production, and this has meant that the Hunter Coalfield has increased from 6.3 Mt in 1972/3 or 20% of the total to 80.4 Mt in 2007/8 or almost 60% of the total. Although the Western Coalfield also increased over the same period from 1.8 Mt/y to 22.2 Mt/y or an increase in fraction from 6% to 16% of the total production.

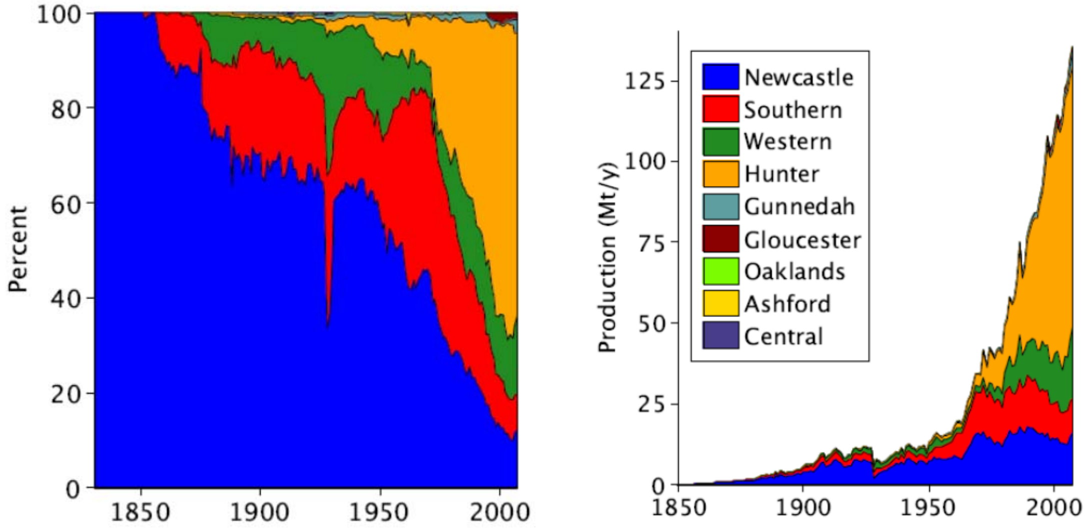


Figure 5: The NSW coal production by region (NSW DPI, 2009; Schmitz, 1988; NSW Legislative Assembly, var; JCB, 2009, var.)

3.4.2. Raw to Saleable ratio

The raw to saleable coal ratio is known for NSW since 1952/3 and is presented in Figure 6. The ratio has been steadily increasing in NSW from 1 in 1952/3 to 1.3 in 2009/10. The ratio for open cut mining is higher than the average and underground mining is lower. The open cut ratio initially rose quickly from 1.22 in 1980/1 to 1.3 in 1984/5 and since then appears to have stabilised at ~1.33. The dominant producer in the region today and probably in the future is the Hunter Coalfield, which is in the Northern region. The Northern region ratio has been steadily rising from 1.22 in 1980/1 to 1.38 in 2007/8. For this reason it is likely that the raw to saleable coal ratio will continue to increase in the future.

3.4.3. Coal production method

The underground and open cut coal production fractions are shown in Figure 7. As shown in the graph the fraction of open cut production has been increasing from around 10% in 1971 to 67% in 2007/8. The growth in open cut production is due to the bulk of Hunter coalfields production coming from open cut mines. The open cut to underground ratio has reached a plateau in recent years and it is possible that underground mining fraction will increase.

Average annual coal production from individual mines has been increasing exponentially over time as shown in Figure 8. The reason for the increase in mine size has been a steady increase in technology, with bigger trucks, draglines, longwall mining techniques etc all enabling more coal to be extracted from individual mines.

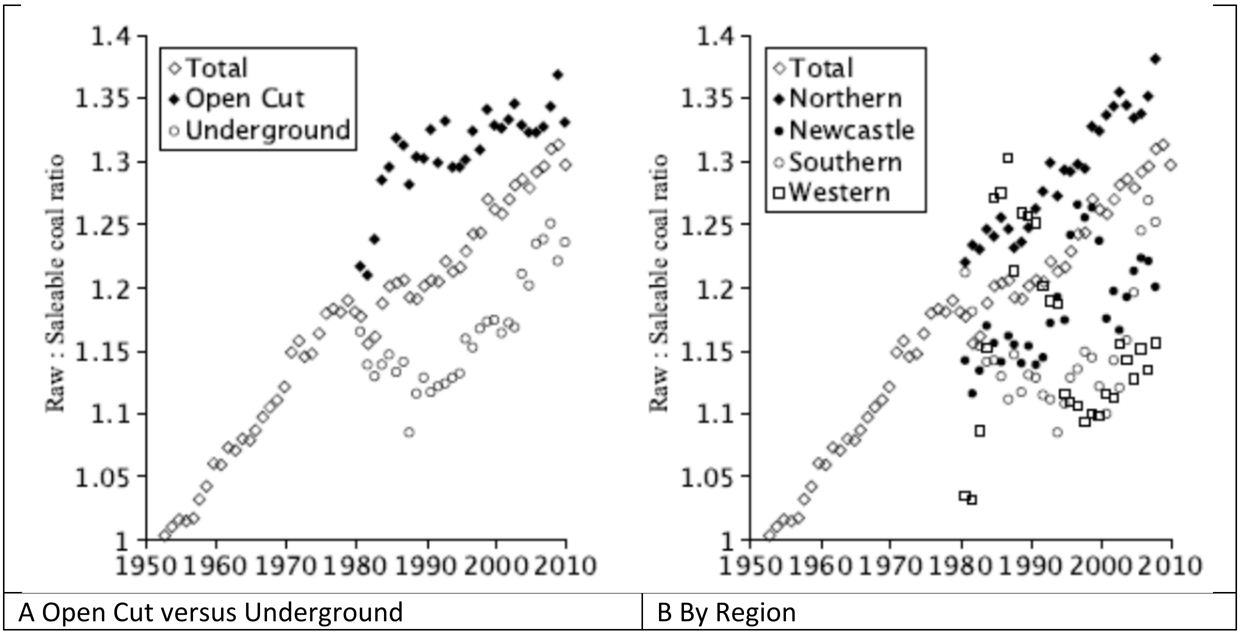
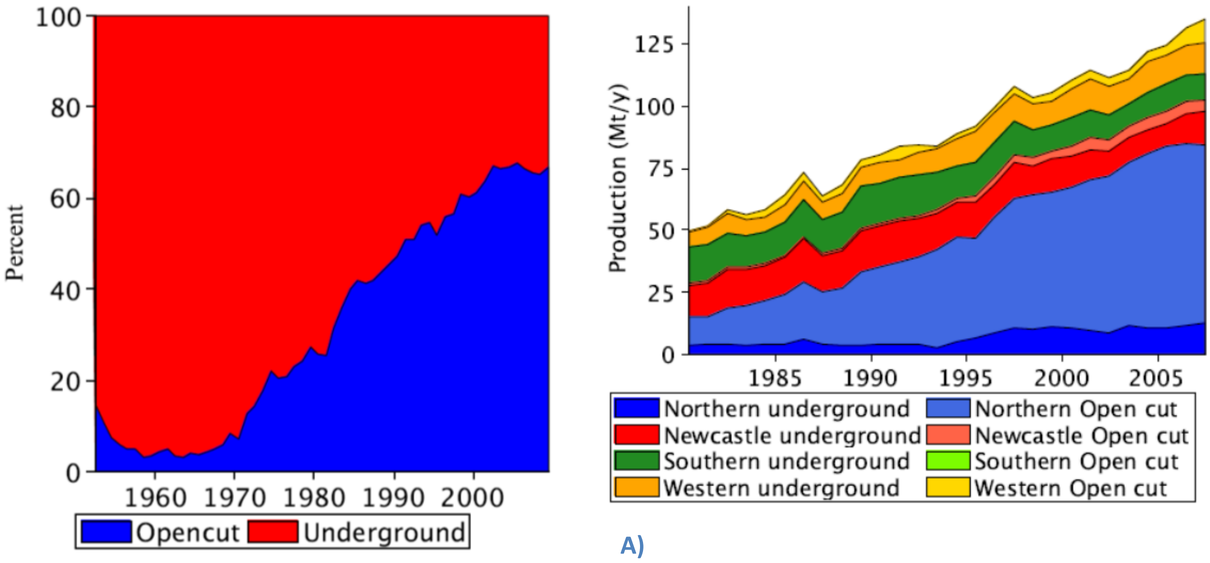


Figure 6: The raw to saleable coal ratio for NSW (Mudd, 2009; NSW DPI, 2009; NSW Minerals Council, 2010a)



B)

A)

Figure 7: The Underground and Open cut production in NSW, A) as a percentage based on raw production statistics, B) Saleable production by region (NSW DPI, 2009; NSW Legislative Assembly, var; JCB, var.)

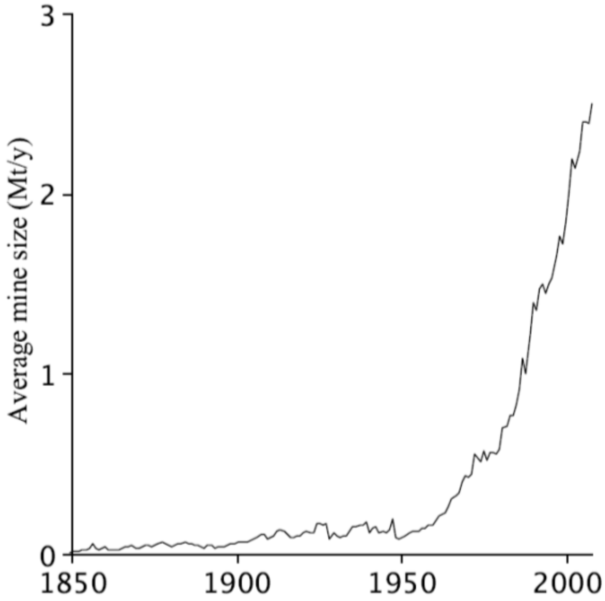


Figure 8: The average size of coal mines in NSW.

3.4.4. Overburden.

The overburden ratio in NSW is shown in Figure 9. As shown, the overburden ratio has been steadily increasing from 3.8 m^3/t in 1989 to around 5 m^3/t today. Similarly to mine scale, increasing overburden ratios is due mainly to bigger trucks and draglines and improved economics at larger scales.

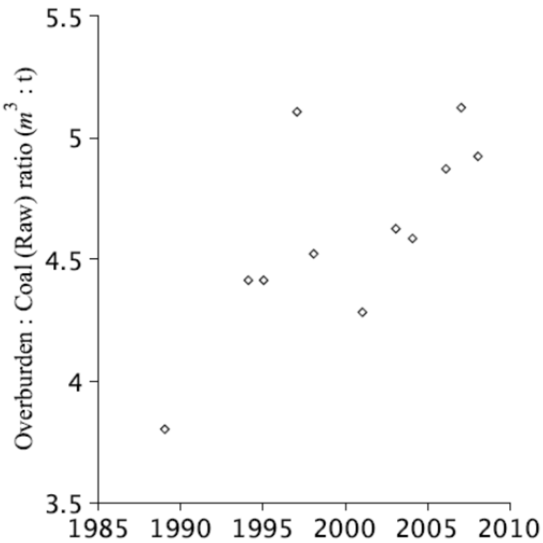


Figure 9: The overburden ratio of NSW coal (data from Mudd, 2009)

3.5. Consumption

The consumption of coal in NSW is shown in Figure 10. Coal consumption has been increasing steadily from13.7 Mt/y in 1960-61 to 35.4 Mt/y in 2007-08 (NSW DPI, 2009; JCB, var). The fraction of coal consumption for electricity production has increased significantly from 30% in 1960-61 to 86% in 2007-08 (NSW DPI, 2009; JCB, var). The Iron/Steelworks consumption was 5 Mt/y in 1960-61 (37%) rose to a maximum of 8.6 Mt/y (43%) since then it has steadily declined to 4 Mt/y in 2007-08 (11%). All other uses of coal have steadily declined since the 1960's.

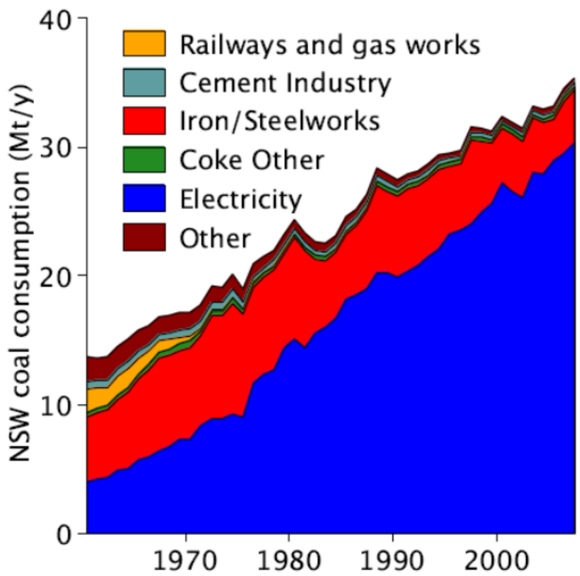


Figure 10: The consumption of coal in NSW by type (NSW DPI, 2009; JCB, var.).

3.6. Exports

3.6.1. Export by ports

The amount of coal exported by NSW ports is shown in Figure 11. The port of Newcastle dominates NSW coal exports as almost all coal from the Gunnedah, Hunter, Newcastle and Gloucester Coalfields and ~50% of the coal from the Western coalfield are exported via the port of Newcastle NSW DPI (2009). In contrast only 50% of the Western Coalfield and almost all of the Southern Coalfield coal are exported via Port Kembla NSW DPI (2009). Given the future potential of coal in the Hunter and Gunnedah coalfields it is likely that the port of Newcastle will continue to dominate the export of coal.

Although the Port of Newcastle is likely to be a key to future exports from NSW it is important infrastructure bottlenecks are managed in a timely fashion. Key infrastructures that may become bottlenecks in the future include the number of ships that can enter and leave the harbour and the number of coal trains that can run on the rail infrastructure.

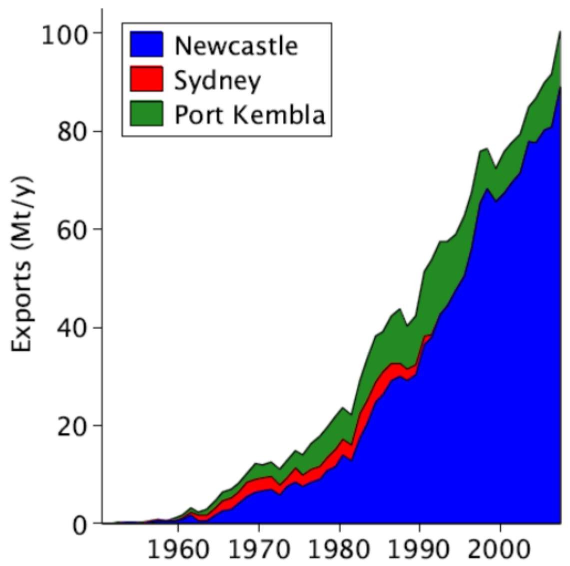


Figure 11: The amount of coal exported by NSW ports (NSW DPI, 2009; NSW Legislative Assembly, var.; JCB, var.; Joint Coal Board, var.).

3.6.2. Main buyers

The countries that import coal from NSW are shown in Figure 12 and Table 8. Table 8 shows the amount of coal exported to individual countries for the 2007-08 year. Although NSW coal production is exported all around the world, 96% of coal exports are shipped to Asian countries (NSW DPI, 2009). In particular, three countries (Japan, South Korea and Taiwan) account for 88% of NSW exports and Japan dominates buying 60% of the NSW exports (NSW DPI, 2009). Japan has been consistently the dominant buyer of NSW coal exports.

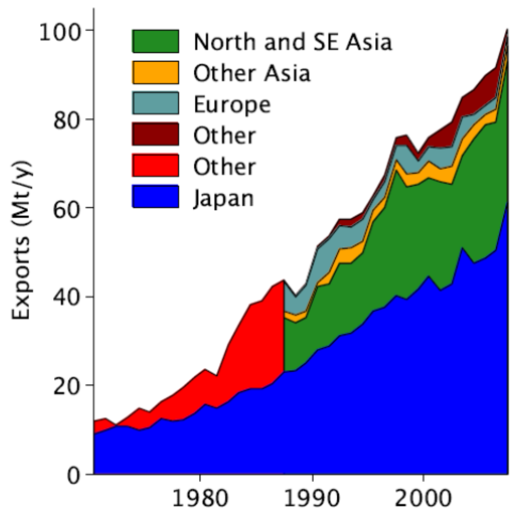


Figure 12: NSW coal exports by country (NSW DPI, 2009; JCB, var.).

Table 8: NSW coal exports by country in 2007-08 Mt (NSW DPI, 2009)

Country	Steaming	Metallurgical	Total
Japan	48.181	13.103	61.284
Korea S.	9.702	4.169	13.871
Taiwan	11.938	1.708	13.646
India		2.796	2.796
Thailand	1.523		1.523
Malaysia	1.204		1.204
China		1.149	1.149
Philippines	0.344		0.344
Pakistan	0.036	0.160	0.196
Asia	**72.928**	**23.085**	96.113
Ireland	0.527		0.527
Italy		0.468	0.468
Turkey		0.447	0.447
Netherlands		0.384	0.384
Germany		0.276	0.276
UK		0.248	0.248
France	0.140		0.140
Sweden	0.117		0.117
Belgium/Luxembourg		0.074	0.074
Europe	**0.784**	**1.897**	**2.681**
Mexico	0.979		0.979
North America	**0.979**		**0.979**
New Caledonia	0.302		0.302
New Zealand	0.080		0.080
Pacific	**0.382**		**0.382**
Brazil		0.215	0.215
Chile	0.050		0.050
South America	**0.050**	**0.215**	**0.265**
Egypt		0.145	0.145
Africa		**0.145**	**0.145**
Total	**75.123**	**25.342**	**100.465**

The fraction of exports to Japan was around 80 or more % in the early 1970's but steadily declined to around 50% in the mid 1980's; since the late 1980's the Japanese fraction has stabilising at around 55-60%. The metallurgical and steaming coal exports to Japan are shown in Figure 13, and also highlights that the metallurgical coal exports to Japan have been relatively flat with a minimum of 9.1 Mt/y in 1970-71 and a maximum of 15.9 Mt/y in 1995-96 NSW DPI (2009); JCB (var). In comparison, steaming coal to Japan has increased dramatically from negligible amounts of steaming coal exported in the early 1970's to a current export of 48.2 Mt/y in 2007-08 (NSW DPI, 2009; JCB, var). It is immediately apparent that NSW coal exports are heavily dependent on the amount of Japanese electricity use and policy decisions by the Japanese government regarding new electricity generation sources and/or tackling climate change issues.

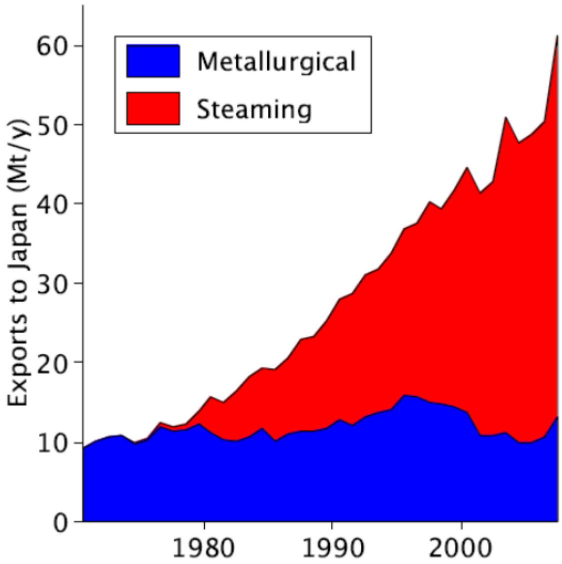
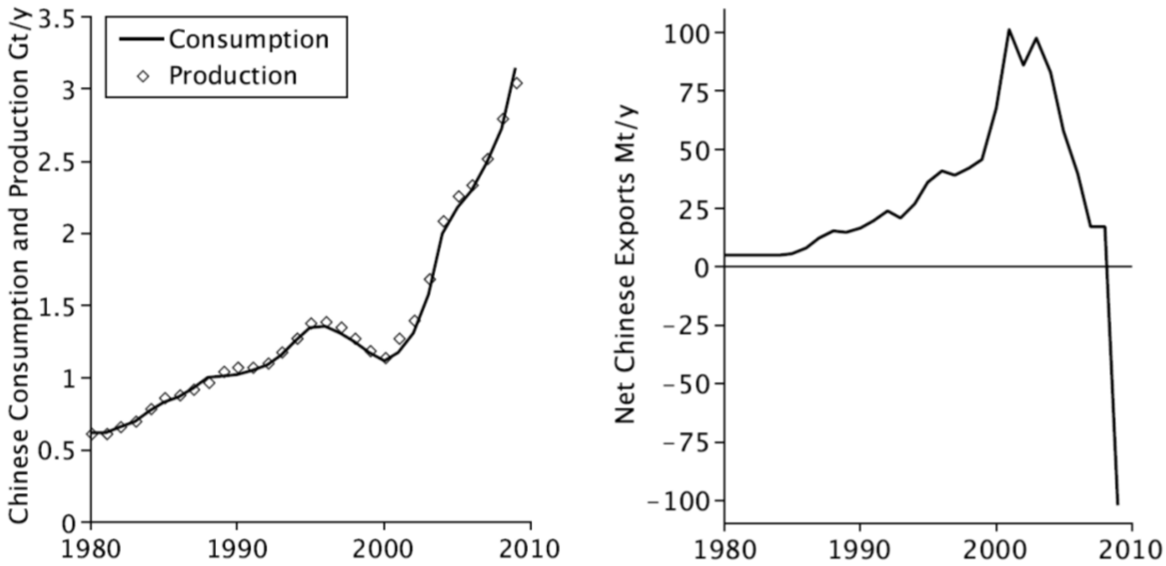


Figure 13:. The coal exports to Japan (NSW DPI, 2009; NSW Legislative Assembly, var.; JCB var.)

Although NSW exports are currently heavily dependent on Japan, there is a potential to export to China. Currently China is the largest consumer and producer of coal; see Figure 14. As shown Chinese consumption has risen sharply in the last 10 years resulting in 2009 consumption being higher than production (EIA, 2011). Figure 2.14 shows the net export from/imports to China since 1980. As indicated, China was a net exporter of coal and increased exports steadily to 100 Mt/y in 2001. Since 2001 the booming Chinese economy has resulted in coal exports decreasing rapidly until in 2009 China was importing a net 102Mt/y of coal (EIA, 2011). To put this into perspective, in 2001 China was contributing 14% of the world's coal exports, in 2009 it was importing 10% of the world's exports (EIA, 2011); further, the net Chinese imports in 2009 are similar to the amount of coal NSW exported in 2007-08. Additionally, recently literature points to Chinese coal production peaking sometime between 2010 and 2033 (Tao and Li, 2007; Lin and Liu, 2010; Höök et al., 2008; Zittel and Schindler, 2007; Mohr, 2010). The result is that China will either have to rapidly change its sources of electricity, reduce economic growth or find countries with large coal resources willing to export coal to China. China may in the near future (10-15 years) buy more coal from NSW than Japan.

3.6.3. Export by coal type

Exports of NSW coal by type are shown in Figure 14, indicating that metallurgical coal exports have grown only modestly from 9.9 Mt/y in 1970-71 to 25.3 Mt/y in 2007-08 (NSW DPI, 2009; JCB, var). By comparison steaming coal exports have increased dramatically over the same period from 2.0 Mt/y to 75.1 Mt/y (NSW DPI, 2009; JCB, var). The principal reason for the limited expansion in metallurgical coal exports is due to Japanese demand for metallurgical coal being relatively flat whereas Japan has rapidly increased its steaming coal imports from NSW (see Figure 13 above).



A) Consumption and production **B) Net consumption**

Figure 14: The coal consumption and production in China (EIA, 2011)

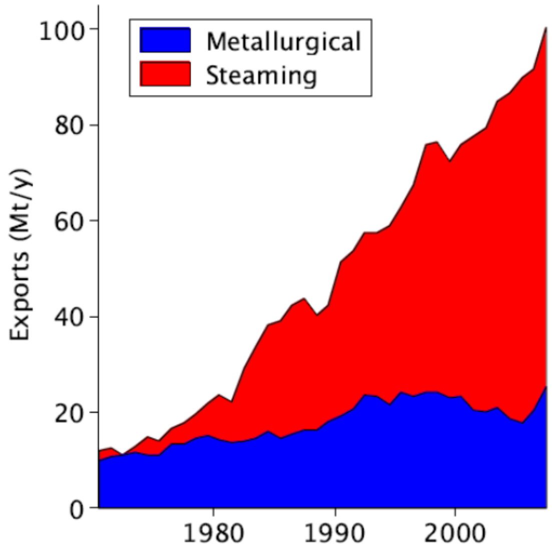
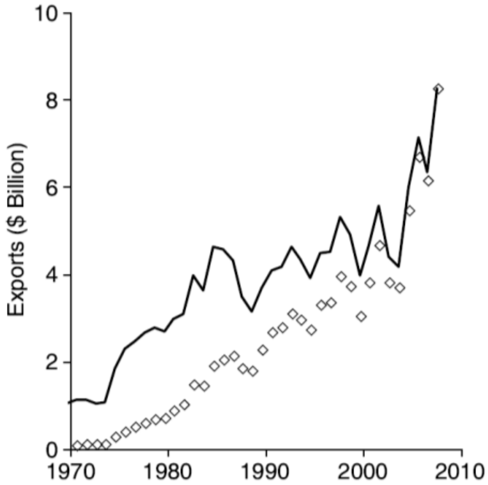


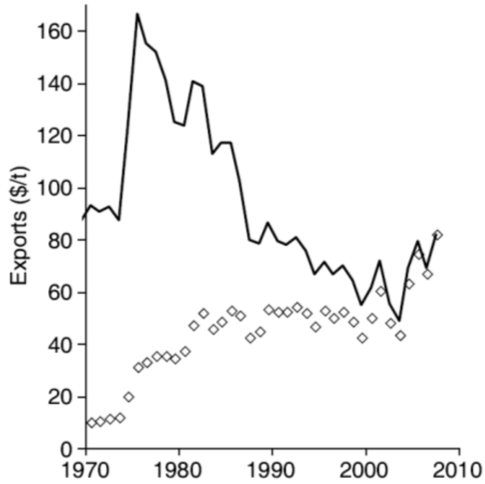
Figure 15: The coal exports in NSW by coal type (NSW DPI, 2009; NSW Legislative Assembly, var.; JCB, var.)

3.6.4. Value of Exports

The value of NSW coal exports has increased rapidly from $15 million in 1960-61 to $8.3 billion in 2007-08 since the 1960's as shown in Figure 16 (NSW DPI, 2009; JCB, var). In addition to the increasing coal exports, the price per tonne of coal exports has also risen as shown in Figure 16. The value of coal per tonne from NSW has changed significantly since the 1960's, with the value remaining relatively flat at $10/t between 1960 and 1974, rising sharply between 1974 and 1981 to $50/t and remaining at ~$50/t until 2000 where it has since increased to now be worth $82/t (NSW DPI, 2009; JCB, var). Metallurgical coal is generally more valuable than steaming coal (in 2007-08 metallurgical was worth $100-110/t compared with $76/t for steaming coal NSW DPI (2009)) hence the increase in coal export prices has occurred despite the fact that the fraction of metallurgical compared to steaming coal exports have decreased.



The value of coal exports A) Total



The value of coal exports B) Per tonne

Figure 16: (NSW DPI, 2009; JCB, var.) Inflation determined from (Rate Inflation, 2011).

3.7. Financial information

3.7.1. Value of coal

The value of NSW coal has increased in a similar trend to the coal export values. Figure 17 shows that the value of coal has been rising exponentially from $80 million in 1958 to $14.2 billion in 2009-10. The value of coal per tonne of saleable coal has had a history of rising quickly and stagnating as shown in Figure 17. Between 1958 and 1970 the value of coal was stable at $5/t before rapidly rising in the 1970's to reach approximately $30/t in 1981–82. During the 1980's to 1997-98 the coal price was stable at $30–40/t, however since 1997-98 the price of coal has risen rapidly to reach a peak in 2008–09 of $146/t. The steep rise in the value of coal is unsurprising given the Chinese coal industry changing from a net exporter to a net importer. It is likely that in the near future the price of coal will continue to rise as a result of the growing Chinese demand.

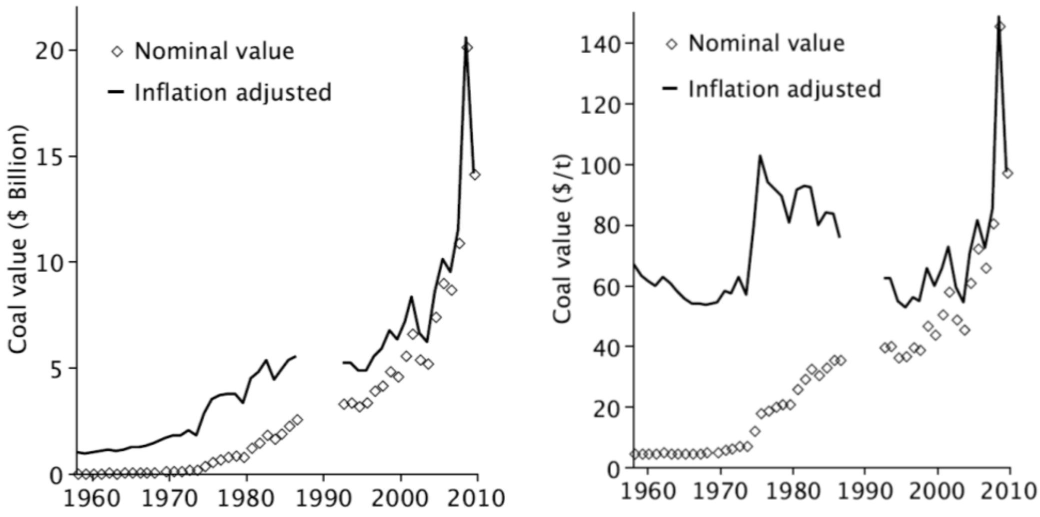


Figure 17: The value of coal produced in NSW A) Total and B) Per tonne (DM, var.; JCB, var.; NSW Minerals Council, 2010a; Trewin, var.; Skinner, 1999; Castles, 1994a,b) Inflation determined from (Rate Inflation, 2011).

3.7.2. Employment.

The total number of employees has ebbed and flowed over the decades as highlighted in Figure 18. As shown in Figure 18, the increase in coal production in the Hunter coalfield has significantly increased the workers in the Northern region from around 800 workers in the 1960's to a currently level of 8000. The Southern region initially rose from 4000 employees in 1955 to a maximum of 8000 in 1981 before decreasing to now be 2500. The Newcastle region was 12000 in 1955 and rapidly decreased to 6000 by 1961 and remaining at those levels until 1987 when employment decreased to now be around 2000 workers. Finally the Western region has fluctuated over the decades and is now currently at 1700 workers. As expected the number of workers in open cut mining has been increasing as open cut mining has increased from 12 Mt in 1980-81 to 95 Mt in 2007-08. Although two thirds of NSW production is from open cut mining, only 51% of workers are employed in open cut mining. This indicates that underground mining is considerably more labour intensive.

The number of employees needed to mine a kt of saleable coal is presented in Figure 19. As shown in Figure 19 between 1910 and the great depression the number of workers needed was reasonably stable at 2 employees per kt. During the great depression coal production was drastically reduced and this causes a significant disturbance to the statistics. Since the great depression the number of workers needed has steadily decreased and now currently 0.1 employees per kt are needed. As indicated previously, underground mining is considerably more labour intensive than open cut mining with 144 miners needed produce 1Mt of underground coal compare with 85 miners for open cut.

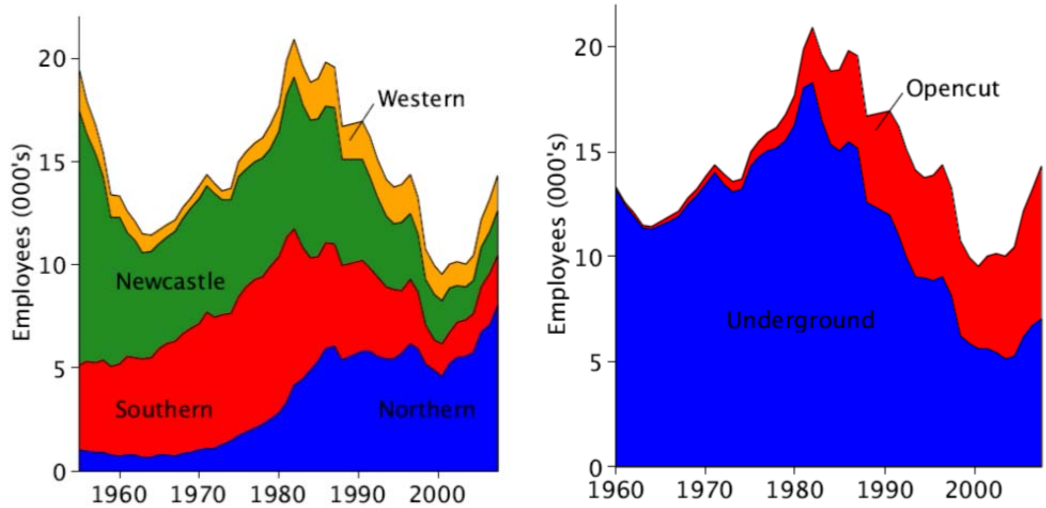
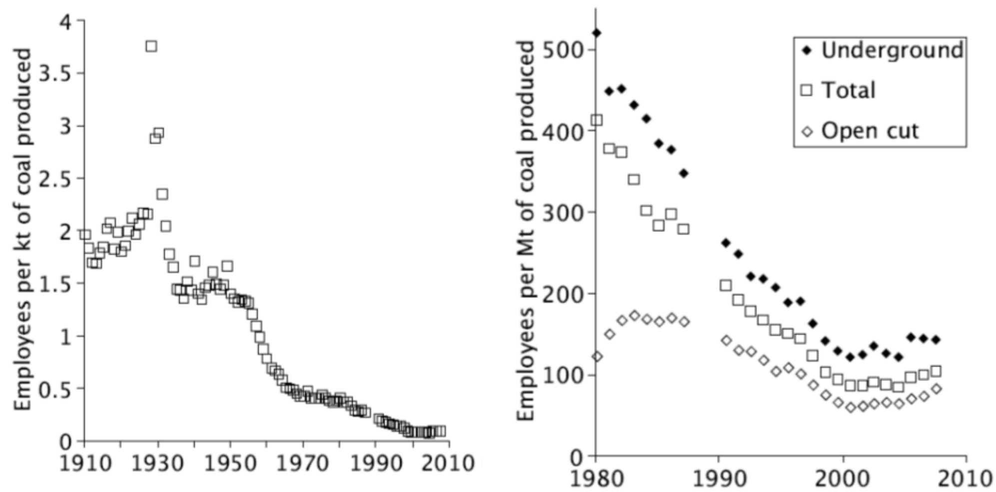


Figure 18: The number of coal workers by region and method (JCB, var.; NSW DPI, 2009)



A) Total **B) by mine type**

Figure 19: The number of coal workers per kt of saleable coal produced A) total, B) by mine type (JCB, var.; NSW DPI, 2009, Joint Coal Board, var.)

4. Future production

The future of NSW coal production has been projected using the URR values estimated in sub-section 3.3.4. A modelling technique of determining production from typical mine sizes (which is allowed to change with time) and the URR for the region has been developed in the literature (Mohr, 2010). The inputs used in the modelling process have been described in appendix B.

The modelling technique has been applied and the resulting projections are shown in Figure 20 with a summary of the peak dates in Table 9.

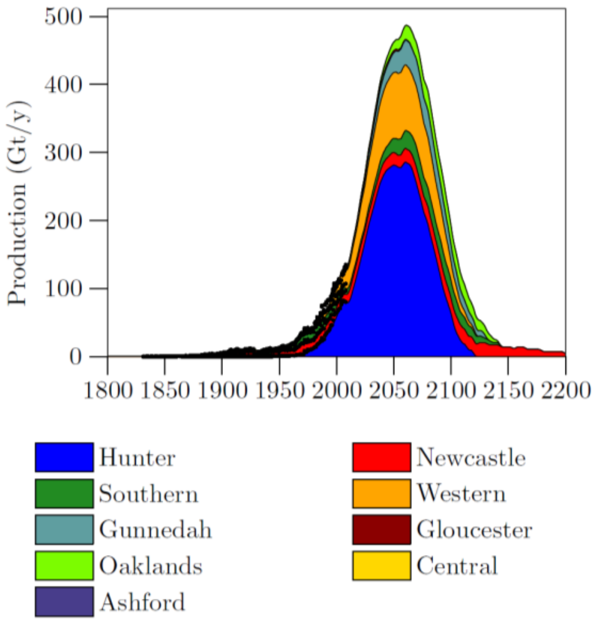


Figure 20: Anticipated future production for NSW

As illustrated in Figure 20, NSW is anticipated to reach peak production in 2069–2077 at around 540–620 Mt/y, with the bulk of the production sourced from the Hunter, Gunnedah and Southern basins.

Table 9: Peak years for NSW

Region	Peak Year	Max. Production (Mt/y)
Hunter	2060	286.0
Newcastle	2081	26.3
Southern	2070	30.2
Western	2058	98.1
Gunnedah	2070	39.9
Oaklands	2093	31.0
Gloucester	2028	5.3
Central	1919	0.1
Ashford	2025	0.1
Total	2061	487.2

5. Contribution to Global Supply of Coal and Alternatives

5.1. World Supply of Coal

As Australia is the world's largest coal exporter it is import to examine the world's production of black coal to determine the overall importance of Australian and specifically NSW coal production to the global supply.

A projection of black coal production was created using an algorithm-based model described in Mohr (2010). The model required Ultimately Recoverable Resources (URR) estimates for all countries. To achieve this black coal cumulative production statistics from Mohr and Evans (2009); World Energy Council (2010); Minerals UK (var); EIA (2011) where combined with recoverable reserve estimates from World Energy Council (2010), with the exception of Australia, which used URR value from Mohr et al. (2010) and for NSW the values shown in Section x. The URR estimates are shown in Table 10.

Table 10: URR estimates used (Gt)

Region	URR estimate
Africa	39.9
Asia	225.8
Australia	106.6
Europe	79.5
FSU	228.5
North America	281.7
South America	13.9
Total	976.1

The URR values were applied to all countries with black coal to generate projections of world coal production as shown in Figure 21.

As indicated in Table 11 world black coal production is anticipated to peak in 2017 at 7.6 Gt/y. The relatively early peak date for black coal production may appear strange, but can be explained by examining the production of China.

The projection of Chinese coal production Figure 22, indicates that the rapid growth in production will be followed by a rapid decline. Since the Chinese black coal production represents over 40% of current world production, world coal production also peaks at this point. Unless significant reserves of Chinese coal are discovered, Chinese and therefore world coal production will peak before 2020. It is important to note that China does not have an open and transparent reserve and resource accounting system (such as the JORC code), and hence the amount of black coal that will be produced from China remains uncertain.

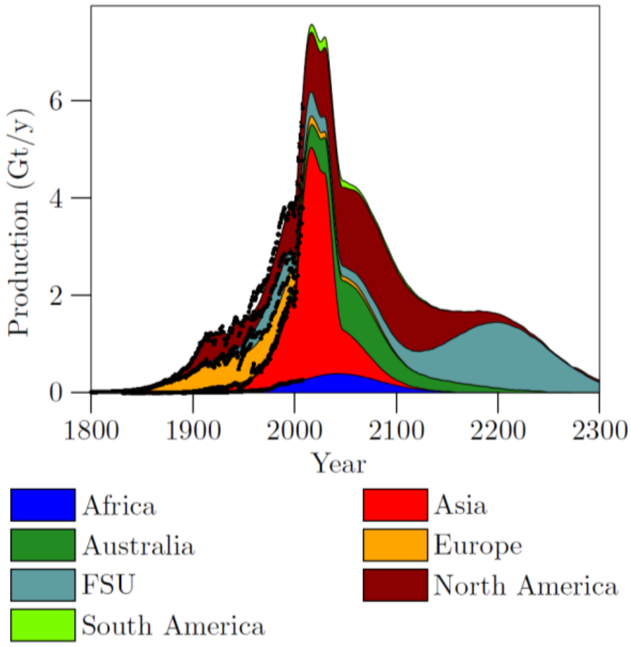


Figure 21: Scenarios for the World by continent

Table 11: Peak years for World by Continent

Region	Peak Year	Max. Production (Gt/y)
Africa	2039	0.4
Asia	2016	4.7
Australia	2060	1.1
Europe	1973	0.6
FSU	2202	1.4
North America	2065	1.7
South America	2029	0.2
Total	2017	7.6

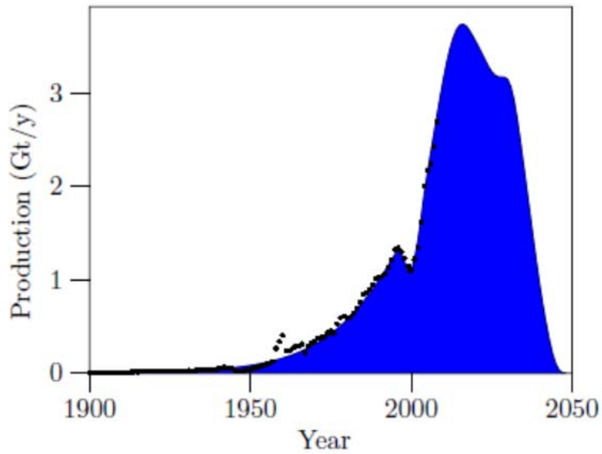
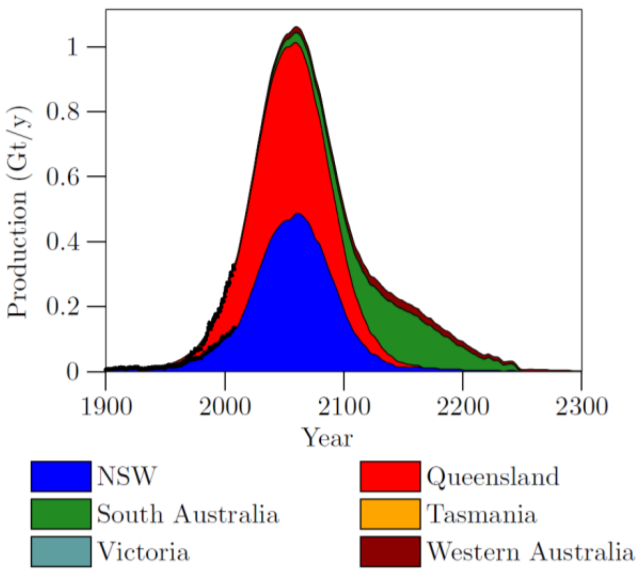


Figure 22: Modelled scenario for China

5.2. Australian supply of coal

Although world production is anticipated to peak in the near future the outlook for Australia is much brighter, with a peak of 1.1 Gt/y in 2060, as shown in Figures 23 and 24 and Table 12. As can be observed, the contribution of Australia to world production reaches a maximum of 25.4% in 2065 and NSW reaches 11.7% in the same year.



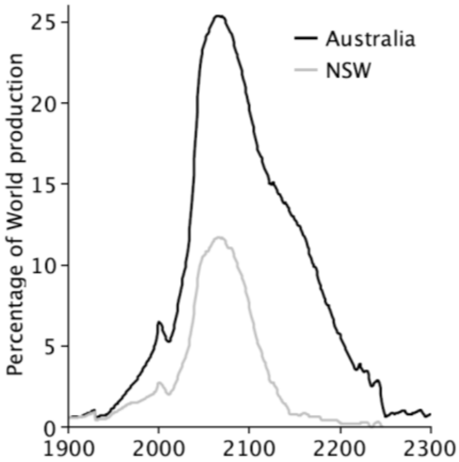


Figure 23: Scenarios for Australia by state

Figure 24: Australia's fraction of world coal production

Table 12: Peak years for Australia by state

Region	Peak Year	Max Production (Gt/y)
NSW	2061	0.5
Queensland	2056	0.5
South Australia	2145	0.2
Tasmania	2101	-
Victoria	1917	-
Western Australia	2132	-
Total	2060	1.1

6. Coal mining methods and impacts

6.1. Open Cut

Open cut coalmines operate by stripping away the overburden by using explosives and then mining the coal underneath. Currently around 65% of coal in NSW is extracted via open cut mines (NSW DPI, 2009). Open cut mining has several key advantages over underground mining. First, open cut mining has a recovery of around 90% compared with 60% for bord and pillar (Edgar, 1983). Open cut mining is also considerable safer for mine workers than underground mining (Edgar, 1983) and issues such as subsidence are avoided. However, the principal drawbacks include a greatly increased area of disturbance, final pit voids, massive overburden piles and increased dust, noise and water management issues, as well as greater final mine rehabilitation requirements.

6.2. Bord and Pillar

Bord and pillar mining works by mining coal in such a way that the rock above the coal stays in place (that is the rock does not collapse). To do this pillars of coal are left unmined in such a way that the roof of the mine is supported (Speight, 1983). Typically, the mine consists of many long straight corridors and paths running perpendicular creating a checkerboard pattern, with the rectangular pillars of remaining coal supporting the roof of the mine (Edgar, 1983). Bord and pillar mining was once common in NSW with 35% of coal extracted using this method in 1987-88, however the method is in decline due to the inherent inefficiency of the method and now only around 4% of coal is mined via the bord and pillar method (NSW DPI, 2009). Bord and pillar typically recover around 50-60% of the coal (Edgar, 1983). Bord and pillar mining generally occurs in the Newcastle coalfield at mines such as Awaba State and Chain Valley (NSW DPI, 2009).

6.3. Longwall

Longwall mining works where the rock above the coal is allowed to collapse into the mine in a controlled fashion. To do this, first, a hydraulic system supports the roof of the mine while the face is mined (Speight, 1983). The mined coal travels via a conveyor belt underneath brings the coal out to the side of the coal face to be brought to the surface, the roof behind face is allowed to collapse behind the hydraulic supports (Edgar, 1983; Speight, 1983). As the machinery moves forward the ceiling behind the machine collapses into the space behind (MSEC, 2007; Edgar, 1983). The key advantages of longwall mining are the increased recovery and safety (compared with Bord and Pillar) and cheap cost, however the main drawback is the potential for subsidence. Most underground mining in NSW is via Longwall techniques with longwall mining now producing 31% of coal production in NSW (NSW DPI, 2009).

7. Existing Use and Alternatives

7.1. Alternatives to Coal

The predominant use of coal is in three industries, electricity generation, iron and steel industry and cement manufacturing. All three industries can become significantly less reliant on coal. These three uses of coal and possible alternatives will be briefly discussed.

7.1.1. Alternatives for the steel industry

The steel industry needs a reducing agent to convert iron oxide into iron. Typically, coal is used as the reducing agent and approximately 0.7 tonnes of coal are needed to create a tonne of (non-recycled) steel (South Gippsland Shire Council, 2011). Currently, research is continuing into investigating other methods of reducing iron oxide into iron. Some alternative reducing agents include hydrogen or syngas (CO + H2), electricity and biomass (Worldsteel Association, 2009). The production of syngas could be created via numerous feedstocks including gasification of oil, natural gas, natural bitumen or biomass and hydrogen could be created via natural gas, oil or electrolysis of water. The syngas/hydrogen could be used in flash reactors to create steel (Worldsteel Association, 2009). Electricity could eventually be used to make steel by electrolysis of the iron oxide into iron and oxygen (Worldsteel Association, 2009). Finally biomass in the form of a bio-charcoal could be used in a charcoal blast furnace or added with the coke (Worldsteel Association, 2009). New technologies are currently being further researched and it is plausible that in the future, methods of creating less coal-intensive iron from iron oxide will be developed.

7.1.2. Alternatives for the cement Industry

Currently the manufacturing of portland cement requires significant amounts of energy. This energy is typically obtained by burning natural gas or coal with other materials such as used tyres. Although coal is used in cement manufacturing, less carbon intensive fuels such as natural gas could readily be used as an energy source in the rotating kiln. In addition to different energy sources, geopolymer cements are currently being heavily researched and offer a promising way to make cement without needed considerable amounts of energy.

7.1.3. Alternatives for energy production.

Currently 40% of the world's electricity is supplied by coal-fired power stations (ACA, 2008a). Curiously a conventional coal fired power station has remained technologically virtually unchanged for the past 100 years. Technologies such as IGCC may be implemented that ensure a higher energy efficiency hence requiring less coal to be burnt for the same amount of electricity produced. Alternatively, electricity can be generated in numerous methods that require very small amounts of coal, for instances, nuclear power stations, gas power stations, hydro electricity, wave, solar, wind etc.

8. CONCLUSION

This case study has presented national and global data for black coal, as well as a more detailed exploration of coal production, consumption and export, at the sub-national scale, in New South Wales. This data provides a comprehensive basis for understanding production trends and impacts that should be considered in an assessment of the future of this commodity in Australia.

Modelling of future production indicates that there may be a global peak in the annual production of black coal before 2020, and that a peak in Australian black coal could occur well before the end of the 21st Century, around 2060.

Alternatives for industries in which black coal is presently a critical input become a key consideration, when attempting to understand the impact of a global or national peak in production, and provide a starting point for thinking about how these activities can be supported in future.

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10. APPENDIX A

Table A1: The reserve and resource information for all known coal deposits.

a) Mine name	b) Type	c) Energy	d) Ash	e) R. Prod.	f)PvMr	g) Pvr	h) MsR
i) Basin	j) Method	k) Overburden	l) Sulfur	m) S. Prod.	n) PbMr	o) Pbr	p) IdR
q) Company	r) Market	s) Moisture	t) Moisture	u) C. Prod.	v) IMr	w) Ir	x) IR
y) Employees	z) Quality	aa) Reference	ab) JORC?	ac) Com.	ad) TMr	ae) Tr	af) TR
a) Boulder	OC	26.2-28.6	13.5-20	NA	4.2	4.4	4.4
Western	T&S	Unk	Unk	NA			
7MQ 40%	E,D	7D 8E	2.5	NA			
Unk	Unk	CIP09	N	NA	4.2	4.4	4.4
a) Dartbrook	OC,UG	25.9	Unk	NA			170.1
Hunter	Unk	Unk	Unk	NA			51.9
Anglo 78%	Unk	Unk	Unk	25.23			
Unk	Unk	Anglo AR08	Y	1995-07			222.1
a) Drayton	OC	24.2 - 28.1	14.5	4.89	25.1	26.5	35.8
Hunter	D,E&T	7	Unk	4.61	13.7	14.4	26.8
Anglo 88%	E,D	9	2.5	95.4			1.3
328	Th	Anglo AR08	Y	1983-	38.8	40.9	63.9
a) Saddlers Creek	UG	26.8	Unk	NA			398.9
Hunter	L	NA	Unk	NA			137.9
Anglo 88%	Unk	Unk	Unk	NA			
NA	Unk	Anglo AR08	Y	NA			536.8
a) Maules Creek	OC	29.9	8.5	NA		151	172
Gunnedah	D,T&S	6.4	Unk	NA		205	267
Aston 100%	E,D	10	3.5	NA			170
NA	Th,SSC	Ashton AR10	Y	NA		356	610
a) Mt Arthur	OC	25.5	21.4	14.3		579	947
Hunter	D,E&T	4.7	0.6	11.8		447	1868
BHP 100%	E,D	8.5	3.5	106.6			1035
993	Th	BHP AR09	Y	1948-	753	1026	3850
a) Appin	UG	Unk	9.5	1.9		8	113
Southern	L	NA	0.37	1.6		43	71
BHP 100%	E,St	9	9	62.8			261
529	C,Th	BHP AR09	Y	1962-	44	50	445
a) Cordeaux	UG	~27.6	~30	NA			5
Southern	L	NA	0.53	NA			54
BHP 100%	Unk	~7%	1%	54.7			143
NA	C,Th	BHP AR09	Y	1889-01			202
a) Dendrobium	UG	Unk	9.5	3.6		2	89
Southern	L	NA	~0.56	2.5		44	55
BHP 100%	E,St	9	9	7.11			185
324	C,Th	BHP AR09	Y	2003	33	46	329
a) West Cliff	UG	Unk	9.5	3.4		1	49
Southern	L	NA	~0.36	2.9		15	27

BHP 100%	E	9	9	47.3			144
454	C,Th	BHP AR09	Y	1974-	13	16	220
a) Bickham	OC	27.2	~8	NA			
Hunter	Unk	NA	Unk	NA			36
Big ben Holdings 50%	Unk	<15	8	NA			
NA	Unk	Bickham Coal website	N	NA			36
a) Rix's Creek	OC	28.1	9.5-15	2.2		60.1	155.8
Hunter	D,L&T	4.7	Unk	1.3			
Big ben Holdings 100%	Unk	9	Unk	15.6			
106	C,Th	CIP09	N	1991-		60.1	155.8
a) Bloomfield	OC	28.1	9-15.5	0.8		21.8	37.7
Newcastle	T&S	6.1	Unk	0.5			
Big ben Holdings 100%	E	8-9	Unk	39.1			
72	C,Th	CIP09	N	1874-		21.8	37.7
a) Awaba	UG	26.8	18.5	0.8		1.6	32.8
Newcastle	B&P	NA	Unk	0.8			11.8
Centennial 100%	D	8	2.5	30			
95	Th	Centennial AR09	Y	1948-	1.6	1.6	44.6
a) Mandalong	UG	28.3	14	4.8		39.5	105.4
Newcastle	L	NA	Unk	4.8		56.5	239.3
Centennial 100%	E,D	8	2.5	40.4			
358	Th	Centennial AR09	Y	1981-	96	96	344.7
a) Mannering	UG	24.5	24	0.8		2.1	45.1
Newcastle	B&P	NA	Unk	0.8		8.2	247.8
Centennial 100%	D	6	3	44.4			11
107	Th	Centennial AR09	Y	1962-	10.3	10.3	303.9
a) Munmorah	UG	Unk	Unk	NA			
Newcastle	Unk	Unk	Unk	NA			
Centennial ?	Unk	Unk	Unk	37			
NA	Unk		N	1965-05			0
a) Myuna	UG	25.9	20.5	1.2			
Newcastle	B&P	NA	Unk	1.2		18	347.2
Centennial 100%	D	8	2.5	32.2			104
178	Th	Centennial AR09	Y	1981-	18	18	451.2
a) Newstan	UG	25.4-30.8	9.2-23.5	2.7		3.1	22.5
Newcastle	L	NA	Unk	2		14.4	97.2
Centennial 100%	E,D	8-8.5	2.5	63.8			8
158	Th,SSC	Centennial AR09	Y	1950-	14.9	17.5	127.7
a) Newstan Lochiel[a]	UG	Unk	Unk	NA			0.4
Newcastle	L	NA	Unk	NA		58.3	150.1
Centennial 100%	Unk	Unk	Unk	NA			
NA	Th,SSC	Centennial AR09	Y	NA	49.6	58.3	150.5
a) Airly	UG	24-29.5	14-24	NA			
Western	B&P	NA	Unk	NA		34.4	98.2

Centennial 100%	E,D	8	Unk	0.1			21
NA	Th	Centennial AR09	Y	1998-99	34.4	34.4	119.2
a) Angus Place	UG,OC	34	19-23	3.2		31.5	88.1
Western	L	NA	Unk	3.2		2.2	172
Centennial 50%	E,D	Unk	2.4	45.6			
251	Th	Centennial AR09	Y	1978	33.7	33.7	260.1
a) Berrima[b]	UG	23.2	30	0.2		3.5	7.9
Southern	B&P	NA	Unk	0.2		5.7	99.1
Centennial 100%	E,C	5.5	1.5	11.8			27
23	Th	Centennial AR08	Y	1930	9.2	9.2	134
a) Charbon	OC,UG	28.5	14	1.2		1.2	9.5
Western	B&P,L&T	5.3	Unk	0.9		6.7	6.7
Centennial 95%	E,C	9	2.5	16.6			
137	Th	Centennial AR09	Y	1979	6.7	7.9	16.2
a) Cherry Tree	UG	Unk	Unk	NA			0
Western	Unk	NA	Unk	NA			54.4
Centennial 95%	Unk	Unk	Unk	NA			19
NA	Unk	Centennial AR09	Y	NA			73.4
a) Clarence	UG	28.9-30.3	9.5-13.5	1.7		8	40.4
Western	B&P	NA	Unk	1.5		44.5	196.2
Centennial 85%	E	Unk	2.2	40.5			
196	Th	Centennial AR09	Y	1979-	49.4	52.5	236.6
a) Ivanhoe North	UG,OC	23.2	25	NA		1.6	3.3
Western	B&P,T&S	NA	Unk	NA		0.5	4.2
Centennial 100%	D	8	2.5	13.8			
NA	Th	Centennial AR09	Y	1894-06	2.1	2.1	7.5
a) Springvale[c]	UG,OC	24-28.7	16-22.6	3.2		39.5	107.2
Western	L,T&S	10	Unk	3		29.3	73.3
Centennial 50%	E,D	7-9	4.8	30.7			
316	Th	Centennial AR09	Y	1994-	68.8	68.8	180.5
a) Neubecks	OC	Unk	Unk	NA		4.4	5.8
Western	Unk	NA	Unk	NA		1.7	1.9
Centennial 100%	D	Unk	Unk	NA			
NA	Th	Centennial AR09	Y	NA	6.1	6.1	7.7
a) Wolgan Road	OC	Unk	Unk	NA		12	25.2
Western	Unk	NA	Unk	NA			
Centennial 100%	D	Unk	Unk	NA			
NA	Th	Centennial AR09	Y	NA	12	12	25.2
a) Invincible	OC	29.1	13.5	0.5			
Western	T&S,H	3.9	Unk	0.4			
CET 80%	D	8	2	17.5			
17	Th	National Native Title Tribunal	N	1905-		7	7
a) Cullen Valley	OC	23.4-27.2	13.5-24	0.4	0.8	0.8	51.3
Western	T&S	4.7	Unk	0.3	5	8	13.6
CET 80%	D	8	Unk	4			1.9

60	Th	CIP09	N	2001-	5.8	8.8	66.8
a) Ferndale	OC,UG	Unk	Unk	NA			
Hunter	Unk	NA	Unk	NA			
Coalworks 90%	Unk	Unk	Unk	NA			
NA	Th,C	Coalworks AR10	N	NA			330
a) Oaklands	OC	16.3	18.2	NA			121
Oaklands	Unk	4.7	0.2	NA			572
Coalworks 100%	CTL	26	Unk	NA			129
NA	Th	Coalworks AR10	Y	NA			822
a) Vickery South	OC	26.7-30.4	8	NA			
Gunnedah	T&S	NA	0.6	NA			
Coalworks 100%	Unk	Unk	2.9-3.8	NA			
NA	C,Th	Coalworks AR10	Y	NA			42
a) Sutton Forest	UG	28.5-29.5	14-18	NA			
Southern	L	NA	Unk	NA			
Cockatoo coal 100%	Unk	8-10	1.5	NA			
NA	Unk	Cockatoo Coal ASX release 7/7/2010	Y	NA			115
a) Bylong	UG	29.5	10.5	NA			
Western	L	NA	Unk	NA			
Cockatoo coal 100%	Unk	Unk	3	NA			
NA	Th	Cockatoo Coal ASX release 7/7/2010	Y	NA			423
a) Pine Dale	OC	24	20	0.2	20	20	20
Western	L&T	3	Unk	0.2			
Enhance Place ?	Unk	8	8	0.5			
11	Th	CIP09	N	2006-	20	20	20
a) Ashton	OC	30.4	9.5	2		29.1	84.9
Hunter	L&T	5.8	Unk	1.3		19.9	25.9
Felix 60%	E	9	2.5	7.3[d]			8.1
350[d]	SSC	Felix Resources AR09	Y	2004-		49	118.9
a) Ashton	UG	30.4	9.5	2.9		23.5	163.6
Hunter	L	NA	Unk	1.7		23.9	112.7
Felix 60%	E	9	2.5	7.3[d]			46.4
350[d]	SSC	Felix Resources AR09	Y	2004-		47.4	322.7
a) Moolarben	OC	Unk	Unk	NA		40.4	257.4
Western	Unk	NA	Unk	NA		237.3	96.5
Felix 80%	Unk	Unk	Unk	NA			52.7
NA	Th	Felix Resources AR09	Y	NA		277.7	406.6
a) Moolarben	UG	Unk	Unk	NA		44.1	88.8
Western	Unk	NA	Unk	NA		35	114.6
Felix 80%	Unk	Unk	Unk	NA			96.4
NA	Th	Felix Resources AR09	Y	NA		79.1	299.8
a) Duralie - Main Pit	OC	Unk	Unk	1.8[e]			0.7
Gloucester	T&S	4.8	Unk	1.2[e]			10.8

Gloucester Coal 100%	E	Unk	Unk	5.9[e]		
82[e]	Th,C	Gloucester AR09	Y	2003-[e]	8.9	11.5
a) Duralie - Clareval West	OC	Unk	Unk	1.8[e]		9.9
Gloucester	T&S	3.5	Unk	1.2[e]		4.5
Gloucester Coal 100%	E	Unk	Unk	5.9[e]		1
82[e]	Th,C	Gloucester AR09	Y	2003-[e]	10.5	15.4
a) Duralie - Railway pit	OC	Unk	Unk	1.8[e]		1.2
Gloucester	T&S	3.4	Unk	1.2[e]		0.5
Gloucester Coal 100%	E	Unk	Unk	5.9[e]		
82[e]	Th,C	Gloucester AR09	Y	2003-[e]	0.9	1.7
a) Duralie -North East	OC	Unk	Unk	1.8[e]		
Gloucester	T&S	3.4	Unk	1.2[e]		9.2
Gloucester Coal 100%	E	Unk	Unk	5.9[e]		3
82[e]	Th,C	Gloucester AR09	Y	2003-[e]	6.5	12.2
a) Duralie -UG	UG	Unk	Unk			0.9
Gloucester	Unk	NA	Unk			39.9
Gloucester Coal 100%	E	Unk	Unk			59
82[e]	Th,C	Gloucester AR09	Y			99.8
a) Grant and Chainley	OC	Unk	Unk	NA		
Gloucester	Unk	Unk	Unk	NA		
Gloucester Coal 100%	Unk	Unk	Unk	NA		33
NA	Unk	Gloucester AR09	Y	NA		33
a) Stratford - Bowens Rd	OC	26-28	10.3-24	1[f]		3.8
Gloucester	T&S	1.9	Unk	0.7[f]		1.1
Gloucester Coal 100%	E	7-9	2	18.6[f]		
70[f]	Th,C	Gloucester AR09	Y	1995-[f]	3.3	4.9
a) Stratford - South	OC	26-28	10.3-24	1[f]		3.3
Gloucester	T&S	4.3-5.3	Unk	0.7[f]		3.5
Gloucester Coal 100%	E	7-9	2	18.6[f]		2
70[f]	Th,C	Gloucester AR09	Y	1995-[f]	2.8	8.8
a) Stratford - Rosville	OC	26-28	10.3-24	1[f]		
Gloucester	T&S	4.3-5.3	Unk	0.7[f]		11.7
Gloucester Coal 100%	E	7-9	6.5-8.5	18.6[f]		8
70[f]	Th,C	Gloucester AR09	Y	1995-[f]	5.1	19.7
a) Stratford - Avon North	OC	26-28	10.3-24	1[f]		
Gloucester	T&S	Unk	Unk	0.7[f]		0.9
Gloucester Coal 100%	E	7-9	6.5-8.5	18.6[f]		
70[f]	Th,C	Gloucester AR09	Y	1995-[f]		0.9

a) NRE1	UG	23.2	31.5	0.5		14.9	25.5
Southern	B&P	NA	Unk	0.5		77.1	127.5
Gujarat NRE 100%	E	Unk	1.2	60.9		36	161.9
320	Unk	Gujarat NRE AR10	P	1888-		128	314.9
a) NRE Wongawilli	UG		9.5	-		2.7	21
Southern	B&P,L	NA	Unk	-		5.1	24
Gujarat NRE 100%	E	9	Unk	52.4		23	213
87	Unk	Gujarat NRE AR10	P	1908-		30.8	258
a) Muswellbrook	OC	29	11-12.5	1.5	8	9.5	12.9
Hunter	T&S	6	Unk	1.2			
Idemitsu Australia 100%	E,D	Unk	2.5	52.3			
125	Th	CIP09	N	1908-	8	9.5	12.9
a) Sandy Creek	UG	29	11-12.5	NA	18	18	18
Hunter	B&P	NA	Unk	NA			
Idemitsu Australia 100%	E	Unk	2.5	NA			
NA	Th	CIP09	N	NA	18	18	18
a) Boggabri	OC,UG	30	9	1.3			274
Gunnedah	T&S	8.8	Unk	1.3			302.1
Idemitsu Australia 100%	E	9	3.5	2.31			
94	Th	CIP09	N	2007-			576.1
a) Wallarah No2	UG	33.9-34.3	12.5-20	NA			445
Newcastle	L	NA	0.35	NA			737
Kores Australia 82%	E,D	Unk	Unk	NA			27
NA	Th	CIP09, Wallarah.com.au 23/03/11	N	NA			1209
a) Abel	UG	Unk	Unk	NA		50	
Newcastle	B&P	NA	Unk	NA			
Noble Group 100%	Unk	Unk	Unk	NA			
NA	Unk	CIP09	N	NA		50	182
a) Donaldson	OC	28.5	14	2.2	5	11	36
Newcastle	T&S	2.2	Unk	1.4			
Noble Group 100%	E	9	Unk	10.35			
145	Th	CIP09	N	2001-	5	11	36
a) Tasman	UG	28.1	15	0.5			16.3
Newcastle	B&P	NA	Unk	0.3			3.2
Noble Group ?	E	9	Unk	0.41			
131	Th	CIP09	N	2007-			19.5
a) Cobbora	OC	Unk	Unk	NA			
Western	Unk	Unk	Unk	NA			
NSW Gov. 100%	D	Unk	Unk	NA			
NA	Th	Cobbora Environmental report	N	NA			400
Doyles - West bh	UG	Unk	31.3	NA			
Hunter	Unk	NA	Unk	NA			
Nucoal 100%	Unk	Unk	Unk	NA			59.5

NA	SC,SSC	Nucoal.com.au (23 March 2011)	Y	NA			59.5
Doyles - Whybrow	UG	Unk	17.7	NA			
Hunter	Unk	NA	Unk	NA			7.8
Nucoal 100%	Unk	Unk	Unk	NA			105.6
NA	SC,SSC	Nucoal.com.au (23 March 2011)	Y	NA			113.4
Doyles - Redbank	UG	Unk	31.4	NA			
Hunter	Unk	NA	Unk	NA			
Nucoal 100%	Unk	Unk	Unk	NA			98.7
NA	SC,SSC	Nucoal.com.au (23 March 2011)	Y	NA			98.7
Doyles - Whynot	UG	Unk	8	NA			
Hunter	Unk	NA	Unk	NA			5.1
Nucoal 100%	Unk	Unk	Unk	NA			80.2
NA	SC,SSC	Nucoal.com.au (23 March 2011)	Y	NA			85.3
Doyles - Woodlands	UG	Unk	38	NA			
Hunter	Unk	NA	Unk	NA			
Nucoal 100%	Unk	Unk	Unk	NA			140.8
NA	SC,SSC	Nucoal.com.au (23 March 2011)	Y	NA			140.8
Wambo	OC,UG	28.9	12	5.7	74	133	436
Hunter	L,T&S	5.6	0.5	3.9	76	100	213
Peabody ?	E	10	3	59.5			
490	Th,SSC	CIP09, Peabody Website (23 March 2011)	N	1969-	150	233	649
Chain Valley	UG	24	Unk	0.6			0.7
Newcastle	B&P	NA	Unk	0.6			81.8
Peabody 80%	E,D	3	Unk	29.4			3.4
122	Th	CIP09	N	1962-	18.6	18.6	85.9
Metropolitan	UG	Unk	8.8-11	1.5	39.7	43.7	91.7
Southern	L	NA	Unk	1.2			
Peabody 100%	E,COKE	6.5-8	Unk	38			
393	C	CIP09	N	1888-	39.7	43.7	91.7
Wilpinjong	OC	23.9	15	7			116
Western	T&S	1.3	0.5	5.9			34
Peabody 100%	E,D	9	Unk	8.5			150
101	Th	Peabody Website (23 March 2011), CIP09	N	2007-		251	300
Bengalla	OC,UG	28.21	13.5	6.8	64	86	116
Hunter	D,T&L	3.1	0.47	5.4	62	81	162
Rio Tinto 30%	E,D	10	3	47.7			59
304	Th,C	Rio Tinto AR09	Y	1999-	126	167	337
HVO	OC,UG	28.7-30.4	9.5-13.5	14.2	218	314	407
Hunter	D,T&L	6.1	0.54	10.6	60	89	658
Rio Tinto 76%	E,D	10	2.5	303.1			751
1530	Th	Rio Tinto AR09	Y	1969-	278	403	1816
Mt Pleasant	OC,UG	26.7	Unk	NA			200

Hunter	D,T&L	NA	0.51	NA	350	459	677
Rio Tinto 76%	Unk	Unk	Unk	NA			281
NA	Th,C	Rio Tinto AR09	Y	NA	350	459	1158
Mt Thorley - Mt Thorley	OC,UG	29.4	9-13.5	13.4[g]	21	31	32
Hunter	D,T&L	4.2[g]	0.43	8.9[g]	3	5	59
Rio Tinto 76%	E	9	2.5	190.3[g]			74
1170[g]	Th,C	Rio Tinto AR09	Y	1979-[g]	24	36	165
Mt Thorley - Warkworth	OC,UG	30.7	9-13.5	13.4[g]	149	228	232
Hunter	D,T&L	4.2[g]	0.44	8.9[g]	121	185	429
Rio Tinto 42%	E	8.5	2.5	190.3[g]			282
1170[g]	Th,C	Rio Tinto AR09	Y	1979-[g]	270	413	943
Oaklands	OC	17.5	12	NA			480
Oaklands	Unk	NA	Unk	NA			800
Rio Tinto 76%	D	28	Unk	NA			
NA	Th	Rio Tinto AR09	Y	NA			1280
Camberwell	OC	29-30.4	9.5-12.5	3.9	4	6.4	10.5
Hunter	T&S	4.6	Unk	2.3			
Vale 61%	E	8.5	2.5	33.6			
268	Th,SSC	CIP09	N	1991-	4	6.4	10.5
Glennies Creek	UG	31.2	9	2.9		3.59	36.6
Hunter	L	NA	Unk	1.6		52.8	112.9
Vale 61%	E	9	2	7.3			43.9
290	SHC	CIP09	N	1999-	34.5	56.4	193.4
Glennies Creek	OC	31.2	9	NA		8.7	
Hunter	Unk	NA	Unk	NA			12.3
Vale 61%	E	9	2	NA			1.2
NA	SHC	CIP09	N	NA		8.7	13.5
Gledon Brook	Unk	Unk	Unk	NA			
Hunter	Unk	NA	Unk	NA			
White Energy 100%	Unk	Unk	Unk	NA			
NA	SSC	White Energy ASX release 30th November 2010	N	NA			50
Mt Penny	OC	34.5	17-20	NA			95.3
Western	Unk	NA	0.5	NA			22.3
White Energy 100%	E,D	Unk	<3	NA			56.1
NA	Th	White Energy ASX release 30th November 2010	Y	NA			173.7
EL5183	UG	Unk	Unk	NA			0
Gunnedah	Unk	NA	Unk	NA			7.2
Whitehaven 100%	Unk	Unk	Unk	NA			32.2
NA	Unk	Whitehaven AR09/10	Y	NA			39.4
Block 7 CCL701	OC	Unk	Unk	NA			0
Gunnedah	Unk	NA	Unk	NA			0
Whitehaven 100%	Unk	Unk	Unk	NA			1.4
NA	Unk	Whitehaven AR09/10	Y	NA			1.4

Block 7 CCL702	UG	Unk	Unk	NA			0
Gunnedah	Unk	NA	Unk	NA	4	4	12.9
Whitehaven 100%	Unk	Unk	Unk	NA			2.5
NA	Unk	Whitehaven AR09/10	Y	NA	4	4	15.4
Narrabri North	UG	29	9	NA	66	66	169.4
Gunnedah	L	NA	Unk	NA	67.4	67.4	171
Whitehaven 70%	E	10	2.5	NA			135
NA	Th	Whitehaven AR09/10	Y	NA	133.4	133.4	475.4
Narrabri South	UG	29	9	NA	19.4	24.7	45.2
Gunnedah	L	NA	Unk	NA	47.1	61.5	114
Whitehaven 70%	E	10	2.5	NA			220
NA	Th	Whitehaven AR09/10	Y	NA	66.5	86.2	379.2
Rocglen	OC	29.3	10	NA	8.6	9.8	11.7
Gunnedah	T&S	NA	Unk	NA	3.4	3.9	6.2
Whitehaven 100%	E	11	3.5	NA			2.1
NA	Th	Whitehaven AR09/10	Y	NA	12	13.7	20.1
Rocglen	UG	29.3	10	NA			
Gunnedah	Unk	NA	Unk	NA			2.1
Whitehaven 100%	E	11	3.5	NA			2.1
NA	Th	Whitehaven AR09/10	Y	NA			4.2
Sunnyside	OC	24.5	22	NA	7.1	7.1	20.4
Gunnedah	T&S	NA	Unk	NA	20.9	20.9	47.8
Whitehaven 100%	E,D	9	2.5	NA			22.9
NA	Th	Whitehaven AR09/10	Y	NA	28	28	91.1
Tarrawong	OC	28.9-30.8	6.5-12	1.3	4.5	4.8	17.4
Gunnedah	T&S	9.1	Unk	1.2	28.6	30.8	41.6
Whitehaven 70%	E	11	3.5	1.7			19.1
63[h]	Th/PCI	Whitehaven AR09/10	Y	2007-	33	35.6	78.1
Tarrawong	UG	28.9-30.8	6.5-12	NA			6.6
Gunnedah	Unk	NA	Unk	NA	3.1	3.7	13.6
Whitehaven 70%	E	11	3.5	NA			20.1
63[h]	Th/PCI	Whitehaven AR09/10	Y	NA	3.1	3.7	40.2
Werris Creek	OC	28-29.7	8-13	1.1	27.6	27.6	30
Gunnedah	T&S	6.2	Unk	1.1	4.4	4.4	4.8
Whitehaven 100%	E,D	11	3.5	3.3			2.7
112	Th/PCI	Whitehaven AR09/10	Y	2006-	32	32	37.4
Vickery	OC	Unk	Unk	NA			30
Gunnedah	Unk	NA	Unk	NA			151.6
Whitehaven 100%	Unk	Unk	Unk	NA			91.1
NA	Unk	Whitehaven AR09/10	Y	NA			272.7
Vickery	UG	Unk	Unk	NA			
Gunnedah	Unk	NA	Unk	NA			
Whitehaven 100%	Unk	Unk	Unk	NA			22
NA	Unk	Whitehaven AR09/10	Y	NA			22
Bluevale[i]	OC	Unk	Unk	NA	3.1	3.3	8.8
Gunnedah	Unk	NA	Unk	NA	6	6.4	5.7

Whitehaven 100%	Unk	Unk	Unk	3.9			1.1
NA	Unk	Whitehaven AR09/10	Y	1985-1999	9.1	9.8	15.5
Whitehaven[j]	OC	31	6.5	0.6			
Gunnedah	T&S	11.2	Unk	0.5			
Whitehaven 100%	E	10	4	5.1			
56	SS,PCI	CIP09	N	2001-09			
Brunt	OC	Unk	Unk	NA			
Ashford	Unk	NA	Unk	NA			2.6
Whitehaven 100%	Unk	Unk	Unk	NA			0.3
NA	Unk	Whitehaven AR09/10	Y	NA			2.9
Arthur's Seat	OC	Unk	Unk	NA			
Ashford	Unk	NA	Unk	NA			
Whitehaven 100%	Unk	Unk	Unk	NA			1.7
NA	Unk	Whitehaven AR09/10	Y	NA			1.7
Bulga[k]	UG,OC	Unk	9-14	6.8	135.6	200.5	733.6
Hunter	D,T&S,L	6	Unk	4.5	23.4	31.5	394.6
Xstrata 68%	E	9	2.5	124.7			528
876	Th	Xstrata AR09	Y	1975-	159	232	1656.2
Cumnock	OC	30.4	8.5-9.5	1.2	144.7	218.6	366
Hunter	T&L	6.4	Unk	0.9	3.9	5.9	184
Xstrata 90%	E	<8.5	2.5	24.6			
70	SSC	Xstrata AR09	Y	1991	148.6	224.5	550
Liddell	OC	28.5	9.5-14	4.3	40	59.6	108.6
Hunter	T&L	5.1	Unk	2.9	15.9	24.5	204
Xstrata 68%	E	9	2.5	67.8			393
194	Th,SSC	Xstrata AR09	Y	1940	55.9	84.1	705.6
Mangoola	OC	26.8	11.8	NA	111.1	151	155.5
Hunter	Unk	NA	Unk	NA	8.9	12.1	31.3
Xstrata 100%	E,D	10.5	5.5	NA			1300
NA	Th	Xstrata AR09	Y	NA	120	163.1	1486.8
Mitchells Flat	OC,UG	28.9	14	NA			
Hunter	L,T&S	NA	Unk	NA			120.7
Xstrata 80%	Unk		2.8	NA			394
NA	Th	Xstrata AR09	Y	NA			514.7
Mt Owen (Mt Owen)	OC,UG	29.3	9-12.5	9.1[l]	37.9	60.7	85.4
Hunter	T&S	5.9[l]	Unk	5.2[l]	9	14.7	66.2
Xstrata 100%	E,D	9	2.5	61.3[l]			79
611[l]	Th	Xstrata AR09	Y	1994-[l]	46.9	75.4	230.6
Mt Owen (Ravensworth East)	OC	29.3	9-12.5	9.1[l]	8.8	12.7	54.5
Hunter	T&S	5.9[l]	Unk	5.2[l]			9.7
Xstrata 100%	E,D	9	2.5	61.3[l]			2
611[l]	Th	Xstrata AR09	Y	1994-[l]	8.8	12.7	66.2
Mt Owen (Glendell)	OC	29.3	9-12.5	9.1[l]	32.9	47	84.3

Hunter	T&S	5.9[l]	Unk	5.2[l]	1.1	1.7	33.9
Xstrata 100%	E,D	9	2.5	61.3[l]			83
611[l]	Th	Xstrata AR09	Y	1994-[l]	34	48.7	201.2
Narama (Ravensworth)	OC	>18.5	<35	4.1[m]	8.5	8.5	13.9
Hunter	D	5.7[m]	Unk	4.1[m]	5.5	5.5	14.4
Xstrata 100%	Unk	<10	2.5	125.6[m]			
138[m]	Th	Xstrata AR09	Y	1977-[m]	14	14	28.3
Narama (Ravensworth West)	OC	>18.5	<35	4.1[m]	26.7	38.7	75.9
Hunter	D	5.7[m]	Unk	4.1[m]			
Xstrata 100%	Unk	<10	2.5	125.6[m]			
138[m]	Th	Xstrata AR09	Y	1977-[m]	26.7	38.7	75.9
Newpac (Ravensworth)	UG	30.8	9	1.1			157.2
Hunter	L	NA	Unk	0.7	35	47.1	28.3
Xstrata 100%	E	9	2.5	3.32			85
252	Th	Xstrata AR09	Y	2003-	35	47.1	270.5
United	UG	Unk	<9	3.4	1.3	1.7	54.4
Hunter	L	NA	Unk	2.6			181.4
Xstrata 95%	E	9	2.5	23.9			610
182	Th	Xstrata AR09	Y	1990-	1.3	1.7	845.8
Cardiff BH	Unk	Unk	Unk	NA			
Newcastle	Unk	NA	Unk	NA			12.4
Xstrata 80%	Unk	Unk	Unk	3			22
NA	Th	Xstrata AR09	Y	1948			34.4
New Wallsend[n]	UG	Unk	Unk	NA			
Newcastle	Unk	NA	Unk	NA			
Xstrata?	Unk	Unk	Unk	21.2			
NA	Unk	No Source	N	1970-03			
Teralba	UG	31.4	7.5-16.5	NA			2.1
Newcastle	L	NA	Unk	NA			83.6
Xstrata 80%	E	9	2.3	13.7			
NA	Th,C	Xstrata AR09	Y	1988-01			85.7
West Wallsend	UG	Unk	<9	2.1	16.7	24.3	73.1
Newcastle	L	NA	Unk	1.6	8.1	13.5	44.7
Xstrata 80%	E	<9	2.3	54.8			
390	Th,SSC	Xstrata AR09	Y	1888-	24.8	37.8	117.8
Westside	OC	Unk	Unk	0.8	1.9	1.9	2.4
Newcastle	T&S	2.1	Unk	0.8			
Xstrata 80%	D	Unk	Unk	10			
22	Th	Xstrata AR09	Y	1987-	1.9	1.9	2.4
Tahmoor	UG	Unk	9.5	1.8	11.4	15	43.1
Southern	L	NA	Unk	1.4	14.8	20.3	67.1
Xstrata 100%	E	9	1.5	32.5			113
506	Th	Xstrata AR09	Y	1978-	26.2	35.3	223.2
Baal Bone	UG,OC	25.5	19.4	2	3.4	4.6	19.3

Western	L	4.5	0.6	1.5			16.8
Xstrata 74%	E	Unk	2.5	45.2			157
214	Th	Xstrata AR09	Y	1983-	3.4	4.6	193.1
Running Stream	OC,UG	27	13	NA			28.2
Western	T&S	NA	Unk	NA			22.1
Xstrata 78%	Unk	Unk	Unk	NA			62
NA	Th	Xstrata AR09	Y	NA			112.3
Ulan	UG	28.7	12.5-25	6.4	167.7	177	284.4
Western	L	NA	0.6	5.2	15.6	18.7	500.5
Xstrata 90%	E,D	9	Unk	129.2			2568
414	Th	Xstrata AR09	Y	1948-	183.3	195.7	3352.9
Austar	UG	32.2	6	1.5	4.7	5.7	14.5
Newcastle	L	NA	Unk	1.2	32	38.1	79.5
Yanzhou 100%	E	7	2.5	41.1	6	7.2	19
190	Unk	CIP09	N	1916-	42.7	51	113
Denman[o]	UG	Unk	Unk	NA			
Hunter	Unk	NA	Unk	NA			
NA	Unk	Unk	Unk	NA			
NA	Unk	CIP95	N	NA			505
Monee[p]	UG	Unk	Unk	NA			
Newcastle	L	NA	Unk	NA			
NA	Unk	Unk	Unk	11.8			
NA	Unk	CIP	N	1987-03			
East Lithgow[q]	UG	26-28	16-18	NA			
Western	L	NA	Unk	NA			
NA	Unk	8	Unk	NA			
NA	Unk	CIP95	N	NA			123

[a] Awaba East.
[b] Centennial recently sold Berrima.
[c] Includes Lamberts Gully
[d] Value is for Ashton underground and opencut.
[e] Value is for all of Duralie.
[f] Value is for all of Stratford.
[g] Numbers include both Mt Thorley and Warkworth.
[h] Numbers are for both Tarrawong underground and opencut.
[i] This mine has also been termed West Bluevale and Vickery.
[j] Also known as Canyon.
[k] Also known as Beltana.
[l] Numbers are for the Mt Owen Complex which includes Mt Owen, Ravensworth East and Glendell.
[m] Numbers are for both Narama Ravensworth and Narama Ravensworth West.
[n] Mine has been rehabilitated.
[o] Only referred to in CIP95. It appears to either be part of the Mt Arthur complex or to the immediate west of the complex.
[p] Mine located very close to Catherine Hill Bay whose residences are protesting against plans to develop the area for residential purposes.
[q] Mine deposit only referred to in CIP95.

11. APPENDIX B

The inputs used in the models are shown in Tables 2.A1 and 2.A2. Y_s is the start year and Q_T is the URR values, these constants have been determined previously. r_{QT} is the rate constant and is selected so that production is close to historic production. The constants M_L,M_H,L_L,L_H, t_t, r_t control the size of the mines coming online as a function of time. Specifically, M_L and M_H are the initial and final size of the mines, so the first mine will have a production rate ofM_L Mt/y and the final mine will have a production rate of M_H Mt/y. Similarly L_L and L_H are the operating lifes of these mines, so the initial mine operates for L_L years and the final mine for L_H years. r_t controls the rate at which the mines grow in size and t_t is the year the mines are operating for $(L_L + L_H)/2$ years at $(M_L + M_H)/2$ Mt/y. The production statistics for all mines has been collated and using this data the average size of the mines as a function of time can be readily calculated, and these constants approximated. Additionally a small number of disruptions have been included to account for disturbances in the historic production (such as the great depression) as shown in Table 2.A2.

Table 2.A1. Mining constants used in the model

Name	Y_s	Q_T	R_{QT}	M_L	M_H	L_L	L_H	t_t	r_t
Ashford 1	1950	3.3	4.5	0.1	0.1	40	70	2050	0.03
Ashford 2	2020	4.6	4.5	0.1	0.1	40	70	2050	0.03
Central	1907	1	4.5	0.05	0.05	40	70	2050	0.03
Oaklands	2020	2102	4.5	1	5	40	70	2050	0.03
Gloucester	1995	232	2.5	1	1	30	30	2012	0.03
Gunnedah 1	1890	10	2	0.01	0.2	50	50	1950	0.03
Gunnedah 2	1977	24	4.5	0.75	0.75	25	25	2050	0.03
Gunnedah 3	2000	2731	4.5	1	5	40	70	2050	0.03
Western 1	1850	100	4.5	0.01	0.1	50	50	1910	0.03
Western 2	1930	7203	6	0.02	5	50	70	2015	0.03
Southern 1	1850	120	5	0.025	3.5	50	80	2010	0.03
Southern 2	1942	650	6	1	1	40	40	2010	0.03
Southern 3	2000	2304	6	0.025	3.5	50	80	2010	0.03
Newcastle	1800	4472	2.5	0.025	3.5	50	80	2012	0.03
Hunter	1938	20077	5.5	0.02	10	20	60	2010	0.03

Table 2.A2. Disruption constants for NSW

Name	Ds	Df	Dn
Newcastle	1928	1929	0.2
Newcastle	1989	2005	0.25
Hunter	2003	2008	0.75